SportE² - Intelligent Management System to integrate and control energy generation, consumption and exchange for European Sport and Recreation Buildings
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D5.4 Integrated SPORTE2 System Product complete

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Abstract

Integrated SPORTE2 System product complete: Report for SPORTE2 System. This document will update the integration process and include application guidelines for the SPORTE2 system

Versions

Date	*Partner*	*Content*	*Ver*
27/08/2014	DAPP	First draft	0.0
28/08/2014	DAPP	Complete version after internal review.	1.0
29/08/2014	DAPP and UNIVPM	Complete version data integration	1.9
30/08/2014	UNIVPM	Content review and minor corrections	2.0
31/08/2014	DAPP	Final Version	2.1

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EXECUTIVE SUMMARY

This report provides in-depth overview the SportE2 solution as a unique integrated product. As such, it represents a first complete release of the potential market catalogue that could be presented to potential customers, in the immediate future. For this reason, the document has been edited in brief and concise way, deciding not to implement too many technical details, and maintaining a rather explanatory and commercial approach, focussing on the benefits attained and the implementation into the end use cases.

The integrated SportE2 solution composed by HOW, WHEN, and WHY modules, plus WHERE whether there is the customer need to perform multi facility benchmarking, is available as a combination of a baseline package. Additionally, six add-on packages are made available, as follows:

1. *SportE2 AHU Pool Package*
2. *SportE2 Pool Package*
3. *SportE2 Fitness Package*
4. *SportE2 Solar Thermal Package*
5. *SportE2 Boiler Package*
6. *SportE2 Lighting Package*

These packages have been defined and tested during the experience developed on the field in specific scenarios, and will be appropriately configured and customized on the customer particular needs and wishes, to improve the energy efficiency in sport facilities, reducing the energy demand, cost of management, and ultimately leading to inferior CO_2 emission, at no compromise for the adequate comfort level for end users.

1. INTRODUCTION

Facility management is subject to continuous innovation and development, under pressure to reduce costs and add value. According to the report "Facility Management Market by Solutions (CAFM, IWMS, CMMS, BIM, IWMS) & Services - Worldwide Market Forecasts and Analysis (2014-2019)"[1] by MarketsandMarkets, the facility management market is expected to grow globally from $24.65 billion in 2014 to $43.69 Billion by 2019. This represents a Compound Annual Growth Rate (CAGR) of 12.1% from 2014 to 2019.

A study from Navigant Research[2] shows that the worldwide spending on industrial energy management systems and services (IEMS), including software components, will grow from $11.3 billion in 2013 to $22.4 billion in 2020, which amounts to a CAGR of 10.3 %. The North American market is the largest global region for IEMS revenues, only by a slim margin larger than European one.

Places like gyms, swimming pools, indoor playing courts and even outdoor playing courts consume massive amounts of energy. The energy usage patterns in sports centres are extremely irregular, with long periods of low usage and peak periods of intense demand – for example during sporting events.

In this scenario, the SportE2 solution proposes six packages to optimise energy consumptions and maintaining user comfort as a mandatory requirement through the continuous monitoring of all comfort parameters and the control of the water and air treatment machines.

The experience has been developed, refined and validated not only theoretically, but also on practical real-life case studies. During the project course three sport facilities active and working have been exploited as test cases, permitting to measure and quantify the advantages achievanble: FIDIA (Rome, Italy), EMTE (Extebarri, Spain), SELF (Santa Maria de Lamas, Portugal).

The experience matured has enabled us to recognize and address situations and risks, such as black outs, voltage drops on the line, improper installation, insufficient or weak wiring, broken or unexpected malfunction of sensors and actuators that in the design phase were not properly considered. Having considered and addressed the above mentioned issues allowed us to deliver a series of solutions with higher technological added value.

Regarding the analysis and presentation of the results obtained during the validation of the above packages on the three project pilots, please refer to deliverables D6.2 for Pilot 1, D6.3 for Pilot 2, D6.4 for Pilot 3 and D6.5 Pilot Final Report.

The document is structured in six chapters: Introduction, SportE2 Framework, SportE2 Modules, SportE2 System as a Product, SportE2 System Application Guidelines, and Conclusions.

Chapter 2 inserts the SportE2 framework in a concise market analysis and the general integrated architecture system.

Chapter 3 provides a schematic description of the four modules composing the SportE2 system product: HOW, WHEN, WHY, WHERE highlighting the main characteristics, functionalities, benefits, requirements and relations to other SportE2 modules.

[1] "Facility Management Market by Solutions (CAFM, IWMS, CMMS, BIM, IWMS) & Services - Worldwide Market Forecasts and Analysis (2014-2019)"[1] by MarketsandMarkets

[2] http://www.energymanagertoday.com/energy-management-market-to-almost-double-by-2020-091048/

Chapter 4 provides analysis and presentation of the six SportE2 packages that are proposed as final products.

Chapter 5 presents and includes some application guidelines for the SportE2 system.

Chapter 6 presents the conclusions, providing an overview of the main benefits for final customers that the SportE2 solution would unlock.

2. SPORTE2 FRAMEWORK

2.1 Sports facility energy management

Effective energy management for facilities is becoming increasingly important in view of rising energy costs, governments' legislations on reduction of energy consumption and human comfort requirements.

The market related to sport has been growing in recent years, promoted as beneficial to health and to maintain good social relationships. The worldwide sporting facility industry is involved in the operation of venues that host indoor and/or outdoor sports events at both professional and amateur levels. Some facilities are open air; others are closed; while some others cater for spectators with or without seating.[3] The three disciplines that have a higher cost structure are football, tennis and swimming. For tennis and swimming, the reason is the comparatively higher cost associated with the maintenance of the facilities, whereas for football, the main reasons for the higher average cost are a comparatively high payment to the federation, high expenditures on sporting goods, and, again, high expenditures on the facilities.

There are around 1.5 million sporting facilities in Europe. SportE2 approach, methodology, and technologies are dedicated to energy savings in sport facilities.

Sport facility energy management is an activity that spans all aspects of a sport facility. Some of the traditional energy management measures include thermostat regulation and investing in energy-efficient capital equipment. However, electrical consumption control is the responsibility of all the employees of a sport facility. Examples include lighting in offices being turned off when not in use; lighting in courts, spectator areas, and other activity areas being dimmed or turned off when not in use; thermostats' values being lowered during down times and closed times (turn down 1 h before closing and turn up to 2 h before opening); and computers and other electronics being turned off when not in use.

To give a practical example, swimming pools represent the sport facilities that consumes most energy compared to the other ones. Swimming pool water needs to be continually heated in order to overcome the cooling effect of evaporation and maintain comfortable temperatures. It has also to be continuously filtered and treated, so it is not surprising that pools are significant users of energy. Pool halls and changing areas are typically kept warmer than other spaces, as pool users are wet and less dressed. Moreover, bathers consume large volumes of shower water, which adds to the overall energy consumption of pool facilities. Using energy efficiently, for example with the SportE2 solution, can save up to 25% of overall operating costs of a typical swimming pool. Implementing good energy management techniques can minimise consumption without lowering the standard of service to users. In order to achieve the greatest savings potential, pool hall managers should know where the majority of their energy is being consumed.

However, energy costs are among the biggest expenses for all types of sport facility (usually second to staffing). Taking steps to reduce these costs can significantly improve the operation of a sport facility by increasing the financial resources available for other areas. Many facility operators are looking for ways to lower utility expenses through the use of new building management technology, construction methods, and new product innovations.

[3] IBIS World

In each of the key consumption areas, there are three main opportunities to save energy:

- Refurbishment – energy saving measures taken when planning major building refurbishment can be extremely cost-effective;
- Maintenance – a number of energy efficiency measures can be carried out as part of routine maintenance for little or no extra cost;
- Control – all energy-consuming equipment should be controlled carefully to give the required conditions and switched off when not required.

The SportE2 solution focuses on maintenance and control, providing a scalable, flexible, non-invasive, cheap solution that increases the level of automation through ICTs where there is none or rather supports and optimizes the management of installations already automated and controlled by suitable BMS.

2.2 General architectural framework for integrated SportE2 system

The SPORTE2 integrated architecture describes conceptually the link between the different modules that compose the SPORTE2 system. In order to guaranty the interoperability and flexibility of the overall system, industry standards and widely supported communication protocols have been chosen.

Regarding to the low level communication protocol, KNX, BACNet and ModBUS are supported; in addition the integration between high level modules is supported by XML based Web-Service interfaces.

The picture below describes the SPORTE2 integrated architecture.

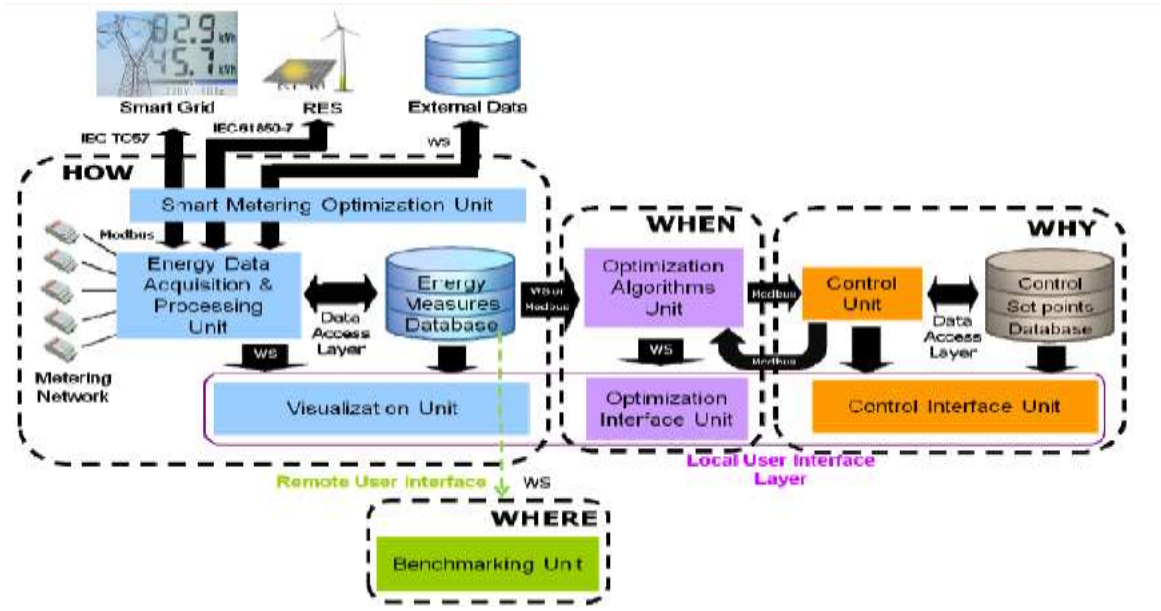

Figure 2.1 Integrated SPORTE2 system

Each of the SPORTE2 modules has well defined functionality:

- **HOW module**: Retrieves real time data to feed rest of the modules
- **WHEN module**: Deals with control loops and optimizations released by the WHY module
- **WHERE module**: Enables the energy performances across the managed facilities

- **WHY module**: Runs the optimization routines

The SPORTE2 architecture is modular and based on open-standards. This makes it more versatile and allows an easier adaptation to different facility types. Taking into consideration the functionalities described above and the interfaces between the modules, different deployments for the SPORTE2 are supported:

- **BMS based deployment**: Deployment taking advantage of the currently installed BMS. This type of deployments is based on software based integration
- **Non BMS based deployment**: This type of deployment integrates directly the field devices into the HOW and WHERE modules

The general deployment diagram is illustrated in the picture below.

SPORTE2 WHERE module and Local Database are installed within D'Appolonia Test Environment, but in the future they can be moved on a Cloud system. It can be accessed by using a Web browser connected to the internet.

SPORTE2 WHEN module communicates with **HOW**, **WHY** and External web services through Internet connection.

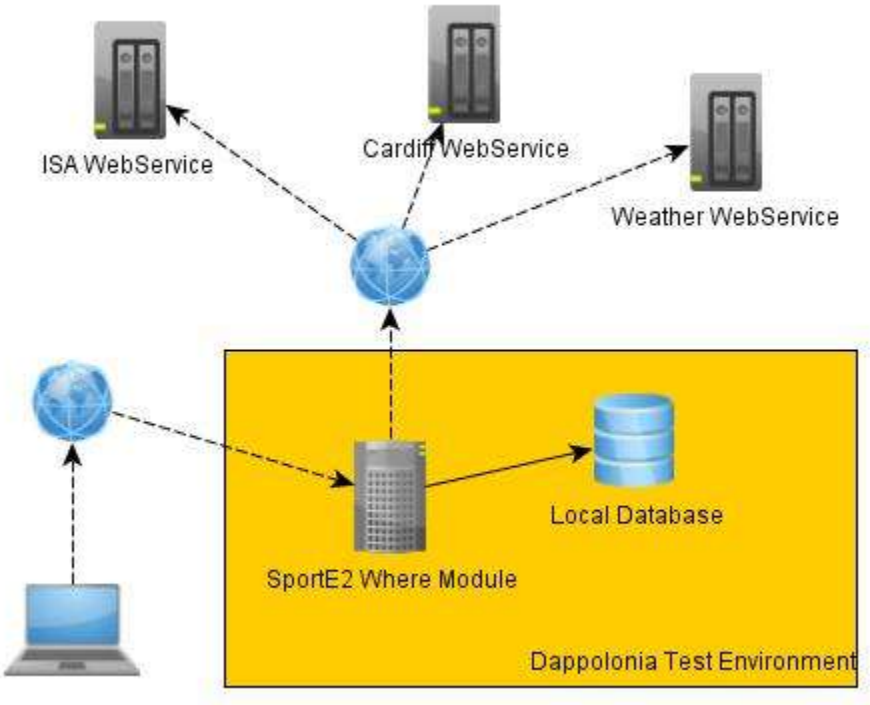

Figure 2.2 Deployment diagram

Thanks to the application of SportE2 solution to the three project pilots, we have developed expertise in three completely different contexts without having to revise the architecture designed and prototyped:

1. Highly automated context for EMTE pilot where an existing BMS is present
2. Slightly automated context for SELF pilot where a local control system is present

3. Context with lack of automation for FIDIA pilot where neither an existing BMS nor a local control system is present

3. SPORTE2 MODULES

3.1 HOW module overview

The HOW Module is a smart metering system dedicated to sports and recreational buildings able to provide aggregated information about the energy (consumption, usage, exchange and generation) and the comfort level in the facility. This module makes all the other modules possible by producing High Quality Data Sets.

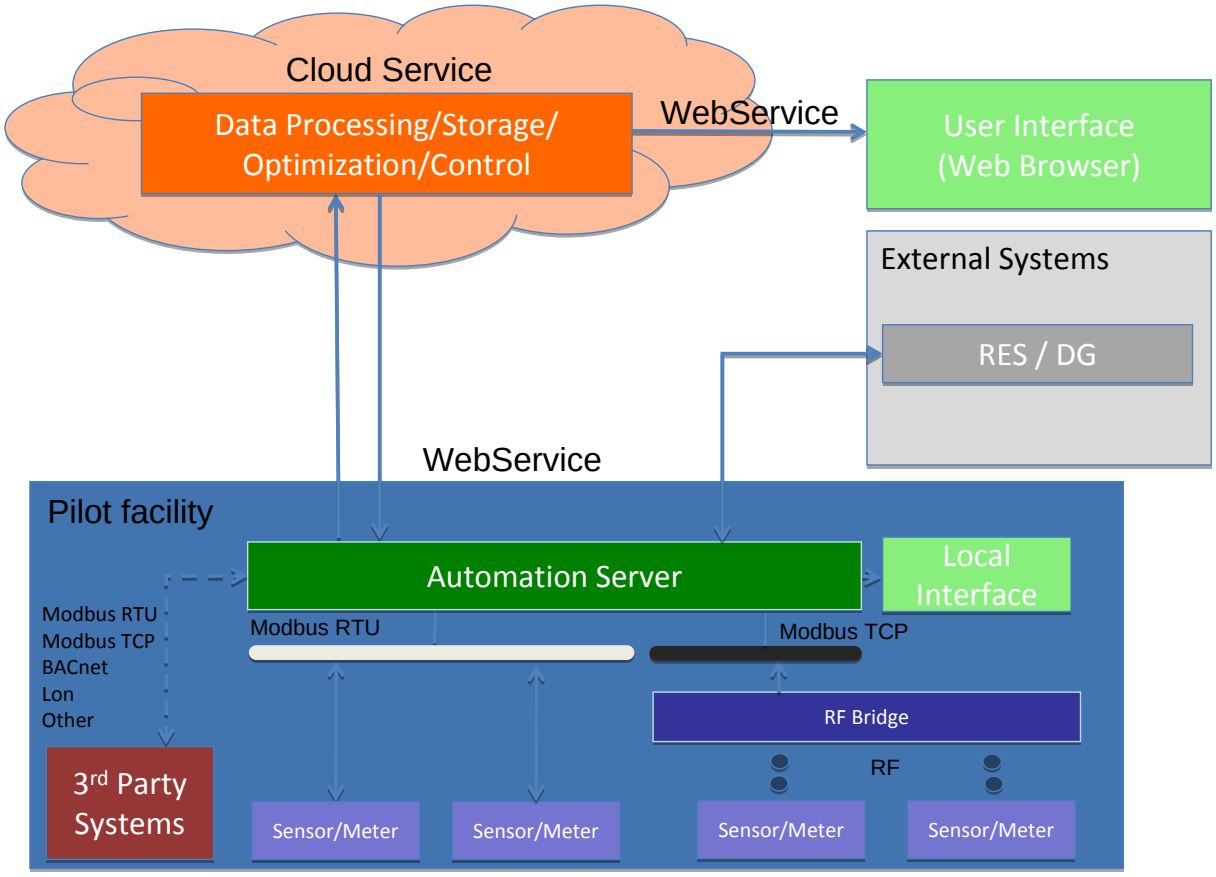

Figure 3.1: How Module Architecture

In the table below the main characteristics, the functionalities, the benefits, SW and HW requirements, and the relations between How module and the other SportE2 modules are listed. For further details on HOW module please refer to D2.4 How Module Complete.

Table 3.1: How module details

Main Characteristics	It is mainly composed of a field level, a local network, a cloud service for data processing and a user interface. The system is supported also with a stand-alone tool, named Sensor Optimization Unit, for the design of the sensor network in large spaces.
Functionalities	The HOW Module is a smart metering system able to provide high-level data on how the energy is used within the building and with which level of comfort.
Benefits	Awareness of how energy is used and used throughout the building; functional area-based analysis of the energy consumption; direct feedback for control strategies tuning.
Requirements	Internet connection
Relations to other SportE2 modules	The integration serves two main functions: to provide live, short-term and long term historical metering data for the other modules; and to provide additional computed variables used for the control or optimization.

3.2 WHEN module overview

Providing integrated control and energy management system, this module will establish the hardware, software and GUI that enable the control and management of lightning, heating and cooling, indoor air quality and ventilation, co-generation and renewable energy production by acquiring information from the smart metering network and from the site plants and analysing the demand and the usage of energy in sport facilities.

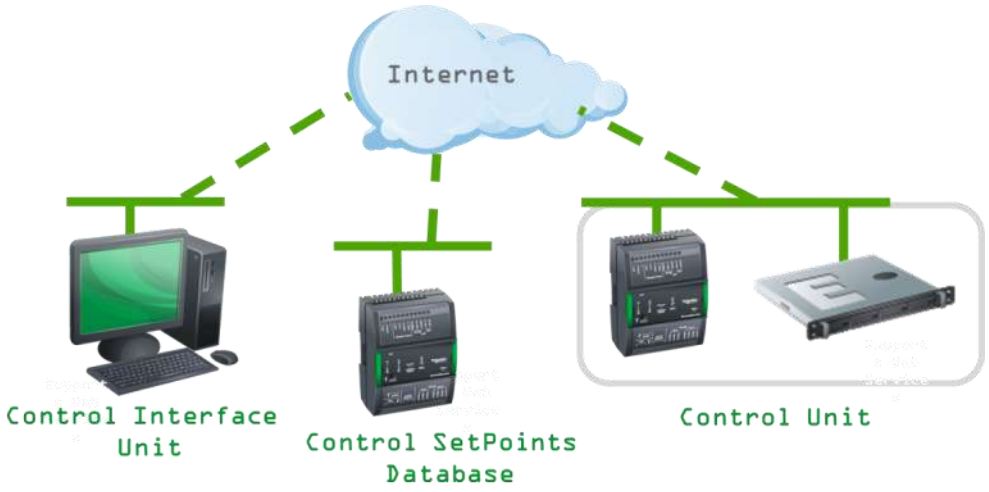

Figure 3.2: SportE^2 When module layout

The table below shows the main characteristics, the functionalities, the benefits, SW and HW requirements and the relations between WHEN module and the other SportE2 modules. For further details on WHEN module please refer to D3.4 When Module Complete.

Table 3.2: When module details

Main Characteristics	WHEN module consists essentially of a Control Unit and its I/O modules, a Control Set points Database and an Interface Unit. It is provided of a graphical, web-based, operator interface.
Functionalities	Provide a fully integrated, customized solution that ensures different players to have the most efficient and effectively managed building configuration for their needs or requirements.
Benefits	Provide to building managers supervision and management capabilities with respect to sport facilities plants/systems and spaces monitoring and control.
Requirements	The Local Area Network (LAN) shall be either a 10 or 100 Mpbs Ethernet network supporting BACnet, Modbus. Field devices such as sensors or actuators have to support Modbus TCP and RTU protocols natively or require the use of gateways. Unit Power Supply.
Relations to other SportE2 modules	The communication with the WHERE module is enabled by web services methods that can be accessed via Internet for getting the result data of the optimisation process. Interfacing with the WHEN module is the first stage for facilitating an automatic optimization process. WHEN module provides the data required for configuring various optimization scenarios associated with the pilots.

3.3 WHY module overview

This module has the capability to help the user manual control or to automatically control energy management decision and actions, leveraging smart metering data and making use of an integrated control system, focusing on energy optimisation.

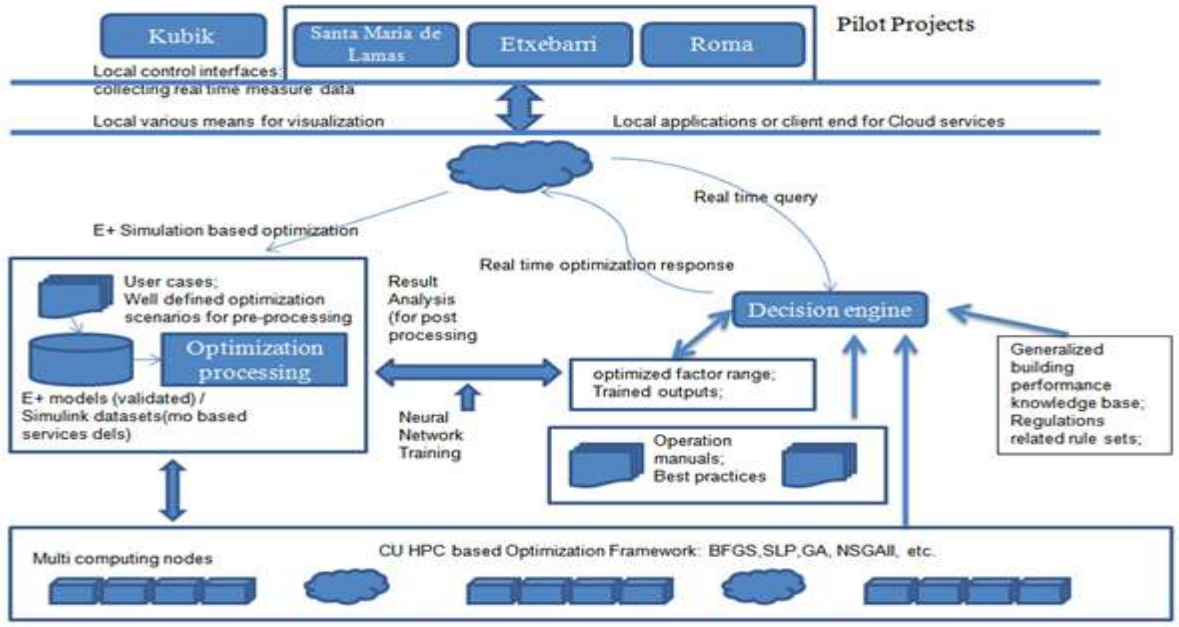

Figure 3.3. SportE2 WHY Module System Architecture and Data Flow

The table below shows the main characteristics, the functionalities, the benefits, SW and HW requirements, and the relations between WHY module and the other SportE2 modules. For further details on WHY module please refer to D4.4 Why Module Complete.

Table 3.3: Why module details

Main Characteristics	It consists of five components: (1) simulation engine – Simulink based or EnergyPlus based; (2) ANN prediction engine; (3) distributed optimization framework; (4) large scale Cloud supporting system; (5) communication among different modules.
Functionalities	Provide a continuously changing, context-based, optimization of the control variables (i.e. set points) to meet the scenario objectives and rely on the right computational power that can process up to thousands/millions of permutations (depending on the inherent complexity of the considered scenario) and consequently find the optimum set points.
Benefits	The entire optimization flow is fully functional and practically helping pilot facilities to achieve energy saving and other multi-objectives.
Requirements	Secure and reliable internet connection
Relations to other SportE2 modules	WHY module communicates with HOW module to get monitored sensor data, with WHEN module to deliver the optimized set points for actuating. All the communication are based on Web services.

3.4 WHERE module overview

This is a multi-facility energy benchmarking system. Inspired by the needs and requirements of the partners SELF and EMTE, together managing 19 facilities, this module will collect, analyse, and display energy demands, consumptions, production across multiple facilities.

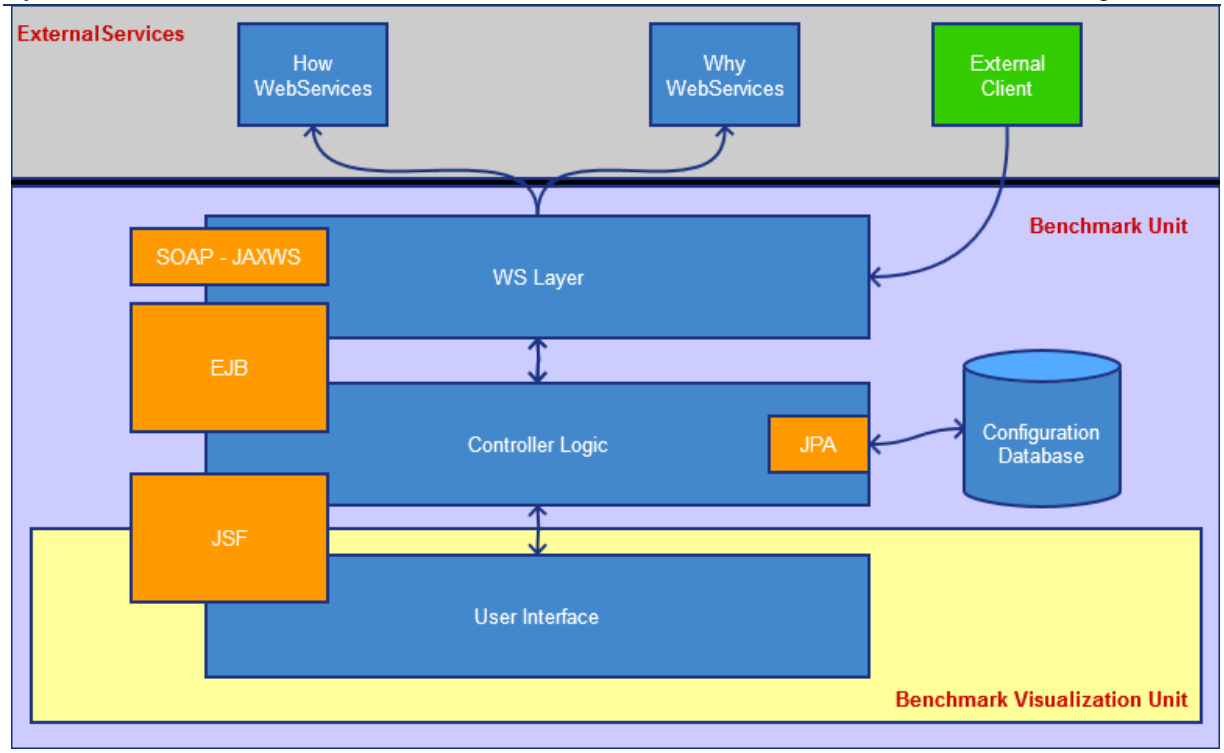

Figure 3.4: SportE2 Where module Application layers

The table below shows the main characteristics, the functionalities, the benefits, SW and HW requirements, and the relations between WHERE module and the other SportE2 modules. For further details on WHERE module please refer to D5.3 Where available as a Product Module.

Table 3.4: Where module details

Main Characteristics	The WHERE module comprises different components: Web Service (WS) Layer, Controller Logic, User Interface, Configuration Database.
Functionalities	Provides a web application for accessing to the information of each managed sport facility, externally to the facilities, to monitor the actual situation of energy demands, consumptions, and production. Offer benchmarking capabilities by means of the comparison of energy situations and measures from the different monitored and controlled facilities.
Benefits	Software interface provides information to human operators in the remote Data Center (Administrative Unit of the customer) in the form of: charts and Tables enabling historical data evaluation, comparison metrics, energy reports.
Requirements	Common internet browser (i.e., Mozilla Firefox, MS Internet Explorer, etc.), HTTP connection
Relations to other SportE2 modules	The communication with the others modules is enabled by standard Web Service interfaces that ensure loose-coupling interaction and then high flexibility to the SPORTE2 system as a whole.

4. SPORTE2 SYSTEM AS A PRODUCT

There are various possible application scenarios that can be optimized in a sport facility for reducing energy consumptions and maintaining wellness, health and safety measures. High level of user comfort is a mandatory requirement achieved by SportE2 solution through the monitoring of all comfort parameters continuously measured by the installed sensors. However, the selection of the feasible scenarios depends on several factors, which include energy audit results, practicability analysis and cost constrains.

A preliminary comprehensive energy audit is required to investigate the sport facility needs and then to identify the more energy consuming areas. The application scenarios built on the basis of the energy audit, need to be feasible and implementable. According to our experience, a detailed description of each identified use case scenario, the adopted methodology and its implementation is fully documented and available on D4.3 Why Module as a Product.

Therefore, in this section is briefly presented the experience grew in five implemented scenarios:

1. FIDIA: Optimisation of AHU system for regular swimming pool,
2. FIDIA: Optimisation of swimming pool Pump Control/Status
3. EMTE: Optimisation of HVAC fitness/gym room
4. EMTE: Optimisation of swimming pool Water Heating System by using solar thermal panels
5. EMTE: Optimisation of the logical control of the Lighting system
6. SELF: Optimisation of AHU system for Olympic swimming pool
7. SELF: Optimisation of the logical control of Boiler

In these five scenarios the integration of the SportE2 modules HOW, WHEN, WHY generates six different packages that have been implemented, tested and validated. For each scenario, the fourth module, WHERE, is an extension of the package composed by HOW, WHEN, WHY in the case a customer manages similar multiple facilities or needs to compare, control and optimise similar environments in different sport facilities.

For each installation of SportE2 system in a sport facility, along with these six packages, has been defined a baseline available in three different version characterised by price increases with the facility energy consumptions. The six packages above mentioned are financially handle like “add-on” that could be integrated depending on the type of facility considered. For further financial details please refer to D7.2 Business Plan.

This experience has led us to define six main configurable and customizable packages that are finite products ready to be put on the market. These packages are:

1. *SportE2 AHU Pool Package* refined on scenarios 1 and 6
2. *SportE2 Pool Package* refined on scenario 2
3. *SportE2 Fitness Package* refined on scenario 3
4. *SportE2 Solar Thermal Package* refined on scenario 4
5. *SportE2 Boiler Package* refined on scenario 7
6. *SportE2 Lighting Package* refined on scenario 5

4.1 SportE2 AHU Pool Package

The main objective of the *SportE2 AHU Pool Package* is to optimize the management of the indoor air treatment of swimming pools, minimising the energy consumption and maintaining the indoor comfort conditions.

This package has been refined thanks to the growing experience around two well defined and tested scenarios: FIDIA and SELF optimisation of AHU system for regular and Olympic swimming pools.

Background

FIDIA swimming pool area, a large volume with two pools takes a large part of energy consumption, more than 50 % of electricity consumption and even more of thermal energy onsite. In SELF pilot there are two pools, like for FIDIA, but the larger one is an Olympic pool. Swimming pools loose energy in many different ways, out of which evaporation is one of the largest sources of energy loss. The two scenarios considered for the SportE2 AHU Pool Package propose air treatment in the zones which aim to provide sufficient conditioned air to the areas to reduce evaporation of surface water. By controlling the supplied inlet air temperature, FIDIA AHU scenario can maintain comfort requirements whilst reducing energy usage. SELF AHU scenario also optimises the heating set point to ensure that there are right amount of heated air supplied during winter.

HOW module

In FIDIA pilot, the monitoring of energy, comfort and magnitudes for the control has been implemented. Also, the SOU was implemented to optimize the measurement of temperature and humidity in the environment.

The module performs the monitoring of the following variables:

- Swimming pool area total thermal and electrical energy consumption
- Pool Air temperature and relative humidity
- Pool occupancy (male and female)
- Pool air quality Cl2 and CO2
- Pool water temperature
- Pool supplied Air temperature and Air flow velocity

In SELF pilot, the swimming pool area where the sensor network optimization has been implemented into, has an external wall that is completely glazed with shading while the opposite side includes bleachers. The air heating and ventilation system is composed by two Air Handling Units providing the air supply and return through a distribution system described in details on D2.3 How Module as a Product. Also in this case the energy consumed by the swimming pool is metered together with the parameters needed for the monitoring and control of the indoor conditions.

The module performs the monitoring of the following variables:

- Swimming pool AHUs electrical consumption
- Total heat delivered from boiler to swimming pool AHUs
- Occupancy of swimming pool (male and female count)
- Chlorine sensor for the swimming pool air
- Swimming pool air duct Air speed 1 and 2
- Swimming pool area temperature and relative humidity
- Swimming pool CO2 concentration

WHEN module

In both scenarios, the main objective is the control of the temperature and the quality of the air inside the swimming pool through the proper management and optimisation of the air flow and time schedule.

The main automation based intervention performed in FIDIA entailed the pump control bleeding of the AHU and the fan control AHU of the pool, as well as the handling ventilation, hot water valves and dampers.

Instead in the Portuguese pilot, the automatic regulation has been done for controlling AHU pool, north tower small and big gym. The list of the control sensors and actuators exploited for those regulations comprises:

- Supply fan with modular speed
- Extraction fan with modular speed
- Air damper supply, expulsion and recovery
- Supply temperature
- Swimming pool area temperature, relative humidity and chlorine
- Extraction air CO2 sensor
- Supply valve, already installed on the pilot facilities

WHY module

The aim of the WHY module in this package is to optimise the set points air temperature inlet in order to achieve the optimal PMV with the minimum electrical and thermal energy consumption, on the basis of several input variables gathered form the How module and control systems of the When Module.

The input variables used for the optimisation are the following:

- Occupancy
- Indoor Temperature and relative humidity
- Water temperature
- Air temperature inlet
- Supplied air flow rate

In SELF, the module optimises supplied thermal energy and fan electrical consumption to achieve the optimal indoor thermal conditions minimizing the energy used for the air treatment.. The input variables used for the optimisation are the following:

- Occupancy
- Indoor temperature and relative humidity of pool area
- Supplied air flow rate
- CO2 Concentrations
- Thermostat set point
- Outdoor temperature and relative humidity

4.2 SportE2 Pool Package

The main objective of the *SportE2 Pool Package* is to optimise the water pumping system control in swimming pools, maintaining water quality whilst efficiently controlling pumps operation.

This package has been refined thanks to the growing experience around the scenario of FIDIA optimisation of swimming pool Pump Control/Status.

Background

Before Sporte2 intervention, the pumps in FIDIA worked 24 hours a day which results in huge energy consumption. The pumps control FIDIA rule based scenario aims to use pumps only when it is needed. A schedule has been thus introduced first to ensure the pumps (PUMP1, PUMP2, PUMP3) availability during various courses which take place in the area. For example, in periods with courses, two out of the three pumps (PUMP 1 AND PUMP 2) in FIDIA are turned on to allow a full water change. Whereas during the early morning hours, both these pumps are switched off for three hours (from 00:00 to 3:00). The third pump (PUMP 3) is always active and it turns on if the water temperature is lower than the required set point. The second pump (PUMP 2), during time periods when no courses are scheduled, can only be turned on based on the occupancy and water quality parameters (pH and chlorine). The best practise values programmed in the rules can be optimised as explained in the following section.

How module

The module performs the monitoring of the following variables:

- Swimming pool area total thermal and electrical energy consumption
- Total water consumption
- Pool occupancy (male and female)
- Pool water quality Cl2 and pH
- Pool water temperature

WHEN module

The main objective of the WHEN module is the control of the temperature and the quality of water in the swimming pool through the proper management and optimisation of set point temperature and time schedule. The main automation based intervention affected the control heat exchanger of the pump of the pool, the pump control bleeding showers and fan coil of the dressing room.

WHY module

The best practise values initially defined through literature and normative in rules of FIDIA pump control scenario, were adjusted and tuned, after their implementation in the given facility, once a decent set of monitored results will be available to study the current behaviour of the system. Historical data consisting of key variables/parameters collected from this scenario could be used for further analysis and these rules can be improved with time. The values, in FIDIA, were not optimised as frequently (or real time) as the other model based scenarios but over a period of time.

In further analysis, in the facility where the system will be installed, the behaviour of the set points (best practice values used in rules) could be analysed using statistical technique to find if any anomalies exist. According to the statistical results, set points could be updated using monitored data (min 6 months data) using ANN based optimisation process. In this process, the collected data could be used for ANN training and consequently the trained ANN could be embedded as a cost function engine into the optimisation process to determine the optimised set points.

The input variables used for the optimisation are the following:

- Number of Occupancy
- pH and Cl level in water

- Control pump status/power
- Electrical energy total, energy machine
- Water temperature
- Thermal Energy and Domestic hot water consumption

4.3 SportE2 Fitness Package

The main objective of the *SportE2 Fitness Package* is to optimise the indoor air quality of fitness rooms, minimising energy consumption but maximising indoor comfort.

This package has been refined thanks to the growing experience around the scenario of EMTE optimisation of HVAC fitness/gym room.

Background

A hybrid approach is developed to meet this multi-objective problem. In winter, the major objective is to reduce the heating energy consumption by optimising the outside fan ventilation rate. The pilot does not have any cooling system in place and hence in the summer, natural ventilation using autonomous windows is applied on a rule basis, to try meet most of the cooling demand. As a backup, fan coil can also be used to provide mechanical ventilation without any heating. In the case where the facility in which the package will be installed, also have a cooling system, we will proceed with the optimization even in summer.

HOW module

The sensor network optimization is tailored for the fitness room called Room#1. Room#1 is a medium volume room, it has two neighbour rooms and faces a corridor, it has three windows and the heating system is a single unit of fan coil with three inlets as shown in D2.3 How Module as a Product.

The module performs the monitoring of the following variables:

- Room#1 total thermal energy consumption
- Room#1 Air temperature and relative humidity
- Room#1 occupancy
- Room#1 CO2 level
- Supply Air flow velocity

WHEN module

The main characteristics of the WHEN module for this package is its interoperability; in facts, it lays over the local BMS, in the sense that all the field controls are performed through it. This fact is not a limitation but is an added value to the demonstrated scalability and interoperability of the module.

WHEN Module integrates both BMS variables and HOW Module ones and it delivers optimized control set points and rules (from WHY module) to the local BMS without directly acting on the physical field layer. Only lighting system is not integrated into the local BMS and its control is done directly by the WHEN Module.

The module controls the following variables:

- Electric energy consumption for lighting and fan coil of Room#1
- Total thermal energy consumption of Room#1
- Air temperature and Relative humidity (SOU)

- CO2 level
- Supply Air flow velocity

WHY module

The aim of the WHY module in this package is to optimise the set points fan coil heating, energy consumptions, PMV, on the basis of some input variables.

The goals and scope of the HVAC scenario for the Room#1 lead us to divide the scenario into two sub scenarios based on the times of the season, which are the summer times and winter times. The main reason to divide this scenario into two sub scenarios is related to the objectives in each term. Therefore, two different ANN models are generated for this scenario to consider both summer and winter times.

The input variables used for the optimisation are the following:

- Occupancy
- Air temperature and relative humidity
- CO2 Concentrations
- Activity type
- Thermostat heating set point
- Supplied air flow rate
- Outdoor temperature and relative humidity

4.4 SportE2 Solar Thermal Package

The main objective of the *SportE2 Solar Thermal Package* is to optimise the usage of hot water produced from solar thermal systems, minimising the thermal energy consumption.

This package has been refined thanks to the growing experience around the scenario of EMTE optimisation of swimming pool Water Heating System by using solar thermal panels.

Background

The EMTE pilot currently adopts a fixed schedule executed by a local BMS for renovation.

The aim of EMTE water heating scenario is to maximise the usage of installed solar thermal energy to heat water used in the adult swimming pool. According to Spanish regulations, 5% of total swimming pool volume needs to be renovated every 24 hours. The optimization rules developed in the EMTE scenario will make sure:

1. When the water temperature in the solar tank is favourable, the water will be used to supply the swimming pool and ACS (hot sanitary water tank) when the temperature there drops below the required set point.
2. The 5 % renovation of water (about 20 m^3 of water in EMTE adult swimming pool) will be achieved every 24 hours. In order to meet this requirement, the water flow going into the swimming pool needs to be checked (for renovation) daily between 8 am to 10 pm.

HOW module

The module performs for the monitoring of the following variables:

- Thermal energy through heat exchanger adult pool for boilers and for solar system
- Pool water temperature
- Water tank temperature

- Pool area occupancy 1, 2 and 3

WHEN module

This module offers an integrated control system able to manage and control the water pump, making the facility manager able to control the facility swimming pool trough the meters installed in UC-1. The meters analyze the water flow in order to minimise energy consumption without to reduce the pool water comfort.

The module controls the following variables:

- Solar total thermal energy production
- Pre-heated water temperature after the pre-heating heat exchanger
- Pool Water temperature
- Water tank temperature
- Water supply temperature to pool
- Level of the water of the tank
- Pool area occupancy 1,2 and 3

WHY module

WHY module in this package is referred to optimization of the solar panels system associated with the water treatment renovation of the pool. It is based on measured data to train a neural network that will provide the optimal rules in order to optimize the use of the solar panels system.

The monitored historical data (at least a year) is used to generate a dynamic schedule for a month or a season. The new schedule will take into account the occupancy period to predict how many 'hours' that solar water can be utilised to meet heating demand. Schedule is generated in a format of '1'/'0', where '1' stands for ON for renovation and '0' means renovation OFF. If the renovation has not been completed during the occupancy hours, other energy sources are used to renovate the pool water.

The module optimises the following variables:

- Occupancy
- Water temperature of swimming pool
- Air temperature and relative humidity in the swimming pool
- Valve Status after heat exchanger (connecting solar tank and adult swimming pool)
- Water temperature of solar tank
- Energy consumption (heat meter) for heat exchanger between solar system and adult swimming pool and between boiler and adult swimming pool
- Schedule for renovation

4.5 SportE2 Boiler Package

This package is composed by the How and When modules without the Why module because the application environment was completely automation based.

Background

In SELF pilot there were three systems for the generation of hot water: solar system, CHP, boilers. This scenario focuses on two gas boilers usage optimization. In this real case scenario,

it was not possible to integrate the functionality of the boilers through a communication bus. For this reason the set point temperature will only be changed from the control panel of the individual boilers. The circuit consisted of 2 pumps from 22 kW each, that after the intervention are handled by a dedicated clock and direct command.

HOW module

The module performs the monitoring of one single variable: Total heat delivered from boiler to swimming pool AHUs.

WHEN module

The clocks currently installed was replaced with two digital commands on AS in order to control the switching on and off according to actual needs and not just through the clock.

Furthermore, two inverters whose frequency can be varied according to two curves were installed, one linked to the outside temperature and the other to the occupation.

WHY module

Due the fact this is a completely based automation package no optimisation has been integrated.

4.6 SportE2 Lighting Package

Background

For EMTE pilot, the lighting level is monitored in different areas of the facility. The acquired lighting level will be used as visual comfort parameter for all the areas where a sensor is installed and, in some functional areas, it is used also for actuating a control of the lighting system. The areas in which are installed some sensors are: multisport court area, corridor, gym area.

HOW module

The module performs the monitoring of electrical energy consumption and the illuminance level inside the areas where the control is applied.

WHEN module

The lighting system is not integrated into the local BMS and its control will be done directly by the WHEN Module. Lighting control foresees the automatic switching of lights in different areas: multisport court, pool, corridors, gym room, fitness room. Light level sensors (e.g. sensors for controls) were installed while lights will be controlled by Schneider Electric Xenta 421 modules connected via LON to the AS.

WHY module

Due the fact this is a completely based automation package no optimisation has been integrated.

5. SPORTE2 SYSTEM APPLICATION GUIDELINES

Along with the purchase of one or more SportE2 packages for optimising energy consumptions and maintaining user comfort in sport facilities, we offer also something more; a sequence of preparatory activities that are necessary for the optimization of the integration of the four modules presented in Chapter 3 SportE2 Modules.

The activities to be performed for implementing one SportE2 package comprise:

1. Energy Audit
2. Structural Audit (explicitly requested by customer)
3. Planning
4. Modelling
5. Sensors and Actuators (Eletrical Meter + Heat Meter baseline)
6. Installation Support
7. Automation Server + configuration
8. Optimization system
9. Training

The first activity, Energy Audit, is a preliminary activity that is useful to define a snapshot of the energy management in the facility. Through the study and consultation of energy bills, plant of the sport facility, layout of the installed equipment and pre-requirements like internet connection, it is possible to extract the status of the existing equipment, the guidelines on "how to optimize the use of existing equipment", the identification of the most energy absorbing areas, of the needed automation interventions and recommendations and the outline design of SportE2 package.

The Structural Audit is performed only on explicit request of the facility owner and aims to analyze the facility from the structural point of view, to identify the general condition of the buildings including physical characteristics, details and materials of the existing building components with respect to the existing codes and regulations. Specific building deficiencies (based on site reviews) are noted including the assignment of prioritization levels for the various building deficiencies with suggestion for remedial repair of the reported deficiencies.

The activities from 3 to 8 are purely technical. The planning provides an input to energy and structural audit in addition to define energy saving scenarios and types and numbers of the sensors that have to be installed in the sport facility. With proper planning, an organization can save costs and win efficiency.

The Modelling activity, defines a model with a modelling software for the considered facility. This model is needed to extract virtually the facility energy system behaviour after performing the Energy and eventually the Structural Audit, on the operative point of view.

The fifth activity is called Material Procurement and consists of the purchase of sensors, actuators, field devices, that was already identified in the Modelling phase. Planning, Modelling and Material Procurement are activities performed specifically for each SportE2 packages, developed ad hoc for the interested sport facility.

Regards to the sixth activity, Installation Support, the most suitable choice is to contact local systems installer. The consortium will provide to local systems installer, full English documentation shared all around Europe schemas and technical support developed thanks to

the learning experience during the project. It is recommended that the facility owners would subscribe a one-year maintenance contract with local systems installer specific for SportE2 package to deal with possible installation issues.

The seventh activity performs the installation, and configuration of the Automation Server, ad hoc for the selected SportE2 package. The Automation Server installation instruction are described in details on D 3.4 When module complete.

The Optimization System leads a way of utilizing Cloud based High Performance Computing (HPC) for smart building energy management, which fundamentally makes it possible using powerful optimization to provide timely responses without over simplifying the analysis models.

The Training is the last but not least activity that has not to be underestimate and can be performed on site or remotely, sending specific documentation for a full understanding of all the functionalities of the modules composing the chosen SportE2 package.

6. CONCLUSIONS

This document presented the integrated SportE2 solution composed by HOW, WHEN, and WHY modules, plus WHERE whether there is the customer need to perform multi facility benchmarking.

The SportE2 solution is actually available in six packages:

1. *SportE2 AHU Pool Package*
2. *SportE2 Pool Package*
3. *SportE2 Fitness Package*
4. *SportE2 Solar Thermal Package*
5. *SportE2 Boiler Package* refined on activity performed on SELF pilot
6. *SportE2 Lighting Package* refined on activity performed on EMTE pilot

These packages have been defined and tested during the experience developed on the field and will be appropriately configured and customized on the customer particular needs and wishes to improve energy efficiency in sport facilities and maintain user comfort.

The main benefits presented by SportE2 System Product are:

1. Awareness of how energy is produced and used throughout the building;
2. Functional area-based analysis of the energy consumption;
3. Automated control of actuators and control devices installed in the sport facility;
4. Implementation of basic optimization rules based on past experience and historical data;
5. Scheduling of control actions (e.g. activating and deactivating water pumps or boilers or air handling units at specific time during the day).
6. Provides alarms in case of malfunctioning of equipment, supporting predicting maintenance;
7. Real-time optimisation system, exploiting a cloud-based infrastructure; which can be executed autonomously or by facility managers through specific software interface.

The integration of WHERE module leads to one additional benefit:

8. Allows multi-facility analysis, based on KPIs, exploiting weather forecast and GIS data.

The Validation Campaign description will be presented in the deliverables dedicated to each Pilot (D6.2, D6.3, and D6.4).

For exploitation of SportE2 as a product, further information is provided within D7.2 Business Plan Competitive Analysis.