Green@Hospital project

Final report

Project Acronym	:	Green@Hospital
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Project coordinator		Cristina Cristalli (AEA Srl – Loccioni Group)
		c.cristalli@loccioni.com
		+39 0731 816 280
Website	:	www.greenhospital-project.eu
Web platform		www.greenhospital-emcs.eu

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1. Introduction

Hospitals are known to be among the most energy consuming public buildings due to aging building stock, 24/7 operation and high comfort requirements. Governments spending reviews rather than European environmental targets require low cost investments able of creating healthier comfort conditions, energy savings and lower CO_2 emissions. There is a growing urgency to implement ecological solutions promoting the health of people and of the environment.

Green@Hospital goes in this direction using Information and Communication Technologies to **"Re-energyze healthcare"**. Green@Hospital energy saving solutions allows having more resources available for medical treatments, guaranteeing a better healthcare quality and preserving the environment.

Four pilot hospitals, two research centers and five firms have worked together since 2012 testing innovative solutions in real operating conditions. Important savings have been reached exceeding the expectations and replicability has been verified, including the calculation of the Pay Back Time. The tested solutions are suitable to be easily replicated in other healthcare facilities reducing by **15.4%** the energy consumption in the selected areas.

The main project output is the Web based Energy Management and Control System which communicates with the hospital facilities, integrates different energy systems and implements energy saving strategies. A multidisciplinary team has identified, through an energy audit, nine energy saving solution sets concerning: lighting, heating, ventilation and air conditioning, data centre cooling and surgery theaters ventilation. Then models and software simulations have been used to calculate the energy saving potential of each solution set. Advanced algorithms have been developed based on fuzzy architecture which demonstrate significant energy savings on the developed thermal and lighting model.Pilot Hospitals

Green@Hospital demonstrated the validity of the solutions in real operating conditions involving in the project four European hospitals. Each hospital made available and tested the developed technologies while normalization factors were identified to predict the benefit of the same solutions in other operating conditions.

Hereafter Green@Hospital pilots are briefly introduced.

Azienda Ospedaliero Universitaria Ospedali Riuniti Umberto I- G.M. Lancisi – G. Salesi (AOR)

Location: Ancona, Italy	Beds: 1000
Surface: 120,000 m^2	Employees: 3100
Built/Restored: 1970/2001	Surgical rooms: 18

A new lighting system with presence-sensors, LED lights and smart controllers, has been implemented in different areas of the hospital. It guarantees optimal comfort light level mixing natural and artificial light in the departments of the onco-hematological path. Energy-saving strategies have been implemented also in Agora, the hospital Data Centre.

Hospital Virgen de las Nieves of the Servicio Andaluz de Salud (HVN)
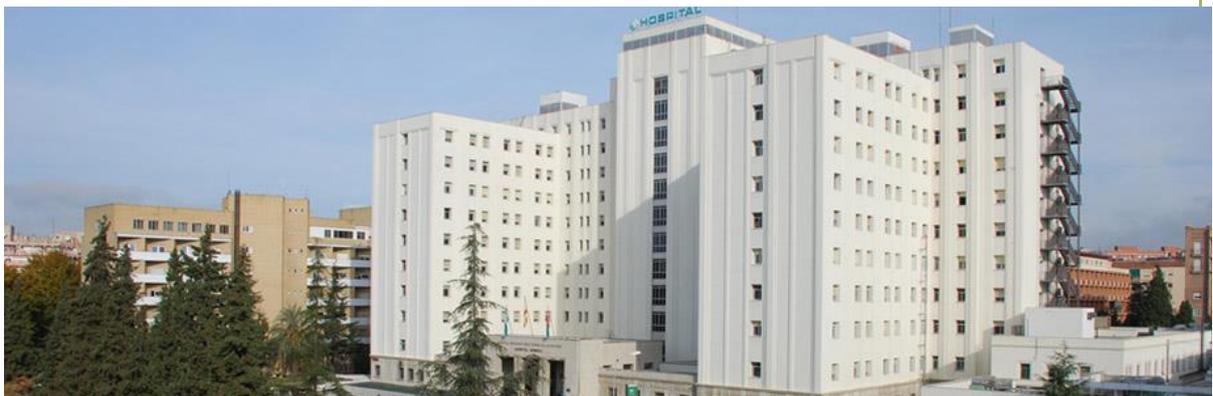
Location: Granada, Spain	Beds: 915
Surface: 133,600 m^2(11 buildings)	Employees: 4,500
Built/Restored: 1953/1984	Surgical rooms: 41

New sensors and new controllers have been installed in the Emergency Area and in the surgery theatres to save energy through an improved control applied to Air Handling Units. Before implementation, the impact of the new solutions has been simulated using advanced software tools. New meters have been installed in order to reduce the energy needed to cool down the Data Center.

General Hospital Chania Saint George (SGH)

Location: Chania, Greece

Surface: 51,000 m^2

Built/Restored: 2000

Beds: 460

Employees: 1150

Surgical rooms: 17

New controllers have been installed to manage artificial lights and fan coils in the pediatric ward. Some rooms were equipped with light and presence sensors, window contact sensors and comfort sensors. New algorithms have been developed in order to guarantee optimal lighting and thermo-hygrometric comfort conditions to room occupants.

Hospital de Mollet (HML)

Location: Mollet, Spain

Surface: 26,645 m^2

Built/Restored: 2010

Beds: 160

Employees: 700

Surgical rooms: 6

This hospital is equipped with geothermal heat pumps, gas boilers and chillers. Meters have been installed to support the management of the heating and cooling system according to seasons and loads. Furthermore, an innovative control strategy based on biological particle concentration detection tested in surgery theaters ensures safe conditions while reducing energy wastes.

2. Consortium

Green@Hospital project was conceived to help hospitals to save energy through the most modern ICT technologies and ad-hoc new algorithms. To reach the ambitious goals a consortium consisting of four hospitals, two research centers and five companies was put together and worked together since 2012 testing innovative solutions in real operating conditions.
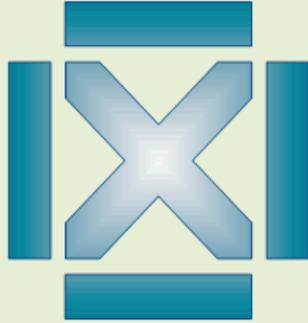
Hereafter project partners are briefly introduced.

LOCCIONI	**AEA Srl - Loccioni Group (AEA)** integrates its skills in measurement and testing for quality control, automation, ICT and service on several fields among which are Energy, Environment, Industry, Humancare and Mobility. Loccioni Group has 384 direct employees, with a turnover in 2014 of 70 M€ and operates in 40 countries around the world. 5% of the turnover is invested in R&D activities. ROLE: Project coordinator, web platform developer, responsible for data validation, Italian pilot support Contact: Cristina Cristalli c.cristalli@loccioni.com
Schneider Electric	**Schneider Electric (SCH)** offers integrated solutions across multiple market segments, including leadership positions in energy and infrastructure, industrial processes, building automation and data centres/networks, as well as a broad presence in residential applications. Company's 160,000 employees achieved sales of 24 billion Euros in 2010. In Italy there are more than 2750 employees, including front-office and production. ROLE: Leader solution set identification, installation and maintenance. Contact: Giacomo Grigis giacomo.grigis@schneider-electric.com
	The **Technical University of Crete (TUC)** was founded in 1978 and educates students on both undergraduate and graduate levels. Two research groups are involved in the project: Energy Management in the Built Environment Research Unit which covers a wide range of knowledge subjects on energy efficiency in buildings and built environment. Electric Circuits and Renewable Energy Sources Laboratory (ECRESL) with significant contribution in the operation of energy efficient buildings and renewable sources systems. ROLE: development and testing of the building optimisation and control algorithms leadership, Greek pilot support. Contact: Denia Kolokotsa dkolokotsa@enveng.tuc.gr

IREC logo	**IREC** is the leading research centre in energy in Catalonia. Created in 2008, it specializes in researching and developing technology in connection with energy savings and efficiency and with renewable energies. More specifically, it has lines of work in technologies related to micro-grids, electric vehicles, energy storage, efficiency in buildings, bio energy and bio fuels and offshore wind energy. The centre has about 160 researchers and highly-qualified engineers. ROLE: models and control algorithm development, Spanish pilot support. Contact: Jaume Salom jsalom@irec.cat
Dalkia Catalunya logo	**Dalkia Catalunya (AGE)**, with over 500 employees and a turnover of more than 45 M€, has provided facilities, maintenance and technical management of energy since 1974. Dalkia Group leverages their expertise to help customers analyses production processes, boostes productivity and operating efficiency, and services and maintains the equipment. It also manages high-tech and efficient energy technology for energy production such as the cogeneration and the district heating and cooling. ROLE: Energy audit performance, Spanish pilot support Contact: Ferran Abad ferran.abad@veolia.com
if logo	**IF Technology B.V. (IFTEC)** was established in 1989 and its core competence is about Ground Source energy. A skilled team of geologists, hydrologists, civil and well engineers offer consultancy to any ground source energy related problem. A multi-disciplinary approach is applied to projects providing risk assessments, permit applications, technical and financial analysis and engineering. IF technology counts on 55 professionals and has an experience on more than 1,000 geothermal projects. ROLE: geothermal system optimization leadership. Contact: Martijin van Aarssen M.vanAarssen@iftechnology.nl
Deerns logo	**Deerns Raadgevende Ingenieurs BV (DEE)** is a multi-disciplinary consulting and engineering firm founded in 1928 with its headquarters in the Netherlands and multiple offices in different parts of the world, including the United States, Germany, France, Spain, the United Kingdom, and Dubai. Deerns is focused on designing and managing the implementation of critical infrastructures including data centres, airports, hospitals, clean rooms, and labs. This area of expertise, Deerns has grown into one of the largest independent consulting firms in the international engineering services industry with 450 engineers employed worldwide. ROLE: Exploitation management Contact: Goffe Schat goffe.schat@deerns.com

	AZIENDA OSPEDALIERO UNIVERSITARIA OSPEDALI RIUNITI Umberto I-G.M. Lancisi – G. Salesi. (AOR) is a University hospital and part of the National Health Service working in cooperation with Polytechnic University of Marche, Faculty of Medicine and Surgery. The faculty has long experience in international academic research whereas the hospital is the most important one of Marche Region. ROLE: Italian pilot testing lighting and data centre cooling solutions, dissemination leader Contact: Roberto Penna r.penna@ospedaliriuniti.marche.it
	Servicio Andaluz de Salud (SAS) is an autonomous body attached to the Ministry of Health of the Autonomic Government of Andalusia including 1,491 primary care centers, 29 hospitals and 84.706 employees. The University Hospital Virgen de las Nieves, one of SAS main hospitals, is among the Green@Hospital project pilots. It offers a wealth of health services, and the number of professionals working in is close to 5,000. ROLE: Spanish Pilot testing HVAC and data centre cooling solutions Contact: Jesus Arbol jesus.arbol.sspa@juntadeandalucia.es
	General Hospital Chania Saint George (SGH) was founded in the late 19th century and was initially placed in the old town of Chania. In 1905 the hospital was moved to a new building, was nationalized in 1948 and was named General Hospital of Chania "Saint George". Today Saint George Hospital of Chania Crete is a hospital with 450 beds and is situated in new modern premises in Mournies Chania, expanded to an area of 49 400 m². Role: Greek pilot testing lighting and HVAC solutions Contact: Emmanouil Papadogiannis papaem@cyta.gr
	Hospital de Mollet of the **Fundacio Sanitaria de Mollet (HML)** was built in 2010 and can be considered a pioneer public hospital in environmental responsibility and energy efficiency. It provides coverage to over 150,000 inhabitants of 10 municipalities of East and West Vallès (Barcelona, Spain). The hospital covers an area of 27,000 m², it has 160 beds, 42 consulting rooms and 6 operating theatres. Role: Spanish pilot testing HVAC and surgery ventilation solutions Contact: David Barrachina d.barrachina@fsm.cat

3. Project objectives

The Green@Hospital project aimed at delivering a Web-based Energy Management and Control System (Web-EMCS) that integrates multiple building systems, monitors and controls building systems at the component-level and implements new algorithms tuned on the real acquired data for the optimization of energy consumption in specific Hospital applications. The Web-EMCS makes results available to the energy manager, the hospital employees, users and visitors through web interface for a better management of energy resources.

The percentage total reduction of the energy consumption in real operational conditions was estimated to range between 15% and 20%, basically depending on the starting infrastructures and technologies already present in the hospital where the Web-EMCS is installed, directly affecting the optimal energy management strategies.

A final but not less important objective of the Green@Hospital project was related to the development of an automatic performance monitoring (implemented in the Web-EMCS system) and of a maintenance service whose function is to guarantee the improved energy performance over time.

Energy saving solution sets selected for each of the four pilot hospitals had to be validated under real operating conditions, for a period of at least 12 months.

The specific Green@Hospital objectives have been:

-   To develop a standard benchmarking model for energy measurement in hospital environment

-   To develop and Integrate a Web based Energy Management and Control System

-   To develop holistic control algorithms for energy consumption optimization

-   To implement and validate the proposed solution in the pilot hospitals

-   To implement a Maintenance service

4. Technical activities

The activities performed to reach the project objectives have been organized into six work packages. The interaction among the Work Packages are presented in the following PERT diagram. The tasks performed are briefly detailed in this paragraph.
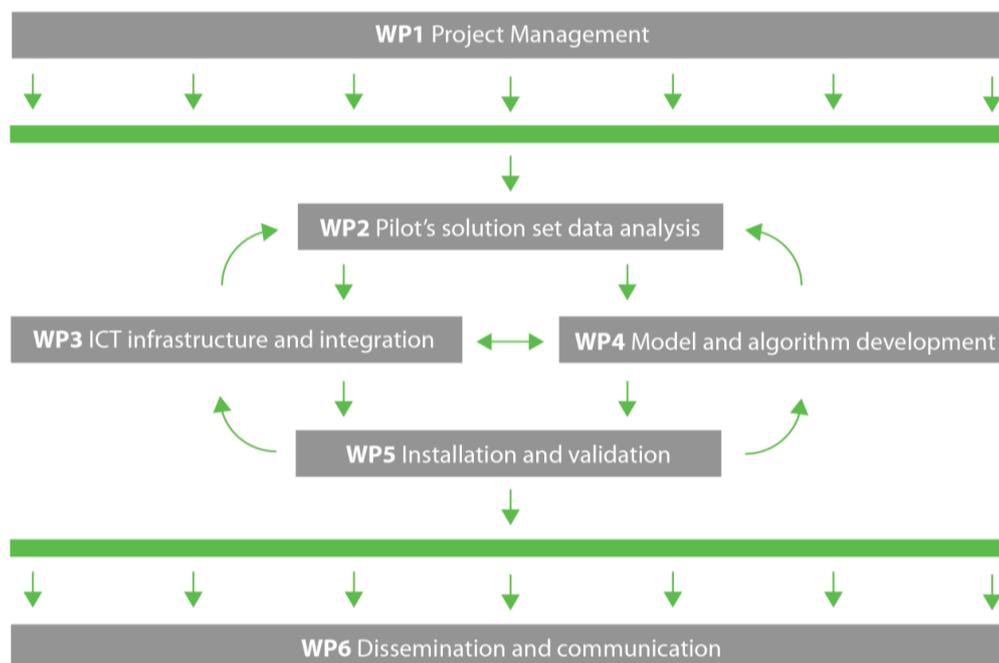
While **WP1** was dedicated to project management and **WP6** to project dissemination, communication, and exploitation the other work packages dealt with technical development.

WP2 was devoted to energy saving solution set identification. An energy audit procedure was defined and applied in pilot hospitals. After the definition of the audit team, questionnaires were submitted to different stakeholders. Data were collected through documental analysis and technical inspections including ICT architectures. Nine energy savings solution sets were selected concerning artificial lighting, HVAC, data centre cooling and surgery theatres ventilation. Energy saving potential for each solution was assessed through data collected and models. Finally a benchmarking model was defined associating energy consumption to a list of KPIs.

Information collected was used in **WP3** to define the communication strategies among the Web-based Energy Management and Control System and the subsystems installed in the pilot hospitals. For each pilot a VPN connection was created, a communication framework was installed and specific drivers were developed. Afterwards the overall Web-EMCS architecture based on a tree and node structure was set and specific acquisition services, business logic services and visualization services were implemented. Specific GUIs were dedicated to technical users to general users displaying data collected from the fields and energy savings obtained from each solution set. The platform, named Green@ platform, is online since January 2014 and available at this URL www.greenhospital-emcs.eu.

Solution sets chosen in WP2 were modelled using simulation tools in **WP4**. Models were used to calculate the energy saving potentials of each solution set and to test energy saving algorithms before implementation. For each solution set, a list of modeling strategies and tools was analyzed in order to choose the most promising, the model architecture was defined and the model developed and validated. Building Optimization and Control algorithms were developed for each solution set based on fuzzy logics and artificial neural networks. Hardware and software based safety features were implemented in order to guarantee safe operation in case of system failure.

Developed control strategies were implemented in **WP5** and solution sets installation was finalized integrating new variables in the Web-EMCS. A data validation procedure was set up and new Web-EMCS tools were developed according to user requirements addressing data management and system maintenance issues (Dashboard, Configuration, Workbench, System monitor, EMS writer). Control algorithms were fine tuned. Data collected were validated and savings achieved were calculated according to ICT PSP project common methodology and presented in terms of energetic, economic and environmental figures. The impact of tested solutions in the overall hospital facility, in hospitals with different climate and internal loads and in other public buildings were assessed. Maintenance guidelines to make savings durable were developed from literature and pilot experience.

5. Main challenges

The planning and the execution of the activities described in the previous chapter required to overcome several challenges. Below the most challenging tasks are presented together with the solutions adopted.

5.1.   Energy auditing

Energy Audit was the main task during the first year of the project. It proved to be one of the most critical project tasks for several reasons:

- It involved multidisciplinary teams

- It involved personnel from different project partners

- Most of the data were available just in paper form and in pilot national language

- Some data were missing or owned by third parties.

The complexity of this task has been clear since the project planning but its toughness was underestimated.

The definition of an energy audit procedure helped a lot in maintaining the activities performed in different pilots coherent. Particularly the definition of multidisciplinary teams merging personnel working for different project partners allowed providing for each hospital the required expertise.

Meetings where organized with third parties to arrange how to share data owned by them. However the cooperation revealed to be not so open especially regarding energy consumption data, considered by the third party "Business Critical".

Although these preventive measures where agreed, data collection in pilot hospitals revealed to be a process longer than expected and delays encountered in this task affected also other tasks.

5.2.   Web-EMCS development

The Web based Energy Management and Control system is one of the main project output and the activities connected to its development were critical for the project success.

The following points made this task so challenging:

- A completely new architecture had to be developed.

- Each hospital has different ICT architectures and different data access policies.

- Different hospital technical teams were involved in this task such as:

    o IT department

    o Facility management

    o Hospital engineering

- The platform is addressed to both technical and non technical stakeholders.

- The platform was developed according to stakeholders requirements and their requirements could not be planned at the beginning of the project.

Further difficulties emerged during the project:

- Dealing with complex and/or old systems required to install new hardware devices increasing hospital integration time due to hardware purchasing and installation.

- Some connections between hospitals and the Web-EMCS proved to be unreliable due to hardware failure and software bugs.

5.3. Models and algorithms development and implementation

Models and algorithms development and integration require a deep knowledge of the physical system to be modeled and a clear figure about the variables to be read and written. Moreover model validation and training (in case of soft computing techniques) require a great amount of validated data. The complexity of the physical system and the variety of operating conditions increase the effort needed to develop models and algorithms.

Furthermore modeling and implementation activities involved different partners and different software: compatibility issues had to be faced but these difficulties were overcome through frequent conference calls among involved partners.

The lack of information concerning the physical systems to be modeled caused great difficulties in model design and model training process. In order not to delay too much model finalization, soft computing models were trained using data obtained through dynamic simulations. Then when monitored data were available model were trained again using real data.

5.4. Installation and Validation

Implementing a new infrastructure in an active hospital ward operating on critical systems such as artificial lighting, HVAC, data centers and surgery room ventilation system is a critical task. It requires a big coordination effort in order to avoid disruptions in healthcare activities and preserve patients and clinicians safety.

Installation activities vary case by case but a list of common actions to be performed can be highlighted:

- Clinicians involvement

- Installation planning (it usually requires the temporary stop of involved technical system activity)

- Eventual involvement of third parties required for:

    o working on switchboards

    o integrating the new infrastructure with the existing one

    o Replaced hardware disposal

- Area cleaning and disinfection

- Documentation update

With respect to validation process the identification of a reliable baseline and the respect of a common methodology with the other ICT PSP project is a key point to obtain trustworthy and comparable data.

Baseline identification process was quite complex since project schedule did not plan a long period between installation and test period. For this reason baseline had to be built interpolating available data or assessing indirectly the required variable from existing databases.

5.5.   Project coordination

Technical and financial project coordination was a challenging task for several reasons:

- Project coordinator (AEA) was at its first experience as project coordinator of European project.

- Most of the partners were at their first experience in European funded projects (namely SCH Italy, AGE, IFTEC, SGH, HML, DEE).

- Most of the partners did not have a team fully dedicated to the project.

- Pilot hospital team did not have enough technical and administrative experience to face the entire project.

In order to deal with these issues some important decisions were taken during the project preparation phase:

- A strict time schedule was agreed and the project coordinator verified with a continuous interaction with project partners the fulfilment of project objectives in the due deadlines;

- Technical partners flanked pilot hospitals supporting them in technical and administrative tasks. Technical partners where chosen mainly according to geographical location in order to guarantee a constant and prompt support without increasing travel costs. Particularly:

  o AEA supported AOR in developing technical solutions.

  o TUC supported SGH in both technical activities and administrative tasks

  o IREC supported HVN in some technical activities

  o AGE supported HML in technical tasks

During the project other actions were performed to face project management issues:

- Project coordinator prepared templates and guidelines to support the other partners in the financial reporting.

- Specific sessions during project meetings where dedicated to support project partners in financial reporting.

6. Web-EMCS platform

The main project output is a Web-based Energy Management and Control System that for simplicity has been named Green@. The tool is accessible from the URL http://www.greenhospital-emcs.eu/.

This platform was designed to empower the final users with a piece of software which communicates with existing systems (BMS, SCADA), collects monitored data in a single platform providing energy monitoring, energy management and maintenance tools to both technical and non technical users.

Green@ aims to be a valuable tool for energy managers who are asked to manage multiple buildings and multiple systems which were not designed to work together.

Green@ platform advantages are resumed below:

- Integrability: Green@ can be easily integrated with existing platforms. The architecture described in paragraph 7.1 based on a communication framework can be replicated easily just creating specific drivers. The connection to existing systems can be realized at different levels: component level, database level, system level.

- Modularity: Green@ can be easily expanded connecting other systems or adding new data analysis tools.

- Scalability: Green@ is structured to be applied to room, floors, buildings and cluster of buildings.

- Reliability: Green@ data validation tools allow validating data through both manual and scheduled data validation algorithms.

- Web based structure: It allows an easy access and the early detection of problems and failure thus enabling a prompt intervention.

Green@ use is not limited to healthcare facilities but can be applied to different types of buildings with no limitation. Its application is particularly suitable when different facilities are merged in a single infrastructure.The following paragraphs present the platform architecture, the interfaces available for non technical users and the tools developed for technical users. For more detailed information, please refer to Deliverable D 3.1, D 3.2 and D3.3.

6.1. Web-EMCS architecture

The platform architecture can be divided into two main parts:

- A communication framework installed in the hospital facility

- A remote platform including services, databases and tools
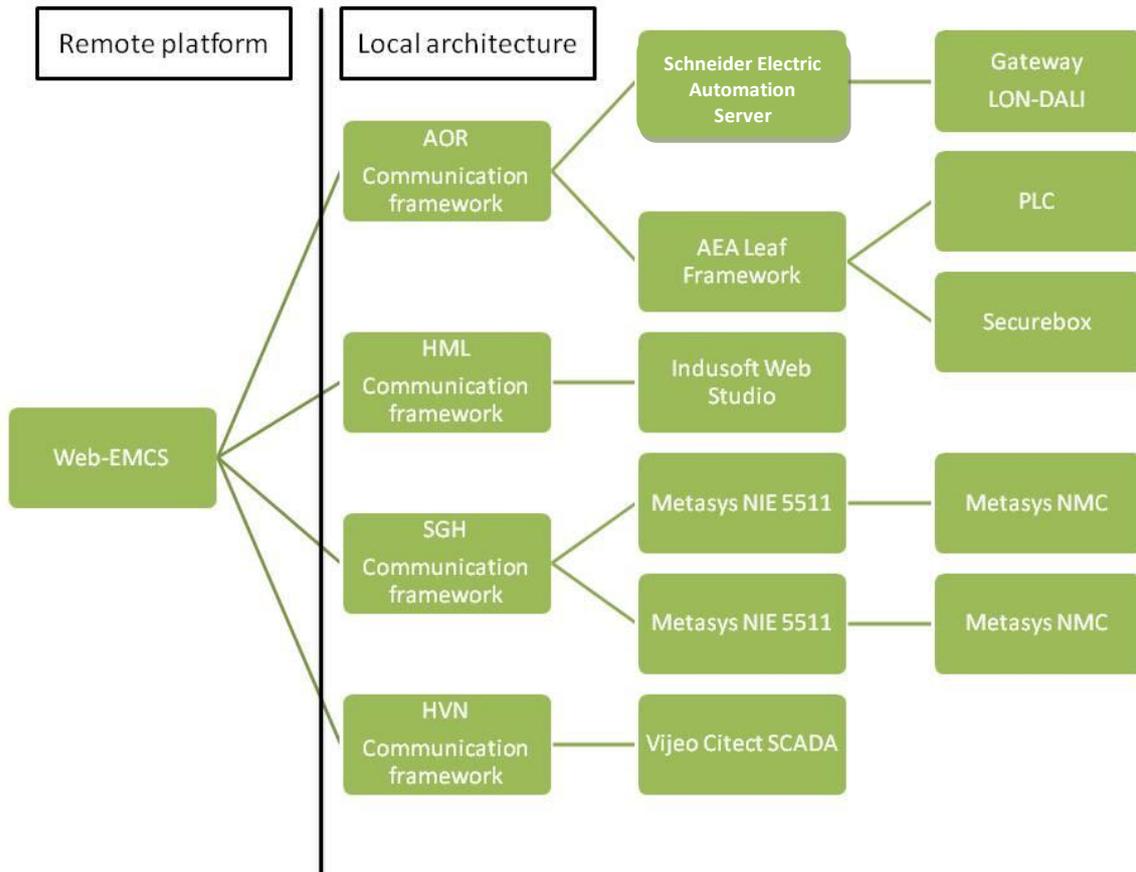
The communication framework is responsible for data exchange between the Web-EMCS and the hospital infrastructures. Data exchange is developed according to the following procedure. This infrastructure ensures system reliability and flexibility.

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┌─────────────────────────────────────────┐
│           Driver development            │
└─────────────────────────────────────────┘
                     ↓
┌─────────────────────────────────────────┐
│           VPN network creation          │
└─────────────────────────────────────────┘
                     ↓
┌─────────────────────────────────────────┐
│    Communication framework installation │
└─────────────────────────────────────────┘
                     ↓
┌─────────────────────────────────────────┐
│          Local network creation         │
└─────────────────────────────────────────┘
                     ↓
┌─────────────────────────────────────────┐
│          System fully operating         │
└─────────────────────────────────────────┘
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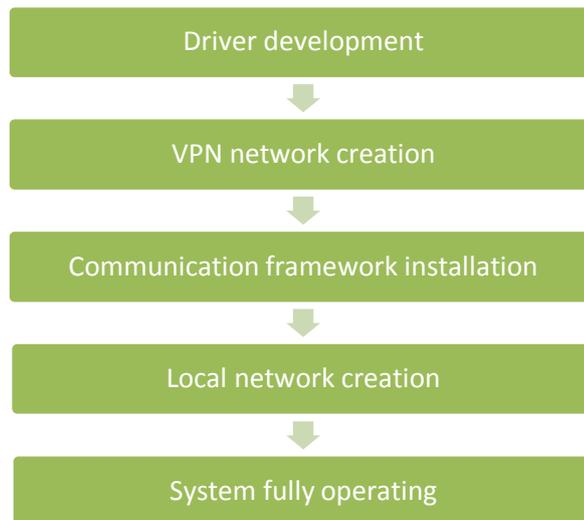
The communication framework is not only responsible for data exchange between local and remote elements but it is also responsible for integrating optimization algorithms as described in Chapter 8.

The remote platform hosts:

- Acquisition services

- Databases

- Data analysis tools

With respect to acquisition, services they are responsible for the communication between the Web-EMCS and the local communication framework, for data storage in a rawlog database and for data import from the rawlog database to the normalized database where data are organized with a node and channel structure. This makes possible to work on normalized data without corrupting data collected directly from the field.

6.2. Non technical user area

Non technical users can enter the platform from the URL http://www.greenhospital-emcs.eu/emcs.

From the homepage "Hospitals" page can be entered. This page introduces the four pilot hospitals which are identified through a picture, their name, some key data and a brief description of the building. Hospitals pictures are a link to the four hospital pages.

For each pilot hospital a specific main page has been developed in order to present the main results reached in each healthcare facility. These pages are meant to be the main access points for the platform users, accessing the Web-EMCS from the monitors installed in the four Pilot hospitals.

Starting from the left side, the page hosts two different menus allowing the user to navigate the website both using an area centred approach and a solution set centred approach:

- Menu 1: it lists hospital buildings and floors;

- Menu 2: it lists the solution sets installed in the hospital.
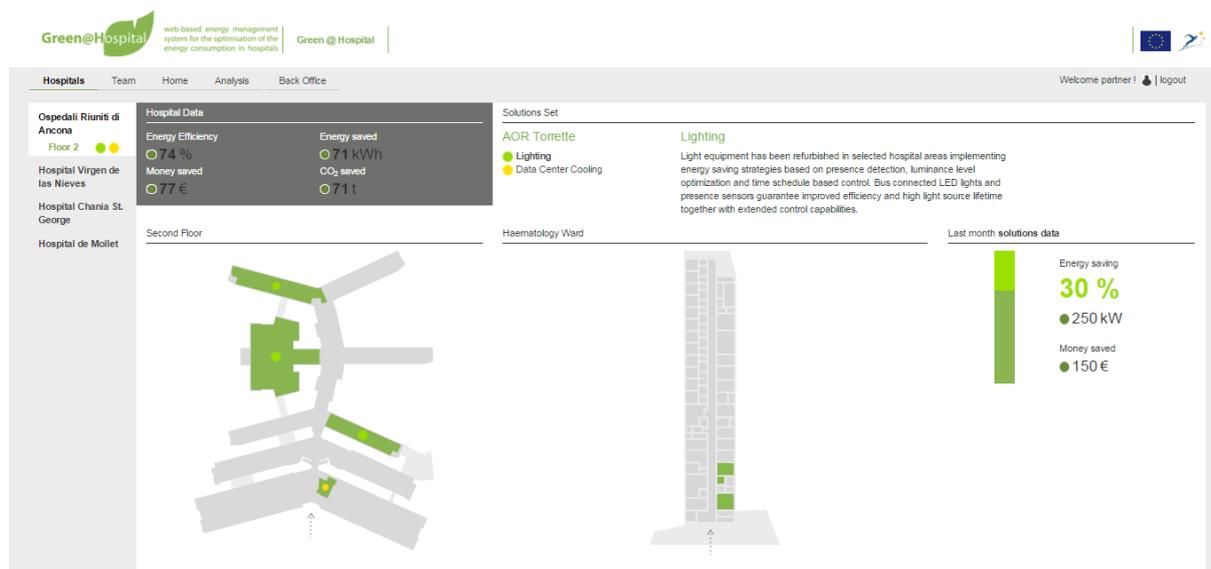
Web-EMCS hospital page

When a solution set is selected its description appears in a box located below the menu. The text depicts the innovative approach used and the ICT technologies that are behind the solution set.

When a floor is selected, its map appears in the dedicated box. The wards where solution sets are installed are highlighted in green. Colored symbols associated to each solution set help the user to identify the areas where each solution set has been installed.

The user has the possibility to select a ward: in this case a further map appears identifying the rooms where solution sets are available. Finally clicking on the room a popup is opened. The popup contains infographics showing in a simple and intuitive way the benefits coming from the ICT upgrade.

There are two types of infographics shown in each hospital page and they are both related to energy savings.

The "Hospital Data" infographic can be found in the top-left side of the page.

Hospital Data infographic shown in the hospital page

This infographic has been created to present in a simple and schematic way the energy savings obtained in the areas included in the project. Savings are expressed in terms of energy efficiency, energy, money and CO_2.

The "last month solutions data" can be found in the right side of the page.
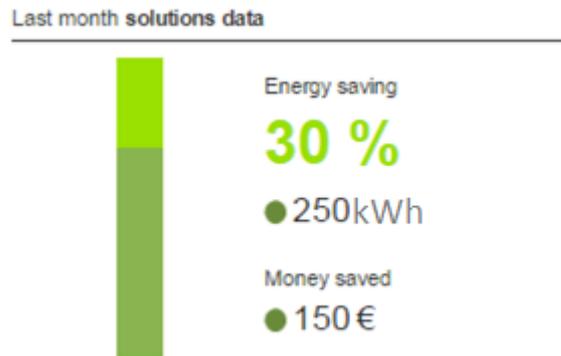
Last month solutions data infographic shown in the hospital page

This infographic shows, related to the area currently selected, the saving's goal that the solution set allowed in the previous month. It presents the percentage and the net value of energy saving, in both kilowatt and euro. Moreover, it provides an immediate feedback about the percentage of energy saving through an intuitive bicoloured bar.
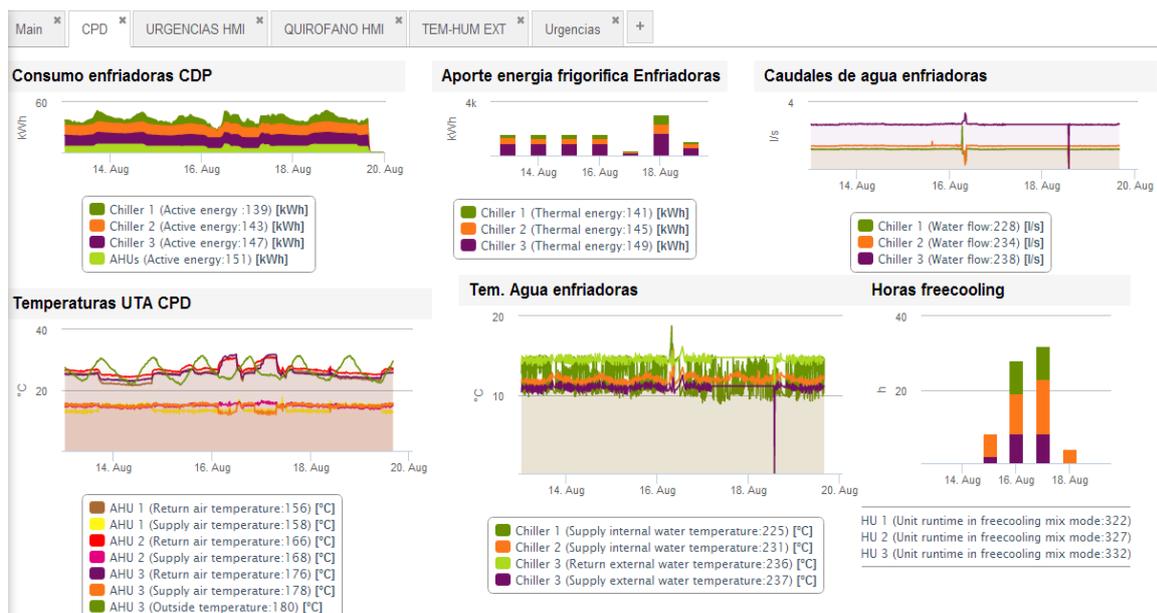
6.3. Technical user area

A specific area of the Web-EMCS is dedicated to the energy manager of the building. From the EMCS homepage a user can reach this particular section of the website clicking on the Back Office button, which becomes available, upon the slideshow, once logged in.

Before gaining access to the extra functions, the user must provide his credentials as Facility manager.

The back office is designed for administrators/energy managers who want to control every aspect of the Web-EMCS: from the data management, to the creation of new data channels. There are six different tools which can be reached clicking on the correspondent button in the top green bar.

- **Dashboard**: it provides each user with a dashboard to be populated with graphs presenting the data he wishes to see each time he enters the back-office. It is a powerful tool to monitor the main building or system KPIs. Each user can build its own dashboard creating customized widgets through a user friendly interface. For each widget it is possible to chose:

  o Target period

  o Plot type (Area, column, pie, staked area, stacked column)

  o Data aggregation

  o Refresh time (for real time data display)

Dashboards are a key tool in the early detection of hardware failures allowing a fast solution.

Dashboard tool example for HVN

- **Analysis**: it allows the energy manager to graph stored variables and compare them through query tools. It is a tool useful to perform detailed and customized data analysis operations. It is particularly useful to search the cause of malfunctions previously identified through the dashboard tool.

- **Configuration**: it allows system administrators to create and configure channels. Channels can read physical variables or calculated logical variables according to customized formulas. This can help the user to calculate KPI or convert measurements. Comparing different measurements savings can be calculated and they can be finally converted in €, kg of CO2 or expressed in terms of percentage values.


Channel configuration tool example for HML

- **Workbench**: it permits data validation through validation algorithms that can be manually or automatically triggered. *It ensures high data reliability applying an agreed and standardized procedure.*
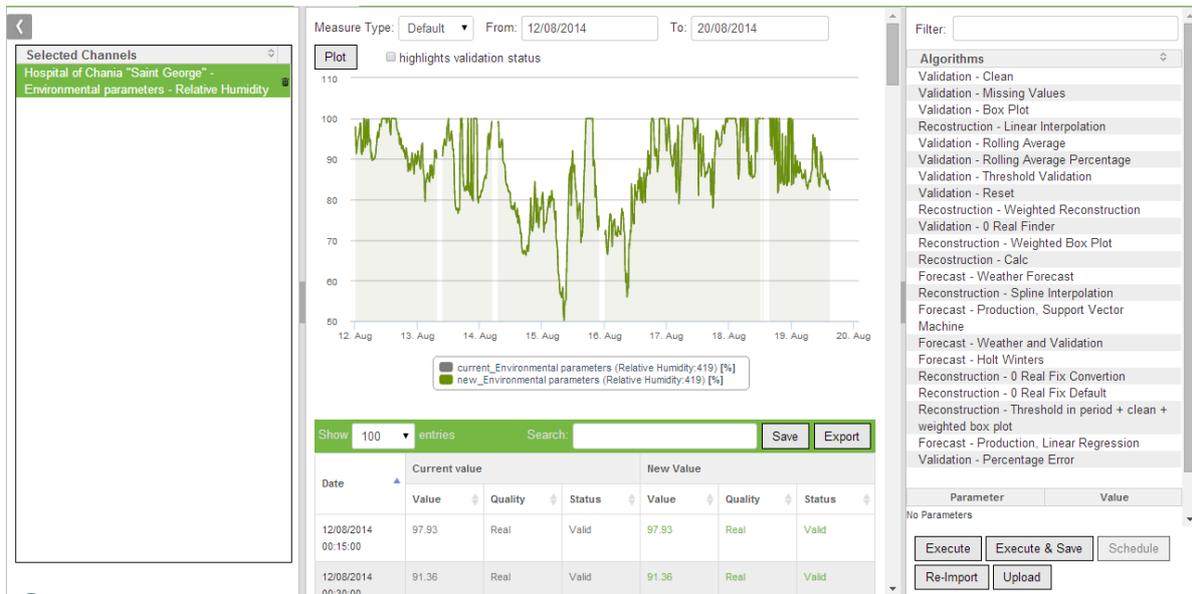

Workbench tool example for SGH

- **System monitor**: two different Graphical User Interfaces (Framework and Geoleaf) are available to support respectively hospital IT managers and Web-EMCS administrators in checking the communication status.
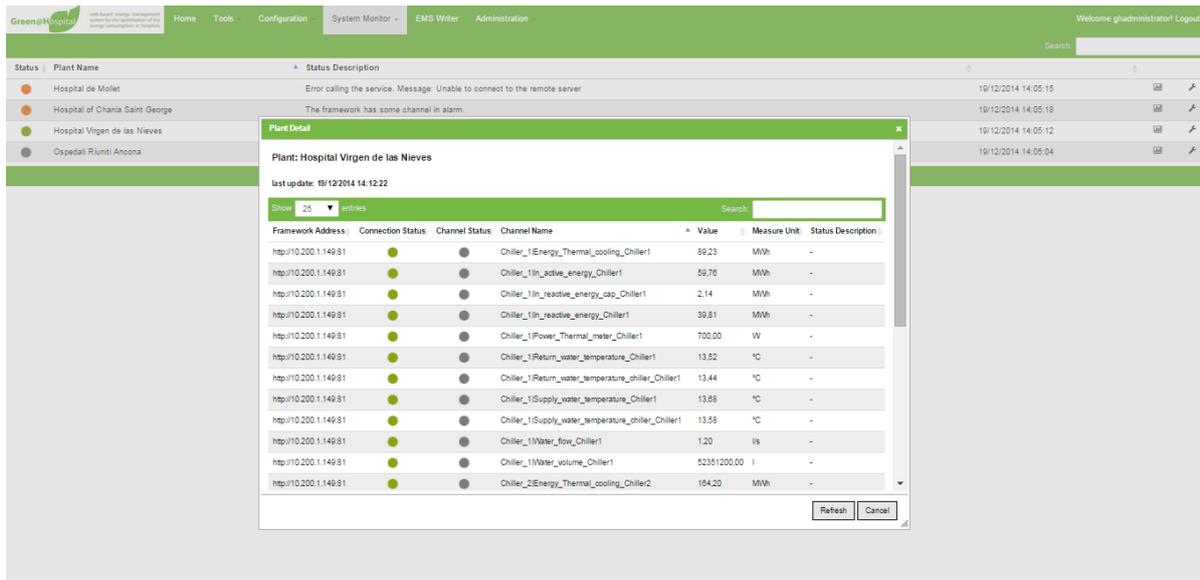
System monitor tool (Framework interface) example for HVN

- **EMS writer**: it provides a Graphical User Interface for system operators to override the control algorithms implemented without the need of programming skills. It is particularly useful in case of sensor failure when algorithm output is not reliable. The tool can be applied also when different setpoints from usual ones are required.
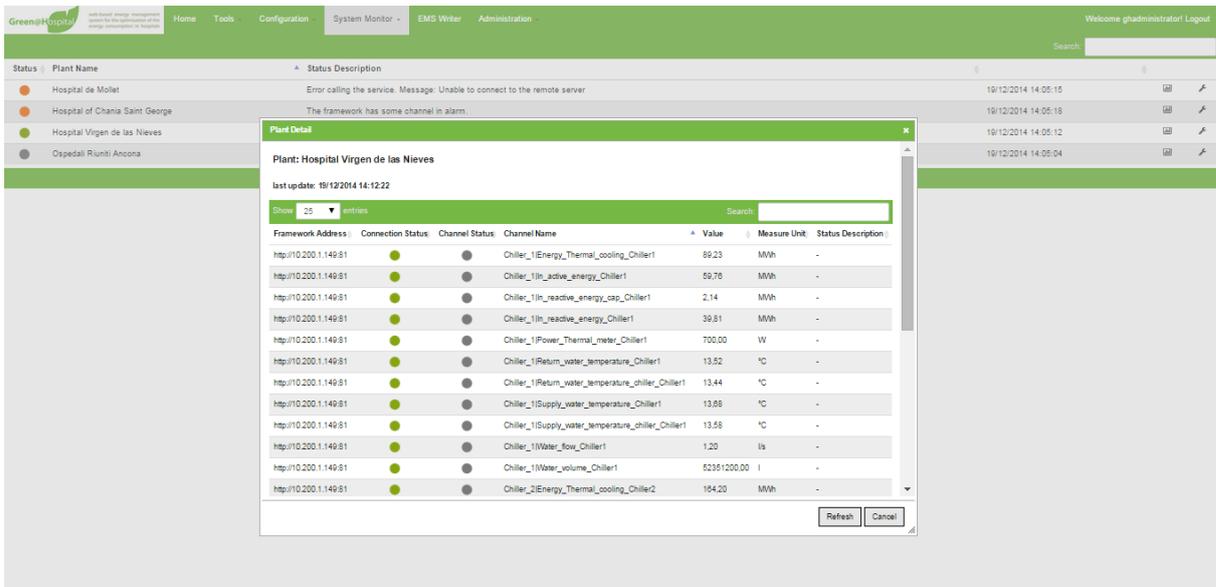

- **EMS writer interface: example for AOR**

The tools developed have been widely tested by the hospital stakeholders and have satisfied their expectations. Moreover, the flexibility of the tool in terms of adaptation of the analysis and the dashboard reflecting their specific needs has been largely appreciated and had created a wide acceptance of valorization of the Web-EMCS.

7. Models and algorithms

In the Green@Hospital project, validated simulation models were developed from the data collected from the pilot hospitals. The validate models accurately represent the indoor conditions of the selected pilot hospitals solution sets under typical outdoor conditions, and the operation of the HVAC systems and the artificial lights. The effect of HVAC and Light equipment in the energy consumption and the thermal/ visual comfort has been studied in order to identify the effect of the control and optimization algorithms in the performance of the buildings.
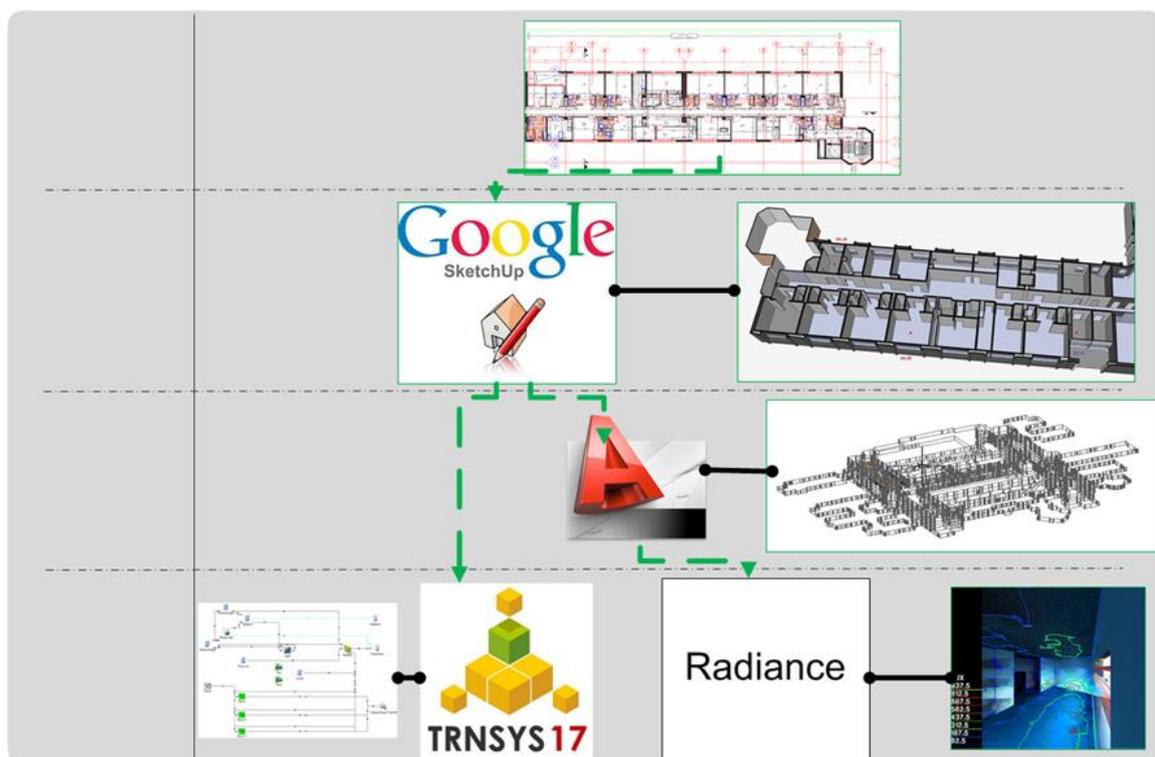
Development of simulation models from data collected from the pilot hospitals

The models were also developed to evaluate and guarantee the performance of the control algorithms due to the sensitive nature of the building type and estimate the energy saving potential.

The developed control algorithms focus on maintaining the comfort of patients and employees while saving energy. Data from installed sensors are compared to set points and the operation of the systems is adjusted using advanced control techniques based on fuzzy architecture which demonstrate significant energy savings on the developed thermal and lighting models.
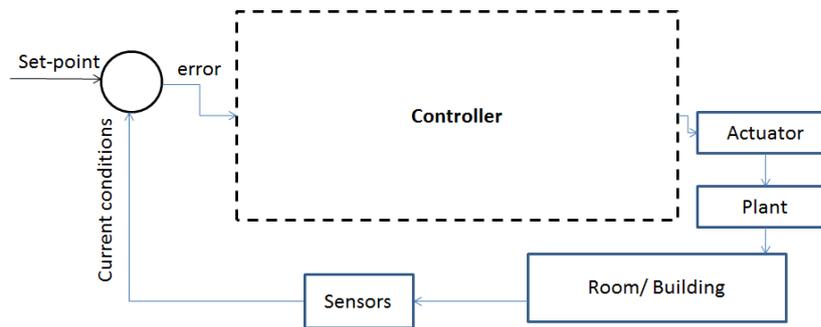
Architecture of the developed controller

Due to the sensitive nature of hospitals' departments the control algorithms integrated override software based features which take priority over the control algorithms so that authorized personnel can send commands directly to the actuators of the HVAC. Thus in the case of failure (sensor, communication or extreme conditions) authorized personnel can adjust the operation of the system as performed before the Green@Hospital project.

The developed control algorithms run in real time, while optimization algorithms have been developed to run off-line and predict the evolution of indoor conditions and select the parameters which minimize the running cost of the HVAC, while in parallel maintain the indoor comfort level.
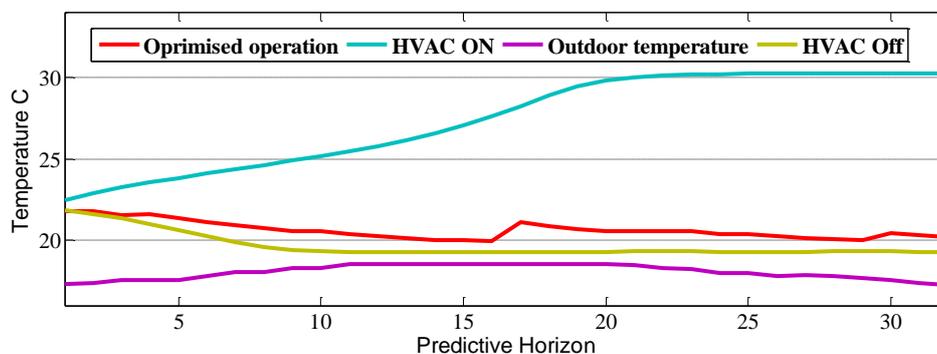
Execution of the optimization algorithm which estimates the optimized set-point for the next 8 hours.

The optimization algorithm integrates predictive algorithms for outdoor air temperature prediction, indoor air temperature prediction which have been trained and validated using measurements collected from the Web-EMCS infrastructure.

For additional details, please refer to the following deliverables: D 4.1, D4.2, D4.3 and D4.4.

8. Monitoring phase results

This chapter presents a catalogue of the eight non hospital specific energy saving solution sets and the one hospital specific solution set developed in the project. They are classified in four main categories: HVAC (Heating Ventilation and Air Conditioning), Lighting, Data Centres and Surgery room.

For each solution the following information is presented:

- Name of the solution set and short name of the pilot where it was implemented

- Representative picture

- Solution set description

- Solution set impact on EN15232 classes

- Pilot savings in terms of final energy, primary energy, percentage and CO_2. Pilot savings are the direct result of the monitoring campaigns performed in the pilot sites.

- Pilot economic figures (investment costs, cost savings and PBT). Investment costs are calculated considering the cost of equipment and of the man hours needed to implement the pilot solutions.

- Overall hospital potential savings and economic figures (presenting the results achievable is the solution set were replicated in all the areas of the pilot facility). These figures are the result of an extrapolation done considering that the hospital areas with the same final use as the pilot areas have the same use profile.

This catalogue is aimed to be a guide for replication presenting the main information useful for decision makers.

For further details, please refer to D2.5, D5.1 and D5.2.

8.1. HVAC control

Heating Cooling and Ventilation plants represent one of the most important energy intensive area inside the hospital, excluding medical equipments. The solutions tested in the project involves both the production and the distribution area.

8.1.1. Heating and cooling production optimization (HML)

Solution set description

Hospital heating and cooling can be provided by geothermal heat pumps or by traditional systems (gas boilers and chillers). The solution aims at scheduling the three different systems in order to use the most efficient one without saturating the ground. Meters have been installed to measure the performance of each system in real operating conditions.

Two different baselines were defined:

1st baseline: without geothermal system

2nd baseline: with geothermal system but without monitored data based control

EN15232:2012 classes of Energy Efficiency

			Definition of classes							
			Residential				Non residential			
			D	C	B	A	D	C	B	A
3.8		Sequencing of different generators								
	0	Priorities only based on running times					✖			
	1	Priorities only based on loads								
	2	Priorities based on loads and demand								
	3	Priorities based on generator efficiency								✖

Pilot savings (1st Baseline) – MEASURED DATA	Pilot savings (2nd Baseline) – MEASURED DATA
Gas saving: 861,172 kWh/year	Gas saving:241,172 kWh/year
Electricity saving: 365,172 kWh/year	Electricity saving: 103,022 kWh/year
Tot primary energy saving: 1,754,046 kWhpe/year	Tot primary energy saving: 492,945 kWhpe/year
Total primary energy saving: 22.3%	Total primary energy saving: 7.5%
CO_2 saving: 522,692 kg/year	CO_2 saving: 147,165 kg/year
Pilot economic figures (1st Baseline) – MEASURED DATA	**Pilot economic figures (2nd Baseline) – MEASURED DATA**
Implementation cost (meters purchasing, installation and commissioning): 62,672 €	Implementation cost (meters purchasing, installation and commissioning): 62,672 €
Cost saving: 163,514 €/year	Cost saving: 42,810 €/year
PBT: 0.4 years	PBT: 1.5 years

Overall hospital potential savings
Same as the pilot area since the solution already affects the overall building

Overall hospital economic figures
Same as the pilot area since the solution already affects the overall building

Heating and cooling production optimization datasheet

8.1.2. Emergency zone Air Handling Unit Control (HVN)
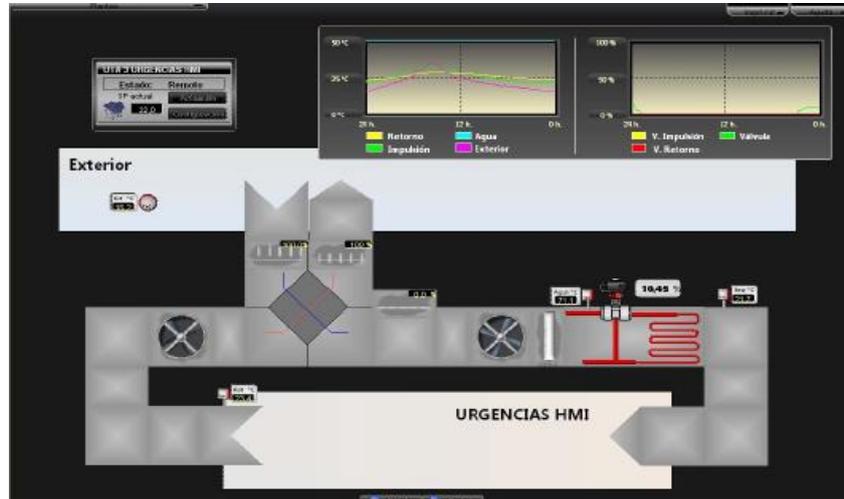
Solution set description

Emergency area of HVN Maternity Hospital was refurbished in 2009 including HVAC system that combines a primary air flow supplied by 3 AHUs, with a fan coil system that provides the final comfort temperature. Each AHU has a two pipe water coil system and system switches from cold to hot water production according to seasons.

Different control logics are tested for one of the AHUs included in Green@Hospital pilot which was equipped with energy meters. The relevant values of AHU like temperature, humidity, were integrated in the hospital BMI system.

The main purpose of the Green@Hospital pilot was to demonstrate that savings could be obtained with the optimization of the AHU management, including free cooling and free heating capabilities.

EN15232:2012 classes of Energy Efficiency

Pilot savings – MEASURED DATA

Cooling: 5,569 kWh/year

Heating: 4,632 kWh/year

Tot primary energy saving: 9,848 kWhpe/year

Total primary energy saving: 42%

CO_2 saving: 2,057 kg/year

Pilot economic figures – MEASURED DATA

Implementation cost (programming and commissioning cost): 976 €

Cost saving: 611 €/year

PBT: 1.6 years

Overall hospital potential savings – EXTRAPOLATED DATA

Cooling: 662,711 kWh/year

Heating: 551,208 kWh/year

Tot primary energy saving: 1,171,912 kWhpe/year

Total primary energy saving: 42%

CO_2 saving: 244,783 kg/year

Overall hospital economic figures – EXTRAPOLATED DATA

Implementation cost (programming and commissioning cost and controller purchasing for those AHU not equipped with a controller): 564,720 €

Cost saving: 72,709 €/year

PBT: 7.8 years

Emergency zone Air Handling Unit Control datasheet

8.1.3. Surgery theatres AHU control (HVN)

Solution set description

In the Maternity Hospital (HMI), there are four surgery theatres fed by the same multi zone AHU. Temperature in each zone is controlled by a room thermostat that drives a mixing damper. The amount of supply air is constant; the dampers (one for each of the four areas) change the ratio of air that comes from the 2 available plenums (first stage and second stage chamber). First stage chamber has a heating and a cooling coil and the second stage has only a heating coil. Coils valves used to be manually controlled.

The main purpose of the Green@Hospital pilot was to demonstrate that savings could be obtained with the implementation of a new automatic controller that manages the water flow to the preheating coil, pre cooling coil and reheating coil.

EN15232:2012 classes of Energy Efficiency

			Residential				Non residential			
			D	C	B	A	D	C	B	A
4.6		Supply air temperature control								
	0	No automatic control								
	1	Constant set point						✖		
	2	Variable set point with outdoor temperature compensation								
	3	Variable set point with load dependant compensation								✖

Pilot savings – MEASURED DATA

Cooling: 12,315 kWh/year

Heating: -22 kWh/year

Tot primary energy saving: 10,690 kWhpe/year

Total primary energy saving: 9%

CO_2 saving: 2,232 kg/year

Pilot economic figures – MEASURED DATA

Implementation cost (controller purchasing programming and commissioning cost): 6,192 €

Cost saving: 736 €/year

PBT: 7 years

Overall hospital potential savings – EXTRAPOLATED DATA

Cooling: 36,945 kWh/year

Heating: -66 kWh/year

Tot primary energy saving: 32,070 kWhpe/year

Total primary energy saving: 9%

CO_2 saving: 6,696 kg/year

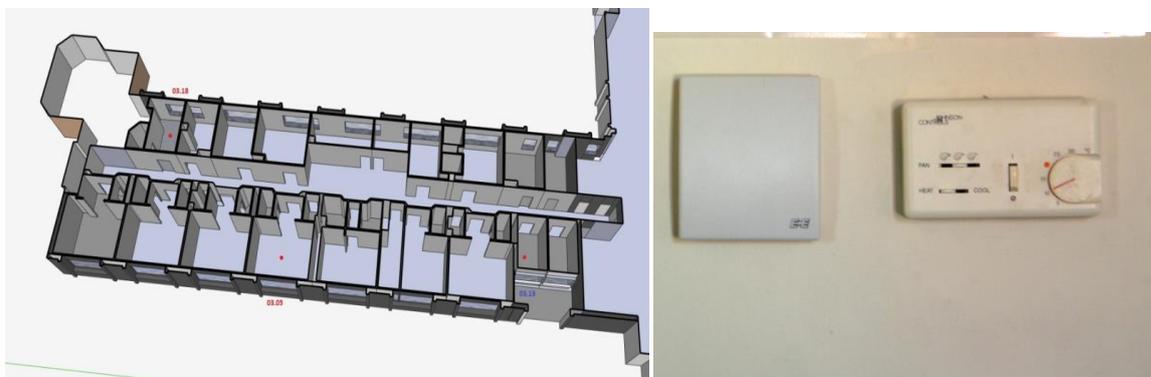**Overall hospital economic figures – EXTRAPOLATED DATA**

Implementation cost (controller purchasing programming and commissioning cost): 18,576 €

Cost saving: 4,464 €/year

PBT: 7 years

Surgery theatres AHU control datasheet

8.1.4. Air handling units of paediatric department control (SGH pediatric clinic)

Solution set description

In the 3 selected rooms of the paediatric department equipment is installed for the monitoring and control of the air handling units and the indoor comfort conditions of doctors and patients.

The main purpose of the Green@Hospital project is to demonstrate the energy savings in the selected rooms in order to propose their replication in the other clinics of the hospital. Analysing the results from the simulations and the collected data, it has been identified that significant energy savings has been achieved.

Developed building optimization and control algorithms have been applied in the 3 selected rooms to preserve the temperature within limits set by the regulations and reduce the energy consumption from potential energy losses, such as operating the air handling units with the windows open or when no presence is detected, or use indoor temperature set-points which increase significantly the energy consumption.

EN15232:2012 classes of Energy Efficiency

Pilot savings – MEASURED DATA

Electricity: 6,436 kWh/year

Oil: 584 litre/year

Tot primary energy saving: 26,321 kWhpe/year

Total primary energy saving: 55%

CO_2 saving: 8,152 kg/year

Pilot economic figures – MEASURED DATA

Implementation cost (equipment purchasing programming and commissioning cost): 6,192 €

Cost saving: 1,035 €/year

PBT: 3.4 years

Overall hospital potential savings – EXTRAPOLATED DATA

Tot primary energy saving: 1,040,624 kWhpe/year

Total primary energy saving: 56%

CO_2 saving: 392,044 kg/year

Overall hospital economic figures – EXTRAPOLATED DATA

Implementation cost (controller purchasing programming and commissioning cost): 121,122 €

Cost saving: 49,186 €/year

PBT: 2.5 years

Air handling units of paediatric department control datasheet

8.2. Data center optimization

One of the area of interest of the project was the Data center, typically an environment where is concentrated a high level of consumption.

Two different applications were developed and documented hereinafter, both related to the Cooling plants. These applications are analyzed separately due to the particular environment where they are used.

8.2.1. Data centre cooling optimization (AOR)

Solution set description

AOR Data centre called Agorà was refurbished in 2011 and several hardware based energy saving strategies were implemented:

- Cold aisle, hot aisle containment

- In row CRAC unit installation

- Efficient chillers

- Indirect freecooling

The main purpose of the application was demonstrating that further savings could be with an improved management of the infrastructure. Through simulations and algorithms the energy consumption needed for data centre cooling could be reduced acting on pumps and chillers variables speed drive. Moreover an improved control strategy was implemented in order to extend the use of indirect free-cooling with a wider range of external temperatures.

EN15232:2012 classes of Energy Efficiency

Pilot savings – MEASURED DATA

Electricity: 4,943 kWh/year

Tot primary energy saving: 10,726 kWhpe/year

Total primary energy saving: 4%

CO_2 saving: 2,625 kg/year

Pilot economic figures – MEASURED DATA

Implementation cost (programming and commissioning cost): 1,000 €

Cost saving: 741 €/year

PBT: 1.3 years

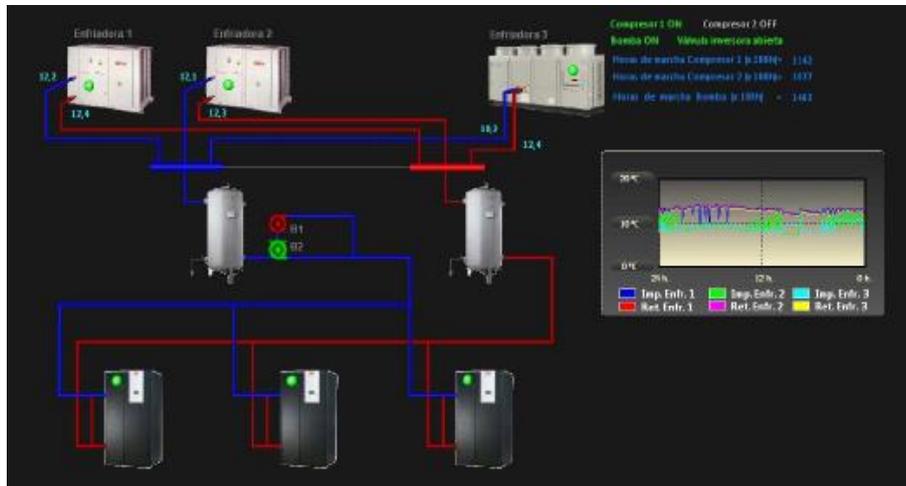**Overall hospital potential savings**

Same as the pilot area since the solution cannot be replicated in other areas of the building

Overall hospital economic figures

Same as the pilot area since the solution cannot be replicated in other areas of the building

Data centre cooling optimization datasheet

8.2.2. Cold water production management (HVN)

Solution set description

HVN Data center was refurbished in 2007 to add more cooling capacity due the increasing IT load in the room. A new and more efficient chiller was added to the two existing ones and three new AHUs with free-cooling capacity were added. The more relevant data center environmental parameters such as temperature and humidity, were integrated in the hospital BMS, based on a SCADA system, but the data storage capacity was limited to a couple of months.

The main purpose of the Green@Hospital pilot was to demonstrate that savings could be obtained with an improved management of the chillers water temperature set points in order to reduce their start and stop cycles. Through simulations and algorithms the energy consumption needed for data center cooling could be reduced acting on chillers set points.

EN15232:2012 classes of Energy Efficiency

Pilot savings – MEASURED DATA

Electricity: 43,437 kWh/year

Tot primary energy saving: 99,035 kWhpe/year

Total primary energy saving: 14%

CO_2 saving: 13,465 kg/year

Pilot economic figures – MEASURED DATA

Implementation cost (programming): 1,304 €

Cost saving: 5,820 €/year

PBT: 0.2 years

Overall hospital potential savings

Same as the pilot area since the solution cannot be replicated in other areas of the building

Overall hospital economic figures

Same as the pilot area since the solution cannot be replicated in other areas of the building

Cold water production management datasheet

8.3. Lighting optimization

Artificial lighting represents one of the most important energy intensive area inside the Hospital since hospitals are open 24/7. Two different solutions have been tested in two different pilots: one replacing the lights and another without replacing the lights available.

8.3.1. Smart Lighting System (AOR)

Solution set description

Hospital wards and corridors are equipped with traditional T8 fluorescent lights. Main corridors are usually lit 24 hours per day, ward corridors are manually controlled from the ward switchboard while room lighting is controlled from dedicated switches installed in each room.

Solution consists in the installation of LED DALI dimmable luminaries, presence sensors and controllers in order to implement control strategies based on presence detection, luminance level optimization, natural/artificial light mix, time schedule and variable luminance setpoint.

EN15232:2012 classes of Energy Efficiency

Pilot savings – MEASURED DATA

Electricity: 12,912 kWh/year

Tot primary energy saving: 28,020 kWhpe/year

Total primary energy saving: 81%

CO_2 saving: 6,856 kg/year

Pilot economic figures – MEASURED DATA

Implementation cost (LED lights, sensors and controllers purchasing, installation and commissioning): 25,663 € (41.67 €/m^2)

Cost saving: 1,937 €/year

PBT: 13.24 years

Detailed results for each room

Dept	Room	Saving [%]	Saving [kWh]	Saving [€]	Saving [kWhpe]	Saving CO_2 [kg]
Oncology	Visitors waiting room corridor	80%	379	57	823	201
	Visitors waiting room middle	73%	688	103	1494	366
	Visitors waiting room window	82%	389	58	844	206
	Patients waiting room	76%	378	57	819	201
	Nurse office	56%	572	86	1242	304
	Doctor office	52%	59	9	127	31
	Archives shelves	94%	592	89	1284	314
	Archives PC	47%	56	8	122	30
Haematology	Warehouse door	63%	17	3	36	9
	Warehouse window	99%	622	93	1350	330
	Nurse office	82%	746	112	1620	396
	Doctor office	74%	3.3	0	7	2
Analysis lab	Waiting room queue	76%	1910	286	4144	1014

Overall hospital potential savings – EXTRAPOLATED DATA

Electricity: 5,534,029 kWh/year

Tot primary energy saving: 12,008,842 kWhpe/year

Total primary energy saving: 75% (43% excluding contribution of light retrofit)

CO_2 saving: 2,938,569 kg/year

Overall hospital economic figures – EXTRAPOLATED DATA

Implementation cost (LED lights, sensors and controllers purchasing, installation and commissioning): 4,054,085 €

Cost saving: 830,104 €/year

PBT: 4.9 years

Smart Lighting System datasheet

8.3.2. Artificial Lighting Management in rooms (SGH pediatric clinic)
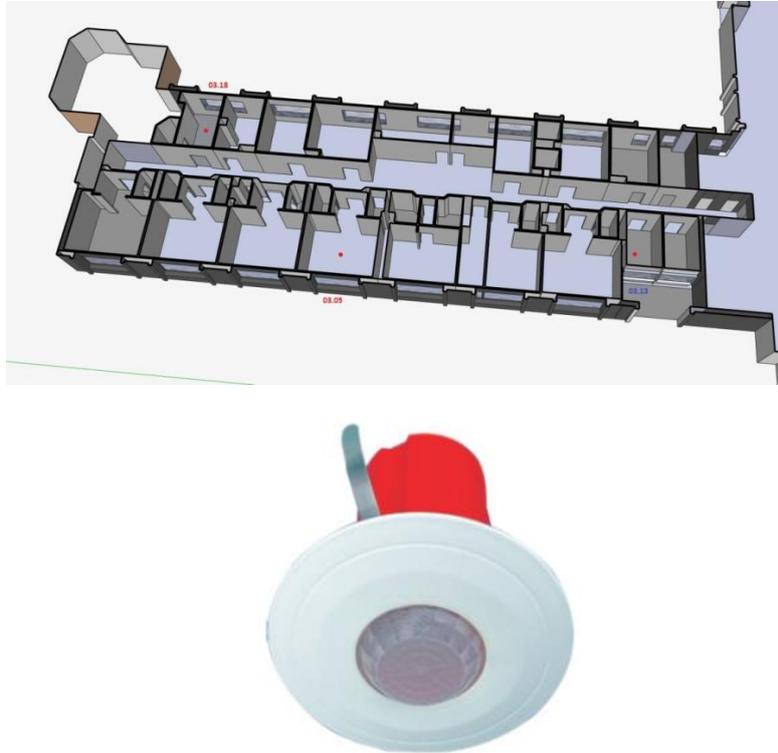
Solution set description

In the 3 selected rooms of the pediatric department equipment is installed for artificial lights monitoring and controlling.

The main purpose of the Green@Hospital project is to demonstrate the energy savings in the selected rooms in order to propose their replication them in the other clinics of the hospital. Analyzing the results from the simulations and the collected data, it has been identified that significant energy savings can be achieved.

Developed building optimization and control algorithms have been applied in the 3 selected rooms to preserve the luminance level within limits set by the regulations.

EN15232:2012 classes of Energy Efficiency

			Definition of classes							
			Residential				Non residential			
			D	C	B	A	D	C	B	A
5	LIGHTING CONTROL									
5.1	Occupancy control									
	0	Manual on/off switch					❌			
	1	Manual on/off switch + additional sweeping extinction signal								
	2	Automatic detection								❌
5.2	Daylight control									
	0	Manual					❌			
	1	Automatic								❌

Pilot savings – MEASURED DATA

Electricity: 977 kWh/year

Tot primary energy saving: 2,835 kWhpe/year

Total primary energy saving: 57%

CO_2 saving: 966 kg/year

Pilot economic figures (3 rooms) – MEASURED DATA

Implementation cost (sensors and controllers purchasing, installation and commissioning): 1,492 € (41.67 €/m^2)

Cost saving: 68 €/year

PBT: 21 years

Overall hospital potential savings (replicating the solution just in the Doctor offices) – EXTRAPOLATED DATA

Electricity: 29,752 kWh/year

Tot primary energy saving: 86,280 kWhpe/year

Total primary energy saving: 58%

CO_2 saving: 31,596 kg/year

Overall hospital economic figures (replicating the solution just in the Doctor offices) – EXTRAPOLATED DATA

Implementation cost (sensors and controllers purchasing, installation and commissioning): 10,080 €

Cost saving: 2,082 €/year

PBT: 4.8 years

Artificial Lighting Management in rooms datasheet

8.4. Surgery Rooms Ventilation control (HML)

Solution set description

HML surgery rooms are equipped with a dedicated AHU which controls and regulates their internal thermo-hygrometric conditions. Each AHU has two VSD (variable speed drives) motors that control the air flow to ensure the air quality required by the legislation. The objective of this solution set is to reduce the ventilation rate of surgery rooms in order to ensure high air quality levels and to avoid too high flow rates when not needed.

Two baseline scenarios were defined:

- First Baseline scenario (2011): the surgery room ventilation system is not managed at all and a fixed flow rate feeds HML surgery theatres.

- Second Baseline scenario (2013): a preliminary state based control is implemented: surgery room ventilation system is managed according to three different states: use, no use and cleaning. Ventilation flow rate is controlled accordingly.

EN15232:2012 classes of Energy Efficiency

Not covered by EN15232:2012 further comments in paragraph 4.5

Pilot savings (1st baseline scenario) – MEASURED DATA	Pilot savings (2nd baseline scenario) – MEASURED DATA
Tot primary energy saving: 94,259 kWhpe/year Total primary energy saving: 33% CO_2 saving: 39,221 kg/year	Tot primary energy saving: 65,967 kWhpe/year Total primary energy saving: 26% CO_2 saving: 40,686 kg/year
Pilot economic figures – MEASURED DATA Implementation cost (particle detector purchasing, programming and commissioning cost): 15,340 € Cost saving: **11,013** €/year PBT: 1.4 years	**Pilot economic figures – MEASURED DATA** Implementation cost (particle detector purchasing, programming and commissioning cost): 15,340 € Cost saving: 7,857 €/year PBT: 1.9 years
Overall hospital potential savings **(1st baseline scenario) – EXTRAPOLATED DATA** Tot primary energy saving: 754,072 kWhpe/year Total primary energy saving: 33% CO_2 saving: 313,768 kg/year	**Overall hospital potential savings** **(2nd baseline scenario) – EXTRAPOLATED DATA** Tot primary energy saving: 527,736 kWhpe/year Total primary energy saving: 26% CO_2 saving: 325,488 kg/year
Overall hospital economic figures **(1st baseline scenario) – EXTRAPOLATED DATA** Implementation cost (particle detector purchasing, programming and commissioning cost): 122,720 € Cost saving: 88,104 €/year PBT: 1.4 years	**Overall hospital economic figures** **(2nd baseline scenario) – EXTRAPOLATED DATA** Implementation cost (particle detector purchasing, programming and commissioning cost): 122,720 € Cost saving: 62,856 €/year PBT: 1.9 years

Surgery Rooms Ventilation control datasheet

8.5. Conclusion concerning monitoring results

Results presented in the solution set catalogue are summarized hereafter and grouped per Pilot Hospital and per asset category. Then the results have been generalized for a typical hospital through an estimation.

8.5.1. Pilot results

Azienda Ospedaliero Universitaria Ospedali Riuniti Umberto I- G.M. Lancisi – G. Salesi (AOR)

The Smart lighting system is an example of invasive retrofitting since it requires the renewal of the overall lighting infrastructure. Results achieved are very promising since the impact of lighting management can be summed to the impact of LED higher efficiency compared to the use of fluorescent tubes. Results achieved varies according to room typology and pattern of use. Extrapolating pilot results for each room typologies a reduction of **75% of the overall consumptions for lighting** can be estimated.

Room typology	Saving [%]	Saving [kWh]	Saving [kWhpe]	Saving [€]	Saving CO_2 [kg]
Archives and WC	87%	154237	334695	23136	81900
Warehouse	97%	1049431	2277265	157415	557248
Corridor	77%	908236	1970872	136235	482273
Ambulatory	52%	30090	65295	4514	15978
Nurse office and other offices	56%	113546	246396	17032	60293
Waiting room	76%	27905	60554	4186	14818
Laboratory and technical areas	70%	3250583	7053765	487587	1726060
TOT	**75%**	**5.534.029**	**12.008.842**	**830.104**	**2.938.569**

The Data Centre cooling optimization is an example of low cost solutions realized without installing any hardware. It was demonstrated that just through software optimization it is possible to obtain a **4% reduction of energy consumption of Data centre cooling** also in a very modern and efficient facility (it was refurbished in 2011).

The total estimated impact of the two solutions in the overall hospital is of:

Primary energy saving: 12,019,568 kwhpe

Money saved: 830,845 €

CO_2 saved: 2,941 t

Hospital Virgen de las Nieves of the Servicio Andaluz de Salud (HVN)

Surgery room AHU optimized management proved to bring **9% savings** mainly linked to the cooling season since new controls allows exploiting freecooling. This solution can be easily replicated in three other surgery theatres with a similar configuration.
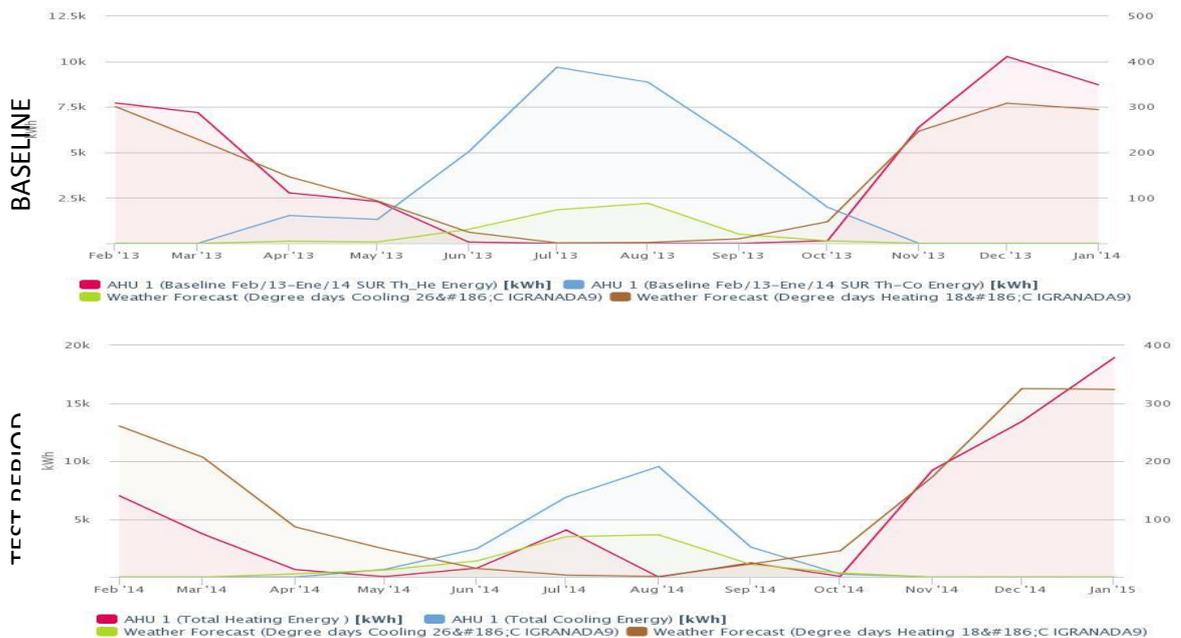
Surgery room AHU: Baseline vs Test period data

Emergency area AHU optimized management proved to bring **42% equally spread savings** between heating and cooling season. This solution can be replicated in 28 similar AHUs. The replication is possible also in other 91 AHUs even if the PBT is longer since they are not equipped with a controller.

Emergency area AHU: Baseline vs Test period data

Data centre cooling optimization, provided 14% of savings and improved the cooling system reliability by reducing the number of chiller switch on/off cycles.
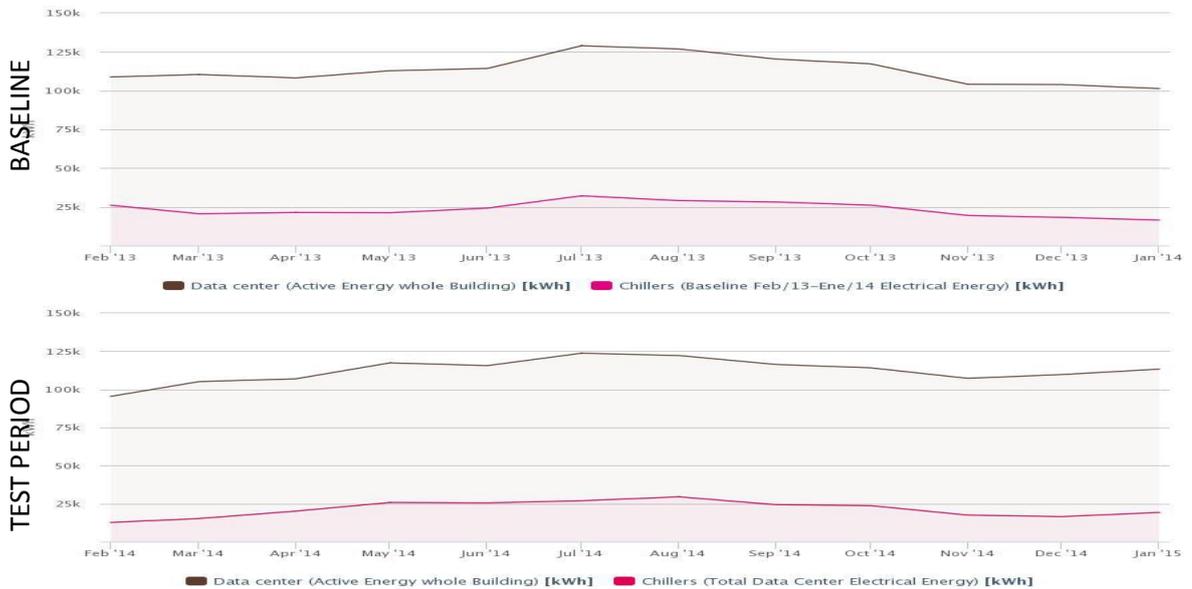
Data centre cooling optimization: Baseline vs Test period data

The total estimated impact of the three solutions in the overall hospital is of:

Primary energy saving: 1,126,904 kwhpe
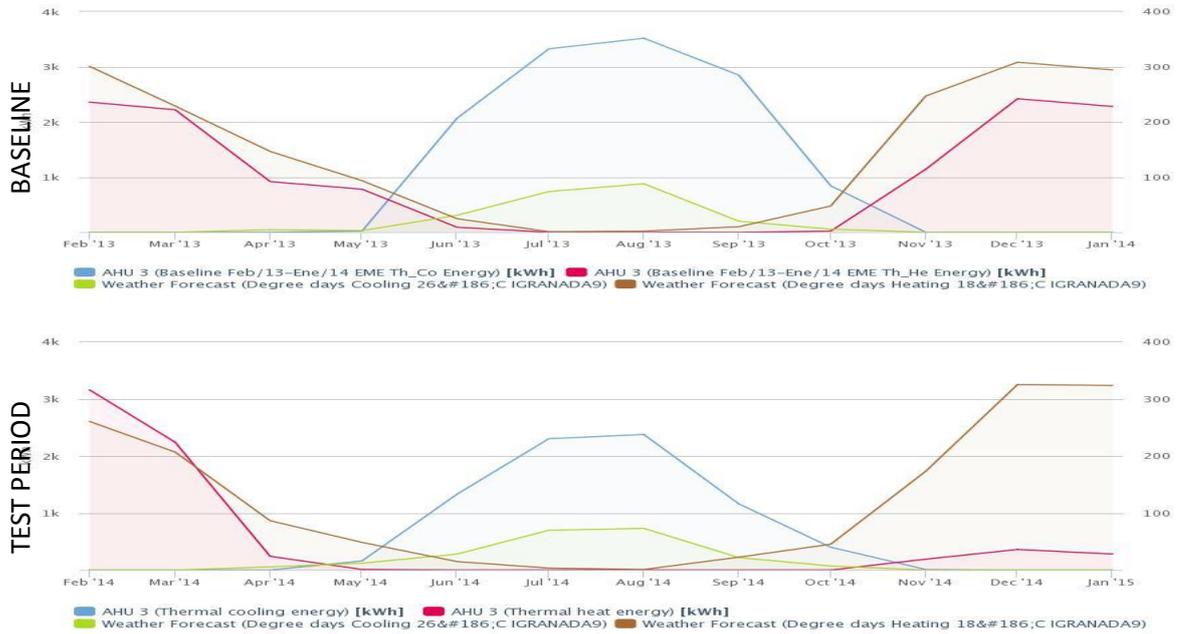
Money saved: 51,268 €

CO_2 saved: 423 t

General Hospital Chania Saint George (SGH)

Artificial light control based on presence detection proved to provide **54% of energy savings**. Fluorescent tubes are controlled in order to provide 0%-50% or 100% of their lighting power
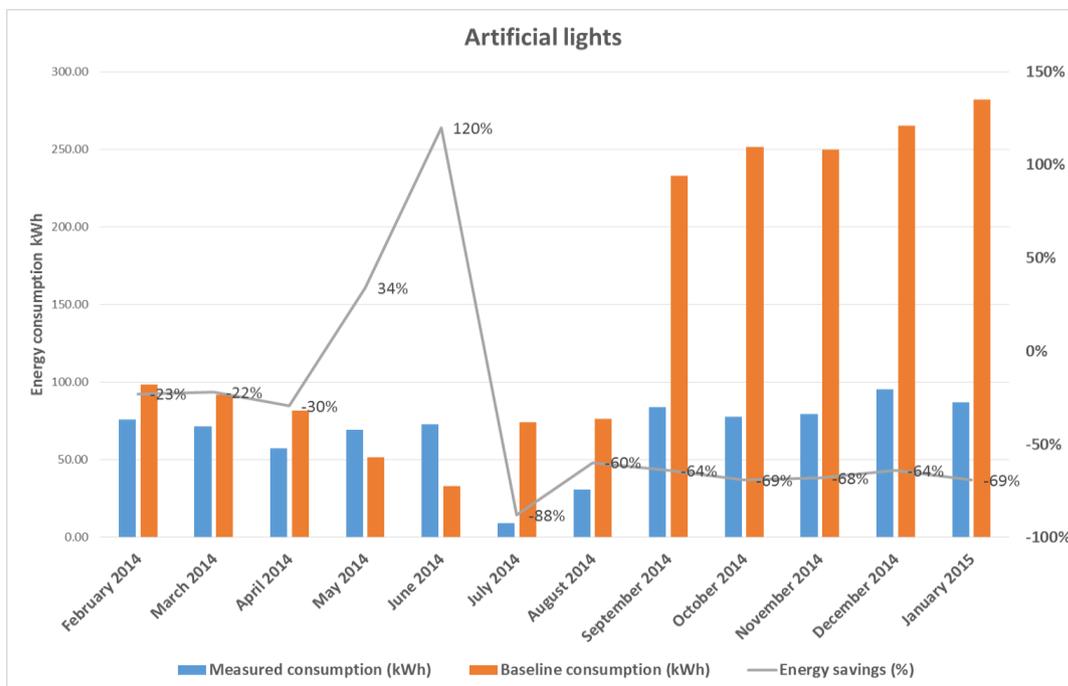
Artificial lights: Baseline vs Test period data

Air handling units new controls in the rooms of the pediatric clinic provided **savings for 56%** through an optimized control based on presence detection.
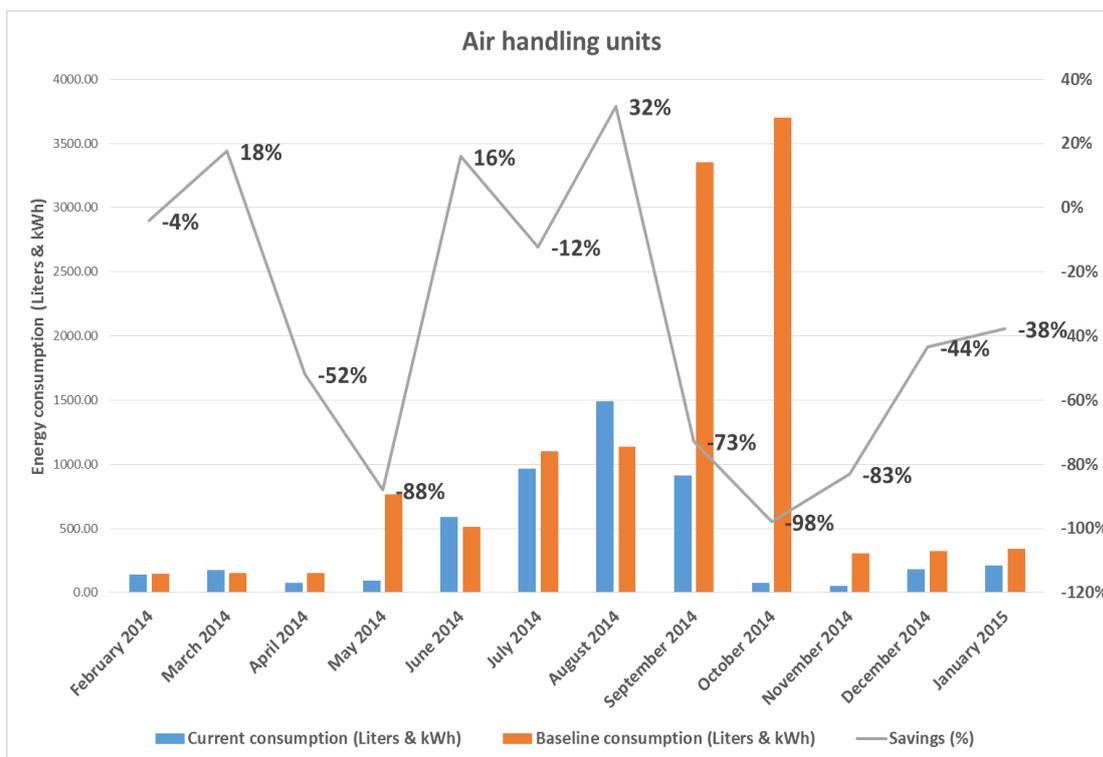
Air handling units: Baseline vs Test period data

The total estimated impact of the two solutions in the overall hospital is of:

Primary energy saving: 2,103,017 kwhpe

Money saved: 82,993 €

CO_2 saved: 269 t

Hospital de Mollet (HML)

The Heating and Cooling generation system optimized management tackle the overall hospital energy consumption for heating and cooling and demonstrates that managing in the best way the different systems available (Chillers, Geothermal heat pumps and Boilers) **significant savings of 7.5%** can be achieved even if the system is already very efficient. Ground capacity can be preserved at the same time making results achieved durable.

Green@Hospital
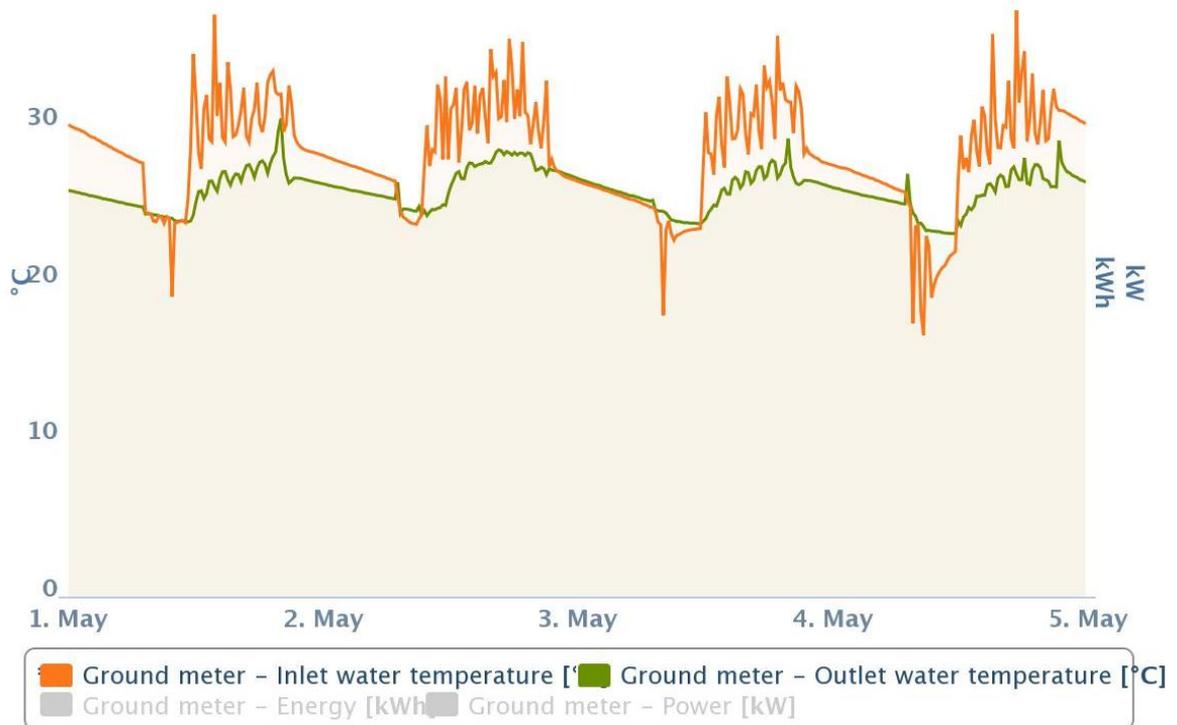
Ground temperature tendency

The particle detection based control implemented in the Surgery room ventilation system allows reducing energy consumptions while guaranteeing safety levels inside the rooms. **26% savings** were achieved comparing the performance to a state control scenario (Use-No Use-Cleaning); higher savings can be achieved in case a fixed flow rate control is applied.

Comparison between particle control flow rate (purple) and state based control flow rate (light blue)

The total estimated impact of the two solutions in the overall hospital is of:

Primary energy saving: 558,912 kwhpe

Money saved: 50,667 €
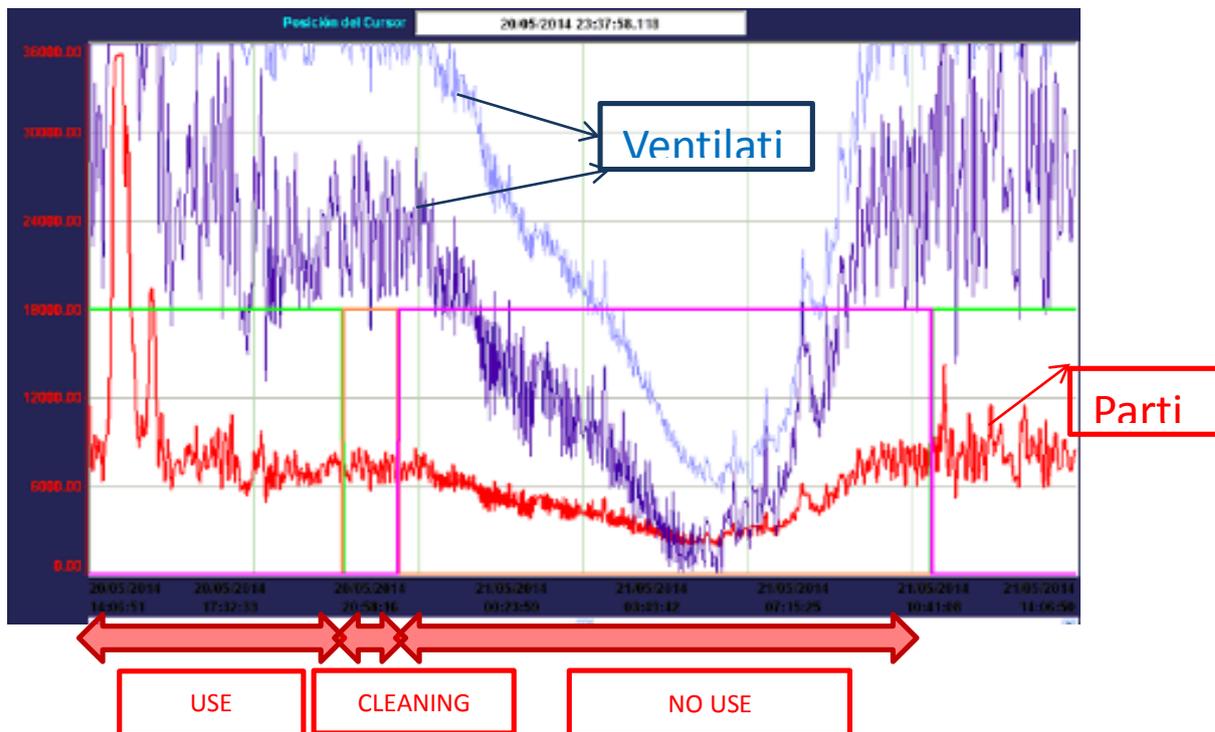
CO_2 saved: 187 t

8.5.2. Solution set results

Lighting

Two different solutions were tested in the pilot hospitals:

- LED dimmable lights installation and control based on presence and light level detection.

- Control based on presence and light level detection applied on existing fluorescent lights (0%-50%-100% control)

Comparing the results it can be noted that lighting retrofitting increases the investment cost required but ensures higher savings (75% vs 54%). The calculated PBT as a consequence is very similar and it is around 5 years.

HVAC

Different solutions were tested concerning HVAC in different pilots. One of them concerns heating and cooling generation while the others affect room conditioning through AHUs.

The two solutions categories can be combined together bringing to high savings in the energy consumption for HVAC. Emergency zone Air Handling Unit Control, Surgery theatres Air Unit Control and Fan coils management in selected rooms of the paediatric clinic provide different results one from another (42%, 9% and 55% respectively). This means that savings achievable are strongly dependent from the hardware available and from the area pattern of use.

Data Centre

Data centre cooling strategies were implemented in two pilots with different characteristics: one of them was recently retrofitted and equipped with efficient cooling technologies (savings achieved 4%). The other was more traditional and equipped with three different chillers whose start and stop was not optimized (savings achieved 14%). The pilots demonstrates that savings can be achieved acting just on a proper management of the cooling system and that results are affected by the hardware caracteristics.

Surgery room

This hospital specific solution set was tested just in one pilot. Results achieved are very promising (26% or more) even if particle based control is not allowed at the moment by the norms requiring a fixed flow rate to ensure safe conditions. Green@Hospital project proved that through particle

detection safe conditions can be ensured and that there is room for improvements to the actual national and international norms.

8.5.3. Generalization

The results measured (% savings) in the four pilot hospitals concerning the selected nine energy saving solution sets are presented below.

Energy saving solution set	Saving achieved [%]
Data centre cooling optimization	4%
Smart lighting system	43% (excluding lighting retrofit) 75% (including lighting retrofit)
Emergency zone Air Handling Unit Control	42%
Surgery theatres Air Unit Control	9% (calculated on 10 months)
Data centre cold water production management	14%
Fan coils management in selected rooms of the paediatric clinic	55%
Artificial lighting management in selected rooms of the paediatric clinic	54%
Heating and cooling generation system optimized management	7.5% (compared to 2013 scenario) 22.3% (compared to 2011 scenario)
Optimized control strategies for Surgery Rooms ventilation	26% (compared to state based control) 33% (compared to fixed speed control)

Savings achieved for each solution set

In order to evaluate the potential impact of all the energy saving solution set on a single hospital building a typical hospital energy breakdown is chosen. The reference chosen for D2.4 "Report on data collection analysis and saving potentials" is the CBECS (Commercial Building Energy Consumption Surveys) by Lawrence Berkeley National Laboratory.

Final use	CBECS Hospitals Energy use [%]
Space Heating	37%
Cooling	7%
Ventilation	8%
Water Heating	19%
Lighting	16%
Cooking	2%
Refrigeration	1%
Office Equipment	2%
Other	7%

Hospital end-use energy percentages, CBECS

Next table resumes the estimated impact of Green@Hospital solution on the overall energy performance of a typical hospital. Results show that if Green@Hospital solutions were applied to a typical hospital, energy savings would be the **15.4%** of the overall hospital energy consumption.

Final use	Energy use [%]	Green@Hospital solution set saving [%]	Potential saving on the overall hospital consumption [%]
Space Heating and cooling	44%	7.5%	3.3%
Ventilation	8%	42.0%	3.4%
Water Heating	19%	0.0%	0.0%
Lighting	16%	54.0%	8.7%
Cooking	2%	0.0%	0.0%
Refrigeration	1%	0.0%	0.0%
Office Equipment	2%	0.0%	0.0%
Other	7%	0.0%	0.0%
Total	**100%**	/	**15.4%**

Estimated impact of Green@Hospital solutions on the overall hospital energy consumption

The potential replication of Green@Hospital solution sets in other hospitals is based on a sensitivity analysis performed to estimate the efficiency of the implementation of the BOC algorithms in similar solution sets under different conditions. Models developed during the Green@Hospital project were used to evaluate solution set replicability.

The simulated scenarios are based on different assumptions:

- Weather conditions

- Internal gains

Just one Green@Hospital solution set is hospital specific, i.e. Surgery room ventilation. All the other solutions are suitable to be applied also in other public buildings. In order to have a rough estimation about the potential impact of Green@Hospital solutions in other public buildings the energy breakdown presented in CBECS (Commercial Building Energy Consumption Surveys) by Lawrence Berkeley National Laboratory for public buildings is used. Following the same approach previously presented for hospitals the potential impact of Green@Hospital solutions in other public buildings can be estimated and is presented in the following table.

Building type	Definition	G@H solutions impact estimation
Education	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses.	16%
Food Sales	Buildings used for retail or wholesale of food.	13%
Food Service	Buildings used for preparation and sale of food and beverages for consumption.	9%
Lodging	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	17%
Retail	Buildings used for the sale and display of goods other than food.	22%
Office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	19%
Public Assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	16%
Public Order and Safety	Buildings used for the preservation of law and order or public safety.	3%
Service	Buildings in which some type of service is provided, other than food service or retail sales of goods	10%

Green@Hospital data were uploaded in the eeMeasure platform. eeMeasure is a software that enables ICT and energy efficiency projects to calculate and record energy saving results using a consistent methodology. In turn this enables the European Commission and other interested parties to produce a better quantitative analysis of the energy savings potential of ICT based solutions in residential and non-residential building. Furthermore the use of a common methodology makes results achieved by different project comparable.

At the end of this process the following conclusions can be presented:

- The calculation methodology has been applied correctly and manually calculated results are compatible with eeMeasure calculated results.

- Reports for each solution set and for each final energy type have been successfully created and are available in the eeMeasure platform.

9. Socio-economic impacts

This chapter presents the socio-economic impacts achieved by the Green@Hospital project that deserve to be highlighted among the project best practices.

9.1. Public Private Partnership

The project demonstrated that Public Private Partnerships can be a valuable driver to bring innovation in hospitals and other public buildings.

Due to spending review hospitals and other public bodies are reducing the personnel dedicated to technical activities and their investment on innovation. For this reason finding new opportunities to bring industry technical and economical resources is fundamental to push investments for energy efficiency generating a virtuous cycle where savings are reinvested in other initiatives.

From the Green@Hospital experience it emerges that the application of a Win-Win approach in which private and public bodies share benefits from common activities is a winning strategy. In fact this approach allows achieving important savings without reducing comfort conditions and operators safety.

9.2. Contribution to standardization bodies

Different initiatives aimed at presenting Green@Hospital solutions to national and international standardization bodies.

A first action was addressed towards CEN/TC247 committee responsible for EN15232:2012 (Energy performance of buildings - Impact of Building Automation, Controls and Building Management), the standard that gives the detailed methods to calculate the Integrated Controls contribution to the Energy Performance of the Buildings.

Each Green@Hospital solution set was classified according to EN15232 and the Efficiency class before and after the intervention was identified. Furthermore global results achievable applying all Green@Hospital solution sets are compared with the overall improvements that the EN15232:2012 associates to Hospitals Building class improvement even if Green@Hospital solutions are just a subset of the applications foreseen by EN15232.

Since EN15232:2012 data are not referred to the single application, a quantitative comparison between Green@Hospital and EN15232 cannot be done. For this reason the result of the Green@Hospital can enrich the knowledge database referred to Hospital Buildings.

The second standardization action deals with the only hospital specific solution set (Surgery room ventilation) and is addressed towards CEN / TC156 committee working on a new suite of standards for hospital ventilation.

As demonstrated Green@Hospital application can guarantee the requested level of concentration of particles controlling the Air Changes Rate per Hours (ACRH) in an efficient way, combining the respect of the ISO16466 limits and the energy efficiency of the application.

The Green@Hospital project demonstrated that is possible to control and reduce the air changing rate, ensuring at the same time that the concentration of particles in the air is maintained below the level defined to ensure the safety of the room.

Green@Hospital results can contribute to the definition of the new suite of standards for hospital ventilation CEN / TC156 is working on. Contacts with the committee were built in this direction.

9.3.   Replication projects

Green@Hospital promising results pushed Pilot hospitals and other hospitals decision makers to setup replication projects in order to extend Green@Hospital solution to other areas, buildings and settlements. The cooperation with MARTE project is particularly relevant in this direction. MARTE stands for "MArche Region Technical assistance for healthcare buildings Energy retrofit". This project, co-funded by IEE (Intelligent Energy Europe) Programme, aims at creating innovative financing models and strategies to support energy efficiency investments in hospital and in other similar buildings.

Below the replication projects already activated by each pilot Hospital are briefly introduced.

Ancona University Hospital

Lighting system solution implemented at Ancona University Hospital registered stimulating results in terms of energy efficiency and the same solution can be replied in several rooms of the building.

Even if return of investment of Green@Hospital solution is interesting it is not planned to implement the solutions retrofitting the existing overall structure.

Nevertheless it is important to remark:

- the dynamicity of most of healthcare buildings;

- the process of Salesi Hospital (mother and child hospital) removal.

Concerning the dynamicity of most of healthcare buildings it can be underlined that refurbishment of hospital departments are not rare. Hospital structure follows:

- citizens user needs: during some emergency (e.g. H1N1 or Ebola virus) some refurbishments have been realized in infective department;

- physicians specialization: it is frequent that a physician during working lifetime improve his/her competencies with, sometimes, a consequent involvement of a lot of new patients;

- strategic investment: according to local healthcare system it is also recurrent the introduction of innovation in terms of diagnosis/treatments/rehabilitation (sometimes having particular request in terms of space/equipments/devices).

In particular, in this period in Ancona University Hospital Pharmacy Department is renewing and it is already planned to use some lighting system solution tested in Green@Hospital project.

The same solution as well the other validated during Green@Hospital project will be applied in future refurbishments. The maintenance department of the Hospital involved in Green@Hospital activities has knowledge and competence to carry out a specific assessment about the opportunity to use project solutions.

Salesi Hospital is a specialized pediatric structure belonging to Ancona University Hospital with about 250 beds and around 1300 personnel. In last year it began the process for a removal from the actual location in the centre of Ancona to Torrette area. Of course it will have a big impact on the structure and several plants will be renewed. This can be the right opportunity to implement Green@hospital solutions in a quite big area of the Hospital.

Hospital Universitario Virgen de las Nieves

The Hospital Universitario Virgen de las Nieves (HVN) as a member of the Green@Hospital project has participated with three pilots in the areas of HVAC. One of the main objectives of the hospital management is the implementation of an energy management system that can be certificated according to ISO 50001, and the participation in the Green@Hospital project has been a great help in achieving these objectives.

Besides the implementation of control systems and validation of savings in the selected pilots, it was discovered that thanks to the Web-EMCS, savings can be achieved by analyzing energy measurements. This allowed to better understand hospital processes, to identify malfunctions, to act on them and to check the results.

In the middle of last year, a process of convergence of the university hospitals in Granada was carried on resulting in the "Complejo Hospitalario Universitario de Granada", formed by the "Hospital Universitario Virgen de las Nieves" and "Hospital Universitario San Cecilio"

This hospital convergence considerably increases the number of energy consuming facilities and opens up enormous possibilities to replicate the technology learned in the Green@Hospital project to new installations, since the potential savings are very high.

The goal of implementing an Energy Management System in the short term is also presented in the rest of the hospitals in the Andalusian Health Service (SAS) at the corporate level.

For this reason, the influence of the good results obtained in the project will be decisive to replicate the Green@Hospital solutions in other hospitals in Andalusia as a mean to achieve savings.

Chania Saint George Hospital

Saint George Hospital (SGH) tested room lighting and room conditioning solutions in specific areas of the pediatric department. The results from the monitoring period indicate that the selected solution sets can be replicated in all the clinics of Saint George Hospital including more offices used for technical activities apart from those used only by doctors.

Finally in cooperation with the Ministry of Health, Saint George Hospital will push the implementation of advanced Building Energy Management Systems in new hospitals which can control each room individually integrating all the technologies applied in the Green@Hospital project.

Hospital de Mollet

Thanks to the results and findings of the Green@Hospital project in HML it was decided to change one of the boilers of thermal energy production with a new condensing boiler with a greater variation in power delivery. This will allow to minimize switching on and off of the boiler, and therefore to have a better and more consistent power delivery. This will result with a greater efficiency.

The most probable action within the HML as a continuation and development of the project is the placement of particle sensors in all surgery rooms and the expansion of areas with LED lighting, light sensors and presence detection.

9.4. Impact on maintenance

Green@Hospital aimed at achieving long lasting results: several studies demonstrated that up to 8% per year can be lost without an effective monitoring and maintenance program. The concept is illustrated in the following figure.
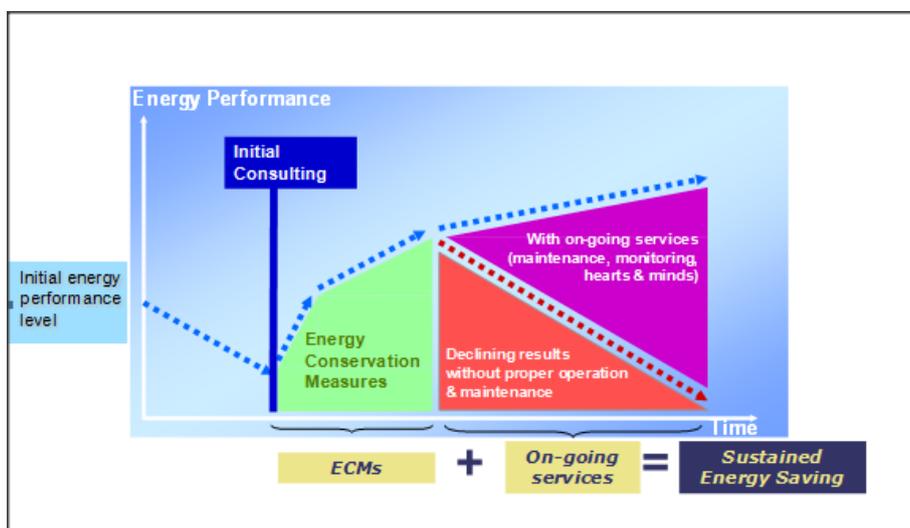
Impact of maintenance on energy performance (Source Marchais J.J)

In order to make the savings achieved durable also after the end of the project, a methodology was setup in the pilot hospitals and some guidelines were developed.

It has been demonstrated that the Web-EMCS platform is useful to inform about the status of the different systems installed and also to quantify the energy saving caused by maintenance actions.

Moreover, the Web-EMCS has been useful to monitor energy consumption monthly. The connection between the BMCS and the Web-EMCS has provided a deep knowledge for the energy consumption of every production unit, such as chillers, boilers, geothermal plant but also at sensor level.

Another important aspect to take into account is the involvement of the technicians devoted to maintenance and their training in order to be able to understand and use an ICT tool like the Web-EMCS. From the Hospital of Chania experience, we can say that one week was sufficient to train the technicians at different level. Therefore the cost of training is not so relevant with respect the advantages of an effective and almost real time maintenance.

The immediate benefits for the pilot hospitals and the main achievements reached are reported hereafter, underlying how the use of the Web-EMCS can bring tangible results also in terms of maintenance cost reduction.

Ancona University Hospital

During the monitoring period some conditions of lighting system have been re-calibrated. In particular for some rooms in oncology ward the minimum dimmer value has been reset to a fixed value:

- due to specific requests by clinicians (nurses and doctors office)

- in archives when the room were unoccupied.

During the monitoring period the system worked correctly, without any replacement or repair. If the system fails, the Web-EMCS platform is very useful to inform about the status and also to quantify the energy saving caused by maintenance actions.

Hospital Universitario Virgen de las Nieves

During the monitoring period the Hospital experienced some problems with drivers and data acquisition software and it worked to identify and fix those problems.

Hospital had the opportunity to detect some faults or potential improvements after analyzing the information provided by the Web-EMCS, that otherwise would not have been possible to know, but it cannot quantify the energy saving for the maintenance action. Examples of faults are:

- Detection of broken transmission belt in Emergency AHU (fall in the power consumed by the fan)

- Detection of temperature probes misplacement after a mechanical disassembling of cooling coil in Operating Room AHU (heat energy measurements in summer)

- Detection of continuous start and stops in Data Centre chillers (variations in active power consumptions)

- Detection of air in chiller pipes (variations of water flow)

Chania Saint George Hospital

After the implementation phase the Hospital had to solve some problems related to the communication of the hospital's infrastructure with the centralized Green@Hospital server. Another complication that was introduced and solved with the proper maintenance of the Green@Hospital equipment was a delay in the "switch on" of the artificial lights that has been identified due to slow communication speed of the existing BEMS with the Web-EMCS. Thanks to reporting of the clinic's personnel and the maintenance team work, the problem has been solved and the energy savings have been significantly increased during the latest months of the monitoring period.

For the Green@Hospital solution set the Web-EMCS platform assists in the scheduling of maintenance plans for the installed equipment. The real-time monitoring provided by the Web-EMCS platform assists in identifying potential problems in the sensors (communication or validation) which can potentially affect the comfort level of users and the energy saving targets set by the hospital. Saint George Personnel is planning a major evaluation of all the sensors in March 2015.

Hospital de Mollet

The Web-EMCS has been useful to monitor energy consumption monthly. The connection between the BMCS and the Web-EMCS has provided a deep knowledge for the energy consumption of every production unit (chillers, boilers, geothermal plant).

The surgery room air unit subsystem data have been disseminated among the stakeholders with great interest and success. The final savings have proved the initial forecast.

In the heating & cooling production subsystem, the maintenance of the Geothermal unit is critical to achieve the expected savings. The project has provided information about the soil capacity for heat and cool storage. This information has been transferred to the predictive maintenance software to avoid the saturation of the soil and, eventually, to avoid the reduction of the Geothermal Unit annual operating hours.

9.5. Lessons learnt

During the three year project, the consortium had the opportunity to learn different lessons when a concepts like energy efficiency wants to be applied in hospitals.

- The main purpose of the hospital is the patient healthcare and other aspects, like energy efficiency, is not a priority. Anyway the Green@Hospitals demonstrated that it is possible to save energy and therefore to save costs that could be invested in new equipments or treatments. In this way the interest of stakeholders and managers on energy saving solutions and methodologies has been reinforced.

- It is important to underline the concept of energy data monitoring to understand where the hospital is consuming energy.

- It is not unusual that technical activities related to energy are outsourced through global service contract. In this way the maintenance activities, the maintenance management and program are performed by an external company. This means that also data related to consumes and use of energy are not available and difficult to obtain. In the Green@Hospital project it has been chosen to involve the technical partner related to the specific hospital and where it was not possible, some difficulties have been encountered in gaining the complete set of data. It is important to have the full accessibility to energy data and consumes in order to optimize the use of energy. The unavailability of data for the energy audit has been one of the main difficult task of the project.

- Each hospital has different ICT architectures and different data access policies and this fragmentation limits the application of a standardized approach and solution.

- The involvement of nurses and doctors has been fundamental for the acceptance of the applied solutions.

- Different hospital technical teams have to be involved as well for the implementation of the solutions.

- Implementing a new infrastructure in an active hospital ward operating on critical systems such as artificial lighting, HVAC, data centers and surgery room ventilation system is a critical task. It requires a big coordination effort in order to avoid disruptions in healthcare activities and preserve patients and clinicians safety.

- Training of the technical persons on the use of ICT tools is very important. In fact, having information and data in real time through the Web-EMCS platform is helpful for evaluations about the system and energy consumption. It helps daily job of those technicians involved in maintenance (including global service personnel), for example for failures detection and to program scheduled activities.

- The Web-EMCS has been useful to monitor energy consumption monthly. The connection between the BMCS and the Web-EMCS has provided a deep knowledge for the energy consumption of every production unit (chillers, boilers, geothermal plant) and it allowed a prompt verification of malfunctions of components.

- Since the implementation of the Green@Hospital solutions, the knowledge level of the systems is higher than before. Now system operators can know a huge amount of detail of what is happening and they can optimize the operation of the equipment without loosing comfort conditions.

- Hospital had the opportunity to detect some faults or potential improvements after analyzing the information provided by the Web-EMCS, that otherwise would not have been possible to know.

- Regulations are fundamental for the acceptance of a new solution to be implemented inside a hospital. It is very important to have the necessary information and start as soon as possible the process of standardization involving the proper stakeholders.

- Disseminations of the results and data are very important in order to sensibilize a large audience around the topic of energy efficiency in the hospitals.

10. Dissemination impact

Energy efficiency in hospitals confirmed to be an interesting topic for a wide audience. Green@Hospital project has been followed by a large and heterogeneous audience. Dissemination activities performed by project partners contributed to increase the project impact on the stakeholders customizing the content of dissemination according to different categories.

An important role was covered by dissemination material: brochures and posters (developed both in English and in partner languages), and a project video revealed to be tools useful for disseminating project purpose and results during events.

Material	Picture	Link
Brochure		Link
Poster		Link

| **Video** | | |

Project website was a powerful dissemination tool gathering a community of different stakeholders belonging to different categories:

- Decision makers working in the Healthcare field

- Technical stakeholders working in the Energy field

- General public

Links addressed to different stakeholders in the project Website homepage

For this reason Website contents were addressed to these stakeholders' categories. The website gained more than 10480 unique visitors, 398 persons subscribed the project newsletter, 114 posts were published.

Project objectives and results attracted the interest of media: 17 articles on paper press, 45 articles on online press and 3 TV/radio interviews were dedicated to the project.

Interest gathered around the project is proved by the 15 letters of interest received. Most of them asked for information about the project and for data from the pilots.

Green@Hospital partners presented the project to several events and four events were organized by Green@Hospital pilots:

Green@Hospital workshops	
	1st Green@Hospital workshop The event called "Strategies to reduce energy consumption in Hospitals: Green@Hospital tools for energy management" was held in Granada (Spain) on October 25th, 2013. Hosted by Hospital Universitario Virgen de las Nieves counted
	2nd Green@Hospital workshop The event called "Smart Energy Systems for Sustainable Hospitals: Lessons learnt from the Green@Hospital Project" was held in Chania (Greece) on September 25th 2014. Organized by Technical University of Crete and Chania Saint George Hospital counted 65 attendants.
	3rd Green@Hospital workshop The event called "Control strategies to reduce energy consumption in hospitals" was held in Mollet del Vallèe (Spain) on October 15th 2014. Hosted by Hospital de Mollet counted more than 70 attendants.
	Green@Hospital Final event The event called "Re-energizing healthcare, a sustainable challenge?" was held in Ancona (Italy) on February 20th 2015. Hosted by Ancona University hospital and organized together with Loccioni Group counted about 70 attendants.

Furthermore Green@Hospital was selected to participate to **ICT2013**, held in Vilnius from 6th to 8th November 2013, in the "Smart and sustainable cities for 2020+" cluster.

Green@Hospital work was valuable also from a scientific point of view: 14 articles were published in Journals or conference proceedings.

Publication list
S. Papantoniou, D. Kolokotsa, A. Pouliezos, Neuro-Fuzzy model based predictive algorithm for environmental management of buildings, International Conference on Industrial and Hazardous Waste Management, 2012.
Juan Lino Navarro Flórez, Open borders of the i+d+i in health: experiences in international projects, Oficina de Proyectos Internationales, 2012.
S. Papantoniou, D. Kolokotsa, A. Pouliezos, Neuro-Fuzzy model based predictive algorithm for environmental management of buildings, International Conference on Industrial and Hazardous Waste Management, 2012.
S. Papantoniou, D. Kolokotsa, A. Pouliezos, Neuro-Fuzzy model based predictive algorithm for environmental management of buildings, International Conference on Industrial and Hazardous Waste Management, 2012
Juan Lino Navarro Flórez, Open borders of the i+d+i in health: experiences in international projects, Oficina de Proyectos Internationales, 2012.
P. Foutrakis, S. Papantoniou, K. Kalaitzakis, D. Kolokotsa, Development of a smart sensor for controlling artificial lights and venetian blinds, AIVC conference, 2013.
Sotiris Papantoniou, Denia Kolokotsa, Kostas Kalaitzakis, Davide Nardi Cesarini, Eduard Cubi and Cristina Cristalli, Development of a lighting controller using smart sensors, AIVC conference, 2013.
Nadia Zabbeo, ICT techno-companies & domestic market co-evolution, Book Chapter 14.
Claudio Loccioni, Alessandro Palombi, "Green@Hospital: un progetto europeo per la sostenibilità energetica delle strutture e dei processi ospedalieri" (The Green@Hospital: a European project for energy sustainability of hospital buildings and processes), "Hospital and public health" journal, December 2013.
E. Cubi, D. Nardi Cesarini, J. Arbol, J.M. Fernandez, J. Salom. "Potential benefits in terms of thermal comfort and energy use of adding a control loop to an existing multizone Air Handling Unit in a hospital setting" eSim conference proceedings, May 2014
S. Papantoniou, D. Kolokotsa, K. Kalaitzakis, D. Nardi Cesarini, E. Cubi, C. Cristalli, "Adaptive lighting controllers using smart sensors", International Journal of Sustainable Energy, June 2014
E. Cubi, J. Salom Tormo, N. Garrido Sorano "Indoor environmental quality and infection control in surgery rooms: Code requirements vs. performance motivation. A critical review" HVAC&Research, August 2014
E. Cubi "Energy efficient ventilation strategies for surgery rooms", Phd Thesis, December 2014
S. Papantoniou, D. Kolokotsa "Prediction of outdoor temperature using Neural Networks application in 4 European cities", 3rd IC2UHI conference proceedings, October 2014
S. Papantoniou, D. Kolokotsa, K. Kalaitzakis "Building Optimization and Control algorithms implemented in existing BEMS using a Web based Energy Management and Control System" Energy and Building Journal (accepted and waiting to be published

11. Public deliverables

Del. no.	Deliverable name	Description and link
D2.1	Standard energy audit procedure	It describes the procedure to perform the energy audit in the pilot hospitals. http://www.greenhospital-project.eu/wp-content/uploads/2012/04/D2-1.pdf
D2.2	Energy saving solution set description	It describes the energy audit results and the nine energy saving solution set selected in the four pilot hospitals http://www.greenhospital-project.eu/wp-content/uploads/2012/04/D2.2_Energy-saving-solution-set-description-1.pdf
D2.3	Data collection active from all pilot hospitals	Prototype: the report presents the database structure to store data from the pilots http://www.greenhospital-project.eu/wp-content/uploads/2012/04/D2.3-Data-collection-active-from-all-pilot-hospitals.pdf
D2.5	Standard benchmarking spreadsheet including manual	It describes the benchmarking model useful to normalize results according to the main KPIs. http://www.greenhospital-project.eu/wp-content/uploads/2013/11/D2-5-Standard-benchmarking-spreadsheet.pdf
D3.3	Web-EMCS online	Prototype: It describes the Web-EMCS development process. The platform URL is www.greenhospital-EMCS.eu http://www.greenhospital-project.eu/wp-content/uploads/2014/01/D3.3-Web-EMCS-on-line.pdf
D5.1	Monitoring guidelines and evaluation plan	It describes data validation procedure and to ensure durable results. http://www.greenhospital-project.eu/wp-content/uploads/2012/04/D5.1_Monitoring-guidlines-and-evaluation-plan.pdf
D6.1	Green@Hospital website	It describes the project Website structure. The Website URL is www.greehospital-project.eu http://www.greenhospital-project.eu/wp-content/uploads/2012/06/D6.1_31.05.2012.pdf
D6.2	Preliminary dissemination plan	It describes the dissemination plan elaborated by project partners in the first phase of the project http://www.greenhospital-project.eu/wp-content/uploads/2012/04/D6-2.pdf
D6.3	Rolling dissemination report	It describes the dissemination activities realized in the first project year.

			http://www.greenhospital-project.eu/wp-content/uploads/2013/03/D6_3-Rolling-Dissemination-Report.pdf
D6.4	Rolling dissemination and exploitation report		It describes dissemination and exploitation activities completed in the second project year. http://www.greenhospital-project.eu/wp-content/uploads/2014/04/D6.4-Rolling-dissemination-and-exploitation-report.pdf
D6.5	Video on Green@Hospital		It describes the Video making process. http://www.greenhospital-project.eu/wp-content/uploads/2014/04/D6.5-Video-on-Green@Hospital.pdf
D6.6	Final dissemination and exploitation report		It describes dissemination and exploitation activities completed in the third project year. http://www.greenhospital-project.eu/wp-content/uploads/2012/04/D6.6-Final-dissemination-and-exploitation-report.pdf
D6.7	Best practice and Standardization Guide		It describes the main project results, the impact of possible replication and the contribution to standards. http://www.greenhospital-project.eu/wp-content/uploads/2012/04/D6.7-Best-practice-and-standardization-guide.pdf

12. Exploitation

A list of exploitable results has been identified and based on it, business plans for the industrial partners and exploitation actions for the hospitals and University / Research Center partners have been developed.

The identified exploitable results have been classified into the following categories:

- Technical results – technical systems
- Technical results – software and models
- Information – papers and deliverables, etc.
- Information – databases and benchmarks
- Brand – Green@Hospital Logo

The technical results include the technical systems which have been installed and tested in the pilot hospitals and integrated in the Web-EMCS. These parts together are exploitable for applications in existing and new hospitals.

In order to make the exploitation effective and quickly applicable to market, the following further steps of analysis have been performed:

- Identification of Target Stakeholders
- Value Proposition for each result category
- Business plan strategy

At consortium level, the Green@Hospital concept, results and data will remain available through the creation of a Community in order to share with a wider variety of stakeholders the data and results obtained.

The Community will be the centerpiece of the future development of the project, where we could share the experiences gained through the Green@Hospital project and growth through a scientific and collaborative approach, leading the consortium partners to advancements in products, services and most important, knowledge.