GREENING THE HEALTHCARE SECTOR: 4 HOSPITALS DEMONSTRATING ADVANCED CONTROLS FOR LIGHTING AND HVAC

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ABSTRACT

In the complex environment of a hospital, Heating, Ventilating, Air-Conditioning (HVAC) and Lighting account for nearly 80% of all energy use. The potential savings achievable with investments with a payback time less than seven years can reach up 40% depending on the current condition of the hospital, where HVAC and lighting are the major contributors. Half of it, being 20%, can be attributed to the impact of ICT.

The HosPilot project aims to support the decision makers with an integrated approach which helps drastically reduce the energy consumption of newly built hospitals and existing hospitals being refurbished, increasing well being and comfort. The main objective of the project is to develop a methodology that will be able to provide a hardware description for an energy efficient system for any hospital, based on specific requirements of that hospital. This methodology will be proven by creating pilot sites in the partner hospitals, and by monitoring those pilots during one year. In addition, it will be ensured that this HosPilot methodology is applicable everywhere in Europe.
This paper elaborates on the developed methodology and the advanced ICTs demonstrated in the pilot buildings in The Netherlands, Spain, Finland, and France.

HosPilot is a project focused on energy efficiency in hospitals. It is co-funded by the EC (contract no. 238933) and involves 11 partners in 5 European countries. The project belongs to the ICT Policy Support Programme. It has started in March 2009 and will end in February 2012.

Keywords: energy efficient hospitals, smart lighting, HVAC automation, monitoring.

INTRODUCTION

In a constantly changing environment, the pursuit of economic growth is not without consequences for the world surrounding us. The recent natural disasters caused by global warming made people more and more aware of the emergency to take care of our environment. This awareness goes through legislations, like the Kyoto protocol that sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions [1].

Through its EU's Europe 2020 strategy plan [2], the European commission has put energy savings at the top of the political agenda. Until recently, schools and offices were the principal targets of energy reduction, but hospitals also use large amount of energy [3]. The mission for hospitals is to provide environments for healing patients. Healthcare facilities and their systems must support that primary mission. The challenge is to reduce energy use in healthcare facilities while enhancing patient well-being.

Hospital buildings and its surroundings are among the most complex, diverse, and energy-intensive facilities, providing services 24 hours a day and 7 days a week. They are hosting patients, visitors, medical and administrative staff who often have contradictory needs. For instance, there is general difficulty in hospitals for adapting temperature to personal requirements because patients are ill and not moving while medical staffs are healthy and active. HVAC must be fine-tuned to ensure indoor air-quality and comfort, avoid virus transmissions and protect patients. In various parts of the hospital, lighting must be running all night long: indoor, for allowing the medical staff to make security patrols; in the surroundings for allowing ambulances and patients to find their way to first aid.

The HosPilot project has chosen to demonstrate advanced technological solutions for achieving significant energy reductions in four European hospitals. These solutions are targeting both HVAC and lighting. Furthermore, a methodology based on a software tool is developed, in order to facilitate the replication of these pilots in any other healthcare facilities.

1. METHODOLOGY

The HosPilot project is designing a service, which is able to propose the most efficient technical solutions about HVAC and lighting for a refurbishing hospital, while increasing well being and comfort for the end users. It takes into account specific characteristics and current equipment of a given hospital. The service will be distributed as a software tool designed for decision makers of hospitals.

SysML Design

HosPilot is using the systems modelling language SysML [4] for the design of its methodology [5]. It is a general purpose modeling language systems for systems engineering application. It is used for specifying and modeling complex systems, like the HosPilot application, that may include hardware, software, processes and facilities. This language provides standard graphical representations for system requirements, use-cases, behaviour and structure of a system.

The SysML method applied to HosPilot has some advantages:

- It forces a modular system design;
- A more easily readable description of the HosPilot methodology can be created;
- A broad variety of diagrams and descriptions is possible;
- An unambiguous documentation of requirements for future implementation can be guaranteed.

Requirements towards the HosPilot tool

The main considered requirements are:

- To provide expert knowledge as an energy saving service ;
- To enable decision makers to choose the most efficient technical solution for lighting and HVAC according to the specific characteristics of the hospital;
- To enable calculation of energy savings, total costs and give feasibility indications.

The proposed architecture of the HosPilot methodology implementation is divided into 3 parts:
- The graphical user interface ;
- The HosPilot calculation engine, which is the most important part of the system. Indeed, it provides the estimation of energy consumption with and without applied Energy Conservation Opportunities ;
- Database that incorporates several data, such as weather, Energy Conservation Options (ECO), technical solutions and expert advices.

Activities

In the HosPilot methodology, three main phases can be identified:

Phase 1: Collecting and processing useful information about the hospital through a questionnaire

All the parameters that can influence the room's climate and brightness have to be known. A questionnaire [6] has been designed to ask the following basic characterizing parameters:
- Hospital building location (longitude, country, city, etc.);
- Building data (orientation, outer envelope, structure, etc.);
- Room level data (room geometry, windows, walls, room size, etc.);
- Existing systems concerning HVAC and Lighting.

First, the decision makers have to fill in general hospital data. Then they choose the rooms that they want to refurbish. Afterward the following questions are based on local regulations and local default values, helping the decision makers to fill in room data and room requirement easily.

Phase 2: Proposing possible solutions to exploit the opportunities.

According to the hospital needs, the HosPilot engine will propose appropriate solutions by analyzing existing systems. It also takes into account default room requirements, based on European and National norms and standards applicable for lighting and HVAC. The decision maker is able to change these parameters, but if the user chooses a parameter that is outside the norms, he/she will be warned. The HosPilot engine will give applicable solutions for the selected rooms, and the energy demand for them is calculated.

Phase 3: Calculate estimations of energy savings, total costs and give feasibility indications according to the solutions chosen.

To make these appraisals, the hospital's baseline energy demand is calculated. These calculations are based on:
- Reference energy demand calculation (without any energy conservation opportunity applied, and based on requirements);
- Energy savings calculations per ECO, taking into account the interdependencies of used ECO combinations;
- Purchase cost indication, except for HVAC. Indeed, it only provides installation difficulty indications as this highly depends on the specific situation;
- Installation costs indication, except for HVAC. Concerning lighting, it provides either estimation of installation costs or installation difficulty;
- Finally, the HosPilot generates a final end-user report, showing which ECO and combinations are achievable, proposing additional energy saving measures and giving the effect of each ECO on the annual energy consumption. Moreover, energy savings on building level also appear.

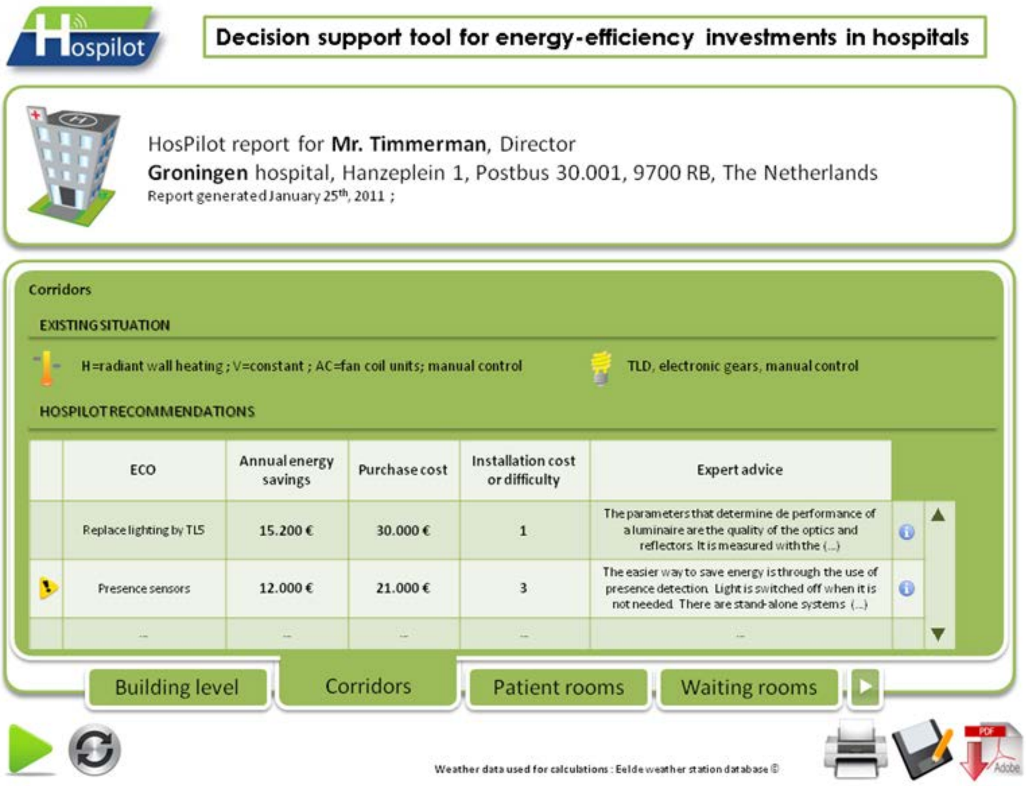

Figure 1. Prototype of the Graphical User interface for the final HosPilot report

The HosPilot tool makes possible for the hospital facility manager to simulate different refurbishment scenarios, watch instantly their estimated impact, and therefore decide the best way and place to invest money. The main HosPilot innovation is thereby this integrated and independent decision support service regarding lighting and climate control for the hospital and its surroundings, by taking into account its specific usage.

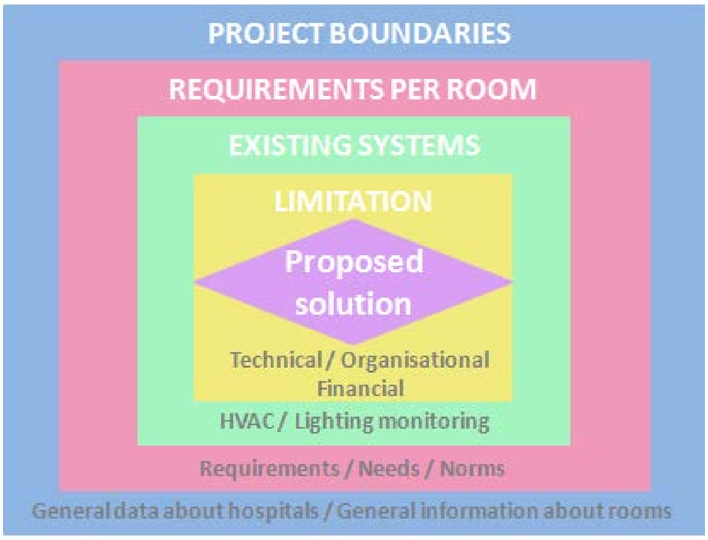

Figure 2: Gathering the HosPilot information and coming to the situation

In order to demonstrate the HosPilot service, the methodology has been applied to four European pilot hospitals. Based on the questionnaires outputs (Phase 1), a number of different ECOs have been selected for each pilot (Phase 2). The ECOs have been physically implemented in the pilots, and a comprehensive monitoring system has been put in place to calculate actual energy savings (Phase 3). The analysis of the monitoring results will allow checking and refining the HosPilot tool accuracy.

2. THE FOUR PILOT HOSPITALS

This section presents the four HosPilot pilot hospitals and the ECOs that they demonstrate. The table below summarizes the pilot characteristics, and the following sub-sections provide further technological details about each installation.

Hospital name	Acronym	Location	Main implemented ECOs
Hospital District of South Osthrobotnia	EPSHP	Seinäjoki, FINLAND	• Variable Air Volume ventilation • LED downlights and LED linear tubes • Presence detection information shared for lighting and HVAC • LonWorks room controllers communicating with BMS
Universitair Medisch Centrum Groningen	UMCG	Groningen, THE NETHERLANDS	• BMS for dimming and controlling of lights according to time schedules • Advanced HVAC management with windows sensors, carbon dioxide sensors, radiator valves and air valves
Servicio Riojano de Salud, Hospital San Pedro	SERIS	Logroño, SPAIN	• Occupancy schedules of the room • Presence detection strategies and windows status monitoring • Optimization of ventilation based on presence detection and CO2 control • T5 lighting technology and LED downlights • Daylight and occupancy sensors for lighting adjustment
Centre Hospitalier de Castelluccio	Castelluccio	Ajaccio, Corsica, FRANCE	• LED outdoor street lighting • Remote management of luminaires with dimming according to time schedules and weather

Table 1: Main ECOs demonstrated in each pilot hospital

A. FINNISH PILOT: EPSHP

EPSHP provides healthcare services for 26 Finnish municipalities with about 190.000 inhabitants. The whole second floor of the H-Building acts as pilot area. One-half is renovated with standard equipments; the other half is equipped with new Information and Communication Technologies (ICT). By pairing identical room side by side of each part, it is possible to compare the total electricity usage.

System information

The hospital uses a TAC Supervisory Control and Data Acquisition solution (SCADA) from Schneider. It provides solutions for energy management, such as detailed information about HVAC and electricity. However, as the information are not accurate enough, an upgrade of the system is necessary to collect data that are more detailed without interfering with the normal operations and maintenance functions in the other parts of the hospital.

To do so, it was decided to add a new server in the hospital, used as a virtual part of the TAC system, to collect data to a separate database. Then by synchronizing the databases of the servers, this data is linked to a server hosted at VTT (Technical Research Centre of Finland) facilities and which is used for analyzing and visualizing the data.

The TAC's Vista 5 version has been upgraded to make it possible to use all existing Local Outed Network (LON) and new MODBUS installations. MODBUS is the standard communications protocols in the industry, and it is used to connect industrial electronic device.

The system produces automated monthly reports of energy usage that will mainly be used by maintenance personnel.

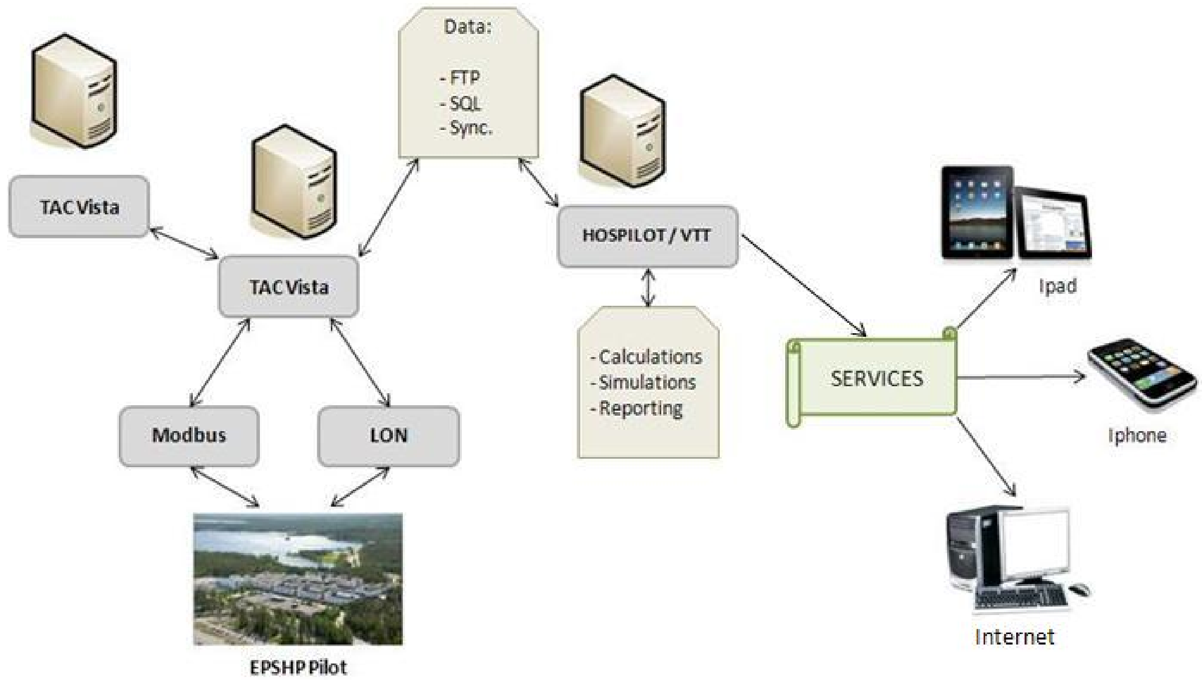

Figure 3: EPSHP pilot monitoring architecture

Refurbishment concept

The lighting of one part of the floor is composed of new technologies equipment, such as LED-solutions and presence detection sensors. Measurements are compared with the other half of the floor equipped with conventional technical solutions. In the first part, the installations include DALI-gateway technology. The corridor lights are decreased by 10% thanks to PIR sensors outside office-hours. On each part of the floor, the monitoring system allows to measure the lighting consumption independently from the whole electricity consumption. There is a rough estimate to save from 20 to 30% of electricity with the new technologies in relation to the conventional technologies.

On patient rooms and meeting rooms, different HVAC components are implemented.

- Air flow control (variable air volume: VAV) based on occupancy, room air temperature and room air quality;
- Air flow control (minimum flow/normal flow) based on occupancy only;
- Occupancy controlled heating;
- Window and door switch activated energy saving mode for air flow and heating control.

The energy performances of these advanced technologies are benchmarked to the other rooms equipped with a basic HVAC solution that is to say without any air flow control system, and heating control by simple thermostatic radiator valves (TRV). Energy savings implemented by the use of intelligent systems about HVAC are usually estimated up to 20%.

Monitoring concept

Monitoring includes a total of 254 channels (e.g. temperature) and 206 status channels (e.g. presence of somebody or not). Data channels are sampled every 600 seconds and the monitoring of the status channels is “timestamping” status change events. The SQL database in the TAC Vista server is synchronized via SSL with the VTT HosPilot server. The data are used for validating calculations of energy savings, and show the status of the measurements in real time through services like iPhone/iPad and the Internet.

Mobile Service for iPhone and iPad

The monitoring data, located in the VTT HosPilot server, has been used to create and test an iOS service. The main objective of this service is to show all the monitored data through an iPad or an iPhone application. For example, the service is producing a graph of various data concerning a selected sensor device or energy meter, etc. Then it sends this information to a mobile device, using an Obix gateway and SSl.
Furthermore, the service is planned to show the comparison between the actual value and simulated values. For example, real data of total energy consumption of a specific room can be compared to theoretical simulated values which are calculated according to building’s characteristics.

B. DUTCH PILOT: UMCG

UMCG is one of the biggest hospitals (350 000 m²) in The Netherlands with 1 300 beds. It provides healthcare for over 1 000 patients every day, and more than 31 000 treatments take place every year. The UMCG pilot introduces more efficient and smarter lighting and climate control systems to make patients feel more comfortable. Three areas have been equipped for the pilot: 2 nursery departments (2400 m²), corridors and sanitary.

System information

The installation of controllers and measurement devices at the pilot locations have been made on the Building Management System (BMS) and the UMCG’s own power management system, called VBS. The BMS used is the Metasys® building management system from Johnson Controls. It ensures all of the building system to operate together in harmony by coordinating and organizing all the information logically, and delivering them at any time. This BMS has been upgraded to be the main system with built-in integration and migration to a web-based architecture. It protects existing investment with backward and forward compatibility with other systems. Then all of them are integrated into a common platform with a single user interface.

The BMS supports LON and N2 bus devices. HVAC and lighting have been fitted on the LON-bus.

Energy measurement for electrical power is connected to the VBS, where the data server takes care of saving the current power factor and reactive power data. On the refurbished nursery departments, the VBS is also used for monitoring. For the other parts of the HosPilot in the UMCG, the BMS is used for monitoring because this was easier to implement with less investments.

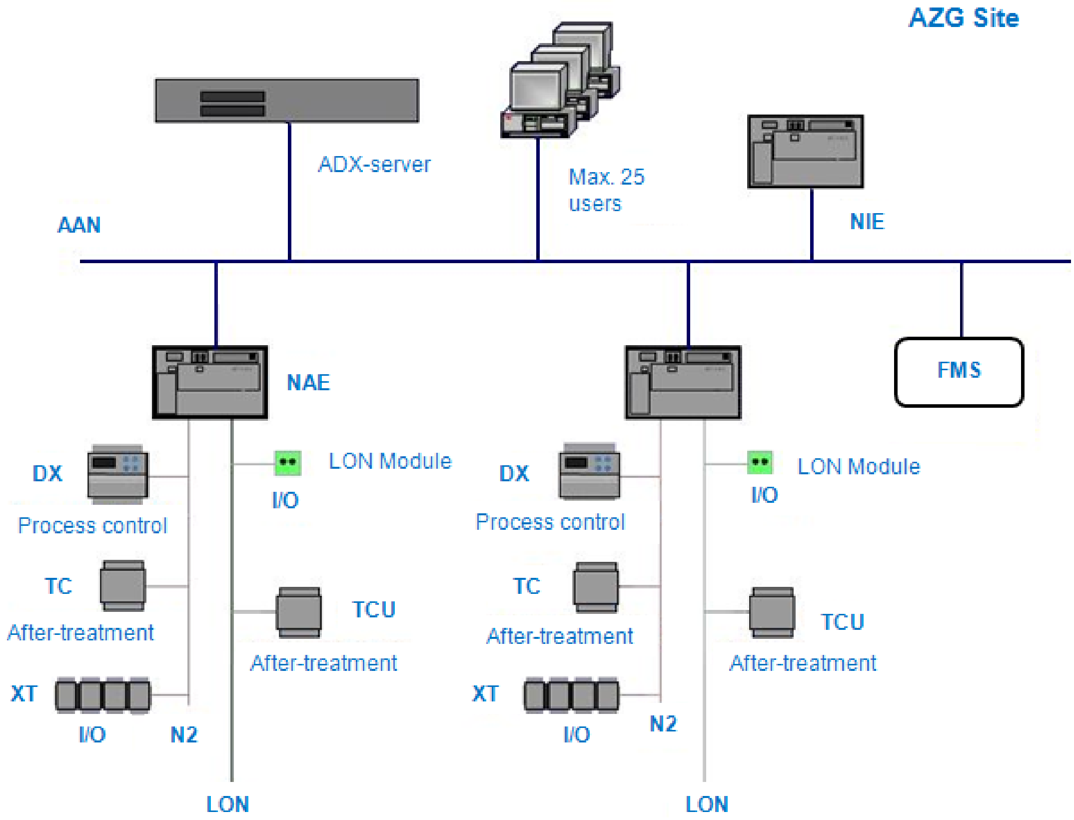

Figure 4: Simplified network topography of the Building Management System

Refurbishment concept

- Nursery departments
    - Lighting

They are refurbished with new lighting and controls. Lots of new sensors have been installed: they guarantee the right lighting at the right time. Moreover, the pilot specifically focuses on lighting in individual rooms. Such rooms are often used in various ways – for example, examination rooms can also be used for short meetings with staff members: rooms are multi functions. This affected the lighting and climate control system needed in these rooms. The refurbishment of these departments includes a cosmetic update with minimal modifications to existing infrastructure and building envelope, but with a higher sense of comfort.

- HVAC

New HVAC parts are added to the existing system in one department, on the 2nd floor. There are window sensors, carbon dioxide sensors, radiator valves and air valves. All of them are connected to a data concentrator, so their information can be treated. For example, if a window is opened, radiators will shut down and the ventilation will decrease. If there is no user inside the room, the rate of carbon dioxide will stay constant, and the air flow will decrease. The 2nd floor is compared to the 3rd floor, which is not equipped with new smart HVAC parts.

- Main corridors

Lights of the main corridors have been replaced, as they were almost 25 years old. New lighting has been installed with more possibilities for dimming the light, and also another wither color of light. It uses LON-module technology connected to the Building Management System (BMS). Thanks to the BMS, different time schedules are defined and lighting is modified according to these schedules. In the new situation, the complete line of lights is dimmed instead of switched on/off in several parts.

- Sanitary

In sanitary rooms, for example toilets, showers and changing rooms, a lot of energy is wasted, as many people leave the room without turning off the light. Movement detectors (PIR) and LED luminaries are used to save energy.

Monitoring concept

Monitoring is for the main part done by the BMS. It includes a total of 240 data channels (e.g. temperature, CO2, actuators) and 50 status channels (e.g. window switches, on/off switches). Data channels are sampled every 1200 seconds and the monitoring of the status channels is "time-stamping" status change events. The associated SQL database makes calculations possible, and it also enables users to view the status of the measurements in real time through the Internet.
On the departments K1 and K2, the lighting is monitored by the VBS instead of the BMS. This was done because of the already installed infrastructure.

C. SPANISH PILOT: SERIS

The SERIS pilot in Logroño is a though challenge for the developed HosPilot methodology, as it is a newly constructed building, and therefore already using recent technologies.

Two pilot areas have been chosen:

- The third floor of the hospital, which is divided in five different zones. This configuration was chosen to include, as much as possible, all room types necessary to evaluate and get necessary information about specific energy behaviors of the whole hospital. Comparisons will be done thanks to "twin room": one room equipped with the advance Information and Communication Technologies (ICT) solutions and the other assigned control room are not equipped, as reference. Especially, one of the twin long corridors has been equipped with new lighting technology, and will be compared to the other one.
- A waiting room on the first floor for outpatient consultation: half of the lighting installation has been changed with ICT and LED solutions in this large room, to be measured and compared with the other half, which has been maintained as it was originally.

System information

The rooms equipped with the Energy Conservation Option's (ECO) devices have three kinds of hardware:

- ISA: it collects energy information such as dioxide carbon concentration data;
- Maxfor devices: It collects the environmental and comfort parameters (temperature, luminance and humidity);
- Beckhoff: It monitors HVAC controls (valve actuators, fan activators, etc.).

Monitoring concept

ISA: The purpose of these devices is to monitor the energy consumption parameters of the pilot. They are deployed in the primary and secondary areas of the pilot. The electrical monitoring solution has 2 different communication means, one for the main switchboards and other for the floor rooms. In the main switchboard, ISA has connected CTs to the board and to the iMeterRail that communicates the data through RS-485 to the iHub concentrator. Then this last one sends the data to the Ethernet Network and to the central server. In the floor rooms, PLC technology has been used. PLC-Ethernet converters have been deployed in all rooms that are also connected to the iHub.

Maxfor: These devices are used to monitor the comfort. A number of network motes have been deployed on each zone selected. Sensor motes installed measure the selected comfort/environmental

parameters. These motes store the parameters in a buffer and transmit them when requested by the root mote. The root mote is physically connected to a PC and acts as a controller of the sensor motes. Every 1200 seconds the root mote asks to the sensors for their measurements and they upload them to the PC. The last mote is the bridging mote, which acts as the re-transmitters of the information exchanged between the root and the sensor motes.
Once the information is stored in the PC, it is sent periodically over the Internet to the Acciona HosPilot Server, and is stored on a PostgreSQL database. Then the Acciona HosPilot server makes it available via its web interface, and the data are monitored in "real time".

Beckhoff: These devices are used to monitor and control the HVAC parameters at room level. It is based on a PLC platform and incorporates interoperability and scalability functionalities. These functionalities are powered by Windows XP embedded system. It will measure temperature, valve and fan status in order to calculate energy transfers into rooms, and door and windows status to detect heat gains or leaks. Data collected by the different distributed measure devices will be stored in a MySQL local database, located at the pilot level concentrator. This data is transferred periodically to a project server and is analyzed.

D. FRENCH PILOT: CASTELLUCCIO

The Castelluccio pilot in Corsica has been selected to implement technologies focusing on remotely managed outdoor LED lighting for the hospital surroundings. The road selected is one of the main roads leading to the hospital. It is mainly used by cars and some pedestrians. It comprises 15 luminaries, all connected to the same energy meter. A similar road (same number of luminaries, same environment) has been identified to be used for comparison and benchmarking.

System information

On this pilot, a remote lighting management system is used: the StarSense Solution.
It allows saving energy by dimming as soon as possible lighting depending on the traffic and weather conditions, reduced costs by a more efficient maintenance and enhanced security. To maintain the same level of illumination throughout the night is hardly the best solution. Motorists do not need the same amount of light when traffic is low. StarSense can be used to dim the light depending on the traffic volume. Also depending on the weather or the conditions if we have the illumination values in real time during the day, it is possible to dim the sources to get the right level of illumination. The benefits of StarSense also include improved maintenance: better maintenance planning is possible thanks to user feedback, best replacement of defective sources is possible without recourse to patrols, and providing information on end of lamp life eliminates the predicting works for some facilities.

The StarSense software provides a graphical user interface for the equipment and supervision:

- StarSense Configurator: Web oriented application used to configure and activate a Segment Controller (SC) and the Outdoor Lighting Controllers (OLCs) attached to it. It is user-friendly and can be used on-line or off-line. Thanks to that tool, the facility manager is able to configure gradation curves, calendars, I/O configuration, groups, etc.
- StarSense Supervisor: Web oriented application too, but for controlling and visualizing a complete system of SCs and OLCs, easily interpretable. Data can be presented on a map, and operations such as operation hours analysis, identification and location of lamps which are at the end of their life, verification of actual gradation curves can be done.

Monitoring concept

The following table summarizes the main monitoring indicators for this pilot:

	No pilot area		Pilot area	
	Y/N	Technology	Y/N	Technology
Area usage (car detection) - This parameter will be monitored mainly to fine-tune the dimming strategy during the experimentation	N	Not useful (no dimming on the "no pilot" area)	Y	Presence or pressure sensor on the road
Electricity consumption of the area	Y	Energy meter	Y	Using StarSense + Energy meter
Programmed dimming strategy	Using StarSense			
Installed Lighting power	This measurement is done only once according to the chosen luminaries.			
Luminance (Lux levels)	This calculation is done only once with a luxmeter, according to the norm called EN-13201-3			
Lamp lifetime forecast	Using StarSense			

Table 2: Monitoring indicators in the French pilot

The implementation of the ECOs in these four pilot hospitals has been mostly realized in 2010 and the first half of 2011. Monitoring data will be collected over one year, and the first conclusions (actual energy savings and end-users feedback) should be available at the end of 2011.

CONCLUSION

The four pilot hospitals described in this paper will not only demonstrate that significant energy efficiency improvement can be achieved by using advanced energy technologies in hospitals: the monitoring results will also contribute to prove and fine-tune the HosPilot service for hospitals' decision makers. This service is a unique proposition, as it allows the effects of a certain Energy Conservation Option to be explored by simply checking a box and in combining expertise from HVAC, lighting and ICT controls domains.
During the first two years of the project, the complete HosPilot tool architecture has been designed [5], as well as a demo-system that is supporting a limited number of ECOs. The HosPilot project consortium is now planning to continue developing this demo-system into a final software tool.

The HosPilot Methodology and the piloting activities are described in detail in the project deliverables. The public deliverables can be found on the project website www.hospilot.eu

ACKNOWLEDGMENTS

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