

Work Package 6

Dissemination and Communication

Deliverable D6.7

Best practice and Standardization Guide

Document version	3.0
Document Preparation Date	07/04/2015
Dissemination level	Public
Author(s)	All partners

Project Acronym	Green@Hospital
Grant Agreement numbers:	ICT PSP 297290
Project Title:	web-based enerGy management system foR the optimization of the EnErgy coNsumption in Hospitals
Website	www.greenhospital-project.eu

Revision	Date	Author	Organization	Description
1	11/02/2015	Ivan Mangialenti	SCH	Index and first draft
2	06/03/2015	David Barrachina	HML	Contribution about HML activity concerning surgery theatres
3	16/03/2015	Davide Nardi Cesarini	AEA	Final results from D5.2
4	18/03/2015	Ivan Mangialenti	SCH	Second draft
5	27/03/2015	Davide Nardi Cesarini	AEA	Final review

Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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1. Introduction

This document is meant to present the main project results to project stakeholders. In fact Deliverable 5.2 “Final report on evaluation phase”, which describes in detail the activities performed before and after the installation phase to assess energy savings achieved and project results, is a restricted document, therefore this report is meant to summarize the main project outputs to be available to stakeholders.

In order to support the reader in integrating project results in the European normative framework Chapter 2 is dedicated to introduce briefly the regulations (mandatory, voluntary and under evaluation) applicable to the subject of the project.

Then Chapter 3 introduces the height non hospital specific energy saving solution set catalogue presenting for each of them a brief description, the results achieved in compliance with the EN 15232, the main results in terms of energy, percentage and CO₂ emission savings and the potential impact of the solutions on the overall building.

Chapter 4 is dedicated to the only hospital specific solution introducing the existing regulation, the results achieved and the guidelines to introduce this innovative Ventilation control in the operating theatres. Finally a proposal to be submitted to the Standardization bodies is presented.

2. Regulatory framework

This brief chapter presents the main references to norms affecting ICT applications for energy efficiency that is the main project topic.

For this reason, the following regulations are introduced:

- EPBD Energy Performance Buildings Directive
- EN15603:2015 Energy Performance of Buildings – Overarching standard EPBD
- EN15232:2012 Energy performance of buildings - Impact of Building Automation, Controls and Building Management

2.1. EPBD Directive

The DIRECTIVE 2010/31/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 (recast), also named EPBD Energy Performance Buildings Directive is the main reference of any project that involve the Energy Efficiency of a building.

In particular, speaking about ICT technologies, we have to consider the Article 8, Technical building systems:

“8.1. Member States shall, for the purpose of optimizing the energy use of technical building systems, set system requirements in respect of the overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control of the technical building systems which are installed in existing buildings. Member States may also apply these system requirements to new buildings.

System requirements shall be set for new, replacement and upgrading of technical building systems and shall be applied in so far as they are technically, economically and functionally feasible.

The system requirements shall cover at least the following:

- (a) heating systems;
 - (b) hot water systems;
 - (c) air-conditioning systems;
 - (d) large ventilation systems;
- or a combination of such systems.

8.2. Member States shall encourage the introduction of intelligent metering systems whenever a building is constructed or undergoes major renovation, whilst ensuring that this encouragement is in line with point 2 of Annex I to Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity (1). Member States may furthermore encourage, where appropriate, the installation of active control systems such as automation, control and monitoring systems that aim to save energy”.

2.2. EN15603:2015

One of the main issues about the application of Integrated Controls is related to how to calculate the impact on the Building Energy Performance. This calculation is relevant not only to evaluate the impact of the intervention (impact on OPEX), but also because the market value of the building itself is more and more related to its Energy performance (impact on CAPEX).

The regulation that indicates the overall method to calculate the Energy Performance of the Building and refers to the regulation to calculate the Integrated controls contribution is the EN15603:2015 Energy Performance of Buildings – Overarching standard EPBD

A brief extract is reported hereafter:

“ Introduction

.... This standard specifies a general framework for the assessment of overall energy use of a building, and the calculation of energy ratings in terms of primary energy or other energy related metrics.

This standard replace EN15603:2008 and parts of other EN or EN-ISO standards published in 2007-2008 under the mandate M/343 on the EPBD.

.....

8. Calculated Energy Rating Routing

.....

8.1.4 Effect of integrated controls

The impact of integrated controls, combining the control of several systems shall be taken into account according to EN15232”

2.3. EN15232:2012

As introduced in the EN15603:2015, the regulation that gives the detailed method to calculate the Integrated Controls contribution to the Energy Performance of the Buildings is the EN15232:2012 Energy performance of buildings - Impact of Building Automation, Controls and Building Management.

“ Introduction

This European Standard was created to establish conventions and methods for estimation of the impact of building automation and control systems (BACS) and technical building management (TBM) on energy performance and energy use in buildings.

....

This European Standard specifies a method to estimate energy saving factors which can be used in conjunction with energy assessment of buildings. This European Standard supplements a series of standards which are drafted to calculate the energy efficiency of technical building services, e.g. heating, cooling, ventilation, lighting systems. This European

Standard takes into account the fact that with BACS and TBM the energy consumption of a building can be reduced.”

The EN15232:2012 classifies each ICT based application in four different classes, each of them identifying a different level of Energy Efficiency:



Figure 1EN15232 classification

For each of the Pilot site we analyze in the following the application that was realized and the improvement of Energy Class obtained. The table indicates the Energy Class of the application before the intervention (red cross) and the Energy Class after the intervention (green cross).

Resuming we were able to move to Class A all the applications involved in the project.

3. Non hospital specific Energy Efficiency Use Cases

This chapter presents a catalogue of height non hospital specific energy saving solution sets. They are classified into three main categories: HVAC (Heating Ventilation and Air Conditioning), Lighting and Data Centres.

In order to understand the potential impact of Green@Hospital solutions in hospitals and in other buildings, the CBECS (Commercial Building Energy Consumption Surveys) by Lawrence Berkeley National Laboratory has been identifies as the reference presenting for hospitals and other public buildings a typical energy breakdown reported in the Tables 1 and 2.

Final use	Hospital	Office	Food sale	Education
Space Heating and cooling	44%	45%	19%	57%
Ventilation	8%	6%	3%	10%
Water Heating	19%	2%	1%	7%
Lighting	16%	25%	18%	14%
Cooking	2%	0%	4%	1%
Refrigeration	1%	3%	47%	2%
Office Equipment	2%	9%	2%	4%
Other	7%	10%	5%	5%

Table 1 CBECS energy breakdown 1/2

Final use	Services	Public assembly	Lodging	Public order	Food service
Space Heating and cooling	28%	63%	25%	9%	23%
Ventilation	4%	17%	1%	1%	6%
Water Heating	1%	1%	31%	2%	16%
Lighting	11%	7%	27%	2%	10%
Cooking	46%	1%	4%	0%	25%
Refrigeration	1%	2%	2%	0%	16%
Office Equipment	1%	1%	2%	83%	1%
Other	8%	7%	7%	2%	4%

Table 2 CBECS energy breakdown 2/2

For each Green@Hospital solution a brief description, the results achieved in compliance with the EN 15232, the main results in terms of energy, percentage and CO₂ emission savings and the potential impact of the solution on the overall building are presented.

3.1. 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.

3.1.1. 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												

<p>Pilot savings</p> <p>Gas saving: 241,172 kWh/year</p> <p>Electricity saving: 103,022 kWh/year</p> <p>Tot primary energy saving: 492,945 kWhpe/year</p> <p>Total primary energy saving: 7.5%</p> <p>CO₂ saving: 147,165 kg/year</p>	<p>Pilot savings</p> <p>Gas saving: 861,172 kWh/year</p> <p>Electricity saving: 365,172 kWh/year</p> <p>Tot primary energy saving: 1,754,046 kWhpe/year</p> <p>Total primary energy saving: 22.3%</p> <p>CO₂ saving: 522,692 kg/year</p>
<p>Pilot economic figures</p> <p>Implementation cost (meters purchasing, installation and commissioning): 62,672 €</p> <p>Cost saving: 163,514 €/year</p> <p>PBT: 1.5 years</p>	<p>Pilot economic figures</p> <p>Implementation cost (meters purchasing, installation and commissioning): 62,672 €</p> <p>Cost saving: 42,810 €/year</p> <p>PBT: 0.4 years</p>
<p>Overall hospital potential savings</p> <p>Same as the pilot area since the solution already affects the overall building</p>	
<p>Overall hospital economic figures</p> <p>Same as the pilot area since the solution already affects the overall building</p>	

Table 3 Heating and cooling production optimization datasheet

3.1.2. 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

		Definition of classes											
		Residential				Non residential							
		D	C	B	A	D	C	B	A				
4.5	Free mechanical cooling												
0	No automatic control												
1	Night cooling												
2	Free cooling												
3	H.x-directed control												

Pilot savings

Cooling: 5,569 kWh/year

Heating: 4,632 kWh/year

Tot primary energy saving: 9,848 kWhpe/year

Total primary energy saving: 42%

CO₂ saving: 2,057 kg/year

<p>Pilot economic figures</p> <p>Implementation cost (programming and commissioning cost): 976 €</p> <p>Cost saving: 611 €/year</p> <p>PBT: 1.6 years</p>
<p>Overall hospital potential savings</p> <p>Cooling: 662,711 kWh/year</p> <p>Heating: 551,208 kWh/year</p> <p>Tot primary energy saving: 1,171,912 kWhpe/year</p> <p>Total primary energy saving: 42%</p> <p>CO₂ saving: 244,783 kg/year</p>
<p>Overall hospital economic figures</p> <p>Implementation cost (programming and commissioning cost and controller purchasing for those AHU not equipped with a controller): 564,720 €</p> <p>Cost saving: 72,709 €/year</p> <p>PBT: 7.8 years</p>

Table 4 Emergency zone Air Handling Unit Control datasheet

3.1.3. 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

		Definition of classes							
		Residential				Non-residential			
4.6	Supply air temperature control	D	C	B	A	D	C	B	A
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

Cooling: 12,315 kWh/year

Heating: -22 kWh/year

Tot primary energy saving: 10,690 kWhpe/year

Total primary energy saving: 9%

CO₂ saving: 2,232 kg/year

Pilot economic figures

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

Cost saving: 736 €/year

PBT: 7 years

Overall hospital potential savings

Cooling: 36,945 kWh/year

Heating: -66 kWh/year

Tot primary energy saving: 32,070 kWhpe/year

Total primary energy saving: 9%

CO₂ saving: 6,696 kg/year

Overall hospital economic figures

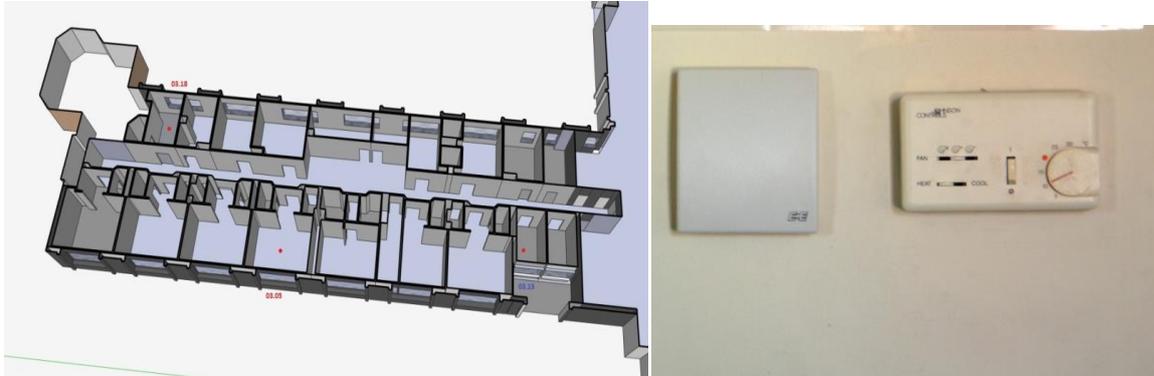
Implementation cost (controller purchasing programming and commissioning cost): 18,576 €

Cost saving: 4,464 €/year

PBT: 7 years

Table 5 Surgery theatres AHU control datasheet

3.1.4. 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

		Definition of classes							
		Residential				Non residential			
		D	C	B	A	D	C	B	A
AUTOMATIC CONTROL									
1	HEATING CONTROL								
1.1	Emission control								
	<i>The control system is installed at the emitter or room level, for case 1 one system can control several rooms</i>								
0	No automatic control								
1	Central automatic control								
2	Individual room control								
3	Individual room control with communication								
4	Individual room control with communication and presence control								

also for cooling control (function 3.1)

Pilot savings

Electricity: 6,436 kWh/year

Oil: 584 litre/year

Tot primary energy saving: 26,321 kWhpe/year

Total primary energy saving: 55%

CO₂ saving: 8,152 kg/year

Pilot economic figures

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

Cost saving: 1,035 €/year

PBT: 3.4 years

Overall hospital potential savings

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

Total primary energy saving: 56%

CO₂ saving: 392,044 kg/year

Overall hospital economic figures

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

Cost saving: 49,186 €/year

PBT: 2.5 years

Table 6 Air handling units of paediatric department control datasheet

3.2. 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 energy 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.

3.2.1. Data Center cooling optimization (AOR)



Solution set description

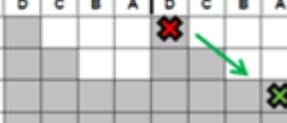
AOR Data Center called Agorà was refurbished in 2011 and several hardware based energy saving strategies were implemented:

- 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 Center 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

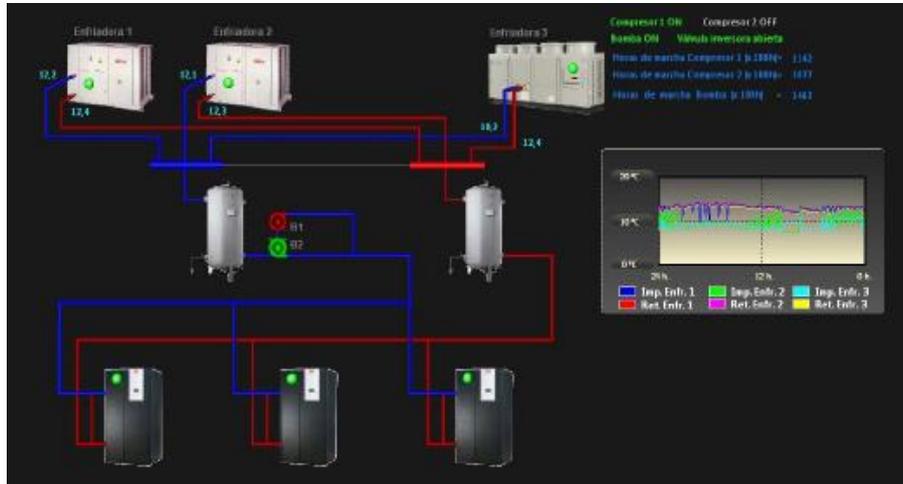
		Definition of classes							
		Residential				Non residential			
		D	C	B	A	D	C	B	A
4.5	Free mechanical cooling								
	0 No automatic control								
	1 Night cooling								
	2 Free cooling								
	3 H.v- directed control								



<p>Pilot savings</p> <p>Electricity: 4,943 kWh/year</p> <p>Tot primary energy saving: 10,726 kWhpe/year</p> <p>Total primary energy saving: 4%</p> <p>CO₂ saving: 2,625 kg/year</p>
<p>Pilot economic figures</p> <p>Implementation cost (programming and commissioning cost): 1,000 €</p> <p>Cost saving: 741 €/year</p> <p>PBT: 1.3 years</p>
<p>Overall hospital potential savings</p> <p>Same as the pilot area since the solution cannot be replicated in other areas of the building</p>
<p>Overall hospital economic figures</p> <p>Same as the pilot area since the solution cannot be replicated in other areas of the building</p>

Table 7 Data Center cooling optimization datasheet

3.2.2. 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

		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

- Electricity: 43,437 kWh/year
- Tot primary energy saving: 99,035 kWhpe/year
- Total primary energy saving: 14%
- CO₂ saving: 13,465 kg/year

Pilot economic figures

- 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

Table 8 Cold water production management datasheet

3.3. 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.

3.3.1. 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 set point.

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								✗

<p>Pilot savings</p> <p>Electricity: 12,912 kWh/year</p> <p>Tot primary energy saving: 28,020 kWhpe/year</p> <p>Total primary energy saving: 81%</p> <p>CO₂ saving: 6,856 kg/year</p>
<p>Pilot economic figures</p> <p>Implementation cost (LED lights, sensors and controllers purchasing, installation and commissioning): 25,663 € (41.67 €/m²)</p> <p>Cost saving: 1,937 €/year</p> <p>PBT: 13.24 years</p>
<p>Overall hospital potential savings</p> <p>Electricity: 5,534,029 kWh/year</p> <p>Tot primary energy saving: 12,008,842 kWhpe/year</p> <p>Total primary energy saving: 75% (43% excluding contribution of light retrofit)</p> <p>CO₂ saving: 2,938,569 kg/year</p>
<p>Overall hospital economic figures</p> <p>Implementation cost (LED lights, sensors and controllers purchasing, installation and commissioning): 4,054,085 €</p> <p>Cost saving: 830,104 €/year</p> <p>PBT: 4.9 years</p>

Table 9 Smart Lighting System datasheet

3.3.2. 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

Electricity: 977 kWh/year

Tot primary energy saving: 2,835 kWhpe/year

Total primary energy saving: 57%

CO₂ saving: 966 kg/year

<p>Pilot economic figures (3 rooms)</p> <p>Implementation cost (sensors and controllers purchasing, installation and commissioning): 1,492 € (41.67 €/m²)</p> <p>Cost saving: 68 €/year</p> <p>PBT: 21 years</p>
<p>Overall hospital potential savings (replicating the solution just in the Doctor offices)</p> <p>Electricity: 29,752 kWh/year</p> <p>Tot primary energy saving: 86,280 kWhpe/year</p> <p>Total primary energy saving: 58%</p> <p>CO₂ saving: 31,596 kg/year</p>
<p>Overall hospital economic figures (replicating the solution just in the Doctor offices)</p> <p>Implementation cost (sensors and controllers purchasing, installation and commissioning): 10,080 €</p> <p>Cost saving: 2,082 €/year</p> <p>PBT: 4.8 years</p>

Table 10 Artificial Lighting Management in rooms datasheet

3.4. Overall results

3.4.1. Savings and Pay-Back Time

Solution sets results in terms of percentage and PBT are resumed in the following table.

Area of application / Application (Hospital)	Saving [%]	PBT [Years]
Heating & Cooling Control		
Optimized management of generators (HML)	7,5%/22,3%	1.5/0.4
Emergency zone Air Handling Unit Control (HVN)	42%	1.6
Surgery theatres AHU control (HVN)	9%	7
Fan coils management in rooms (SGH pediatric clinic)	55%	3.4
Data center optimization		
Cooling optimization (AOR)	4%	1.3
Cold water production management (HVN)	14%	0.2
Lighting optimization		
Smart Lighting System (AOR)	75%	4.9
Artificial Lighting Management in rooms (SGH pediatric clinic)	57%	21.81

Table 11 Summary of solution sets savings and PBT

In order to evaluate the potential impact of all the energy saving solution sets on a single hospital building the hospital energy breakdown from CBECS (Commercial Building Energy Consumption Surveys) by Lawrence Berkeley National Laboratory is recalled.

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%

Table 12 Impact of Green@Hospital solution sets on a typical hospital facility

Results show that if Green@Hospital solutions were applied to a typical hospital, energy savings would be the **15.4%** of the hospital energy consumption.

3.4.2. Web-EMCS implementation impact

The introduction of an integrated platform to manage all the implemented application means that, starting from the end of the project, the pilot sites will have a consistent interface to monitor energy consumption and indoor conditions.

The availability of this information, in a structured and easy to read format, is a really powerful tool to manage the system, ensure the continuity of the obtained results and program future improvements.

Also if these functions are not easy to be defined in terms of % of savings and PBT, for sure they will have an important impact on the Energy Efficiency of the Hospitals.

According to EN15232:2012 classes of Energy Efficiency the implementation of the Web-EMCS moves hospitals from class D or C (according to the pilot) to class A

			Definition of classes									
			Residential				Non residential					
			D	C	B	A	D	C	B	A		
7.2	Reporting information regarding energy consumption, indoor conditions and possibilities for improvement											
0	No											
1	Yes											

Table 13 EN15232:2012 classes of Energy Efficiency applied to the Web-EMCS

3.5. Compare to EN15232:2012 overall improvements

The detailed results in terms of improvements of the Energy Performance are reported in the previous paragraphs. These results have to be compared with the overall improvements that the EN15232:2012 gives for the Hospitals Buildings, separately for the Thermal Energy:

6.3 Overall BACS efficiency factors for thermal energy $f_{BACS,th}$

The BACS efficiency factors in Table 5 and Table 6 for thermal energy (heating, DHW and cooling) are classified depending on the building type and the efficiency class the BACS/TBM system is related to. The factors for efficiency class C are defined to be 1 as this class represents a standard functionality of BACS and TBM system. The use of efficiency classes B or A always leads to lower BACS efficiency factors, i.e. an improvement of building performance.

Table 5 — Overall BACS efficiency factors $f_{BACS,th}$ – Non-residential buildings

Non-residential building types	Overall BACS efficiency factors $f_{BACS,th}$			
	D	C (Reference)	B	A
	Non energy efficient	Standard	Advanced	High energy performance
Offices	1,51	1	0,80	0,70
Lecture hall	1,24	1	0,75	0,5 ^a
Education buildings (schools)	1,20	1	0,88	0,80
Hospitals	1,31	1	0,91	0,86

Figure 2 Overall BACS efficiency factors for thermal energy

and for the electrical energy:

6.4 Overall BACS efficiency factors for electric energy $f_{BACS,el}$

Electric energy in this context means lighting energy and electric energy required for auxiliary devices as defined in Table 4. The BACS efficiency factors in Table 7 and Table 8 for electric energy (i.e. lighting energy and electric energy required for auxiliary devices (but not electric energy for the equipment)) are classified depending on the building type and the efficiency class of the BACS and TBM system. The factors for efficiency class C are defined to be 1 as this class represents a standard functionality of BACS and TBM system. The use of efficiency classes B or A always leads to lower BACS efficiency factors, i.e. an improvement of building performance.

Table 7 — Overall BACS Efficiency factors $f_{BACS,el}$ – Non-residential buildings

Non-residential building types	Overall BACS efficiency factors $f_{BACS,el}$			
	D	C (Reference)	B	A
	Non energy efficient	Standard	Advanced	High energy performance
Offices	1,10	1	0,93	0,87
Lecture hall	1,06	1	0,94	0,89
Education buildings (schools)	1,07	1	0,93	0,86
Hospitals	1,05	1	0,98	0,96

Figure 3 Overall BACS efficiency factors for electrical energy

3.6. Conclusions about not Hospital specific solution sets

The Solution Sets defined in Green@Hospital project are fully covered by EN15232:2012 Applications. Only the Solution Set related to occupancy detection in Operating Theatre required a separate evaluation due to some critical constrains and a separate legislation (see chapter 4).

Unfortunately the data provided by the EN15232:2012 are not referred to the single application, but to the overall result (applying all the application). However it can be noted that the overall result achieved by the Gree@Hospital project (15.4% of energy savings) reached working just on artificial lighting, HVAC, surgery rooms ventilation and data center cooling is in line with the saving estimated by EN15232:2012 for thermal energy and overcomes by far the savings estimated for electricity.

Moreover all the results obtained by the single application realized in the Green@Hospital project exceed the value estimated by the EN15232:2012. This result may be justified by the fact that the Efficiency Factors expressed by the EN15232:2012 are generally referred to very conservative evaluations.

The conclusion is that the Solution Sets defined in Green@Hospital impact on the calculation procedure of energy performance of building, generally exceeding the expected results of EN15232:2012 for the Hospitals building. Nevertheless, the fact that Green@Hospital implement only a subset of the EN15232:2012 Application means that the two set of results (expected by EN15232:2012 and obtained by Green@Hospital) cannot be compared in a consistent way.

Anyway, the results of the Green@Hospital project can enrich the knowledge database referred to Hospital Buildings under evaluation of the CEN/TC247 (owner of the activities related to the EN15232:2012).

4. Hospital Specific Energy Efficiency Use Cases

4.1. Surgery Rooms Ventilation control

Looking at the results in terms of Energy Efficiency, a very interesting Green@Hospital solution set is the control of ventilation inside Surgery Rooms, varying the air changing rate as a function of concentration of particles in the air.

Below the solution set datasheet is reported.



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)

Tot primary energy saving: 94,259 kWhpe/year
 Total primary energy saving: 33%
 CO₂ saving: 39,221 kg/year

Pilot savings (2nd baseline scenario)

Tot primary energy saving: 65,967 kWhpe/year
 Total primary energy saving: 26%
 CO₂ saving: 40,686 kg/year

<p>Pilot economic figures</p> <p>Implementation cost (particle detector purchasing, programming and commissioning cost): 15,340 €</p> <p>Cost saving: 11,013 €/year</p> <p>PBT: 1.4 years</p>	<p>Pilot economic figures</p> <p>Implementation cost (particle detector purchasing, programming and commissioning cost): 15,340 €</p> <p>Cost saving: 7,857 €/year</p> <p>PBT: 1.9 years</p>
<p>Overall hospital potential savings (1st baseline scenario)</p> <p>Tot primary energy saving: 754,072 kWhpe/year</p> <p>Total primary energy saving: 33%</p> <p>CO₂ saving: 313,768 kg/year</p>	<p>Overall hospital potential savings (2nd baseline scenario)</p> <p>Tot primary energy saving: 527,736 kWhpe/year</p> <p>Total primary energy saving: 26%</p> <p>CO₂ saving: 325,488 kg/year</p>
<p>Overall hospital economic figures (1st baseline scenario)</p> <p>Implementation cost (particle detector purchasing, programming and commissioning cost): 122,720 €</p> <p>Cost saving: 88,104 €/year</p> <p>PBT: 1.4 years</p>	<p>Overall hospital economic figures (2nd baseline scenario)</p> <p>Implementation cost (particle detector purchasing, programming and commissioning cost): 122,720 €</p> <p>Cost saving: 62,856 €/year</p> <p>PBT: 1.9 years</p>

Table 14 Surgery Rooms Ventilation control datasheet

4.2. Existing Regulation

ISO 14644 is the family of Regulations applicable to Clean Rooms (including the Operating Theatres). The ISO14644-1 defines the Classes of Clean Rooms, based on the following formula:

$$C_n = 10N (0.1 / D)^{2.08}$$

where:

C_n = maximum permitted number of particles per cubic meter equal to or greater than the specified particle size, rounded to whole number

N = is the ISO class number, which must be a multiple of 0.1 and be 9 or less

D = is the particle size in micrometers

Applying this formula we have the following results:

Maximum Concentration Limits (particles/m³ of air)

Class	0.1 µm	0.2 µm	0.3 µm	0.5 µm	1 µm	5 µm
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1000	237	102	35	8	
ISO 4	10000	2370	1020	352	83	
ISO 5	100000	23700	10200	3520	832	29
ISO 6	1000000	237000	102000	35200	8320	293
ISO 7				352000	83200	2930
ISO 8				3520000	832000	29300
ISO 9				35200000	8320000	293000

Figure 4 Maximum concentration limits for each clean room class

In Operating Theatres, which are generally considered an ISO 7 environment (but also in all the other ISO environments) the ventilation flow rate is designed to maintain the Particle Concentration Limit inside the Regulation limits.

Unfortunately, for the Operating Theatre, the Regulation is not limited in defining the expected level of Particle Concentration, but it defines also the Air Changes Rate per Hour (ACRH) to be applied in order to obtain the expected result, and in some cases specifying an Absolute Minimum Value, based on different usage of the rooms.

In addition, regulations are different in different Countries, specifying different rules for different conditions of use, and sometimes allowing a reduction of the ACRH only when the Operating Theatre is not operational.

The following table gives a short summary of all the local Regulations applicable to the Operating Theatre in a subset of European countries:

		Total air change	Air renewal	Air recirculation	Flow rate control
		Air volumes per hour/Flow rate	Air volumes per hour/Flow rate	Yes/No	
IT	DPR 14/01/1997 DCR 616-3149/2000	≥ 15 vol/h	≥ 15 vol/h	Not specified	
	CTI 2010	≥ 15 vol/h	≥ 15 vol/h	YES	YES (not operating locals)
	ISPESL 2009	≥ 15 vol/h	≥ 15 vol/h	YES	YES (inactive station)
USA	ASHRAE 170-2008	Class B,C: 20 vol/h minimum Class A: 15 vol/h minimum	Class B,C: 4 vol/h minimum Class A: 3 vol/h minimum	YES	
F	NFS 90-351	≥ 50 vol/h (zone 4) 25÷30 vol/h (zone 3) 15÷20 vol/h (zone 2)	≥ 6 vol/h (no use)	YES	YES when inactive: reduction up to 6 vol/h while keeping different pressures
B	EDIN 1946-4	2400 m ³ /h	1200 m ³ /h	YES	Night reduction in room 1a
CH	CH 99-3/2003	8000 m ³ /h (maximum)	>100 m ³ /h person 800÷1000 m ³ /h (anesthetist)	YES	
D-CH	VDI 2167		800÷1200 m ³ /h	YES	
NL	NBHF 2004		20 vol/h	YES	
A	ONORMH 6020-1	Not specified	20 m ³ /h per m ²	YES	Variable flow rates allowed. Turning them off is allowed for class I and II, but they must be reactivated 30 minutes before the usage
E	UNE 100713-2003		20 vol/h		

Table 15 Surgery Rooms Ventilation national regulation summary

4.3. Strategy control considered (Scenarios)

Below baseline and test scenarios are detailed.

1st baseline scenario: **“WITHOUT CONTROL”**:

- 24 hours of operation with a fixed flowrate
- Environmental conditions fixed in permanent mode of operation
- It implies maximum energy cost.

2nd baseline scenario: **“STATES BASED CONTROL: USE / NO USE / CLEANING”**:

- Programming the AHU based on actual use of the operating room. (Controlled through the technical assistance panel)
- Reduced consumption when not in USE mode
- Energy saving environmental conditions because when not in USE mode the conditions of temperature and humidity are not so extreme.

Test scenario: **“PARTICLE COUNTER”**:

- Input and output flow rates are regulated maintaining the required pressure. The control algorithm regulates the flow rate according to a particle counter measurement.
- Concerning temperature and humidity the same set point available in the 2nd baseline scenario is respected.

4.4. Control algorithm in test scenario: particle counter

Input flow rate (VI) and Output flow (VE) rate must be controlled in order to maintain in the surgery room adequate differential pressure and air changes.

For this reason, a relationship between biological particle concentration and Input and Output flow rates are set and reported in the following table. It can be noticed that 11,000 ppm represents the maximum allowed limit to enable control: above this limit ventilation runs at 100%.

Temps Resposta	INPUT	OUTPUT				VARIABLES DEPENDENTS	
	CP	VI		VE		PD	Renovacions hora
5s	ppm	%	m3/h	%	m3/h	Pa	nº
	0-3500	0%	1600	0%	1332	5	13
	3500	25%	2000	0%	1332	8	16
	4000	30%	2080	0%	1332	10	17
	4500	35%	2160	0%	1332	12	18
	5000	40%	2240	15%	1450	7	18
	5500	45%	2320	15%	1450	8	19
	6000	50%	2400	40%	1640	9	20
	6500	55%	2480	40%	1640	10	20
	7000	60%	2560	40%	1640	12	21
	7500	65%	2640	40%	1640	13	22
	8000	75%	2800	60%	1790	8	23
	8500	80%	2880	60%	1790	9	24
	9000	85%	2960	60%	1790	10	24
	9500	90%	3040	60%	1790	11	25
	10000	95%	3120	80%	1950	12	26
	10500	100%	3200	80%	1950	13	26
	11000	100%	3200	80%	1950	13	26
	> 11000	100%	3200	100%	2100	14	26

Figure 5 Relationship between particle concentration (CP) and Input (VI) and Output (VE) flowrates

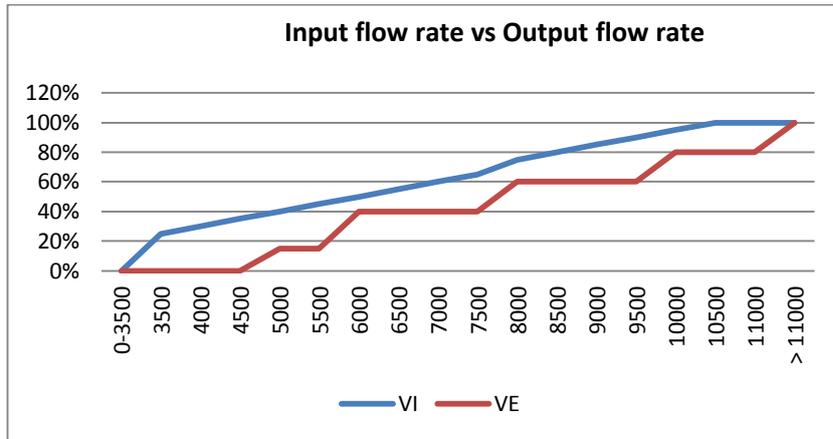


Figure 6 Comparison between Input and Output flow rate variation with particle concentration

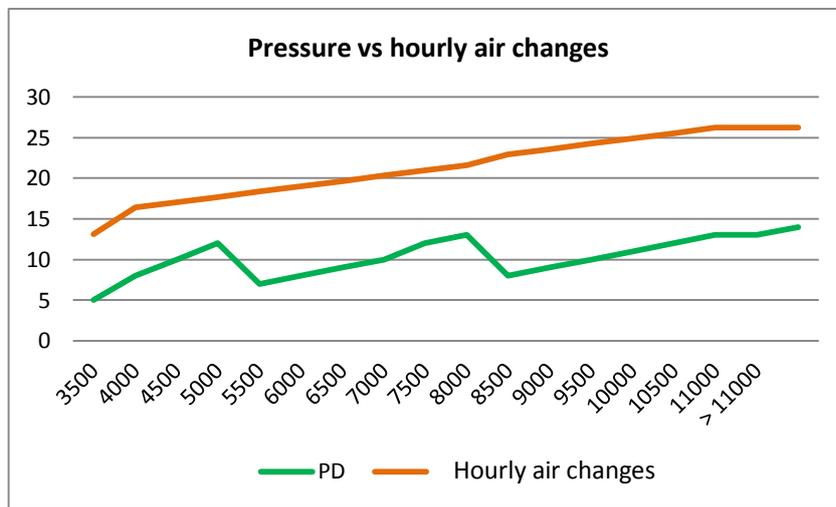


Figure 7 Pressure and hourly air changes variation with particle concentration

1st Baseline scenario: “WITHOUT CONTROL”

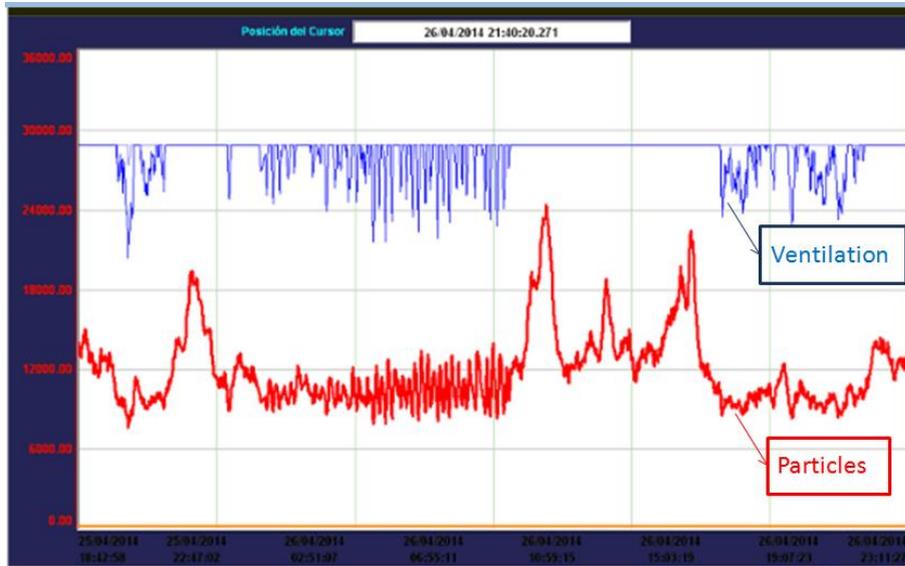


Figure 9 Particle concentration and ventilation rate in WITHOUT CONTROL mode

In this scenario the ventilation is kept at a fixed flowrate and particle concentration is directly related to the activity performed inside the room. Data are collected from the Hospital SCADA system. Ventilation costs are high since there is no control.

2nd baseline scenario: “STATES: USE / NO USE / CLEANING”:

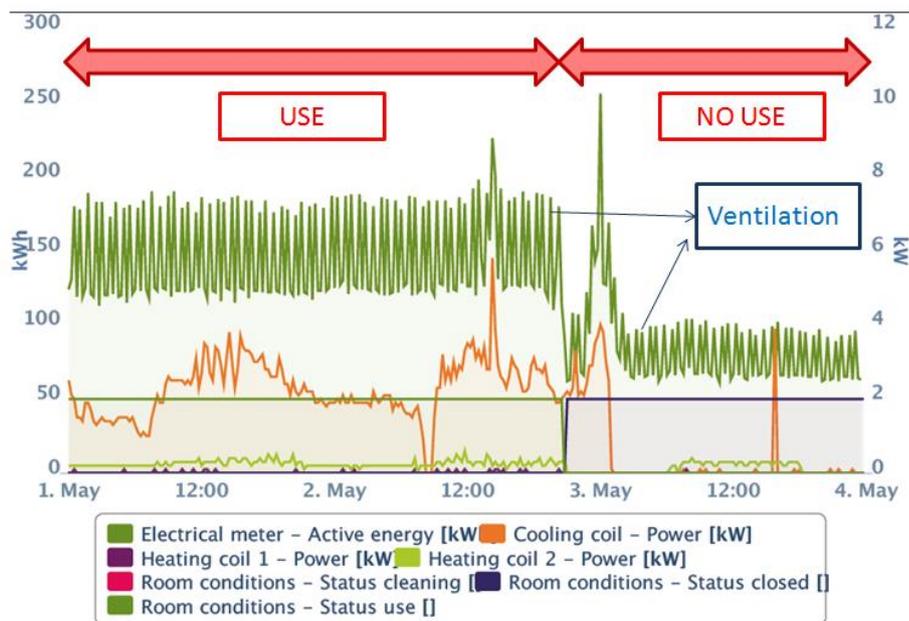


Figure 10 Particle concentration and ventilation rate in STATE BASED CONTROL mode

Ventilation is regulated according to states (USE, NO USE and CLEANING). Also environmental conditions are regulated accordingly. As a consequence both consumptions related to fans and cooling coils are reduced.

3rd scenario: **“PARTICLE COUNTER”**

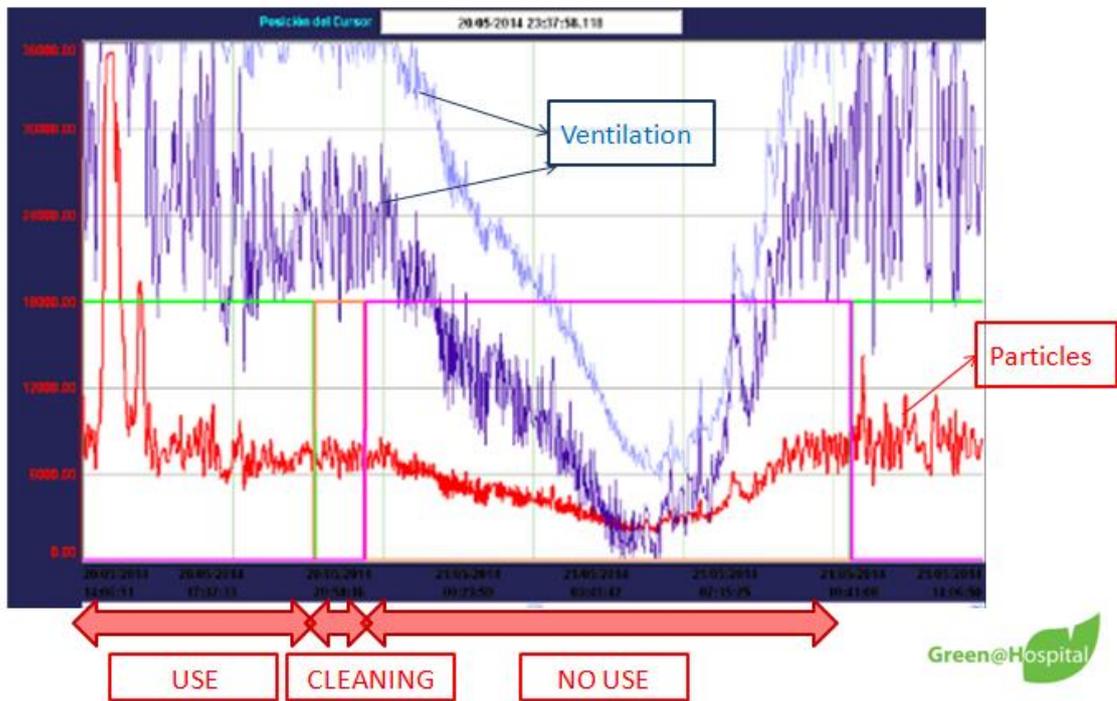


Figure 11 Particle concentration and ventilation rate in PARTICLE CONCENTRATION BASED CONTROL mode

Ventilation is controlled according to the algorithm described in Figure 5. As it can be seen in Figure 11, ventilation rate is reduced when particle level is low corresponding to NO USE state. Room ventilation rate can be reduced significantly, ensuring good environmental quality and having under control particle concentration at all times.

4.7. Guidelines to introduce Control of Ventilation in the Operating Theatre

In the following paragraphs, the approach used in the Green@Hospital project to validate this specific solution set is described. It is an innovative procedure since it is not defined by regulation or national legislation, but it indicates an operational approach that can bring to a result shared and approved by the Hospital organization.

Obviously, the European, national and local regulations have to be respected in any case.

4.7.1. Replication guidelines

To ensure a safe replication of the surgery room particle based ventilation control tested in HML, the following steps are recommended:

- To study in detail (in par. 4.2 there is only an introduction) the national regulatory system for:
 - air conditions in surgery rooms;
 - particle limits in surgery rooms.
- To get a good knowledge on how the surgery room ventilation system works in relation to the surgical schedule. In particular:
 - To check the main control parameters: indoor temperature and humidity set point, pressure and ventilation rate.
 - To ensure the availability of a BMS control that allows future interaction between the particle counter and the air handling unit.
 - To check that the air handling units have a variable flow and return.
 - To implement a time control device in line with the surgical schedule.
- To select, to install and to validate a measurement system to monitor the number of particles during operation with the help of an expert on validation of surgery rooms.
- To implement new channels in the BMS to get the following data:
 - the energy consumption of the ventilation, heating and cooling;
 - the number of particles in the surgery room.

- To design a new algorithm for the control of the ventilation system in a surgery room using the particle counter as the main sensor. This has to be done keeping in mind the regulatory limits as a threshold level.
- To organize a test in one surgery room for 1-2 days. Get the approval from the Infectious Committee and from the medical team of the surgery department of the hospital.
- To run the pilot experience.
- To analyze the data, to get to conclusions over the different strategies applied.
- To share these results with:
 - o the technical Committee of the National Regulatory Board
 - o the infectious Committee of the hospital.
- To implement the new control algorithm as the definitive control strategy.
- To organize the maintenance procedure to periodically control the output of the particle level.
- To monitor periodically the environmental quality of the surgery room by third party controls.

4.7.2. Involvement of the Infectious Committee

As specified in the replication guidelines, all the interventions to the existing plants have to be submitted before implementation, to the hospital Infectious Committee to inform about the objectives and have their involvement and specific authorization.

The first document is the authorization, that in case of HML, was emitted in date 11/06/2013 by SEGLA a third party specialized in validation and qualification of surgical rooms.

SEGLA.

Informe técnico: Contaje de partículas en quirófanos Proyecto Green Hospital Hospital de Mollet

Proyecto	Fecha	
Green hospital Hospital de Mollet	11/06/2013	Elección de quirófano
Documento	Normas	Técnico
002	ISO 14644-1 UNE 171340	Gloria Cruceta

Introducción
<p>El objeto del estudio, es calcular el ahorro de energía que nos permitiría ajustar las renovaciones y sobrepresión de un quirófano, para seguir obteniendo la clasificación según la Norma ISO 14644-1, necesaria para mantener la bioseguridad ambiental que precisa el quirófano, según la clase de cirugía que se realiza en él. Para ello debemos escoger un quirófano que sea representativo.</p>

Desarrollo
<p>Se escoge el quirófano 5, ya que se realizan intervenciones de:</p> <ol style="list-style-type: none"> 1.- Oftalmología, clase requerida A (ISO 5 ó ISO 6), intervención con baja emisión de partículas al ambiente, el equipo quirúrgico trabaja en una superficie muy pequeña, y está compuesto por poco personal sanitario. 2.- Intervenciones de cirugía convencional, clase requerida B (ISO 7), intervenciones con emisión más elevada de partículas, el equipo quirúrgico trabaja en una superficie grande, y está compuesto por bastante personal sanitario. 3.- Traumatología, clase requerida A (ISO 5 ó ISO 6), intervención con alta emisión de partículas al ambiente, el equipo quirúrgico trabaja en una superficie grande, con varios equipos, en ocasiones utilizan técnicas que por si mismas emiten partículas al ambiente y está compuesto por bastante personal sanitario.

Firma:



Figure 12 Authorization to modify the surgery room control system

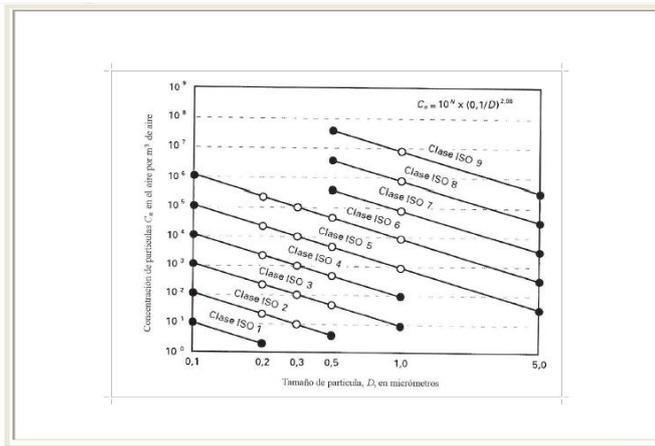
Next figure shows the results acceptance and certification document, analyzing the results in respect the different kinds of infections (and the correspondent dimension of Particles).

Informe técnico: Selección del tamaño de las partículas en la monitorización por sonda isocinética de la clase ISO en quirófano.
 Proyecto Green Hospital
 Hospital de Mollet

Proyecto	Normas	
Green hospital Hospital de Mollet	ISO 14644-1 UNE 171340	Selección tamaño partículas
Documento		Técnico
003		Gloria Cruceta

Introducción

El objeto del estudio, es calcular el ahorro de energía que nos permitiría ajustar las renovaciones y sobrepresión de un quirófano, para seguir obteniendo la clasificación según la Norma ISO 14644-1, necesaria para mantener la bioseguridad ambiental que precisa el quirófano, según la clase de cirugía que se realiza en él.
 Para ello debemos escoger el tamaño de partículas adecuado para realizar la monitorización de la medición de partículas en continuo en un quirófano que sea representativo.



Firma:

Figure 13 Results acceptance and certification document

4.7.3. Involvement of Surgical Teams

The involvement of Surgical Teams is an important step to create awareness about the new application, and to transmit a clear message about the safety of the new implementation for both patients and operators. One of the basic clauses for the success of the process is the support of the surgical teams, which have to be convinced by demonstrating without any doubt the safety of the application.

During the Green@Hospital project, the 24th of April 2014 in HML, a specific workshop was organized with this specific scope.

The whole project was presented, but a particular focus was on this application and an all the real data representing the effort to verify and ensure the safety for the patient:

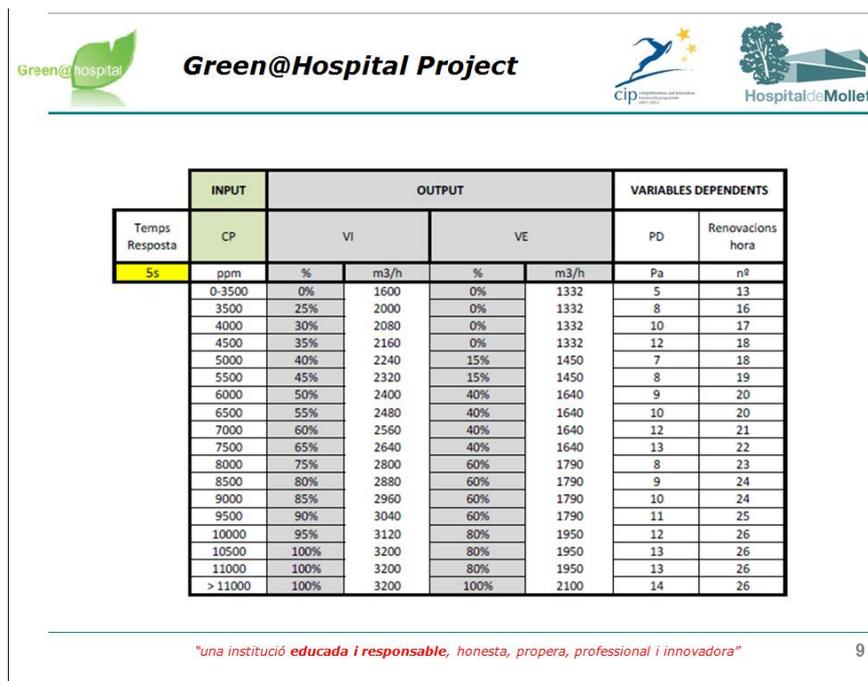


Figure 14 One of the slides presented during the workshop

4.8. Request of changing existing Regulation

As demonstrated in the previous paragraphs the 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.

The variation of air changing rate is an application covered by EN15232, but when realized inside the Operating Theaters, due to Safety reason, it becomes an application which is subject of many standards and regulations: international, national and, in some countries, regional too. Many on these standards define generally a fixed level of air changing rate.

CEN / TC156 is working to a new suite of standards for hospital ventilation. Green@Hospital results can be useful to validate and support innovative approaches able to ensure safety operating conditions while reducing energy wastes.

5. Conclusion

The main results achieved in the Green@Hospital pilots have been presented and a datasheet for each solution is made available to stakeholders interested in replicating the solution in other hospital facilities.

It was possible to demonstrate that their applications in an overall hospital facility could lead to 15.4% of energy savings on the overall hospital energy bill.

Applying hospital results to other public buildings typical energy breakdown (as the ones presented in chapter 3) estimating the impact of Green@Hospital solutions to other public buildings is possible and results are reported hereafter.

Building type	Green@Hospital solution set impact
Education	16%
Food Sales	13%
Food Service	9%
Lodging	17%
Retail	22%
Office	19%
Public Assembly	16%
Public Order and Safety	3%
Service	10%

Table 16 Green@Hospital solutions impact in other building typologies

Global results are in line with the results estimated by the EN15232 even if it is not possible to have a comparison solution by solution since the EN15232 does not provide quantitative results for each solution.

Eight of the nine solution sets are not hospital specific and their replication does not require any particular indication. Only the solution addressing hospital surgery room ventilation is hospital specific and can have implications on patients and clinicians safety. For this reason some guidelines are presented for its replication.

Finally as anticipated in the document chapters, Green@Hospital provides a relevant contribution to standards:

- Green@Hospital project can enrich the knowledge database referred to Hospital Buildings under evaluation of the CEN/TC247 (owner of the activities related to the EN15232:2012).
- CEN / TC156 is working to a new suite of standards for hospital ventilation. Green@Hospital results can be useful to validate and support innovative approaches able to ensure safety operating conditions while reducing energy wastes.