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Civil work activities methodology

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1 Introduction

"*I believe that renovation of buildings to high energy performance standards could be one of the most cost effective investments a nation can make, given the benefits in term of job creation, quality of life, economic stimulus, climate change mitigation and energy security that such investments deliver*".

Oliver Rapf, Executive Director, BPIE [1]

This document in the first part (chapter 2) describes the methodology that was used to install the Building Automation System for energy performance improvement in existing/historical buildings at Politecnico di Torino campus for the SEEMPubS project. The contents are divided into:

- *Methodology used in SEEMPubS.* Step by step potential administrators or building owners are briefly driven among the links between building, technology, civil work, cost and saving.
- *Installation works (based on the SEEMPubS demonstrator).* There are situations when it is desirable to make measurements in locations where the use of cabled sensors is problematic. This is the case of historical buildings like Valentino Castle. In this case, a WSN provides a reliable, low maintenance, low power method for making measurements in applications where cabled sensors are impractical or otherwise undesirable.

  In other cases, like Main Campus and Cittadella Politecnica, wired sensors can be installed easily.
- *Installation costs (based on the SEEMPubS demonstrator).* Although the capital cost of individual meters has reduced in recent years, the cost of installing direct metering throughout a large building can still be significant. However, it is not always necessary to install large amounts of direct metering to establish the consumption of the end-use of the energy . In fact, starting from detailed control strategies, it is possible to optimize measurements and the correct use of the energy working on the improvement of the end user's awareness (see D3.4).

The second part (chapter 3) synthetizes the analysis of the potential savings based on results obtained in the different rooms (Test and Reference) studied in the project.

Finally, the last part (chapter 4) is dedicated to a tentative of cost benefit analysis, in spite of the small number of Test and Reference rooms selected for the demonstrator in comparison with the total number of rooms at Polito.

2 The installation of the Building Automation System for energy performance improvement in existing/historical buildings

From literature it is known that in Europe, around 40% of the existing building stock was constructed before the 1960s when building energy codes were minimal [2]; that new construction represents only about 1% of building stock [3]; and that most energy usage of buildings throughout their life cycle is during the operational stage (~80%). Moreover, the decisions made in the conception and design stages of new buildings, as well as in renovation stages of existing buildings, influence about 80% of the total life cycle energy consumption [4]. Prior to the crisis, the constant increase in the real estate prices had hidden the depreciating value of the existing building stock. The challenge companies are faced with today is how to maintain the value of the existing stock in the short term while increasing the long-term value of the portfolio. Large private companies with real estate portfolios in the EU building sector have already begun tackling retrofits, paying attention to energy efficiency.

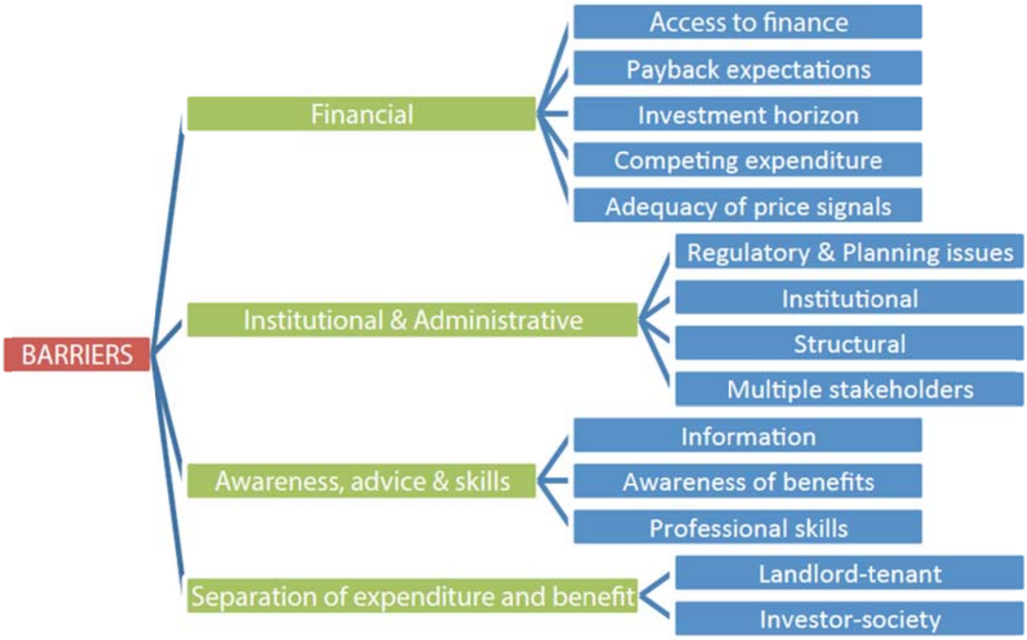

Figure 1: Main types of barriers encountered in building renovation [5]

As the impact of user behaviour and real-time control is in the range of 20%, ICT has been identified as one possible means to design, optimize, regulate and control energy use within existing and future (smart) buildings, also historical.

In this context, when general retrofits of the buildings are not necessary or possible (historical buildings), the installation of Building Automation System (BAS) is the only way forward. This is the approach adopted and tested with the SEEMPubS project as described in detail in several other deliverables (e.g. D1.4, D2.4.2., D5.6, etc.) and summarized in this deliverable.

2.1 Calculation of the costs: the SEEMPubS' methodology

For the calculation of the cost in the SEEMPubS project has been used the diagram below. Step by step it can be used also from administrators or building owners that decide to implement the SEEMPubS methodology in its buildings.

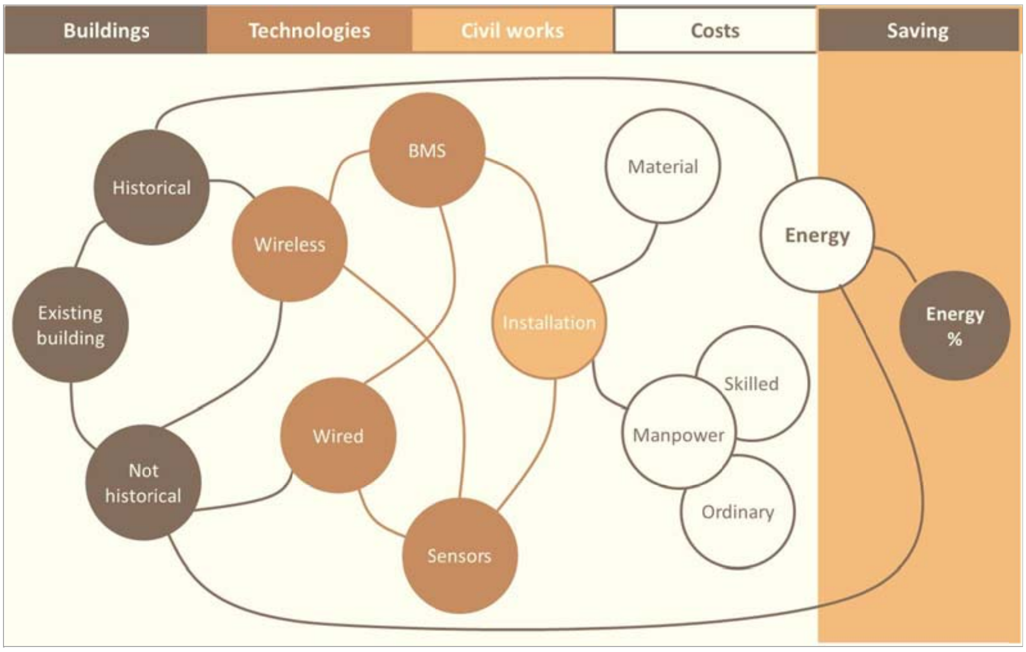

Figure 2: The diagram of the elements used to calculate the costs.

First step - Building. **Existing buildings** have been divided between **Historical** and **Not historical** to design the best technologies that must be used (see D2.1.1). For each of them several twin rooms have been selected as Test and Reference.

Second step - Technologies. Only **wireless** technologies has been used in historical buildings to preserve the architectural elements (stuccos, paint, etc.). **Wireless and wired** technologies have been used in not historical building to integrate the existing ones with the new ones (see D. 4.6.1, D4.6.2 and D4.6.3). Different kind of **Sensors** and **BMS** have been used (see D5.6).

Third step – Civil work. Civil works in this case means essentially **installation** of the technologies used, because one of the main goals of the SEEMPubS project is to save energy in existing buildings without civil works (see D5.4). In case of refurbishment this step includes all works necessary to renovate the building.

Fourth step – Costs. To calculate the total costs of the BAS (Building Automation System)) is necessary to add the costs of BMS (Building Management System) and sensors with the installation. Particularly, installation costs have been divided into **manpower** (**ordinary** and **skilled**) and basic **material** used to support/contain sensors, cables etc. (see figures in Chapter 2.2).

Fifth step – Saving. In this case, the percentage of **energy** saving can be linked with the energy cost in order to calculate the economical saving due to the new BAS. So, based on simulation is possible to evaluate the ROI (Return of Investment).

2.2 Installation works

As described in D1.4 and D5.6 different technology choices were made for the demonstrator rooms. Consequently, each room has been interested by different installation works in relation to: the architectural elements (if historical or not), the electric and HVAC systems and the designed wired or wireless sensor network.

Briefly, installed sensors are listed below.

Manufacturer	Technology	Model	Communication protocol
Thermokon Sensortechnik GmbH	Wireless	SR04PST, SR65 AKF, SR-MDS Solar, SR65 DI	EnOcen
Thermokon Sensortechnik GmbH	Wired	MDS	BACnet
SIEMENS	Wireless	QAX95.1	EnOcean
SIEMENS	Wired	QAX30.1, QAX32.1, QAP22	BACnet
ST Microelectronics	Wireless	STEVAL-IHP004V1	ZigBee/802.15.4
Plugwise B.V.	Wireless	Home Basic type F	ZigBee

Table 1: Sensors classification and communication protocols

At Valentino Castle, only wireless sensors are placed, while at the Main Campus and Citadella Politecnica most of the sensors are wired. For this reason the installation works have been different for each of them.

Where wired sensors were installed system adaptation works were necessary in order to enable data monitoring and collection. As explained successively, this has resulted in higher costs than wireless technology.

On the following pages sensors installed are shown in their final location.

Figure 3: Wired sensors installed in the Cittadella Politecnica, DAUIN Labs, Test room.

Figure 4: Wired sensors installed in the Cittadella Politecnica, DAUIN Labs, Reference room.

Figure 5: Wired sensors installed in the Cittadella Politecnica, DAUIN Offices, Test room.

Figure 6: Wired sensors installed in the Cittadella Politecnica, DAUIN Offices, Reference room.

Figure 7: Wired sensors installed in the Main Campus, Administrative Offices, Test room.

Figure 8: Wired sensors installed in the Main Campus, Administrative Offices, Reference room.

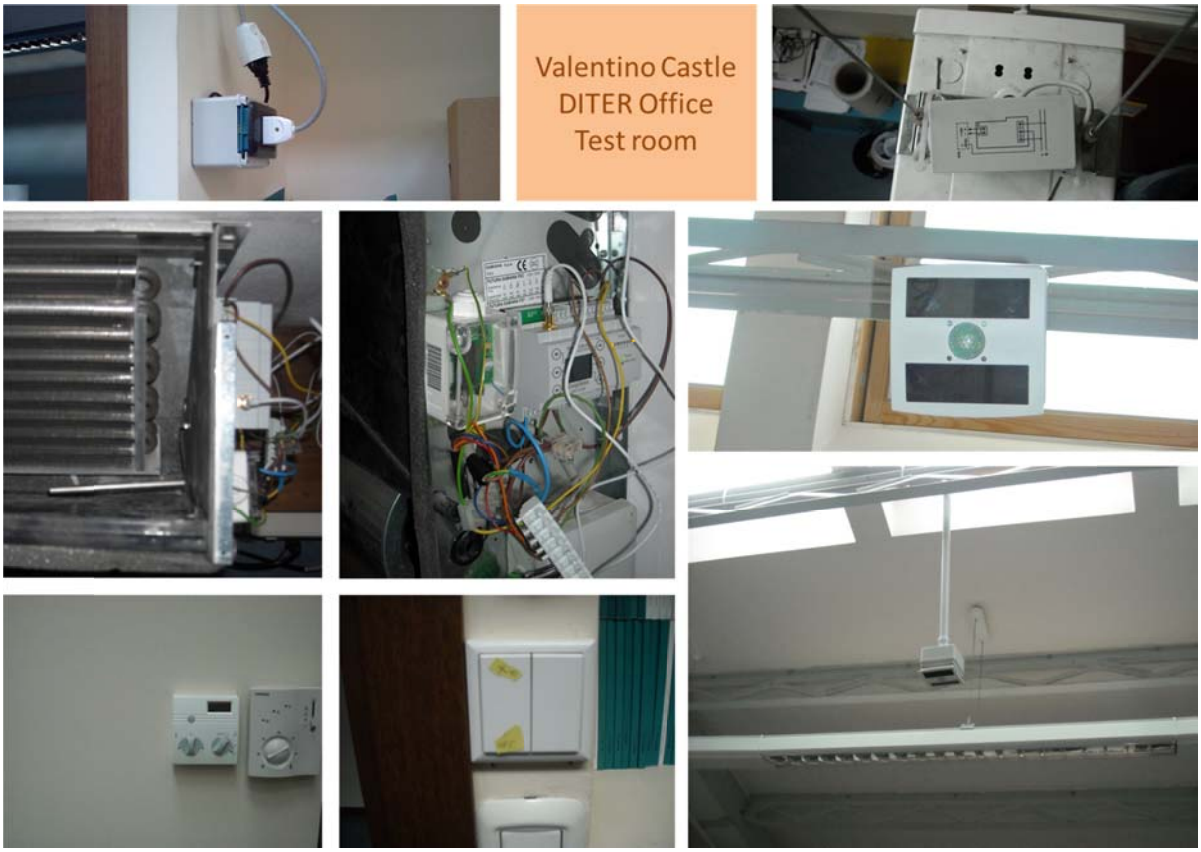

Figure 9: Wireless sensors installed in the Valentino Castle, DITER Offices, Test room.

Figure 10: Wireless sensors installed in the Valentino Castle, DITER Offices, Reference room.

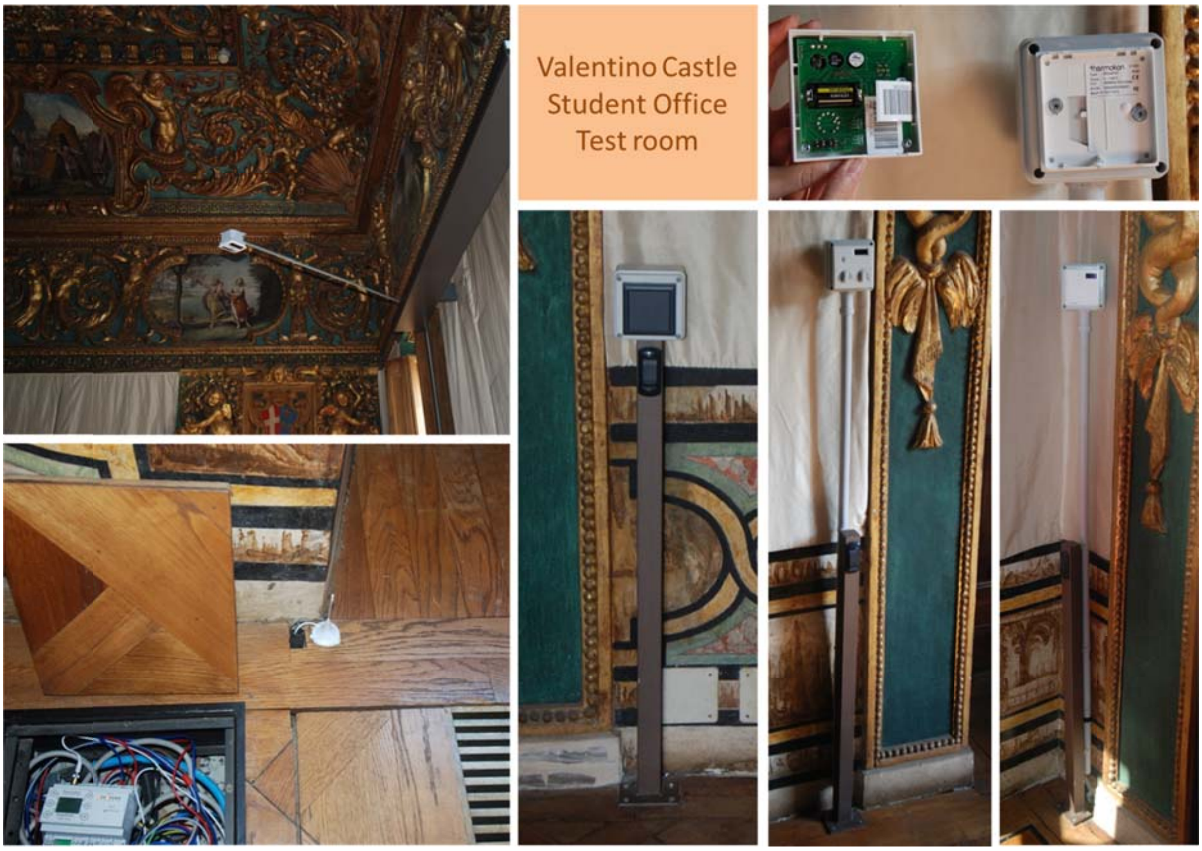

Figure 11: Wireless sensors installed in the Valentino Castle, Student Offices, Test room.

Figure 12: Wireless sensors installed in the Valentino Castle, Student Offices, Reference room.

2.3 Installation costs

According to D5.4, where a preliminary costs study was conducted, a detailed analysis about the installation cost is shown below.

As result from D5.4, costs can be divided into three categories: sensors costs, building management system (BMS) costs and installation.

At the end of the SEEMPubS project the situation is the following:

Valentino Castle	
Description	Cost
Sensors	€ 8.322,79
BMS	€ 3.000,00
Installation	€ 1.919,68
Cittadella Politecnica	
Description	Cost
Sensors	€ 10.537,82
BMS	€ 7.438,00
Installation	€ 8.300,00
Main Campus	
Description	Cost
Sensors	€ 7.219,91
BMS	€ 3.719,00
Installation	€ 8.260,00
TOTAL	€ 58.717,20

Table 2: Total cost divided by place and typology.

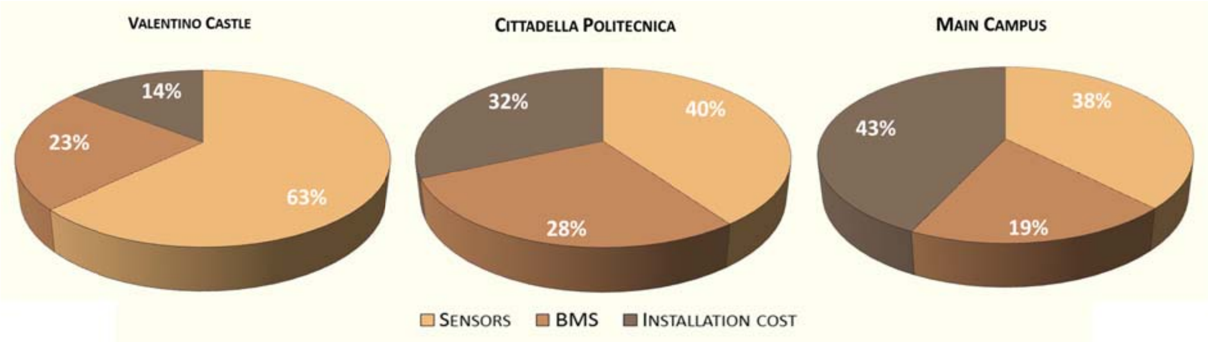

Figure 13: Cost items percentage.

The installation costs vary from 14% at Valentino Castle (the minimum) to 43% at the Main Campus (the maximum). The main influencing factor is the technology chosen in relation to the constructive characteristics of demonstrator buildings.

Subsequently, the installation costs can be divided into manpower and materials cost with the following results:

INSTALLATION COST				
Place	Worker Type	Hourly cost	Hours	Cost
Cittadella Politecnica DAUIN Offices and Labs	Skilled	€ 32,63	64	€ 2.088,32
	Ordinary	€ 27,36	64	€ 1.751,04
	Material cost			€ 4.460,64
Main Campus Administrative Offices	Skilled	€ 32,63	56	€ 1.827,28
	Ordinary	€ 27,36	56	€ 1.532,16
	Material cost			€ 4.900,56
Valentino Castle DITER and Student offices	Skilled	€ 32,63	32	€ 1.044,16
	Ordinary	€ 27,36	32	€ 875,52
	Material cost			€ 0,00*
	TOTAL COST			€ 18.479,68

Table 3: Installation cost divided between manpower and materials cost.

*** In this case material cost is approximately 0 euro because we used only WSN and we re-used the existing lighting and thermal devices.**

Even in this case, wireless technology is cheaper than wired, indeed, both the labors and materials are lower than the other cases. Furthermore, in Valentino Castle the cost of the additional materials is about zero.

Sensors or its specific equipment (like the connection between sensors and electricity grid or specific support in historical building to preserve stuccos and so on) are not considered additional material, but in this category are included all components necessary to allow the correct functionality of the sensors network. In this way, new lighting devices, electrical wiring or component and generally all elements necessary for system updating are included in this category.

Regarding manpower costs, hourly cost are calculated taking in to consideration a net income of 27,43 €/h for skilled worker and 23,00 €/h for ordinary worker, then increased by 24,3% (overheads and company profits). Moreover, Polito's technical office benefits by a commercial discount. For a complete scheme see the table below.

MANPOWER COST					
Worker type	Net income [€/h]	Gross up	Gross income [€/h]	Discount rate	Discounted cost [€/h]
Skilled	€ 27,43	24,3%	€ 34,10	22%	€ 32,63
Ordinary	€ 23,00	24,3%	€ 28,59	22%	€ 27,36

Table 4: Hourly labour cost.

The discounted rate is applied to the overheads and company profits.

Overall installation costs are about € 18.500, dividing it according to demonstrator rooms the following results are obtained:

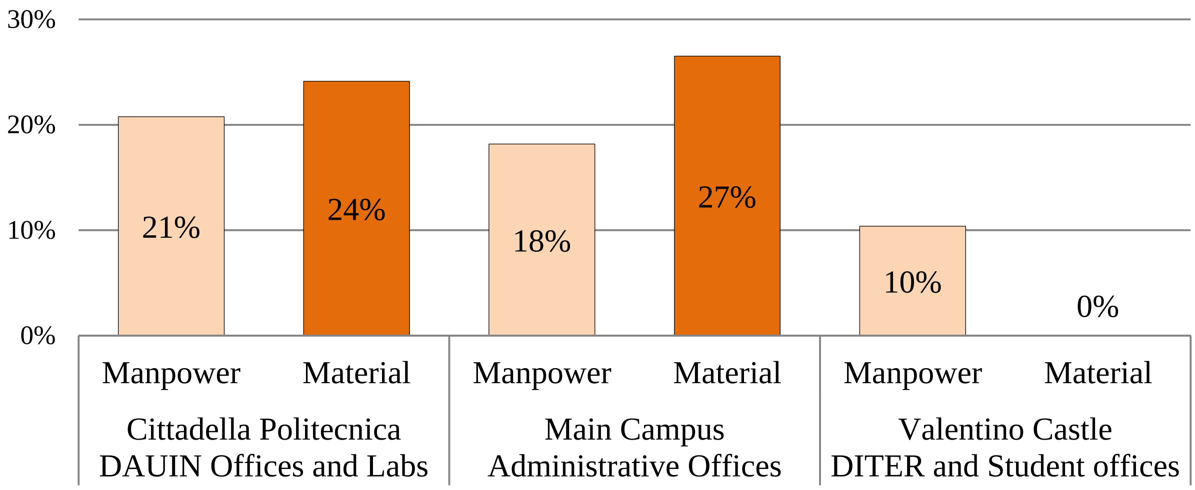

Figure 14: Percentage of the labor and materials at the various sites.

Cittadella Politecnica and Main Campus material costs represent about 50% of overall installation costs. This is mainly due to the pre-existence of DESIGO that required very expensive cost to integrate the new sensors with the existing one due to the high cost of SIEMENS technicians. Furthermore, the need to install the new sensors in specific locations that enable them to function properly integrating the existing technologies with the new one. Consequently, in such environments labour cost is a relevant factor.

3 Analysis of the potential savings

The percentage savings obtained through simulations in WP1 and presented in Deliverable D1.3 are in this section analysed in order to reach an estimation of the corresponding absolute energy and economic savings.

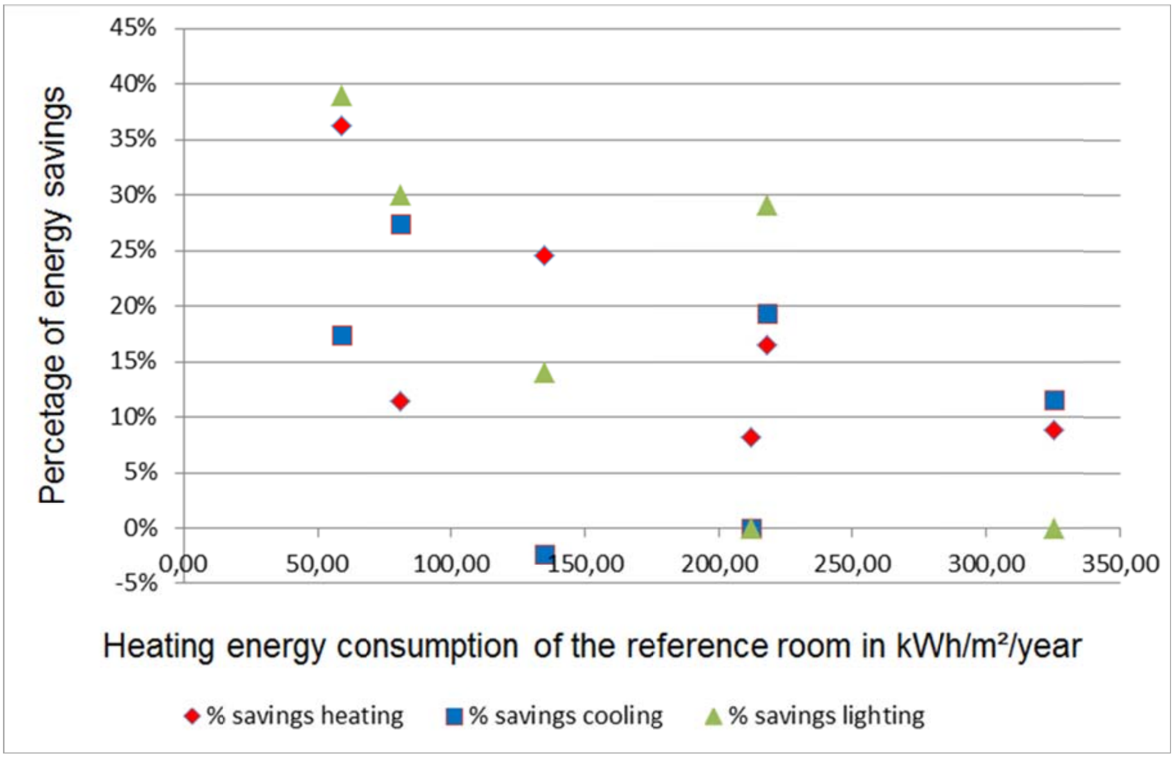

Figure 15: Energy savings (in %) for the different test rooms (each point corresponds to the result of a test room) plotted versus the energy consumption (only for heating) of the corresponding reference room.

Figure 15 presents the percentage of savings, obtained for lighting, heating and for cooling. In abscises the energy demand, only of heating, are reported (the energy demand is the one calculated for the corresponding Reference rooms). We have a general mean tendency of about 20% of savings for all types of dispenses. It is clear that for low demand (good insulation and generally low inertia) that it is possible to make a maximum of savings for heating. The heating savings are lower, in %, for low insulation and high inertia. For lighting, we have indicated no savings for the secretariat and classrooms because in the D1.3 these rooms have not been studied, as no lighting control strategies have been implemented due to low or no daylight availability.

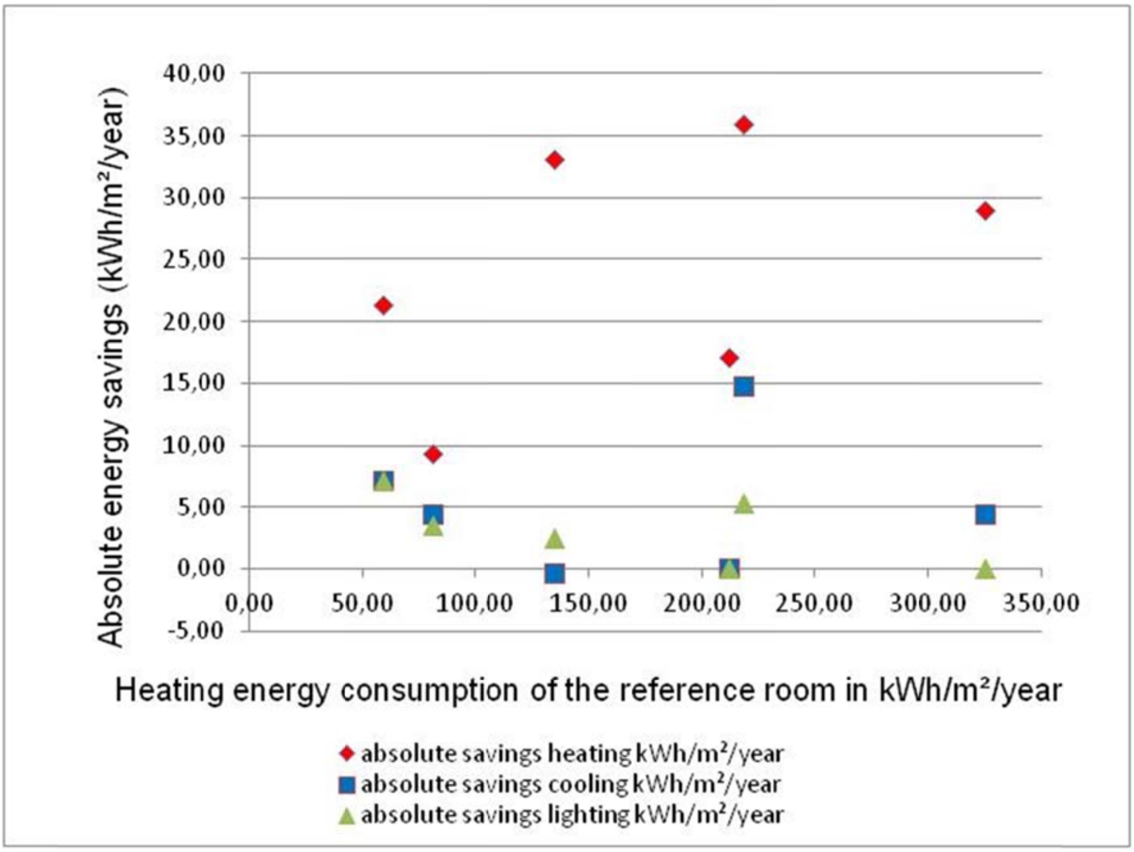

Figure 16: Energy savings (in kWh/m²/year) for the different test rooms studied reported to the heating energy consumption of the reference room.

Considering the absolute energy gains of each room, we see in figure 16 that there are no real variations with the existent insulation or inertia. We have about 25 kWh of savings for heating and 5 kWh of savings for cooling and for lighting (per m² and per year). The variations exist but are due to the height of the room, the windows areas and daylight availability, the occupancy schedules, the internal gains, the specific thermal insulation and inertia.

Table 4: energy savings (in kWh and euros) estimation for the different test rooms studied

Room	Area (m²)	absolute savings heating kWh/m²/year	absolute savings cooling kWh/m²/year	absolute savings lighting kWh/m²/year	total absolute savings/m2 heating + cooling + lighting kWh/m2/year	total absolute savings/m2 heating + cooling + lighting euros/m2/year	total absolute savings heating + cooling + lighting for the test room euros/year
secretariat	65,00	17.17	0.00	0.00	17.17	1.72	111.62
diter office	17,00	35.97	14.74	5.30	56.01	6,13	104.23
admin office	35,32	9.32	4.38	3.50	17.20	2.07	73.11
classrooms	315	29	4.5	0	33.50	3.35	1055.25
dauin office	15,62	21.36	7.13	7.20	35.69	4.29	67.00
dauin lab	88,99	33.08	-0.34	2.50	35.24	3.77	335.84

In table 1 it is possible to have an idea of the gains obtained with our new system installed in the different test rooms of Polito. The hypotheses taken for the cost of energy have been:

- Electricity cost: 0.2 euro/kWh (used for lighting consumption)
- Heating and cooling cost: 0.1euro/kWh (considering district heating and thermodynamic refrigeration, with a COP around 2, for the energy needs of the rooms).

The gains depend essentially on the area of the room (see fig. 15). We can approximate the gains with a linear function given in figure 3.

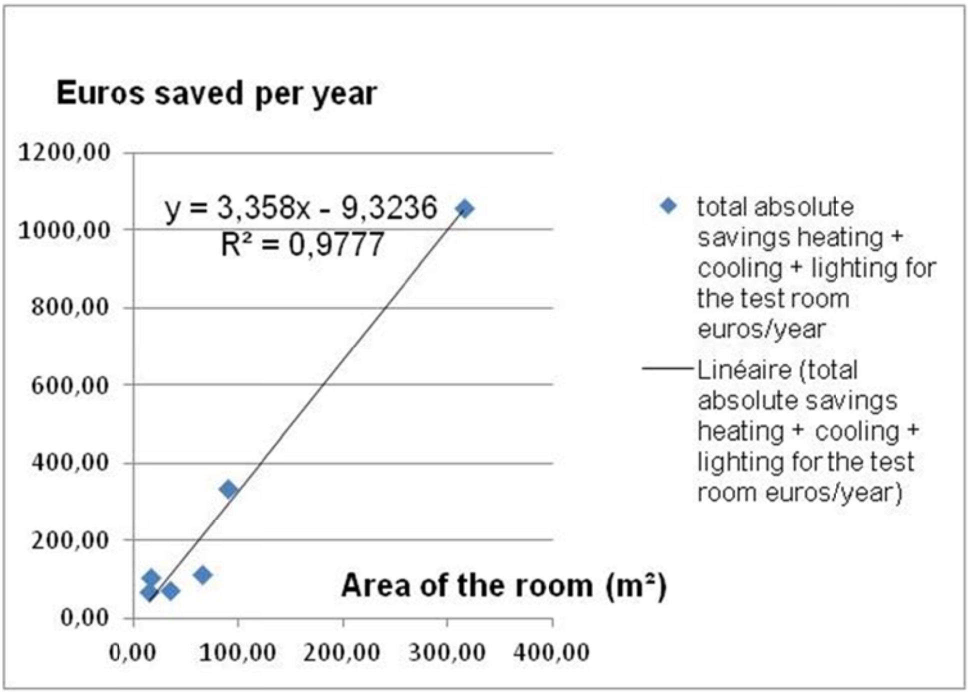

Figure 17: total absolute savings/m2 heating + cooling + lighting euros/year versus area of the room.

4 Cost-benefit analysis

The economic evaluation of the SEEMPubS investments is not the aim of the project, but we have tried to create a control scheme in order to summarized our results.

Subsequent table is based on the following assumptions:

- Sensors and installation costs are considered reduced of about 40% for wireless part and of about 30% for the wired one; this is because only test rooms are considered for energy savings estimation.
- BMS costs are broken down between all rooms of the Polito's campus because these costs are mainly software costs and they are independent by the number of rooms.
- Installation costs are reduced by 20%; in fact, a considerable part of this costs are represented by provisional works, which allow the correct functionality of old control system during its updating.
- It is assumed an operation and maintenance cost of about 1% of sensors cost per year.

INCOME STATEMENT									
		0	1	2	3	4	16	17	18
Years		2013	2014	2015	2016	2017	2029	2030	2031
Costs									
Sensors	-€ 17.424,00								
BMS	-€ 42,00								
Installation	-€ 10.195,00								
TOTAL	-€ 27.661,00								
Annual saving	€ 1.750,00		€ 1.750,00	€ 1.750,00	€ 1.750,00	€ 1.750,00	€ 1.750,00	€ 1.750,00	€ 1.750,00
Operation & Maintenance	-€ 174,24		-€ 174,24	-€ 174,24	-€ 174,24	-€ 174,24	-€ 174,24	-€ 174,24	-€ 174,24
NET VALUE			€ 1.575,76	€ 1.575,76	€ 1.575,76	€ 1.575,76	€ 1.575,76	€ 1.575,76	€ 1.575,76
Ammortization			-€ 1.742,40	-€ 1.742,40	-€ 1.742,40	-€ 1.742,40			
NET PROFIT			-€ 166,64	-€ 166,64	-€ 166,64	-€ 166,64	€ 1.575,76	€ 1.575,76	€ 1.575,76
CASH FLOW									
NET PROFIT			-€ 166,64	-€ 166,64	-€ 166,64	-€ 166,64	€ 1.575,76	€ 1.575,76	€ 1.575,76
Ammortization			€ 1.742,40	€ 1.742,40	€ 1.742,40	€ 1.742,40	€ -	€ -	€ -
CASH FLOW			€ 1.575,76	€ 1.575,76	€ 1.575,76	€ 1.575,76	€ 1.575,76	€ 1.575,76	€ 1.575,76
CASH FLOW CUMULATED		-€ 27.661,00	-€ 26.085,24	-€ 24.509,48	-€ 22.933,72	-€ 21.357,96	-€ 2.448,84	-€ 873,08	€ 702,68

Table 5: Test rooms Cash Flow

As result, the payback period is about 18 years. It is a quite long term investment and with this assumptions it is not economically convenient for an investor.

This result is however affected by high installation cost that can be drastically reduced if there is not a pre-existence control system. Indeed, the main problem is represented by the necessity to always guarantee the correct functionality of the system because the demonstrator is not a prototype but a real building used day by day by staff, students, visitors, and so on. It is not possible to take off the old system before the new one is up and running, especially if rooms are populated. Furthermore, installation costs can be reduced if the new system is designed in a new building, where there is not necessary to remove the old one before new installation. Obviously, these aspects are relevant especially for the wired technology which require cable connections.

Moreover, in the SEEMPubS project, only 10 rooms of about 2600 were equipped and this not allowed to create economics of scales.

5 Conclusion

Metering per se does not save energy. It is the actions taken as a result of installing and monitoring meters that can achieve quantifiable energy savings. Meters and automation that are selected and installed correctly provide the information for the monitoring and targeting process that is an essential part of energy management. As a matter of fact, the objective of a Building Management System (BMS) is to achieve optimal level of control of occupant comfort while minimizing energy use, starting from a well designed control system.

As demonstrated with this deliverable, the traditional wired sensors has higher cost than wireless, not to mention the complexity and difficulty in installation and, in summary, the detailed steps of the technical & economic appraisal are:

1. Building stock analysis (see D1.1);
2. Cost effectiveness appraisal of “renovation” options (see D1.4 and D5.6 in addition to this deliverable);
3. Quantification of energy saving potential (see D1.3);

Moreover, based on the SEEMPubS results, the energy and cost savings analyse described in chapter 3 has pointed out interesting conclusions. Even if some very basic hypothesis on the price of energy have been made, it is possible to construct a very simple correlation with the area of the controlled rooms of the possible gains.

If an administrator or a building owner has to take the decision or not to implement the SEEMPubS methodology and system, he has a very simple law that calculates the economies (see Chapter 2.1). Given the cost of the system to deploy, he can more easily take the decision calculating the return time of the operation. An example of the calculation template is in Appendix 1.

This return time has no signification for the demo buildings we instrumented in this project because the material has been applied on very little areas of each building studied. Deploying the system in a larger number of rooms will permit a better possible return.

Furthermore, unfortunately, the short time of the project – three years for the survey of the buildings and the BAS existing, the design of the new BAS, the definition of the control strategies and the ontologies for the middleware, the installation of the new technologies and the energetic simulations – is not enough to calculate a certain Return of the Investment (ROI).

Fortunately, based on the SEEMPubS results, with the DIMMER project it will be possible to calculate it with precision.

To conclude, it is essential to remember that when undertaking an economic appraisal of an energy saving investment for a building, the only benefit that is normally monetized by the potential investor is the energy cost saving, yet doing so undervalues the full impact. However, many benefits accrue to society at large and hence are not valued by individual investors. These benefits are: economic, societal, environmental and energy system.

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[6] In this case "renovation" means installation of a BAS.

[7] The main elements of the District Information Modeling for Energy Reduction project are described in D6.5.3.

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[D4.6.1] Initial Prototype of the SEEMPubS platform, 2011.

[D4.6.2] Updated Prototype of the SEEMPubS platform, 2012.

[D4.6.3] Final Prototype of the SEEMPubS platform, 2013.

[D5.4] Transformation principles of an existing building in a building automation, 2012.

[D5.6] Equipments definition, 2013.

[D6.5.3] Final Internal Report on dissemination and exploitation activities, 2013.