Deliverable D1.4

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Deliverable D1.4
"SmartBuild Final Report"

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- Smart Build Final Report -

Reducing the Energy Demand and Improving the Comfort in the Existing Public Building Stock via Smart Information and Communications Technology

This project is co-funded under the ICT Policy Support Programme (ICT PSP) as part of the Competitiveness and Innovation Framework Programme by the European Community.

1 Summary

The project SmartBuild demonstrated that the implementation of smart Information and Communications Technology (ICT) in the existing public building stock can significantly reduce the energy demand and improve the comfort. SmartBuild achieved impressive results:

- **High savings in thermal energy demand**
  Savings achieved in the annual thermal energy demand by implementing ICT are high. On building level savings range between 21% and 47%. Absolute savings are highest for historic buildings with moderate thermal insulation.

  Table 1. Savings on building level post ICT implementation.

		Offices/ Labs - Pilot #1	School - Pilot #2	School - Pilot #4	School - Pilot #5	School - Pilot #6	School Gym -Pilot #7	School offices - Pilot #8	Offices/Labs - Pilot #9
Thermal Energy Demand									
Overall energy demand post SmartBuild ICT up-scale	[kWh/m²*year]	**91**	**72**	**51**	**37**	**36**	**80**	**34**	**17**
Overall savings via ICT	[%]	**21**	**29**	**30**	**32**	**29**	**22**	**33**	**47**

- **High savings in electricity demand**
  In buildings using an electric heating pump for heating and cooling savings achieved [kWh] via ICT based control of the heating pump and via ICT based control of the fan coils may be significant. SmartBuild demonstrated a saving potential of 47%.

  In schools the electricity demand for electric based room lighting may amount to 80% of the annual electricity demand of a classroom. It was shown that light control can significantly contribute to reduce this demand and to increase comfort. However, LED based light systems are reaching a high level of maturity that would soon no longer justify an investment in conventional, less efficient, electric lighting and the respective light control systems.

- **Significant potential for reduction of peak electricity demand & production**
  Within SmartBuild considerable peaks in the electricity demand [kW] were measured in a building with heat pump based heating/cooling. In this building the heat pump is the appliance with the highest power demand. It was found that the peak electricity demand of such heat pump systems can be reduced by 45% via ICT control in combination with a simple cost-efficient small heat/cold storage system.

  Peak electricity demand/production in combination with PV system
  Should a solar PV system be available on-site the heat pump operation can be aligned with the peak solar production via the integration of a medium size heat/cold storage system. This reduces both, peaks in electricity demand as well as peaks in electricity

production.

In the social housing sector ICT controlled Combined Heat and Power (CHP) system operation on building level in parallel to solar Photovoltaic (PV) system operation can compensate for lows in solar electricity production and stabilise the grid.

Note: in schools and offices peaks in electricity demand in the investigated pilot buildings were related to room lighting. This electricity demand is asynchronous to solar electricity production and ICT based control cannot contribute significantly to reduce these peaks.

- **Acceptable ICT costs and pay-back periods**
  By 2014 typical SmartBuild pilot building ICT replication costs start at approximately 9 €/m² for the largest building with the largest average building area per ICT controlled room. For smaller buildings and smaller average building areas per ICT controlled room costs may duplicate to approximately 15 to 18 €/m². Best pay-back times are achieved in those buildings that are not yet energetically refurbished (six years pay-back time).

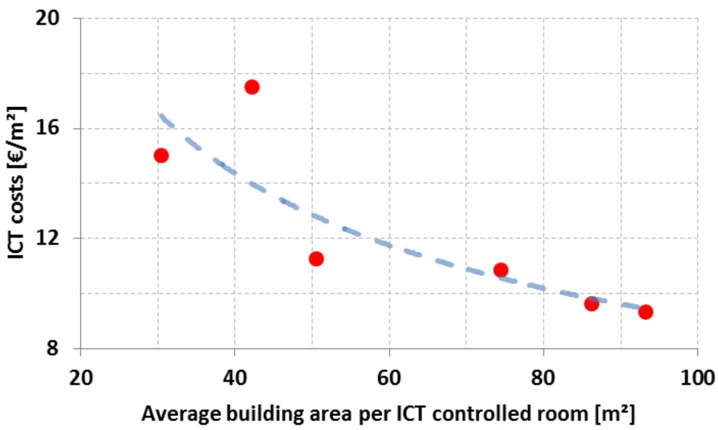

Figure 1. Decrease of average ICT costs for buildings with larger rooms.

In all pilot cases analysed reasonable economic trade-offs favouring the implementation of ICT systems were achieved already based on the existing framework conditions. Internalising the external costs would lead to further reduced pay-back times from three years onward (best case).

The rapid further development of smart ICT components will lead to lower ICT system implementation costs. Amongst others significant progress is made in the following sectors: further standardisation of interfaces; increased level of multi-functionality; introduction of energy harvesting technologies.

- **Significant increase in living comfort**
  Post implementation of ICT based heating/cooling control on room level room temperatures are kept within a predefined comfortable range whenever the room is occupied: no more cold rooms in the winter on Monday mornings; No more overheating on sunny days; No more heating when windows are open.

To achieve best results a proper framework is required:

- **On-site energy manager structures lead to better results**
  Large public buildings (> 50 occupants) should have one assigned, paid and trained "energy manager" who is in the position to (1) regularly verify the proper operation of all energy systems, (2) to monitor and interpret key energy flows, (3) to get defective components exchanged without long-lasting administrative processes, (4) to keep and up-date an archive on all relevant documentation. If no such "energy manager" is available such a position should be established in the course of the ICT implementation process.

  Within SmartBuild results achieved in buildings with available energy manager structures were clearly superior.

- **Involving the building occupants is key**
  In general surveys and a follow-up discussion of results were considered as a beneficial instrument to include the occupants and the building administration in the ICT planning and evaluation process. When implementing ICT in the existing building stock it is recommended to start conducting surveys among occupants about their comfort and behaviour right at the beginning of the works.

2 Introduction

Why is ICT technology, its further development and its application in the building sector considered as so relevant for the future of Europe?

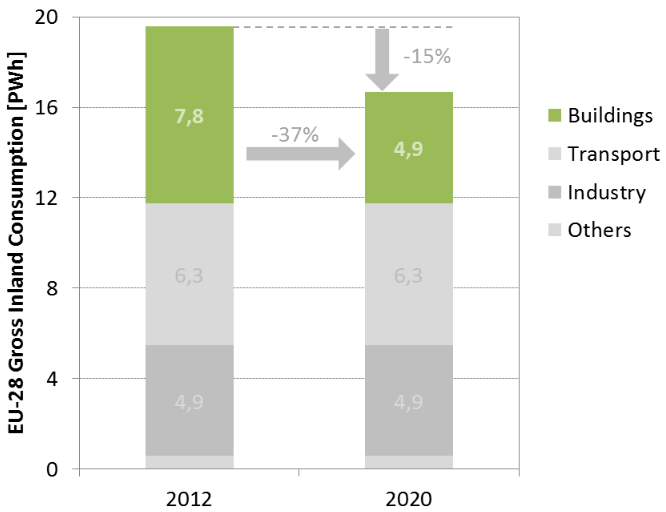

Figure 2. Potential impact of smart ICT on EU-28 Gross Inland Consumption by 2020.

By 2012 the majority of the EU-28 gross inland consumption (40% or 7.8 PWh annually) is allocated to buildings[1]. SmartBuild showed that smart ICT can help to reduce the energy demand of buildings by between 21% and 47%. In the short-term an average reduction in

[1] http://ec.europa.eu/eurostat/statistics-explained/

the energy demand of 37% is considered to be realistic. Projected on the European building stock such a reduction would lead to overall energy savings in Europe of 15% - a colossal contribution to Europe's 2020 targets!

This would not only reduce the EUs dependency on imported fuels, the environmental burdens and indirectly the health costs but also increase options for Europe's energy supply via clean Renewable Energy sources. Additionally ICT implementation improves the living comfort in the buildings and creates new highly qualified jobs in Europe.

But where can building operators best start with implementing novel ICT concepts? Where are such technologies most reliable, cost and energy efficient? What are the bottlenecks when implementing ICT in the existing building stock? SmartBuild contributed to find responses and solutions to these questions.

This report focuses on the following topics:

Project objectives
This section briefly describes the structure of the consortium, the objectives of SmartBuild and the web based energy portal used as basis for ICT implementation in all pilot buildings.

Work performed
A summary of the work performed is presented. It provides an overview on the set of activities performed to successfully implement ICT in the existing public building stock. Most of these activities would be part of any project replication. The background about the nine project pilots is key to classify the project results which are case specific (specific for site, building type, occupancy profile, etc.).

Results achieved
Key results are discussed. Examples provided relate to (a) savings in heating energy obtained for different room/building types and occupancy profiles, such as classrooms, offices, gyms, (b) to the impact of the ICT control on room temperatures, the indoor CO_2 concentration level and on peaks in power demand/ production.

Lessons learned
Main lessons learned with reference to the practical project implementation and end-user acceptance are presented.

Socio economic impact and wider societal implications
The socio economic benefit for the society related to the implementation of ICT in public buildings is higher than the pure direct economic benefit. This benefit is quantified and wider societal implications are discussed.

The document is directed to the following target group:

- Decision makers on political level
- Operators/ owners of buildings with focus on public buildings (public authorities)
- Energy service providers to public buildings & energy managers of buildings
- The interested public building occupant &tenants of buildings who pay the energy bill

3 Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
CHP	Combined Heat and Power
eTRV	Electronic Thermostatic Radiator Valve
HRV	Heat Recovery Ventilation
HP	Heat Pump
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communications Technology
ICT1	Monitoring phase within SmartBuild project. In this phase parameters related to (1) energy streams in the building, (2) building occupancy, (3) comfort and (4) on-site meteorology are acquired and visualized to the occupants.
ICT2	Control phase within SmartBuild project. Additional to ICT1 defined energy systems are now controlled automatically via ICT.
KPI	Key Performance Indicator
Prosumer	Prosumers are energy consumers who are in part creating their own energy, in example via Renewable Energy sources and, in some cases, selling it back into the grid
PV	Photovoltaic
RE	Renewable Energy

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5 Project Objectives

Within SmartBuild existing public buildings in Italy, Slovenia and Greece were to be retrofitted with a smart ICT concept in order to reach energy savings in annual and peak consumption of up to 35% and to provide social-economic benefits to building users, to building managers, to public authorities and to distribution network operators.

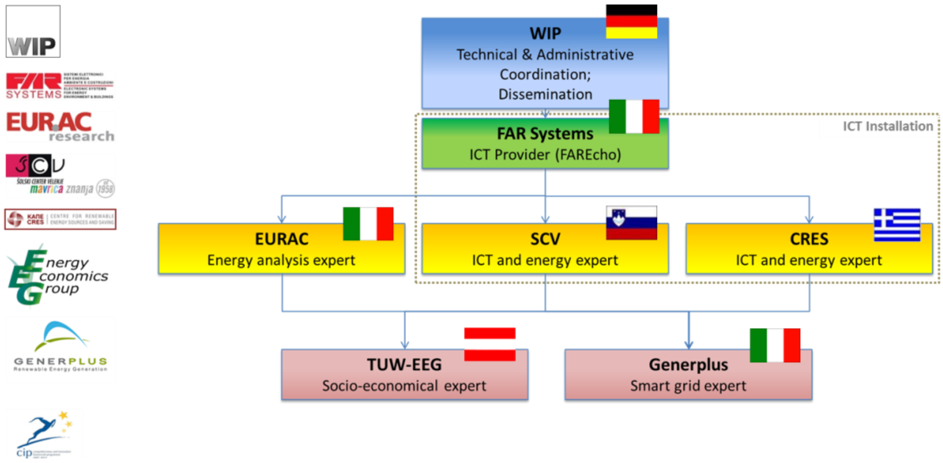

Figure 3. SmartBuild participants and responsibilities.

The ICT concept is based on the off-the-shelf "FarEcho Energy Monitor", developed by the partner FAR, a subsidiary of the Italian Tosoni Group. The "FarEcho Energy Monitor" was to be implemented in each pilot building according to the building characteristics and national standards.

Figure 4. The "FAREcho Energy Portal" and its interface with ICT system components.

The ICT solution is open and flexible; it is not proprietary: sensors, actuators and local control units using a large variety of communication technologies can be integrated and interfaced, including with the existing systems in the building.

This is beneficial because it permits a continuous system up-grade and the utilisation of latest most versatile and economic technologies in a quickly developing market.

An accurate energetic analysis was to be carried out at the beginning of the project and a strategy was to be developed to achieve the foreseen reduction in the energy consumption. The analysis is based on a classification for each pilot of the main loads and energy supply systems, considering their efficiency, timely profile, and the capacity of the current control (if available). The control system was to be improved via the installation of the proposed concept based on the "FAREcho Energy Monitor".

A concluding analysis should compare the energy demand with and without ICT as well as investigate the behaviour/impact of the building occupants and the resulting comfort for the occupants. It should elaborate the benefits of the concept from the technical, economic and societal perspective.

6 Work Performed

Within the initial project phase custom designed pilot ICTs were implemented in nine public buildings with different character, located in three countries. These ICT systems were used for a detailed scientific monitoring of energy streams and comfort parameters and are internally named ICT1 systems. The pilot ICTs are:

- Pilot ICT #1 Instituto Agrario San Michele All' Adige, Italy (public office and lab), responsible partner: FAR
- Pilot ICT #2 Secondary school "Aldo Stainer" Lavis, Italy (public school), responsible partner: FAR
- Pilot ICT #3 Hospital Silandro, Italy (public hospital), responsible partner: EURAC
- Pilot ICT #4 School Centre Velenje, Slovenia – public school (Building A: gymnasium), responsible partner: School Centre Velenje
- Pilot ICT #5 School Centre Velenje, Slovenia – public school (Building B: higher secondary school), responsible partner: School Centre Velenje
- Pilot ICT #6 School Centre Velenje, Slovenia – public school (Building C: higher secondary school), responsible partner: School Centre Velenje
- Pilot ICT #7 School Centre Velenje, Slovenia – public sport halls (Building B/C: gyms), responsible partner: School Centre Velenje
- Pilot ICT #8 School Centre Velenje, Slovenia – public offices (Building D: offices), responsible partner: School Centre Velenje
- Pilot ICT #9 Research centre CRES Pikermi, Greece (public office and lab), responsible partner: CRES

This action encompassed the complete and complex process for pilot ICT implementation in several steps:

1. the development of a project specific “energy auditing process”,
2. the development of a suited “energy auditing documentation tool”,
3. the actual on-site building inspection, the “energy audit”,
4. the definition of building/ user specific reference ICT hot-spots,
5. the selection of proper ICT technology, including communication technology, in agreement with the building operator,
6. pre-testing of new ICT components,
7. purchasing of the ICT components,
8. the definition of an ICT parameter code that can clearly be allocated to a specific building, to the location in the building and to the individual ICT component,
9. developing/ adapting the “FAREcho Energy Monitor” software for the ICT system and the data visualisation,
10. pre-setting and programming of the individual components and testing them at real operating conditions - before
11. implementing the ICT systems in the individual buildings and connecting it to the web,
12. commissioning the pilots via a standard procedure and
13. operate, maintain and continuously optimise the systems.

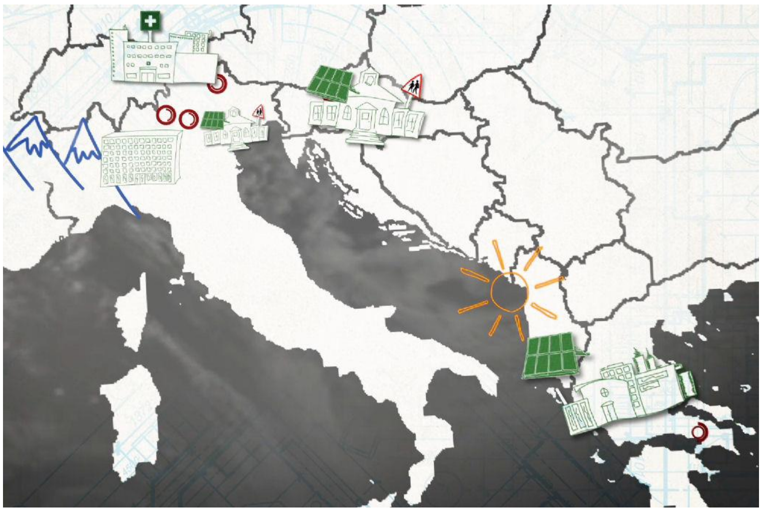

Figure 5. Location of the nine SmartBuild pilots comprised with ICT systems in Europe.

ICT implementation was complemented by the development and “on-going feature integration” into the “FAREcho Energy Monitor” of a function to generate and download monthly reports for every pilot. These are reports that can be custom designed with selected KPIs and charts. For the non-specialised building occupant a further feature was integrated: once registered he is enabled to give “real-time” user feed-back about the building comfort and about his satisfaction with the ICT system functions.

Standardised ICT commissioning procedures were developed to assure

- correct functionality of the installed ICT system,
- best exploitation of available ICT capacities and, in the following,
- a correct understanding and evaluation of the collected operational data via the SmartBuild ICT for result assessment

This commissioning procedure was flanked by the creation of a web based tool permitting to regularly conduct surveys among the building occupants with an acceptable effort.

A set of training materials was prepared and adapted to the respective national and pilot context. It was applied in various courses to train occupants and professionals on topics around the SmartBuild ICT system. The set includes questionnaires to occupants on relevant issues allowing for the identification and evaluation of challenges/ benefits related to ICT in buildings.

The implementation of the second series of ICT systems, the control systems, internally named ICT2, basically followed the above procedure described for the first ICT1 implementation phase. Part of this work had a stronger scientific character. Since the project aimed at the demonstration of ICT technologies with replication potential the aim was to include, where possible, cutting-edge technologies promising to cut down investment and O&M costs in future replications.

Figure 6. All pilot buildings were comprised with numerous sensors to measure energy streams and comfort parameters within the building. This picture shows electricity meters installed to monitor electricity flows on branch level.

Amongst others, the basis for the continuous ICT1 optimization and for ICT2 implementation was increased by two activities: (1) a review of successful ICT implementations that included a scientific evaluation of pilots realised in Germany and Austria and (2) the development of monitoring procedures, post-processing tools and algorithms to support ICT optimization which were continuously applied and improved. These tools were used to determine the technical, economic and societal benefits of SmartBuild and to draft guidelines for project replication.

Project activities were accompanied by a series of events to interact with key stakeholders, disseminate project results and foster new collaborations. Activities included the implementation and maintaining of a project web site, the organisation of events and workshops, publications, the installation of SmartBuild energy saving screens at the pilot buildings and the preparation of video material.

Figure 7. ICT data are collected in central electric cabinets on room, zone and/or floor level. The web based "FAREcho energy portal" connects to the central electric cabinet of any building.

Figure 8. Selection of ICT technologies implemented, including for cutting edge wireless electronic thermostatic radiator valves, eTRVs, using energy harvesting technology (picture to the right).

7 Results Achieved

With the end of the project all ICT pilots were fully operational in nine public buildings in Italy, Slovenia and Greece. The structured commissioning procedure developed and applied and the results obtained prove that the ICT systems are performing as expected and especially that the key project target to reach energy savings in annual and peak consumption of up to 35% and to provide social-economic benefits to building users, to building managers, to public authorities and to distributor network operators was realistic.

SmartBuild found that retrofit ICT implementation in the public buildings investigated is of highest value to increase comfort and to reduce the energy demand of the HVAC systems (Heating, Ventilation and Air Conditioning). On room level measured savings in energy related to the implementation of ICT based monitoring and control HVAC technologies were maximum 55% at an increased level of comfort. The comfort was measured and depicted using the ASHRAE comfort zones.

Table 2. Exemplary annual energy savings measured for typical room categories post ICT2 implementation at the School Centre Velenje, SCV (period: 2014-09 to 2015-02).

School room category	Annual Energy Savings [%]
Class room - Gymnasium	35
Class room - Secondary school	31
Class room - Secondary school / experimental class	33
Office - continuous use	55
Gym	16

Figure 9. Temperature profiles of two classrooms in comparison. Green line: room with ICT controlled heating on room level. During occupancy periods indoor room temperatures are kept at a defined level. During non-occupancy temperatures are regulated down; Red line: room with manual control based on standard thermostats (normally thermostats are turned by pupils on maximum). Temperature levels do sometimes reach high uncomfortable levels. As a consequence windows are opened.

Automatic control allows for occupancy and schedule based heating control at defined (comfortable) indoor room temperatures. The heating system is automatically switched off if windows are opened. Standard thermostat based control reacts slower. Room level scheduling is not possible and if windows are opened the radiators operate at maximum power to maintain the room temperature.

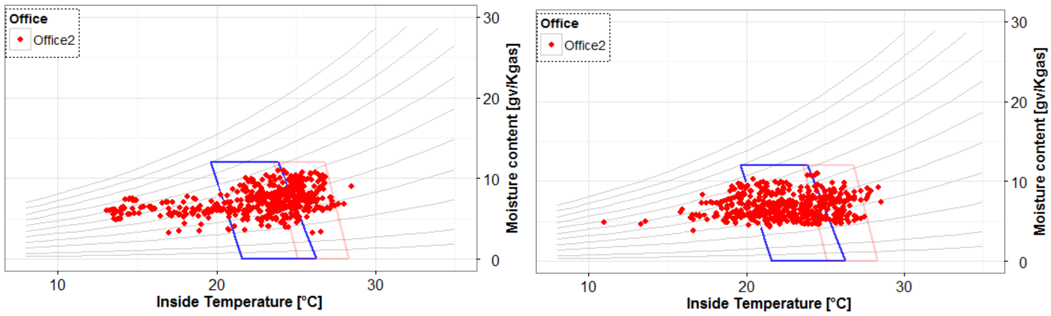

Figure 10. Examplary ASHRAE comfort zone diagrams before and after ICT2 implementation in a SmartBuild pilot office during room occupancy. In this case the measured internal discomfort was reduced by 17% via ICT2 implementation. (Left: w/o ICT control; Right: with ICT control).

On building level savings may cumulate to between 21% and 47% for the studied pilot buildings, depending on the type of building, the ICT implemented, the buildings occupancy profile and its location. Also, depending on the on-site operation & maintenance strategy a significant part of these savings was achieved already via the implementation of the projects' first phase, the monitoring phase. In general savings resulting from an optimization of existing systems post ICT based monitoring were between 3% and 9%, but there was an exception too, with 34%.

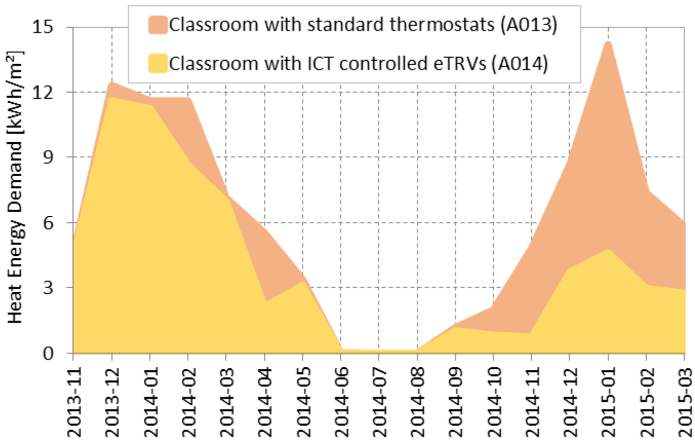

Figure 11. Benefit of ICT temperature control in classrooms: comparison in specific heating demand of classrooms between standard room and reference room; Yellow field: room with ICT controlled heating on room level[2]; Red field: room with manual thermostat based control.

[2] By February 2014 the first ICT2 eTRVs had been installed but operation was not reliable. Post exchange of the eTRVs by a new model savings were constant (from September 2014).

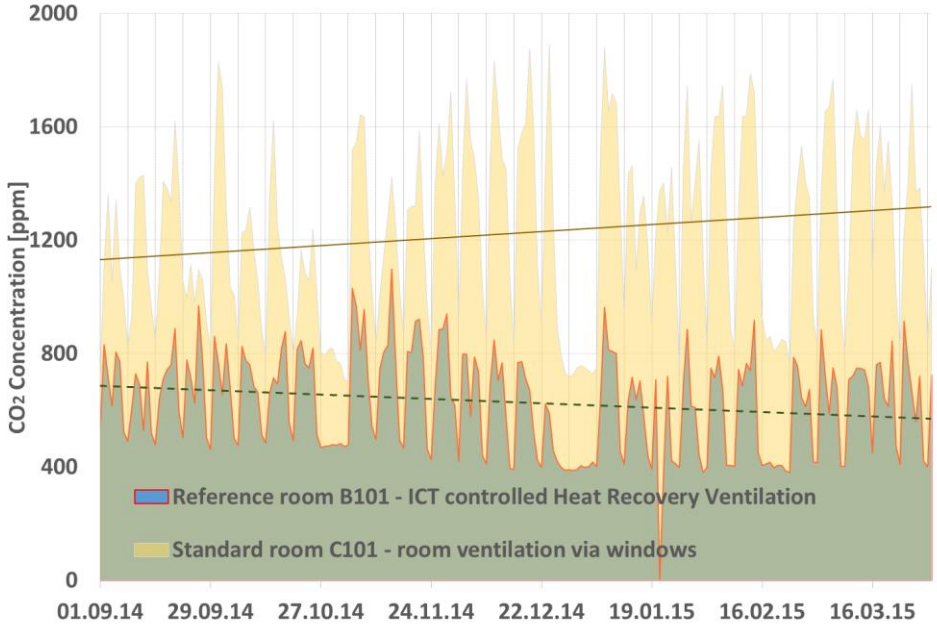

Figure 12. Benefit of ICT based HRV in classrooms: CO_2 level comparison for two classrooms (red line for room with controlled ventilation system; yellow line for room without ventilation system). If windows are not opened regularly for ventilation the CO_2 concentration increases to non-acceptable values. Controlled heat recovery ventilation keeps the CO_2 level in an acceptable range at a minimum additional energy demand.

Figure 13. Increase in comfort and reduction of energy consumption post optimization of the primary heating control temperature settings. The ICT monitoring systems allow for a precise adjustment to the "optimum" average indoor room temperature (green line post adjustment by mid of February 2014).

Professional, state-of-the-art and pilot specific "ICT system performance reports" were created which allow for a periodic verification of the function of every individual ICT system and of the efficiency of the respective rooms and buildings. This way the informed building operator can take corrective actions to optimize the comfort in a building and/or to reduce the energy demand without delay.

Figure 14. Exemplary extracts of a typical monthly report.

Because of changed framework conditions and because of the measured specific Renewable Energy (RE) generation and load profiles at the pilot buildings the work under the topic RE prosumers had to be refocused. Nonetheless, the tests and the analysis made allowed to clearly define (1) if and how electric air conditioning systems - heating pump based systems - can be best matched with the production profile of a solar photovoltaic (PV) system[3], (2) to identify factors of relevance for electric power management, specifically in combination with PV production at schools and (3) to develop new cost efficient RE system implementation schemes for a further category of public buildings, social housings, where the financial viability of the RE systems is substantially increased and reached with an ICT based control, such as the FAREcho "energy portal". At this place two exemplary solutions proposed, the solution (1) and (3) above, shall be summarised. The two solutions are suited for typical "prosumers".

Solution (1) is a cost efficient solution for new installations (Heating Pump system + PV system) with significant increase in the self-consumption of PV electricity and significant reduction in electricity peaks from and to the grid. It implements and integrates a medium size water based thermal storage tank with a reduced power Heating Pump (HP) system. Such a system enables a constant HP system operation during day time around PV solar noon, thus maximising PV electricity self-consumption. Additionally, it reduces peaks in electricity demand of the HP system during start-up periods by 50%. A further relevant benefit of this solution is that the HP system capacity for new systems can be downsized by 50% in comparison to systems with no thermal storage capacity, thus reducing HP system installation costs significantly. This solution is economically viable for new systems already today and requires no financial support schemes.

[3] Within SmartBuild this was the pilot where a significant reduction in peak electricity demand can be achieved at lowest costs (>50% reduction in peak demand).

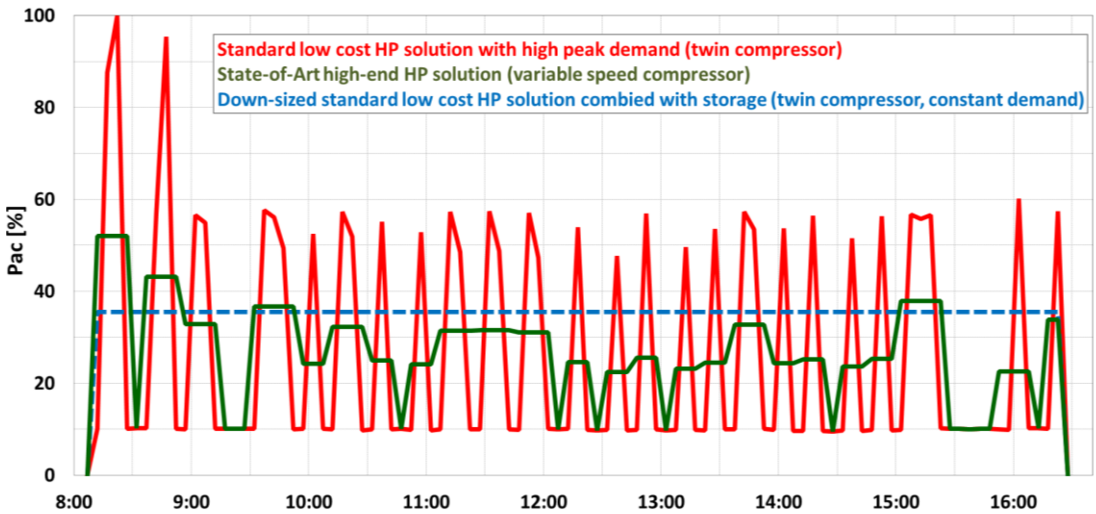

Figure 15. Consumption profile for an exemplary Heat Pump system satisfying the same cooling demand with: a) 15.5 kWel twin compressors (red), b) a 10.0 kWel compressor supporting variable load operation (green) and c) 7.0 kWel reduced power twin compressor in combination with medium size heat storage system. This system can be operated at a constant operation point for all working hours (blue).

Solution (3) was developed for residential building blocks such as public social housings. Normally, such buildings have large roof areas combined with a high electricity demand (multi-storey houses). The study made within SmartBuild proofs that new direct power marketing schemes in this category of public buildings, the social housings, in combination with a smart energy monitoring and RES control technology system, such as the “FAREcho energy monitor”, can result in the economic viability of solar PV and mini Combined Heat and Power (CHP) installations.

Five larger-scale dissemination actions were organized in in the course of the project in Frankfurt, Paris, Verona, Athens and Velenje. Project results were and are further disseminated via the project web page, via specific publications, via SmartBuild energy saving screens installed at the pilot buildings and via a video about the project.

8 Lessons Learned

8.1 Practical project implementation

Aside of project specific considerations that will vary for every case some general considerations will prevail:

- **Verification of electric and heating system lay-outs used for the planning process**
  At the project start it is relevant to verify with the building operator that the received electric and heating system lay-outs of the building to be used for the planning process were periodically up-dated, correspond exactly to the latest status and were made considering a defined standard. The ICT system implementation contract should refer to these plans and should define who would take over responsibility in case the

available documentation is not correct. Post completion of the work the ICT implementing party would have to deliver up-dated lay-outs that are to be verified with the respective energy manager of the building.

- **Keeping of an energy system log-book**
  An energy system log-book shall be maintained for the building during its operative life. It will report about the actions carried out on building level, the building energy system and specifically the buildings ICT system (changed settings of system; exchange and calibration of components; etc.), including commissioning and maintenance as well as other events influencing the data and therefore the assessment of impacts.

- **Access to key energy meters**
  If key energy meters are not fully accessible to the ICT implementation team but results are accessible only via invoices of the utility a clear procedure has to be agreed right from the beginning that guarantees automatic forwarding of the respective results to the ICT implementing party without delay. If monitoring shall rely on existing meters proper calibration has to be verified before start of the project (effort to be considered). Utilising mobile meters is, in most of the cases, more cost intensive than implementing fixed installed solutions.

- **Standard international code for parameters measured and controlled**
  Every parameter measured or generated via the ICT system should have a clearly defined code that allows to allocate the code to a building, a room in a building, the type of parameter measured and ideally also the sensor/ actuator type and serial number. SmartBuild developed such a code. The ICT system shall ideally be operated for decades. Codes will have to be clear as well for a follow-up service team.

- **Reliable uninterrupted power supply for ICT system**
  Especially the existing old building stock is often subject to refurbishment actions. Refurbishments may result in the cut-off of the electricity supply. In such situations monitoring devices and actuators may have to be restarted and in part reprogrammed manually. This is why small UPS systems to supply the ICT system during short black-outs in power may be beneficial.

- **Selection of ICT supplier**
  When selecting the supplier of your ICT system be aware that this system shall be operated for many years and a non-proprietary system provides significant advantages: only a non-proprietary system can be up-dated using standardised interface components from any supplier. This way you will be able to profit from latest developments in the sector at lowest costs.

- **Replacing of inefficient/defective building energy system components**
  Make sure the buildings energy manager is consulted before getting any inefficient/defective building energy system component replaced! Often achievable savings in annual energy demand or reductions in peak power demand are significant

and can be realised at low or marginal additional costs.

- **Public areas in use for private RE production**
  If public areas are made available to private investors installing RE systems such as solar PV systems, CHP systems, etc. make sure that the building operator has full access rights to the energy system production data in high resolution (minimum 15 minutes). In the near future it might be beneficial for the building operator to conclude an energy supply/production contract combining the energy demand of the building and the energy production of the RE system (direct RE marketing).

- **Continuous ICT system commissioning**
  Periodic ICT system commissioning according to a standardised procedure is a must to keep the ICT operating efficiently. Changed occupancy profiles may require the adaptation of settings; sensors and actuators may have to be reallocated and/or re-calibrated; wireless communication may suffer due to new furniture; etc.

- **Allocation of ICT costs**
  Part of the infrastructure required for ICT implementation may be required as well for other purposes in the building and cost allocation should be done accordingly. Two prominent examples are: (a) a strong Ethernet infrastructure and (b) a web based tool for the O&M of the buildings energy systems.

8.2 End-user acceptance

In general we observed that ICT implementation, if properly done, increases the occupants' comfort and decreases the energy demand, as long as the system is properly set-up, operated and maintained. However, there are ways to further increase the benefit and end-user acceptance:

- **Strengthening/ implementing effective energy management structures**
  Large public buildings (> 50 occupants) should have one assigned, paid and trained "energy manager" who is in the position to (1) regularly verify the proper operation of all energy systems, (2) to monitor and interpret key energy flows, (3) to exchange defective components without long-lasting administrative processes, (4) to keep and up-date an archive on all relevant documentation. If no such "energy manager" is available such a position should be established in the course of ICT project implementation.

  The energy manager should be rewarded for energy savings resulting from his direct intervention. This is possible if energy savings can properly be quantified and attributed (in example via a professional periodic energy report).

  The energy manager should be the direct communication partner for building occupants, he should have disposition about the necessary budget for his regular work and ideally he should be authorised to communicate targets at every level of the organisation.

- **Training of building energy manager**
  Before implementing an ICT system the energy manager of the building should participate at a training to familiarize him with the basic features and requirements of an ICT system in general and of the specific system. His feed-back may be of benefit to fine-tune the ICT design. Post ICT implementation the "energy manager" would support the ICT optimization (optimize set-up, identify further topics of intervention, etc.).

- **Involving building occupants**
  In general surveys were considered as a beneficial instrument to include the occupants and building administration in the ICT planning and evaluation process. For ICT implementation projects in the existing building stock it is recommended to conduct surveys among occupants about their comfort and behaviour right at the beginning of the works.

  Within SmartBuild the results of the surveys helped to identify "hot spots" that require solution. In example it was found that indoor temperatures in selected rooms increased significantly post thermal refurbishment of the outdoor walls and proper measures to bring back temperatures to a comfortable level had to be taken.

  Especially when training young pupils in primary/ secondary schools it is helpful to offer prizes for active participation. We found that it is better to award the most active class community instead of individuals. In general the effectiveness of trainings in schools with young pupils depends more on the trained teacher than on the pupils because the pupils are still obedient. The benefit of the training is that the pupils take the message home as well.

  If teachers shall take over (limited) training functions it is important that these teachers are given the required time to get trained and to train the pupils by the school administration. If trainings are to be done within the existing schedule results may be moderate.

- **Privacy issues**
  Consider that effective and cost efficient room-level control of energy streams (heating; cooling; light; ventilation; etc.) will require to monitor real occupancy and behaviour data. Depending on how these data are collected and stored this might be considered as a privacy issue. It is important to communicate options to the building administration and to the building occupants right from the beginning so that proper solutions can be agreed-upon before defining the ICT system.

- **Presenting and discussing results**
  It is important to evaluate results short after availability of data (monitoring phase; survey; etc.) and to inform the participants but also the building administration about the key results. This will not only give additional motivation for occupants to contribute and participate - because they see that their feed-back is used - but it will also highlight the impact of their behaviour/ response.

- **Highlighting the societal benefit**
  Especially when implementing ICT in public buildings[4] it is relevant to quantify the avoided external cost due to ICT implementation. This shows additional impressive positive effects on welfare economics. In a social-welfare economics context the avoided external costs need to be added to the pure economic heating/cooling cost savings as a result of ICT implementation. From society's point-of-view the pay-back time of the ICT technologies is significantly shorter than determined for the pure economic case.

9 Socio Economic Impact and Wider Societal Implications

In terms of social benefit analyses, the quantification of the avoided external cost in the SmartBuild pilots due to ICT implementation shows impressive positive effects on welfare economics. In a social-welfare economics context the avoided external costs need to be added to the pure economic heating/cooling cost savings as a result of ICT implementation. In doing so, this also implies that from society's point-of-view the pay-back time of the ICT technologies in the individual SmartBuild pilots is significantly shorter than determined for the pure economic case. The inclusion of the avoided external cost may result in 50% lower pay-back times of ICT implementation and namely in pay-back times below 3 years.

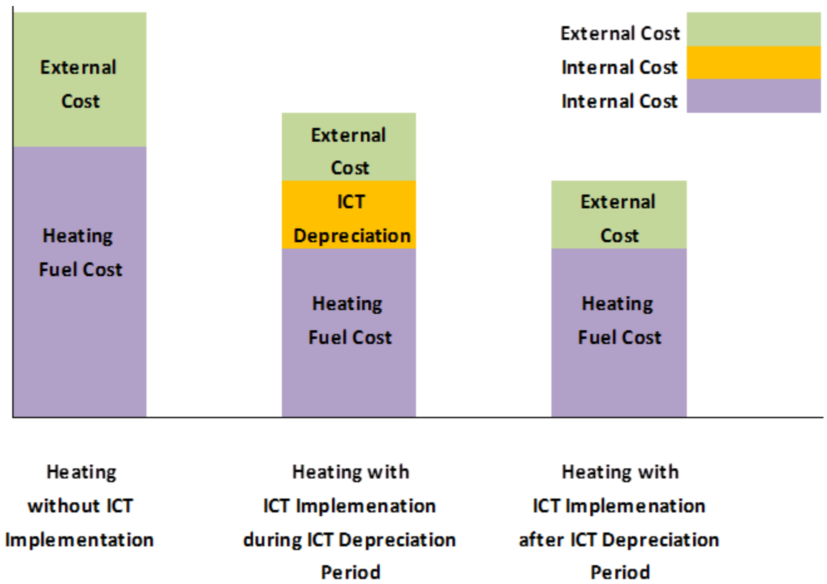

Figure 16. Internal versus external cost of heating - comparison of economic and social benefits in case of ICT technology implementation.

A quantitative analysis of the so-called external costs has been performed per SmartBuild pilot. The external costs are costs caused by damages on human beings, crops, and materials by CO_2, SO_2, NO_x and PM_{10}. The figures in **Table 3** indicate the monetary value of fossil fuel based heating generation technologies (in Greece: electricity based/ Heat Pump operation). CO_2 abatement cost are included.

[4] For public buildings the owner is the "society".

Table 3. Avoided external costs from fossil fuel based heating generation to humans, crops, materials and CO_2 cost (€cent/kWh).

	Italy	Slovenia	Greece	EU28
Avoided external costs [€cent/kWh]	4,0	4,2	4,7	2,4

As energy markets, in general, do not intrinsically internalise external costs, internalisation of them can only be achieved by adequate policy measures, such as financial support mechanisms (e.g. investment grants) for novel ICT technologies to trigger larger-scale implementation in the public building sector. From a social-welfare economics' point-of-view, the social benefit analyses in the SmartBuild pilots clearly demonstrated how science (to understand the nature of the impacts) and economics (to value the impacts) need to work together to create analytical approaches and methodologies, finally delivering results upon which policy-makers can base their decisions for appropriate measures and policies, notably in the segment of public buildings (e.g. schools, labs, offices etc.).

The public building segment is supposed to be of key importance, because here young people are educated and – once getting familiar with innovative technological solutions like ICT in the build environment – they have a high potential in the future to trigger accelerated implementation of similar innovative technological concepts not only in the public building sector, but also in several sectors in the medium to long-term.

Impact of living comfort on productivity

A comfortable ambient in a public building (school, office, hospital) significantly increases productivity of the people working there - e.g. in an office around 80% of the costs incurred in the building are labour costs[5]. This means that the actual energy costs in an office building are a small factor compared to the remaining cost (i.e. labour cost, financing and other operating cost). Therefore, the energy-efficient renovation of an office building needs to place the comfort in the rooms at the centre of its considerations. This is also confirmed by further studies[6]. E.g., these studies show clearly that – on average – a person in summer clothing and sedentary employment at a room temperature of 23 °C has its highest efficiency. If the temperature rises above, the efficiency drops dramatically. At room temperatures of e.g. 28 °C, the productivity of a person is reduced by around 25%.

Impact of living comfort on health

Poor indoor climate in public buildings – regardless whether these are office buildings, hospitals or schools – burden not only the occupants productivity but also health performance. Moreover, poor indoor climate can significantly reduce concentration, cause headaches or even infections and illness. In quantitative terms, e.g. the results of a recent study among 7,000 individuals in Austria[7] show that in more than 80% of the participating public building offices the measured indicators (CO_2 value, humidity, indoor temperature,

[5] see e.g. Eberhardt (2014)

[6] see e.g. Zimmermann (1999), Blümel/Fink (2004)

[7] see Austria's largest office-air measurement study in the public building sector conducted in 2013/2014; Platform "MeineRaumluft.at"

cold draught) have been exceeded at least at certain points, even when using average values (not peak values).

Impact of ICT technology implementation in Europe on export and creation of jobs
Recent studies show that initiatives to improve the energy efficiency of the building stock (i.e. the building's envelop, ICT and control equipment for heating/cooling, etc.) can represent a strong driver for job creation. Job creation is one of the most important co-benefits from improved energy efficiency and ICT implementation, particularly in a period of poor economic growth and high unemployment. Recent studies[8] found that - on average - we can expect that investing *€1 million in upgrading the energy efficiency (incl. the implementation of ICT technologies) of the public building stock will create 19 new direct jobs* in the construction and technology equipment implementation sector and that the vast majority of these jobs will be local and non-transferable, thus jobs that lead to economic vibrancy in the European Union.

Implications on policy/ ways to overcome barriers
There are different policy instruments to support the implementation of energy efficient measures and technologies and, consequently, to internalise external cost of fossil energy use. Among others, the following instruments proved to be successful:

- Short-term: investment grants, tax exemptions, energy contracting models or white certificate schemes for triggering energy efficiency measures and/or ICT technology implementation on a volunteer basis.
- Short-term: Implementation of a CO_2 certificate or a CO_2 tax scheme to increase total fossil fuel cost and, as a result, improve the benefit/cost ratio of alternative investments (e.g. energy efficiency and ICT technology implementation) in the heating/cooling sector.
- Long-term: Stipulating mandatory building codes and technology standards for both existing and new public buildings like schools, hospitals and offices.

10 Conclusions

The SmartBuild project implemented smart ICT systems in nine existing public buildings in Europe including schools, administrative buildings, labs and a hospital. The project proved that properly designed and maintained ICT can significantly reduce the annual energy consumption levels in public buildings. Savings in annual heating/cooling energy demand range between 21% and 47%. In buildings using electric powered heating pumps ICT control in combination with small heat/cold storage systems may reduce the peak load demand by over 50%.

If these results are projected on the European building stock we expect that overall energy savings in Europe of 15% are possible - a colossal contribution to Europe's 2020 targets!

[8] See e.g. like Janssen/Staniaszek (2012)

ICT implementation in buildings requires accompanying measures to maximise the benefits, such as the strengthening of on-site energy management structures and the involvement of occupants.

In all pilot cases analysed reasonable economic trade-offs were achieved that favour the implementation of ICT systems. Internalising the external costs of energy would lead to even shorter pay-back times - from three years onward (best case). Since public buildings are in the ownership of the society it is of benefit for the society to consider external costs and other aspects, such as local and national job creation, the impact of improved living comfort on productivity and health as well. Public authorities should therefore be encouraged by EU law to calculate the economic viability of ICT in buildings considering external effects.

11 Project Beneficiaries

All information about the project beneficiaries is available too on the project web site http://www.smartbuild.eu, see section: “about us”.

Beneficiary #1 (project coordinator)
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12 Dissemination Activities

12.1 Major dissemination activities realised and planned (status 31.01.2015).

Table 4. Major project meetings dates and venues within the third reporting period.

No.	Date	Location	Description
1	25.09.2012	Frankfurt, Germany	“Smart Solutions Forum I” in Frankfurt, Germany, on the occasion of the 27th European Photovoltaic Solar Energy Conference and Exhibition; WIP, FAR, Eurac, CRES, TU Vienna
2	18.06.2013	Vienna, Austria	Oral presentation of SmartBuild project by TUW at the 8th International Energy Economics Conference at the TUW.
3	11.09.2013	Nice, France	Oral presentation by Eurac at ICT for sustainable places Conference: “Key Performance Indicators (KPI) for Continuous Commissioning”
4	24.09.2013	Velenje, Slovenia	Training of occupants by SCV
5	01.10.2013	Paris, France	“Smart Solutions Forum II” in Paris, France, on the occasion of the 28th European Photovoltaic Solar Energy Conference and Exhibition; WIP, CRES, TU Vienna

6	03.10.2013	Lavis, Italy	Training of professional by FAR, Eurac, Generplus
7	11.11.2013	Velenje, Slovenia	Training of energy managers by SCV
8	21.11.2013	Lavis, Italy	Training of occupants by FAR, Eurac, Generplus
9	16.01.2014	San Michele, Italy	Training of administrative employees and energy managers by FAR, Eurac, Generplus
10	21.01.2014	Celje, Slovenia	Co-organisation of EUTRIP workshop on smart buildings with three SCV presentations.
11	30.01.2014	Velenje, Slovenia	MIC ŠC event organised by SCV with cooperating organisations on "Energy Management in Public Buildings" with participation of Slovenian officials from Slovenian Ministry of Education, the Slovenian Ministry of Science and Sport and the Slovenian Ministry of Infrastructure.
12	12.03.2014	Velenje, Slovenia	Training of energy managers by SCV
13	20.03.2014	Lavis, Italy	Training of energy managers by FAR, Eurac, Generplus
14	20.03.2014	San Michele, Italy	Training for Energy Managers by FAR, Eurac, Generplus
15	20.03.2014	Velenje, Slovenia	SmartBuild presentation by SCV at seminar of Society of maintenance workers of SI at the Inter-Company Training Centre.
16	25.03.2014	Škofja Loka, Slovenia	Presentation by SCV at school centre on "structure integrated energy management of public buildings" (application of SmartBuild).
17	22.05.2014	Riva del Garda, Italy	Workshop about the SmartBuild ICT concept at the School "Istituto Floriani" by FAR.
18	25.09.2014	Amsterdam; The Netherlands	Oral presentation of WIP at 29th European Photovoltaic Solar Energy Conference and Exhibition: "Attractive direct power marketing, incl. for small residential PV on local pool level" new fields of application for FAREcho system in social housing sector.
19	08.10. – 10.10.2014	Verona, Italy	FAREcho system presented by FAR, Eurac and Generplus in the framework of the "Smart Energy Expo 2014". FAR was present with an own booth.
20	13.10.2014	Velenje, Slovenia	Training of energy managers by SCV
21	21.11.2014	Athens, Greece	Side-event co-organised by CRES at "Building Green Expo" 2014 on smart buildings.

22	26. – 28.11.2014	Thessaloniki, Greece	Oral presentation of CRES at 10th National conference on Renewable Energy Sources organised by the Institute of Solar Technology: “Energy balanced buildings with the use of RES, active Energy Saving technologies and electric consumption predictive models”.
23	27.11.2014	Velenje, Slovenia	Training of energy managers by SCV (heating system set-up strategy at SCV 2014/2015).
24	28.11.2014	Piombino, IT	SmartBuild propmotion/training event by Generplus for energy managers and teachers at school centre Piombino (three upper secondary schools).
25	09.12.2014	Velenje, Slovenia	Workshop by SCV on “Energy Management in Public Buildings: Best Praxis Examples” with participation of Slovenian officials from Slovenian Ministry of Education, the Slovenian Ministry of Science and Sport and the Slovenian Ministry of Infrastructure.
26	19.12.2014	Piombino, IT	Training course for pupils by Generplus for energy managers at school centre Piombino (three upper secondary schools).
27	05.01.2015	Velenje, Slovenia	Training of occupants by SCV
28	21.01.2015	Velenje, Slovenia	Training of occupants by SCV
29	23.01.2015	Collesalvetti, IT	SmartBuild propmotion event by Generplus for energy managers and councillors of the municipality. The aim is to equip public buildings of the municipality with ICT systems.
30	04. – 06.02.2015	Bozen, Italy	Oral presentation by Eurac at 2nd IBPSA-Italy Conference of the International Building Performance Simulation Association: “Estimation of the water flow rate and energy consumption of a central heating system in an office building using system identification”
31	11. – 13.02.2015	Vienna, Austria	Oral presentation of SmartBuild project by TUW at the 9th International Energy Economics Conference at the TUW.
32	18.03., 27.04., 30.04.2015	Piombino, IT	Training course for pupils of upper secondary schools by Generplus; Specific tasks assigned to pupils (energy audit; energy bills analysis)

12.2 Publications by SmartBuild

1. M. Grottke (WIP), A. Manni (Generplus), C. Fendre (SCV): Benefit of Implementing electronic Thermostatic Radiator Valves (eTRV) in Schools, 23.07.2015. Publication prepared for a SmartBuild eTRV supplier and published via the project web page (smartbuild.eu).
2. C. Fendre (SCV): Modern Heating Control System in the Living Areas via EnOcean Standard Technology, professional Slovenian language journal "ElektroTehniska Revija" 02/2015 (Obnovljivi viri energije - Sodobni regulacijski ogrevalni sistem bivalnih prostorov in standard EnOcean).
3. D. Antonucci, F. Noris, U.F. Oberegger, (Eurac) and A. Gasparella (Free University of Bolzano): Estimation of the water flow rate and energy consumption of a central heating system in an office building using system identification, 2nd IBPSA-Italy Conference of the International Building Performance Simulation Association, Bolzano, Italy, 04.-06.02.2015.
4. A.Kyritsis, E.Mathas, E. Tselepis (CRES): Energy balanced buildings with the use of RES, active Energy Saving technologies and electric consumption predictive models, 10th National conference on Renewable Energy Sources organised by the Institute of Solar Technology (Greek language), Thessaloniki, Greece, 26. – 28.11.2014.
5. F. Noris, D. Antonucci (Eurac): Smart Build Project - Case Study San Michele all' Adige (IT) & CRES in Athens (GR), Smart Energy Expo (Italian language), Verona, Italy, 08. - 10.10.2014.
6. A. Manni (Generplus): The feed-back of building occupants in the pass towards building management system optimisation, Smart Energy Expo (Italian language), Verona, Italy, 08. - 10.10.2014.
7. N. Pontone, F. Besana, L. Podestá (R&D): La soluzione Cloud di FAR Systems e Qualta per il risparmio energetico, Smart Energy Expo (Italian language), Verona, Italy, 08. - 10.10.2014.
8. M. Grottke (WIP), T. Theenhaus, P. Oßwald (Buzzn), U. Haushofer: People Power - Attractive direct power marketing, including for small residential PV plants, on local pool level; EUPVSEC 2014; Amsterdam, The Netherlands, 25.09.2014
9. C. Fendre (SCV): Energy management in public buildings (presentation of Smart Build project), EUTRIP d.o.o. event (Slovenian language), EUTRIP, Celje, Slovenia, 21.01.2014
10. C. Fendre (SCV): Building energy management and central monitoring system of buildings (Smart Build as example of good practice), EUTRIP d.o.o. event (Slovenian language), EUTRIP, Celje, Slovenia, 21.01.2014
11. C. Fendre (SCV): Web energy management and bookkeeping, EUTRIP d.o.o. event (Slovenian language), EUTRIP, Celje, Slovenia, 21.01.2014
12. M. Grottke, I. Weiss, S. Caneva (WIP): Results of the Smart Build Project; Smart Solutions Forum, PVSEC 2013, Paris, France, 01.10.2013

13. D. Antonucci, F. Noris, M. Castagna, R. Lollini (Eurac): Key Performance Indicators (KPI) for Continuous Commissioning; ICT for sustainable places Conference, Nice, France, 11.09.2013
14. I. Weiss: The Smart Build Project - Implementing Smart Information and Communication Technology (ICT) concepts for energy efficiency in public buildings; European magazine “European Energy Innovation”, October 2012