Efficient ENergy for EU Cultural Heritage

Reporting

Project Information

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Final Report Summary - 3ENCULT (Efficient ENergy for EU Cultural Heritage)

Executive Summary:
Challenges
3ENCULT bridges the gap between conservation of historic buildings and climate protection. Historic buildings are the trademark of numerous European towns and will only survive if maintained as a living space. Energy efficient retrofit is important – both for improving the comfort and reducing energy demand (in terms of money and in terms of resources) and for structural protection in heritage buildings. 3ENCULT demonstrates that it is feasible to reduce the energy demand also in historic buildings to 1/4 or even 1/10, depending on the case and the heritage value.

Main features of the project
A core element in 3ENCULT was the multidisciplinary team, who elaborated a comprehensive refurbishment strategy for historic buildings: tools for the diagnosis, passive and active retrofit solutions as well as monitoring and control devices. The results are demonstrated at 8 case studies and transferred into building practice via diverse channels, including advice to CEN, virtual library on buildup.eu and a handbook with guideline for planners as well as targeted information and training material for education and industry, but also study tours, workshops and e-guidelines for local governments and decision makers and last but not least information for building owners and a wide audience through web and TV.

Results
There is no “one-fits-all”-solution – too unique is each historic building. The project rather proposes a “pool” of solutions and guidance how to find the right one for the specific building:
- a highly energy-efficient conservation-compatible window
- improved capillary active internal insulation
- a low impact ventilation based on active overflow principle
- a LED wall washer for high quality and low impact illumination (e.g. in museums)
- integrated PV solution and guideline on RES integration in Historic Buildings
- the web-based “roombook” integrating conservation and energy aspects supporting the multidisciplinary diagnosis and design
- wireless sensor networks and a BMS system dedicated to Historic Buildings
- adaptation of PHPP and integration of historic buildings in EnerPHIT certification

As regards the impact: 14% of EU building stock dates before 1919, 26% before 1945 – and even if only part of it is listed, most of it constitutes our built heritage and should be treated with care. Reducing its energy demand (~855 TWh) by 75% will result in more than 180 Mt CO2 saved (3.6% of EU-27 emissions in 1990).

For more information, please consult the project website www.3encult.eu

Partnership

Project Context and Objectives:
3ENCULT bridges the gap between conservation of historic buildings and climate protection. Historic buildings are the trademark of numerous European towns and will only survive if maintained as a living space. Energy efficient retrofit is important – both for improving the comfort and reducing energy demand (in terms of money and in terms of resources) and for structural protection in heritage buildings. 3ENCULT demonstrates that it is feasible to reduce the energy demand also in historic buildings to 1/4 or even 1/10, depending on the case and the heritage value.

Historic Buildings
Historic buildings are the trademark of numerous European cities, towns and villages: historic centres and quarters give uniqueness to our cities. They are thus a living symbol of Europe’s rich cultural heritage and diversity. As these areas reflect the society’s identity they are precious and need to be protected. Yet, this is also an area where the high level of energy inefficiency is contributing to a huge percentage of greenhouse gas emissions – mostly due to inefficient insulation, obsolete technological plants and inevitable replacing of original use. With climate change posing a real and urgent threat to humanity and its surroundings, also to historic buildings and surrounding infrastructure, it is necessary to act in this area and guide an improved approach to all refurbishment actions in historic buildings.

In numbers – more than 150 towns and urban fragments in Europe are declared to be World Cultural Heritage sites. Going from the level of monuments of exceptional interest to a broader definition of historical urban areas, further, highlights the significance of the built cultural heritage even more: this includes over 55 million dwellings across Europe dating before 2nd World War, with more than 120 million Europeans living in these buildings.

Figure 1. Share of dwellings in classes for periods of construction for EU-27, reference year 2001
Figure 2. Dwellings built before 1919 and between 1919 and 1945 for EU-27. The area of the circle is proportional to number of dwellings

Economy & Energy
The “old Europe” is an important drawing card for tourists all over the world, and maintaining this has a significant economic impact. Cultural heritage is a major contributor to the income from tourism, which stands for 5,5% of the EU GDP, generates more than 30% of its revenues from trade in external services, and employs 6% of the EU workforce. Tourism has an expected growth rate of 57% in the period 1995-2010. On May 2008, the Assembly of European Regions (AER) Committee with regional politicians and officers from across wider Europe, outlined the position for cultural tourism and its impact on the employment sector - Alan Clarke, an expert from the University of Pannonia, stated that “Developing cultural tourism not only creates a sense of knowledge and pride regarding local history and identity, but also helps to conserve cultural heritage, foster economic growth and create new employment opportunities”.

Seen from this perspective, as well as in context of expected rising prices of fossil fuels (e.g. gas and oil),
energy security and climate protection – there is clearly a need to reduce energy use in these buildings as well, which make up a huge number of building stock in Central, Eastern and Western Europe: more than one forth of building stock dates from before 1945, its energy demand related CO2 emissions can be estimated to 240 Mt – a definitely not negligible amount. Furthermore the comfort of users and “comfort” of heritage collections are also important factors to consider.

With Factor 4 reduction in energy demand, the CO2 emissions can be decreased by 20150 by what corresponds to 3.6 % of 1990’s EU-27-emissions.

Objective
A reduction of Factor 4 to Factor 10 in energy demand is achievable, also in historic buildings, respecting their heritage value is feasible – if an multidisciplinary approach guarantees the implementation of high quality energy efficiency solutions, specifically targeted and adapted to the specific case. This is the basic concept behind the proposed project. 3ENCULT has developed necessary solutions, both adapting existing solutions to the specific issues of historic buildings and developing new solutions and products. A wide partnership involving all the stakeholders allowed a holistic approach considering all the aspects of the problems towards the definition of shared solutions. In this case project consortium includes all relevant players – either as direct partners or in local teams/advisory board.

Our unique heritage and resource can be conserved if maintained as living space and as SUIT underlines "urban areas are living systems, where private action and investment are crucial". Not (or at least not only) a top down approach leads to good results, but the involvement and mobilisation of endusers and stakeholders; therefore target groups such as architects, municipalities, builders, owners (usually proud of its own building quality and performances) are addressed by 3ENCULT. Technical solutions for energy retrofit of historic buildings very often involve SMEs due to the specialist knowledge needed (e.g. 90% of all construction works in the field of historic buildings are performed by regional craftsmen enterprises).

General public engagement and improved awareness on the necessity for energy optimization is also needed – with a vast potential for action in historic buildings.

Specific objectives
The following main objectives are addressed:
- Objective 1: Develop passive and active solutions, as result of open and constructive dialogue among stakeholders in several fields; considering the constriction of handling with cultural heritage both passive and active solution have been developed starting with materials and products already available on the market and from solution already applied for new buildings. This with the aim to ensure the widest possible dissemination of the achieved results all around Europe, considered SMEs (and their capacities of innovation) involvement in the works on the historic buildings.
- Objective 2: Define diagnosis and monitoring instruments in order to study historic buildings and find out the best technological and constructive energy retrofit solutions, to support their commissioning, assess the actual performances of buildings once retrofitted and monitor such performance.
- Objective 3: Develop tools and concepts supporting the implementation of the developed solutions in other urban context, ensuring their effective transferability to historic buildings located in urban centres or their surroundings across Europe. The tools include calculation software, solutions inventories, dedicated internet portal to connect the stakeholder community with enterprises, monitoring systems and assessment approaches.
- Objective 4: Issue position papers suggesting possible integrations and/or implementations of the present regulation framework for improving energy efficiency of historic building in urban areas and in particular Energy Performance of Building, Environmental Impact Assessment and Strategic Environmental Assessment Directives and SUIT guidelines, taking into account the European position charter signed by the member states.

- Objective 5: Define a methodological approach in order to use the developed monitoring system also for IEQ controlling in historic buildings where cultural heritage collections are located. Improving the energy efficiency of historic buildings in urban areas means also taking care of requirements of comfort for users and “comfort” for heritage collections, issues that were also faced with the present project.

The research activities in the project were accompanied and stimulated by the involvement of eight case studies. At the same time, the different case studies allowed the assessment of the developed solutions, delivering feasibility studies as the first step of possible building energy retrofit. From here an analysis was conducted to generalize the found solutions, identify replicable factors and the context where replication is possible.

Both solutions and buildings chosen as case studies will allow to easily transfer the project results to other protected and unprotected historic buildings. The project results are to be applied to the majority of the European built heritage with residential and social functions in urban areas. It will allow to suggest an integration/consideration in the EPBD that presently excludes historic buildings

Project Results:
Main scientific & technological results

1 Introduction
The FP7 project 3ENCULT “Efficient Energy for EU Cultural Heritage” aims to bridge the gap between conservation and energy efficiency, which is not a contradiction at all: historic buildings will only survive if maintained as living space – and energy-efficient retrofit can improve structural protection and “comfort”, both for users and heritage collections. Reducing the energy demand by Factor 4 to 10 is feasible also in historic buildings respecting their heritage value, if a multidisciplinary approach guarantees high-quality energy-efficiency-solutions, targeted and adapted to the specific case.

Diagnosis and monitoring instruments have been defined in order to study historic buildings, to find out the best technological and constructive energy retrofit solutions, to support their commissioning, to assess the actual performances of buildings once retrofitted and to optimize such performances through a continuous fine-tuning.

Tools and concepts to support the implementation in different urban context and to ensure the effective transferability to historic buildings located in different locations.

On the other hand side a number of specific technical solutions have been developed and demonstrated at the case studies.

3ENCULT has defined a methodological approach on how to integrate monitoring and control system in a dedicated BMS system to guarantee a suitable Indoor environmental Quality (IEQ) – for the comfort of inhabitants, for avoiding damage of the building fabric and for optimal conservation of valuable interiors – with the lowest possible energy demand.

Furthermore, position papers suggesting the possible integrations and/or the implementations of the
present regulation framework for improving energy efficiency of historic building in urban areas have been issued.

2 Analysis of Built Heritage

2.1 Demand analysis and historic building classification
Measures improving energy efficiency are only acceptable for heritage preservation if they do not destroy the historic value or disturb its lasting. We showed how protected and other historic buildings can be sorted in a way that corresponds to technical solutions for refurbishment and modernization. Based on these theories we proposed to develop a catalogue for architects and conservation officers to be used as guidance and support in decision making, considering consequences and finding adequate solutions to match the demands for an increase of energy efficiency.

2.2 Criteria for the assessment of conservation compatibility of energy efficiency measures
Several experiences and strategies as well as recommendations are collected, checked, discussed and evaluated to generate a wide basis how to approach resilient and wide accepted criteria for the assessment of conservation compatibility of the energy efficiency measures within and beyond 3ENCULT. It should be brought to mind that this accounts for all built heritage independent from its listed or non-listed status.
Within this the basic hypothesis is always to respect multiple aspects in parallel. Thus for the decision on the single case possibly always the work of a multidisciplinary team is needed. Several ways of decision are possible to come to best practice solutions, but the work to do so has to be managed. No energy saving measure on a building is conservation compatible or incompatible per se. As a result of 3ENCULT the approach starting on one hand with a single heritage building and on the other without prejudice with the collection of all actual and effective energy solutions is the only possible way to come to a sustainable answer. For all retrofitting measures at all possible places of installation the impact on the monument, on the heritage value, the loss of original material and the change of the appearance has to be balanced. Also has the effectively to be weight as the sustainability in terms of damage risks and the reversibility of the new addition.

2.3 Integration in Aalborg commitments
Guidelines for local governments, exploring how they can address energy efficient historic building renovation in a comprehensive, strategic, integrated and effective approach – outlining how to best utilize these buildings as vehicles for sustainable development at local community level. The Aalborg Commitments on Sustainable European Cities provide a holistic framework for discussion and implementation of sustainable indicators and recommendations. 3ENCULT provided additional and replicable recommendations and strategies for the inclusion of historic buildings into sustainable urban planning, as well as for local climate and energy action plans. The guidelines outline how a local government in Europe, as the owner of historic buildings and monuments, as the developer of local strategy and policy, and as administrator and regulator of its geographical area, can engage and use the local cultural heritage to move a step closer to achieving a sustainable community.

2.4 3ENCULT methodology in the context of EIA
This position paper on EIA method discusses Environmental Assessments and presents the 3ENCULT
methodology to ensure a process, which incorporates cultural and architectural considerations and arguments along with technical, social, economical and functional parameters, when decisions are taken for energy saving interventions in built heritage. The 3ENCULT method is a practical scheme to support and guide the assessment process. It is developed to support a process to survey, assess and guide decision-making to meet the requirements for energy retrofit of built heritage. Its target is to support and coordinate the argumentation for the process, and to establish comparable references and a shared language when it comes to argue for the balance of energy and culture. The 3ENCULT method minimises the negative impacts on cultural values here and now. At the same time it maximises the value of the historic building in a long-term perspective.

2.5 Comprehensive diagnosis of historic buildings

Comprehensive conservation strategy to diagnose and support active interventions with historic buildings, was proposed as the draft proposal for a methodology and a checklist for efficient energy for European cultural heritage.

The strategy include the use of a tool for integrated documentation of conservation and energy issues, based on the “Raumbuch” concept. It was developed und used within the project as a digital database. For the selection of possible existing database, the following criteria were important: (i) the focus on the needs of conservation and restoration practice, (ii) the web-based system as well as (iii) a modular design that allowed the addition of the aspects of energy. The decision was made in favor of the Monument Information System (DIS) developed by ProDenkmal, a web-based and modular database which is targeted at conservation and planning in the context of preservation. Working with a database gives the opportunity to bring together all available information in a way that nothing gets lost and everything is taken into account on the way to project planning. It makes communication and handling easier because standard forms with standard terms are used and information has to be inserted only once – data can be made visible in several related places within the database, but also imported from and exported to external software tools. A database gives finally a clear “plus” of information by connecting documents and pictures as well as catalogues to different building layers.

3 Energy Efficient Solutions

3.1 Internal insulation

Diffusion-open, capillary-active interior insulation systems: These systems allow vapour diffusion into the walls, buffer the resulting moisture and remove the liquefaction from the condensation zone back inside. The moisture load of the wall is therefore considerably reduced. The hygroscopic storage capacity of a diffusion-open, capillary-active interior insulation system buffers humidity peaks of indoor air and regulates the indoor climate.

Work started with further development of a highly capillary active material as a filling gel to be combined with polyurethane foam to create an as well good insulating and capillary active insulation board. Due to the fact that the boards must be wrapped shortly after application of the filling-gel it has to contain an amount of water that is exactly enough for hydraulic hardening but not anymore. If there would be too much water inside the filling-gel there will be a risk of mould for the boards. Polyurethane foam panels are basically an inflammable construction material. Therefore some first prototypes have been produced using foam glass and aerogel panels, made of siliceous aerogel. Both varieties were brought to the point that they are technically feasible but there is still a need for major optimization from the point of view of
production technology. We apply the solution in all building of CS6: the Warehouse City house in Potsdam

3.2 Airtightness
In order to be able to study a selection of products for integrating old wooden beams in an airtight manner, we wrote to a number of specialist manufacturers to ask for their solutions to this well-known problem. Ten of the companies we wrote to, both inside and outside of Germany provided the Passive House Institute with product samples. From the samples, we put together seven different material combinations for sealing a sample beams (8 x 8 cm). The material combinations of the commercially available variants consist of up to three materials from the following product groups: adhesive tape, sealing mass/adhesive, bonding primer, elastic butyl rubber adhesive tape, a special solution and plaster joint tape. Each studied method uses products from only one manufacturer so that incompatibility between the products can be mostly ruled out.

For the combination of adhesive tape + bonding primer + sealing mass/adhesive (ABS), we also compared two manufacturers, so that a total of eight series of measurements were conducted on three samples each.

In the case study Waaghaus, Bozen interior insulation is installed in part of the exterior wall. Depending on the insulated area, the insulation will be penetrated by old ceiling joists. At this point the full airtightness sealing between the airtightness layer of the interior insulation and the joists was crucial.

3.3 Moisture transport at beam ends
In general the beam-wall connection does not present particular moisture problems in case of retrofitting with external insulation. For this reason in 3Encult only systems with internal insulation in combination with beam ends are taken in to account. Different solutions are described and evaluated considering the following evaluation parameters: usability in historic buildings, cost, energy efficiency improvement

The following solutions for internal insulation have been considered: internal insulation boards in combination with an air and vapour tight sheet; capillary active internal insulation with fine plaster (air tight and vapour open) on the internal surface (e.g. Remmers IQ Therm, Cellulose fibre with clay boars); capillary active internal insulation combined with an air tight (vapour diffusion open) layer (e.g. Cellulose with gypsum boards and air tight sheet behind).

For Hötting school case study the influence of applying 8 cm thick internal insulation (calcium-silicate insulation plaster) has been investigated thorough numerical simulation. The risk of mould growth before and after the retrofit of the building has been quantified for different cases. It was observed that reducing the internal relative humidity, mould growth would be excluded. Considering that, the installation of a ventilation system was recommended.

The Waaghaus in Bolzano presents a masonry wall connected with a wooden beam ceiling. The application of internal insulation on the external wall of the lower floor has been investigated through numerical simulation. As internal insulation a product available on the market (Remmers iq therm), which combine capillary active plaster and PU insulation, has been chosen.

With a 3D-analysis the position presenting highest water activity has been identified at the beam side delimiting the air cavity. Even at this position the water activity remains within a not critical range during all the year. These preliminary results confirm that the considered insulation system is appropriate for this kind of construction.
3.4 Windows
The recommended solution (smartwin historic) is to separate the thermal insulation layer from the window as it is seen from outside the building. So the (triple glazed) insulation layer can cover the needs of comfort, hygiene and air tightness, while the outside layer can perfectly fit to conservation issues and even can consist of a reconditioned historical window. Depending on the special situation of the protected building, the layers can be more or less separated to each other: In a coupled window, they are directly connected to each other. This is the cheaper solution. In a box window, you are totally free in the design of the outside visible layer and the higher depth of the combined frames can make the installation in the wall more easily compared to a casement window. In addition, the 4th glazing improves the thermal properties and raises the temperature of the glass edge.
Because, the concept of smartwin historic is a modular one, it can be adopted to a very wide range of various construction types and categories of historic buildings. That concept means to separate the, from the outside visible layer from the thermal one. By that, the design of the old window and even the old window itself can be kept, so the appearance of the historical buildings outside will be nearly not affected. The habitus of the buildings inside will be affected. That might be a problem of the implementation. The new window consists out of mainly the same material, as the old one, it might even be an option to integrate parts of the old window in the new one.
A first prototype of the window smartwin historic was implemented to the case study building “Waaghaus” in the city of Bolzano, Italy.

3.5 Shading
The alternative, to integrate the shading system within the window or glazing system might be a compromise between the architectural/conservational and the comfort/energy aspects. Hence the goal of this sub-task was to investigate shading solutions, which are especially adapted for the use in historic buildings by integration. The following objectives were taken into account: optimizing of thermal and visual behaviour of frame, glazing and shading/daylighting device; performance measurements regarding thermal and visual comfort; simulation and parameter variation of thermal and visual performance in a class room; integration of BMS system for shading devices management.
The question of integration of shading systems in the window/glazing system from conservational point of view strongly depends on the building, the window, the type and colour of the shading. In the monumental school in Innsbruck has been applied a lamellas redirecting system (mid pane) which fits very well into the cavity of a box type window with a wide space between the glazing. It is not applicable in coupled windows, because of the wide lamellas.
On the other hand, the height of the stack of lamellas will be larger in case of smaller lamellas, hence another type of solution is necessary in case of a small space between the glazing. Roller blinds made of thin foils or textile are applicable in those cases.

3.6 Space saving ventilation
In general, two different solutions especially adapted for the use in listed buildings were found to be suitable for integration of energy efficient heat recovery:

- Wall integration of the heat exchanger.
Placing the ventilation unit at the wall under the window (at the parapet) the architectural disadvantages (negative influence on daylight and room design) can be avoided. The ambient air is taken under the
window sill (slit inlet) whereas the exhaust air outlet is placed in the vertical window post. The extract air outlet is located besides the window, whereas the supply air is distributed via a slit under the ceiling above the window. This way, the air is vented without draft risk and with a minimum of shortcut. The thickness of the system should be restricted to a minimum; hence a flat counter flow heat exchanger in combination with flat ducts should be applied without any crossing of the air ducts. The system is covered with boards including maintenance openings from inside.

- Active overflow principle.

A central heat recovery system ventilates the staircase and the corridors with preheated fresh air. The active overflow system (one for each class room) takes the air from the corridor to the class room and vents the extract air back to it. The draft risk free air distribution in the class room is solved by textile hoses, which are laser-perforated (air inlet). To avoid airborne sound transmission between class room and corridor, the overflow elements are equipped with silencers. Finally the air is sucked to the toilets and cloakrooms and from there, via vertical ducts, back to the central heat recovery system located at the attic.

The active overflow principle was transferred to school buildings (Hötting, Innsbruck, Austria). The air passes (driven by fan) from the corridor via silencers into that hoses, which are perforated by laser for uniform flow distribution. To minimize the sound transmission between the class rooms and corridor, also the overflow openings are equipped with silencers. In this case, the high flow rate (about 700 m³/h) calls for a dedicated air distribution system to avoid complaints due to draft risk and airborne noise. This was realized by textile hoses for supply air distribution. The staircase is directly linked to the open space of the corridors; the fire doors will only be closed in case of emergency. A central heat recovery system ventilates the staircase and the corridors with preheated fresh air. The active overflow system (one for each class room) takes the air from the corridor to the class room and vents the extract air back to it. Finally the air is sucked to the toilets and cloakrooms and from there, via vertical ducts, back to the central heat recovery system located at the attic.

The active overflow system was installed as prototype (designed and manufactured by ATREA) in two class rooms. The central heat recovery in the case study is located at top floor level (attic), the fresh air is vented into the staircase, whereas the extract air is vented back to the heat exchanger via vertical ducts from wardrobes and toilets.

3.7 Automatic Air-flow volume balancing

Ventilation systems with automated air flow balance have the advantage that the delivered air flow rates are nearly independent from pressure drop differences during operation (e.g. rising filter pressure drop). That guarantees a secure operation with a steady heat recovery rate during the operation time, even with changing pressure drops in the ducting system.

Another advantage of ventilation units that provide systems for automated air flow balance is a lower amount of maintenance and time and cost savings when putting the ventilation device into operation. It is assumed that ventilations devices without automatic air flow balance must be readjusted at least every 5 years in order to prevent decreasing heat recovery rates caused by increasing imbalance.

Different solutions were investigated:

- Constant flow fans (built-in solution of ventilation devices)
- Air flow balancing according to the pressure difference in the fan inlet (built-in solution of ventilation devices)
- Enthalpy difference at the heat exchanger (built-in solution of ventilation devices)
- Temperature differences at heat exchanger (built-in solution of ventilation devices)
- Dynamic pressure measuring system (external system for installation in ducts)

Especially in refurbishment of building with cultural heritage ventilation devices with automated air flow balance can prevent structural damages. In historic buildings, even though a carefully planned energetic refurbishment, the air tightness of the building envelope after the refurbishment usually still is poor compared to new buildings due to construction details that are difficult to seal (for instance beam-ends in the buildings envelope). Automatic air flow balance can prevent outdoor air surplus which might lead to structural damage caused by condensate in the buildings envelope.

3.8 Daylighting
The use of daylight in historic buildings highly depends on the intention of the builders but also on the availability of other sources of energy for heating and lighting. Thus the design of a historic building reflects the significance, which granted the former owners to comfort requirements on brightness and warmth.

Investigated solutions:
- Integrable Daylightsystems (for Box-Window)
The Systems consist of daylight redirecting lamellas. The foil screen is a new product developed by industry outside of the 3encult project, but fits into box type windows, but there is of course no daylight redirecting. The lamellas/or screen could be implemented in box type windows. Some systems have package height, which allow hiding them in the top plate of the window box.
- Roof Opening (light pipe)
This solution allows enhancing the usability of top floors. Through the light pipe system, the rooms are illuminated with daylight. The daylighting system has a precise cut-off characteristic.
- Redirecting window shutter
The typical window shutters could be adjusted for daylight redirection. The complete sky hemisphere could be redirected into the room, onto the ceiling. For complete sunshading, each lamelle should be realized tiltable (turning, so that direct sunlight can’t enter the building.) The pollution of the reflective surfaces is to be solved.
- Applied films on windows
Applied films can reduce the damage potential of daylight significantly. They are applied on inner surface of a glazing system or even within the laminate, where their lifetime is optimized.

In 3encult case study- Weight House in Bolzano- a first analysis of the surrounding has been carried out, in order to evaluate shading conditions due to external obstructions
Then a daylight simulation of the case study has been performed (overcast sky conditions) to evaluate the inside illumination levels. In order to improve the low illumination levels, a system to redirect daylight inside the building has been planned. The system re-utilizes the ancient chymneys of the building as lighting tunnels. The efficacy of the idea has been tested in the Bartenbach artificial sky.
In case 2 and case 3 in Bologna daylight measurements were executed to better understand the actual status and risk to the objects of exhibition. The recommendations include a kind of screen for reducing the luminances of the (real) windows during day times and the utilization of the product developed Palazzo d’Accursio is characterized by high vulnerable surfaces with frescos (in the ceiling as well as on the walls), requiring advanced protection strategies. In line with the simulation results the current daylight
situation affect the vulnerable surfaces
In Höttiger school the classrooms were badly illuminated by daylight. The existing daylighting system is made of a textile screen.
Every single room was characterized by its utilization and the table of illumination requirements was created in relation with the user’s needs. Then, several market products where analysed, if they could fit into the cavity. The conservator insisted on having the lamella package invisible hided from views from the exterior by the window frame.
After the identification of several lamella systems with different possible geometries, these systems where analysed for their daylight redirecting, glare protection and daylight uniformity characteristics.
The standard classroom was simulated with the considered daylighting systems. Two situations were further compared: installation of a mirror ceiling (highly specular); no installation of a mirror ceiling (diffuse). They were especially compared regarding their daylighting potential. Uniformity was the final judgement criteria.
In the decision making process has been evaluated the advantage in using mirror ceiling to optimize the daylight distribution inside the classrooms for windows with different orientation.
The major advantages in planning mirror ceiling are identified on south west/ south east side and northwest window side.
The best performing system 30° Lamelle (Warema E80LD) was installed in winter 2012/13. Together with an external industrial partner a control strategy is implemented which controls the artificial light according to a chosen illumination-scenario, the lamella tilt angle, the thermal situation of the classroom and the actual sky conditions.

3.9 Artificial lighting
Besides requirements defined by needs of human beings also materials respectively surfaces (e.g. pigments in frescoes) are limiting the lighting solution (both day lighting and artificial lighting), because physical and chemical reactions may be triggered by electromagnetic radiation. These reactions cause deterioration of materials.
Sala degli Stemmi in Palazzo d’Accursio represents a very common room category in listed buildings: Its dimensions are enormous, the exhibition is the room itself i.e. the frescoes on the walls. The existing installation is absolutely none glare-free. The resulting luminance distribution is far beyond the well-established and recommended ratios. Knowing the current lighting installation the idea to illuminate these uneven walls by a new concept was defined in the EU project 3encult.
A well-known problem of museum luminaires or wallwasher is solved by the ‘3encult wallwasher’. Each little reflector is illuminating a very constraint rectangle at the wall. In any general wallwasher (e.g. from Iguzzini) the luminous intensity distribution is not constraint in lateral direction. Mounted on adjacent walls they will always partly illuminate also the neighbouring wall, where a significant pattern is visible. The 3encult Wallwasher allows to illuminate this kind of Italian rooms appropriately by its horizontal and vertical cut-off characteristics. The mechanical realization of the luminaire allows to mount it on a bearing rope structure (only a few screws are needed), to hide it on top of existing cornices or event have it as a stand-alone luminaire completely reversible. The colour temperature can be adjusted by choosing the proper LED chip (also tuneable between 2600K and 6500K). For very specific conservator requests, the correlated colour temperature could be even very warm (2400K) for particular incandescent remakes. The luminous intensity distribution curve is very unique, the luminaire has a lateral cut-off, which let it nearly disappear in the field of view respectively doesn’t irritate the view of the frescoes in the historic
room. The luminaire is illuminating with perfect homogeneity a rectangle at a surface. The luminaire ‘wallwasher’, that can be installed in a non-invasive way provides on the one hand an optimized visual scenery, on the other hand it can slow down the deterioration process that any material undergoes in its natural (or artificial) environment. Any LED product doesn’t emit in damaging but non visible parts of the electromagnetic spectrum.

3.10 Passive heating and cooling

Historic buildings usually have massive, stone-made external walls. There are no standardised passive solution to reduce heating and cooling need, but a specific combination of envelope features depending on peculiar context. Within 3Encult we developed a methodological approach to find the most efficient solutions for the comfort conditions, the energy efficiency and the costs saving, exploiting the big potential of thermal mass combined with a smart ventilation system. The following steps have been performed:

1. Definition of a typical stratigraphy for a masonry room in an historic building, based on the case study Waaghaus in Bolzano/Bozen
2. Definition of the variable parameters that will be improved for the energy simulation
3. Simulation model of the room in the dynamic software Energyplus
4. Use of the genetic optimization algorithm NSGA II (prof. Kalyanmoy Deb, Indian Institute of Technology) to find the best solutions
5. Analysis of the best solutions and comment of the advantages and disadvantages

The different combinations of the listed parameters have been tested with the simulation software EnergyPlus. The genetic algorithm NSGA II combines all the different parameters and defines the best Pareto optimal solutions for each climate condition. A genetic algorithm is a search heuristic mimicking the process of natural evolution. The algorithm creates a random initial population where each individual is identified with a set of design parameters, called chromosomes. During each successive generation, part of the existing population is selected to breed a new generation. The goal is to increase the fitness of the population with each generation. The nearer a solution is to the targets, the higher is its fitness. In the selection process, fitter individuals are more likely to be selected. These individuals are then considered parents of the next generation. Their children are formed through genetic operators such as recombination and mutation. Mutation and the inclusion of weaker individuals in the mating pool is important to ensure diversity and avoid a too-early convergence of the algorithm to locally optimal, but globally sub-optimal solutions.

In multi-objective optimization, as a solution may be good with respect to a certain target, but bad with respect to another, the decision which solution should make it into the mating pool is not obvious. NSGAII performs non-dominated sorting of the chromosomes of the selected individuals and puts the highest ranked chromosomes into the pool. Solutions which are distant from other solutions are preferred to avoid crowding. In the pool, tournament selection and crossover are done. Further, elitism is used to prevent the loss of good solutions once they have been found.

For our case-study we have done a multi-objective optimization, the goals have been: minimizing the sum of heating and cooling consumptions and minimizing the retrofit and ventilation costs. For a building that would be placed in Bolzano a good compromise between costs and energy saving is the use of 8 cm of EPS and triple or even double windows. Also the setback point temperature influences the consumptions, it seems that the system consumes less maintaining the temperature during night around the 14°C than keeping the temperature lower at night and increasing it suddenly at 9 a.m. with the
start of the occupancy period. In Bologna a good compromise between costs and performance is to use up to 5 cm insulation and double windows. Finally in Palermo the heating load is almost zero and the night summer ventilation is the most important parameter to reduce cooling load. The maximum number of air changes considered in this case room was of 10 ac/hour, but in Palermo to reach more comfortable conditions it would be surely better to increase them. As in the previous cases of Bolzano and Bologna, to reduce the cooling energy it is better to set at 1 °C the minimal difference between the internal and external temperature for the activation of the ventilation.

3.11 Active energy efficiency solutions
Several active system were investigated and classified in terms of possible constrains when used in historic buildings, costs and potential energy efficiency improvements.
For each analysed solution are exposed all the restraints and recommendations that need to be considered for an intervention in an historic building.
Although all the proposed solution can be generally adopted for existing building it is necessary to study each application case by case. In historical buildings where generally the heating or cooling system is not existing it is necessary to strike a balance between the conservation issues and the required internal comfort conditions. If for the generation system it is only necessary to provide adequate spaces, for the distribution and emission system it is also necessary to envisage their impact on the existing structure (e.g. risers, false ceiling, floating floor etc.).
To support the research done and to guide any future development as well as to define an assessment methodology that can be followed in each new project, a development matrix and an assessment method is defined.
The idea was to define a process and a graphical output that can be easily repeated in any further study. Results will be easily comparable and integrated with the results obtained for other solutions. The process is arranged in five main steps:
- Definition of the different climate zones and choice of the reference cities/climate data
- Selection of uses, definition of a baseline model
- Passive strategies
- Active strategies
- RES (renewable energy sources) integration

3.12 RES integration
From the point of view of the integration in historical buildings, the aesthetic aspects are very important. These installations should be planned carefully to maintain the historic character of each site and to make best use of the available renewable energy sources. It is important to make sure that the system works effectively but it is vital to consider its visual effect on the external appearance of the building.
Besides these aesthetic aspects, noise, emissions and vibrations are other sensory factors that have to be considered in relation to planning permission.
Working with preservation professionals to identify the character-defining features and the potential location for a renewable energy system is an important early step in the process to ensure that the system does not negatively impact these features.

Solutions and/or products
- Solar semitransparent double glazed isolating PV window
The main problem of semitransparent PV glass when used close to the inhabitants is the heat that the glass can reach. For avoiding this, G1S has developed semitransparent insulating PV glass, consisting in a semitransparent double glazed PV device plus an air chamber done with aluminium spacers and a back glass. This back glass can be different depending on the use.

An a-Si PV material is deposited by PECVD on a glass with a front contact. Laser patterning is used for obtaining the desired semitransparency degree, ranging from 10% to 40%. The back contact is deposited by Magnetron Sputtering and then it is encapsulated by lamination with another glass. Then usual techniques for double glazed glasses with air chamber in between are used, obtaining a semitransparent PV glass with thermal isolation properties suitable for windows, curtain walls and atria.

- Ventilated façades with heat recovery properties

Ventilated façades with heat recovery properties can be achieved by using semitransparent or opaque PV glasses. G1S has designed a fully monitored ventilated façade. Apart from the PV energy production, the air is heated up, flows up and is introduced in the building.

- Semitransparent solar thermal panel

Both sides of the collector are covered by a Transparent Insulating Material (TIM) patented by G1S, enabling at the same time thermal insulation and transparent properties. The selective absorber is cut and welded to each of the pipes of the grid in any angle, so that the plate enables the light to pass. It is designed for façades where the angle of the plate can have 45º and the ambient light passes through it. The finish of both sides is glass.

All the case studies have been analysed separately taking into account their characteristics (barriers to installing renewable systems and by their historic status) and the opinion of their owners. This information has been collected from the same questionnaire distributed along the case study responsible, involving both technical experts and conservators and owners. The questionnaires already contain the requirements of energy in the building, the possible solutions in the building and the conservation aspects of the solutions in order to have a clear idea of the possibilities in every single case study. Therefore, the study realised keep in mind the conservation aspects (aesthetic, historical and cultural values or structure damages) and the energy needs. In fact, a lot of solutions were discarded in the analysis according to the heritage concerns. Thus, the different solutions gathered in this section for each case study are based on the answers compiled.

3.13 Integrated solutions

Historic buildings can be retrofitted with compatible and conservatively passive and active solutions to achieve high efficiency energy standards. The developed approach included the following steps:

Step 0: Definition of representative climate zones.

Step 1: Definition of the baseline building: an existing historical building has been modelled with E+. The most common and representative uses are considered and modelled for each climate zone. This part of the study allowed to understand the energy consumption of a reference historical building, with a common HVAC System.

Step 2: Improvement of the HVAC System: the most suitable HVAC system has been defined for the considered building types in each climate zone. The analyses have been run using the software E+, in order to assess the improvement in terms of energy consumption.

Step 3: Combination of active and passive strategies: passive and active strategies have been combined and optimized. Using E+ the energy consumption has been assessed, and results compared each other.
Step 3-A: infiltration reduction and windows replacement. They were integrated with the active systems analysed in the Step 2.

Step 3-B: this second passive strategy is the insulation of roof and external slabs and was combined with the precedent ones in Step 3-A.

Step 3-C: In this final step, a last passive strategy is combined with the precedent scenario (3-B): natural ventilation is introduced in all thermal zones.

Finally all the comparisons between each step have been analysed in order to understand the importance of each strategies on the total energy saving and the maximum energy reduction for each climate zone and building type.

4 Monitoring and Control

4.1 Recommendations on variables & sensors

We collected description of variety of sensors and meters that are commercially-driven and can be used during the project in the different case studies is presented. Furthermore we defined an overview over the available sensors from the wireless network in development stage. To complete recommendations we fixed an overview regarding the sensors / actuators, which could be used in an automation system. Proposed sensors network allow to collect data of all the relevant parameters and metrics for characterizing the energy behaviour of the building, the climate situation and comfort in the rooms, the climate-related stress on valuable surfaces, moisture and heat situation in the energy upgraded building construction and energy consumption. Furthermore based on this information, an adjustment and optimization of the operation of building services compatible to the demand for energy efficiency and preservation of monuments can be coped with.

The monitoring concept needs to be planned and implemented object-specifically, in this process. In a second step, strategies for the control technique can be worked out to determine an operation mode which runs the technical systems optimally from an energy perspective. Building automations systems carry out such tasks in new buildings. These tasks must be taken over by individual approaches to the instrumentation in historic buildings, such as process measuring and control technology.

4.2 Monitoring and automation concept

We analysed the general parameters affecting the indoor climate and possible mechanism of damage and damage patterns, including recommendations for the planning and operating of heating and ventilation systems in historic buildings with large volume spaces. From such a basis monitoring and automation concept to be implemented in a measurement and control system was developed.

Monitoring & automation concept includes building and damage models as well as optimization algorithms. The implemented system includes an automated report generation of all monitored sensors and context specific results. Influences of microclimate, intensity of usage and state of operation of the building plant were identified. Furthermore, the possible improvements of control system to optimize the indoor climate and the energy consumption are explained on basis of reliable control algorithms. Recommendations on using heating and ventilation systems in visited historic buildings with rooms of huge volumes like churches, museums, etc. were discussed based on CFD analysis.

4.3 Wireless sensor network
We implemented and deployed a Wireless Sensor Network targeting the energy efficiency and preservation of historic buildings. The Wireless Sensor Network (WSN) can be a key tool to design and implement the cultural heritage building refurbishment. In fact the easy installation and pervasive deployment of the WSN, permit an extensive building analysis before the intervention. Moreover the reduced impact in term of cost, cable expense, installation masonry and maintenance, underline the capability of the WSN to realize a smart building control system with minimum invasive building renovation.

Systems already on the market have proved the reliability of the WSN for building management. However they are not able to interoperate with pre-existing sub-system and they cannot perform an extended pervasive WSN battery supplied able to operate for years, as should be in a cultural heritage building. Thus we developed a new WSN able to perform an extended and pervasive network, completely battery supplied, that can last for years.

Our WSN is designed for cultural heritage building, presenting the following characteristics: (i) physical microsystem node size of few cubic centimeters, to reduce the aesthetic impact (ii) sensors lifetime from several years to tens of years, to reduce the maintenance (iii) field configurable and remote configurable, to easiness the installation and maintenance (iv) modularity, to provide higher exploitability (v) dynamic deployable capabilities, in order to have an adaptable WSN (vi) easy extensibility, to support multi steps HVAC renovation (vii) multi sensors and external board sensors data collection capability, to support any kind of data acquisition (viii) easy pre-existing system integration (ix) optimized Trade-off between lifetime and quality of service (QoS) (x) standard protocols for WSN and thus ability to communicate with components already on-site (xi) wireless actuators, which can reduce installation effort considerably in historic building, where existing distributed autonomous components have to work together.

4.4 Building management system

Building Management System was developed according the constraints presented by heritage buildings and according to the ZigBee sensor network developed in the project in order to fullfil with the premises required by this kind of constructions. Due to the limitations which must be faced when working with historical buildings, the BMS was designed and developed gathering the biggest amount of information from the different case studies. Therefore, taking into account the feedback of the case studies, the BMS was defined as a multiprotocol and multiservice platform, whose services can be adapted and upgraded to meet all the buildings’ needs. Moreover, all the functionalities included in each service have been tuned with the requirements and limitations of this kind of buildings in order to adapt them to the real needs of cultural heritage buildings. Additionally, different interface concepts were designed and included in this document, with special focus on strengthening the usability and bring the information to the user in an easy and efficient way.

4.5 Guidelines for the implementation of monitoring system

The guidelines present the requirements of a monitoring system and explains why the building should use this kind of system. Moreover, they present the constraints and general restrictions to take into account when the monitoring system is set up in a historic building. More concretely, heritage and preservation issues are deeply analysed with a special interest. Furthermore, available protocols in the market which could fulfil the requirements and constraints are detailed. This section is extended with the ZigBee protocol developed in 3ENCULT where the identified restrictions have been coped. Last but not least, the Building Management System features and how to install it in a historic buildings are described.
5 Design Tools & Quality Assurance

5.1 PHPP
The Passive House Planning Package (PHPP) is a structured design tool that can be used by architects and designers. Within 3Encult project new features were built into the PHPP version 2007, which was the currently distributed version at the beginning of the 3encult project. In Sep. 2011 PHPP Version 6, the first of 3 major PHPP updates since, was released. In 2012 PHPP7 was released, which already included the EnerPHit verification for certification of historic buildings carried over from the 3encult PHPP 2007. The other two main new features, the Variants and the Comparison worksheet are still in version 2007 only, in which they originally have been developed. This version is also available as final deliverable for 3encult. However, these two new features will not be abandoned, but will be integrated into the upcoming PHPP 9, which will probably be released in the second half of 2014. For this integration work no 3encult funds will be used.

5.2 Hygrothermal dynamic simulation guidance
A particular advantage of numerical simulation is that the investigation of constructions consisting of different materials under various climatic loads requires relatively little work in comparison to field experiments. Thus a hygrothermal assessment of constructions can be evaluated in a short time. Construction building details and building materials can be optimized using the numerical simulation as well as renovation measures can be planned.

The aim of hygrothermal dynamic simulation guidance is to facilitate the application of simulation tools for planners, including: elaboration of tutorials, based on simulations performed within the project; development of training material; elaboration of guidelines on how to use simulation results in design tools as PHPP.

The guidance is based on documentation of the Delphin-training material and the way of using Delphin-tools and its material data files (simulation, program data base, user data base). The reader should understand a hygrothermal tools and material file and learn how to create and manipulate own material data files and how to import and export material data into his hygrothermal simulation.

5.3 Certification Scheme for energy retrofit of historic or listed buildings
A certification scheme called EnerPHit already existed before the start of the 3encult project. However the criteria were only applicable to refurbishments of residential buildings in Central European climate with exterior insulation and without any cultural heritage preservation restrictions. Within the 3encult project the criteria have been adapted to enable certification of historic/listed residential and non-residential buildings in all European climates with exterior or interior insulation.

One focus was on determining climate-zone-dependent qualities for components used in energy refurbishments, which are optimal regarding economics, thermal comfort, protection against moisture damage, indoor climate and reduction of CO2 emissions (see climate zone table). The EnerPHit certification scheme is supported by guidelines for certifiers on how to evaluate constructions with interior insulation regarding moisture issues.

A greater part of the extension of the applicability of the EnerPHit criteria achieved in the 3encult project for historic/listed buildings, is also valuable for certification of “normal” non-listed refurbishment projects. Passive House Institute plans to officially release the below set of criteria for use by all of its accredited EnerPHit certifiers (currently 25 European certifiers) within the second quarter of 2014. Pilot certifications
with the new criteria carried out directly by the Passive House Institute can already start before this date.

5.4 Proposal for the integration of historic buildings in the EPBD and related CEN standards
Within the EU project 3ENCULT we analysed the recasted Energy Performance of Buildings Directive (EPBD), especially where it concerns old and historic buildings. The link between the EBPB and the EPBD CEN Standards is discussed and also the relation between the EPBD CEN Standards and historic buildings. Moreover we evaluate the status of historic buildings in the EPBD, especially what additional requirements within the EPBD would help to realize a more ambitious energy saving level in historic buildings and what are its pros and cons. The findings were related to EPBD requirements that are valid for historic buildings, EPBD requirements of which Member States are allowed to exempt historic buildings and the possibility to add a requirement in the EPBD for an obligatory analysis of energy saving potentials&options in historic buildings.

Stated all energy performance calculation methods are a simplification of reality, and uses assumptions and preconditions. Due to uncommon construction aspects or details, the methodology might not fit some historic buildings, which might affect the usability of the energy performance calculation methods. Items that need specific attention related to the energy assessment of historic buildings have been discussed in a multidisciplinary team and questions and advice to the CEN EPBD working groups are formulated. Finally our suggestions regarding a CEN Standard on the energy performance of historic buildings is given.

5.5 Standardisation project in CEN TC 346 Cultural Heritage
3Encult coordinator Alexandra Troi contribute to setting up CEN standards on energy efficiency for protected buildings within TC 346.

Since the effective work on the content within WG8 (former TG15 of WG4) could start only with the green light given by the TC in its meeting end of March 2012 the standard was not ready for inquire in 2013 as originally foreseen. The work on the task was therefore prolonged beyond month 30 (the originally foreseen date for final deliverable of the document) until the end of 3ENCULT project.

5.6 Low emission concepts on urban and district level
Stated the Leipzig Charter on Sustainable European Cities emphasises the necessity of an integrated planning for a sustainable urban development and recommends the compilation of integrated urban (quarter) development concepts, we define a concept for historic quarters of the city development, including energy retrofitting and heritage preservation. Indeed, the Charta also states that the broad understanding of “Baukultur” is vital in this development. It includes in the context of this study the building of a sustainable city today and preserving the existing built cultural heritage, both of which determine a city’s image and identity.

The term ‘built urban cultural heritage’ describes in this context the urban structures that have developed over time under a multitude of conditions and influences, representing the atmospheric, aesthetic and documentary values of the urban realm. Not all built structures in historic quarters might be listed; nevertheless any action taken for energy refurbishment will possibly alter the substance and visual aspects of the urban environment to great extent. Solutions for the energy-efficient urban restructuring of historic quarters are required that are not only reconcilable with cultural heritage values, but also safeguard and develop the attractiveness of these quarters for the future.
6.1 CS1 Public Weigh House, Bozen/Bolzano (Italy)
During the project 3encult the building was completely empty, which gave us the opportunity to examine the as-is-state of the building very detailed. The application of several different measurement technologies and the acquisition of indoor and outdoor climate gave information about the relevant parameters for energy and comfort simulation and about its behavior. Based on the on-site survey a detailed model in EnergyPlus was created and calibrated with the monitoring data. Starting from this model a possible set of solutions for the energy refurbishment of the building was developed, in strong collaboration with the local heritage office. As in this specific case the major part of the existing windows were not of historic value, as they have been exchanged during the 50th/60th of the last century, it was the aim within the project 3encult to develop a high energy efficient window, that substitutes the existing window and answers to the heritage demands of the building. Within the project also the capillary active insulation IQ Therms was applied and tested on exterior walls of the Public Weigh House, checking its reversibility.

6.2 CS2 Palazzo d’Accursio /Municipal Palace Bologna (Italy)
For the purposes of the project, a particular area of the palace has been selected. It hosts the Municipal Arts Collections museum, with paintings and furniture related to different ages. This area has problems related to the maintenance of movable goods kept inside, with critical issues related to the hygrometric control and mixed construction characteristics.

The project has been developed, where possible, by non-invasive and completely reversible diagnostic and monitoring analysis to increase the level of knowledge of the building and to assess its performance, through:
- GPR radar tests
- Infrared Thermography (IRT)
- Blower door test
- U-value determination
- Monitoring trough WSN.
- An Energetic Analysis of Municipal Collections and offices with PHPP

Diagnostic and monitoring analysis have been carried out by UNIBO and Artemis.

An energy analysis of the most significant spaces (Sala degli Stemmi or Sala Urbana) was done using the Design Builder software, designed for carrying out energetic analysis in dynamic conditions developed with the ENERGY PLUS program.

6.3 CS3 Palazzina della Viola, Bologna (Italy)
The main focus of the work for case study of Palazzina della Viola was the extensive and integrated diagnostic approach developed to obtain information about the structural and energetic health state of this 15th C. building at different time periods: before, during and after the refurbishment works. To reach this aim, several non destructive diagnostic techniques have been applied in an innovative and non-conventional way, following specific and on-purpose designed procedures. The integration of the different
diagnostic techniques and their combined use with the wireless monitoring system installed—which has also been used in un-conventional ways—, represents an added value of the proposed methodology. This novel procedure allowed obtaining an extensive knowledge of the studied historical building without provoking any damage neither to the structure nor to the delicate works of art belonging to it (like frescoes, paintings, painted ceilings...). Thus, the described integrated multidisciplinary approach can lead to a new correct practice for a proper diagnosis of both historic and existing buildings and it could represent an example of good practice to be widespread, with the recommendation to carefully translate it in different and appropriate ways according to the specific case study considered, by employing the diverse possibilities and diagnostic methodologies as shown as a whole in this Case Study.

6.4 CS4 Fæstningens Materialgaard, The Material Court of the Fortress, Copenhagen (Denmark)
It was an already refurbished historic building and the special focus was on what the case could offer to 3ENCULT (a thorough historical and cultural description, a comprehensive list of possible interventions and a very well described multidisciplinary argumentation and decision process as well as simulation of energy conditions)

6.5 CS5 School Building NMS Hötting, Innsbruck (Austria)
Within the 3ENCULT project, two classrooms were refurbished with different methods and techniques. Lessons learnt from the case study CS5 are also part of this handbook, especially the ventilation chapter with the focus on the active overflow principle is mainly based on these results. Different types of capillary active internal insulation were tested and monitored. Moreover the original windows were restored, painted and enhanced with heat protection glass and sealing lips. An integrated day- and artificial light concept was designed. The artificial light was realized by LED-technology with adaptable colour temperature and high efficient fluorescent lamp and glare suppression respectively. The draft free ventilation air distribution is solved with laser perforated textile diffusers. The work was performed respecting the original structure and architecture of the early modernism (Arch. Franz Baumann). The original colours of the walls, frames and furniture as well as the materials, components and details were preserved or reconstructed. As an additional positive result, the enhanced user comfort (thermal and acoustic) and energy efficiency is a strong argument for the conservation of the building and to keep the history and culture alive and in use for future generations.
Focal point: active overflow ventilation

6.6 CS6 Warehouse City Potsdam (Germany)
Several analysis were performed before intervention, including monitoring at both the structural, architectural and engineering levels. Monitoring campaign was carried out by the WSN installed in the building. First case of intervention were defined in terms of needs and requirements, supplemented by constraint conditions that lead to the building guidelines for the sustainability of interventions. Finally the results of the carried out activities were discussed to achieve the assumptions of intervention (PHPP for status pre-intervention; Description of monitoring system installed in the building and the organization of the Case Study in terms of partners and stakeholders involved and their rules and principles of conduct for the constitution of the working group).

6.7 CS7 Industrial Engineering School, Béjar/Salamanca (Spain)
The main problems identified are the overheating in summer, the discomfort owing to the usage of only two
boilers for the whole building and daylight underused and air-tightness. Thus, after the diagnosis, though energy performance and lighting simulations, blower door test and monitoring, the interventions are focused on improving the behaviour of the HVAC systems and favouring the daylight with advanced control algorithms.

6.8 CS8 “Strickbau”/Appenzell, Switzerland
The aim of the investigations of this sample construction is to identify and test ways not only for improving energy efficiency according to the special requirements of conservation in existing buildings, but also ways of creating a significant improvement of the residential usability in order to increase the chances of preserving this historic kind of construction, by adjusting the conditions to modern living standards in other log constructions.

After the last tenant left, in the summer of 2011 the first investigation started. Because the log house is deconstructed at the end of the two-year study period, it was considered a unique opportunity to adapt interior insulation and find solutions and responses relating to the various issues concerning the insulation situation, thickness of insulation, requirements of steam break or block under construction and building physical aspects.

6.9 Transfer of experience
In case of a single monumental building it is possible to realize profound pre-intervention analysis on a high level of detail, which on urban scale would not be feasible. By precise measurements and analysis of the case study Weigh House it was possible to better understand the characteristics and intervention needs of a certain building type. This allowed us to do diagnosis and to find the right solutions also on urban level for the surrounding buildings by visual inspections, without the use of sophisticated measurement tools and within a shorter time. In a second case, we were able to transfer the solutions for construction details that have been already addressed in case of the Weigh House to another building typology.

The evaluation of transferability of solutions was evolved on two scales:
- On Urban scale, investigating the energy potential and defining the possible energy refurbishment interventions for a wide spread medieval building type in the historic city center of Bolzano (Italy), the “Portici”.
- On Building scale, supporting the implementation planning phase of the enhancement of energy efficiency of a historic Villa from the middle of the 19th century, near Lake Como (Italy)

In the first case, within the project 3encult, a group of students from the University of Dresden carried out a documentation of this special typology of building, which is characteristic for the original nucleus of the city of Bolzano. Through questionnaires and project plans data on the existing building, the building envelope, the building use and the building energy consumption were collected for several selected buildings of the Via Portici. Complementary an on-site inspection was carried out. This study has been deepened and completed by a team from EURAC by analyzing the energy potential and the intervention needs of this building typology and by assessing the possible implementation of refurbishment solutions exemplary for one “Portici” building.

In the second case the experiences, gained within 3encult regarding the heritage compatible energy retrofit of historic buildings, the development and implementation of technologies and refurbishment solutions within a multidisciplinary design progress, were introduced into the refurbishment design process of a historic north Italian Villa. During four common workshops among the 3encult partner and
Bolzano case study leader EURAC and the responsible building owner, architect and energy planner, design steps were discussed and verified and detail connections were evaluated.

Potential Impact:

Dissemination activities
Exploitation of results
FP7 project 3ENCULT bridges the gap between conservation of historic buildings and climate protection: it demonstrates that a factor 4 to 10 of reduction in energy demand is achievable, also in historic buildings, respecting their heritage value, if a multi-disciplinary approach guarantees the implementation of high quality interventions, specifically targeted and adapted to the specific case.

Considering that ECTP expects by 2050 the European building stock to be completely renovated, a reduction of energy demand by factor 4 in historic buildings (defined as those built before 1945, making up 26% of the total dwelling stock) would result in saving 180 Mt of CO2 per year – that’s 3.6% of the EU-27 1990 emissions.

To support the realisation of this potential, 3ENCULT on the one hand side supports the multidisciplinary planning process with the developed ICT tool integrating in the in conservation established “Roombook” with energy related aspects, disseminates technical solutions in a virtual library (based on a community in www.buildup.eu) publishes a handbook for architects, clusters with other running projects (organization of EWCHP 2013, contributing to [final] conferences and workshops of a.o. TRAINREBUILD, GOVERNEE, CO2OLBRICKS, ATFORT) and has disseminated the experience a.o. in study tours and at the major European conferences and fairs – both in the energy (e.g. CLIMA 2013, Passive House Conferences) and conservation sector (AR&PA, Denkmal, Salone del Restauro, ICOMOS symposium). At AR&PA 2012 the project was awarded with the “Premio Innovation” for its exemplary actions in boosting links between cultural heritage and society.

On the other hand side a number of specific technical solutions have been developed and demonstrated at the case studies - already commercialised products signed with *: (i) a highly energy-efficient conservation-compatible window* prototype has been installed at the Public Weigh House in Bolzano/IT [commercially available] , (ii) capillary active internal insulation* has been further developed and is under investigation at the four case study buildings around Dresden/DE, (iii) a low impact ventilation system based on active overflow principle is being tested at the Höttinger School in Innsbruck/AT, (iv) wireless sensor networks* are demonstrated at the Palazzina della Viola in Bologna/IT and the first version of a dedicated BMS system is tested at the Engineering School in Bejar/ES, (v) a LED based wall washer* for conservation compatible, high quality and low impact lighting was developed for Palazzo d’Accursio in Bologna/IT and has already been applied in two more cases outside the project by now.

Passive House Certification Criteria have been developed to fit also Historic Buildings and project results have been integrated in the training material for the Passive House Planner Course held in whole Europe.

Regarding specifically the impact on policies, (i) on European, energy related level, the project has given input both to the EPBD and to CEN EPBD working groups under Mandate M/480, (ii) on European, heritage related level, the project contributed to the development of a standard on Energy Efficiency in Historic buildings with CEN TC 346 WG8 and to a symposium organised by MEP Cristiana Gutierez in January 2013 and (iii) on Local Government level, more than 100 policy makers have been reached in workshops and guidelines for integration in municipal sustainability concepts have been elaborated.
1 Dissemination activities
Dissemination activities in 3ENCULT have targeted all relevant stakeholders, to guarantee information spread and implementation of results in practice: From architects and professionals who are decisive for quality design, over enterprises who have to put in practice the solutions, local governments shaping the near future to finally the general public – as the importance of the public opinion and the single house owner refurbishing its “castle” is not to be underestimated.

1.1 General public
1.1.1 Website
The 3ENCULT website [www.3encult.eu](http://www.3encult.eu) was online on 27th December 2010, i.e. within 3 months after project start, and has been updated regularly to provide visitors with new information. It is structured as follows

- **Project** – with the welcome page, featuring background and objectives as well as the news carousel, contact information and a site-map, the info page with the abstract and up-to-date publishable summary, the description of work packages both structure and specific content and finally links to related other sites
- **Partners** – with an overview of the partnership and short descriptions as well as links to single partners
- **Case studies** – with short and more detailed descriptions as well as videos for each case
- **News & events** – with the pages featuring the single news (searchable also by date or keyword) and events, with the newsletter archive and the page for subscription to the newsletter. The newsletter is prepared collecting the news of the reference period and distributed as email with image, teaser and links to the news on the website. In the archive both an html version with links is provided and a downloadable pdf version which includes also the single news.
- **Deliverables** – featuring in a structured way all public available deliverables of the project
- **EWCHP** – the dedicated page for the project’s final conference which was implemented as the 3rd issue of the European Workshop for Cultural Heritage Preservation – EWCHP 2013. It contained the call for abstracts and papers as well as all relevant information for participants and will also provide free access to single papers after the embargo time of one year.

The website had nearly 20’000 visits with a share of more than 50% of returning visitors and average session duration of more than 3 minutes. Visitors are mainly from Europe, but not only. Interesting to note, that the news carousel on the welcome page is an successful access point: from the more than 750 visitors using it to read a news more than 75% stay on the page to read more news or exploring project and case studies.

1.1.2 News & e-newsletter
- The first issue was sent end of November 2011 (M14), featuring 13 articles ranging from a general introduction to the project and its aims to a more detailed description of part of the activities and of related offers and possible synergies.
- The second issue was sent 6 months later, end of May 2012 (M20), and containing 12 single news. The articles address ongoing activities of the project giving space both at dissemination activities (such as promotion of study tours) and technologies developed within 3ENCULT (e.g:active overflow ventilation). Best practice examples within the case studies and achievements of the project are widely addressed.
- The third issue was sent in February 2013, with 15 articles ranging from the feedback and evaluation of the project to the discussion of a newly developed methodology for Environmental Impact Assessment. The newsletter appeals to the media thanks to well written interviews by YOURIS also addressing social themes relevant for local governments. Policy makers are also addressed through a series of workshops
and study tours with focus on Mediterranean countries especially developed for staff and representatives of local authorities. Researchers’ interest is triggered, among others, by the invitation to the 3rd EWCHP Conference – the announcement of the latter was also the main reason for delaying the issue several months.

• The fourth issue released in early June 2013, contains 11 articles, featuring 3ENCULT participation and contributions to events, including the first workshop for local governments and study tour held in Bologna, as well as the launch of the Integrated Quarter Assessment tool, developed to strengthen the implementation of Integrated Urban Development Concepts at district level. The newsletter addressed also the theme of up-take of market ready solution which will be the main focus of an upcoming event organized by ICLEI at EUSEW, and informed of the results of the 3ENCULT workshop at CLIMA 2013, organized by REHVA focusing on heating and ventilation.

• The fifth issue includes 10 articles, and it was published in November 2013. Among other topics, articles include: LED Wallwasher, invitations to events, both for policy makers – the Bolzano & Insbruck study tour, and for experts – the EWHCP. It also addressed the development of BMS in 3ENCULT case studies, and shared information about the 3ENCULT guidelines developed for local authorities on integration of sustainability concepts.

• The sixth newsletter includes a wrap-up of the project’s highlights as well as information on the deliverables produced and will give an outlook to the future opportunities for 3ENCULT case studies. The newsletter also inform about insulation technologies. The newsletter focuses on sharing the outputs of the latest event for local authorities that took place in Romania, and disseminates the four guidelines developed by 3ENCULT for local authorities (recommendations on technologies, on integration of urban sustainability concepts, on integration in urban planning, on replication of case studies). The newsletter also launches the latest 3ENCULT video by Youris.

1.1.3 Flyers
While already at a very early stage of the project a flyer based on two posters describing the project was used (first for AR&PA 2010, updated with logo and corporate design early 2011), the first professionally made Flyer featured the project, the partnership and the case studies. In first step 3000 copies were printed and distributed, for distribution with the conference bags at the 17th International Passive House Conference and the REHVA world congress CLIMA 2013 3000 more were printed.

The second Flyer featuring with focus on the project results and where to find information, was elaborated at the end of the project. Again 3000 copies were printed and distributed to partners. First events were the new flyer was distributed include Light+ Building, Frankfurt (Germany), April 2014, Metropolitan Solution Fair, Hannover (Germany), April 2014, Better Buildings Conference, Dublin (Ireland), Passive House Conference, Aachen (Germany), April 2014 and Renaturing Cities: Addressing Environmental Challenges and the Effects of the Economic Crisis Through Nature-Based Solutions”, 13-14 May 2014, Brussels.

1.1.4 Video news release
Already early in the project, the decision was taken to produce 2 VNRs instead of the one promised with Annex I: one focusing on more technological aspects and another one focusing on social impacts (Appenzell). The video material has been edited and packaged in two formats:

• the VNR teaser, which is a video of a length of about 3 minutes, with voiceover in English. The preview format, and the associated rushes, is intended as the “official” presentation version of the video and as an example of how footage can be edited by a TV station.
• the VNR b-rolls (12 min. footage without voice-over together with the supporting commentary) to feed the project communication mechanisms. Availability of rushes makes the editing process very flexible and easily adaptable to broadcasters’ needs, as through the rushes broadcasters are able to move from the preview version into a customised feature. Supporting written documentation, including the shot lists and the dope sheets are distributed along with the b-rolls.

The first Video News release “Rescuing Swiss Heritage” of the 3ENCULT project was launched on 29th November, 2012. The video covers the story of the Appenzell case study and how scientists, monument preservationists and craftsmen aim at ensuring conservation of the region’s architectural heritage also by optimising energy efficiency. The distribution of the video was supported by an article “Whipping Swiss cottages into green shipshape” and an interview to Niklaus Ledergerber, president of the cultural heritage preservation commission of the Swiss canton of Appenzell.

The second video news release “Restore History and Save Energy” of the 3ENCULT project was launched on January 29, 2014. This video aims at addressing the issue of retrofitting of historical buildings in terms of energy efficiency with a focus on some demonstration achievements implemented in two case studies of the 3ENCULT project. The article “Making Europe’s cultural heritage more energy efficient” and the interview “Retrofitting of historical buildings requires multiple expertise” to Alexandra Troi, vice head of Institute for Renewable Energy of the European Academy of Bolzano, came with the dissemination of the video, to sustain it and further increase 3ENCULT project’s visibility.

Both VNR thanks to the major experience and suitable effort of project partner youris have been taken up by more than 15 TV stations – including euronews which itself already broadcasts in 13 languages and has an overall audience of several tens of millions people per day

For usage at fairs – specifically AR&PA Innovation Fair in Valladolid – a video footage without narration based on the filmed materials and including also existing photo material has been prepared. These material has also been uploaded on youtube and is linked on the 3ENCULT website

1.2 Local governments & policy makers

Energy efficiently retrofitting cultural heritage provides the opportunity for a wide spectrum of actions with social, cultural but also economic impact at the local community level. This makes it an interesting area of engagement for local governments as the leaders and administrators of their local community. They have the mandate and interest to stimulate local sustainable development, making their communities liveable and supporting good quality of life for citizens and businesses alike (jobs, services, etc.).

3ENCULT partner ICLEI – Local Governments for Sustainability, which includes more than 1100 cities, towns, countries and their associations worldwide, has therefore translated 3ENCULT’s results into e-guides for their target audience and disseminated them in a number of workshops and study tours actively involving policy makers and local governments all over Europe

1.2.1 E-guides

ICLEI has elaborated four e-guides with different focus each and complementing each other:

• To learn more about technical solutions for energy efficient retrofit of cultural heritage, Local Governments are directed to the “Summary Guide for Local Decision makers -Technical guidance on energy efficient renovation of historic buildings

• The second guide offers a brief summary of recommendations for local decision-makers on the integration of energetic retrofit of historic buildings into municipal policy, planning and regulation.

• The guide on “Integrating energy efficient retrofit of historic buildings into urban sustainability”, offers a
set of recommendations and indicators for local decision-makers on the integration and advancement of sustainability criteria at urban level, and the role that energy efficiency retrofit of cultural heritage can play in advancing the local sustainability agenda.

- Taking as starting point the guides above, the “Recommendations for transfer & replicability” focusses on the replication potential and on the lesson learnt from each of the eight 3ENCULT case studies – identifying for each of them the policy context, stakeholders, sustainability criteria, some implementation highlights and finally recommendations and replicability.

Click covers to download the e-guide

1.2.2 Study tours

The 1st study tour aimed to local policy makers and technical staff took place in Copenhagen on 26th June 2012. The workshop was aimed at countries with Cold Climate from Northern Europe and the Baltic. 28 participants from 8 countries attended the workshop which showed Copenhagen’ frontrunner actions on integration of historic buildings into climate and energy action plans. The local case study was visited together with two additional exemplary buildings, including the OSRAM building, particularly interesting for its additional function of starter for the renovation (also social) of an entire district.

The 2nd study tour took place in Bologna, on 24th April 2013 and it was addressed to South European and Mediterranean countries. The study tour was held back to back with a workshop for local authorities that took place on 23rd April 2013 and also involved the Italian working group of the Covenant of Mayors Supporters and Coordinators. Sixteen participants from five countries, mostly from the Mediterranean area, visited two 3ENCULT case studies and an additional building, during the tour.

The 3rd study tour took place in Bolzano, Italy and Innsbruck, Austria on 19th September 2013. The study tour included a background introduction on the policy of the two cities concerning the energy and retrofit planning at local and urban level. The cities’ strategies and actions were presented by representatives of the local municipal Councils. 25 participant visited the two case studies

More information on www.3encult.eu

1.2.3 Workshops

The Workshops for Local Governments have been organized involving EU, National and Local authorities. The events targeted local policy maker and technical staff (urban planning, monument protection, energy, environment, cities’ real estate). Particular attention has been paid to involving New Member States (NMS) where the retrofitting of historical building is an emergent topic; two of the workshops have been organized in NMS, respectively in Poland and Romania.

- Bologna Italy, 23rd April 2013 - Preserving community history through energy efficiency
- Brussels, Belgium, 28th June 2013 (within EUSEW) - Cultural heritage and energy efficiency: Market ready solutions for preserving historic buildings using innovative measures and technologies
- Krakow, Poland, 26th November 2013 - Cultural heritage and energy efficiency: Protect historic buildings saving energy
- Alba Iulia, Romania, 4th March 2014 - Bridging the gap between energy efficiency and heritage protection

Out of 145 participants, 45 questionnaires were collected and evaluated: 23 participants rated the workshops as very good, 9 as good; 39 participants stated they will pass on information to their colleagues and 43 will recommend the tours, 29 would like to receive more information and among the presentation and input provided in the sessions, participants particularly appreciated information and exchange on best
practices, technical solutions and funding. Finally, the amount of participants with “good” level of knowledge on the topic moved from 14 to 27, and from 2 to 10 for “very good”.

1.3 Professionals
Very important for the widespread implementation of project results are the professionals: Architects, particularly those specialised on conservation, but also engineers and energy consultants on the one hand side and collaborators of conservation authorities on the other. Therefore a number of 3ENCULT dissemination activities addressed this target audience.

1.3.1 Handbook
The handbook, edited by EURAC and PHI, with the single chapters written by the respective experts within the consortium, will be published with Birkhäuser, a high-level publisher very well known among architects who are the main target group. The book will be published in Autumn 2014 and will be available as printed book, but also as free available e-book.

1.3.2 Scientific publications
Scientific publications include besides more than 50 papers in (mostly peer-reviewed) conference proceeding, sections in books, eight diploma thesis and several PhD thesis – in phase of finalisation. During project duration one paper has been accepted for publication in Energy and Buildings. More are in preparation. Furthermore the proceedings of the 3rd European Workshop on Cultural Heritage preservation have been published with Felix-Verlag (book via EURAC, single articles for free download on EWCHP website).

1.3.3 Presentations at fairs and conferences
3ENCULT results have been presented with more than 50 papers at 28 scientific conferences all over Europe – addressing at equal shares conservation, architecture and technology. Moreover presentations without related papers in proceedings were made at many other seminars all over Europe. More than 20 fairs were covered – including with Denkmal (Leipzig, DE), Salone del Restauro (Ferrara, IT), AR&PA (Valladolid, ES), LuBEC (Lucca, IT) and monument (Salzburg, AT) the major European Heritage fairs and with Light + Building, CLIMA, DeubauKOM and other also major fairs and exhibition in the building and energy sector. Furthermore REHVA disseminated information very effectively with their presence at numerous fair and conferences pertinent to the HVAC and building sector, ICLEI comprehensively covered the major European events for policy makers and municipalities.

1.3.4 Virtual library on Build Up
The 3ENCULT virtual library is intended to be a powerful online resource for stakeholders operating in the field of historic buildings refurbishment and conservation. It presents in a well-structured way the results of the single technological development tasks on energy efficiency solutions for built heritage in line with the priorities and conservation compatibility criteria – done with a strong interrelation with the multidisciplinary teams at the single case studies. In order to optimise impact, the virtual library is based on the well known BUILD UP portal, collecting Europe wide resources on energy efficiency. Technically speaking, the single documents will be uploaded on the BuildUp community on cultural heritage and tagged with specific keywords. They are also made
available via 3ENCULT website in two ways – via guiding images and keywords and via the embedded BUILD UP site. This approach allows to (i) on the one hand side guide users on 3ENCULT website and (ii) on the other hand side make the documents at the same time available to the big community of BUILD UP users.

1.3.5 Frequently asked questions
The FAQ, which have arisen in the case studies and were answered by WP2, WP3 and WP4 partners, were collected and elaborated for a wide audience. They are accessible via the project website and a pdf document. The FAQ catalogue consists of several topics and has been be classified in 7 categories: (i) first step (authorization), (ii) evaluation phase, (iii) design phase, (iv) rehabilitation phase, (v) monitoring phase, (vi) assessment phase and (vii) environmental sustainability at urban level.

1.3.6 Training material
Partners engaged in University training have developed (and implemented) different lectures modules which are available on the 3ENCULT website for further use by other teachers. Covered themes include (i) Environmental monitoring, (ii) Energy efficient solutions for sustainable renovations, particularly related to natural ventilation, windows replacement, internal insulation, damages, (iii) Daylight and artificial lighting and (vi) Methodology for energy retrofitting: diagnosis procedures.

For the preparation of training material a twofold approach has been chosen: On the one hand side, material for a 20 hours course has been prepared and first implemented by EURAC (as module 7 within the overall 200 hours course for professionals on “Trasformare il costruito” organised by CNA in Bolzano in 2013 – the module will be held again in the second issue of the course in 2014). These presentation are available for use and can be downloaded from the website.

On the other hand side PHI has introduced one lesson on historic buildings in their “Certified Passive House Designers seminars”. This material is restricted to the use by PHI and distributed to course participants.

1.3.7 Final Conference
In September 2013 the FP7 project 3ENCULT organized the 3rd issue of the European Workshop for Cultural Heritage Preservation – EWCHP 2013 as the project’s final conference where the most important achievements were discussed and presented in different ways: with oral presentations and posters, but also three training sessions and a number of touchable products to be explored in the exhibition area.

2 Exploitation
Exploitation is a key aspect of the 3ENCULT Project. A list of the most important results generated through the project and their possible exploitation was edited during Consortium agreement preparation and has been used as basis for the first draft of the “Plan for use and dissemination and exploitation of results”. Such plan has been regularly updated during the implementation of the project.

The exploitation of results is based on a strategic cooperation among different partners organized from the beginning phases of the project. Each partner spent much effort in the exploitation activities, with the objective of involving a critical mass of different Target Groups:
- Architects, engineers, technical designers, urban planners;
- Energy audit and energy experts;
- Building owners and investors;
• End-users and their associations;
• Policy makers and public authorities;
• EU, National and local authorities;
• Technological enterprises (with special focus on SME);
• Scientific community.

2.1 Commercial exploitation of R&D results
The commercial exploitation of the results produced in R&D played a very important role in the Project and it has been implemented through the collaboration between industrial and research partners.
Two products in 3ENCULT are protected by patents:

On the one hand side, REMMERS has optimised its patented concept for capillary active interior insulation – based on capillary active wholes distributed over a very cost- and energy-efficient insulation: During 3ENCULT project the capillary active filling gel has been optimised. Furthermore a new capillary active render has been developed, which allows for thinner layers and therefore application also by painters (and not only masons) and a clay based, reversible adhesive has been demonstrated at the Public Weigh House in Bolzano (CS, IT). The tests with several other insulation boards based on different insulation materials showed technical feasibility – there economic market entry depends on cost development of the base materials.

On the other hand side, BLL has developed a wallwasher, which illuminates with high homogeneity a rectangle at a surface. The luminous intensity distribution curve is exquisitely accurate, which let it nearly disappear in the field of view respectively doesn’t irritate the view of the frescoes in the historic room. Hence, the installation is possible from non-invasive to minimal impacting on internal structure. Deterioration is slowed down because LEDs do not emit in damaging but non visible parts of the electromagnetic spectrum. Unique remake of historic incandescent illumination is available thanks to specific coatings of reflectors. (Down to 2200K). The energy efficiency is optimized by the special optical design and by use of a LED of 2013 (overall efficacy 90lm/W). Having been developed for museum application, the product opens however also many other applications (blackboards in schools). The product is market available, has already been applied outside 3ENCULT and is being sold by licensee Projektleuchten.
Patent: BLL, n. DE102012015394A1

Other developments are also market ready and exploited via different approaches:
The window concept which allows to produce highly energy-efficient windows which are compatible with historic buildings, developed within 3ENCULT by ANDRE is exploited via Propassivhausfenster GmbH: The latter was founded by ANDRE together with Franz Freundorfer and an Austrian window producing company and developed the passive house window "Smartwin" (registered trademark) – registering two utility models. This company has up to now 12 partners, window producing SME in 8 European countries. The window for historical buildings (which is more a concept adaptable to local needs rather than a "rigid" product) developed in 3ENCULT uses one of the technologies protected by utility model – and is being part of the family called “smartwin historic”. Propassivhausfenster GmbH can use the development of the "Smartwin historic" window and produce this window. Actually, an Austrian company, specialized in traditional box windows for historic buildings joined the partner network only because of the "Smartwin historic". Beneath them and ANDRE itself, especially the Dutch partner "smartwin NL" in Gouda, is highly
interested in the product and presented it on several trade fairs. For the wall integrated ventilation system to install easily distribute mechanical ventilation system and to offer space saving installation of ventilation heat recovery system and the active overflow systems for school buildings, which allow enormous reduction of ducting work and therefore minimise impact on heritage ambients, UIBK and ATREA have chosen the way to widely publish and disseminate the experience in order to allow for widespread application and implementation also by other enterprises. ATREA itself is of course also interested in follower projects to the case study in Innsbruck and consequently proposing the solution on fairs and pertinent conferences.

Several monitoring systems (components) specifically designed for the cultural heritage have been produced and are exploited in manifold ways:

- Novel Building Management System for heritage by integrating upcoming technologies for monitoring and control purposes through sensor networks (CARTIF, copyrights);
- Management of big-data in a single machine through the Central Server concept (CARTIF, copyrights);
- Wireless sensor network to save time and costs of instrumental monitoring (UNIBO-DIES, Near-term market launch via Spin-Off);
- Low cost solutions for environmental monitoring by the use of free software and micro-PC (ARTEMIS, only for internal use);
- Advanced environmental monitoring services (ARTEMIS, only for internal use).

Moreover, various software and tools for energy efficiency in historic buildings have been developed:

- Historic Building Information System (hBISec), an inventory system to make easier the auditing phase towards energy retrofit of cultural heritage buildings (EURAC, TUD, PRODENKMAL, Medium-term market launch possible);
- 3D simulation model for heat and moisture transfer in building components based on FEM Commercial software Comsol Multiphysics (UIBK and PHI, software with open access);
- Additions to the energy balance calculation tool "Passive House Planning Package" (PHPP) that evaluates the economy of the refurbishment measures in the entire life cycle of the building (PHI, software licenses are sold to users).

PHI will by the end of 2014 put into official use the extended EnerPhit standard for the retrofit with PassiveHouse Components. Before 3ENCULT Project, the EnerPHit certification scheme was only applicable to residential buildings, in cool-temperate climate with exterior insulation. During the project, new requirements for certification of historic, non-residential buildings with interior insulation in all European climates has been considered. Additionally, PHI has been written a guideline for EnerPHit certifiers, on how to evaluate internal insulation for potential moisture problems. Currently buildings are already certified according to the extended scheme by PHI and its international accredited certifiers.

2.2 Exploitation of R&D results via policies & standards

Regarding specifically the impact on policies,

(i) on European, energy related level, the project has given input both to the EPBD and to CEN EPBD working groups under Mandate M/480, analysing (i) what exactly the reasons are why EPBD is not applied to historic buildings until now, (ii) to what extent historic buildings are covered by the CEN EPBD standards, (iii) whether there are special methods needed to label historic buildings and (iv) to what extent
requirements on major renovated historic buildings are possible, what the issues are and how these can be solved

(ii) on European, heritage related level, the project contributed to the development of a standard on Energy Efficiency in Historic buildings with CEN TC 346 WG8 and to a symposium organised by MEP Cristiana Gutierrez in January 2013

(iii) on Local Government level, more than 100 policy makers have been reached in workshops and guidelines for integration in municipal sustainability concepts have been elaborated (see section 1.2)

2.3 General advancement of knowledge
The general advancement in knowledge, as typical for this kind of projects, will be used by the single project partners within their future work – both for consultancy and as basis for further research and development. As – not comprehensive – examples might serve here the simulation model and calibration procedure developed by EURAC for application in retrofit consulting or the simple, effective and free solutions for data communication to remote server developed by ARTEMIS to be part of their monitoring services, for monitoring and

Furthermore, there has also been produced a wide range of materials to guide architects, engineers, technical designers, urban planners, energy audit and energy experts in the energy retrofit of historic buildings and districts. Again, the following list is indicative and not comprehensive:

• To me mentioned first of all: the handbook, published with Birkhäuser and available both as printed book and as free e-book
• Then there are the Proceeding of the Final Conference, again available both as printed book and freely downloadable papers
• Education material for University studies has been elaborated and implemented and is freely available also for other European university courses;
• Training material for professionals categories (has been elaborated and implemented – and historic buildings and their special demands have been introduced as moduk in PHIs course for certifiers which is held for thousands of participants all over Europe;
• The position paper on conservation criteria, together with the guidelines for bringing high energy efficiency concept to historic buildings in order to give referenced methodological approach and to support energy retrofit of EU historical building stock;
• the database of active and passive energy efficiency technical solutions provided via the Virtual Library
• and last but not least, the collected FAQ

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