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

Coordinator – EURAC research, Italy. Austria: Bartenbach Lichtlabor, University of Innsbruck. Belgium: REHVA, youris.com. Czech Republic: ATREA. Denmark: Royal Danish Academy of Fine Arts. France: Menuiserie André. Germany: ICLEI, IDK, Passivhaus Institut, Remmers, Technical University of Dresden, University of Stuttgart. Italy: Artemis, Municipality of Bologna, University of Bologna. Netherlands: TNO. Spain: CARTIF, Grupo Unisolar. United Kingdom: ARUP.

EUROPEAN COMMISSION DG research

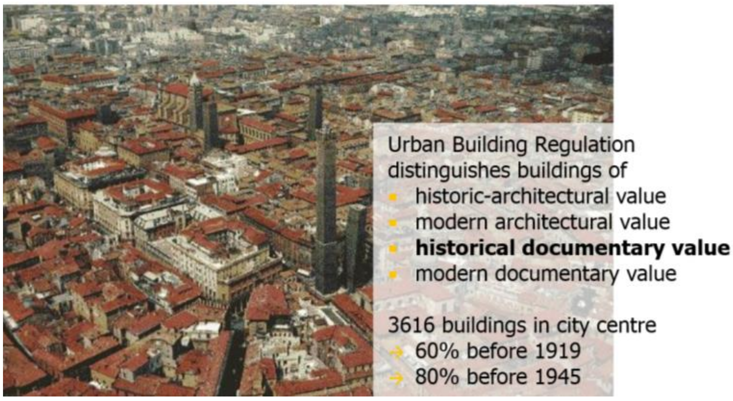
Seventh Framework Programme - Theme [EeB.ENV.2010.3.2.4-1]
Collaborative Project – GRANT AGREEMENT No. 260162

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.

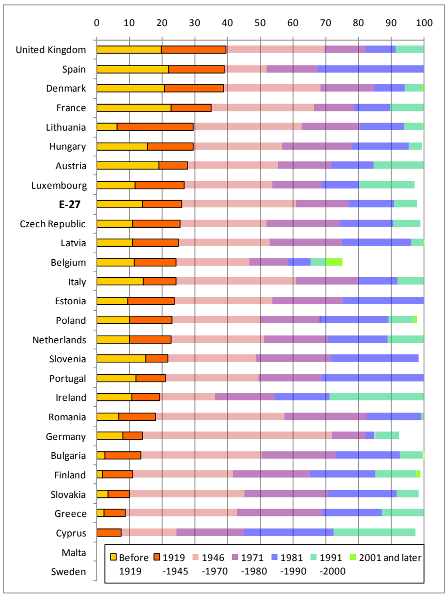


Figure 1. Share of dwellings in classes for periods of construction for EU-27, reference year 2001

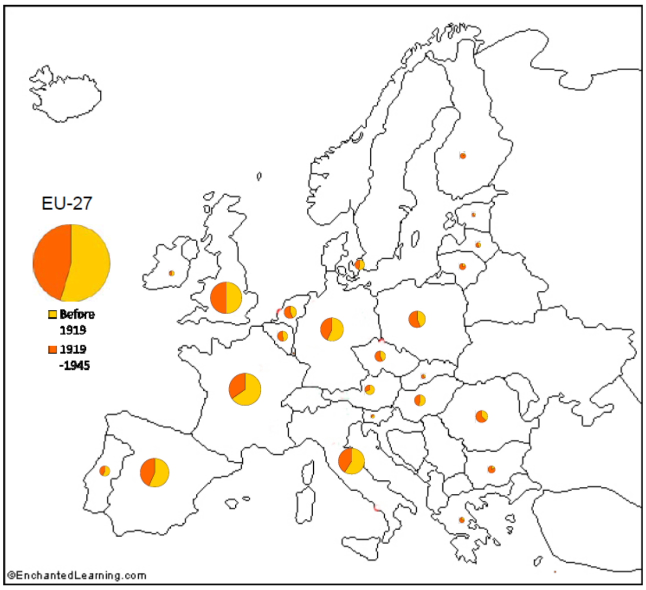
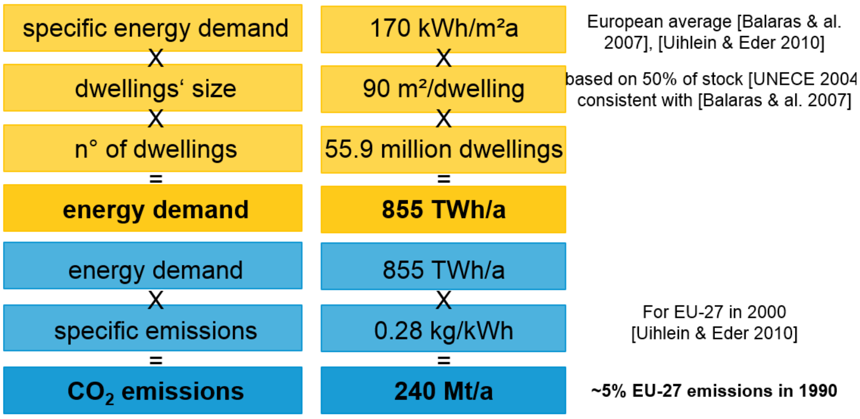


Figure 2. Dwellings built before 1919 and between 1919 and 1945 for EU-27. The area of the circle is proportional to number of dwellings

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 CO_2 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 CO_2 emissions can be decreased by 20150 by

what corresponds to 3.6 % of 1990's EU-27-emissions.

Objective

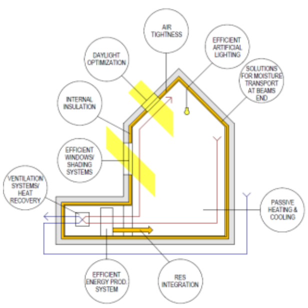
A reduction of Factor 4 to Factor 10 in energy demand is achievable, also in historic buildings, respecting their heritage value is feasible – if an multidisciplinary approach guarantees the implementation of high quality energy efficiency solutions, specifically targeted and adapted to the specific 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.

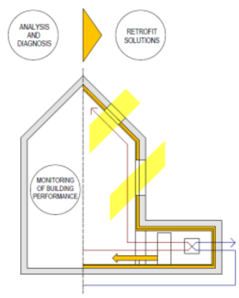
Our unique heritage and resource can be conserved if maintained as living space and as SUIT underlines "urban areas are living systems, where private action and investment are crucial". Not (or at least not only) a top down approach leads to good results, but the involvement and mobilisation of endusers 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

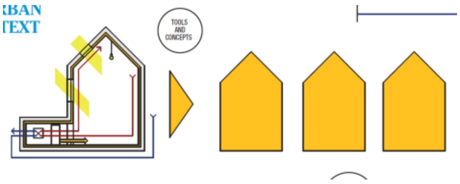
The following main objectives are addressed:



→ **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.

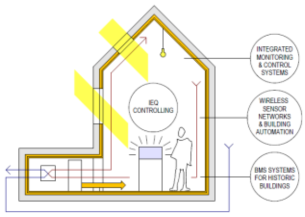


→ **Objective 2: Define diagnosis and monitoring instruments** in order to study historic buildings and find out the best technological and constructive energy retrofit solutions, to support their commissioning, assess the actual performances of buildings once retrofitted and monitor such performance.



→ **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

3encult

EFFICIENT ENERGY FOR EU CULTURAL HERITAGE

Main scientific & technological results

SEVENTH FRAMEWORK PROGRAMME

EUROPEAN COMMISSION DG research

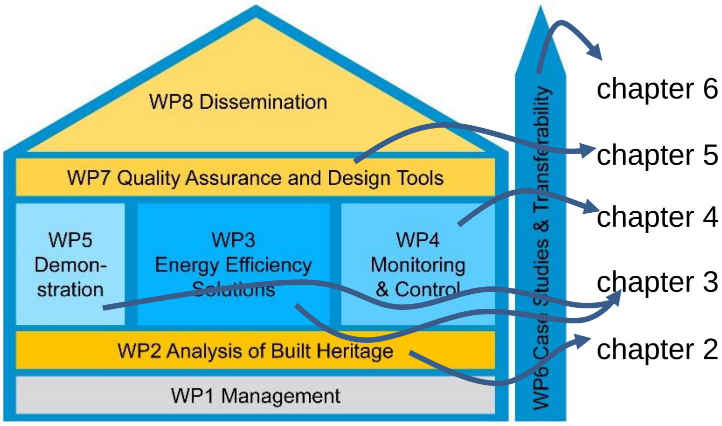
Seventh Framework Programme - Theme [EeB.ENV.2010.3.2.4-1]
Collaborative Project – GRANT AGREEMENT No. 260162

1 Introduction

The FP7 project 3ENCULT "Efficient Energy for EU Cultural Heritage" aimed 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.

Main scientific results are reported here by going work package by work package and deliverable by deliverable through the project* - providing a short descriptive text of the work and result as well as picture or graph where this is helpful.

More detailed information can be found in the single deliverables and on the project website www.3encult.eu.



*Exception: WP3 and WP5 have been combined with the demonstration of products being described together with their development.

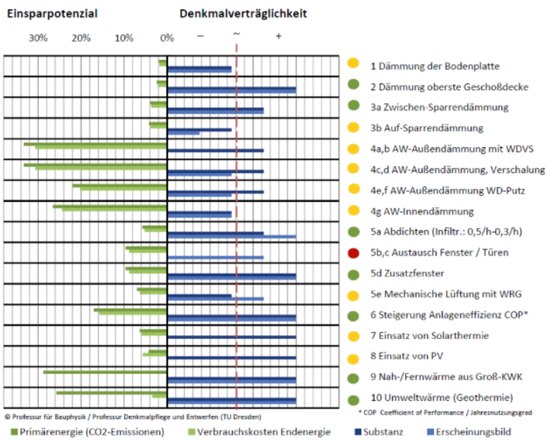
2 Analysis of Built Heritage

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 have been 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.

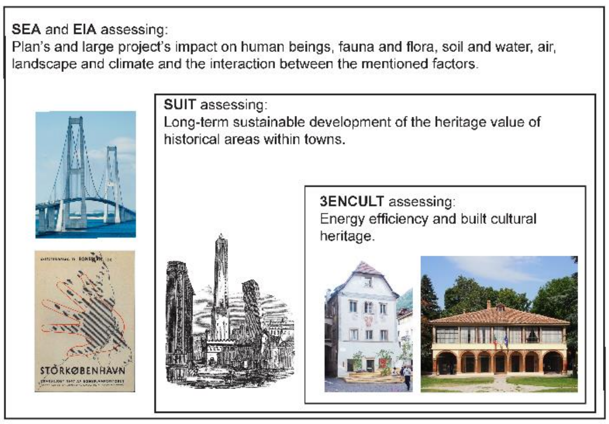


Within this the basic hypothesis is always to respect multiple aspects in parallel. Thus for the decision on the single case possibly always the work of a multidisciplinary team is needed. Several ways of decision are possible to come to best practice solutions, but the work to do so has to be managed. 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 prejustice 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

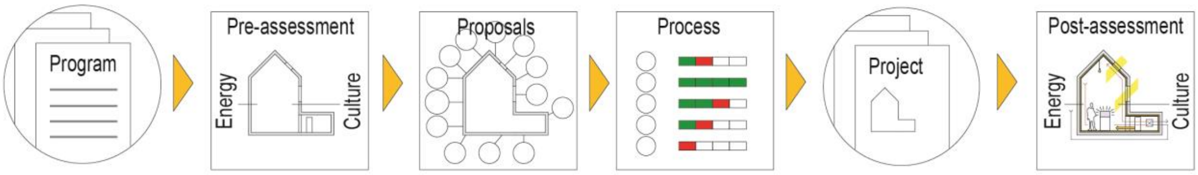
Guidelines for local governments, exploring how they can address energy efficient historic building renovation in a comprehensive, strategic, integrated and effective approach – outlining how to best utilize these buildings as vehicles for sustainable development at local community level. The Aalborg 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



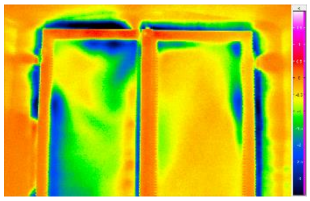
This position paper on EIA method discusses Environmental Assessments and presents the 3ENCULT methodology to ensure a process, which incorporates cultural and architectural considerations and argumentations along with technical, social, economical and functional parameters, when decisions are taken 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

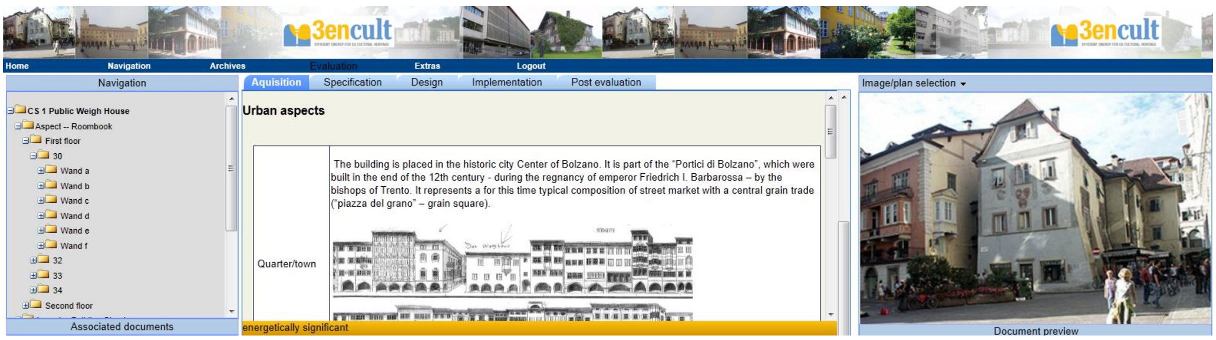
For a major part of our built heritage energy retrofit considerations are indispensable for the sustainable development. The action how and what to do when it comes to assess and preserve cultural heritage, has to be derived from a thorough documentation and an analysis of energy and heritage.



Such a comprehensive diagnosis starts from a historic investigation of the building – including understanding its original energy concept. This is complemented by a structural analysis, the investigation of any damages and potential elements at risk. Input data for the energy balance calculation is collected as well as for more detailed simulations where needed. Very important is also to understand the existing climate, how the building and objects have adapted to it, to which degree it could or should be changed.

Diagnostic interventions on cultural heritage should however be as less distructive as possible – absolute limits being given by the value of the single building. NDT (non destructive testing) plays therefore an important role – and within the project experiences on a number of techniques were collected, implemented and summarised – including determination of heat flux, IR thermography, Blower Door test, GPR radar and ultrasound testing.

The strategy proposed in 3ENCULT includes the use of a tool for integrated documentation of conservation and energy issues, based on the "Raumbuch" concept. The developed hBIS^{ec} gives a clear "plus" of information by connecting documents and pictures as well as catalogues to different building layers.



3 Energy Efficient Solutions

In general, there are two overall ways of approach to come up with energy efficient solutions for cultural heritage.

The **top-down approach** looks for solutions based the evaluation of impact analysis as well as the comprehensive diagnosis of built heritage for sustainable intervention. This approach may start from a wide scale by integration in urban sustainability concepts and strategic environmental assessment integrating the building energy issue as well as from a smaller scale (the building under investigation) assessed by inventory systems (such as “Raumbuch”), historical and structural investigations and diagnosis. The latter is in close link to building physical problems, which, in best case, could be solved collateral with the enhancement of the energy efficiency.

The **bottom-up approach** for the development of energy efficient solutions is to analyse specific case studies and its special needs. Tailor-made solutions for the individual needs of historic buildings can be developed, realised and monitored in real scale. The exemplary solutions are analysed and their transferability and more general applicability to other climates and different context of historic, architectural and conservational values is investigated in an interdisciplinary way.

The following chapters will give an overview about all of the addressed disciplines for energy efficient solutions, each of them being rather specialised on one hand, but closely interlinked on the other hand. The specific disciplines can be grouped in **five larger groups** (window, envelope, ventilation, active [including RES] and passive solutions) with numerous and intensive internal links, and several interfaces in between these groups.

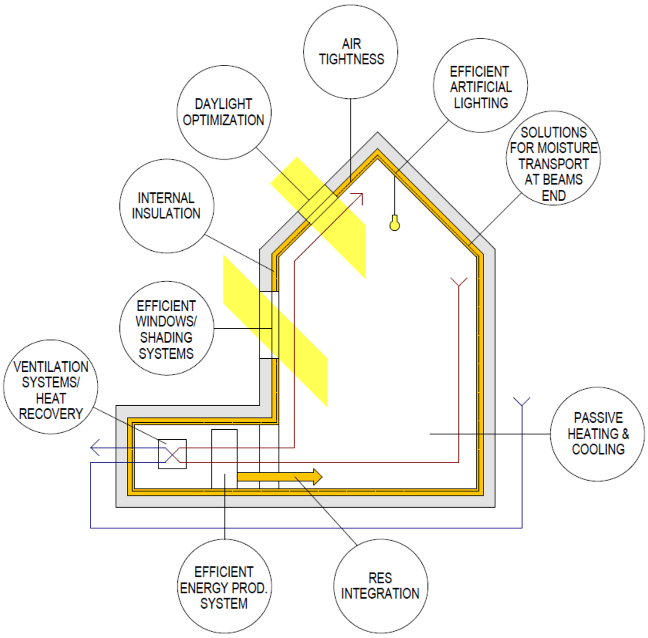
For example, the **window** is a multifunctional building component. From the original Gothic root of the word a “wind eye” (engl. “window”, danish “vindue”) is responsible for the visual reference between inside and outside as well as for the ventilation of the building. Within the 3ENCULT project, energy efficient frames (box-type as well as composite windows) and glazing in accordance with cultural heritage aspects are developed (see chapter 3.4), shading and daylight redirection elements are integrated (see chapter 0) and natural ventilation concepts are investigated (see chapter 3.10).

The enhancement of the **building envelope** of a listed building respecting the conservation issues is mainly a building physical task, the energy efficient solutions developed within 3ENCULT are described in the chapter 3.2 in terms of airtightness. A special problem in historic buildings is the moisture transport at beam ends (addressed in chapter 3.3), which is of special interest in case of application of internal insulation (chapter 0).

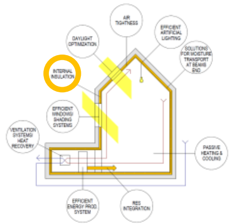
Ventilation in historic buildings has to ensure air quality and humidity control to avoid mould growth and deterioration of the building structure. There is a strong link to the windows and building envelope as well as the passive solutions (night ventilation etc.). Special solutions were developed within 3ENCULT, such as wall integration (chapter 3.6) as well as for flow balance control (chapter 3.7). From a physical point of view, this group is closely linked to the building envelope group.

The difference between **active** and **passive solutions** can be defined as follows: If significant auxiliary energy is necessary a system is called active (see chapter 3.11, and chapter 3.12 for renewable energy system integration) otherwise it is called passive (see chapter 3.10).

The following graph illustrates the variety of themes tackled:



3.1 Internal insulation



Diffusion-open, capillary-active interior insulation 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.

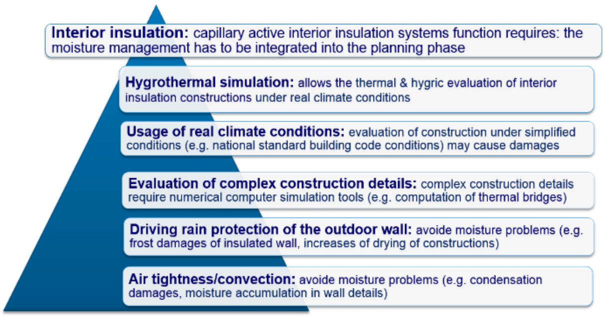
Within 3ENCULT, on the one hand, **REMMERS** together with **TU Dresden** has optimised its patented concept for **capillary active interior insulation –** based on capillary active wholes distributed over a very cost- and energy-efficient insulation:

The capillary active filling gel has been optimised: 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.

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 (CS1, IT).

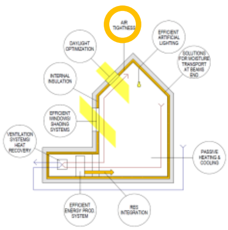
The tests with several other insulation boards based on different insulation materials showed also technical feasibility, foam glass for cases where higher fire resistance is needed siliceous aerogel allowing very reduced insulation thickness. Their economic market entry depends on cost development of the base materials.

On the other hand, based on the experiences in the case studies – both as regards the planning and design process and the monitored performance – guidelines have been elaborated for “Best Practice” design and implementation of capillary active interior insulation systems.



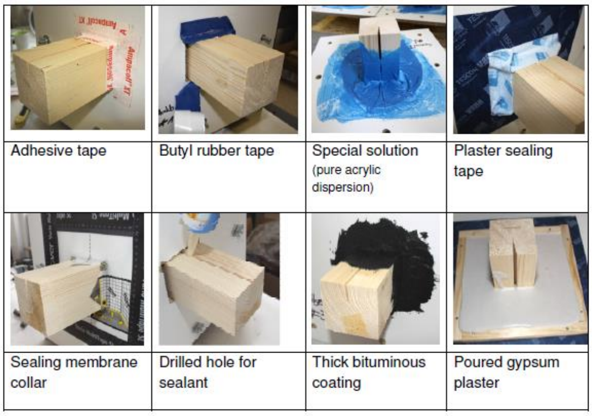
Tested interior insulation systems included: IQ-Therm and Cellulose at the Höttinger Schhol in Innsbruck (CS5, AT), Loam-cork-kieselguhr plaster at the Warehouse City Building in Potsdam, IQ-Therm at the Wilhelminian Villa in Dresedn, Calciumsilicate in the Baroque Building in Görlitz and the Perlite product Tec-Tem at the Renaissance Building in Freiberg (all four CS6, DE) and finally wood fibre panels at the Strickbau in Appenzell (CS8, CH)

3.2 Airtightness of wooden beams penetrating the interior insulation layer



Not only to avoid energy loss, but also to prevent convection of humid indoor air to the wooden beam head (in the cold area behind interior insulation) and related mould and degradation risk, it is very important to provide a durable airtight connection between the wooden beam and the insulation layer. This is not an easy task, particularly with old and cracked wooden beams.

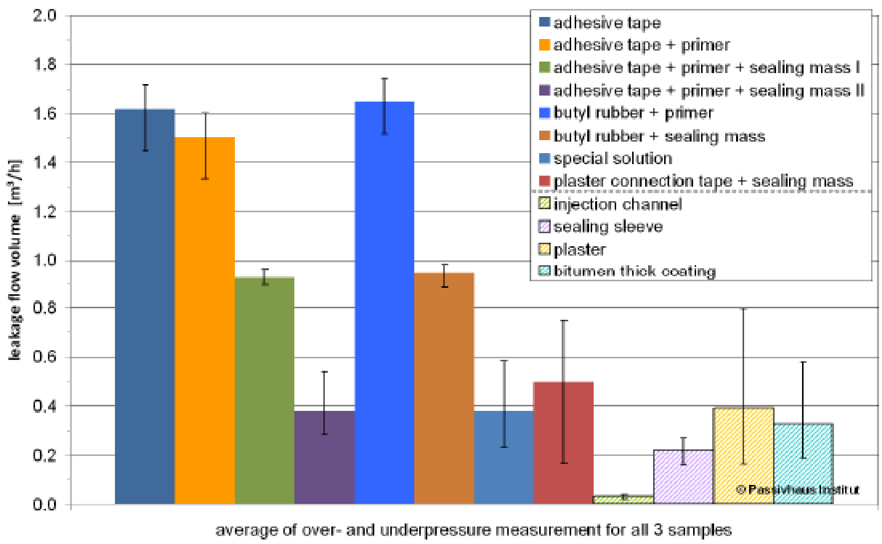
Passive House Institute has tested a number of available solutions on a sample beam (with defined gap). A total of twelve different combinations of the following product groups and methods for airtight joining of wood beams were possible from the product samples of the manufacturers and the "alternative solutions": adhesive tape, sealant/adhesive, adhesive primer, elastic butyl rubber tape, pure acrylic dispersion ("special solution"), plaster sealing tape, sealing membrane collar, thick bituminous coating, drilled hole for injecting sealant, and poured gypsum plaster.



The series of experiments carried out here provides information for successful sealing of exposed wood beams in the area of the beam head in refurbishments of existing buildings and the size of the leakage flows that would occur at a pressure difference of 50 Pa.

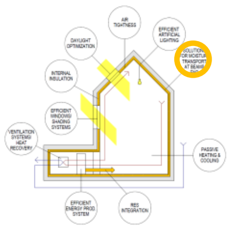
On the whole, it is apparent that the successful methods always involve sealing of the cross-section of the crack in the beam. As soon as this crack was filled in with a suitable material, the leakage volume flow could be reduced significantly compared with simple sealing using adhesive tape.

The best measured value - that is the smallest leakage flow rate - results with the solution with the drilled hole for sealant, with just 0.03 m^3/h (corresponds with a reduction by 98%). This type of sealing of cracks can be combined with all other methods. However, the beam statics must be clarified prior to using this method since it involves drilling.



Comparison of the leakage flows during the measurements, standardised for a pressure difference of 50 Pa (average value of the excess and negative pressure measurement of the three samples respectively). The thin black line depicts the measured minimum and maximum average values.

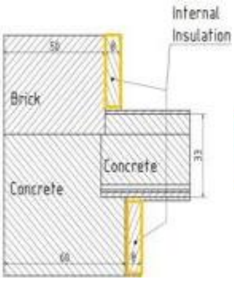
3.3 Moisture transport at beam ends

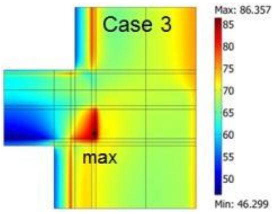


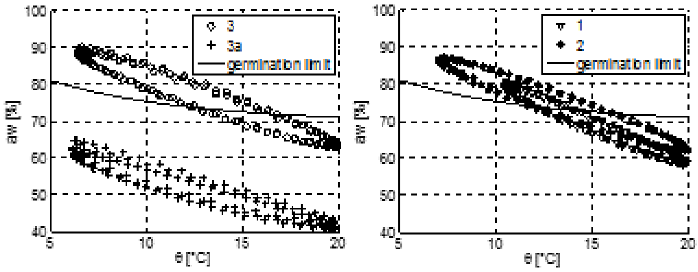
The aim of this sub-task concerns the risk assessment of moisture damages in beam ends by means of multidimensional hygrothermal modelling. In particular, different ways for coupling existing beams with internal insulation in case of refurbishment of the building have been investigated. Both the vapour diffusion process and air leakage through cracks in the masonry or through gaps present between the beam and the wall has been taken in to account. The influence of the leakage rate on the hygrothermal behaviour has been investigated under realistic boundary conditions.

In order to evaluate the hygrothermal performance of the different solutions, numerical simulation models have been developed with the simulation programs Delphin and Comsol Multiphysics. The use of both these programs has been necessary, since Delphin is validated and reliable but limited to two dimensions. In standard cases, where the moisture transfer problem can be realistically described with one or two dimensional models, hygrothermal simulations have been performed using both the programs Delphin and Comsol. The results have been compared for a cross-validation of the models. In the cases presenting pronounced three dimensional effects (e.g. in case of beam ends crossing the internal insulation) three dimensional simulations have been performed using only Comsol Multiphysics.

At CS5 becomes apparent that with installation of internal insulation the risk of corrosion at the reinforcement in the ceiling does rise: In the following figure (1) corresponds to the status quo, (2) to a reduced insulation, (3) to the envisaged 8 cm. Thus the measure has to be carefully planned and modelled to avoid subsequent damages. It was however also observed that reducing the internal relative humidity (3a), mould growth would be excluded. Considering that, the installation of a ventilation system was recommended.



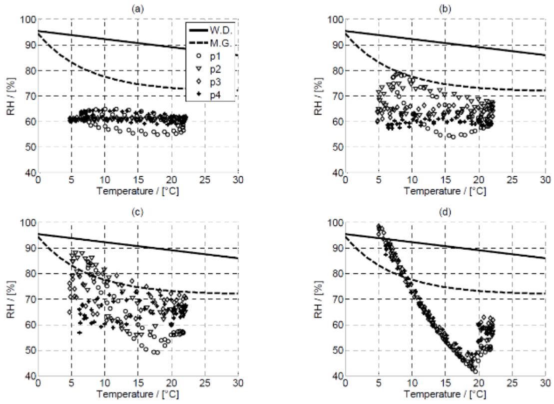




For an example based on the situation at the Public Weigh House (CS1, IT), also the influence of a convective airflow has been investigated:

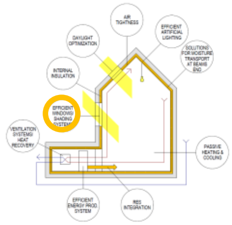
Case “a” represents a perfect air-tight construction. This ideal condition is very difficult to be realized in practice. Cases b refers to a very accurate sealed connection realized employing sealing-compound and adhesive-tape whereas case c represents a not exact execution of the sealing, with higher air leakage. Case “d” concerns sealing due to adhesive-tape only. This last solution admits relevant air leakage.

Notice that case “a” (air tight construction) and “b” (very good sealing) do not present any kind of risk. In case “c” there is no wood damage risk, but mould growth may occur. In case “d” (relevant air flow) even wood damage may occur. From these results it is evident that at least a sealing-quality corresponding to case “b” hast to be reached for a safe construction.

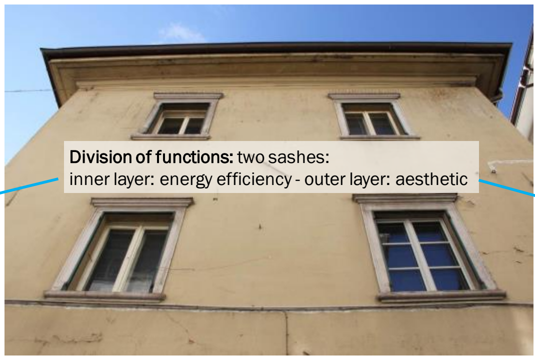


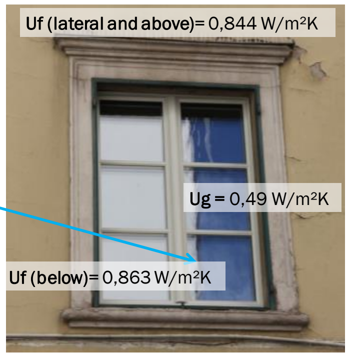
09. Risk-assessment of wood damage (W.D.) and mould germination (M.G., 16-days isopleth, dirty substrate) for increasing air velocity in the gap between beam and wall (case (a) to (d)). In the diagrams the values of moisture and temperature at different positions (p1 to p4, FIG 07) are reported. Every point represents mean values over two weeks, Source: [UIBK]

3.4 Conservation compatible and very energy efficient 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.



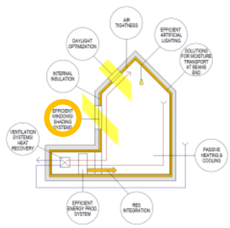


Since the concept of smartwin historic is a modular one, it can be adopted to a very wide range of various construction types and categories of historic buildings. That concept means to separate the from the outside visible layer from the thermal one. By that, the design of the old window and even the 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, in 2012. Based on the feedback from conservation and taking into account also the traces of horizontal posts detected by the building historian in the meanwhile, a 2nd and 3rd prototype were developed and installed – the box-type window version including also the concept of the so-called "goat foot" (Geißfuß)

3.5 Integration of shading system within window/glazing system

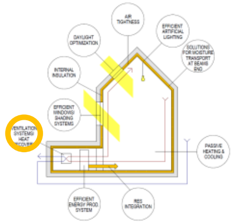
Also in historic buildings, the external remove able shading device was common practice in form of a wooden window shutter. In many cases of use of the building as office, conference room, school or university building, the comfort of those systems is too low. On the other hand, the application of external shading lamellas is not applicable in case of historic buildings. The alternative, the application of internal shading, helps to enhance the visual comfort, the protection against overheating however is insufficient, because the solar gains are absorbed mostly within the thermal envelope.



Placing the shading system in the airspace between the glazing of a box-type window or within the gas-space of a double- or triple glazing might be an option to combine historic windows and modern shading system, especially for buildings with office-use, schools and university buildings. This way, mayor architectural changes of the façade can be avoided if the width of the stack of lamellas (or the coil of a roller blind) is smaller than the facing width of the window frame. New products, such as roller blinds made of thin foils may help to find effective solutions for both, daylight use and glare protection as well as solar protection against overheating. The concave lamellas applied in CS5 (see photo) can be controlled for daylight redirection (upper part) as well as shading and glare protection (lower part)

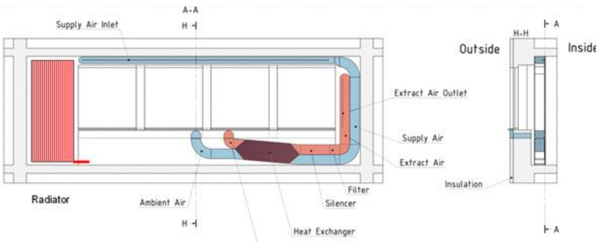
The question of integration of shading systems in the window/glazing system from conservation point of view strongly depends on the building, the window, the type and colour of the shading. In the monumental school in Innsbruck has been applied a lamellas redirecting system (mid pane) which fits very 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.



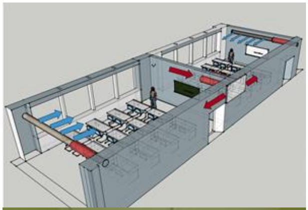
3.6 Space saving ventilation

In general, two different solutions especially adapted for the use in listed buildings were found under guidance of **University Innsbruck** 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.

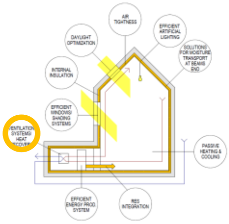


→ **Active overflow principle**.

The active overflow principle, developed and tested for application in residential buildings by the building department in Zürich/Switzerland was within 3ENCULT transferred to the application in school buildings, where the higher flow rate asks for a modified solution.

A 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 prototype installed in the Höttinger School in Innsbruck (CS5, AT) has been implemented by project partner **ATREA**, who is also offering the system on the market now.

3.7 Automatic Air-flow volume balancing

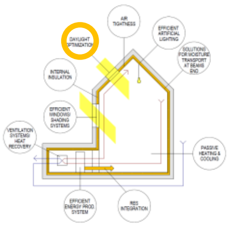


A difference between the outdoor air and exhaust air flow volumes of HRV systems, results in high or low air pressure in the building. This leads to an increased air exchange by forced infiltration through leaks in the building envelope and thus higher heat losses and a correspondingly higher heating demand. It can avoided with automatic air-flow volume balancing systems – which at the same time reduces the effort for putting the ventilation device into operation and maintenance (readjustment otherwise at least every 5 years).

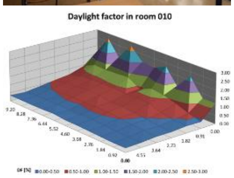
Passive House Institute has investigated different solutions, ranging from : (i) constant flow fans (built-in solution of ventilation devices), over (ii) air flow balancing according to the pressure difference in the fan inlet (built-in solution of ventilation devices), (iii) enthalpy difference at the heat exchanger (built-in solution of ventilation devices), (iv) temperature differences at heat exchanger (built-in solution of ventilation devices), to (v) dynamic pressure measuring system (external system for installation in ducts). Apart providing guidelines on pros and cons for different size of systems, they have analysed the economic advantage.

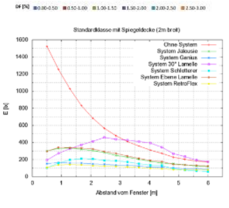
In in refurbishment of building with cultural heritage there is one more advantage: It helps prevent structural damages. In historic buildings, even in a carefully planned energetic refurbishment, the air tightness of the building envelope after the refurbishment is usually still poor compared to new 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 (i.e. overpressure in the building), which would lead to infiltration of warm and humid indoor air into the construction and causing condensate in the buildings envelope.

3.8 Daylighting



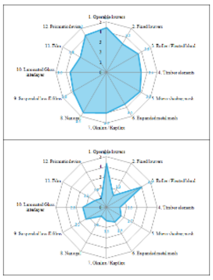
The diversity in daylight exploitation potential is vast in the historic building stock in Europe. On the one hand, buildings with thick mediaeval walls and very small windows represent the lowest potential of exploitation. The opposite extreme is the glass & metal architecture in some regions of Europe. In summary there are listed buildings with a severe lack of daylight while others suffer from overheating in summer and accelerated surface deterioration caused by the immense daylight/solar energy supply.





Within 3ENCULT on the one hand, a number of daylight redirecting solutions have been evaluated with regard to (i) solar shading, (ii) thermal comfort, (iii) visual comfort, (iv) view to the exterior, (v) radiative damage protection and (vi) integration on the basis of a specific study done for the Höttinger School in Innsbruck (CS5, AT): Status was that the classrooms were badly illuminated by daylight, the only existing daylighting system being a textile screen. Therefore every single room was characterized by its utilization and the table of illumination requirements was created in relation with the user's needs. The standard classroom was simulated with the considered daylighting systems both with and without mirror ceiling. 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.

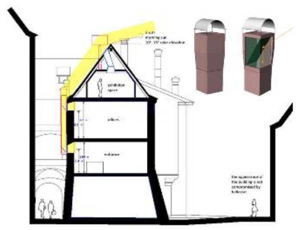
Furthermore a variety of shading systems ranging from integrated slats (operable louvers, fixed louvers, roller blinds, timber elements) over wire metal mesh (micro shading mesh but also expanded metal mesh) and diffusing systems (Okalux, Kapilux, Nanogel), suspended low-E-films and laminated glass interlayers to light redirecting devices (films and prismatic devices) have been assessed with regard to the following indicator categories: building physics, building user requirements, operational management and maintenance, commercial/costs as well as design & conservation.



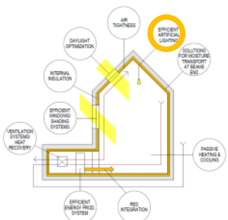
Finally a number of dedicated daylight solutions were developed for CS1 in Bozen

Shutters are typical shading devices for many European regions. They were originally used for solar control and safety reasons. One draft idea shows how some of the slats could be transformed into daylight redirecting devices. In case of required minimum g-values, all slats will be rotated to completely close the face, but if energetically allowed some daylight slats could redirect daylight into the room.

Tthe mostly invisible roof was identified for its daylighting potential. The ancient chimneys have been drafted to become tubular daylighting devices which are fed by heliostats with sunlight. The heliostats would be located on the roof of the building to redirect light to the chimneys of the west façade and the system would not be visible from the pedestrian level, not compromising the historical image of the Waaghaus. The chimneys would be enlarged on the site lighted from the heliostat to catch sunlight. The intervention on the ancient chimneys would however be minimal and not visible for the observer. A light tunnel would bring light to the first and second floor of the building, where low illumination levels are mainly due to the obstruction by the facing building and to the small width of the old street.



3.9 Artificial lighting



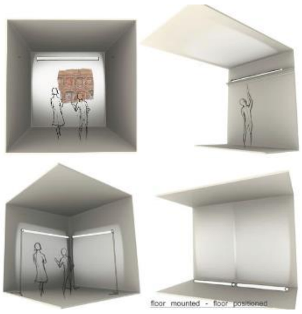
Besides requirements defined by needs of human beings also materials respectively surfaces (e.g. pigments in frescoes) are limiting the lighting solution (both day lighting and artificial lighting), because physical and chemical reactions may be triggered by radiation. These reactions cause deterioration of materials.

Sala degli Stemmi in Palazzo d'Accursio in Bologna (CS2, IT) 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 light installation is absolutely none glare-free. The resulting luminance distribution is far beyond the well-established and recommended ratios and energy consumption however high – task for 3ENCULT to develop a solution – on the basis of the specific case, but replicable beyond.

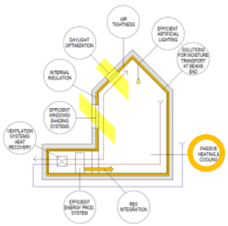
The wallwasher developed in 3ENCULT by Bartenbach (produced by licensee Projektleuchten) is

- very energy efficient – using LED as light source
- not emitting in damaging but not visible spectral ranges
- glare free thanks to the sharp cut-off angle

- homogeneously illuminating surfaces, thanks to specifically developed reflectors illuminating exactly a rectangle of the wall
- easy to be installed in non-invasive way – the luminaire can be mounted on a bearing rope structure (only a few screws are needed), hidden on top of existing cornices or be as a stand-alone luminaire completely reversible
- adjustable in colour temperature from 2600 to 6500 K

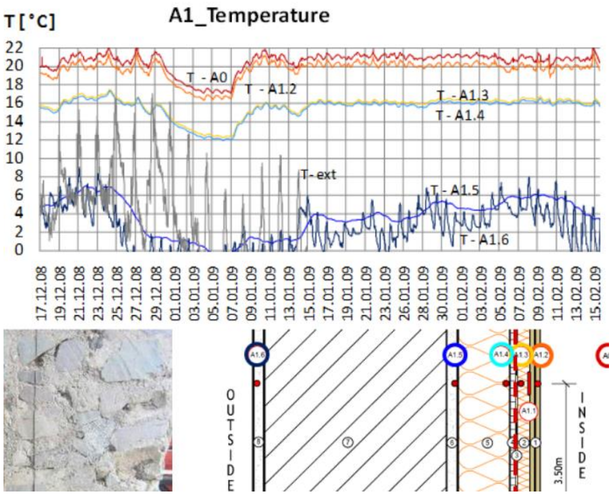


3.10 Passive heating and cooling



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 a methodological approach to find the most efficient solutions for the comfort conditions, the energy efficiency and the costs saving was developed, exploiting the big potential of thermal mass combined with a smart ventilation system.

The different parameter combinations have been tested with the simulation software EnergyPlus. The genetic algorithm NSGA II combined all the different parameters and defined the best Pareto optimal solutions for each climate condition. Actually, 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.



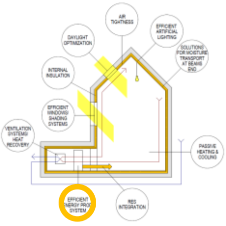
Some snapshots of the results:

The figure on the left shows, how little the massive stone wall contributes to limit the heat flow: While the major temperature drop occurs along the insulation layer between the new interior surface (orange) and the "old" interior stone wall surface (blue), the latter is just slightly higher than the temperature of the outside surface (dark blue)– it mainly oscillates less

However, in Bolzano cooling demand rises with more insulation, since the low night temperature would allow for some heat rejection through wall during night. Nevertheless, the absolute savings in cooling energy without insulation are small compared to the additional heat losses in winter without insulation – the all year optimisation is still clearly in favour of insulation!

In Bologna does the insulation put for winter enhancement not influence the summer behaviour: the outdoor temperatures in summer are that high that heat transfer through the opaque wall is minimal. Passive cooling strategies have to rely on gain minimisation – i.e. shading to reduce solar gains and efficient equipment to minimise interior gains – and ventilation strategies.

3.11 Active energy efficiency solutions



Several active system were investigated and classified in terms of costs and potential energy efficiency improvements by project partner ARUP.

For each analysed solution also the restraints and recommendations that need to be considered for an intervention in an historic building are described.

Although the proposed solution can generally be adopted for existing building it is necessary to study each application case by case. In historical buildings where no heating or cooling system is not existing it is necessary to find a balance between the conservation issues and the required internal comfort. If for the generation system it is usually only necessary to provide adequate spaces, for the distribution and emission system it is also necessary to consider their impact on the existing structure (e.g. risers, false ceiling, floating floor etc.).

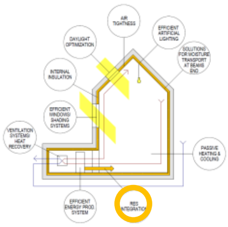
GENERATION SYSTEM: HEAT PUMPS (water condensed)

Brief Description
Heat pumps are hydraulic mechanical system that are used to produce hot water through an inversion of the chilled circuit. Water condensed heat pumps are compression chillers driven by electrical energy where the refrigerant is condensed thanks to circulating water. In this case the circuit can be open and the water source can be ground, lake or sea water (see Ground Heat Pump – Open Loop for further details). Otherwise if the circuit is closed with a closed loop, a ground source can be used again (see Ground Heat Pump – Closed Loop for further details) or it is also possible to use a "more conventional" evaporative tower

Use in Historic Building	
Material: building's material is not affected. **Aesthetic:** HPs are usually placed outside. They require fans that could be noisy. Moreover, depending on the power needed, their dimension can be relevant.	**Cost** €€€€
Reversibility: they are easily removable and replaced. **Visibility:** they are usually placed on the roof.	**Energy Efficiency Improvement** ●●●●○

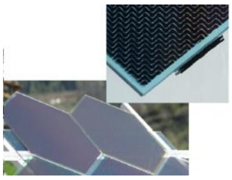
Recommendations
It is necessary to provide space (external) for the cooling tower. Possible disturbing noise from external unit. Higher efficiency is achievable with low temperature emission systems

3.12 RES integration



Analogously to the active energy efficiency solutions, also for the **variety of Renewable Energy sources**, a short description as well as evaluation of cost and energy saving potential were provided by project partner CARTIF. Most importantly also here, typical restraints from conservation point of view are described.

Furthermore project partner Grupo Unisolar specifically developed at **solar energy solutions**:



→ felixible ratios, patterns and colours for semitransparent PV panels: On a-Si PV material, 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.

→ 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.

→ 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.

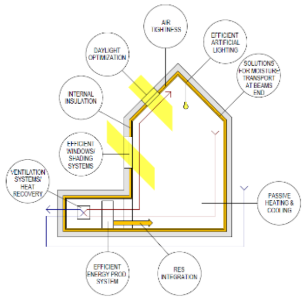
→ semitransparent solar thermal panel: Both sides of the collector are covered by a Transparent Insulating Material (TIM) patented by G1S, enabling at the same time thermal insulation and transparent properties.

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.

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.

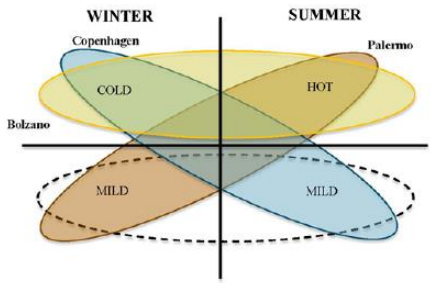
3.13 Virtual library

Numerous papers, reports, design details, sketches and drawings have been produced in the above descried research and development tasks. The 3ENCULT virtual library is intended to make them available online to stakeholders operating in the field of historic buildings refurbishment and conservation.



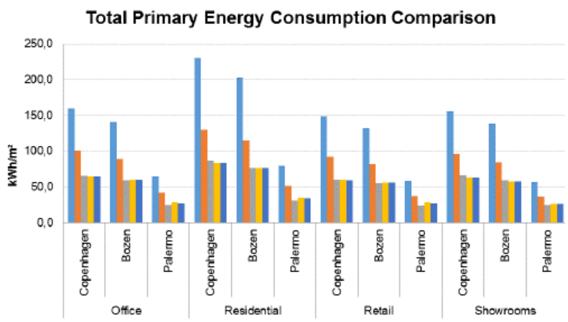
In order to optimise impact, the virtual library is based on the well known BUILD UP portal, collecting Europe wide resources on energy efficiency. Technically speaking, the single documents will be uploaded on the BuildUp community on cultural heritage and tagged with specific keywords. They are also 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

3.14 Integrated solutions



Which combination of active and passive solutions is optimal for a specific building, depends also on the climate and the kind of use. To show this, to generalise the experience at the case studies and at the same time apply also the newly developed solutions and approaches, the following exercise was done:

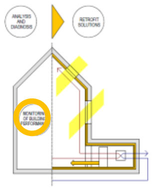
First of all with Copenhagen, Bolzano and Palermo to representative cities in complementary **climate zones** have been identified. The Public Weigh House in Bolzano (CS1, IT) was taken as example for a typical historic building, and its energy performance for the most common **kinds of use** (ranging from office over residential and retails to showrooms) and a standard heating & cooling system was simulated in all these climate zones to determine the **baseline**.



The most suitable HVAC system has been defined for the considered building types in each climate zone, with analyses carried out with Energyplus. Afterwards passive and active strategies have been combined and optimized. Using again energyplus the energy consumption has been assessed, and results compared each other and with the baseline building. Passive energy efficiency solutions covered (a) infiltration reduction and windows replacement, (b) insulation of roof and external slabs, and combination of all.

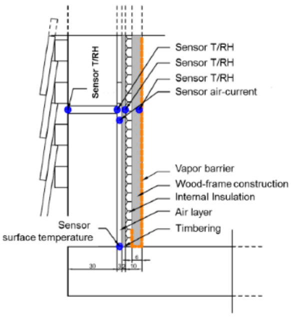
Finally all the comparisons between each step have been analysed in order to understand the importance of each strategies on the total energy saving and the maximum energy reduction for each climate zone and building type.

4 Monitoring and Control



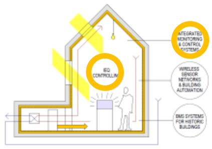
4.1 Recommendations on variables & sensors

This guidelines includes a short introduction on the basis of monitoring – with focus on issues to be considered, when both energy, comfort and heritage related aspects are the target of the monitoring campaign. Description of variety of sensors and meters that are commercially available is presented as well as an overview over the available sensors from the wireless network in development stage. To complete recommendations an overview regarding the sensors / actuators, which could be used in an automation system was added.

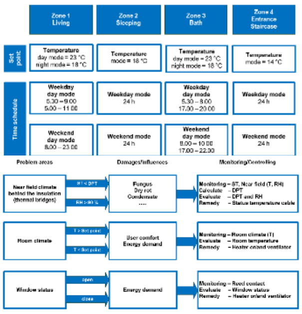


Proposed sensors network allow to collect data of all the relevant parameters and metrics for characterizing the energy behaviour of the building, the climate situation and comfort in the rooms, the climate-related stress on valuable surfaces, moisture and heat situation in the energy upgraded building construction and energy consumption.

4.2 Monitoring and automation concept

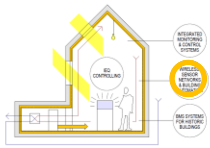


First of all in the document, the general parameters affecting the indoor climate and possible mechanism of damage and damage patterns were analysed, including recommendations for the planning and operation of heating and ventilation systems in historic buildings with large volume spaces. Based on this analysis, the approach on how to develop a suitable monitoring and automation concept is described and applied on the 3ENCULT case studies.



The 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.

4.3 Wireless sensor network

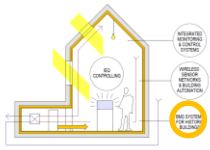


A Wireless Sensor Network (WSN) can be a key tool to design and implement a cultural heritage building refurbishment. In fact the easy installation and pervasive deployment of a WSN, permit an extensive building analysis before the intervention. Moreover the reduced impact in term of cost, cable expense, installation masonry and maintenance, underline the capability of the WSN to realize a smart building control system with minimum invasive building renovation.

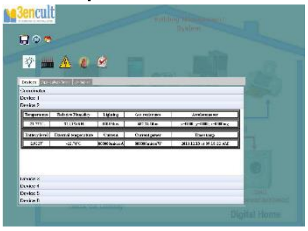
Systems already on the market have proved the reliability of the WSN for building management. However they are not able to interoperate with pre-existing sub-system and they cannot used for extended WSN with only battery supply to operate for years.

The WSN developed in 3ENCULT is designed for cultural heritage buildings and has the following characteristics: (i) physical microsystem node size of few cubic centimetres, 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



The Building Management System 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 are presented in the deliverable, with special focus on strengthening the usability and bring the information to the user in an easy and efficient way.



Building Management System was developed according the constraints presented by heritage buildings and according to the ZigBee sensor network developed in the project.

4.5 Guidelines for the implementation of monitoring system

The guidelines present the requirements of a monitoring system and explain 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 several new features were developed for PHPP:

Firstly, designers can now also verify the energy demand in modernised historic buildings or other refurbishment projects. In a dropdown menu in the Verification worksheet the "old" option "Passive House" or new option "EnerPHit" (Energy retrofit with Passive House components) can now be chosen – and the energy performance of the building in question is subsequently rated according to the corresponding certification criteria.

While new Passive House are usually developed in one consistent, planning design, in refurbishments of historic buildings there are at least two versions to be considered: the states before and after refurbishment. Moreover, frequently refurbishments are not carried out as a complete renovation at one point of time, but step by step. Therefore, as a second new feature, the “Variants” worksheet has been created, which allows for the representation of different refurbishment stages or also of different variants of the same stage

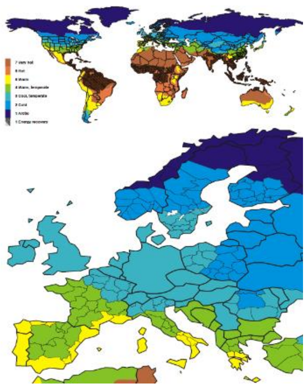
Finally, in the new ‘Comparison’ worksheet it is possible to calculate the economics of energy retrofit measures for insulation of the opaque building shell and thermal bridge reduction as well as for new windows. The results include the calculated yearly net profit generated by the measure as well as the cost for 1 saved kWh of energy. The maximum investment sum, at which the energy saving measure will still be profitable, is also given..

5.2 Hygrothermal dynamic simulation guidance

Hygrothermal simulation can both help to optimize construction details and building materials and support the planning of renovation measures. It is particularly important for verification ofdamage-free application of interior insulation in the specific building under the real climate conditions.

The aim of hygrothermal dynamic simulation guidance is therefore to facilitate the application of such simulation tools for planners. 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, and protection against moisture damage, indoor climate and reduction of CO_2 emissions.

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 will 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.

5.4 Proposal for the integration of historic buildings in the EPBD and related CEN standards

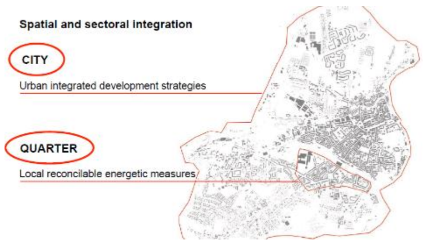
3ENCULT looked at the integration of historic buildings in the EPBD and related CEN standards in two steps: First the status was analysed, pointing out, how and where the recast Energy Performance of Buildings Directive (EPBD) concerns old and historic buildings. The link between the EBPB and the EPBD CEN Standards has also been discussed and the relation between the EPBD CEN Standards and historic buildings. Secondly, specific recommendations were given (i) with regard to EPBD, recommending regular inspection of HVAC systems and energy certificate also for historic buildings and proposing a requirement for obligatory analysis of energy saving potential and options in historic buildings by an expert with advice or review of conservation expert and (ii) with regard to CEN EPBD working groups, pointing out items, that need specific attention related to the energy demand calculation and assessment, including typical construction differences, non-standard use and functionality, lack of information on current performance, ways of expressing energy performance of a building for historic buildings, indoor comfort conditions and dynamic behavior of historic buildings and natural ventilation.

5.5 Standardisation project in CEN TC 346 Cultural Heritage

Besides the above described recommendations to directly EPBD related CEN standardisation groups, 3ENCULT contributed also to the development of a standard on “” within CEN TC 346 “Cultural Heritage”. Project coordinator Alexandra Troi, was part of the editorial group, contributed on 3ENCULT results and discussions to WG8 and vice versa could also feedback concerns and issues discussed in the standardisation group to the consortium. With 3ENCULT closure a draft version status is reached, based on which the work item will officially be activated and is near to public inquiry.

5.6 Low emission concepts on urban and district level

Goal of this tasks was to provide an additional perspective on the energy efficiency of the built cultural heritage from an urban point of view. From such a broader perspective planning instruments for an energy-efficient urban restructuring were be derived, which not only provide the basis for solutions that can verifiably increase the energy efficiency of an urban quarter, but do also help to facilitate a responsible treatment of the built cultural heritage values.

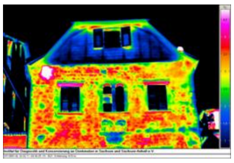


From urban planning point of view, uncoordinated measures of energy efficient retrofit in the building stock are difficult to predict in their cumulative effect and synergies cannot be utilized. In the interest of the cultural heritage, piecemeal measures on individual buildings in the historical city quarters should be avoided. This is especially true if the built urban heritage is in danger of being significantly changed.

In Germany Integrated Urban Development Concepts as called for by the Leipzig Charter are required when applying for urban restructuring grants. These concepts are methodically underpinned here, with the energy goals of a municipality serving as the basis for the strategic planning. The Integrated Urban Development Concepts allow for an integration of communal planning by using citywide strategic goals.

6 Case studies

6.1 CS1 Public Weigh House, Bozen/Bolzano (Italy)



During the project 3encult the building was completely empty, which gave the opportunity to examine the as-is-state of the building very detailed. Several different diagnosis technologies and the acquisition of indoor and outdoor climate provided also the relevant parameters for energy and comfort simulation. 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. Since in this specific case the major part of the existing windows were not of historic value (exchanged during the $50^{th}/60^{th}$ of the last century), the project developed 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, demonstrating its reversibility.

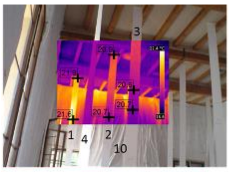
6.2 CS2 Palazzo d'Accursio /Municipal Palace Bologna (Italy)

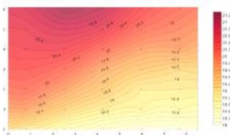
For the purposes of the project, a particular area of the palace has been selected: the Municipal Arts Collections museum, with paintings and furniture related to different ages and an off. This area had problems related to the maintenance of movable goods, with critical issues related to the hygrometric control and mixed construction characteristics.

By non-invasive and completely reversible diagnostic (a.o. GPR radar test, infrared thermography, blower door test, U-value measurement) and monitoring analysis including, the knowledge of the building and it thermal behaviour could considerably be increased, leading also to energy models both in PHPP and energy plus.

The developed renovations concept allowed the reopening of the prestigious Sala Urbana within the Municipal Arts Collection Museum, and included: thermal insulation of the building envelope; installation of high performance windows; installation of an energy saving lighting system; and installation of wireless sensors to monitor the internal climate.

6.3 CS3 Palazzina della Viola, Bologna (Italy)



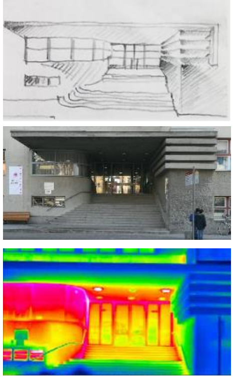


The main focus of the work for case study of Palazzina della Viola was the extensive and integrated diagnostic approach developed to obtain information about the structural and energetic health state of this 15^{th} century building before, during and after the refurbishment works. Several non-destructive diagnostic techniques have been applied in an innovative and non-conventional way, following specific and on-purpose designed procedures. They have been combined with the wireless monitoring system - used also in un-conventional ways. 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, Copenhagen (Denmark)

At this case study, the refurbishment was in its final stage of implementation when 3ENCULT started. 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)



The Höttinger school in Innsbruck from 1930, designed by Baumann and Prachensky, is an outstanding example of Early Modernism in Tyrol. Within 3ENCULT, two test classrooms were refurbished: 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. Ventilation issues were solved with minimum impact applying active overflow ventilation, the draft free ventilation air distribution being guaranteed by 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.

6.6 CS6 Focus “Interior Insulation” (Germany)

	Potsdam	Dresden	Freiberg	Görlitz
Name	loam cork	IQ-Therm	Tec-Tem	Calciumsilicate
Appearance				
insulation effect	λ= 0.08 W/mK	λ = 0.031 W/mK	λ = 0.045 W/mK	λ = 0.065 W/mK
material and form	frame, plaster	board, plaster	board, plaster	board, plaster
capillary active	++	+	+	++
moisture regulation	++	+	+	++
natural material	++	- -	+ / -	+ / -
fire protection	-	-	++	++
soundproofing	++	-	+	+
sustainable	++	-	+	+
workmanship	-	++	+	+
costs	100 €/m²	45 €/m²	45 €/m²	75 €/m²

Case study 6 consists of four different kinds of historic building structures and epochs as well as architecture styles, where four innovative market-available interior insulation systems were analysed: neo-classical Warehouse City of Potsdam from 1834 with loam-cork insulation, a 1890th Wilhelminian Villa in Dresden with IQ-Therm, a Baroque Building in Görlitz from 1714 with TecTem perlite board and a Renaissance Building in Freiberg from 1518 with Calciumslicate.

From the analysis of monitoring data as well as experience in design and implementation, guidelines were elaborated as well as a table comparing the four system with regard to different criteria, including not only thermal performance but also capillary activity, moisture regulation potential, fire protection, sustainability, workmanship effort and cost.

6.7 CS7 Industrial Engineering School, Béjar/Salamanca (Spain)

The Industrial Engineering School was built between 1968 and 1972, following the design project of the architect Manual Blanc Díaz. The formal definition of the building, characteristic of the Modern Movement, supposed a rupture with traditional architecture of the region in that period. However, with the big lattice it reinterprets the façades of the traditional houses of Béjar, made with roof tiling for protecting the most exposed façades to strong winds and rain.

The main problems were overheating in summer, discomfort owing to the usage of only two boilers for the whole building and daylight underused and air-tightness. Thus, after the diagnosis, through energy performance calculation and lighting simulations, blower door test and monitoring, the interventions were focused on improving the behaviour of the HVAC systems and favouring the daylight with advanced control algorithms.

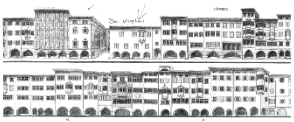
6.8 CS8 “Strickbau”/Appenzell, Switzerland

The aim of the investigations of this sample construction was 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.

After the last tenant left, in the summer of 2011 the first investigation started. Since the log house is would anyway be deconstructed at the end of the two-year study period, it was a unique opportunity to 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, going also towards “limit” situations.

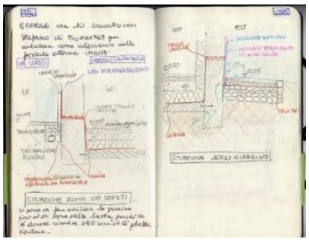
6.9 Transfer of experience

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 the medieval building type in the historic city center of Bolzano (Italy), the “Portici”:

Based on the documentation of the special typology of building, which is characteristic for the original nucleus of the city of Bolzano, carried out by a group of students from the University of Dresden as well as questionnaires and project plans data on the existing building, the building envelope, the building use and the building energy consumption collected for several selected buildings of the Via Portici, a team from EURAC has analyzed the energy potential and the intervention needs of this building typology and assessed the possible implementation of refurbishment solutions exemplary for one “Portici” building.



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 this 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 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.

6.10 Energy efficiency evaluation of case studies

The deliverable shows the results of PHPP-calculations of the heating energy demand of the 3encult case studies put into relation with corresponding monitoring data. As far as available, the calculated and measured energy balance was evaluated and compared, in order to validate the calculation models. In case of obvious discrepancies, the reasons were investigated.

In case the refurbishment works were just partly finished or the monitoring system couldn´t distinguish the consumption in the renovated part of the building from the energy use of the rest of the building, the individual approach and study of all the circumstances made possible to obtain enough information to evaluate the provisional status. In such a case, it was not possible to set up a full energy balance of the building, but at least the available aspects were considered to determine the effect of energy efficiency measures.

CS	CS picture	BEFORE INTERVENTIONS		AFTER INTERVENTIONS		Energy reduction	Match of datas	Kind of used energy
		PHPP	Measured	PHPP	Measured	PHPP	PHPP/Measured	
1) Waaghaus, Bozen (Italy)		17,7	not in use	18,5	in renovation	-	-	Electricity [kWh/(m² a)]
		251,6	not in use	125,7	in renovation	-	-	Gas & Wood [kWh/(m² a)]
		269,3	not in use	144,1	in renovation	-	-	Total [kWh/(m² a)]
2) Palazzo D'Accursio, Bologna (Italy)		52,1	51,0	50,7	in renovation	2,6%	102,0%	Electricity [kWh/(m² a)]
		300,3	123,9	281,6	in renovation	6,2%	242,4%	Gas [kWh/(m² a)]
		352,4	174,9	332,3	in renovation	5,7%	201,4%	Total [kWh/(m² a)]
3) Palazzina della Viola, Bologna (Italy)		0,9	not in use	255,4	no data			Electricity [kWh/(m² a)]
		314,6	not in use	0,0	no data			Gas [kWh/(m² a)]
		315,5	not in use	255,4	no data			Total [kWh/(m² a)]
4) Fæstningens Materialegård, Copenhagen (Denmark)		30,1	62,0	33,1	-	-10,0%	48,5%	Electricity [kWh/(m² a)]
		154,9	83,6	133,2	133,4	14,1%	142,5%	Heat [kWh/(m² a)]
		185,0	145,6	166,3	-	10,1%	127,0%	Total [kWh/(m² a)]
5) Hottinger school, Innsbruck (Austria)		14,9	15,1	16,1	in renovation	-8,1%	98,7%	Electricity [kWh/(m² a)]
		127,5	124,4	39,8	in renovation	68,8%	102,5%	Gas [kWh/(m² a)]
		142,4	139,5	55,9	in renovation	60,7%	102,1%	Total [kWh/(m² a)]
6.3) Baroque build., Görlitz (Germany)		26,8	not in use	22,2	-	17,1%	-	Electricity [kWh/(m² a)]
		414,6	not in use	43,0	18,5	89,6%	232,5%	Gas [kWh/(m² a)]
		441,3	not in use	-	-	-	-	Total [kWh/(m² a)]
6.4) Renaissance build., Freiberg (Germany)		-	not in use	-	-	-	-	Electricity [kWh/m2]
		502,6	not in use	20,6	17,5	95,9%	117,5%	Heating [kWh/(m² a)]
		502,6	not in use	20,6	-	95,9%	-	Total [kWh/(m² a)]
7) University Building, Salamanca (Spain)		20,9	21,9	18,5	-	11,3%	95,4%	Lighting [kWh/(m² a)]
		51,0	-	51,0	-	-	-	Gas [kWh/(m² a)]
		-	-	-	-	-	-	-
8) Appenzell (Switzerland)		284,0	not in use	130,0	100,0	54,2%	130,0%	El. - heating [kWh/(m² a)]
		-	-	-	-	-	-	-
		-	-	-	-	-	-	-

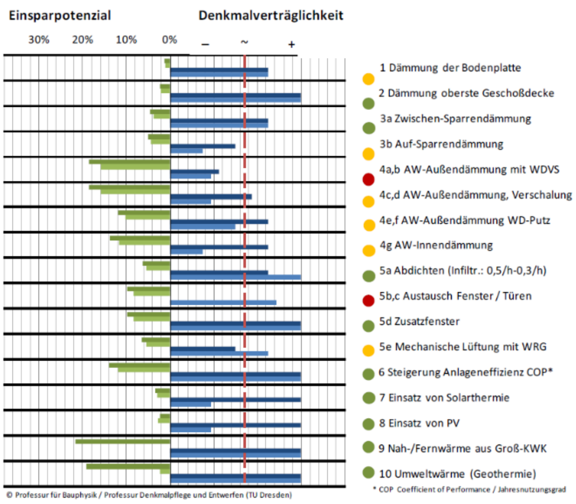
The main message of this delivery is to evaluate critically the ability of prediction of energy savings for the special field of refurbishment of historic buildings and to learn from comparison of the expected and fulfilled energy-savings.

It is possible to point out that PHPP is a suitable calculation tool even for the refurbishment planning of historic buildings, if the input values are based on conditions that correspond to the energy measurements. Several case studies support the message of the 3encult project, that even in historical buildings the reduction of energy demand by “Factor 4+” is possible.

6.11 Conservation compatibility evaluation of case studies

To reinsure the conservation compatibility of the developed products and methods within 3ENCULT, in deliverable D7.6 the conservatory view point for each single case study of is presented. State and form of information for the single study cases are diverse, as also the multidisciplinary dialog achieved different intensity.

Concluding it can be said, that the successful dialogue for sustainable energy intervention actions is based on teams where stakeholder, user, planner and the conservation and energy experts are involved.



3encult
EFFICIENT ENERGY FOR EU CULTURAL HERITAGE

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 CO_2 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.

SEVENTH FRAMEWORK PROGRAMME

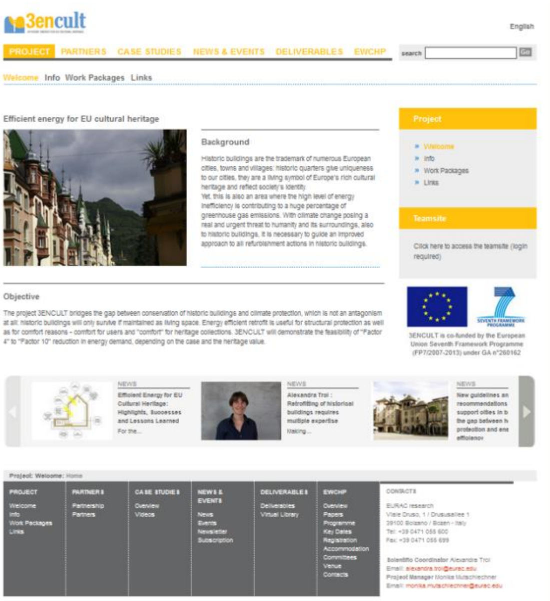
EUROPEAN COMMISSION DG research

Seventh Framework Programme - Theme [EeB.ENV.2010.3.2.4-1]
Collaborative Project – GRANT AGREEMENT No. 260162

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

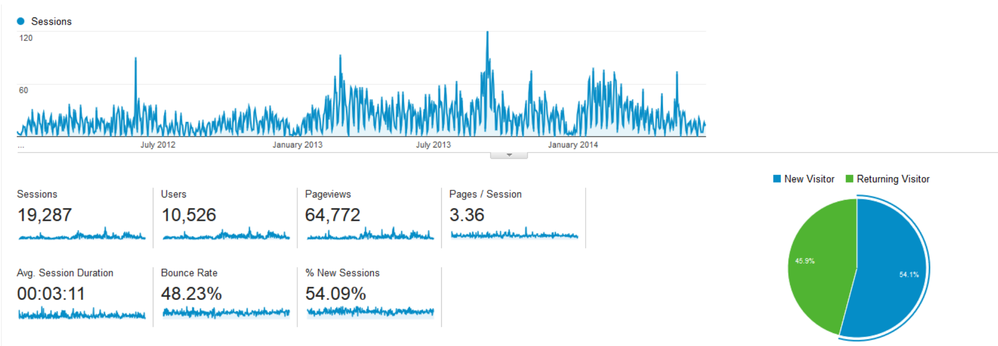


1.1.1 Website

The 3ENCULT website www.3encult.eu 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.

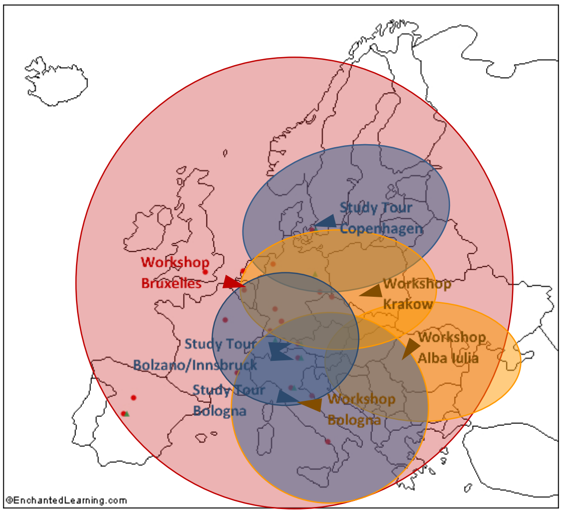
Both VNR thanks to the major experience and suitable effort of project partner youris have been taken up by more than 15 TV stations – including euronews which itself already broadcasts in 13 languages and has an overall audience of several tens of millions people per day

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.).

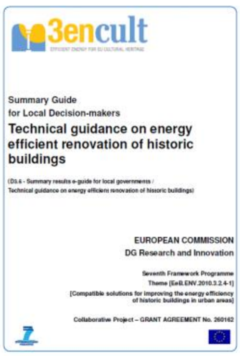
3ENCULT partner *ICLEI – Local Governments for Sustainability*, which includes more than 1100 cities, towns, countries and their associations worldwide, has therefore translated 3ENCULT's results into e-guides for their target audience and disseminated them in a number of workshops and study tours actively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

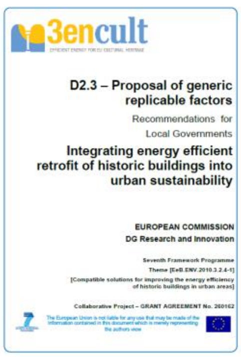


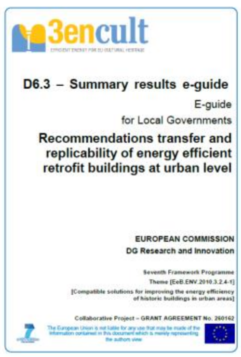
1.2.1 E-guides

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 action**s 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

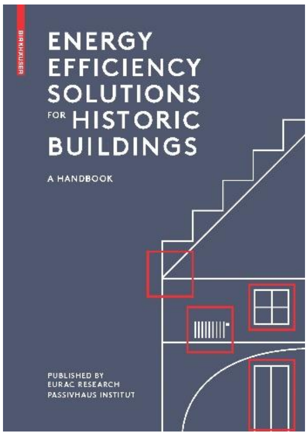
1.2.3 Workshops

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

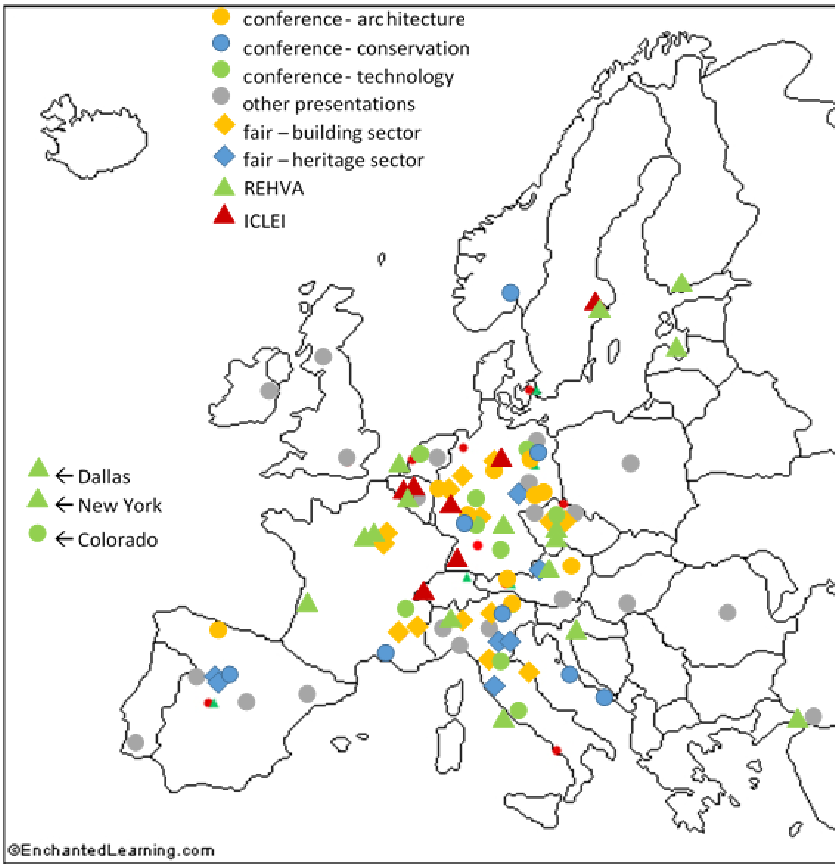
The handbook, edited by EURAC and PHI, with the single chapters written by the respective experts within the consortium, will be published with Birkhäuser, a high-level publisher very well known among architects who are the main target group. The book will be published in Autumn 2014 and will be available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



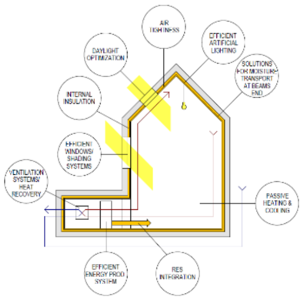
More than 20 fairs were covered – including Denkmal (Leipzig, DE), Salone del Restauro (Ferrara, IT), AR&PA (Valladolid, ES), LuBEC (Lucca, IT) and monument (Salzburg, AT) the major European Heritage fairs and with Light + Building, CLIMA, DeubauKOM and other also major fairs and exhibition in the building 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

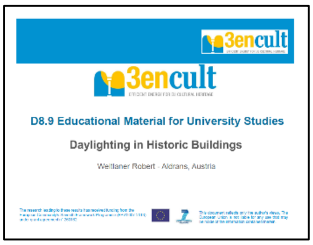


1.3.5 Frequently asked questions

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.


D8.9 Educational Material for University Studies

Daylighting in Historic Buildings

Weitlaner Robert - Aldrans, Austria


Analysis & diagnosis

Camilla Colla, UNIBO
Enrico Esposito, Artemis
Simone Reeb, UNISTUTT
Alexandra Troi, EURAC

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.

Patent: REMMERS, n. DE102007040938A1 EP2183099A1 EP2183099B1 EP2666625A1

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 building**s, 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.

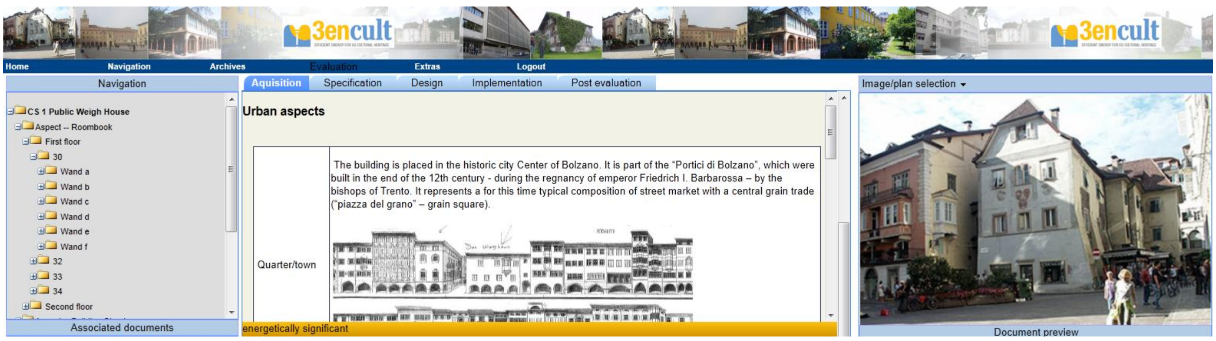
For the **wall integrated ventilation** system to install easily distribute mechanical ventilation system and to offer space saving installation of ventilation heat recovery system and the **active overflow systems** for school buildings, which allow enormous reduction of ducting work and therefore minimise 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 system** (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 net**work 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 (hBIS^{ec})**, 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 Compontents. 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 Gutierez 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 wor**k – 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