Energy retrofit of cultural heritage buildings

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Around a quarter of the existing building stock in Europe was built prior to the middle of the last century. Thus, historic buildings are of significant importance in reducing energy consumption and CO2 emissions. For better integrating historic buildings issues in European Union (EU) level legislation, CEN standards and voluntary retrofit certification schemes the experience and results of the FP 7 research project 3ENCULT [1] targeted the Energy Performance of Buildings Directive (EPBD) and the most important EPBD CEN standards, CEN TC 346 Conservation of Cultural Heritage and EnerPHit Certified Retrofit (PHI).

Keywords: EPBD, energy legislation, requirements, CEN TC 346, conservation, historic buildings, energy retrofit with Passive House components, EnerPHit.

Introduction

Historic buildings are the trademark of numerous European cities, town and villages and are a living symbol of Europe's rich cultural heritage and diversity. They reflect the society's identity and need to be protected. However, they show high level of energy inefficiency contribute substantially to CO_2 emissions and rising energy bills. Even more, these buildings do not offer appropriate indoor environment quality (IEQ) nor the conditions necessary for heritage collections preservation.

Within 3ENCULT a number of solutions have been developed and tested at case studies for improving the energy efficiency while conserving the heritage and guaranteeing long term structural health and preservation of historic buildings. This was possible by including all stakeholders in the design process of the energy retrofit. This base principal is reflected in the multidisciplinary consortium: it has gathered together scientists along with stakeholders from architecture, conservation, building physics and other specific technologies.

This article will present how the integration of historic buildings is assessed in relation to and recommended to be taken into consideration in: EPBD and EPBD CEN standards, then in CEN TC 346 and last but not least in the EnerPHit Certified Retrofit (PHI).

Historic buildings and EPBD

Legislation is a proven instrument to help reaching energy ambitions. The EPBD is such an instrument, put in place at a European level and influencing legislation in all Member States in respect of energy use in the build environment. Integration of historic buildings in the EPBD will be a driving force in striving towards the ambitious goals set. However, (listed) historic buildings were left out the EPBD in the first place. To realize an ambitious energy saving level in historic buildings and really have impact in Europe, integration of historic buildings in the EPBD might be a fruitful tool. This was investigated within 3ENCULT. The results of this investigation are described in the following chapters.

Some requirements in the EPBD do not exempt listed historic buildings. Large heating and air-conditioning systems need to be regularly inspected, which was judged by the multidisciplinary team of 3ENCULT as a reasonable requirement also for historic buildings. Also the EPBD requires national requirements for building systems that are replaced or upgraded. In principle this was agreed upon by the team, but with the warning that the choice, functionality and functioning of the systems should always be respectful of the building inner character and take into account the necessary thermal and hygrometric comfort that is necessary to protect the construction and present works of art (e.g. fresco's) and still be economically feasible under those conditions.

Member States may exempt listed historic buildings under certain conditions from national minimum energy performance requirements for the parts of the building envelope that are retrofitted or replaced. The team agrees that exemptions should indeed be possible. Although it seems reasonable to replace parts of the envelope by high efficiency products when they are being removed anyway, we should be aware that new elements in the façade may influence the indoor climate and that might risk the construction or possible present artefacts. On the other hand, where possible, high energy efficient products should be encouraged.

In general there was agreement among the multidisciplinary team that for transparency reasons making an energy certificate for (listed) historic buildings, as is done for all other buildings as well, is a good idea. Where the complex nature of historic buildings makes it preferable that the certificate is made by an expert who has experience with energy in historic buildings. Also it is suggested that in case of listed historic buildings a logo, including energy and (if available) heritage value figures on the certificate and an explanation warns the user that a skilled design team shall be consulted to judge the proposed measures.

Finally, it was suggested to add a requirement in the EPBD for an obligatory analysis of energy saving potentials & options in historic buildings. The idea behind such obligatory analysis is that in this way in an early phase of the renovation process of an historic building energy saving measures are at least considered. The analysis can show what measures might be fruitful from energy point of view and which don't need additional consideration.

Such an analysis assures that:

- In an early phase of the renovation process of an historic building energy saving measures are at least considered, and biases about impossibilities are taken away where possible;
- Awareness is raised about possible innovations, increasing the chance that these are considered seriously;
- A breeding ground for promotion of energy saving products for historic buildings is created.

How to achieve conservation compatible energy retrofit

The major development in the field of historic building renovation over the past few years is a new openness on the part of architects and conservators to include historic buildings in energy-efficient retrofitting.

When the first version of the EPBD came out in 2002, there was a general fear that historic buildings would be disfigured or ruined. This resulted in a quite defensive attitude and the endeavor to exclude historic buildings from any obligations. Nowadays, this has changed to a more constructive approach: they want to preserve the buildings; they want them to be used and to make them more energy efficient. Of course, this has to be done in a way that is compatible with the heritage value of a building.

Actually, a group of experts within CEN TC 346 proactively approaches the theme, having recognized that the initiative has to come from inside the "community". Being developed is a guidance on how to improve energy performance of historic buildings – not limited to officially protected ones, but covering a whole range of building types and ages, all buildings which are "worthy of preservation". The experts discuss, how the heritage value as well as the physical status of the building are assessed, which peculiarities historic buildings do have compared to new (or newer) ones, what this means for the determination of energy performance, how the potential of the building in all its dimension is understood and best used and finally which aspects from reversibility over cost to (life cycle) energy performance the assessment of possible interventions has to consider.

Definitely, a key factor for success identified within the group is the interdisciplinary team and the dialogue that has to shape the process from the diagnosis to the design and selection of best-suited intervention.

"EnerPHit": A voluntary standard for advanced energy retrofit

While the EPBD and its national adaptations set mandatory requirements for the energy demand of new buildings and renovations, there are also a number of additional voluntary energy standards. The Passive House standard was defined in the 1990s by the Passive House Institute in Germany. It is now widely applied to buildings all over the globe, from the mild climate of Portugal to hot and humid Shanghai or Minnesota's freezing cold winters. For all locations the Passive House standard combines very high energy efficiency with excellent user comfort at minimal life cycle costs.

In many European countries the building renovation market has gained the main market share in the recent past. However, when old buildings are renovated, it is often difficult to achieve Passive House standard. Typical reasons for this are unavoidable thermal bridges as well as a general building design, which was originally not optimized for energy efficiency. For such buildings, the Passive House Institute (PHI) introduced the EnerPHit standard in 2010. The basic principle is to modernize all relevant parts of the building with Passive House components. This way almost all advantages of the Passive House standard can be realized in retrofits, even if the heating demand is not reduced all the way down to the Passive House limit of 15 kWh/(m²a).

Figure 1. EnerPHit seal.

Typical Passive House components, which are required for EnerPHit (**Energ**y Retro**fit** With **P**assive **H**ouse Components) retrofits in cool, temperate climates like Central Europe include an efficient heat recovery ventilation system, windows with triple glazing and insulated frames, more than 200 mm of thermal insulation and a very good air-tightness. Thermal bridge effects should be mitigated as best as possible within reason.

Further development of EnerPHit standard in the 3ENCULT project

Originally the EnerPHit standard could only be applied to retrofits of non-listed buildings in cool, temperate climates. In the 3ENCULT, the EnerPHit criteria have been developed further in order to also allow for certification of listed and historic buildings. This includes special provisions for buildings which can only be renovated with interior insulation, as is often the case in historic buildings with valuable façades. Additionally, exemptions for other parts of the building with restrictions by the cultural heritage authorities were introduced. The concept aims at improving the efficiency of each individual part of a historic building as long as this is compatible with the protection of the cultural heritage value.

Another recent development carried out within 3ENCULT is the adaptation for application in all European climates. The quality requirements for individual building components will continue to be the basis of the international EnerPHit criteria. The new component requirements for different climates were derived by means of an economic optimization process. The process was carried out for each location in a grid of climatic data sets covering all of Europe, with the aim of finding the set of component qualities with the lowest life cycle costs for an example building. 200 combinations of different ventilation, window and shading qualities were combined with different insulation levels of the opaque building envelope. The combination of components leading to the lowest sum of investment and energy costs could thus be determined using the net present value method.

The cost-optimal component set for the end-of-terrace example house (new build) used at first in the studies, resulted in a functional Passive House[1] in almost all locations. At the same time minimum requirements for thermal comfort and prevention of moisture accumulation were met. In order to test the suitability of these component qualities for refurbishments the method was also applied to several variations of another example building, a typical 3-storey Wilhelmenian-style residential building in a historic city quarter. For this building a full refurbishment with Passive House components (with remaining thermal bridges) as well as refurbishment with interior insulation was analyzed. In additional studies only one component was refurbished as could be the case in step-by-step renovations or if selected measures are not possible because of cultural heritage restrictions. The resulting cost-optimal component qualities were often even better than for the example newbuild (see **Figure 2**). This can be explained by the longer heating period in less efficient buildings. Thus an individual improved building component can save more energy over the course of a year than in a Passive House, making it even more economic to invest in better quality. However, as the effect was found not to be highly significant and depends on individual building surroundings, it is not taken into account for the general international EnerPHit component requirements, as not to overcomplicate the matter.

As different component requirements for each location in Europe would not be practical for use in general certification requirements a further step of simplification was required. Locations with similar sets of optimal component qualities were grouped into climate zones with one set of component requirements each (see **Figure 3**). A building in Oslo would for example fall into the "cold"

[1] A functional Passive House can be conditioned by solely heating or cooling the amount of fresh air, which is necessary for hygienic reasons.

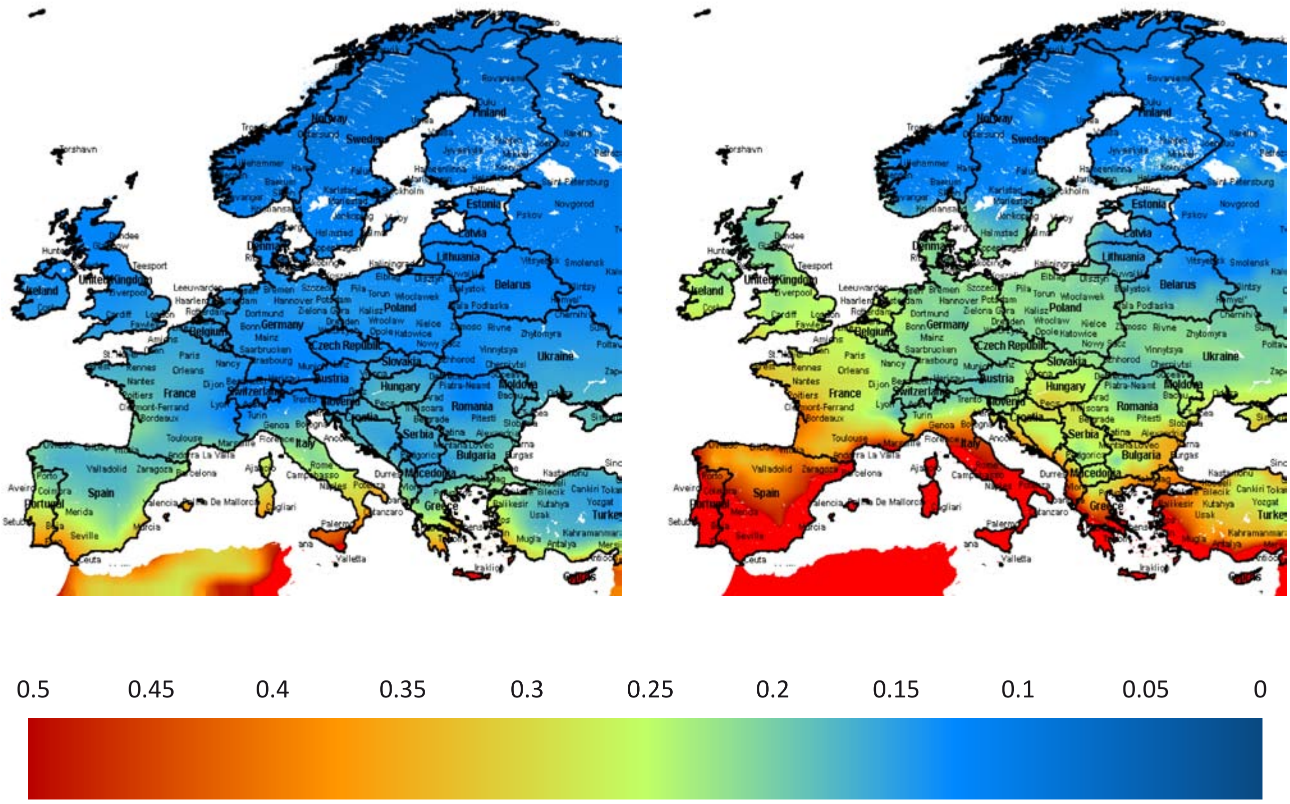

Figure 2. Cost optimal component quality (U-value) for basement ceiling insulation for a new building (left) and a historic building in which only the basement ceiling can insulated (right). In the historic building with only partial refurbishment the economic optimum is at a higher insulation thickness than for the new building.

climate zone requiring relatively ambitious measures such as quadruple-glazed windows with a well insulated frame, more than 25 cm of thermal insulation and heat recovery ventilation with a minimum efficiency of 80 %. The same building located in Lisbon ("warm" climate zone) would only need double-glazing, 6 cm

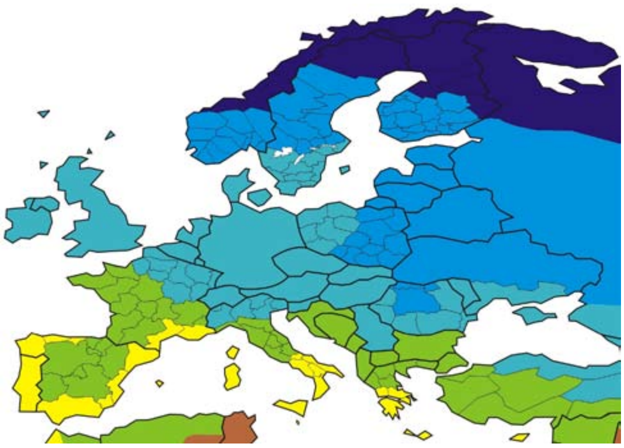

Figure 3. European climate zones map for EnerPHit requirements.

of insulation and a simple extract air ventilation system without heat recovery.

PHI plans to put the international EnerPHit criteria into effect in the second half of 2014. A draft version is planned to be published on the PHI website www.passivehouse.com in April. Certification of some pilot projects by PHI will already be possible based on this draft version.

Conclusion

3ENCULT proposes to the targeted before mentioned entities to use the experience and results of the project not as a "standard solution", but rather as a pool of possible measures and tools, along with guidelines on how to incorporate those into a historic building. ■

References

[1] Efficient Energy for EU Cultural Heritage, funded within FP7, GA No. 260162, www.3encult.eu