Historic Building Atlas

Sharing best practices to close the gap between research & practice

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Abstract – Energy retrofit of historic buildings is a relatively new task in the construction sector. It is therefore important to offer reliable solutions to practitioners and end-users that prevent any undesired outcome. Often, the lack of trust and awareness of the available solutions is limiting the extent of interventions. This has a negative effect on the final energy savings and occupants' comfort, important factors when it comes to the use and conservation of historic buildings. The Atlas will provide an international collection of exemplary case studies that go beyond current practice in their scope and in depth of information provided. This unique collection of experience from all over the world will allow architects and building owners to browse through best practice examples and find the most relevant information to pursue their own renovation. The purpose of this paper is to show and discuss the need for such a repository as well as the functions and possibilities of the database.

Keywords – energy retrofit; database; best practice; case study; historic building

1. INTRODUCTION

1.1 OVERCOMING BARRIERS FOR THE RENOVATION OF HISTORIC BUILDINGS

The carbon saving potential associated with the energy retrofit of existing buildings is well known [1]. Historic buildings account for a large fraction of the residential built stock in many countries around the world. In the UK, Spain, Denmark and France, more than 20 percent of the existing buildings were built before 1919 and almost 40 percent before 1945. Their refurbishment could avoid the emission of up to 180 Mt of carbon dioxide (CO_2). Beyond the opportunity for energy and carbon savings, the built heritage needs continuous care and maintenance to sustain their functionality and avoid decay. As stated by the International Council On Monuments & Sites in their Charter on the built vernacular heritage [2], *"due to homogenisation of culture and of global socio-economic transformation, vernacular structures all around the world are extremely vulnerable, facing serious problems of obsolescence, internal equilibrium and integration"*. Improving the energy performance of these buildings will also improve the internal comfort conditions. Providing users with current standards of comfort is a crucial requirement to ensure the continued use of historic buildings over time and with that their conservation and durability.

Despite the numerous reasons for the renovation of the built heritage, the renovation rate of the existing built stock is still very low. The annual renovation rate in European countries ranges between 1.2 and 1.4 percent according to Dyrbøl et al. [3]. The renovation rate for historic buildings is undoubtedly even lower.

Previous research in the field has provided a first look into the motivations and limitations for the energy retrofit of historic buildings. Looking at previous experiences of 20 owners of traditional properties, Mallaband et al. [4] identified some common "*barriers*" in the improvement of their homes. These were related to (i) the householders' values and preferences, (ii) concerns about professionals' availability and expertise, (iii) the cost and (iv) time needed for the implementation, and ultimately (v) the compatibility with the historic features of their homes. Owners' personal circumstances played a crucial role in the final decision and up to 70 percent of the households abandoned the idea of improving their homes because of "*their personal set of values*". That is, the information and solutions available to the homeowners at the moment of making that decision were not sufficient to persuade them to include energy efficient measures in the renovation of their home.

In the last few years, researchers working in the field of historic building renovation, have developed a number of energy efficient solutions specifically tailored to these buildings. A lack of knowledge exchange between academic and industry environments has created a gap that limits the access of end-users to the most advanced solutions, restraining them from improving the energy efficiency of the built heritage. In addition to that, recent research has also focused on the development of evaluation tools (e.g. Heat, Air & Moisture simulation software to calculate moisture related risks) and procedures (such as the European EN-16883:2017 [5] that guides the designer during the entire decision making process) specific to historic buildings. Transferring this expert knowledge to the end user could be determining in overcoming the scepticism towards the professionals of the construction sector.

As stated by Vadodaria et al. [6], householders' perception of the benefits of improving the building must exceed the disruption caused. In the case of historic buildings, that includes building's appearance and the renovation's effect on its aesthetics and durability. The interviews carried out by Sunikka-Blank & Galvin [7] with historic building owners in Cambridge, revealed the difficulties that "*retrofitters*" faced when trying to balance the improvement of the buildings' efficiency and the aesthetic preservation of their properties. In fact, aesthetics was as important as the economic criteria in the majority of the cases. Nevertheless, homeowners did not share a common vision of aesthetics or heritage

When retrofitting historic buildings, preserving their heritage value (including aesthetic, cultural and social aspects) is of major importance [8]. However, if the assessment of such heritage value is left to unexperienced end-users without additional information, there is a risk of undesired interventions due to users' misjudgement of "*heritage value*". Best practice examples could be a valuable resource for practitioners and owners to learn from, especially if the implemented solutions are presented together with an explanation of the building's heritage value assessment carried out by an expert.

Lastly, Friedman & Cooke [9] suggested that the lack of consistency in the application and planning policies of local authorities might be acting as a barrier for the adoption of low-carbon measures in historic buildings. In some scenarios, a detailed documentation of the decision making process would be fundamental in the negotiation with the local authorities during the planning application.

A collection of well documented best-practice examples could also be a key resource in this process. However, the usefulness of a resource like this would depend heavily on the robustness of the examples showed. The verification and validation process would therefore be crucial in a successful implementation of such a repository.

2. BACKGROUND OF DATABASE ELABORATION

2.1 FOCUS ON HISTORIC BUILDINGS

There are already a number of accessible energy refurbishments compilations, each of them addressing a specific content or local focus. The table in Figure 1 provides an overview of the existing online accessible databases. Although this list does not claim to be complete; it presents the state of the art and serves as base for the argumentation that a new database expressly designed for historic buildings is needed.

None of the identified databases has an (exclusive) focus on the energy efficient renovation of historic buildings, with the exception of the compilation of the Sustainable Traditional Buildings Alliance (STBA). However, this repository has only included two project examples so far. Other databases also incorporate buildings of particular cultural value, either generally under renovations or as a special category and with an associated filter functions (e.g., dena). However, the most comprehensive surveys of energy-efficient renovations, as in Construction21 database or the examples collection of IEA SHC Task37, do not – or not with enough detail and visibility – consider specific requirements of the historic buildings such as (i) the historic and architectural value and the impact of the intervention on these values, or (ii) the decision making process. This process should take equally into account energy and cultural concerns. Furthermore, these databases are lacking a differentiated consideration of the construction details tailored to the diverse and heterogeneous features of historic architecture.

Ultimately, a best practice repository must leave enough room to explain why certain products and solutions have proven to work well in a particular historic building. Dedicated product databases for standard construction solutions (e.g. EffiBUILDING database: http://www.effibuilding.eu/db/) will not meet these requirements since the depiction of the connection between the particularities of the building and the detailed solution is indispensable.

	DATABASE	**PROJECTS INCLUDED** *Renovation in general (R)/ Hist. Build.(HB)/ New Construction(N)*	**RECORDED ITEMS** *Districts (D)/ Buildings (B)/ Components (C)/ Products (P)*	**CONSIDERED REGION** *Europe (E)/ World Wide (W)/ Country/ Region*	**FEATURES CONSIDERED** **General Building** *Information (A)/ Cultural Values (V)/ Construction of the thermal envelope (C)/ Energy Performance (E)/ Building Services (B)/ Renewable Energy Systems (R)/ Planing Process+Business modells (P)/ User comfort (U)/ Economic aspects (X)/ Environmental Assessment and Sustainability (S)/ Monitoring data (M)*	**LEVEL OF INTERACTION** *Only readable (R)/ Content searchable using Filter of building types (FB) and Solutions (FS)/ Leading to Decision Support (D)/ Possibility to comment (C)/ Open to add new projects (A)*	**SIZE OF THE DATA COLLECTION** *Number of recorded items: all projects (N+R)/ only renovation projects (R)/ only historic building renovations (HB)*	**COMMENTS** *enrollment process, reliability of data, quality assessment, level of detail etc.*
(1)	Construction21	N, R	D, B, C, P	W	A, C, E, B, R, S, X	FB, FS, A	468 (N+R) of these 91 (R)	Case studies are declared by the architect in a datasheet, basic data are mandatory, data reliability is stated by the customer; the case studies are generated, among others, from the applications for the Green Solutions Award, which is announced by C21.
(2)	Responsible Retrofit Knowledge Centre, STBA Sustainable Traditional Buildings Alliance	HB	B	UK	A, V, B, U	D, A	2 (HB)	General information on building construction and energy efficiency measures, no construction detail; The evaluation of the case studies should lead to a decision process within the project development.
(3)	IEA SHC Task 37: Advanced Housing Renovation	R, HB	B	W	A, (V), C, E, B, R	R	60 (R)	Report on lessons learned from a collective look at the case studies, involved countries: AT, BE, CA, CH, DE, DK, I, NL, NO and SE.
(4)	IEA SHC Task 47: Solar Renovation of Non-Residential Buildings	R, HB	B	W	A, (V), C, E, B, R, P, S	R	20 (R)	Non-residential buildings in three categories: educational buildings, office buildings and historic & protected buildings; report on lessons learned
(5)	dena (Deutsche Energieagentur)	N, R, HB	B	Germany	A, C, E, B, R	FB	ca. 1300 (N+R), of these 60% (R) and 5% (HB)	Registered buildings have to meet an "Effizienzhaus" standard. Registration of examples by architects with the consent of the owner.
(6)	ExcEED	R,N	D, B	Europe (EU)	A,C,E,B,R,U,S,M	FB, FS, D, A	work in progres	Continuous transmission of monitoring data. Database conceived for last generation of buildings but applicable to any building typology. The database integrates an IEQ survey and geocluster visualization tool
(7)	NZEC Zero Energy Residential Case Study Database Net-Zero Energy Coalition	N, R	B	USA, Canada	A, C, E, B, R, P	R, A	80 (N+R)	The most comprehensive source of North American zero energy residential case studies.
(8)	klimaaktiv Gebäudedatenbank	N, R	B	Austria	A, C, E, B, R, U, X, S	FB, A	605 (N+R), of these 86 (R)	Declaration of all buildings according to klimaaktiv criteria
(9)	Passive House Database	N, R	B, C	W	A, C, E, B, R, U	FB, A	4270 (N+R) of these ca. 210 (R)	Passive House Buildings that have already been completed or are under construction (also EnerPHit certification). All information is based on data entered by the project registrant (planner or building owner)
(10)	SINFONIA Database of best available practices in energy-efficient refurbishment		P					
	Historic Building Atlas	HB	B	W	A, V, C, E, B, R, P, U, X, S, M	FS, FB, A		Elaborated in the IEA-SHC Task 59 as an online database specifically for historic buildings

(1) Construction21: https://www.construction21.org/
(2) Responsible Retrofit Knowledge Centre, STBA Sustainable Traditional Buildings Alliance: http://responsible-retrofit.org/search-results/
(3) IEA SHC Task 37: Advanced Housing Renovation http://task37.iea-shc.org/publications;
(4) IEA SHC Task 47: Solar Renovation of Non-Residential Buildings http://task47.iea-shc.org/publications;
(5) dena (Deutsche Energieagentur) https://www.dena.de/themen-projekte/energieeffizienz/gebaeude/bauen-und-sanieren/effizienzhaus-datenbank/
(6) ExcEED: http://www.exceedproject.eu
(7) Net-Zero Energy Coalition, Case studies: http://netzeroenergycoalition.com/case-studies/
(8) klimaaktiv Gebäudedatenbank: https://klimaaktiv-gebaut.at/
(9) Passive House Database - common project of the Passive House Institute, the Passivhaus Dienstleistung GmbH, the IG Passivhaus Deutschland and the iPHA (International Passive House Association) and Affiliates: http://www.passivhausprojekte.de/
(10) Database of best available practices in energy-efficient refurbishment http://www.sinfonia-smartcities.eu/

Figure 1. On-line available databases with best practice solutions for energy efficient renovation.

2.2 LOCAL – GLOBAL APPROACH

The adaptation of technical solutions specifically to the historic building stock has only been pursued in a local context so far. There are numerous publications (printed and online accessible) of energy-efficient renovations of historic buildings. These are often initiatives of the heritage authorities, sometimes in cooperation with relevant research institutions that tackle the respective stock of the region (i.e. Historic Environment Scotland Refurbishment Case Studies). An online example of these is the previously mentioned database of STBA for the UK. There is also the South Tyrolean historic Building Atlas – energy and culture (hBAT^{ec}, [8]), which is not online accessible yet. These collections are naturally limited in their sample size, but ambitious in the level of detail und the scope of information. In the Interreg Alpine Space project ATLAS, an extension of the data collection beyond the South Tyrolean area will be elaborated, since common building types can be found throughout the entire Alpine space.[9] The extension of a best practice database entails a hard to handle increase of building typologies, but leads to the possibility of global information exchange. The balance between local and global context is therefore a delicate issue that might have an important effect on the final use of the database.

2.3 BUILDING CLASSIFICATION

The decision of restricting the scope of the hBAT^{ec} to the local context was made based on the assumption that potential end-users (building owners and practitioners) would connect the local architecture, climate and handcraft traditions better with predefined local building typologies. Furthermore, it was expected that private owners and architects would rather access a database that is presented in their mother tongue [8]. The building typologies presented in hBAT^{ec} are linked to representative main historic building categories, in order to group similar buildings and promote transferability of solutions.

An approach to building classification based on individualized analysis of the historic building stock, as it was done in local samples, would not be applicable in the global context. In cases of large samples, a detailed questionnaire on the architectural elements and building type, as well as on the location of the building, would allow browsing through the collection in order to find the most suitable reference case.

3. BEST PRACTICE DATABASE FOR HISTORIC BUILDINGS

3.1 ELABORATION OF A NEW DATABASE

The investigation on existing best practice collections revealed that none of the databases meets the requirements of a comprehensive repository of examples of historic buildings energy refurbishment. In order to take the particularity of these buildings into account, the assessment of solutions applied in a historic structure requires a high level of detail and a targeted query strategy, something that none of the existing databases could offer so far. The discussion on the scope and content of such a database was introduced into the IEA-SHC Task 59 (“Renovating Historic Buildings towards Zero Energy”, http://task59.iea-shc.org/) and discussed there with an interdisciplinary panel of experts. The newly-developed Historic Building Atlas (HBA) will fill the gaps of already existing databases by providing an open and web-based information source with the necessary information on historic buildings' specific details. The aim of the HBA is to make existing "best-practice experiences" available to the end-users for inspiration from these examples, and implementation in practice. However, this is not a homogeneous target group as it includes different stakeholders with different understanding of the complexity of the renovation process (e.g. architects & planners, building owners & real estate developers, public administration, and NGOs working in the field of historic buildings). Therefore, it is crucial to identify the characteristics that define a best practice as well as the requirements for the information to be provided. The latter is discussed in section 3.3, whereas the parameters that make a case study a best practice are presented below.

3.2 BEST PRACTICE CRITERIA

The scope of the examples to be included in the HBA will not be limited to a certain level of formal protection. Following EN-16883:2017 definition [5], any "*historically, architecturally or culturally valuable buildings, while respecting their heritage significance*" will be considered in the database. Furthermore, also in line with EN-16883:2017, the selection of case studies is not limited to any typology or construction period.

Every single historic building must be considered as a particular case. Establishing a single quantitative criterion or threshold (i.e. kWh/m^2) to measure the degree of success of an intervention exclusively as a function of the energy saving, would go against this principle. The definition of best practice should therefore also be based on criteria that consider qualitative aspects of the intervention. The minimum requirements that case studies must respect in order to be considered best practice within the HBA are:

- *Renovation of the whole building*. The HBA aims at presenting examples that have considered the intervention in the building as a whole and not as a collection of single retrofit measures. Therefore, the cases included in the database cannot be limited to the improvement of a single aspect of the building and must have aimed at reducing the overall energy demand;
- *The project has been implemented*. Most of the limitations in the renovations of historic buildings appear when it comes to the compatibility with the existing construction and/or use. It is therefore important that the best practice example shows a renovation project that has already been implemented;
- *The intervention followed the results of a thorough heritage value assessment*. Energy improvement in historic buildings cannot be achieved at the expense of their heritage value. Therefore, the cases included in the HBA should include the results of such assessment in order to illustrate the relationship between the particularities of the building and the solutions eventually adopted;
- *A significant reduction of the energy demand was achieved.* The ultimate goal of the HBA is to pursue the lowest possible energy demand in historic buildings. The final value will however depend to a great extent on the

heritage assessment result and therefore will vary greatly from case to case;

- *A detailed documentation of technical solutions & monitoring data is available*. As discussed before, access to detailed and robust information might be important in overcoming the barriers to historic building renovation. Therefore, every example included in the HBA must be well documented and make this information available to the end-users.

3.3 IMPLEMENTATION

The HBA points to visual information transfer to reach end-users – especially building owners as well as planners and architects –: photos, short and concise texts, easy to read charts, drawings of solution details, and peer experience. A good browsing experience is also of major importance. Adapting the presentation of the information to the user device – be it a notebook, a tablet, a smart phone or a big screen. The site of *arch.atlas* (http://arch.atlas.bz.it) serves as an inspiration in this case. This project from the Architectural Foundation of South Tyrol adjusts the order and positioning of photos to the available space with a dedicated algorithm. The concept applied there should however be adapted for the presentation of much more comprehensive information in the case of HBA. The structured information in the background database of the HBA will allow the combination of text and images in a flexible way, side-by-side or consecutive, changing level of visible detail and organising information thematically.

The best practice examples should inspire users. The presentation starts therefore with images of the whole building and its interiors, describing in photos and text the aesthetic and historic values and how the responsible retrofit improved occupants' comfort. Also, some key data and contact details are shown. It then provides detailed information for those who want to learn more from the experience: on the one hand data on the specific context (historic, urban and climatic), architecture and retrofit concept targets – in order to help users to

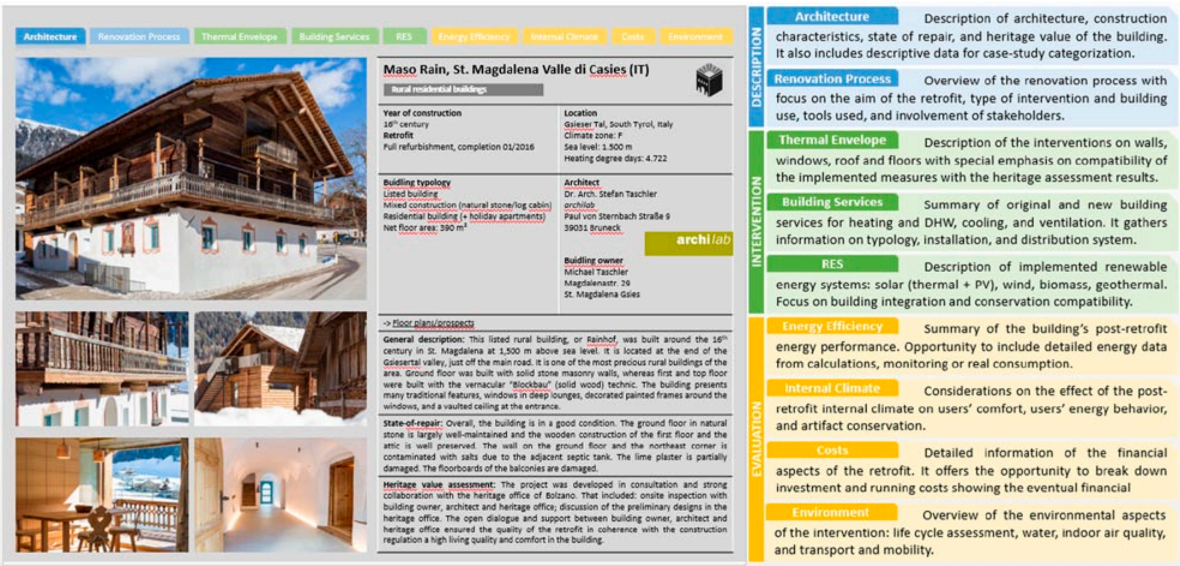

Figure 2. Database interface (draft version based on the hBAT^{ec} proposal) and categories' characteristics.

understand whether the example is comparable to their case –, and on the other hand data on the different retrofit solutions applied, ranging from window, wall and roof improvement over airtightness and ventilation to the building services. Finally, also experiences from the renovation and related decision processes are shared: who were the stakeholders involved, and how decisions were discussed and made. Of course, also links to additional resources can be added. The background structure of the database is flexible: place for all possible aspects is provided, but only some key points are mandatory. What is actually presented depends on the focus of the single best practice and how to best communicate it.

An advanced filter function will allow narrowing down the amount of buildings to those of specific interest to the single user: buildings from a specific geographic area, of a specific period, use (residential, office, other), typology (detached, terraced, tenement), but also buildings with specific solutions applied as e.g. window improvement with secondary window or buildings with interior wall insulation.

Main providers of best practice cases will – at least in the first phase – be the front-runner architects and dedicated research projects. The HBA provides them with a Back-Office that goes far beyond a standard Content Management System (CMS). A self-explanatory tool will guide users through the documentation process, providing the fields for inserting the text pieces that later will be visible online, but also selectable keywords for the filter functions, sections to insert data that is then presented in charts, etc. A preview function helps understanding whether the images and the text pieces provided in single fields form a smooth and readable text.

The HBA aims at interlinking with other existing online resources. On the one hand, it will allow feeding information directly into other databases such as Construction 21 and the BuildUp case study collection. The definition of the database structure behind the website has been optimised to this regard. On the other hand, links can lead from short descriptions of a best practice in other databases to its more detailed description in the Historic Building Atlas.

Furthermore, database and web-concept are structured in a way that parts of the database can be shown in customised web-interfaces. This allows firstly to provide national versions of the HBA, enabling the access in countries where English might not be commonly used. Secondly, other running and upcoming projects can use the database and web-concept within their project website, with specific graphic project identity, showing there project related cases while at the same time feeding into the bigger complete database.

4. CONCLUSION

In conclusion, technological and non-technological barriers hamper raising both the quality and the quantity of energy refurbishments of historic buildings. Insufficient information and confidence are major barriers to energy renovation. The expertise developed by scholars and practitioners in the field of energy retrofit of historic buildings is not arriving to the end-user that still faces many uncertainties when renovating a property due to the lack of specific information. Nevertheless, there are numerous case studies of low-energy renovated historic buildings developed as part of collaborative research projects between academia and industry. Providing end users with access to the information and lessons learnt in those projects, by means of robust and well documented examples organized in an open database, will help overcoming scepticism and prejudice against retrofit.

The HBA, as presented here, is still a work in progress. Aspects like the final interface and browsing features are still to be investigated. In the meantime, a base of exemplary case studies is already being collected within the IEA-SHC Task 59. However, the success of the HBA will be ultimately dependent on its ability to develop and grow over time. The input from researchers and practitioners, beyond the IEA-SHC Task 59, is essential to expand the collection of case studies included in the database.

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