Conservation compatible energy retrofit technologies

Part I: Introduction to the integrated approach for the identification of conservation compatible retrofit materials and solutions in historic buildings

Pfluger, Rainer; Rieser, Alexander; Herrera-Avellanosa, Daniel; Buda, Alessia; de Place Hansen, Ernst Jan; Giancola, Emanuela; Pracchi, Valeria Natalina; Mauri, Sara; Marincioni, Valentina; Gori, Virginia; Fouseki, Kalliopi; Polo Lopez, Christina S; Lo Faro, Alessandro; Egusquiza, Aitziber; Haas, Franziska; Leonardi, Eleonora

DOI (link to publication from Publisher):
10.18777/ieashc-task59-2021-0004

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Pfluger, R. (Ed.), Rieser, A. (Ed.), Herrera-Avellanosa, D. (Ed.), Buda, A., de Place Hansen, E. J., Giancola, E., Pracchi, V. N., Mauri, S., Marincioni, V., Gori, V., Fouseki, K., Polo Lopez, C. S., Lo Faro, A., Egusquiza, A., Haas, F., & Leonardi, E. (2021). *Conservation compatible energy retrofit technologies: Part I: Introduction to the integrated approach for the identification of conservation compatible retrofit materials and solutions in historic buildings* . International Energy Agency, IEA. https://doi.org/10.18777/ieashc-task59-2021-0004

Conservation compatible energy retrofit technologies

Part I:
Introduction to the integrated approach for the identification of conservation compatible retrofit materials and solutions in historic buildings

IEA SHC Task 59 | EBC Annex 76
Renovating Historic Buildings Towards Zero Energy

Conservation compatible energy retrofit technologies

Part I: Introduction to the integrated approach for the identification of conservation compatible retrofit materials and solutions in historic buildings

Editors:
Rainer Pfluger (UIBK), Alexander Rieser (UIBK), Daniel Herrera (EURAC)

Contributing authors:
Alessia Buda, Ernst Jan de Place Hansen, Emanuela Giancola, Valeria Natalina Pracchi, Sara Mauri, Valentina Marincioni, Virginia Gori, Kalliopi Fouseki, Cristina S. Polo López, Alessandro Lo Faro, Aitziber Egusquiza, Franziska Haas, Eleonora Leonardi.

October 2021
SHC Task 59 | EBC Annex 76 | Report D.C1-I
DOI: 10.18777/ieashc-task59-2021-0004

IEA SHC Task 59 | EBC Annex 76: Deep renovation of historic buildings towards lowest possible energy demand and CO_2 emission (NZEB)

Solar Heating and Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives (*"*Implementing Agreements*"*) of the International Energy Agency.

Our mission is *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

IEA SHC members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

Our focus areas, with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statics report
- SHC International Conference

Our members

Australia
Austria
Belgium
Canada
CCREEE
China
Denmark
EACREEE
ECREEE
European Commission
European Copper Institute
France
Germany
International Solar Energy Society
Italy
Netherlands
Norway
Portugal
RCREEE
SACREEE
SICREEE
Slovakia
South Africa
Spain
Sweden
Switzerland
Turkey
United Kingdom

For more information on the IEA SHC work, including many free publications, please visit www.IEA SHC.org.

Energy in Buildings and Communities Technology Collaboration Programme (IEA EBC)

To reach the objectives of SHC Task 59 the IEA SHC implementing Agreement has collaborated with the IEA EBC Implementing Agreement at a "Medium Level Collaboration", and with the IEA PVPS Implementing Agreement at a "Minimum Level Collaboration" as outlined in the SHC Implementing Agreement's Policy on Collaboration.

Contents

Contents iii
1 Introduction 2
2 Drivers and barriers when implementing retrofit solutions in the built heritage 3
3 Aims and objectives 3
4 Work methodology and report structure 3
  4.1 Methodology 3
    4.1.1 Compilation methodology 4
    4.1.2 Assessment methodology 4
  4.2 Report structure 5
5 Results - A new decision guidance tool for the adoption of energy retrofit solutions in historic buildings 6
  5.1 Results 6
    5.1.1 Documentation of Solutions 6
    5.1.2 Decision trees 9
    5.1.3 HiBERtool 9
  5.2 Discussion 11
6 Publications 11

Disclaimer

Some of the text presented in this report has been published elsewhere as journal papers and conferences proceedings. All the texts have been written by the authors of these report and as part of the activities developed in the course of Subtask C. All text reproduced here is reference below.

1. Introduction	Buda, A.; de Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.N.; Mauri, S.; Marincioni, V.; Gori, V.; Fouseki, K.; Polo López, C.S.; Lo Faro, A.; Egusquiza, A.; Haas, F.; Leonardi, E.; Herrera-Avellanosa, D. Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach. *Sustainability* **2021**, *13*, 2927. https://doi.org/10.3390/su13052927
2. Drivers and barrier when implementing retrofit solutions in the built heritage	Buda, A.; de Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.N.; Mauri, S.; Marincioni, V.; Gori, V.; Fouseki, K.; Polo López, C.S.; Lo Faro, A.; Egusquiza, A.; Haas, F.; Leonardi, E.; Herrera-Avellanosa, D. Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach. *Sustainability* **2021**, *13*, 2927. https://doi.org/10.3390/su13052927
3. Aims and objectives	Buda, A.; de Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.N.; Mauri, S.; Marincioni, V.; Gori, V.; Fouseki, K.; Polo López, C.S.; Lo Faro, A.; Egusquiza, A.; Haas, F.; Leonardi, E.; Herrera-Avellanosa, D. Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach. *Sustainability* **2021**, *13*, 2927. https://doi.org/10.3390/su13052927
4. Work methodology and report structure 4.1. Methodology	Buda, A.; de Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.N.; Mauri, S.; Marincioni, V.; Gori, V.; Fouseki, K.; Polo López, C.S.; Lo Faro, A.; Egusquiza, A.; Haas, F.; Leonardi, E.; Herrera-Avellanosa, D. Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach. *Sustainability* **2021**, *13*, 2927. https://doi.org/10.3390/su13052927
4.1.1. Compilation methodology	Rieser, A.; Leonardi, E.; Haas, F; Pfluger, R. A new decision guidance tool for the adaption of energy retrofit solutions in historic buildings. SBE21 Heritage Conference
4.1.2. Assessment methodology	Rieser, A.; Pfluger, R.; Troi, A.; Herrera-Avellanosa, D.; Thomsen, K.E.; Rose, J.; Arsan, Z.D.; Akkurt, G.G.; Kopeinig, G.; Guyot, G.; Chung, D. Integration of Energy-Efficient Ventilation Systems in Historic Buildings—Review and Proposal of a Systematic Intervention Approach. *Sustainability* **2021**, *13*, 2325. https://doi.org/10.3390/su13042325
5. Results	Rieser, A.; Leonardi, E.; Haas, F; Pfluger, R. A new decision guidance tool for the adaption of energy retrofit solutions in historic buildings. SBE21 Heritage Conference, Bolzano (Italy) 14-16 April 2021 in *IOP Conference Series: Earth and Environmental Science* (In press)

1 Introduction

According to the United Nations Environment Programme (UNEP), existing European buildings consume about 40% of the total energy consumption in Europe. For this reason, in the last decades, several energy policies have been directed to deep renovation of the existing stock (as last 2018/844).

Considering that more than one quarter of all European buildings were constructed before the 1950s, we can assume that many of them are of cultural, architectural, social and heritage values, hence in need of special attention for conservation purposes.

As preservation means maintaining the integrity, identity, and functional efficiency of a cultural asset, the renovation process may be an opportunity to improve the active functionality and avoid the decay of our built heritage. Tailored retrofit solutions (also referred to as "measures" or "interventions" in the text below) may improve the building conservation while acting on users' comfort and reducing the energy demand, which are crucial to ensure the continued use of buildings over time and consequently their endurance. In addition, and more crucially, by preserving the material fabric, the built heritage values are sustained. This is important to achieve holistic sustainable developments.

In stark contrast, projects mainly addressing environmental sustainability focus almost exclusively on measures enabling energy efficiency and cost savings, which may not be necessarily compatible with heritage values preservation. It may turn out challenging for designers and practitioners to preserve cultural built heritage values while implementing retrofit solutions aiming at energy consumption reduction to achieve the key targets set in the 2030 Climate & Energy Framework [1]. Indeed, some authors have identified risks of destruction or significant impairment of some buildings' inherent heritage values if energy efficiency measures are implemented in isolation, verifying only the energy savings [2].

The number of publications addressing ways to improve the energy efficiency of buildings with cultural and architectural value recognized by the users has been constantly increasing during the last decade. The balance between energy consumption reduction and conservation principles was the dominant criterion in recent literature, due to a pressing need to conserve the physical integrity of historic buildings.

However, the variability of historic constructions does not make it possible to identify in the literature retrofit strategies that can be considered exemplars applicable to all buildings. As indicated in several studies [3,4], professionals, and users, i.e., the building owners or the building occupants, emphasize the need for support during the decision-making process, as well as means to share best practices and repositories of retrofit solutions deemed suitable for the built heritage.

IEA SHC Task 59: A Collaborative Research Project

In 2017, the International Energy Agency (IEA) has made the built heritage the focus of a new collaborative research project. Within the Solar Heating and Cooling programme (SHC), 25 organisations (including public and private research institutions, heritage authorities, public administration, and industry) from 13 countries have joined forces in the IEA SHC Task 59/Annex 76 "Deep renovation of historic buildings towards lowest possible energy demand and CO_2 emission (nearly Zero Energy Buildings-nZEB)" [5].

As Shah put it [6], "collaboration is used for solving problems that are too difficult or complex for an individual" (p. 216), and the identification of retrofit solutions that are compatible with historic buildings (and the barriers that prevent their implementation), is without a doubt an intricate task that profits from a multidisciplinary approach. The work carried out in IEA SHC Task 59 relied heavily on knowledge exchange and task sharing, profiting from the wide and varied group of experts collaborating in the project. Thus, the methods used in this study were based on an iterative process of information seeking, comparing and synthesizing, making decisions, and finally making use of the synthesized solution.

This report presents the work carried out within the IEA SHC Task 59 project (Subtask C) to support decision-makers in the adoption of conservation-compatible retrofit solutions for historic buildings, as suggested by the EN 16883:2017 [7] standard. The main objective of the study was to identify and evaluate examples that both satisfy the conservation of historic buildings and lower their energy demand.

2 Drivers and barriers when implementing retrofit solutions in the built heritage

Many of the limitations preventing people from the energy retrofit in historic buildings are neither purely social nor purely technical, but rather the combined result of socio-technical issues.

Consequently, four clusters are proposed to group these barriers, as described in the following: (i) lack of confidence of decision makers in adopting technical solutions due to energy performance legislation requirements; (ii) lack of users' engagement in the retrofitting of historic buildings due to the reduced economic viability; (iii) lack of support and guidance in the retrofit design process for historic buildings, often too complex for non-specialised professionals and owners; and (iv) limited access to documented conservation-compatible retrofit measures that can ensure heritage compatibility and long-term performance. These clusters are described in detail in [8].

The need to systematize solutions deemed suitable for historic buildings is accompanied by that of defining an integrated, adaptable, and consistent evaluation method that supports a whole-building assessment of scenarios, with the objectives of energy saving, environment, indoor quality, economic saving, and conservation.

3 Aims and objectives

To overcome the mentioned barriers, the aim of the IEA SHC Task 59 project was to streamline and facilitate the highly complex and interdisciplinary work on conservation-compatible retrofit and to find an appropriate procedure as well as specific well documented solutions. The objective was to fill that gap by providing decision support for most of the renovation tasks and issues. Based on an integrated approach to find materials and solution for historic buildings (compilation method) the goal was to structure and edit all the information in a user-friendly way as a decision support tool, guiding through the solutions on walls, windows, HVAC and onsite renewables (solar thermal and PV). In terms of the assessment, the goal was to adapt the criteria given in the European standard EN 16883 in a general and generic way specifically to these groups of solutions. The objectives of the project were fulfilled within a highly international and interdisciplinary team of scientists, designers, and practitioners in the wide range of professionals from conservation over architecture to building physics, materials science, and engineering.

4 Work methodology and report structure

4.1 Methodology

The different aspects of the IEA SHC Task 59 project shall be seen in the broader context of the sustainable improvement of historic buildings. In this sense, a "whole building approach" is necessary, meant as an "integrated" approach that can maximize the strengths of different disciplines.

For this reason, the IEA SHC Task 59 project has gathered a solid knowledge base on how to cost-effectively save energy in the retrofit of historic and protected buildings, thanks to the existing research and new findings shared by the partners involved in this interdisciplinary collaboration. The new approach developed to change the negotiation space of suitable retrofit measures was presented in a paper resulting from the IEA SHC Task 59 [9] (figure 1).

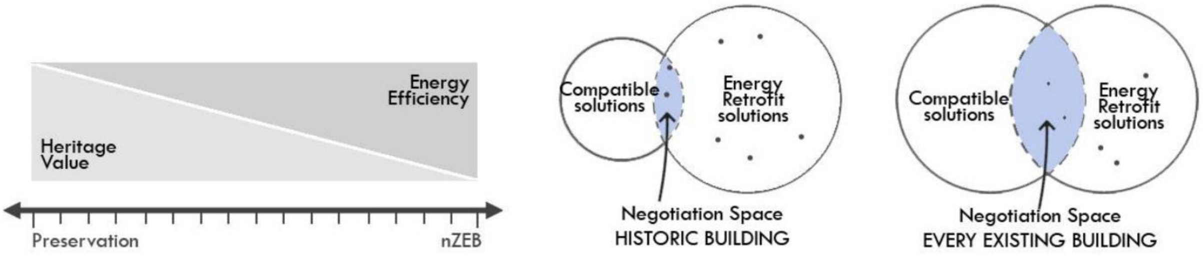

figure 1: Negotiation space to select retrofit solutions in historic buildings. Data from [9].

For existing buildings without any heritage values to be considered during the renovation process, the choice of suitable solutions is much more extensive than for historic buildings. For the latter instead, the negotiation space includes all interventions that are considered compatible with the building characteristics, and it strongly depends on the interaction of the involved stakeholders. The integration of all compatible solutions in this negotiation space would result in the lowest possible energy demand of the building.

The concept of “lowest possible energy demand” introduced in [9] acknowledges that in historic buildings the preservation of the heritage building value may sometimes result in absolute constraints on certain interventions. Similarly, it also spans a space from the concept of reducing energy demand close to the nZEB standard but do this with a focus on preserving as much as possible of the buildings aesthetic value to that of reducing the energy demand as much as possible while preserving all the buildings heritage values. Reality will lie in between, depending on the value of the building, and it will also consider additional parameters like comfort and economic feasibility.

4.1.1 Compilation methodology

In collaboration with the Interreg Alpine Space project ATLAS [10], it was possible to include the knowledge of a widely based group of international experts in the compilation of suitable solutions. The different experiences of the partners from research and practice as well as the geographical distribution across Europe guaranteed a broad and scientifically sound data set.

The basic aspects that had to be fulfilled for each documentation of a solution were: (1) the energetic improvement of the considered element, (2) the technical functionality as well as (3) the consideration of the compatibility with historic structures. Thus, in order to achieve a coherent and comparable documentation, for every single solution a set of questions was answered under the aforementioned aspects:

- What is the solution?
- Why does it work? (compatibility with conservation, technical function, energy improvement)
- Description of the context (What is special about the building and its surroundings?)
- Pros and Cons of the solution
- Additional Information (Publications, Links to further information)

The written documentation is visually supported by drawings and photos. The main value of the collection, however, is that most of the solutions presented are used in practice. Many of the solutions can be linked to the documentation of the overall renovation project in the HiBERatlas.(www.hiberatlas.com) Through this reference, one can better understand the considerations that led to the decision for the specific solution and gets a more comprehensive insight.

Furthermore, some of the documented solutions have been studied in detail by means of numerical simulation and/or in-situ monitoring as part of research projects. All of these data provide useful information in the appraisal of the solutions. A few of them are innovative solutions that are still not commercialized but provide an insight on future development.

4.1.2 Assessment methodology

The European standard EN 16883:2017 [7] acts as a guideline for building owners, authorities, and professionals to apply the existing standards in the field of energy efficiency to the specific requirements of historic buildings. It proposes and describes a systematic procedure for improving energy performance of historic buildings and, in particular, the assessment and selection of the appropriate measures that match the requirements of the building in question. Section 10.3 of the standard proposes to compile a list of possible measures as a starting point.

The next step is the assessment of the measure for the specific refurbishment case. For this purpose, the standard provides a number of assessment criteria in the following categories:

- Technical compatibility
- Heritage significance of the building and its settings
- Economic viability
- Energy
- Indoor environmental quality
- Impact on the outdoor environment
- Aspect of use

In the course of IEA SHC Task 59, the criteria of the standard were specified in detail in order to be able to carry out a detailed assessment of the individual topics. The aim was to show how to apply the assessment criteria and to illustrate the scope of such a detailed assessment.

4.2 Report structure

Due to the volume of results, this report is divided into 5 parts.

- **Part I**: Introduction to the integrated approach developed within IEA SHC Task 59 for the identification of conservation compatible retrofit materials and solutions in historic buildings
- **Part II:** Documentation and assessment of conventional and innovative solutions for conservation and thermal enhancement of window systems in historic buildings
- **Part III:** Documentation and assessment of materials and solutions for external wall insulation in historic buildings
- **Part IV:** Documentation and assessment of energy and cost-efficient HVAC-systems and strategies with high conservation compatibility.
- **Part V:** Documentation and assessment of integrated solar thermal and photovoltaic systems with high conservation compatibility.

Part I describes the basics such as the methodology and the overarching conclusions. In Part II to V, the results of the respective working groups of Subtask C are presented. This includes a general information part on the respective component as well as the collection of all documented solutions. Furthermore, the results obtained for the assessment of solutions are presented.

5 Results - A new decision guidance tool for the adoption of energy retrofit solutions in historic buildings

The development of the new decision guidance tool is based on two main pillars: the collection of technical solutions for the application in historic buildings and the establishment of a query structure that intuitively leads to the appropriate solution. Finally, the compilation is presented in a well-structured online guidance tool to building owners and technicians.

From the beginning, the collection of technical solutions pursued the documentation of realised and tested solutions down to the technical detail, as well as the evaluation of these solutions for their applicability in the historical context. So far, such in-depth descriptions have been found mainly in separate publications and mostly focused on a limited number of solutions. The value of such a compilation therefore is less the presentation of technical innovations and more the synopsis of the state of the art.

In the course of the project, decision trees were defined for the respective elements to lead the user to appropriate solutions and exclude irrelevant possibilities. The query mostly relates to two points: (1) what stock is to be assumed and (2) what options are available with regard to historical values. These question trees are presented by an online tool, the so-called Historic Building Energy Retrofit Tool - HiBERtool (link will be provided soon at www.hiberatlas.com). The purpose of this tool is to ensure that the solutions finally identified in this way can be downloaded as a PDF and for most cases contain the link to the respective best practice example on the HiBERatlas.

5.1 Results

Three different sets of results were achieved as a result of the work carried out in Subtask C: first the documentation of the different solutions for the various building elements; second the developed query which is the basis for the third, and ultimately the final result, the online decision guidance tool HiBERtool.

5.1.1 Documentation of Solutions

As already mentioned, the solutions are assigned to the building elements Walls, Windows, Heating, Ventilation and Solar. In the following, the currently available documentation results are summarized and briefly illustrated with an example.

Walls

In the group of wall solutions, a total of 39 solutions were documented. The solutions were assigned to different categories: internal insulation, external insulation, external insulation combined with internal insulation, frame infill insulation, cavity insulation, reversible systems and innovative solutions. Especially when renovating historic buildings, the external appearance is in many cases of heritage significance. It is therefore not surprising that a large proportion, namely 18 of the 39 solutions, are assigned to the category "internal insulation". But interesting renovation approaches for filling existing cavities were also documented. Innovative reversible systems show a completely different approach in preserving existing building fabric and unusual insulation materials such as aerogel, hemp concrete or reed mats show a range of possibilities for energetic improvement.

figure 2: left: installation of internal insulation (Perlite) at Villa Castelli © Eurac; middle: Blowing on the wet cellulose insulation material © HES; right: installation of wood fibre © Eurac

Windows

The window solutions were also divided into different groups. The first distinction was made on the basis of the historic window type: (1) single window, (2) coupled window, (3) box type window and (4) single window with winter windows. With the classification according to the type of window to be retrofitted, the possible impact of the refurbishment on the historic appearance and character of the building as well as on the window itself was defined in a second level. The higher the possible impact, the higher the energy efficiency that can be achieved.

In total, 16 solutions were documented. Solutions for (i) interventions with low impact are measures such as repairing the window, installing additional seals on the frame, additional foils on the glass or repairing the shutters. These solutions have no impact on the visual appearance and material and also no spatial impact on the building. In the case of solutions with (ii) impact on the internal appearance of the window, the glass or the inner sash of e.g., box-type windows are replaced. Furthermore, solutions of additional modern windows on the inside of the original window are also documented (Figure 7, right). In total, six solutions were documented for this category. The next level of impact of the intervention is an (iii) additional change of the exterior view. Changing the external glass can result in an important change of appearance, as the reflection of new modern glass is different from the historical glazing. The last category (vi) affects the whole historic window. In this group solutions such as replacing the existing window with a replica are included.

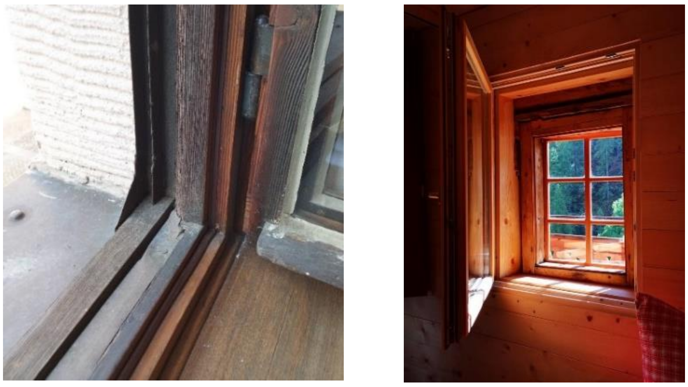

figure 3: left: insert sealing at Dante School Bolzano © EURAC; right: new added window layer on the inside at the “Giatlahaus” in Innervillgraten ©UIBK

Heating and Ventilation

In the course of documenting the ventilation solutions, the focus was on different topics. A total of 18 solutions were documented, including some general descriptions of solutions that cannot be assigned to a best practice example. Three solutions about airtightness were integrated which deal with the planning and execution of airtight levels using practical examples. Three fact sheets for cascade ventilation, extended cascade ventilation and active overflow systems were created with regard to low disruption of air distribution and planning. Another documentation includes the use of existing chimneys or shafts for the distribution of the ventilation pipes. The remaining 11 solutions refer to the location of the ventilation unit (central, decentral) as well as to the possible distribution in the floor, ceiling and façade based on best practice examples.

figure 4: left: supply air opening in a farmhouse in Tyrol © Michael Flach, right Ventilation pipes in the floor at Doragno Castle in Switzerland © L. Carugo

The documentation of solutions (25 solutions in total) for heating can be divided into two groups. The heating production and distribution. Especially in historic buildings, the question of heat distribution is typically more difficult to answer than the production itself. Various practical solutions for floor heating, wall heating and normal radiators are described in the documentation. Alternative distributions such as radiators with visible piping, air heating and infrared heating panels are included as general descriptions.

Since most of the documentation is related to a practical best practice example, many of the documents contain a description of the distribution and the associated production (local stoves, heat pumps, pellet boiler, wood chip boiler, cogeneration plant, district heating and biogas).

Solar

The solar energy solutions documented mainly concerned solar thermal collectors and photovoltaic systems compatible with historic buildings. A total of 37 solutions were documented up to now. They are divided in the following categories: plants attached to the roof, roof integrated, attached to the wall, façade integrated and free-standing solar plants and solution for the integration into the landscape. Additionally, in order to give an alternative for extreme cases and have a comprehensive documentation, some solutions for local sharing of renewables and models for sharing the renewables energy via power-network are documented. The case studies documented demonstrate that most solutions used to date in historic buildings are roof-integrated systems (22 solutions out of 37).

figure 5: left: colour modules terracotta of PV © Solaragentur Prix Solaire Suisse 2018, Maison rurale Galley, 1730 Ecuvillens/FR; middle: solar thermal units on ten protected blocks of flats in the City of Edinburgh. © HES; right: side view of the House Breuer (Austria) with non-reflecting PV modules with a dark background ©FG Marcello Girardelli

In some case studies, the solar thermal and photovoltaic systems have the same colours as the roof and therefore well camouflaged. In other cases, these systems are not visible from the street and sometimes they are just part of the architectural concept.

5.1.2 Decision trees

As already mentioned, four decision trees were developed for the respective categories. These decision trees allow a simple and quick pre-selection of the previously described categories of the respective elements. Since the exact assignment of a solution is very complex, especially in the case of historic buildings, the questions are formulated in very general terms and in a way that is simple to understand.

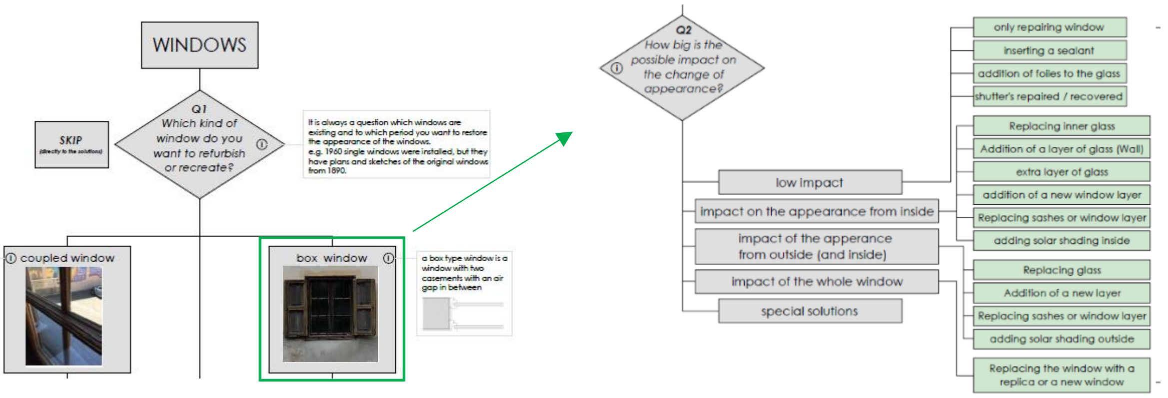

figure 6: decision tree of windows: Q1 about the type of the windows, Q2 about the possible impact on the appearance. The resulting categories refer to the documented solutions.

Basically, the decision trees follow a basic structure. The first questions should provide information about the existing building or the situation to be renovated. In the case of walls, the question is obviously directed to the type of the wall to be retrofitted. In the case of windows, it is the window type. For ventilation, information about the airtightness of the building, the room height and the availability of existing chimneys and shafts must be requested. For heating, the current heat distribution situation is interesting. In the case of solar & photovoltaic solutions, it is important to know where an integration of modules is possible at all (roof, façade or neighbouring properties). Depending on the answers to these questions, the user is led to suitable categories containing the various solutions.

A further subdivision is provided by the question of the historical context or elements worthy of preservation. In the case of walls, this can concern the façade, or in the case of windows, the possible influence on the appearance of the windows and the building as already described above. An example of the window decision tree can be seen in figure 6.

5.1.3 HiBERtool

After explaining the structure and classification of the solutions, the final result is presented: the HiBERtool. Based on the decision trees, the tool presents the online mask and actual interfaces for the user. On the website, the respective element can be selected. The questions of the decision trees lead then to the final output, a PDF describing the appropriate solution that can be downloaded and the link to the best practice example.

figure 7: Website HiBERtool: (1) Choosing the element, (2) Answer the questions, (3) final result: Download of the PDF Documentation of the Solution and the Link to the best practice example of the HiBERatlas.

As an example, solutions are requested for the refurbishment of the walls of a farmhouse in solid timber construction. Starting from the structure of the tool, the question tree for the element "Walls" is started. Figure 7 illustrates the course of the questioning and leads to the result category "internal insulation".

For internal insulation, a wide variety of practically implemented solutions are given as results (perlite / aerogel for stone walls, calcium silicate for brick masonry, dense wood fibre for stone masonry, etc.). After reviewing the solutions, these are relevant for the above described farm: Cellulose for log walls - farm "Neuhäusl" as well as sheep wool with vapour control layer - Giatlahaus.

,

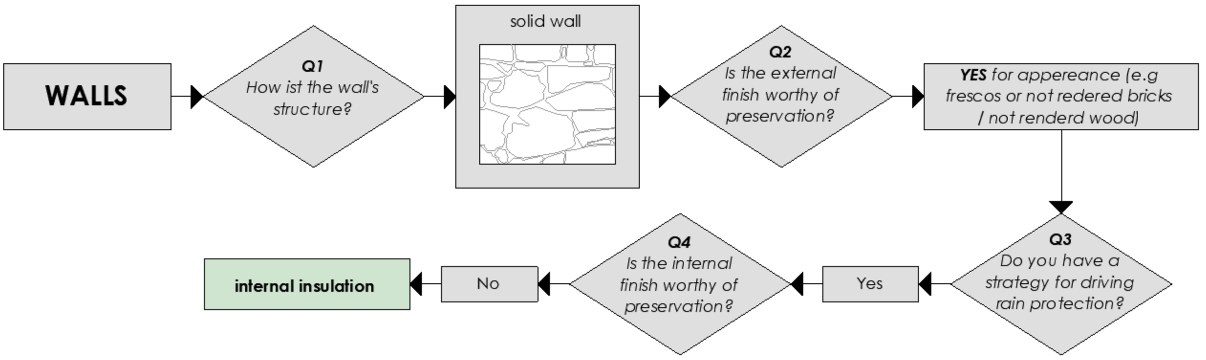

figure 8: example of a decision path of a historic farmhouse with log walls

The example should illustrate the discussion on the benefits of the documentations, the decision trees, and the tool. The basic structure and the type of documentation have been determined and provide the necessary transparency of practically implemented examples where not only the technical function of the solution is examined but also consideration has been given to the context of the building and it´s heritage significance. Of course, the current scope is only a start to answering this issue, because to stay with the example described above, the output of 20 solutions with associated best practice documentation would be of far greater benefit.

figure 9: left: Black wind paper and the frame construction for the OSB panels in "Hof Neuhäusl" © DI Hans Peter Gruber; right: New block wall on the inside of the "Giatlahaus". The space between the old log wall and new log wall was insulated with sheep wool. ©Benjamin Schaller

5.2 Discussion

The documented solutions and the tool structure aim to offer to the user a basis, inspiration, and source of information for further planning. Of course, the tool does not want to substitute the technician in his job and makes this clear in the solutions' documentation. Each historic building must be analysed and retrofitted with targeted solutions that must be evaluated by an expert case by case.

Regarding the tool structure, a classification according to building types and regions was discussed in the course of the research projects. The existing HiBERtool currently contains about 130 solutions. For a building-specific classification as envisaged in the beginning, however, many more solutions would be necessary. Other elements such as the roof and the floor are not yet included in the tool. However, the tool is designed in such a way that further elements can be added in future projects and further subdivisions can be made. The current result is the basis for a comprehensive catalogue for the energetic renovation of historic buildings. This will become more comprehensive and relevant with each additional documentation.

6 Publications

The work carried out within Subtask C has resulted in a number of international publications in the form of contributions to scientific journals and conference proceedings. Some of these publications have informed the text of this report. A detailed list of all publications linked to Subtask C can be found below:

- Buda, A.; de Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.N.; Mauri, S.; Marincioni, V.; Gori, V.; Fouseki, K.; Polo López, C.S.; Lo Faro, A.; Egusquiza, A.; Haas, F.; Leonardi, E.; Herrera-Avellanosa, D. Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach. *Sustainability* **2021**, *13*, 2927. https://doi.org/10.3390/su13052927
- Marincioni, V.; Gori, V.; de Place Hansen, E.J.; Herrera-Avellanosa, D.; Mauri, S.; Giancola, E.; Egusquiza, A.; Buda, A.; Leonardi, E.; Rieser, A. How Can Scientific Literature Support Decision-Making in the Renovation of Historic Buildings? An Evidence-Based Approach for Improving the Performance of Walls. *Sustainability* **2021**, *13*, 2266. https://doi.org/10.3390/su13042266
- Rieser, A.; Pfluger, R.; Troi, A.; Herrera-Avellanosa, D.; Thomsen, K.E.; Rose, J.; Arsan, Z.D.; Akkurt, G.G.; Kopeinig, G.; Guyot, G.; Chung, D. Integration of Energy-Efficient Ventilation Systems in Historic Buildings—Review and Proposal of a Systematic Intervention Approach. *Sustainability* **2021**, *13*, 2325. https://doi.org/10.3390/su13042325
- Polo López, C.S.; Lucchi, E.; Leonardi, E.; Durante, A.; Schmidt, A.; Curtis, R. Risk-Benefit Assessment Scheme for Renewable Solar Solutions in Traditional and Historic Buildings. *Sustainability* **2021**, *13*, 5246. https://doi.org/10.3390/su13095246

- Rieser, A.; Leonardi, E.; Haas, F; Pfluger, R. A new decision guidance tool for the adaption of energy retrofit solutions in historic buildings. SBE21 Heritage Conference, Bolzano (Italy) 14-16 April 2021 in *IOP Conference Series: Earth and Environmental Science* (In press)
- Mauri, S.; Pracchi, V. High-performance materials and technological solutions to improve the thermal performance of historic buildings. SBE21 Heritage Conference, Bolzano (Italy) 14-16 April 2021 in *IOP Conference Series: Earth and Environmental Science* (In press)
- de Place Hansen, E.J.; Hansen, T.K.; Soulios, V. Deep renovation of an old single-family house including application of a water repellent agent – a case story. SBE21 Heritage Conference, Bolzano (Italy) 14-16 April 2021 in *IOP Conference Series: Earth and Environmental Science* (In press)
- Polo López, C.; Mobiglia, M. Swiss case studies examples of solar energy compatible BIPV solutions to energy efficiency revamp of historic heritage buildings. SBE21 Heritage Conference, Bolzano (Italy) 14-16 April 2021 in *IOP Conference Series: Earth and Environmental Science* (In press)
- Borderon, J.; Gabillat, A.; Héberlé, E.; Latorre, J. Assessment of Void Insulation Panels for innovative thermal insulation of apartments in heritage buildings. SBE21 Heritage Conference, Bolzano (Italy) 14-16 April 2021 in *IOP Conference Series: Earth and Environmental Science* (In press)

References:

[1] European Council. EUCO 169/14 CO EUR 13 CONCL 5, 23 and 24 October 2014, 2030 CLIMATE AD ENERGY POLICY FRAMEWORK. 2014. Available online: https://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/ec/145397.pdf (accessed on 19 December 2020).

[2] Historic England. Energy Efficiency and Historic Buildings: Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings; English Heritage: Swindon, UK, March **2011**

[3] Webb, A.L. Energy retrofits in historic and traditional buildings: A review of problems and methods. *Renew. Sustain. Energy Rev*. **2017**, 77, 748–759.

[4] Buda, A.; Pracchi, V. Potentialities and criticalities of retrofit guidelines in their application on different case studies. In Proceedings of the 3rd International Conference on Energy Efficiency in Historic Buildings (EEHB2018), Visby, Sweden, 26–27 September **2018**; pp. 283–293.

[5] IEA SHC Task 59. Deep Renovation of Historic Buildings towards Lowest Possible Energy Demand and CO_2 Emission (NZEB). Available online: https://task59.IEA SHC.org/ (accessed on 19 December 2020).

[6] Shah, C. Collaborative Information Seeking: A Literature Review. In Advances in Librarianship Advances in Librarianship; Woodsworth, A., Ed.; Emerald Group Publishing Limited: Bingley, UK, 2017; Volume 32, pp. 3–33.

[7] EN-16883. Conservation of Cultural Heritage-Guidelines for Improving the Energy Performance of Historic Buildings; Comité Europeen de Normalisation: Brussels, Belgium, 2017.

[8] Buda, A.; de Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.N.; Mauri, S.; Marincioni, V.; Gori, V.; Fouseki, K.; Polo López, C.S.; Lo Faro, A.; Egusquiza, A.; Haas, F.; Leonardi, E.; Herrera-Avellanosa, D. Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach. *Sustainability* **2021**, *13*, 2927. https://doi.org/10.3390/su13052927

[9] Herrera-Avellanosa, D.; Haas, F.; Leijonhufvud, G.; Bröstrom, T.; Buda, A.; Pracchi, V.; Webb, A.L.; Hüttler, W.; Troi, A. Deep renovation of historic buildings: The IEA SHC Task 59 path towards the lowest possible energy demand and CO_2 emissions. Int. J. Build. Pathol. Adapt. **2019**, 38, 539–553

[10] ATLAS Interreg Alpine Space project. *Advanced Tools for Low-carbon, high value development of historic architecture in the Alpine Space (https://www.alpine-space.eu/projects/atlas/en/home)*.