Final report

1. Project details

Project title	Danish participation in a new IEA SHC Task 59 - Deep Renovation of Historic Buildings towards lowest possible energy demand and CO_2 emission (NZEB)
File no.	64017-05175
Name of the funding scheme	EUDP
Project managing company / institution	BUILD, AAU
CVR number (central business register)	29102384
Project partners	Ernst Jan de Place Hansen, Jørgen Rose and Kirsten Engelund Thomsen, Department of the Built Environment (former SBi), AAU.
Submission date	16 July 2021

2. Summary

In English:

The main purpose of the IEA SHC Task was to demonstrate the possibilities regarding deep energy renovation of historic buildings in achieving the lowest possible energy demand and thereby CO_2-emissions. The knowledge gained will promote the implementation of several far-reaching renovations of historic buildings.Thereby, Denmark can help meet individual and joint international demands for extensive reductions in CO_2 emissions.

All primary project objectives have been fulfilled, e.g. to develop a solid knowledge base on how to save energy in renovation of historic and protected buildings in a cost efficient way; to identify the energy saving potential of historic and buildings worthy of preservation divided into different typologies of buildings under study (residential, administrative, cultural) and to identify specifically the potential for the use of solar energy (passive and active, heating, cooling and electricity) and promote best practice solutions.

Several reports, conference papers and papers for international journals have been produced. Three Danish examples of deep renovation have been added to the HiBERatlas (Historic Building Energy Retrofit Atlas) database: The Osram Building (a factory / office from 1953 in Copenhagen, which has been converted into a cultural center), Klitgården (a single-family house from 1875 located in Hundested) and Ryesgade 30 (a Copenhagen apartment building from 1896). HiBERatlas has been published (www.hiberatlas.com).

Five working groups were established, each with their own specialty: "exterior walls", "windows", "HVAC", "solar heating and PV" and "strategies”. The Danish team led the windows group and has contributed to all groups with many examples on specific solutions. The work fed into a decision-making tool (HiBERtool), which is a decision-making tool connected to the HiBERatlas. Dissemination of project news and results are carried out on the project website (task59.iea-shc.org) and through the social media Twitter, Facebook and LinkedIn.

In Danish:

Hovedformålet med IEA SHC Task var at demonstrere mulighederne for dyb energirenovering af historiske bygninger for at opnå det lavest mulige energibehov og derved CO2-emissioner. Den opnåede viden vil fremme implementeringen af adskillige dybgående renoveringer af historiske bygninger. Dermed kan Danmark hjælpe med at imødekomme individuelle og fælles internationale krav om omfattende reduktioner i CO_2-emissioner.

Alle primære projektmål er opfyldt, fx at udvikle en solid videnbase om, hvordan man sparer energi ved renovering af historiske og bevaringsværdige bygninger på en omkostningseffektiv måde; at identificere energibesparelsespotentialet for historiske og bevaringsværdige bygninger opdelt i forskellige typer af bygninger, der undersøges (beboelse, administrative, kulturelle) og specifikt at identificere potentialet for brug af solenergi (passiv og aktiv, opvarmning, køling og elektricitet) og fremme ”best practice” løsninger.

Adskillige rapporter, konferencepares og papers til internationale tidsskrifter er produceret. Tre danske eksempler på dyb renovering er tilføjet til databasen HiBERatlas (Historic Building Energy Retrofit Atlas): Osram-bygningen (en fabrik / kontor fra 1953 i København, der er blevet omdannet til et kulturcenter), Klitgården (enkelt familie hus fra 1875 beliggende i Hundested) og Ryesgade 30 (en lejlighedsbygning i København fra 1896). HiBERatlas er blevet offentliggjort (www.hiberatlas.com).

Der blev oprettet fem arbejdsgrupper med hver deres speciale: "udvendige vægge", "vinduer", "HVAC", "solvarme og solceller" og "strategier". Det danske hold var ansvarlig for vindues-gruppen og har bidraget til alle grupper med mange eksempler på specifikke løsninger. Arbejdet indgår i et beslutningsværktøj (HiBERtool), som er et værkstøj, der er forbundet med HiBERatlas. Formidling af nyheder og resultater meddeles på projektets hjemmeside (task59.iea-shc.org) og via de sociale medier Twitter, Facebook og LinkedIn.

3. Project objectives

The key objectives of the project was:

- Develop a solid knowledge base on how to save energy in renovation of historic and protected buildings in a cost efficient way.
- Identify the energy saving potential for historic and protected buildings according to typologies of building studied (residential, administrative, cultural…)
- Identify and assess replicable procedures on how experts can work together with integrated design to maintain the heritage value of the building and at the same time make it energy efficient
- Identify conservation compatible retrofit solutions in a “whole building perspective”
- Identify specifically the potential for the use of solar energy (passive and active, heating, cooling and electricity) and promote best practice solutions
- Identify the policy and marketing strategies to implement the energy saving potential
- Demonstrate good energy solutions in exemplary case studies.

The Task was structured in the following Subtasks:

A. **Knowledge Base**
Collection of Best Practice cases, following the approach of IEA SHC Task 37 and 47. In these projects some quite comprehensive templates were used also including user comfort, environmental aspects and information on the planning and design process. In the new Task specific information about cultural heritage value and conservation also has to be included.
Develop an understanding and demonstration of what is possible in these buildings, when all experts work together towards the same goal.
Assessment of the existing experience. A database will be used to document the knowledge base and in this way also communicate the critical issues in a structured way.
B. **Multidisciplinary planning process**
Identify replicable procedures on how experts can work together with integrated design to maintain both the expression of the building, and at the same time make it energy efficient. This includes also providing feedback from practical application on FprEN 16883: this standard describes a procedure which after a comprehensive diagnosis, narrows down from a long list of potential measures that are assessed on multiple criteria to the final proposed solution in an iterative process by the multidisciplinary design team.
C. **Conservation compatible retrofit solutions and strategies (a holistic view of the building)**
Identify replicable solutions from case studies. Connect and integrate ongoing R&D on conservation compatible retrofit solutions. Assessment of technical solutions from both energy and conservation point of view. It is the intention to make a list of techniques and how to use them and lessons learnt.
D. **Demonstration and dissemination**
Workshop series for different target groups. Guidelines/recommendations for policy makers. A handbook will be written, both a digital and a printed version. Possibly specific case studies for demonstration [to be decided during task definition phase]. The handbook should be accompanied by short videos/e-lessons, introducing the content. Some demonstration sites will be included in the project. Dissemination of results will be done by workshops and articles as well as training activities.

Task 59 was carried out involving experience from several previous projects, e.g. IEA SHC Task 47 'Renovation of non-residential towards NZEB, including integration of solar energy', IEA SHC Task 37 'Advanced housing renovation in domestic buildings', and the EU Horizon 2020 project 'Robust Internal Thermal Insulation of Historic Buildings' (RIBuild, www.ribuild.eu). The objectives of Task 47 was to develop a solid knowledge base on how to renovate non-residential buildings towards the NZEB standards (Net-Zero Energy Buildings) in a sustainable and cost efficient way and to identify the most important market and policy issues as well as marketing strategies for such renovations. The Task 37 objective was to develop a solid knowledge base on how to renovate housings to a very high energy standard and to develop strategies which support market penetrations of such renovations. Task 37 included both technical R&D and market implementation as equal priority areas. The aim of RIBuild was to strengthen the knowledge on how and under what conditions internal thermal insulation is to be implemented in historic buildings, without compromising their architectural and cultural values, with an acceptable safety level against deterioration and collapse of heavy external wall structures. The general objective of RIBuild was to develop effective, comprehensive decision guidelines to optimise the design and implementation of internal thermal insulation in historic buildings across the EU. RIBuild focuses on heavy external walls made of stone, brick and timber framing, as most historic buildings are made of these materials.

4. Project implementation

The Danish participation of Task 59 started 1. October 2017 and the international project ended officially 30. April 2021.

The following meetings and seminars were held (see table 1).

Table 1. Meetings and seminars held in IEA SHC Task 59.

NUMBER AND LOCATION	HOST PARTNERS	DATE	MEETING FOCUS
1ST – EDINBURGH	HES	23-25 Oct 2017	Kick off meeting
2ND – DUBLIN	ICOMOS	01 March 2018	
3RD – VISBY	UU	27-29 Sep 2018	
4TH – COPENHAGEN	SBi/AAU	08-10 April 2019	
5TH – VIENNA	e7	14-15 Oct 2019	
6TH – ONLINE	EURAC	23-24 April 2020	
7TH – ONLINE	EURAC	19-21 Oct 2020	
8TH – ONLINE	EURAC	31 May-01 June 2021	Final meeting

Some of the meetings were held in connection with seminars and conferences.

The Visby meeting in September was planned to follow the EEHB Conference on Energy Efficiency in Historic Buildings from 26-27 September 2018, giving project participants the opportunity to participate and contribute in/to the conference.

In connection with the fourth meeting in Copenhagen a stakeholder event was held 8 April 2019 at the Fortifications Depot in Copenhagen. The stakeholder event included Danish stakeholders and international participants. The project was presented and afterwards there were a discussion on energy renovation of historic buildings. Furthermore, the EU project RIBuild "Robust Internal Thermal Insulation of Historic Buildings" was presented. In total approx. 40 people attended the meeting.

The fifth meeting of IEA Task 59 was held 14-15 October in Vienna, Austria in connection with the conference: 8th European Congress on the Use, Management and Conservation of Buildings of Historical Value - BHÖ congress 2019 on 16-17 October 2019.

Originally, it was the intention that the final meeting would be held in conjunction with the SBE21 Heritage conference “Renovating historic buildings for a low-carbon built heritage” (14-16 April 2021). However, the meeting was postponed at the last minute in the hope that participants would be able to meet face-to-face at a later date. Unfortunately, this was not possible and the last meeting was instead held online on 31 May-1 June 2021.

All milestones of the project were achieved. The project was delayed 4 months due to COVID-19.

Figure 1. Meeting and networking in Copenhagen, April 2019.

5. Project results

Project results

All primary project objectives have been fulfilled, i.e.

- Develop a solid knowledge base on how to save energy in renovation of historic and protected buildings in a cost efficient way.
- Identify and assess replicable procedures on how experts can work together with integrated design to maintain the heritage value of the building and at the same time make it energy efficient
- Identify conservation compatible retrofit solutions in a “whole building perspective”
- Identify specifically the potential for the use of solar energy (passive and active, heating, cooling and electricity) and promote best practice solutions
- Demonstrate good energy solutions in exemplary case studies.

Several reports and papers have been produced as part of the project. In the following the main findings of each subtask is described.

Subtask A:

In Subtask A, three Danish examples have been added to the HiBERatlas (Historic Building Energy Retrofit Atlas) database, evolved as part of the project: The Osram Building (a factory / office from 1953 in Copenhagen, which has been converted into a cultural center), Klitgården (a single-family house from 1875 located in Hundested) and Ryesgade 30 (a Copenhagen apartment building from 1896).

HiberAtlas has been published (www.hiberatlas.com), and the database is constantly being expanded as new case studies are added and ongoing case studies are completed. At present the database contains 58 projects and within the next few months this number should increase beyond 70.

The three Danish case studies are described below.

The Osram building

Figure 2. The Osram building after renovation.

The Osram building was originally built in 1953 as an office and warehouse for A/S Dansk Osram. When the building was originally erected it was a breath of fresh air to an otherwise grey, worn down and monotone part of Copenhagen. Today the building acts as a culture and community centre and exploits daylight and natural ventilation to improve the indoor climate. In connection with the Climate Change Conference (COP15 2009), the City of Copenhagen initiated a strategic cooperation with a number of Danish enterprises for the purpose of mutual profiling on climate-friendly buildings. The target was to minimize the resources required (and, consequently, the CO_2 emissions) both during construction and upkeep. The renovation of the OSRAM Culture Centre was a part of this cooperation and acted as a spearhead for possibilities and methods of renovating old industrial and commercial buildings worth preserving. The overarching aim was also to reduce energy consumption by improvement of the thermal envelope, improving ventilation and utilizing energy saving lighting.

Klitgaarden, Hundested

Figure 3. Klitgaarden, before renovation.

Klitgaarden is located in Hundested, in the northern part of Zealand about seventy kilometers northwest of Copenhagen. Klitgaarden is a free standing single-family house from 1875 in two stories with a total floor area of 221 m^2. The building was erected with solid masonry walls and a foundation of granite boulders on top of a stone foundation. The renovation project of the building aimed for a minimum heating requirement and a preservation of original facade details. It included thermal insulation of the facades, roof and ground floor, new windows, floor heating, mechanical ventilation, installing a drain around the building and water proofing the foundation. It was finished in 2016. In 2018, the facades were hydrophobized externally to reduce the wind driven rain load. The renovation was motivated by a very high-energy demand for heating and in general the fact that the house had not been used during the last twenty years.

Ryesgade 30 A-C

Figure 4. Ryesgade 30, before renovation.

This typical Copenhagen residential building from the end of the 19th century, was outdated and in need of renovation. The indoor climate was poor and the energy consumption quite high. After a renovation that included new windows, thermal insulation on walls and ceiling, improved air-tightness, mechanical ventilation with heat recovery, and photovoltaics on the roof, the building achieved a 63% reduction in energy demand.

In addition to the HiBERatlas, Subtask A deliverables also include an in-depth assessment report of all the different renovation interventions carried out in 69 completed case studies. The report compares the 69 cases regarding regional distribution, size, level of protection, building period and year of renovation, heritage value assessment, reason for refurbishment and lessons learned. The report also covers a detailed evaluation of individual energy efficiency measures (walls, roof, floor and windows), HVAC (heating, domestic hot water and ventilation) and renewable energy systems (solar thermal, photovoltaics, geothermal and biomass). For each of these categories the individual solutions across the 69 case studies are compared and general conclusions are drawn. Below is a figure from the report showing examples from projects where windows were replaced with new handcrafted windows that were fabricated to match the original designs as far as possible.

Figure 5. Examples of solutions where windows were replaced by handcrafted replicas.

Subtask B

In Subtask B, a lot of information has been collected about tools, methods and guidelines that are available in the participating countries and beyond. A handbook is under preparation, as an aid to the international *Standard EN 16883: Conservation of Cultural Heritage - Guidelines for improving the energy performance of historic buildings*. The handbook will contain examples illustrating the practical application of the standard.

The handbook follows the systematic approach outlined in EN 16883. It describes how the standard can be applied in practice with chapters on heritage value assessment, building survey and holistic assessment of energy efficiency measures. The handbook draws on the experience from a team of international leading experts in the field of energy efficiency in historic buildings. This handbook is an essential guide for professionals working with the refurbishment of existing buildings: architects, engineers, heritage consultants, building surveyors and professional property owners. It points at the possibilities to lower the energy use in existing buildings without compromising their heritage values, and provides practical guidance on how to identify, assess and select energy retrofit measures through a multidisciplinary planning process. Throughout the handbook case studies illustrate how the different stages of the planning process can be carried out in practice. The text is accompanied by best practice examples, illustrations and links to written and online resources.

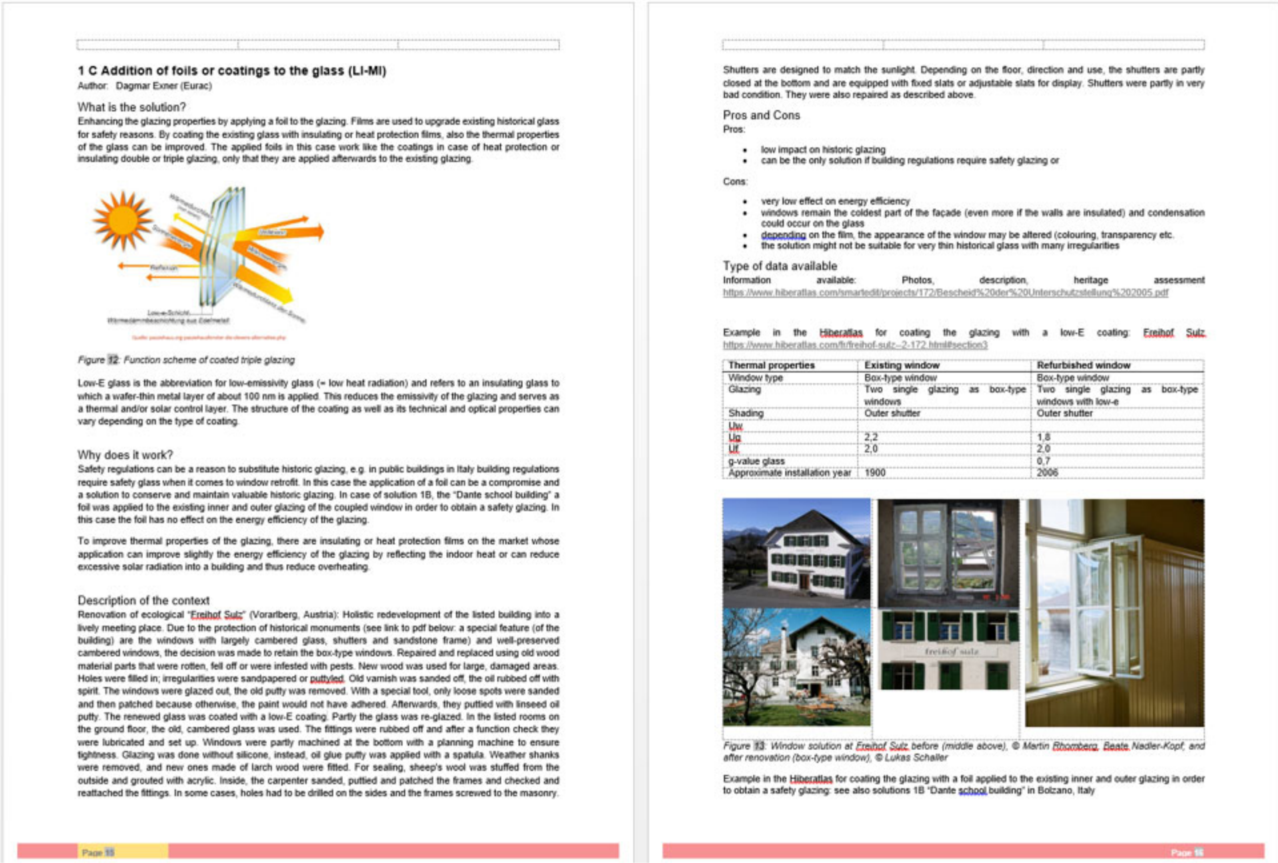
Furthermore in Subtask B, participants were asked to supply information on building energy simulation (BES) tools, LCA/LCC tools, literature related to renovation of historic buildings and guidelines related to renovation of historic buildings. All this information has been gathered in 4 fact sheets:

- Fact sheet BES tools
- Fact sheet LCA LCC tools
- Fact sheet Literature
- Fact sheet Guidelines

Subtask C

In Subtask C, five working groups were established, each with their own specialty: "exterior walls", "windows", "HVAC", "solar heating and PV" and "strategies”. The Danish team led the windows group and has contributed to all groups with many examples on specific solutions. The work of these groups fed into a decision-making tool (HiBERtool) and all five groups have produced reports containing the results.

The HiBERtool is basically a decision-making tool connected to the HiBERatlas. Based on all the individual measures documented in the HiBERatlas regarding each of the categories (exterior walls, windows, HVAC, solar heating and PV and strategies) a decision tree has been made, making it possible to determine which specific solutions can be relevant in a given situation. This means, that if someone is planning an intervention on a historic building, the HiBERtool can be used to quickly determine which solutions could be relevant to take a closer look at. Solutions can be printed as PDF-files directly from the tool and below is an example showing a solution from the windows group “Additions of foils or coatings to the glass”:



1 C Addition of foils or coatings to the glass (LI-MI)
Author: Dagmar Exner (Eurac)

What is the solution?
Enhancing the glazing properties by applying a foil to the glazing. Films are used to upgrade existing historical glass for safety reasons. By coating the existing glass with insulating or heat protection films, also the thermal properties of the glass can be improved. The applied foils in this case work like the coatings in case of heat protection or insulating double or triple glazing, only that they are applied afterwards to the existing glazing.

Figure 12: Function scheme of coated triple glazing

Low-E glass is the abbreviation for low-emissivity glass (= low heat radiation) and refers to an insulating glass to which a wafer-thin metal layer of about 100 nm is applied. This reduces the emissivity of the glazing and serves as a thermal and/or solar control layer. The structure of the coating as well as its technical and optical properties can vary depending on the type of coating.

Why does it work?
Safety regulations can be a reason to substitute historic glazing, e.g. in public buildings in Italy building regulations require safety glass when it comes to window retrofit. In this case the application of a foil can be a compromise and a solution to conserve and maintain valuable historic glazing. In case of solution 1B, the "Dante school building" a foil was applied to the existing inner and outer glazing of the coupled window in order to obtain a safety glazing. In this case the foil has no effect on the energy efficiency of the glazing.

To improve thermal properties of the glazing, there are insulating or heat protection films on the market whose application can improve slightly the energy efficiency of the glazing by reflecting the indoor heat or can reduce excessive solar radiation into a building and thus reduce overheating.

Description of the context
Renovation of ecological "Freihof Sulz" (Vorarlberg, Austria): Holistic redevelopment of the listed building into a lively meeting place. Due to the protection of historical monuments (see link to pdf below: a special feature (of the building) are the windows with largely cambered glass, shutters and sandstone frame) and well-preserved cambered windows, the decision was made to retain the box-type windows. Repaired and replaced using old wood material parts that were rotten, fell off or were infested with pests. New wood was used for large, damaged areas. Holes were filled in; irregularities were sandpapered or puttyled. Old varnish was sanded off, the oil rubbed off with spirit. The windows were glazed out, the old putty was removed. With a special tool, only loose spots were sanded and then patched because otherwise, the paint would not have adhered. Afterwards, they puttied with linseed oil putty. The renewed glass was coated with a low-E coating. Partly the glass was re-glazed. In the listed rooms on the ground floor, the old, cambered glass was used. The fittings were rubbed off and after a function check they were lubricated and set up. Windows were partly machined at the bottom with a planning machine to ensure tightness. Glazing was done without silicone, instead, oil glue putty was applied with a spatula. Weather shanks were removed, and new ones made of larch wood were fitted. For sealing, sheep's wool was stuffed from the outside and grouted with acrylic. Inside, the carpenter sanded, puttied and patched the frames and checked and reattached the fittings. In some cases, holes had to be drilled on the sides and the frames screwed to the masonry.

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Shutters are designed to match the sunlight. Depending on the floor, direction and use, the shutters are partly closed at the bottom and are equipped with fixed slats or adjustable slats for display. Shutters were partly in very bad condition. They were also repaired as described above.

Pros and Cons
Pros:

- low impact on historic glazing
- can be the only solution if building regulations require safety glazing or

Cons:

- very low effect on energy efficiency
- windows remain the coldest part of the façade (even more if the walls are insulated) and condensation could occur on the glass
- depending on the film, the appearance of the window may be altered (colouring, transparency etc.
- the solution might not be suitable for very thin historical glass with many irregularities

Type of data available
Information available: Photos, description, heritage assessment https://www.hiberatlas.com/smartedit/projects/172/Bescheid%20der%20Unterschutzstellung%202005.pdf

Example in the Hiberatlas for coating the glazing with a low-E coating: Freihof Sulz https://www.hiberatlas.com/fr/freihof-sulz--2-172.html#section3

Thermal properties	Existing window	Refurbished window
Window type	Box-type window	Box-type window
Glazing	Two single glazing as box-type windows	Two single glazing as box-type windows with low-e
Shading	Outer shutter	Outer shutter
Uw		
Ug	2,2	1,8
Uf	2,0	2,0
g-value glass		0,7
Approximate installation year	1900	2006

Figure 13: Window solution at Freihof Sulz before (middle above), © Martin Rhomberg, Beate Nadler-Kopf, and after renovation (box-type window), © Lukas Schaller

Example in the Hiberatlas for coating the glazing with a foil applied to the existing inner and outer glazing in order to obtain a safety glazing: see also solutions 1B "Dante school building" in Bolzano, Italy

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Figure 6. An example from HiBERtool showing a solution from the windows group "Additions of foils or coatings to the glass":

Several peer reviewed papers have been written concerning these topics – see under dissemination.

Subtask D

In Subtask D, AAU has been co-lead with the Scottish partner (Historic Environment Scotland).

Day-to-day dissemination of project news and results have been carried out on the project website (task59.iea-shc.org) and through the social media channels Twitter, Facebook and LinkedIn. AAU has been responsible for the LinkedIn profile and partners providing blogs to the website. In addition, AAU also contributed with input to the Newsletter and website in general.

Conference papers

Several conference papers were finalized. Below is mentioned the Danish contributions.

EURAC Research arranged a conference with the support of Interreg Alpine Space ATLAS, IEA-SHC Task 59, and HyLAB and hosted SBE21 "Sustainable Built Heritage: Renovating historic buildings for a low-carbon built heritage" in Bolzano, Italy from 14-16 April 2021. The conference was dedicated to the sustainable improvement of the built heritage. With a focus on renovating historic buildings, the conference aimed at fostering a multidisciplinary dialogue between scholars and practitioners in different field of energy efficiency and historic building conservation in order to find together the solutions that will bring our common heritage into a sustainable future. AAU contributed with two papers to the conference:

Rose, J. and Thomsen, K. E. 2021. *Comprehensive energy renovation of two Danish heritage buildings within IEA SHC Task 59*, SBE21 "Sustainable Built Heritage: Renovating historic buildings for a low-carbon built heritage" in Bolzano, Italy 14-16 April 2021, https://sbe21heritage.eurac.edu/paper-309343/.

Abstract: Historic and heritage buildings present a significant challenge when it comes to reducing energy consumption to mitigate climate change. These buildings need careful renovation and increasing their energy efficiency is often associated with a high level of complexity, since consideration for heritage values can often reduce and impede possibilities and sometimes even rule out certain improvements completely. Despite these issues, many such renovation projects have already been carried out, and therefore the IEA SHC Task 59 project (Renovating Historic Buildings Towards Zero Energy) in cooperation with Interreg Alpine Space ATLAS has developed a tool for sharing these best-practice examples – the HiBERatlas (Historical Building Energy Retrofit Atlas). The Internet platform serves as a best-practice database of both individual energy efficiency measures and whole-building renovation projects. This paper presents two of the Danish projects featured in HiBERatlas. The first project, Ryesgade 30, is a Copenhagen apartment building with a preservation worthy period brick façade. The second project is the Osram Building, a listed Copenhagen office building from 1959 with a protected façade, which today acts as a culture centre. Both renovation projects achieved significant energy savings and consequently CO2-emission reductions, and the indoor climate in both buildings have also improved significantly.

The paper "Comprehensive energy renovation of two Danish heritage buildings within IEA SHC Task 59" was selected as one of the 10 best papers of the conference and therefore an extended version of the paper will be submitted to a Special Issue of MDPIs journal Heritage dedicated to "Energy Efficiency in Historic Buildings".

de Place Hansen, E. J., Hansen, T. K. and Soulios, V. 2021. *Deep renovation of an old single-family house including application of an water repellent agent – a case story*, SBE21 "Sustainable Built Heritage: Renovating historic buildings for a low-carbon built heritage" in Bolzano, Italy 14-16 April 2021, https://sbe21heritage.eurac.edu/paper-590488/.

Abstract: The 145 year old rural case building presented in this paper has undergone a deep renovation including internal insulation of the external walls to reduce the heat loss and improve the indoor thermal comfort. The internal insulation was a PUR-based insulation with channels of calcium silicate, experiencing to some extent capillary active behaviour. Sensors were installed between the existing wall and the internal insulation to monitor the development of hygrothermal conditions. The external façade was later hydrophobized with a water repellent agent to minimize the wind driven rain load. Measurements show that it takes time to get rid of the built-in moisture due to the application of internal insulation, however the moisture content expressed in relative humidity is slowly decreasing, although still high about two years after hydrophobizing the wall. Simulations show that the order of hydrophobizing the wall and applying internal insulation is important to promote drying of the wall.

In addition, Ernst Jan de Place Hansen and Jørgen Rose was both on the scientific committee of the conference and helped with the review process.

At the 12th Nordic Symposium on Building Physics (NSB 2020), held at 6-9 Sep 2020 in Tallinn, Estonia (and online) (nsb2020.org), AAU contributed with one paper on guidelines for internal insulation of historic buildings:

de Place Hansen, E. J., Møller, E. B. & Ørsager, M. 2020. *Guidelines for internal Insulation of historic Buildings,* 12th Nordic Symposium on Building Physics (NSB 2020) (Kurnitski, J. & Kalamees, T., ed.). E3S Web of Conferences, 172, 201004, EDP Sciences. https://doi.org/10.1051/e3sconf/202017201004

Abstract: Internal insulation is often the only possible solution when improving the thermal performance of solid walls of historic buildings, as many of these have architectural or cultural values. However, as internal insulation is regarded risky from a moisture perspective, guidelines are needed. The paper presents a new set of guidelines that combine written guidelines, a web-based preliminary assessment tool and a website that can be used independently of each other. The website provides simple ways of assessing the building to determine whether internal insulation is feasible in the specific case and what needs to be done before it can be applied. It also describes different failure mechanisms. The website includes links to information (written guidelines), described for different types of users, depending on their level of expertise. The web tool is based on an extensive number of simulations of hygrothermal conditions within a solid wall depending on location, orientation, wall type and thickness, and insulation type and thickness. The web tool determines the risk for mould and algae growth in a probabilistic way and determines heat loss and CO2 emission before and after renovation through 1 m² of the wall. The guidelines, the website and the web tool are developed in RIBuild, a research project funded by the European Commission, running from 2015 to 2020.

At the 3rd International Conference on Energy Efficiency of Historic Buildings (EEHB 2018), held at 26-27 Sep 2018 in Visby, Sweden, and hosted by Uppsala University (Task 59 partner), AAU contributed with one paper to the conference related to renovation of historic buildings in general:

de Place Hansen, E. J. & Wittchen, K. B. (2018). *Energy savings due to internal façade insulation in historic buildings.* 3rd Int. Conf. on Energy Efficiency in Historic Buildings, 26-27 Sep 2018, Visby, Sweden. (T. Broström, L. Nilsen, S. Carlsten ed.). pp. 22-31. http://eehb2018.com/conference-report/

Abstract: Historic buildings contribute heavily to the energy consumption of the existing European building stock. Application of internal insulation offers a possibility to improve the historic buildings' energy performance, without compromising the buildings' architectural appearance. The paper presents desktop analyses of potential energy savings in historic buildings, carried out using standard boundary conditions for calculation of energy savings, as prescribed in the European building energy performance certification schemes. Internal insulation of the building's façades can potentially reduce the theoretical energy demand for space heating by 9 to 43 percent compared to the energy demand of the original building if installed moisture-safe. Combined with other commonly used energy saving measures, 43–75 percent reduction of the energy demand was estimated. This shows that internal insulation of external walls have the potential of contributing considerable to the overall energy savings in historic buildings and highlights the need for such measures.

In addition, Ernst Jan de Place Hansen was in the scientific committee of the conference and helped with the review process.

Journal papers

Several journal papers were finalized. Below is mentioned the Danish contributions:

Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach - https://www.mdpi.com/2071-1050/13/5/2927

A. Buda, E.J. de Place Hansen, A. Rieser, E. Giancola, V.N. Pracchia, S. Mauri, V. Marincioni, V. Gori, K. Fouseki, C.S. Polo López, A. Lo Faro, A. Eguisquiza, F. Haas, E. Leonardi, D. Herrera-Avellanosa

Historic, listed, or unlisted, buildings account for 30% of the European building stock. Since they are complex systems of cultural, architectural, and identity value, they need particular attention to ensure that they are preserved, used, and managed over time in a sustainable way. This implies a demand for retrofit solutions able to improve indoor thermal conditions while reducing the use of energy sources and preserving the heritage significance. Often, however, the choice and implementation of retrofit solutions in historic buildings is limited by socio-technical barriers (regulations, lack of knowledge on the hygrothermal behaviour of built heritage, economic viability, etc.). This paper presents the approach devised in the IEA-SHC Task 59 project (Renovating Historic Buildings Towards Zero Energy) to support decision makers in selecting retrofit solutions, in accordance with the provision of the EN 16883:2017 standard. In particular, the method followed by the project partners to gather and assess compatible solutions for historic buildings retrofitting is presented. It focuses on best practices for walls, windows, HVAC systems, and solar technologies. This work demonstrates that well-balanced retrofit solutions can exist and can be evaluated case-by-case through detailed assessment criteria. As a main result, the paper encourages decision makers to opt for tailored energy retrofit to solve the conflict between conservation and energy performance requirements.

How Can Scientific Literature Support Decision-Making in the Renovation of Historic Buildings? An Evidence-Based Approach for Improving the Performance of Walls - https://www.mdpi.com/2071-1050/13/4/2266

V. Marincioni, V. Gori, E.J. de Place Hansen, D. Herrera-Avellanosa, S. Mauri, E. Giancola, A. Egusquiza, A. Buda, E. Leonardi, A. Rieser

Buildings of heritage significance due to their historical, architectural, or cultural value, here called historic buildings, constitute a large proportion of the building stock in many countries around the world. Improving the performance of such buildings is necessary to lower the carbon emissions of the stock, which generates around 40% of the overall emissions worldwide. In historic buildings, it is estimated that heat loss through external walls contributes significantly to the overall energy consumption, and is associated with poor thermal comfort and indoor air quality. Measures to improve the performance of walls of historic buildings require a balance between energy performance, indoor environmental quality, heritage significance, and technical compatibility. Appropriate wall measures are available, but the correct selection and implementation require an integrated process throughout assessment (planning), design, construction, and use. Despite the available knowledge, decision-makers often have limited access to robust information on tested retrofit measures, hindering the implementation of deep renovation. This paper provides an evidence-based approach on the steps required during assessment, design, and construction, and after retrofitting through a literature review. Moreover, it provides a review of possible measures for wall retrofit within the deep renovation of historic buildings, including their advantages and disadvantages and the required considerations based on context.

Integration of Energy-Efficient Ventilation Systems in Historic Buildings—Review and Proposal of a Systematic Intervention Approach - https://www.mdpi.com/2071-1050/13/4/2325

Rieser, R. Pfluger, A. Troi, D. Herrera-Avellanosa, K.E. Thomsen, J. Rose, Z.D. Arsan, G.G. Akkurt, G. Kopeinig, G. Guyot, D. Chung

Historic building restoration and renovation requires sensitivity to the cultural heritage, historic value, and sustainability (i.e., building physics, energy efficiency, and comfort) goals of the project. Energy-efficient ventilation such as demand-controlled ventilation and heat recovery ventilation can contribute to the aforementioned goals, if ventilation concepts and airflow distribution are planned and realized in a minimally invasive way. Compared to new buildings, the building physics of historic buildings are more complicated in terms of hygrothermal performance. In particular, if internal insulation is applied, dehumidification is needed for robust and risk-free future use, while maintaining the building's cultural value. As each ventilation system has to be chosen and adapted individually to the specific building, the selection of the appropriate system type is not an easy task. For this reason, there is a need for a scientifically valid, systematic approach to pair appropriate ventilation system and airflow distribution solutions with historical buildings. This paper provides an overview of the interrelationships between heritage conservation and the need for ventilation in energy-efficient buildings, regarding building physics and indoor environmental quality. Furthermore, a systematic approach based on assessment criteria in terms of heritage significance of the building, building physics (hygrothermal performance), and building services (energy efficiency, indoor air quality, and comfort rating) according to the standard EN 16883:2017 are applied.

Reports

Several reports were finalized in the project.

A – Case Studies Assessment Report

B – EN 16883 Handbook

C – Part I – Introduction

C – Part II – Windows

C – Part III – Walls

C – Part IV – HVAC

C – Part V – Solar

D – Subtask 'D' Final Report

Blogs

An important part of the website was the Task59 blog, available on https://task59.iea-shc.org/blog. This was published approximately monthly, starting in November 2019. Partners had the chance to write a blog about an area of research, announcement or similar.

Table 2. Blog articles published throughout the project.

BLOG TITLE	PARTNER	DATE	AUTHORS
THE EFFECT OF CLIMATE CHANGE ON RETROFITTED HISTORIC BUILDINGS: THERMAL MASS, NATURAL VENTILATION AND OVERHEATING RISK	EURAC	Nov 19	L. Hao, D. Herrera, A. Troi
REPORTING ON NATIONAL FRENCH CONFERENCE ON RESPONSIBLE RETROFITTING OF HISTORIC BUILDINGS	Cerema	Dec 19	J. Borderon, E. Héberlé
DYNAMIC THERMAL AND HYGROMETRIC SIMULATION OF HISTORICAL BUILDINGS: CRITICAL FACTORS AND POSSIBLE SOLUTIONS	PoliMi IETB	Jan 20	F. Leonforte
DECISION SUPPORT TOOL FOR INNOVATIVE AND SUSTAINABLE RENOVATION OF HISTORIC BUILDINGS (HISTOOL) SUMMARY	EEHB2018	Feb 20	W. Hüttler, D. Bachner, G. Hofer, M. Krempl, G. Trimmel, I. Wall
THE ROP ERDF SICILY 2014/2020 FOR PLANNING THE ENERGY RETROFIT OF 106 PUBLIC HISTORIC BUILDINGS	PoliMi CHPC	March 20	A. Buda, V. Pracchi, R. Sannasardo
RIBuild guidelines for internal insulation of historic buildings	AAU	April 20	E.J. de Place Hansen

A SPATIAL-BASED APPROACH FOR ENHANCING THE ENERGY RENOVATION OF HISTORIC SETTLEMENTS	EURAC	June 20	E. Lucchi, A. Troi
SWEDEN LAUNCHES A NEW STAGE OF THE NATIONAL RESEARCH PROGRAM ON ENERGY EFFICIENCY IN HISTORIC BUILDINGS	UU	July 20	T. Broström
OLD BUILDINGS CAN'T BE ENERGY EFFICIENCY, RIGHT?	HES	Aug 20	L. Angelaka
SBE21 HERITAGE CONFERENCE, THE FINAL EVENT OF TASK59	EURAC	Oct 20	D. Herrera, A. Troi
EMBEDDING THERMAL COMFORT INTO RETROFITTING DESIGN	UCL	Nov 20	A. Petsou
THERMAL PERFORMANCE OF HISTORICAL MASONRY STRUCTURES: EXPERIMENTAL DATA AND NUMERICAL MODELLING	UniCt	Dec 20	A. Lo Faro, V. Constanzo, G. Evola, F. Nocera
BIPV IN DIALOGUE WITH HISTORY	SUPSI	Jan 21	C.S. Polo Lopex, P. Corti, P. Bonomo
BRIGHTLY COLORED SOLAR MODULES FOR BUILDING FACADES: STATE OF DEVELOPMENT OF MORPHOCOLOR® TECHNOLOGY	Fraunhofer ISE	Feb 21	T. Kroyer, A. Dinkel
WEBTOOL TO HELP OWNERS AND DESIGN PROFESSIONALS TO CHARACTERIZE THE QUALITIES AND NEEDS OF HISTORICAL RESIDENTIAL BUILDINGS WITH HERITAGE VALUE	Uni Lou	March 2021	D. Stiernon, S. Altomonte
NON-DESTRUCTIVE TECHNIQUES AND TOOLS FOR THE THERMAL CHARACTERISATION OF HISTORIC BUILDINGS	CARTIF	April 2021	S. Álvarez-Díaz
SBE21 HERITAGE: FINAL CONFERENCE KEY MESSAGES	EURAC	June 2021	A. Troi, D. Herrera

LinkedIn, Twitter, Facebook

Twitter, Facebook and LinkedIn were used as social media channels. The social media has had regular posts, with good interaction over the project duration. Linking to different partner organizations has enabled a linking of issues and relevant topics.

Trade journal articles

The Danish team has written an article for HVAC Magasinet, June 2021 – in Danish:

Vidtgående renovering af historiske bygninger mod lavest muligt energibehov og CO_2 udledning
(In English: Deep renovation of historic buildings to reach lowest possible energy demand and CO_2 emission)
http://ipaper.ipapercms.dk/TechMedia/HVACMagasinet/2021/?page=22

Further, the project has been mentioned in an article for Bygge- og Anlægsavisen, Feb 2020 – in Danish:

Hvordan kan energiforbruget reduceres i historiske bygninger?
(In English: How can the energy use be reduced in historic buildings?)
https://bygge-anlaegsavisen.dk/hvordan-kan-energiforbruget-reduceres-i-historiske-bygninger-

Finally, the project has been mentioned in an article for Energiforum Danmark, Feb 2020 – in Danish:

Når energiforbruget i historiske bygninger skal reduceres
(In English: When the energy demand in historic buildings is to be reduced)
https://www.energiforumdanmark.dk/nyt/2020/nar-energiforbruget-i-historiske-bygninger-skal-reduceres/

Newsletters

The newsletter has been published from 2019 to 2021, resulting in 8 issues. The newsletter has 100 subscriptions at the time of writing this report. The first newsletter was published in Spring 2019, which gave an introduction to the project and described the partner meetings and activities which happened until then. Subsequent newsletters gave updates about the project meetings, the partner organisations as well as events and activities. Features included information about the expert meetings, publications and external events.

All deliverables described will be uploaded on the website as soon as approval from the EXCO exists: http://task59.iea-shc.org.

6. Utilisation of project results

The project involves participation in the IEA project, so there is no apparent technology added value for users. The project has generated some of the necessary knowledge to help Denmark to meet stringent national energy policy objectives on energy retrofit of the historic building stock. Thereby, Denmark can help meet individual and joint international demands for extensive reductions in CO_2 emissions.

The project has had the purpose of securing Danish participation in an IEA project and did not have the purpose to develop commercial products. However, it should not be excluded that future methods developed during the project can be commercialized at a later stage.

The Hiberatlas will be used in our education in AAUs “Master in Building Physics”.

The Danish participation did not involve PhD-students.

7. Project conclusion and perspective

The main purpose of the IEA SHC Task was to demonstrate the possibilities regarding deep energy renovation of historic buildings in achieving the lowest possible energy demand and thereby CO_2-emissions. The knowledge gained will promote the implementation of several far-reaching renovations of historic buildings.Thereby, Denmark can help meet individual and joint international demands for extensive reductions in CO_2 emissions.

All primary project objectives have been fulfilled, i.e. to develop a solid knowledge base on how to save energy in renovation of historic and protected buildings in a cost efficient way; to identify the energy saving potential of historic and worthy of preservation buildings divided into different typologies of buildings under study (residential, administrative, cultural) and to identify specifically the potential for the use of solar energy (passive and active, heating, cooling and electricity) and promote best practice solutions.

Several reports, conference papers and papers for international journals have been produced. Three Danish examples of deep renovation have been added to the HiBERatlas (Historic Building Energy Retrofit Atlas) database: The Osram Building (a factory / office from 1953 in Copenhagen, which has been converted into a cultural center), Klitgården (a single-family house from 1875 located in Hundested) and Ryesgade 30 (a Copenhagen apartment building from 1896). HiBERatlas has been published (www.hiberatlas.com).

Five working groups were established, each with their own specialty: "exterior walls", "windows", "HVAC", "solar heating and PV" and "strategies”. The Danish team led the windows group and has contributed to all groups with many examples on specific solutions. The work fed into a decision-making tool (HiBERtool), which is a tool connected to the HiBERatlas. Dissemination of project news and results are carried out on the project website (task59.iea-shc.org) and through the social media Twitter, Facebook and LinkedIn.

Task 59 was organised as an international network project, expecting to encourage greater international co-operation concerning research and knowledge related to extensive energy retrofit of historic building projects. The project could be instrumental in ushering in deep renovation of historic building and break down some of the barriers that exist in this area. At a national level this could result in large energy savings, since Danish enterprises will be able to access the latest knowledge and information about good and efficient examples of renovation.

One of the main results from the project is the evaluation of innovative overall solutions for extensive energy retrofit of existing historic buildings, which can form the basis for future renovation projects. This allows the results of the project to help reducing gross energy consumption in the existing Danish building mass, so that the overall energy policy goals can be obtained.

8. Appendices

TASK 59
RENOVATING HISTORIC BUILDINGS
TOWARDS ZERO ENERGY

You can sign up to our seasonal newsletters here:
http://eepurl.com/glyfBr

Follow us on Twitter: @HistoricNZEB
Like us on Facebook: HistoricNZEB
Connect with us on LinkedIn: HistoricNZEB
Email us: task59@eurac.edu
Check out our website: http://task59.iea-shc.org

HISTORIC ENVIRONMENT SCOTLAND | ÀRAINNEACHD EACHDRAIDHEIL ALBA

List of partners

ABBREVIATION	PARTNER	COUNTRY
AAU	Aalborg University, Department of the Built Environment (former SBi)	Denmark
BBRI	Belgian Building Research Institute	Belgium
CARTIF	CARTIF	Spain
Cerema	CEREMA	France
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas	Spain
DU	Drexel University	United States of America
e7	e7 Energy, Innovation & Engineering	Austria
EURAC	EURAC Research	Italy
FHA	Flanders Heritage Agency	Belgium
Fraunhofer ISE	Fraunhofer Institute for Solar Energy Systems	Germany
HES	Historic Environment Scotland	United Kingdom
ICOMOS	ICOMOS Ireland	Ireland
IIT	Izmir Institute of Technology	Turkey
PoliMi CHPC	Politecnico Milano University, Cultural Heritage Planned Conservation	Italy
PoliMi IETB	Politecnico Milano University, Innovative Energy Technologies for Buildings	Italy
SUPSI	University of Applied Sciences and Arts of Southern Switzerland	Switzerland
Tecnalia	Tecnalia	Spain
UCL	University College London	United Kingdom
UIBK	Universität Innsbruck	Austria
UniCt	Università di Catania	Italy
Uni Fer	Università di Ferrara	Italy
Uni G	Università di Genova	Italy
Uni Lou	Université catholique de Louvain	Belgium
UU	Uppsala University	Sweden