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IEA-EBC Annex 76

Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO2 Emissions

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Zusammenfassung

Das Hauptziel des gemeinsamen Projekts IEA EBC Annex 76 / IEA-SHC Task 59 ist es, denkmalverträgliche energetische Sanierungsansätze und Technologien für historische – nicht notwendigerweise denkmalgeschützte – Gebäude mit geringer Energieeffizienz und geringem Komfort zu finden. Um dieses Ziel zu erreichen, wurde das IEA-EBC Annex 76/ IEA-SHC Task 59 Projekt in 4 Subtasks (A-D) gegliedert, mit dem Ziel, eine solide Wissensbasis zu entwickeln, wie durch die Renovierung historischer Gebäude (HG) Energie eingespart werden kann, wobei der Bedarf - auch dank der Optimierung der passiven und aktiven Solarnutzung - in Richtung NZEB deutlich gesenkt werden kann. Die Methodik basierte auf der Sammlung und Dokumentation von Best-Practice-Beispielen, die das Energieeinsparpotenzial nach Gebäudetypologien aufzeigten, um replizierbare Verfahren zu bewerten, die die Energieeffizienz erheblich verbessern und gleichzeitig die kulturelle Bedeutung und die Werte des Gebäudes erhalten (Subtask ST-A); um fortschrittliche Werkzeuge zu identifizieren, die diese Verfahren unterstützen (Subtask ST-B), und um Informationen über denkmalverträgliche Sanierungsstrategien zu bewerten und zu sammeln, wobei die Nutzung von Solarenergie, passive und aktive Strategien - Heizung, Kühlung und Strom - berücksichtigt wurden (Subtask ST-C). Eine Arbeitsgruppe aus multidisziplinären Experten hat sich mit der Förderung von Best-Practice-Anwendungen und -Lösungen befasst (Subtask ST-D). Als Ergebnis dieser Arbeit wurde eine weltweite Online-Datenbank mit Best-Practice-Beispielen entwickelt, der Historic Building Energy Retrofit Atlas HiBERatlas. Diese Datenbank enthält beispielhafte energieeffiziente Maßnahmen in historischen Gebäuden sowie eine Zusammenstellung vorhandener Unterlagen zu Instrumenten, Methoden und Leitlinien zur Verbesserung der Energieeffizienz historischer Gebäude (HG) und Arbeitsverfahren für die Auswahl von Maßnahmen zur Verbesserung der Energieeffizienz. Eine Überprüfung und Bewertung der europäischen Norm EN 16883:2017, die die Leitlinien für die Verbesserung der Energieeffizienz historischer Gebäude enthält, wurde durchgeführt und ergänzt mit einem informativen Anhang mit Verbesserungsvorschlägen und einem Handbuch mit einer Bewertung der Benutzerfreundlichkeit. Darüber hinaus wurden ein umfassendes Archiv und eine Entscheidungshilfe, das Historic Buildings Energy Retrofit Tool HiBERtool, mit detaillierten Informationen über energetische Sanierungsstrategien und denkmalgerechten Sanierungslösungen zur Verfügung gestellt. Obwohl die gesammelten Informationen über Best-Practice-Beispielen oder technisch-kompatible Lösungen dank der aktiven Zusammenarbeit aller beteiligten Akteure (d.h. Eigentümer, Architekten, Ingenieure oder Energieberater, öffentliche Stellen und Denkmalschutzbehörden) gut dokumentiert wurden, ist die Überwachung vor Ort nach der Intervention leider immer noch sehr selten und scheint sich meist auf Forschungsprojekte zu beschränken.

Résumé

L'objectif principal du projet conjoint IEA EBC Annexe 76 / IEA-SHC Task 59 est d'identifier des approches et des technologies de rénovation énergétique compatibles avec la conservation des bâtiments historiques - pas nécessairement protégés - avec un faible niveau d'efficacité énergétique et de confort. Pour atteindre cet objectif, l'annexe 76 de l'IEA-EBC/la tâche 59 de l'IEA-SHC a été organisée en 4 sous-tâches (AD) dans le but final de développer une base de connaissances solide sur la façon d'économiser l'énergie en rénovant les bâtiments historiques (HB) avec une réduction significative de la demande - également grâce à l'optimisation de l'utilisation solaire passive et active - vers NZEB. La méthodologie a été basée sur la collecte et la documentation de cas de bonnes pratiques identifiant le potentiel d'économie d'énergie en fonction des typologies de bâtiments, afin d'évaluer des procédures reproductibles, qui améliorent significativement les performances énergétiques tout en conservant leur signification et leurs valeurs culturelles (sous-tâche ST-A) ; identifier les outils avancés qui soutiennent ces procédures (sous-tâche ST-B), et évaluer et recueillir des informations sur les stratégies de rénovation compatibles avec la conservation, tout en considérant l'utilisation de l'énergie solaire, des stratégies passives et actives -chauffage, refroidissement et électricité- (sous-tâche ST- C). Un groupe de travail d'experts multidisciplinaires a travaillé ensemble pour promouvoir les meilleures

applications et solutions (sous-tâche ST-D). Grâce à ce travail, une base de données mondiale de meilleures pratiques en ligne a été développée : l'Atlas HiBERatlas de rénovation énergétique des bâtiments historiques. Cette base de données contient interventions exemplaires d'efficacité énergétique dans les bâtiments historiques ainsi qu'une compilation de la documentation existante sur les outils, les méthodes et les lignes directrices pour l'amélioration de la performance énergétique des bâtiments historiques (HB) comme procédure de travail pour sélectionner des mesures pour améliorer la performance énergétique. Une revue et une évaluation de la norme européenne EN 16883:2017 qui contient les lignes directrices pour l'amélioration de l'efficacité énergétique des bâtiments historiques ont été effectuées, avec la publication d'une annexe informative pour son amélioration et un manuel avec une évaluation de l'utilisabilité. En outre, un référentiel complet et un outil d'aide à la décision (l'outil de rénovation énergétique des bâtiments historiques HiBERtool) contenant des informations détaillées sur les stratégies de rénovation énergétique et les solutions de rénovation compatibles avec la conservation, ont été mis à disposition. Cependant, même si les informations collectées sur les meilleures pratiques ou les solutions techniques compatibles étaient bien documentées grâce à la collaboration active de toutes les parties prenantes impliquées (c'est-à-dire propriétaires, architectes, ingénieurs ou consultants en énergie, organismes publics et patrimoniaux), malheureusement, sur place le suivi post-intervention est encore très rare et semble se limiter principalement aux projets de recherche.

Summary

The main goal of the joint project IEA EBC Annex 76 / IEA-SHC Task 59 is to find conservation-compatible energy retrofit approaches and technologies for historic – not necessarily protected – buildings with a low level of energy efficiency and comfort. To achieve this objective IEA-EBC Annex 76/ IEA-SHC Task 59 was organized in 4 subtask (A-D) with the final aim to develop a sound knowledge based on how to save energy by renovating historic buildings (HB) with a significant reduction in demand - also thanks to the optimization of passive and active solar use - towards NZEB. The methodology were based on the collection and documentation of best-practice cases identifying the energy saving potential according to building typologies. The project proposes replicable procedures that improve energy performances significantly whilst retaining their cultural significance and values (subtask ST-A); identify advance tools which support these procedures (subtask ST-B), and to assess and gather information on conservation-compatible retrofit strategies, still considering the use of solar energy, passive and active strategies -heating, cooling and electricity- (subtask ST-C). A working group of multidisciplinary experts have worked together to promote best practice applications and solutions (subtask ST-D). As result of this work an online best-practice cases worldwide database has been developed: the Historic Building Energy Retrofit Atlas HiBERatlas. Exemplary energy efficient interventions in historic buildings plus a compilation of existing documentation on tools, methods and guidelines for improving the energy performance of historic buildings (HB) as working procedure for selecting measures to improve energy performance are proposed. A review and assessment of the European standard EN 16883:2017 that contains the guidelines for improving the energy efficiency of historic buildings has been performed, with an informative annex for its improvement, a handbook with an evaluation of the usability. Furthermore, a full repository and a decision guidance tool, the Historic Buildings Energy Retrofit Tool HiBERtool about detailed information on energy renovation strategies and conservation compatible retrofit solutions has been made available. However, even though the information collected about best-practices cases or compatible technical solutions was well-documented thanks to the active collaboration of all stakeholders involved (i.e. owners, architects, engineers or energy consultants, public and heritage bodies) unfortunately, on-site monitoring post-intervention is still very rare and seems to be limited mostly to research related projects.

Main findings

The synergies between renewable energy and energy efficiency in the buildings studied showed that energy demand can be significantly reduced even in historic buildings, regardless of whether the building has a high level of protection or is listed, even achieving near Net ZEB (zero energy buildings) or Net plus energy buildings targets. The most important aspect is that the whole building have to be considered as an integrated system. Renovation measures in the building envelope (i.e. improving the insulation of building fabrics, windows, roofs, etc.) should work together with the domestic systems: heating, cooling, ventilation and hot water preparation with a rather reasonable combination of other technological systems and renovation strategies (e.g. heat recovering, efficient lighting and daylighting, etc.). The share of renewable energy needed to satisfy buildings' energy demand depends directly on the level of energy efficiency achieved after the renovation to reach a good compromise with the protection constrains, mostly in the specific case of listed buildings or in protected areas. Collaboration between academics and practitioners facilitates "knowledge co-creation" and in this case, a multidisciplinary expert group that was not only formed by scholars but included also industry partners and members of heritage authorities and the public administration collaborated in gathering examples of best-practices and of compatible solutions implemented in retrofits of historic buildings or tested in research projects.

The final aim of this work was to make these resources available to citizens and to professionals of the construction sector. This should speed up, in the Swiss real estate portfolio and in EU building stock, "systemic renovations" with particular attention to historic buildings to achieve the objectives set for energy efficiency, sustainability and a 100% renewable society and find new retrofit approaches to save our common heritage and guarantee a sustainable future.

Contents

Abbreviations

HB - Historic Building

EU - European Union

EGD - European Green Deal

EUSALP - EU Strategy for the Alpine Regions

GHG - greenhouse gas emissions

ETS - Swiss emissions trading scheme

LEne - Federal energy law

PEC - Cantonal Energy Plan

MoPEC / MuKEn - Modello di prescrizioni energetiche dei Cantoni, Modèle de prescriptions énergétiques des cantons / Mustervorschriften der Kantone im Energiebereich

RES - Renewable Energy Sources

NZEB - Nearly zero-energy buildings

BIPV - Building-integrated photovoltaics

BIST - Building-integrated solar thermal

IEA – International Energy Agency

SHC - Solar Heating and Cooling Programme

EBC – Energy in Building and Communities Programme

ICOMOS - International Council on Monuments and Sites

UNESCO - Nations Educational, Scientific and Cultural Organization

ISCES - International Scientific Committee on Energy and Sustainability

HEREIN - European Cultural Heritage Information Network

ExCo – Executive Committee

PM - Project Meeting

ST - Subtask

AG – Action Group

KPIs - Key Performance Indicators

HiBERatlas - Historic Building Energy Retrofit Atlas

HiBERtool - Historic Building Energy Retrofit Tool

CEN - European Committee for Standardization

EPC - Energy Performance Certificate

PVT - Photovoltaic thermal hybrid solar collector

MVHR - mechanical ventilation with heat recovery

DSS - Decision Support Systems

CESBA - Common European Sustainable Built Environment Assessment

1 Introduction

1.1 Background information and current situation

Nowadays the proper use of energy towards ever major energy efficiency is a topical issue also for heritage buildings (hereinafter HB) which have special value both as a material testimony of our past and as a cultural asset. Buildings account for 40% of energy consumed and until now the annual renovation rate of the building stock varies from 0.4 to 1.2% in the Member State [1]. In Switzerland the renovation rate remains much lower than 2% even if since 2010 the "Buildings Program" of the Confederation and the Cantons, has proved to be an effective tool for implementing energy measures, in the Swiss real estate portfolio. In recent years, “systemic renovations” have increased in particular, that is to say, single complete renovations, in broader phases with multiple interventions, focusing on interventions for thermal insulation and building technologies [2]. The issue of improving the energy efficiency of historic buildings is highly controversial and of great importance, considering that historic buildings constitute a large part of the European building stock. There is a need to preserve the values and characters of the heritage, as widely demonstrated by many funded research projects at the European [3–6] and Swiss level [7, 8]. Even if it is not always possible to comply with current energy standards, it is considered essential trying to improve their energy efficiency as much as possible [9-11]. However, the combination of main factors such as protection constrains, energy efficiency, technical and economic feasibility, and end user usability must be carefully weighted and evaluated.

The revised Energy Efficiency Directive (European Union, EU) 2018/2002 [12] as part of the 'Clean energy for all Europeans package' sets an energy efficiency target for 2030 of at least 32.5%. As part the European Green Deal (EGD) policies that aims at becoming climate-neutral by 2050, a set of binding measures to help EU Climate Target Plan to achieve a level of greenhouse gas emission reductions of at least net 55% are promoted [13]. Clean energy transition must be at the center of economic recovery plans post-pandemic, to build secure and sustainable energy systems, as part of e Next Generation EU recovery plan [14]. Transition towards on-site energy production in buildings and districts to enhance the energy efficiency contribution for CO_2 mitigation is becoming more realistic in European Union (EU) countries but even also Alpine Space trans-regional areas, including Switzerland. Moreover, since 2015, the EU Strategy for the Alpine Regions (EUSALP, Action Group 9) provide a framework for cooperation, coordination between and within states and regions, focusing on macro-regional strategies for greater regional cohesion and more coordinated implementation of European policies towards a model region for energy efficiency and renewable energy. The traditional historic architecture in the Alps is a key enabler for sustainable development in the social, ecological and economic spheres. Over a quarter of the European building stock is classified as “historic” with vast majority of it concentrated in the rural areas [15].

Switzerland is in line with the relevant EU regulations to increase the energy efficiency in the building sector together with major use of renewable energies and their expansion is granted the status of a national interest. Swiss Federal Council has drawn up the Swiss Energy Strategy 2050 with a significant revision of the CO_2 Act (Energy Act 2050), as key piece of climate change legislation that includes a number of measures that may accelerate greenhouse gas (GHG) emissions reduction. The most important ones, besides Swiss emissions trading scheme (ETS), are the introduction of a CO_2 levy, building standards and energy programs among others. In response to the COVID-19 crisis and the negative economic consequences due to the lockdown, the Federal Council recently approved spending packages of about CHF 60 billion, primarily targeting job preservation, with special provisions in place to protect the development of renewable energy projects. Strategies to promote the use of RES are set usually at national level (Federal energy law, LEne) [16] and subsequently implemented on regional and local scale. At regional level, the Cantonal Energy Plan (PEC) [17] is the reference document of the cantonal energy and climate policy in the sectors of buildings, as well as the introduction of regulatory principles in accordance with the 2014 model of cantonal energy regulations (MoPEC / MuKEn) [18].

For this reason, the low renovation rate of existing buildings in EU suggests that it will take a long time to upgrade the building stock to modern standards of near-zero energy [19]. Non-recoverable fossil fuels are wasted mainly in heating and cooling of existing and historical buildings without achieving good levels of energy efficiency and comfort. Heating of space and water consequently represents about 79% of the final energy consumed by households [20]. In parallel, owners of old buildings struggle to keep their homes warm safety and comfortable. Although if energy renovations cannot reduce energy consumption to the levels expected of newly built houses with modern standards of insulation and energy labels, adaptive measures and passive strategies, as well as renewable energies, can be used together with other technical energy upgrade measures but a minor final environmental impact [21-24].

The promotion of Renewable Energy Sources (RES) has an important role in this process, thanks to Directive 2018/844 has introduced the concept of nearly zero-energy buildings (NZEBs) [25] for new buildings and for existing buildings subjects to major renovations. Renewable energies (e.g. solar, geothermal or biomass energies) can couple with other refurbishment technical measures to achieve high-energy efficiency standards and comfort in historic buildings [26-28]. In recent years, also in historical contexts the use of solar energies registered major interest, including solar integrated solutions. Building integrated solar thermal (hereinafter BIST) and above all building integrated photovoltaic (hereinafter BIPV) are gaining importance due to the growing development of the photovoltaic market with new suitable products to be integrated in sensible contexts and for landscape integrated [29, 30]. This has been the focus of different tasks of the International Energy Agency (IEA) [31-34] and national and international research projects [35-40]. Furthermore, the integration of photovoltaic modules in architecture has been increasingly evolving very fast, thanks to continuous research on competitive and innovative solutions [41, 42] that are similar to other traditional building elements [43, 44] where the aesthetic and perceptive aspect is considered as a plus to return a coherent and harmonious overall vision with the surrounding environment [45-47]. Furthermore, there is a willingness on the part of producers of solar photovoltaic (PV) cutting-edge technologies to reduce the impact of new products on buildings and Switzerland is today at the forefront of solar BIPV product innovation [48, 49].

Switzerland, as well as, other countries moves in this direction. For this reason, a Swiss research university (SUPSI) has participated in IEA-EBC Annex 76 activities, a Technology Collaboration Programme of the International Energy Agency (IEA) under the Solar Heating and Cooling IEA SHC programme. The assigned Task number 59 focused on the "Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO2 Emissions (NZEB)" setting up a joint project IEA-EBC Annex 76 / IEA-SHC Task 59 [50]. Historic Buildings (HB) in this Task are defined according the scope of the European Standard EN 16883:2007 "Guidelines for the improvement of the energy performance of historic buildings" [51] considering that HB is not limited to buildings with statutory heritage designation and formally "listed" or protected, but includes all buildings that have something that is worth preserving. The new standard aims at facilitating the sustainable management and conservation of HB by integrating specific measures for energy performance improvements taking care of an adequate conservation. The energy performance of HB can be improved considerably if a package of retrofit measures specifically suitable of a select building is identified.

Role of the institute ISAAC-SUPSI was to provide the expertise available in Switzerland by means of solar renewable knowledge on new BIPV technologies, as well as the well-known expertise on the energy efficiency of the existing building stock and historical assets in the international discussion foreseen in the IEA SHC Task59. IEA-EBC Annex 76 / IEA-SHC Task 59 activities and objectives were linked to the Interreg Alpine Space research project ATLAS: Advanced Tools for Low-carbon, high-value development of historic architecture in the Alpine Space (Interreg B, ERDF Transnational Cooperation Programmes 2014-2020) in which SUPSI participated as Swiss partner [52]. The participation at the Annex 76 / Task 59 activities had carried an important benefit to the activities developed within ATLAS Interreg Alpine Space project and vice versa, considering that the activities have been strongly connected.

Main challenges for energy retrofit interventions in historical buildings is to preserve them for future generations decreasing the long-term deterioration to facilitate their conservation, lowering energy bills and increasing comfort [53, 54]. The choice of the most appropriate type of intervention is crucial and the compatibility with the heritage value should be assessed on a case-by-case basis, which was certainly considered for the collection and appraisal of solutions in a step-by-step process. Risks and benefits of possible technical energy improvement solutions (single solution or a combination of retrofit scenarios) need to be weighted between the costs and benefits, as well as considering the impacts on the heritage significance. Nevertheless, energy retrofit to historic buildings must be guided by indistinctive conservation principles intended to preserve their significance (building fabric and character) based on processes of managing changes] as delineated in several international charters by the International Council on Monuments and Sites (ICOMOS) [55] and the United Nations Educational, Scientific and Cultural Organization (UNESCO) [56-58]. Keeping historic buildings alive, reuse or bringing them back to life, although if with a new use, is part of the contemporary sustainable approach to saving resources as key pieces highlighted by several institutions (e.g., ICOMOS, UNESCO, etc.). It is a significant challenge to preserve this historic heritage, most of the time no longer used or in decay, by enriching it with new content, and enhancing its modernity and attractiveness, which requires as well the pondering of economic processes and investments.

1.2 Purpose of the project

Within the project IEA EBC Annex 76 / IEA-SHC Task 59 policies, decision tools and technical solutions for high-level energy retrofit, including RES, for historic – not necessarily protected – has been evaluated capitalizing best practices. SFOE funds have covered the participation to the meetings while ISAAC-SUPSI Institute can contribute to IEA-EBC Annex 76 / IEA-SHC Task 59 activities and objectives because are linked to the ATLAS research project. The research project ATLAS has been approved in spring 2018 to July 2021 and has been led by EURAC Institute (European Academy Bozen in Italy), that also was the operating agent at IEA-SHC Task 59.

ATLAS promotes existing best practice for energy retrofit of historic buildings and sustainable regional development and make them available for the Alpine Space macro region. Tools for decision support on building level and toolkits for regional planning will support both the valorization of cultural heritage and the development of the territory as a model region for energy efficiency and renewable energy (EUSALP, Action Group AG9[1]). ATLAS foster the collaboration among municipalities, regional authorities, research institutes and organizations actively involved in heritage conservation and energy retrofit on a transnational scale and contributed to develop policy instruments at three levels: 1) A Historic Building Atlas for the Alpine Space will be established as a tool for the capitalization of best practice building retrofit. 2) Concepts for low carbon retrofit and RES integration will be socially, culturally and technically evaluated and adapted to the Alpine archetypes and 3) Historic building retrofit as part of sustainable regional development strategies and new business concept will be established.

This research project fit the objectives of IEA-EBC Annex 76 / IEA-SHC Task 59. Within ATLAS, SUPSI is the Swiss partner of a wide EU consortium, among other EU institutions and municipalities from the Alpine Space macro region area. All partners with expertise in energy efficiency, heritage preservation and regional development that will work closely together in ATLAS to ensure the knowledge exchange and implementation of project outputs. SUPSI could benefit from project synergies with past or current EU projects or initiatives.

[1] The **EU Strategy for the Alpine Region (EUSALP)** points out the outstanding value of the Alpine natural and cultural environment and mentions the **Energy Efficiency of Buildings** as one of the key actions for the sustainable growth. The area is characterized the similarity of building types, construction materials and climatic conditions where the valorization and retrofit of the historic architecture is in the interest of the whole society since the entire Alpine area draws its identity from the cultural landscapes.

SUPSI enrolment to IEA EBC Annex 76 / IEA-SHC Task 59 aimed both to continue playing a role in defining and developing new procedures to enhance energy efficiency in existing buildings and to accelerate the renovation rate and penetration of solar technologies and BIPV products in the global market of renewables. The contribution of SUPSI in the different subtask aimed to encourage measures of the federal government and the cantons to reduce the energy consumption and CO_2 emissions of the Swiss housing stock. In this sense, SUPSI worked to support the measures of the "Environment package - energy and climate part" by collecting examples of good practices and technical solutions to restore historic buildings and the existing building stock. The retrofit solutions and best-practice examples documented, taken into account renewable energies in a sustainable and respectful way for the environment and thus to reach goals set up in energy policies at federal and cantonal level. The "Environment package - energy and climate part" is aimed at making more resources available to citizens to accelerate the change necessary to achieve a 100% renewable society through an increase in investments in the energy and climate sector.

Furthermore, SUPSI contribution to IEA-EBC Annex 76 / IEA-SHC Task 59 activities capitalize results of past and ongoing research projects in Switzerland, like VERGE and EnBAU research projects [59-61] (building renovation of historic buildings), PETRATool [62, 63] (retrofit solutions and decision guidance tool) and CarSOL and bFAST research projects [64, 65] (policies on regional development implementation of solar renewables in historical and existing buildings and urban areas). Moreover, the ongoing research, Interreg V-A Italy-Switzerland “BIPV meets history” [66] developed during the period 2019-2022 (Interreg A ERDF Cross-border cooperation programme 2014-2020) has allowed SUPSI to better contribute in IEA SHC T59 activities. The project aims to create a cross-border value-chain and new market to increase the spread and use of integrated photovoltaic solar technologies (BIPV) on existing buildings to achieve the objectives of the Europe 2020 Strategy, in line with the Swiss Regional Policy (NPR).

During the whole project, six project meetings (PMs) were organized to discuss among experts from different research institutions, SMS and industrial partners, members of public heritage authorities together with local stakeholders and observers who participated in each meeting, the activities undertaken and to be developed within the project. PMs have been hosted by European Universities, research institutions and energy&innovation SMEs companies and carried out in parallel with public events and international conferences to allow the dissemination of the results and knowledge transfer to the relevant stakeholders (e.g. architects and consultants, building owners, developers and policy makers, national authorities concerned with historic monuments and cultural heritage, construction industry and crafts members or educational bodies and research institutions, etc.). An example were the BHÖ 8th European Congress on the Use, Management and Conservation of Buildings of Historical Value held in Vienna, Austria in October 2019 or the International SBE21 Heritage Conference, held online in April 2021. An overview of the main results achieved and deliverables have been presented at the closing meeting and during the IEA EBC Annex 76 / IEA-SHC Task 59 ExCo meeting held online in June 2021, highlighting some of the aspects that could be expanded and studied in future activities within the IEA program.

1.3 Objectives

Recovering of the existing building heritage in an eco-sustainable way is now considered strategic at federal level and is an important local economic resource. The aim of this project is to develop a reliable guidelines/tools to support the pre-design decision phase, diagnosis and retrofit planning process of historic – not necessary protected – buildings, of the building stock that have a value worthy of conservation as representative of a certain historical period, constructive typology, specific architectural value, etc.. This approach is coherent with the new European Standard EN 16883:2017 (Conservation of cultural heritage - Guidelines for improving the energy performance of historic buildings) in a trial phase within the IEA-SHC Task 59 activities. A pull of partners with expertise in energy efficiency, heritage preservation and regional development have worked closely together to ensure the knowledge exchange and implementation of project outputs. SUPSI have contributed to IEA-SHC Task 59 on

"Renovating historic buildings towards zero energy" and benefited itself from the exchange on international level and important networks both in the energy (IEA - International Energy Agency) and cultural sector (ICOMOS ISCES).

The project ATLAS, supporting IEA-SHC Task 59, is well positioned in the wider context of the "European Energy Union" and Europe's "2050 energy strategy" – as well as, on the “cultural side”, initiatives of the Council of Europe like the Strategy 21 (launched in April 2017) and HEREIN Heritage network. It contributes to Europe's ambitious targets on emission reduction, energy efficiency and RES increase. Especially, the project is in line with cantonal policies and includes measures for implementation of energy efficiency in buildings to support 2050 Energy Strategy of the Federal Council. ATLAS is coherence with the EUSAPL EU Strategy for the Alpine Region. It contributes to EUSALP first to AG9 (->To make the territory a model region for energy efficiency and renewable energy) with awareness raising and solutions - and by specifically providing harmonized key performance indicators (KPIs). Then to AG6 (->To preserve and valorize natural resources, including water and cultural resources) with its focus on historic buildings. Finally, also to AG2 by supporting regional value chains (e.g. wood and tourism) and AG5 with digitally providing best practice via the Historic Building ATLAS that will be developed together with IEA-SHC Task 59.

Importance to support Swiss Energy Strategy 2050

At Swiss level, the importance and relevance of SUPSI participation on IEA-EBC Annex 76 / IEA-SHC Task 59 activities are supported by the awareness that an energetic adaptation of the existing building stock is now a priority to comply with federal and local energy targets. This will support the application of the energy requirements of MoPEC / MuKEn 2014 in existing and historic buildings (as same as to the European NZEB concept). Project results have been orientated toward the key values of Energy Strategy 2050 and the targets pursued in the Buildings and Cities research programme to improve the energy qualities of buildings, influencing the building process (WP1 Building stock analysis and documentation of good practice building solutions and WP2 Replicable & robust retrofit solutions). In terms of numbers, buildings built in Switzerland before 1980 represent 64% of the national real estate and contribute to major energy consumption as more than 40% of energy consumption and CO2 emissions can to be attributed mainly to buildings that have not yet been retrofitted. Approximately 1.5 million of existing buildings require urgent energy retrofit but the annual renewal rate it is still very low. (SFOE, Buildings program -Annual report 2016). In recent years, the percentage of protected buildings or protected elements that have received a financial contribution for energy retrofit within the Swiss Buildings Program (2013-2016) has risen to between 6.5 and 8.5%. On average, in Switzerland they represent around 7.9% of the total buildings that have requested a contribution to the Building Program. Besides, the technical obsolescence of the main construction elements is much higher than the useful life of the building due to lack of renewal cycles, due to a strategy of reorganization and non-predictive maintenance which leads to an important loss of the economic value of the property in the short- and medium-term time. The necessary and desirable energy improvements of the existing building stock, that also include buildings with heritage or historical significance (e.g. historically, architecturally or culturally valuable buildings), while respecting their heritage value, can be carried out in compliance with modern standards and new construction techniques. This is also possible considering renewable energies and solar technologies to achieve energy self-sufficiency objectives as in the rest of Europe, as will be demonstrated with several examples of best practices collected within the IEA-EBC Annex 76 / IEA-SHC Task 59 activities. Furthermore, on September 1st, 2021, the amendments to the Cantonal Energy Law (Len; RS 740.100) approved by the Grand Council on May 4, 2021 (Message 7894 of October 1, 2020) came into force to adapt cantonal incentives for energy saving and renewable energy production to the new needs of the electricity market and technological evolution. It will therefore be desirable to promote in near future as many plants as possible both in the photovoltaic sector and in other type of RES. Besides, certain activities consider gather enough information on tools, methods and guidelines on replicable procedures and the identification of compatible retrofit solutions that includes solar renewable technologies, meeting the objectives of the Swiss Photovoltaics research program.

The objectives of the collaborative task IEA-EBC Annex 76 / IEA-SHC Task 59 are to:

- 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 protected and historic 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 both the heritage value of the building and at the same time make it energy efficient;
- Identify and further develop tools which support this procedure and its single steps;
- Identify and assess 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;
- Transfer knowledge.

In the strategic plan it was stated that to realize this huge potential for solar heating and cooling in the building sector, it is essential to integrate solar technologies into the built environment in an appropriate way. Solar based renovation of existing building stock is listed as one of the most important activities to achieve this.

Target groups of the project: local public authority; sectoral agency; interest groups including non-governmental organizations (NGOs); higher education and research; education/training centres and school; Small and mid-size enterprises (SMEs); General public.

2 Procedures and methodology

To address the main objectives of the research, the experts have developed the following subtasks:

- ST-A: KNOWLEDGE BASE, developing an important database of a collection of Best Practice cases, following the approach of IEA SHC Task 37 and 47, which can be expanded in the years to come;
- ST-B: MULTIDISCIPLINARY PLANNING PROCESS, with the identification of replicable procedures and tools to support the experts in order they can work together to maintain both the expression of the building, and at the same time make it more energy efficient;
- ST-C: CONSERVATION COMPATIBLE RETROFIT SOLUTIONS AND STRATEGIES, through the identification and assessment of technical solutions from both energy and conservation point of view;
- ST-D: KNOWLEDGE TRANSFER AND DISSEMINATION to the relevant stakeholders: (i) architects and consultants; (ii) building owners and users; (iii) developers and contractors; (iv) policy makers; (v) national authorities; (vi) crafts person and construction industry; and (vii) educational bodies.

These different tasks are the methodological approach in order to develop a sound knowledge base on how to save energy by renovating HB in a cost-efficient way, and in anticipation of a significant reduction in energy demand to go towards a NZEB target. It has been necessary to identify the energy saving potential according to building typologies, in order to assess replicable procedures. The procedures and technical solutions considered improve energy performances of HB significantly whilst retaining their cultural significance and values, through best practice cases (ST-A); identifying advance tools which support these procedures and their single steps (ST-B), and assessing conservation-compatible retrofit strategies, still considering the use of renewable energy including solar energy, passive and active strategies (heating, cooling and electricity) (ST-C). A working group of multidisciplinary experts have worked together to promote best practice applications and solutions (ST-D).

As defined in the research programme, SUPSI have participated in the following sub-task: ST-A, ST-C mainly with an active role while in ST-B and ST-D partially with collaborative and supporting activities.

Main results of the project have been described and summarized in project Reports and Subtask Deliverables as explained bellow.

Work undertaken following this procedure and findings obtained at the end of the project

ST-A: finalization the collection of different number of best cases worldwide in order to be available in the Historic Building Energy Retrofit Atlas HiBERatlas an online best-practice database of exemplary energy efficient interventions in historic buildings; description of the technical solutions applied in the individual case studies, with a focus on the framework conditions that made possible the implementation;

Deliverables:

R1 -- Knowledge base as online database of Best Practice Cases (D.A1 & D.A3);
R2 -- Case study: Assessment report (DA.2).

These reports summarize the process to develop and implement the HiBERatlas database with an analysis and assessment of the best-practice case studies documented and the information gathered, looking back “ex-post” to help future implementations, both re-assuring that targets were reached with qualitative and quantitative assessments and pointing out possibly weak points.

ST-B: compilation of existing documentation on tools, methods and guidelines for improving the energy performance of historic buildings (HB) as working procedure for selecting measures to improve energy performance; review and assessment of the European standard EN 16883 and proposal for its improvement with an informative annex (this activity has given rise to various scientific publications); The handbook with an evaluation of the usability EN-16883:2017 will be published by Swedish standards and available within the whole CEN sphere.

Deliverables:

R1 -- Assessment of existing tools in form of a report with “fact sheets”;
R2 -- Proposal for standard improvement. Handbook: Planning Energy Retrofits of Historic Buildings: EN 16883:2017 In Practice;
R3 -- Platform with tools for holistic historic building retrofit.

These reports describe how the standard can be applied in practice with chapters on heritage value assessment, building survey and holistic assessment of energy efficiency measures. It will be complementary to the standard and provides best practice advice, examples and state-of-the-art tools and methods. The handbook draws on the experience from a team of international leading experts in the field of energy efficiency in historic buildings. It will be an essential guide for professionals working with the refurbishment of existing buildings: architects, engineers, heritage consultants, building surveyors and professional property owners. Furthermore, 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.

ST-C: detailed information on energy renovation strategies and conservation compatible retrofit solutions with high impact on sustainability and energy efficiency for historic buildings that will be made available in the HiBERtool (Historic Buildings Energy Retrofit Tool). Based on the examples, a series of decision trees guide the users and lead to the proposal of a range of possible energy retrofit measures first selected and documented by the experts of IEA-SHC Task59.

The following reports have been finalized:

R1 -- Report on Solutions (Part 1: windows, Part 2, insulation, Part 3, HVAC with ventilation and solar); R2 -- Report on Strategies.

These reports give an overview of the documentation of the solutions in Subtask C and explain the question of content and scope. The documentation of the solutions was mainly done in four working - groups: (i) Windows solutions; (ii) Walls solution; (iii) Building services and HVAC and (iv) Solar systems. Since the solutions do not describe the entire building but only the respective measure, only essential information can be answered in a few open questions briefly but informatively. For more detailed information there is the possibility to integrate publications (PDF) or links into the solution in the best practice examples. The output of the solutions should be an automatically generated PDF integrated in HiBERtool. With regard the strategies, it consist in the collection of existing sources and practices specific applied to historic buildings. The objective of this action is to collect: (a) Guidance documents; (b) Tools to select measures and (c) Decision Support Systems (DSS) with information about the type, level of action and detail, the context and the connection with EN 16883

ST-D: participation on communication and dissemination activities in conjunction with the expert meetings and relevant conferences. The work has been summarized in the deliverable:

R1-- Communication and Dissemination - Summary of Activities, Outcomes and Analysis

During the whole project and especially during the years 2020 and 2021 all project sub-tasks regularly proceeded and the main deliverables are being completed with the collaboration of all the experts for their final publication. Some impacts of COVID-19 on many aspects related the project activities need to be stated, especially as 2020 was the core year for partners and stakeholders to progress on many fronts with full familiarity of the project work. The effects of COVID-19 and its restrictions have been varied, but as the project was well established, with existing relationships developed, the effects could have been much worse. While in mid-2020 there was a pause in activities, and partners readjusted their businesses and operations to the new conditions, by autumn 2020 most were familiar and active with digital means of communication. Most of the outreach and engagement work was able to happen digitally, and it can be argued that dissemination was facilitated in most areas by these circumstances.

Subtask A, Subtask B, C and D have been properly finalized during this year 2021. Coordination with standardization bodies, thanks to work done reviewing the standard European standard EN 16883, has been also undertaken. With the ambition of realizing zero-energy buildings and built environments, also considering the sustainable refurbishment of history buildings a continuation of the Task is important to have a continuity in the topics undertaken, to overcome issues and accelerate the use of renewable energies towards the future vision and to bring ahead an international coordination on the main challenges and potentials.

3 Results and discussion

3.1 Detail of main activities carried out and results achieved by Subtask

ST-A: Knowledge Base and collection of Best Practice projects

The main objective of Subtask A is to collect best practice cases and to assess the existing know-how regarding deep renovation of historic buildings.

The following activities were planned and achieved within ST-A: A.1 Overview on existing best practice examples and detailed definition of scope and format of best practice cases to collect; A.2 Gathering information on best practice cases: criteria, ambition of innovation, available monitoring & evaluation data, energy consumption, costs; A.3 Assessment of best practice cases.

SUPSI collaborates in two of the three main activities: A.1 Overview on existing best practice examples and detailed definition of scope and format of best practice cases to collect; A.2 Gathering information on best practice cases, as specific activities developed in ATLAS in collaboration with other partners.

The goal of the task was to get about 50 relevant projects and case studies published in the database until end of Task59 (at least, 5 from each participating country). As reported in previous report SUPSI has contributed with 10 best-practice projects in Switzerland, model of good practices on energy rehabilitation of historic buildings, the integration of renewable energy and solar energy. The aim is to make existing best-practice experiences available to decision-makers.

This database considers as best-practice any example that fulfils the following requirements:

- Renovation of the whole building;
- The project has been implemented;
- The intervention followed the results of a thorough heritage value assessment;
- A significant energy demand reduction was achieved;
- A detailed documentation of the decision process, technical solutions and evaluation results was made available.

At the moment, more than 50 projects are already active and usable on the platform and some more are expected to be published. The documented projects has been included in the Historic Building Energy Retrofit Atlas a best-practice database of exemplary energy efficient interventions in historic buildings. The online tool is in the form of a Best Practice Database (Subtask A), called HiBERatlas (https://www.hiberatlas.com/en/welcome-1.html). Hosted on its own website, it includes refurbishment case studies by the partners and from countries throughout Europe (Figure 1). The online tool is an important output of the Task 59 project, and the detail of it is covered elsewhere. However, its dissemination will be an important part of getting it out into the construction sector. Directly linked to this repository, the decision guidance tool HiBERtool (Subtask C) provides support to building owners and practitioners in identifying the most suitable solutions for their retrofit. Both tools are a joint development between IEA-SHC Task59 (Subtask C) and the Interreg AlpineSpace ATLAS project.

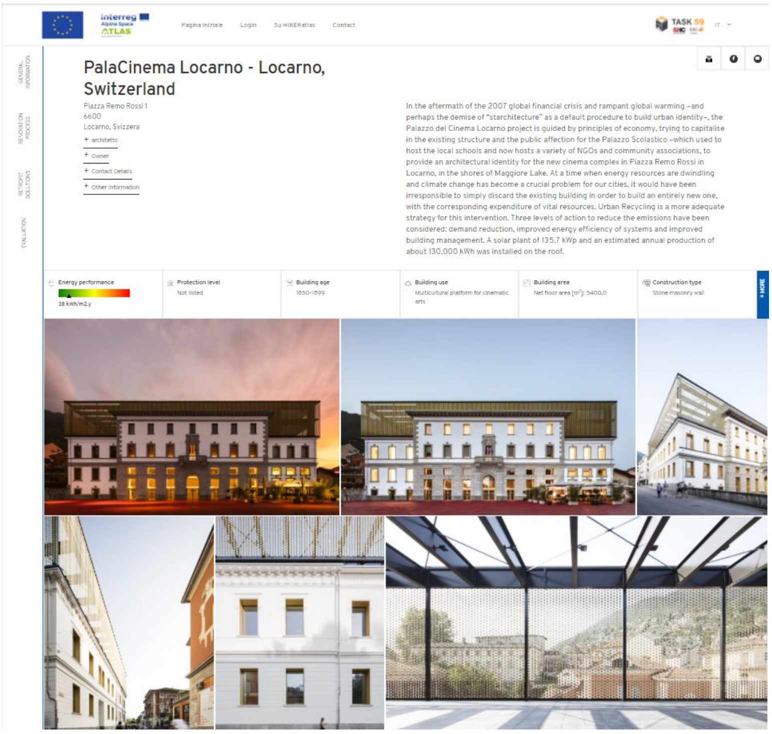


Figure 1. Screenshot of HiBERatlas database www.hiberatlas.com. The Palacinema project in Locarno is one of the last projects completed this year by SUPSI.

SUPSI documented 10 best practice cases in Switzerland as model example of energy retrofit of historic buildings. The case studies chosen are representative projects in favour of a rational use of energy, low-emission or emission-free, which promote renewable energy and in particular the use of solar energy in buildings in historic buildings some listed in federal and cantonal inventories, in urban or natural protected areas or not listed but with worthy elements of being preserved. The retrofit intervention followed the results of a thorough heritage value assessment and a significant energy demand reduction was achieved.

A detailed list of the ten Swiss projects collected and documented in detail in HiBERatlas platform has already been presented 2020 annual report. The report included a variety of uses and typologies (residential single-family houses, multifamily houses and offices and public and private services building).The description of some examples reported in Deliverable Subtask A: Case Studies Assessment Report is presented in the Figure 2.

During the refurbishment of the building on Feldbergstraße 4 + 6 in the old part of Basel, several requirements of the cityscape commission for façade and roof design had to be met. The challenge was to operate a 6-storey residential building with 12 apartments as completely as possible with solar energy in the protected zone of Basel-Stadt. The entire heat energy requirement (hot water, heating, home ventilation and auxiliary energy) is covered exclusively by the solar energy on the roof of the building.

Feldbergstrasse **Basel, CH**	Building Period: 1850 - 1899 Renovation: 2009	Use: Residential (urban) Protection level: not listed	Contact: SUPSI

The multi-family house in Zurich needed a complete modernization. Thanks to the optimal use of building regulations and the vision of the architects, the new roof could be raised on the courtyard side so far that a new storey and thus more living space was created. Despite preservation requirements, the building could be well insulated today reaches the Minergie new construction standard. For the placement of solar collectors, the roof was not optimally aligned and too small. Rentable terrace and energy-collecting panels must therefore share the space on the roof.

Magnusstrasse **Zürich, CH**	Building Period: 1850 - 1899 Renovation: 2007	Use: Residential (urban) Protection level: listed	Contact: SUPSI

The Roman Catholic St. Franziskus Ebmatingen Church is emission-free after the energetic renovation in 2018/19. Thanks to significantly improved roof insulation, the solar-powered geothermal heat pump, the use of solar heat with 161 m2 of photovoltaic thermal modules (PVT) and the LED lighting the church is a plus-Energy-Building with an energy supply of 221%. For this concept in combination with the architecturally outstanding implementation, the project has been awarded in 2019 with the Swiss and European Solar Prize.

St. Franziskus Church **Ebmatingen, CH**	Building Period: 1980 Renovation: 2018	Use: Religious Protection level: not listed	Contact: SUPSI

Figure 2. Short description of Swiss Best practice case studies reported in the Final Report Subtask A.

When looking at possible case studies and good practice examples documented the project team of Task 59 agreed to set the “threshold” not in terms of fixed values for e.g. energy performance or energy reduction but to select cases representing solutions beyond business as usual (for the respective country). In addition to the description of the technical solutions applied in the individual case studies, the focus was also on the description of the framework conditions that made the implementation of the projects possible in the first place.

Such favourable conditions could be, for example (Table 1):

- Financial incentives;
- Integration in research projects;
- Cooperative planning process (owners, planners/architects, heritage authority);
- Fundamental change of use of building

Table 1: Overview on favourable framework conditions in the Swiss Best practice cases documented

No	Case study	Country	Financial incentive	Research project	Cooperative planning	Other
1	Doragno Castle, Rovio (TI)	CH				X
2	Solar silo, Basel (BS)	CH		X	X	X14
3	MFH Feldbergstrasse, Basel (BS)	CH	X			X
4	MFH Magnusstrasse, Zürich (ZH)	CH	X			X
5	St. Franziskus Church Ebmatingen (ZH)	CH			X	X
6	Kindergarten and apartments (PEB) Chur (GR)	CH	X		X	X
7	Single family home Luisenstrasse - Bern (BR)	CH				X
8	Single Family House - Gstaad (BR)	CH				X
9	Glaserhaus in Affoltern im Emmental (BR)	CH			X	X
10	PalaCinema Locarno, Locarno (TI)	CH	X			X

Final Report will include 69 project assessed. They can be categorized according to type of building, age, size and the level of protection. The contributions from partners of Task 59 and the Interreg Alpine Space project ATLAS are expected to add up to 80 case studies. Ensuring the quality of the best-practices displayed in the database has been crucial to ensure their robustness and to improve the way they are presented. For these reasons a review process (following the example of a peer-review process, Figure 3) that can assess the validity of the projects were implemented and SUPSI collaborated as technical expert.

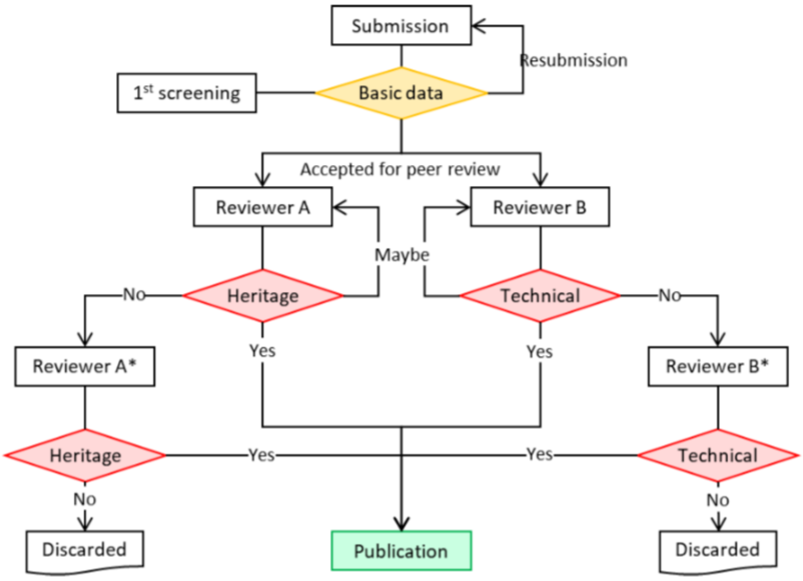


Figure 3. Review process in Task59.

The database presents best-practice examples of how historic buildings can be renovated to achieve high levels of energy efficiency while respecting and protecting its heritage significance. The documentation gathered here provides information on the building and its construction, heritage assessment, building material specifications, energy efficiency, building services and comfort as well as on refurbishment solutions and products.

Some findings of the assessment of the case studies analyzed are summarized in the following paragraphs:

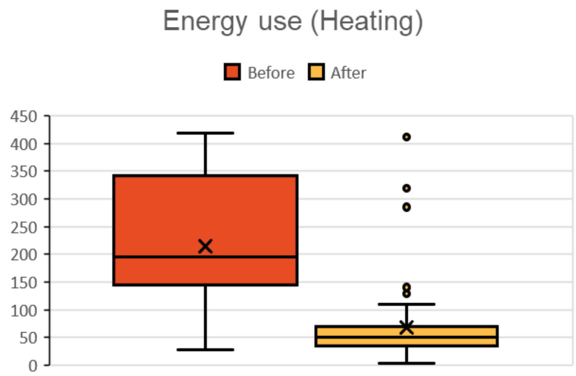
Regarding all the documented buildings, listed are 31 of the 69 case studies assessed, protected are 34 buildings. Situated in a protected area are 24 buildings. Most of the buildings have been in a poor state and have been refurbished for residential use, with improved functionality (including thermal comfort) and improved energy performance as the main goals. All projects have had an ambitious target for energy performance post-refurbishment, but only a few have had an explicit quantitative target. Most of the renovations (56 case studies) took place since 2013. Most transformations (16 case studies) concerned agricultural buildings (partly including residential use) which became mainly residential (including apartments, B&B, etc.). There is also a group of 5 case studies in which private residential buildings were transformed into apartment buildings. In most projects, there is information about which elements are worthy of preservation. Interestingly, in a number of cases it is mentioned that the building owner although if the building is lacking official recognition has wanted to preserve the historic “character” including elements worthy of preservation.

The results of the interventions in terms of energy efficiency improvement, internal climate control, financial assessment, and environmental impact show more detailed information and might only be relevant for users looking for a deeper understanding of the projects. Of the 69 cases studies analysed in the final report Subtask A, 51 (74% of cases) have an Energy Performance Certificate (EPC) and 16 have some sort of voluntary certification (23%). For instance, different standards of Minergie are found among the Swiss cases (Table 2, 30%).

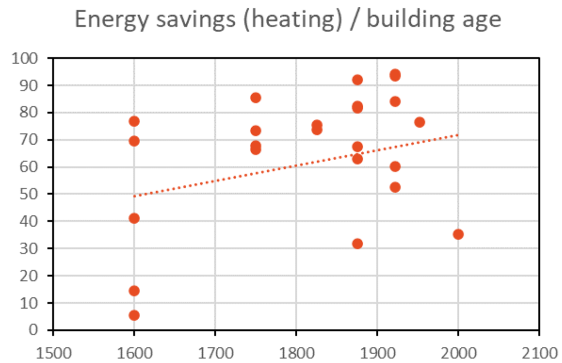
Table 2: Availability of EPC and calculation methods

No	Case study	Country	Building type	EPC	Voluntary certificates
1	Doragno Castle, Rovio (TI)	CH	Residential (rural)	0	0
2	Solar silo, Basel (BS)	CH	Offices	0	0
3	MFH Feldbergstrasse, Basel (BS)	CH	Residential (urban)	0	1
4	MFH Magnusstrasse, Zürich (ZH)	CH	Residential (urban)	0	1
5	St. Franziskus Church Ebmatingen (ZH)	CH	Religious	0	0
6	Kindergarten and apartments (PEB) Chur (GR)	CH	Other	0	0
7	Single family home Luisenstrasse - Bern (BR)	CH	Residential (urban)	1	1
8	Single Family House - Gstaad (BR)	CH	Residential (rural)	1	0
9	Glaserhaus in Affoltern im Emmental (BR)	CH	Residential (rural)	0	1
10	PalaCinema Locarno, Locarno (TI)	CH	Cultural (Cinematic Arts)	1	1

The methodologies, as well as the thresholds between classes, change between countries. Related the 69 case studies analysed, the average energy demand was around 215 kWh/m^{2}y before the intervention and 68 kWh/m^{2}y afterwards. Although these data should treated be carefully, since it includes different methodologies, climatic conditions, and very different building typologies, a first analysis indicates a total energy reduction of around 70% (Figure 4.a). There is a positive relationship between savings and building constructions period suggesting that the more modern buildings profit more (in relative terms) of the energy retrofits (Figure 4.b). It was shown that rural residential buildings and not residential building have a reduction on heating demand after intervention distributed between 25 and 75 kWh/m²y with an energy demand reduction of 60 to 80%.



a)



b)

Figure 4. Analysis of case studies documented in Final Report Subtask A: a) Energy use for space heating in kWh/m2.y before and after retrofit; b) Energy savings (in %) in terms of space heating demand by building age.

To understand the limitations imposed by the legal status of the building (in terms of heritage protection), the analysis also looked into the different performance of listed and not listed buildings. The energy use after the retrofit is slightly higher in listed buildings with an energy use between 25 to 50 kWh/m²y in not listed buildings and 50 to 75 kWh/m²y in the case of listed buildings, which, in most cases, has an energy savings after renovation, in the range between 60 and 80%.

In the sample of case studies documented, the average investment cost of the interventions sums up to 3.350 €/m², whereas the purely energy related costs are less than 600 €/m². That would represent that the energy efficiency improvement of a building represents only the 18% of the regular renovation cost. However, these results need to be considered carefully due to the great variability between countries, and a larger sample would be needed for a further analysis of this parameter. Data related case studies in Switzerland are summarized in Table 3. The greenhouse gas emissions calculations and life cycle assessment (LCA) were conducted in only a few of the documented cases (20% and 5% respectively).

After renovation, the Swiss historic buildings studied reach good Building Energy Rating (BER), which is an indication of the energy performance expressed as primary energy use per unit net floor area per year and equal to the new constructions varying 50 kWh/m²yr to 25 kWh/m²yr (lower most-energy houses). Besides, the integration of solar integrated photovoltaics (BIPV) and solar thermal or solar hybrid PVT panels can be well integrated and conciliated with the historical character of old buildings. As shown in the examples studied the share of renewable energy needed to satisfy buildings' energy demand depends directly on the level of energy efficiency achieved after the renovation to reach a good compromise with the protection constrains, mostly in the specific case of listed buildings or in protected areas. In most of the cases studied, this have lead in an important energy self-sufficient rate. Renovation investment cost varies from 235 CHF/m² as in the Palacinema building (TI), a renovation dated 2017, to 4,744 CHF/m² in the multi-family house MFH Feldbergstrasse (BS) dated 2009. The significant differences are in the type and use of the building, the date on which the interventions were carried out (i.e. currently certain technologies have a lower cost, such as solar) and the type of more or less innovative intervention carried out[2].

[2] More details are available in the scientific article: Polo López, C.S.; Mobiglia, *M. Swiss case studies examples of solar energy compatible BIPV solutions to energy efficiency revamp of historic heritage buildings*. In Proceedings of the SBE21 Sustainable Built Heritage, Online. 14–16 April 2021.

Table 3: Information on financial aspects and LCC: Swiss case studies (note: values are presented in Euros. Conversion rates as for 18.05.2021).

No	Case study	Country	Financial	LCC	Investment costs (total)		Running costs (total/year)		
					Total	*Energy*	*Total*	*Heating*	*Electricity*
1	Doragno Castle, Rovio (TI)	CH	0	0					
2	Solar silo, Basel (BS)	CH	1	0	1,092,000	1,092,000			
3	MFH Feldbergstrasse, Basel (BS)	CH	1	1	4,550,000	455,000			145
4	MFH Magnusstrasse, Zürich (ZH)	CH	1	0	3,003,000	646,100			
5	St. Franziskus Church Ebmatingen (ZH)	CH	1	0	1,023,750	1,023,750	2,275	1,820	
6	Kindergarten and apartments (PEB) Chur (GR)	CH	1	0	3,148,600	127,400			
7	Single family home Luisenstrasse - Bern (BR)	CH	1	0		182,000			
8	Single Family House - Gstaad (BR)	CH	0	0					
9	Glaserhaus in Affoltern im Emmental (BR)	CH	1	0	2,548,000	677,950	1,966	1,365	601
10	PalaCinema Locarno, Locarno (TI)	CH	1	0	30,630,600				
	Total/Average		**8**	**3**	**6,570,850€**	**600,600€**	**2,120.5€**	**1,592.5€**	**103€**

In the last meeting, the peculiarities of HiBERatlas and the tool of retrofit solutions (HiBERtool) have been discussed among the experts participating and how to keep it alive for the future. Such repositories are expected to attract the interest of decision-makers and additionally create the momentum needed to attract new examples from architects, owners or new research projects. Many of the outcomes of the Task59 can have a long-term benefit in informing the construction sector and for owners of such a buildings. As such, its legacy is of important consideration. Unfortunately, COVID-19 had an impact on the work of the Task, such as in the development of the traveling exhibit because its dissemination was limited for much of 2020. This exhibit was to promote the HiBERatlas website, however it will be available afterwards the task 59 end. Since the website is hosted through the IEA SHC, it will remain in its latest state for some time and thus the inheritance of the information hosted on the website is assured. This means, the resources, information and publications gathered here will still be accessible in the future.

This also means that information and links to external scientific publications will remain, as long as these stay the same on external websites. Additionally, the reports produced by the subtask will be available through the website, giving more information about the work done. Furthermore, the HiBERatlas website will also continue to be maintained as a resource for the sector. This will ensure that the knowledge gathered continues to be available.

A tutorial will be prepared for architect's engagement and the contents can be used for teaching activities following previous experiences during these years. The final report (Figure 5) of this activity will be published in June 2021.

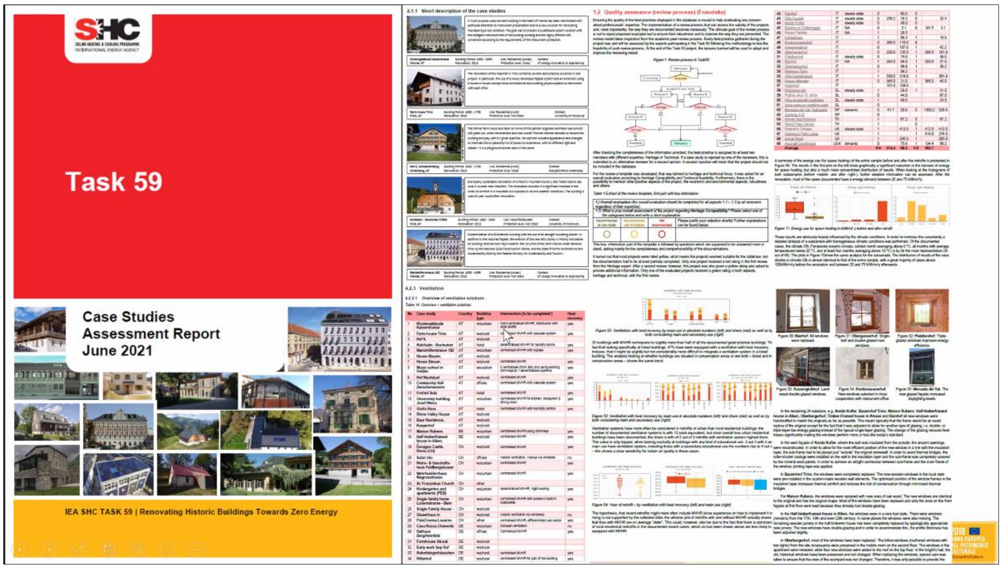


Figure 5. Subtask A Final Report summary.

Within ATLAS project and connected to IEA-SHC activities it was developed a concept for tours of best practice examples, so called EnerCulTours (Figure 6). Due to COVID restrictions, not all planned visits could be carried out. However, a digital map proposing virtual tours was made. It is possible to navigate through three different tours, dedicated respectively to farmhouses (red route), solar energy use (green route), and industry and education buildings (blue route). Several buildings in Switzerland documented by SUPSI, has been included in the virtual tours.

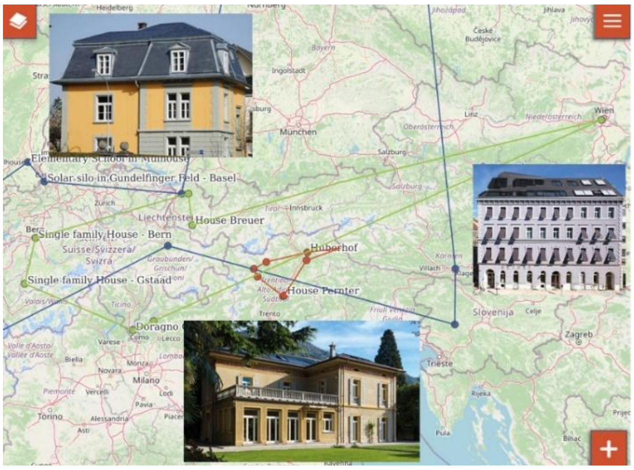


Figure 6. This 'green tour' leads past historic buildings in the Alps while exploring the utility of active solar systems integrated into the building envelope. Source: https://sbe21heritage.eurac.edu/enercultour/

In addition to these tools, two others should also be mentioned, both of which were also sponsored by the Interreg IT-CH BiPV meets History project in which SUPSI participates as co-leader. This is looking particularly at BIPV systems and provides an interactive map (https://www.bipvmeetshistory.eu/mappa-interattiva-bipv-meets-history/) and two other databases complemented the information on case studies in Switzerland (www.solarchitecture.ch) and in Italy (https://bipv.eurac.edu/it) of photovoltaic systems used in heritage contexts. These webpages promote some of the results achieved translated into local Swiss languages (Figure 7 and 8).

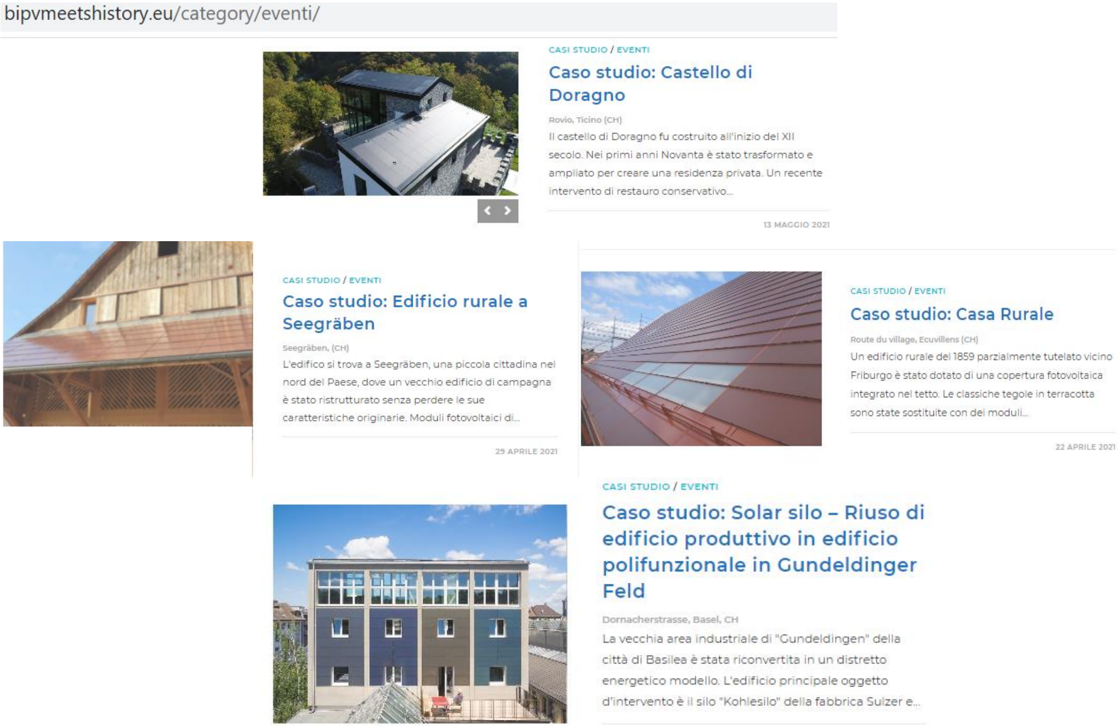


Figure 7. Screenshot website BIPV meets History, Link: https://www.bipvmeetshistory.eu/category/eventi/

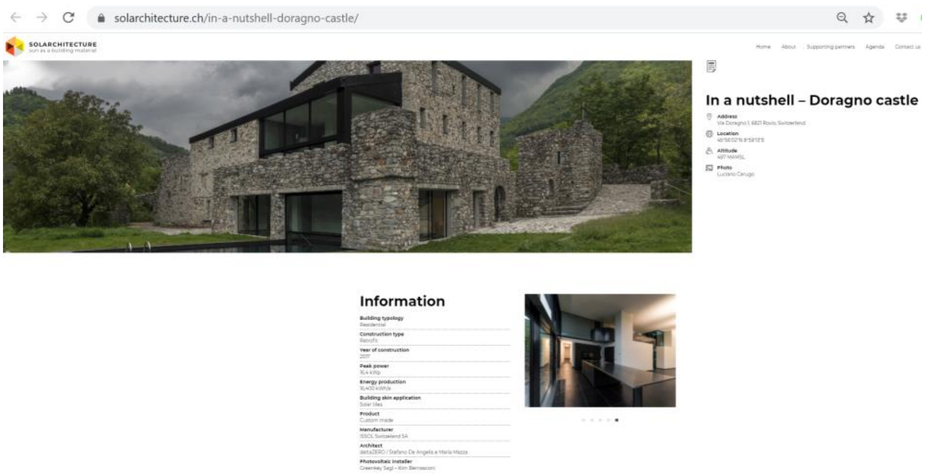


Figure 8. Screenshot website www.solarchitecture.ch. Best-practice projects in Switzerland documented by SUPSI (example).

ST-B: Multidisciplinary planning process

Aim in subtask B is the identification of replicable procedures on how experts can work together to maintain both the expression of the building, and at the same time make it more energy efficient. That's includes the identification and further development of tools which support the process and its single steps. This subtask considers the new European standard EN 16883:2017 Conservation of cultural heritage — Guidelines for improving the energy performance of historic buildings (HB) as working procedure for selecting measures to improve energy performance, based on an investigation, analysis and documentation of the building. This action aims to investigate to what the extent the standard can be improved and complemented in order to better meet the needs of the end users by providing an integrated design platform. Moreover, it looks at how 16883 can be implemented in a way that achieves lowest possible energy demand/NZEB.

This activity is linked with Best Practices (Subtask A). during all phases of the planning process: INITIATING THE PROCESS – BUILDING SURVEY; SET CRITERIA & OBJECTIVES phase; SELECTION OF MEASURES and ASSESSMENT. Specific part related SELECTION OF MEASURES is also linked with the Repository of measures and strategies (Subtask C).

During this year, SUPSI has been contributing in Subtask B activities to complete the information regarding guidelines and handbooks on retrofitting and solar renewables integration in buildings and historic assets in Switzerland and building energy simulation (BES) tools to feed the different B1 / B2 / B3 / B4 activities and contributing in Subtask B Report development.

Related **activity B1**, collecting and compiling existing documentation on tools, methods and guidelines, together with other partners there is a publication in preparation and SUPSI contributes in the compilation of factsheets to be implemented in the Final Report. Each item includes a short description with the specification of the relevance for the task activities.

Activity B2 focused on the assessment of the European standard EN 16883 and proposal for standard improvement with an informative annex. The standard provides a strategic framework for how historic buildings can be made more energy efficient. In essence, it provides a flowchart over a suggested decision process, and brief information about how the different steps can be carried out. For the improvement of energy performance of historic buildings and for the conservation of cultural heritage, the standard EN 16883:2017 proposes a working procedure that takes into account the cultural value of the building. However, there is still a long process of implementation and adaptation. For this reason, a step-by-step process involving an interdisciplinary team is necessary to review the procedure and to adapt the criteria to the retrofitting measures.

Related this part, and within the framework of IEA-SHC Task 59, SUPSI led the multidisciplinary team of experts from around the world to check and adapt the new standard EN-16883:2017 for historic building focusing on the integrated solar systems. Gather retrofit solutions with high impact on sustainability, energy efficiency, and the integration of renewables in historic buildings, have been the main goal of the solar group (Subtask C). Relying on an extensive, detailed, and accurate collection of case studies of application of solar photovoltaic and thermal systems in historic buildings, the assessment criteria of the standard has been reviewed and tailored for a better implementation. 35 documented solutions from Switzerland, Italy, Austria and Germany have been documented by the solar expert group (Figure 9). All these examples have been studied based on technical compatibility, the heritage significance of the building and its settings, the economic viability, the energy performances and indoor environmental quality and use, as well as the impact on the outdoor environment of solar renewables.

CATEGORY	NUMBER OF SOLUTIONS
Renewables attached to the roof	3
Renewables integrated to the roof	22
Renewables integrated to the facade	2
Free standing PV	2
Local sharing PV	2
Model for sharing renewables	1
Integration into the landscape	3

Figure 9. Main solar renewable solutions documented and assessed in Subtask B activities.

The standard scheme was tailored for solar RES systems by discarding inappropriate criteria and introducing other criteria internationally considered for these systems. To verify and validate its applicability to heritage contexts, quick and detailed assessment approaches were used. Limitations of the two assessment approaches were also identified: generally, the experts see the quick assessment as an excellent way to evaluate a solution. The quick assessment (example in Figure 10) dealt with nineteen case studies from four different nations of different building typologies, functions, protection levels, and types of the solar system installed and take into account the status of the buildings analysed (listed or not listed). The second step, as the standard proposes, involves both quantitative and qualitative assessment. The detailed assessment (Figure 11) requires a thorough knowledge of the building, its history, design, and construction technology involving several professionals (i.e., architects, engineers, public bodies related to building protection). At this point, experts must verify if the selected criteria are suited to the size and complexity of the project. It dealt with three case studies from different countries, typologies, protection levels, functions, solar technology types, and solar applications

The evaluation scheme considers the same assessment categories of the standard EN-16883:2017:

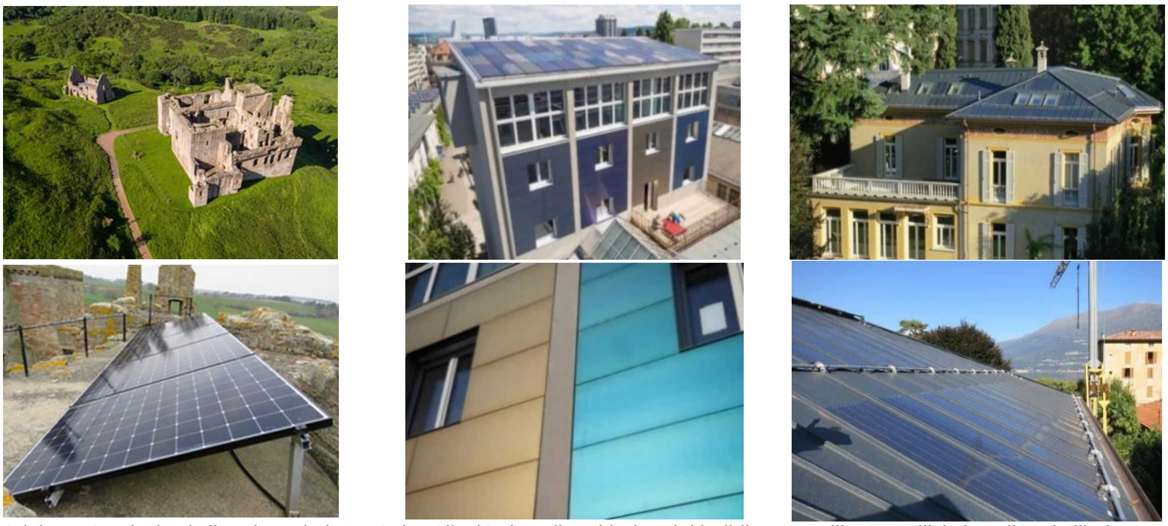
1. Technical compatibility;
2. Heritage significance of the building and its settings;
3. Economic viability;
4. Energy;
5. Indoor environmental quality;
6. Impact on the outdoor environment;
7. Aspects of use.

Quick Assessment

Assessment category	Listed building		Not listed buildings	
	Strengths	Weakness	Strengths	Weakness
Technical compatibility	Hygrothermal risk (9) Structural risk (9) Waterproof (9) Fire safety (9) Design and installation (9) Thermal bridges (9)	Reversibility (9) Reduction efficiency risk (9)	Hygrothermal risk (10) Structural risk (10) Waterproof (10) Reduction efficiency risk (10) Fire safety (8) Design and installation (10) Thermal bridges (10)	Reversibility (10)
Heritage significance	Risks of visual impact (9) Risk of spatial impact (9)	Risk of material impact (9)	Risks of visual impact (10) Risk of spatial impact (10)	Risk of material impact (10)
Economic viability	Operating costs (2) Economical return (2) Economic savings (7)	Capital costs (8)	Operating costs (1) Economic savings (3)	Capital costs (6) Economical return (5)
Energy	Energy performance (9) LCE demand (1)		Energy performance (10)	Life cycle energy demand (2)
IE quality	IE conditions suitable (7)		IE conditions suitable (10)	
Impact on the outdoor environment	Greenhouse gas emission (7)	Natural resources (5)	Greenhouse gas emission (1)	Natural resources (2)
Aspects of use	Effects of RES on users (7) Effects of change of use (7)	Easy to manage and operate (3)	Effects of RES on users (10) Effects of change of use (10) Easy to manage and operate (4)	

Figure 10. Example of the quick assessment results on listed and not listed buildings made by the expert group led by SUPSI.

Detailed Assessment



Crichton Castle (UK): listed castle in Scotland, free-standing PV. Source: © Historic Environment Scotland.

Solar Silo (CH): unlisted industrial building in protected area, roof and façade-integrated BIPV. Source: BFE-SUPSI. Photo: © C. Martig / P. Bonomo.

Villa Castelli (IT): unlisted villa in a protected landscape, roof-mounted BIPV. Source: © Valentina Carì, Progetto Serr@.

Figure 11. Case studies evaluated by the solar expert group to assess the implementation and adaptation of the standard EN-16883:2017.

The detailed assessment of each building has been carried out by a multidisciplinary group of experts on the field on energy, sustainability, and heritage with researchers from a wide variety of scientific fields mainly in the areas of renewable energies, including sustainable energy sources: (i) members of Historic Environment Scotland, the lead public body established to investigate, care for, and promote Scotland's historic environment; (ii) members of the Swiss BIPV competence centre of Switzerland within University of Applied Sciences and Arts of Southern Switzerland (SUPSI), as experts on the field of solar energy and energy efficiency in buildings; (iii) and members of EURAC Research,

This activity results in a scientific article published the Special Issue Advances in Historic Buildings Conservation and Energy Efficiency of the open access journal Sustainability 2021-05-07 | journal-article DOI: https://doi.org/10.3390/su13095246 published online by MDPI (Figure 12). This scientific article investigate the current approaches for the energy retrofit of built heritage with measures compatible with the conservation to verify and adapt the standard EN-16883: 2017. It introduces the activities within the IEA-SHC Task 59 (Subtask C) solar group, focused on integrated solar systems for historic buildings. Relying on an extensive, detailed, and accurate collection of case studies of application of solar photovoltaic and thermal systems in historic buildings, the assessment criteria of the EN-16883 standard have been reviewed and tailored, for better solar implementation in a heritage context. All this is studied on the basis of technical compatibility, the heritage significance of the building and its settings, the economic viability and profitability, the energy performance and indoor environmental quality and use, as well as the impact on the outdoor environment of solar renewables.

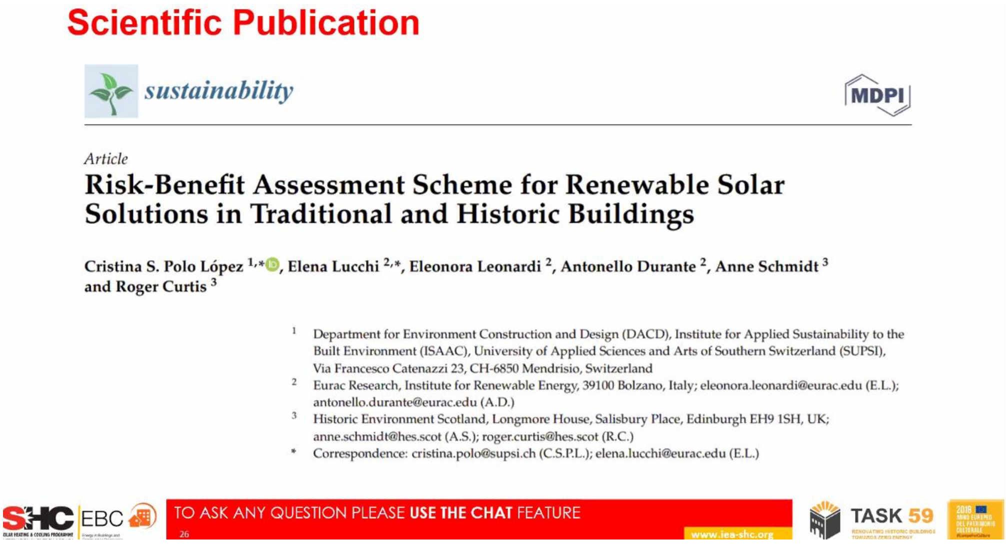


Figure 12. Journal scientific article published in Sustainability MDPI (Basel, Switzerland) as result of the activities carry out by SUPSI in Subtask B. Note: This article is available open source on the web, and on request if necessary.

Activity B3. At the end, thanks the effort of the experts in Task59 a practical guideline (handbook) will be published to support the implementation of the standard, that are supposed to be applicable to all kinds of historic buildings, and to all renovation processes in such buildings. The handbook “An evaluation of the Usability EN-16883:2017” of will be published by Swedish standards and available within the whole CEN sphere. The contents of the papers and deliverables will be used as part of the handbook. As many examples have been documented by SUPSI, related the case studies analysed in Switzerland, a practical application of the standard will be part of the application example of the standard.

Activity B4. Consist in making the outcome available for the end-users. SUPSI contributed in this activity providing information on the result obtained in activity B2 in a way that serves as a guide for the application of the standard as a practical example in a specific case study.

The standard EN 16883:2017 is a universal procedure (valuable also for Switzerland) that support stakeholders during the planning process of energy retrofitting of historic buildings (not necessarily protected). It aims to facilitate the sustainable management of these buildings by integrating measures for energy performance improvements and reduction of greenhouse gas emissions with the adequate conservation of the buildings. It provides a flowchart of a suggested decision process, and brief information about how the different steps can be carried out. The handbook will support professionals by interpreting, explaining, exemplifying and complementing all the steps in the standard. It will serve to communicate the expected benefits of using also to other stakeholders indirectly involved in the planning of energy retrofit projects, such as building owners, building users, funders, etc. It will provide best practice advice, examples and state-of-the-art tools and methods. To use the handbook in a meaningful way it is necessary to have access to the standard. Furthermore, it will give recommendations and good examples of how activities mentioned in the standard can be carried out in practice.

From the evaluation of the EN-16883:2017 standard some strengths and weaknesses has been highlighted by Task59 experts that and make possible to highlight conclusions for the revision of the standard that can be summarized in the following table (Table 4):

Table 4: Availability of Energy Performance Certificate (EPC) and calculation methods

Strenghts	Weaknessess	Revision of the Standard
• Interdisciplinary approach • Focus on the potential for energy efficiency also in protected buildings • Attention to heritage aspects in the early phases (also for non-protected buildings) • Authorities and stakeholder demand the use of the standard	• Not widely used yet • Confusion about what is mandatory or not • Presupposes large projects with multi-disciplinary teams (risk of redundancy with existing procedures) • Overwhelming and questionable benefit in small projects • Lack of examples • Focus only in buildings missing solutions at communal level • Not clear the benefits of using it • Not self-explanatory to most potential users and the iterative character in not well-understood by users	• Focus on the generic procedure for decision-making emphasizing the iterative nature of the planning process • Complemented with additional information and training • Make it clear and adapt to be easily used for a stock and categories of buildings • Easily accessible information • Explanation on how the steps can be carry out • Integration with other standards and procedures • Examples of energy retrofits and energy efficiency measures • Spread the use in training and education for professionals • Resources, literature and tools supplementing the standard

Results on **Activity B5** where SUPSI was not involved, has been presented to the task experts in the last meeting.

Historic buildings are often characterized by uncommon features, such as considerable dimensions, singular architecture complexity and huge wall thickness, that make them unique and not comparable with common buildings. Some of them, moreover, contain works of art that must be preserved over the time. In such framework, the behaviour of historic buildings with respect to boundary conditions variations is a key issue that can be analyzed by means of virtual models. The goal of the activity is to provide a guideline to define a reliable building model methodology able to reduce the gap between simulated and measured data in historic buildings. In such respect, the virtual model can be used for several purposes, such as:

- to control the indoor microclimate level to guarantee building and artefact conservation;
- to guarantee indoor microclimate level to satisfy user comfort;
- to study innovative HVAC system and/or management in order to satisfy the above two points;
- to forecast the behaviour of the building according to a change of the boundary conditions.

Energy simulation can be adapted in the field of historical buildings in order to:

1. Analyse the possible degradation risks (e.g. environmental temperatures and relative humidity ranges);
2. Assess multiple energy retrofit scenarios;
3. To identify some measures for failure during the operation phase.

The work done (Figure 13) consist in the identification of the most common microclimatic parameters used in model validation, the selection of the uncertainty statistical indices able to evaluate the model accuracy to stablish the threshold values to consider a model validated in order to give recommendations to properly carry out the model validation through microclimatic parameters.

Task outcomes will be a guideline for characterization and simulation of historical buildings and “Excel tool” to carry out the model validation.

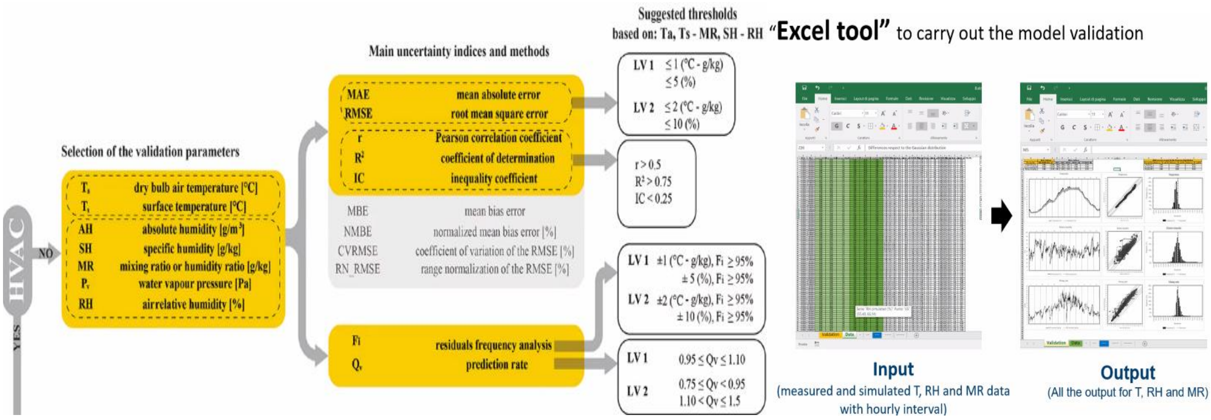


Figure 13. Outcomes from Subtask B, B5 activity. Source: H.E. Huerto-Cardenas et al., Validation of dynamic hygrothermal simulation models for historical buildings: State of the art, research challenges and recommendations, Building and Environment, Volume 180, 2020, 107081, https://doi.org/10.1016/j.buildenv.2020.107081

ST-C: SubTask C. Conservation compatible retrofit solutions and strategies

The main objective of Subtask C is to identify, assess and in case further develop retrofit solutions and strategies for historic buildings, which fulfil both, the conservation compatibility of historic buildings as well as energy efficiency goals towards lowest possible energy demand and CO_2 emissions (NZEB) and to make them available for comprehensive integrated refurbishing concepts and strategies. Subtask C will to this aim identify replicable solutions from case studies documented in Subtask A and ongoing R&D-projects. Specific focus will thereby be given to the following thematic areas or working groups: (i) windows, (ii) internal wall insulation, (iii) ventilation, (iv) HVAC, incl. solar active; (v) retrofit strategies.

Two main activities were programmed: C.1 Review on existing as well as recently developed conservation compatible retrofit solutions with high impact on sustainability and energy efficiency; C.2 Documentation, further development and assessment of the conservation compatible retrofit solutions.

Activity C1. Final Report has been finished in this period. SUPSI provided detailed information on all energy renovation strategies and conservation compatible retrofit solutions for historic buildings with high impact on sustainability and energy efficiency. Furthermore, collaborates in the definition of the Final Report. It has been divided into different sub-chapters according to the retrofit solutions collected during the activities carried out throughout the duration of the task. It is structured in five parts:

- Part I: Introduction;
- 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.

Each chapter related retrofit solutions are basically divided into three subchapters. The first subchapter describes some basic aspects of the procedure and technical aspects of the energy retrofitting of historic of the specific measure analyzed. The second part forms the core of chapter and contains the documentation of a wide variety of retrofit solutions gathered from case studies of all over the participating countries. For the documentation of the solutions, simple open questions were answered in order to enable a continuous structure of the solutions. The third part of each chapter contains an evaluation method of the specific retrofit measures. For this purpose, the assessment categories according to EN 16883 were taken as a basis and adapted in detail for walls, HVAC and solar (link with Subtask B, activity B.3). In order to illustrate the detailed assessment, three different solutions were tested using the adapted assessment criteria and included in the last subchapter.

Activity C2. 161 retrofit solutions has been well-documented, by all experts of the task. The main categories related retrofit solutions investigated are summarized in Table 5. Among these 161 retrofit solutions compatible with historical buildings, 40 solutions have been documented regarding **WINDOWS** (see some examples in Figure 14). The 22.5 % were documented by SUPSI. The solutions documented are mainly with low impact (01, in Table 5), as replacing glass or only repairing the window, or solutions with impact on the whole window (04, in table 5) by replacing the window with a replica/new window; **38 solutions** have been documented in **WALLS** category (Figure 15). Near 23.7% has been documented by SUPSI that includes internal insulation solutions, external insulation and frame infill insulation; **46 solutions** have been documented for **HVAC** systems, that are divided by ventilation, distribution and production strategies (Figure 16). The 34.8% were documented by SUPSI, considering 3 ventilation solutions as for example based on central ventilation with suspended ceiling, central ventilation with ducts integrated in the floor or decentral ventilation solutions with "monoblocks"; 12 different distribution systems with normal radiators or radiating floor and fans and 9 different production strategies using heat pump, geothermal, biomass, cogeneration or district heating.

The following table (Table 5) summarize the categories by each possible retrofit solutions studied in Subtask C. Table 6 summarizes the retrofit measures applied to the documented Swiss case studies.

Table 5: Categories of retrofit measures grouped by the different retrofit solutions gathered by IEA-SHC Task59 and ATLAS research.

RETROFIT SOLUTIONS	CATEGORIES
WINDOWS	01_Solutions with low impact
	01_A_Only repairing window (LI)
	01_B_Inserting a sealant
	01_C_Addition of foils to the glass (LI/MI)
	01_D_Shutter s repaired/recovered (LI)
	01_D_replacing glass
	01_D_replacing glass
	02_Solutions with impact on the appearance from inside
	02_A_Replacing inner glass (includes vacuum and insulation glazing) (LI – MI)
	02_B_Addition of layer of glass on internal walls covering also the windows (MI)
	02_C_Extra layer of glass on the inside (MI)
	02_D_Addition of a new window layer (on the inside) (MI)
	02_E_Replacing the window sashes or window layer (on the inside) (MI - HI)
	02_F_Adding solar shading inside (LI)
	03_Solutions with impact on the appearance from outside (and inside)
	03_A_Replacing (outer) glass (includes vacuum and insulation glazing) (MI - HI)
	03_B_Addition of a new window layer (on the outside) (MI - HI)
	03_C_Replacing the window sashes or window layer (on the outside) (MI - HI)
	03_D_Adding solar shading outside (HI)
	04_Solutions with impact on the whole window
	04_A_Replacing the window with a replica/new window (HI)
	05_Special window solutions

WALLS		Internal insulation External insulation External insulation combined with internal insulation Thin internal insulation Driving rain protection External insulation + internal thin insulation Unremovable external insulation Reversible external insulation panels Reversible external insulated facade Frame infill insulation Cavity insulation Insulation for thin wooden paneling (haylof) Wall drying before to put insulation Reflective Coating
HVAC-SYSTEMS	VENTILATION	
		Improvement of airtightness Natural ventilation Active overflow system Room by room system Central ventilation with flat air ducts and suspended ceiling Classical central ventilation with suspended ceiling Classical central ventilation with ducts integrated in the floor Decentral ventilation with "monoblocks" Air supply via chimney/shaft Facade integration of ducts Window integrated system Ceiling through system
	DISTRIBUTION	
		Radiators with visible piping Infrared heating panels Air heating Local stoves Normal wall heating Normal radiators Normal floor heating
	PRODUCTION	
		Heat Pump Pellet boiler Wood chip boiler Cogeneration plant District heating Biogas
SOLAR		Renewables attached to the roof Roof-integrated Facade-integrated renewable Free-standig renewables & reneables intergrated into landscape Local sharing of renewable energies Models for the sharing of renewable energies via power - network

Figure 14. Examples of retrofit solutions documented by the working group Windows.

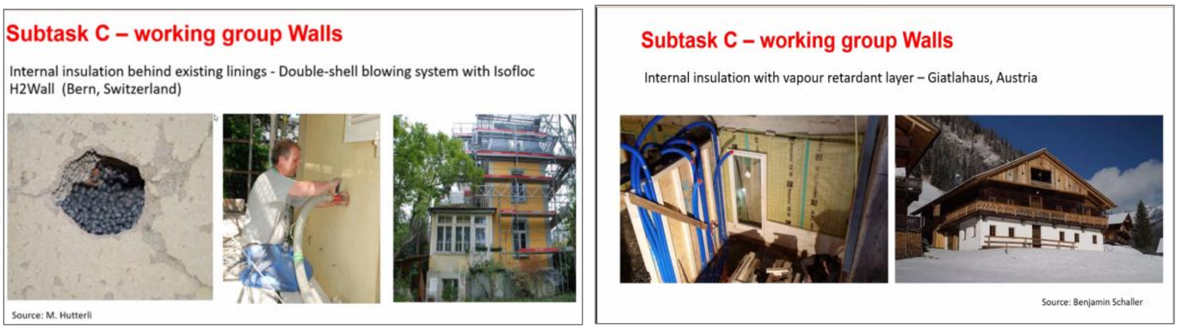


Figure 15. Examples of retrofit solutions documented by the working group Walls.

Figure 16. Examples of retrofit solutions documented by the working group HVAC.

With regard **SOLAR energies**, task59 experts have been documented **37 solutions** divided by solar renewables attached to the roof, roof and façade integrated, free-standing renewables and integrated into landscape, local sharing and models for the sharing of renewable energies via power network. SUPSI due the expertise in that field has contributed with near 73% of the solutions reported (27 solutions in total, an example in Figure 17), part of a Best practice (linked to Subtask A) or from other research projects (Interreg ATLAS and BIPV meets History) under development.

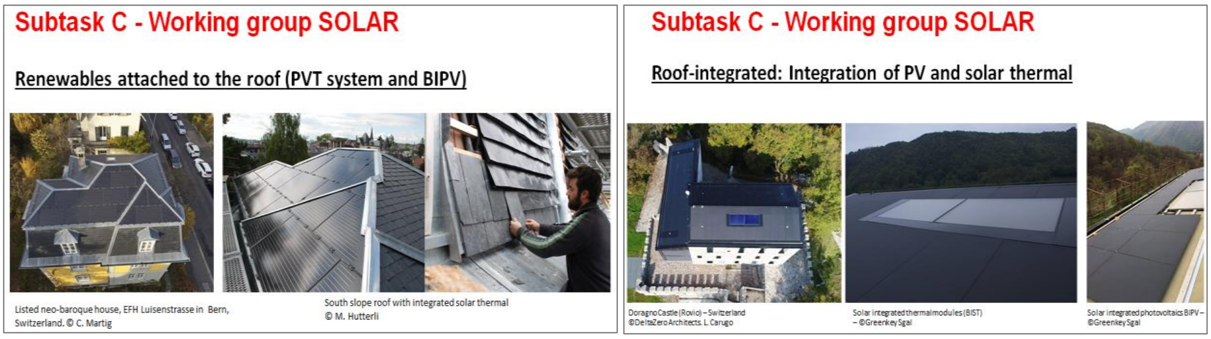


Figure 17. Examples of retrofit solutions documented by the working group Solar.

Table 6: Overview on measures implemented in the case studies (EE, Energy Efficiency; HVAC, Heating, Ventilation and Air Conditioning and RES, Renewable Energy Systems).

			EE			HVAC				RES				
No	**Case study**	**Country**	**Walls**	**Roof**	**Ground floor**	**Windows**	**Heating system**	**Domestic hot water**	**Ventilation system**	**Solar Thermal**	**Photovoltaic**	**Biomass**	**Geothermal**	**Wind energy**
1	Doragno Castle, Rovio (TI)	CH	x	x	x	x	x	x	x	x	x	---	---	---
2	Solar silo, Basel (BS)	CH	x	x	---	x	x	---	x	---	x	---	---	---
3	MFH Feldbergstrasse, Basel	CH	x	x	x	x	x	x	x	x	x	---	---	---
4	MFH Magnusstrasse, Zürich	CH	x	x	x	x	x	x	x	x	---	x	---	---
5	St. Franziskus Church	CH	---	x	---	x	x	x	---	x	x	---	x	---
6	Kindergarten and	CH	x	x	x	x	x	x	x	x	x	x	---	---
7	Single family home	CH	x	x	x	x	x	x	x	x	x	x	x	---
8	Single Family House -	CH	x	x	x	x	x	x	---	---	x	---	---	---
9	Glaserhaus in Affoltern im	CH	x	x	x	x	x	x	x	---	x	---	x	---
10	PalaCinema Locarno,	CH	x	x	x	x	x	x	x	---	x	---	x	---

All groups working in Subtask C have made an assessment of the some solutions documented according the assessment criteria and following the procedure of the European standard EN 16883:2017 to demonstrate its application and to show a structured process in the selection of refurbishment measures (linked with Subtask B activities, previously presented). The standard provides a systematic procedure to facilitate the best decision in each individual case. The general intention is to achieve the best possible energy performance while retaining the heritage significance of the building. The assessment criteria of the standard EN-16883:2017 have been reviewed and tailored for all the Subtask C groups with regard the retrofit solutions studied to better suit their implementation in heritage contexts by experts in technical and conservation fields.

To verify and validate its applicability to heritage contexts, quick and detailed assessment approaches were used. The first procedure is based on a tabular risk–benefit scheme that does not prescribe specific measures or solutions but permits the identification of the needs for energy performance improvements for a historic building. A five-level assessment scale is proposed to allow an overall evaluation of the measure, dividing in high and low risks, neutral, high, and low benefits. Each measure is assessed on the specific building for each assessment criterion in a risk-benefit scheme with a scale ranging from −2 (high risk, red), over −1 (low risk, orange), 0 (neutral, white), and 1 (low benefit, light green), to 2 (high benefit, green). Example of application in solar solutions has been introduced in previous paragraphs. Based on the assessment criteria list, a quick assessment is then undertaken by the expert team using experience rather than thorough analysis. The second step, a detailed assessment (Figure 18), as the standard proposes, involves both quantitative and qualitative assessment. At this point, an extended technical and economic assessment may be needed.

Figure 18. Part of the detailed assessment according EN-16883:2017 performed by SUPSI, applied to Solar Silo building (Basel, CH) case study.

As main output of the activities done within Subtask C, the examples of retrofit solutions documented and assessed, has been made available in the HiBERtool (Historic Buildings Energy Retrofit Tool). Three criteria had to be met by measures to be included: technical viability/robustness/feasibility, improvement of energy efficiency, and taking into account the historical value of the building. Based on the examples, a series of decision trees (example for window solutions in presented in Figure 19) were developed which, via questions on the building's features and heritage values, guide the user and lead to the proposal of a range of possible measures. The output of the HiBERtool can be considered as such a list of potentially applicable measures after being first screened by experts (section 10.4 of the standard EN-16883:2017).

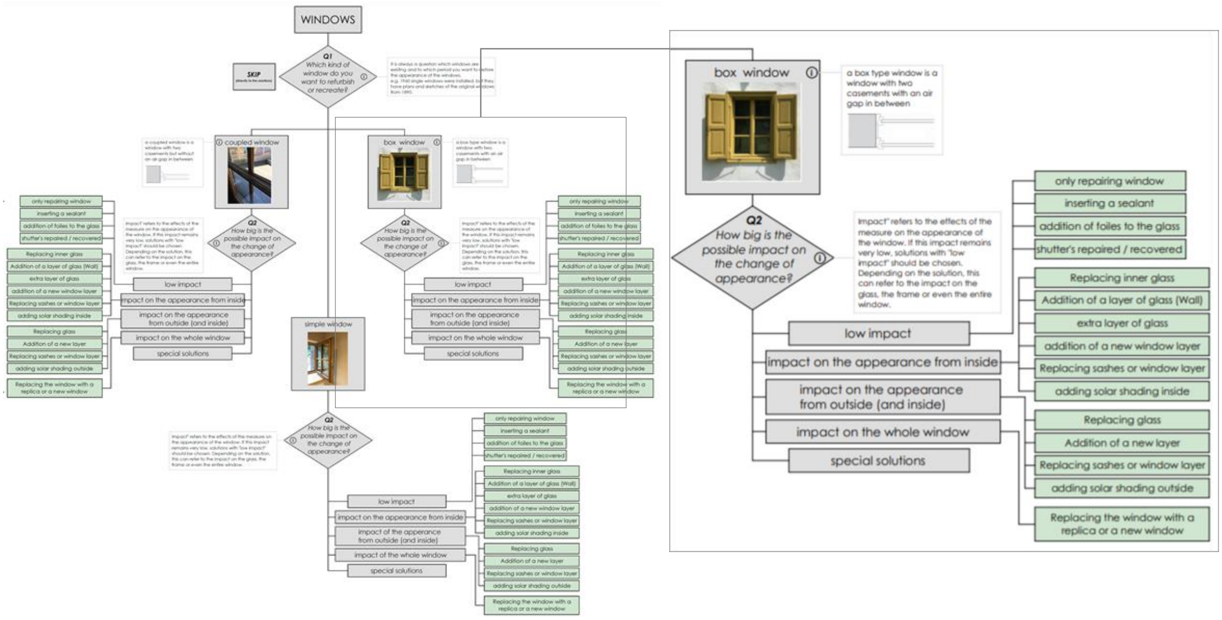


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Figure 19. Decision-guidance tree filtering documented solutions (e.g. windows) and guiding users through HiBERtool.

With the HiBERtool a possibility is given to explore and find different solutions for the energy-efficient retrofit of historical buildings. The tool documents solutions for windows, walls, ventilation, heating and solar. Besides, not only solutions but also general technical information are available for the respective topics. Afterwards it will be possible to download the documentation of the solution as a PDF. Many solutions are part of a fully documented best practice example linked to the building documentation that can be used to get more ideas and inspiration. The tool will be available online from July 2021 from the HiBERatlas website (Figure 20).

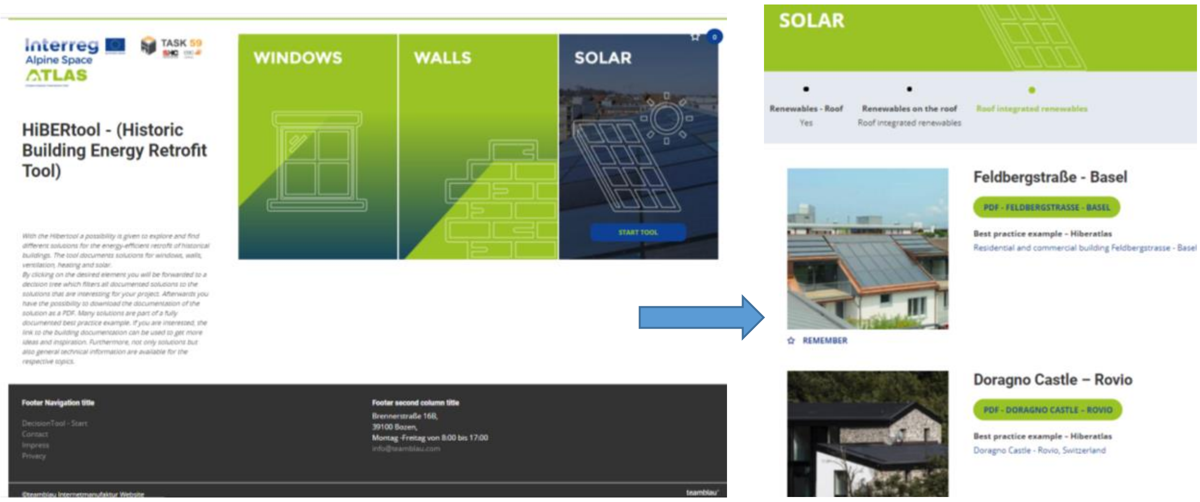
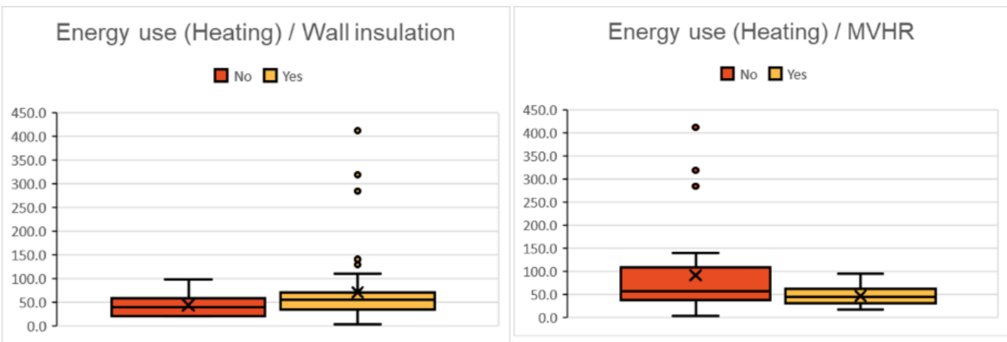


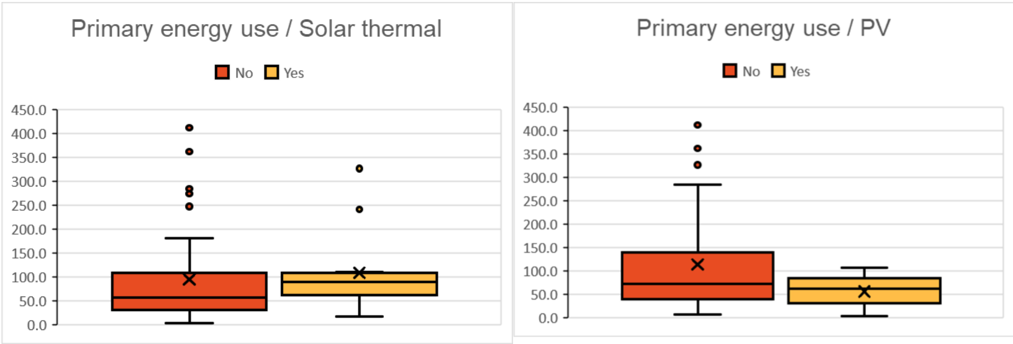
Figure 20. HiBERtool Web, documented examples for solar solutions documented by SUPSI in the beta version of the tool.

SUPSI have participated in drafting and supervision of documents Report D.C1: Conservation compatible energy retrofit technologies and Report D.C2: Renovation strategies for historic buildings.

Furthermore, an analysis of the effect of different parameters of the intervention on the primary energy use of the case studies analyzed in Subtask A report after the retrofit (in kWh/m²y) has been done by Task59 experts and is presented in Figure 21. The plots below show (from left to right, first and second line) the effect of the insulation of the external wall, the use of mechanical ventilation with heat recovery (MVHR) and the effect of renewable energy systems (solar thermal and photovoltaic systems) on the final energy use for space heating. In general, no great differences can be observed when looking at the effect of single variable with the exception perhaps of MVHR. Buildings without heat recovery (and that includes cases relying exclusively on natural ventilation) present a much higher variability and overall higher energy use than those with MVHR. Surprisingly, when looking at the effect of wall insulation, the cases with no intervention present better results. However, it is worth noticing than only 6 cases with no intervention in the external walls are included in the sample and thus the representativeness of the results might be limited. There is a positive effect of solar energy that is even more evident in the case of photovoltaic systems, where the total primary energy use is reduced from 113.6 to 56.1 kWh/m²y.



a)



b)

Figure 21. Analysis of case studies considering different energy retrofit measures after intervention. Energy use (in kWh/m^{2}y) after retrofit according to different parameters: a) retrofit with wall insulation and mechanical ventilation with heat recovery (MVHR) measures; b) with and without solar thermal and PV systems.

SUPSI contributed also in other **Subtask C. C.5 activities.** The aim of this activity is to collect, guidance documents, online tools and different Decision Support Systems (DSS) that are relevant to be specific applied to historic buildings. This activity is directly connected with Subtask B related the EN 16883. Together with other partners is under preparation a scientific publication.

SubTask D. Knowledge transfer and dissemination.

The main objective of Subtask D is to transfer the knowledge created in the Task to the relevant stakeholders. Activities within this Subtask considers: D.1 Online communication and dissemination activities (news, audio-visuals & webinars, etc.); D.2 Onsite communication and dissemination activities (e.g. Touring exhibition, participation in stakeholder events, workshops in conjunction with the expert meetings and relevant conferences, contribution to policy events); D.3 Scientific & professional Communication (scientific papers and articles in trade magazines).

Due COVID-19 most of the outreach and engagement work was able to happen digitally, and it can be argued that dissemination was facilitated in most areas by these circumstances. It could be said that the COVID-19 circumstances, as in many areas, re-enforced existing trends and positions that were already in progress. Online webinars have become another way of addressing project activities or delivering knowledge and dissemination of results.

SUPSI together with other partners were presenting several information in different events during these years on topics developed during the EBC Annex76/Task 59 activities, as for example the online database of best practices, as importance piece of work that allowed attendees to get access this emerging online content. An example during this period were the online event organized by SUPSI at the end of 2020 that involved the participation of local authorities and professional associations and members of solar industry. One of the objectives was to inform and influence building energy policy at national and regional level. This was achieved looking at economic and other factors in large scale refurbishment. These are aimed at regional or national level planners and policy makers. By their nature such events are smaller, and partners contributed with their own expertise and introducing the NZEB project. The objective was to inform planners at municipal level what the art of the possible looked like (with examples from the NZEB case studies) and considerations on how such work could be delivered as part of a regional or national level programme. In the event some architects, surveyors and municipal design and planning officers have been also participates.

Table 7 summarizes all the public events in which SUPSI has participated or carried out directly during participation in the Subtask D.

Table 7: Contribution of SUPSI in different public events during the EBC Annex76 / Task 59 activities.

EVENT	PARTNER	DATE	PRESENTATION TITLE	AUDIENCE
Solaris #03 Event	SUPSI	05 July 2019	Round table with to debate this specific issue together with representatives of local authorities.	32
BHÖ 8th European Congress on the Use, Management and Conservation of Buildings of Historical Value	SUPSI participates with other PPs.	16-17 Oct 2019	Session dedicated to Task 59 Poster to the congress with Swiss best-practice building.	20
14th Conference on Advanced Building Skins	SUPSI	28-29 Oct 2019	Presentation of BIPV Status Report 2020 "Building Integrated Photovoltaics: A practical handbook for solar buildings' stakeholders" 2020. SUPSI-Becquerel Institute. “BIPV in dialogue with history” article in chapter 1.	150
REHABEND 2020	SUPSI EURAC Genoa University	28-30 Sept 2020	8th Euro-American Congress Construction Pathology, Rehabilitation Technology and Heritage Management. Lecturer and scientific paper.	150
HERITECH Florence	EURAC SUPSI	14-16 Oct 2020	A conceptual framework on the integration of solar energy systems in heritage sites and buildings. Lecturer and scientific paper.	40
LUGANO, SWITZERLAND	SUPSI - ATLAS event	04-05 May 2020	Event held online. ATLAS project partners and observers met online for the fourth project meeting, organised SUPSI. Virtual visit to the Bavona valley (Bavona Valley Foundation).	43 (two days)
Energy Renewal of the historic building: a ‘Sustainable Issue’ for debate (Online) **Briefing session with Heritage Authorities**	SUPSI	02 Dic 2020	Conservation and sustainability safeguarding the historical and cultural heritage, to foster the energy retrofit of HB and the integration of RES promoting a theoretical-critical debate with stakeholders.	25

In some cases the level of engagement sought interaction with designers and specifiers of energy improvements. This might include architects, surveyors and municipal design and planning officers. Moreover, reach professionals and furthermore trades (those who do the work), in all countries is difficult, but are important as in many projects there are no architects or designers, and the work is done in agreement with the homeowner and those doing the installation. Some events have been planned to reach these categories of public (Table 8).

Table 8: Contribution of SUPSI in different events to engage professionals and practitioners.

EVENT	PARTNER	DATE	PRESENTATION TITLE	AUDIENCE
Solar Update Svizzera italiana 2019, Bellinzona	SUPSI	24 May 2019	Lecturer during the "Solar Days" in Switzerland addressed solar professionals and Swissolar associates to introduce the topic related to the integration of solar systems in historic buildings.	70
Meeting and worktable for the construction of a solar plan in a historic church, Lugano	SUPSI	27 June 2019	Meeting attended by representatives of the Cantonal Institutions, the Office of Cultural Heritage, and members of the Industrial Companies of Lugano (AIL), of the production and energy efficiency sector.	12
Solaris #03 Event	SUPSI	05 July 2019	Conference about the integration of photovoltaic in historic buildings and protected heritage areas.	50
Multifunctional dry building envelopes Briefing Sessions	SUPSI	09-16 Oct 2019	Two seminars and communication sessions across the territory, in Ticino, together with some SME of the building sector and companies active on solar energy	59
Infoday – BIPV MEETS HISTORY	SUPSI EURAC	5 Dec 19	BIPV meets History - project presentation BIPV digital platform	100

Social media activities

An important part for the dissemination was the social media posts, an example of which is shown in Figure 22. Until now, SUPSI contributes actively in the newsletter of Task59 disclosing the activities carried out in Switzerland. Many of the posts in 2020 and 2021 linked back to the case studies. Lastly, the case studies and information about the database were also included in the individual newsletters. In later newsletters, 2-3 of the new case studies were mentioned and links were included. An updated number of online cases was also mentioned, giving subscribers a good idea of the progress made since the last newsletter.

As the case studies were finalised and available online, they were publicised via a social media post. Features, such as the geographic search, were also mentioned via social media, to show the full range of the tool. The posts served as a hook to invite followers to find out more about the case studies as well as the tool as the whole.

Figure 22. A social media post highlighting one of the Swiss HiBERatlas case studies, linking to the partners responsible as well as the #SolarHeat hashtag.

At local level different news have been promoted solar integration in buildings and the activities done by SUPSI and partners of BIPV meets History project. Some examples in two services of the Italian-speaking Swiss Radio and Television, RSI (Figure 23):

• RSI Obiettivo impatto zero - Al passo del vento. Servizio RSI, Falò, giovedì 11/02/21 21:05 di Roberto von Flüe e Louis Trautmann - di Massimo e Lorenzo Cappon. Interventi di Francesco Frontini, Pierluigi Bonomo (SUPSI) e DeltaZero SA, consulenti in BIPV meets History; https://www.rsi.ch/la1/programmi/informazione/falo/tutti-i-servizi/Obiettivo-impatto-zero-Al-passo-del-vento-13821370.html

• RSI Luci (e ombre) del solare - Servizio RSI, Radiotelevisione Svizzera del 14.03.2021 RG, Ore 18:30 Il servizio di Mirko Priul. Intervista a Kim Bernasconi, titolare azienda Greenkey Sgal, consulente del progetto BIPV meets History. https://www.rsi.ch/news/oltre-la-news/Luci-e-ombre-del-solare-13898224.html

Figure 23. Different radio and television services in Ticino on the topic of integrating solar panels into buildings.

Furthermore, SUPSI has participated in various activities in the dissemination of the project with information technology transfer articles describing the results of the project in Swiss magazines and portals relating to the energy, construction and cultural heritage sectors. In this period, the TuttoGreen magazine, Edition No. 2-2020 (Figure 24), edited by EDIMEN SA, which on page 77 reports the article relating to the press release sent on 20.1.2020 linked to the Environment Package of the Department of the Territory.

Link to the article: https://tuttogreen.ch/

FOCUS

Pacchetto Ambiente: soluzioni pratiche e tecniche per ri-costruire **una società** rinnovabile, sostenibile, futuribile

Come progettare un futuro a impatto zero con la Scuola universitaria professionale della Svizzera italiana.

Il progetto Interreg Alpine Space ATLAS è un esempio, tra quelli realizzati in Svizzera, di buona pratica

Informazioni e contatti

Figure 24. Informative article Gaetano Frongillo, SUPSI communication manager, in TuttoGreen, 2020.

Blog

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. SUPSI as other partners had the chance to write a blog about an area of research, announcement or similar.

A full list of the blog posts can be found in Subtask D Report.

BLOG TITLE	PARTNER	DATE	AUTHORS
BIPV in dialogue with history	SUPSI	Jan 21	C.S. Polo López, P. Corti, P. Bonomo

Learning opportunities

The Task59 project enabled a number of learning opportunities for students and those in the early parts of their career (Table 7), interns and civil services. Real life learning opportunities are a great addition to those studying in the subject and at the start of their career, as it enables them to get understand the workings of these kinds of projects. This was particularly the case for the HiBERATLAS case studies, where students and interns prepared the case studies and helped to input the information. In this way, they become familiar with the case studies themselves as well, providing real life examples of retrofit projects.

Thanks the participation of SUPSI in Annex 76 / Task 59 a collaboration with the Department of Civil Engineering and Architecture (DICAR) of the Catania University (UNICT) in Italy has made possible to develop an Architectural Master Thesis on the topic of solar energy in historic buildings: “Photovoltaic Systems and Architectural Heritage: Between Conservation and Transformation” presented on October 30, 2020. Furthermore, a specific session was scheduled for the integration of the BIPV solar systems in the historic building in the course R677-designing the solar architecture an optional module within the study program of the DACD, Department of Environment, Construction and Design, Bachelor in Architecture (https://www.supsi.ch/dacd/bachelor-master/architecture/piano-studio.html). A total of 24 students have attended in the 2018-2019 and 2019-2020 courses

LEARNING OPPORTUNITY	PARTNER	TASK
Student Internship	SUPSI - UNICT	Preparing case studies, master thesis and scientific article in Sustainability, MDPI, Special Issue "Advances in Historic Buildings Conservation and Energy Efficiency" *Sustainability* 2021, *13*, 5107. https://doi.org/10.3390/su13095107
Interns and civil Services	SUPSI	Documenting wall solutions and inputting them into HiBERATLAS website

In addition, SUPSI participated within the research project BIPV meets History in a post-graduate course and Webinar specialization for the Order of Architects and Planners, Landscape Architects, Conservators of the Province of Treviso (IT). The Webinar “Photovoltaic and protection of landscape and historical centers. Innovative solutions for roofs and facades" took place online on 11 December 2020 thanks to the Arch_Learning Platform (Figure 25). 195 people participated in the event focused on architects and construction professionals. This course In which SUPSI participated together with Swiss companies in the photovoltaic sector and in the production of solar modules, such as Sunage SA is of part of the lifelong learning "Continuous professional updating" and facilitates professional training for the participants and obtaining professional training credits, 3 CFPS.

Figure 25. Course flyer and presentation for the Order of Architects and Planners, Landscape Architects, Conservators of the Province of Treviso (Italy).

3.2 Summary of main result achieved:

- The database of Best Practice examples and the share experience gained in the retrofit will last beyond the duration of the project. The general public, and specifically building owners and Citizens' groups engaged in heritage protection and environment will be inspired by the examples gathered.
- The IEA-SHC Task 59 and ATLAS methodology and guidelines, as well, will be transferable to other European locations and local settlements. Similarity, as the Alpine Space is characterized by the similarity in building archetypes, construction materials and climatic conditions, other regions can transfer the retrofit measures to their comparable building types.
- Higher education and research institutions can build upon on the example compilation as well as further develop KPIs. Local public authorities will use the KPIs for future oriented sustainable development strategies.
- Valuable information developed within the project and the documented good examples of realized solutions will work as reference for future projects and will help practitioners to choose adequate retrofit solutions for their specific buildings. Most of the ideas and principles however are replicable and applicable to other projects for retrofitting or can be adapted specifically.
- The documentation developed has been used and can be used in training courses for professionals (designers, energy consultants, university lectures) and high school students.
- Furthermore, results have been shared to the working group of EUSALP AG 9 and have been published and disseminated. A direct information transfer and dissemination to international organizations has been performed via the participation in the IEA-EBC Annex 76 / IEA-SHCTask 59.
- Moreover, the outputs have been disseminated to scientific audiences via conferences and publications.
- Main project deliverables/outputs have been accompanied by communication/awareness-raising work (especially media work and social media) on general and regional level (communication strategies). SUPSI, as member of Swissolar and Brenet (Building and Renewable Energies Network of Technology) and as Swiss BIPV Competence Center that manage the web portals www.bipv.ch and www.solarchitecture.ch can disseminate the results all over Switzerland.

3.3 Critical examination and experiences gathered from the project

A successful energy refurbishment is one that manages to keep the historic substance in good condition and achieve long-term energy improvement to achieve, as much as possible, net zero-energy building (NZEB) targets, also possible for historic buildings. Efficiency measures commonly used include free solar gains, advanced insulation, reduced thermal bridging, air tightness, use of the thermal mass, daylighting and ventilation strategies, or energy-efficient lighting and appliances. At these point, the remaining and low energy needs, could be satisfied using renewable energy generated both on- and off-site of the buildings, increasing the cost-effectiveness by reducing the size and capacity of the renewable system required. Within the framework of the International Energy Agency Solar Heating and Cooling Program IEA-SHC Task59 / IEA EBC Annex 76 activities and the Interreg Alpine Space "ATLAS" research project, in-depth information about renovated historic buildings in Switzerland and abroad, have been collected and further investigated. A comprehensive visual on success aspects for achieving high standards on energy retrofitting are available on an online web platform, the Historic Building Energy Retrofit Atlas HiBERatlas (https://www.hiberatlas.com/en/welcome-1.html), as main result of the project within Subtask A activities, to advertise model projects all over the world. The case studies chosen are representative projects of a rational use of energy, low-emission or emission-free, which promote renewable energy and in particular the use of solar energy and BIPV in historic buildings some listed in inventories, in protected areas or not listed but with worthy elements of being preserved. The retrofit intervention followed the results of a thorough heritage value assessment and a significant energy demand reduction was achieved.

In parallel, as part of the Subtask B activities, the methodology applied requested a compilation of existing documentation on tools, methods and guidelines for improving the energy performance of historic buildings (HB) as working procedure for selecting measures to improve energy performance. An important result of this task has been the review and assessment of the European standard EN-16883:2017 and proposal for its improvement with an informative annex, a handbook with an evaluation of its usability that will be published by Swedish standards and available within the whole CEN sphere.

Furthermore, among the best practices case-studies documented in Subtask A, retrofit solutions and strategies, which fulfil both, the conservation compatibility of historic buildings as well as energy efficiency goals towards lowest possible energy demand (NZEB) were documented. The specific focus of the solutions documented were: (i) windows solutions, (ii) internal wall insulation, (iii) ventilation and (iv) HVAC and renewable energies, including solar systems (v). The assessment of these technical solutions have been based on the criteria listed in the EN 16883:2017 standard, "Guidelines for the improvement of the energy performance of historic buildings". These criteria, however, have been revised by the different working groups to better adapt to the characteristics of each technology in a collaborative process of comparing, synthesizing, and making decisions. More than seventy experts in the world involved in the project collaborated in gathering examples of compatible solutions implemented in retrofits of historic buildings or tested in research projects. These solutions have been documented in an database, the Historic Buildings Energy Retrofit Tool HiBERtool, a full repository with the detailed information on energy renovation strategies and conservation compatible retrofit solutions with high impact on sustainability and energy efficiency for historic buildings following a common template. This decision guidance tool, developed within Subtask C activities, is based on a series of decision trees guide the users and lead to the proposal of a range of possible energy retrofit measures selected and documented by the experts of IEA-SHC Task59.

In historic buildings, works to improve energy efficiency have so far suffered from underinvestment and greater difficulties linked to possible protection constraints. Especially for historic buildings, investors and individual owners face a greater range of obstacles, higher construction costs and building materials, a lack of skilled workers and reliable information on the most suitable technical solutions. The architectural intervention and cost required in historic buildings for energy efficiency interventions are particularly high in this sector, as demonstrate within the project. However, there is little evidence that industry, policymakers or the public are well informed on these issues. Certainly, it is necessary to address this problem, especially in the context of the energy efficiency renovation, new forms of construction, suitable technical installations together with the possible integration of renewable sources including solar energy (solar thermal and photovoltaics) that respect the historical and cultural character. In addition, to achieve a safe and healthy built environment, adequate information on the relationship between energy efficiency and indoor air quality in traditional and historic built homes is essential.

Similarly, the impact of material choice on the internal environment in traditional buildings should be further investigated, the achievement of the levels of energy efficiency reached, and the technical implementation of advanced technical solutions monitored to evaluate the final effective result over time. Real conditions of habitability, comfort, and health should be the verified studying indoor environmental quality after refurbishment.

From these learnings, and in general from the analysis of the 69 best-practice projects documented in HiBERatlas and evaluated in the Subtask A Final Report, the following general conclusions can be drawn from the perspective of the planning process:

1) An **early and iterative dialogue between the planning team and the heritage authorities** is in many ways a key to a successful result and to an efficient planning process.
2) **Engaged clients** can contribute to the project in many different ways, from identifying what is worthy to preserve to customized technical solutions and lead to an “ownership” of the project
3) Expert dialogue is important, but the **involvement of local craftsmen and companies, who have experience in the region,** is valuable for the planning process as well.
4) **Limited project budgets can hamper innovative solutions** that are cost efficient over the whole life cycle.

4 Conclusions

Although less than 10% of the Swiss building stock has a special value as a material testimony to our past and as a cultural asset (those listed or protected in inventories) in most cases, energy improvements are possible. However, in order for this to succeed without losing substance and historical significance, a dedicated engagement with the task is required considering an interdisciplinary process, through the collaboration of multiple experts.

Clean energy transition must be at the center of economic recovery plans to build secure and sustainable energy systems. Therefore, there is a need to significantly step up energy efficiency efforts. Although if political statements and directives have been moving further towards zero-energy buildings, communities and cities the existing buildings account for 40% of energy consumed. In the Swiss real estate portfolio until now, the renovation rate of buildings still remains much lower than 2% even if in recent years the "systemic renovations", that is, one-off complete renovations, in broader phases with multiple interventions have increased (SFOE, Building Program Annual Report). These numbers are less than half the number needed to achieve the goals of the Energy Strategy 2050 for buildings and according to a study by the Swiss National Science Foundation, building renovation needs to be speeded up. Despite if under the scheme set up by the Swiss government in 2010 in the Building Program, house owners can apply for financial support to refurbish their houses and apartment to higher environmental standards, they do not have the necessary information about possible technical solutions and state subsidies to promote investment in energy efficiency. There is still a lack of rules and clear information to make users aware of the technical options to do major investments in energy-saving measures. To reach federal and cantonal challenges associated with, PV systems, as well as, other renewable solutions play a significant role in this development.

As seen before, European and Swiss targets for climate change mitigation requires the increase of energy efficiency in buildings and, more than ever before, a major penetration of RES applications, which include also solar energies. The Renovation Wave strategy within the EU Green Deal will accelerate building renovation rates by reinforcing provisions on long-term building renovation strategies. Therefore, there is a need to higher increase energy efficiency efforts. Consequently, implementation in the existing building stock becomes even more necessary and will be driven by the new EU strategy to trigger and boost renovation in the construction sector and therefore of the historical buildings. Even for historic monuments, redevelopment can result in significant improvements in energy efficiency. However, this redevelopment is unlikely to be enough to reach net zero energy use if not considered synergies with to adopt specific retrofit measures based on a holistic concept (e.g. building envelope interventions, windows, HVAC and renewables). Greater open-mindedness to find compatible integrated solutions to improve the sustainable use of our built heritage is growing which consider, not only revamping the structural integrity, the indoor air quality and user comfort, even appraise benefits on using innovative materials or construction techniques to increase energy efficiency and exploit renewable and solar energies.

This principle has guided the development of the “Guidelines for the improvement of the energy performance of historic buildings” (EN-16883:2007) but there is still a long process of implementation and adaptation. For these reason, experts from all over the world have been working on in the joint work of the International Energy Agency IEA-SHC Task 59/IEA-EBC Annex 76.

Within the project IEA EBC Annex 76 / IEA-SHC Task 59 policies, decision tools and technical solutions for high-level energy retrofit, including RES, for historic – not necessarily protected – has been evaluated capitalizing best practices. IEA EBC Annex 76 / IEA-SHC Task 59 activities have been supported by the Interreg Alpine Space research project ATLAS that promotes existing best practice for energy retrofit of historic buildings and sustainable regional development and make them available for the Alpine Space macro region. Coordination with standardization bodies, thanks to work done reviewing the standard European standard EN 16883, has been also undertaken.

To address these topics, the experts have developed the following subtasks:

- A: KNOWLEDGE BASE, developing an important database of a collection of Best Practice cases, following the approach of IEA SHC Task 37 and 47, which can be expanded in the years to come;
- B: MULTIDISCIPLINARY PLANNING PROCESS, with the identification of replicable procedures and tools to support the experts in order they can work together to maintain both the expression of the building, and at the same time make it more energy efficient;
- C: CONSERVATION COMPATIBLE RETROFIT SOLUTIONS AND STRATEGIES, through the identification and assessment of technical solutions from both energy and conservation point of view;
- D: KNOWLEDGE TRANSFER AND DISSEMINATION to the relevant stakeholders: (i) architects and consultants; (ii) building owners and users; (iii) developers and contractors; (iv) policy makers; (v) national authorities; (vi) crafts person and construction industry; and (vii) educational bodies.

The tools developed within Subtask A and C are of practical utility for the entire construction value chain and for the whole stakeholders involved in the process of rehabilitation of protected and non-protected historic buildings. The Atlas tool (HiBERatlas) of the best examples and the technical energy retrofit solutions repository (HiBERtool) documented in detail many realized projects and energy retrofit solutions that can be taken as an example. However these tools should be enhanced and customized for local users (e.g. adapted to local languages, building archetypes, considering local materials or architecture, etc.) to include new elements of reference in the respective countries. SUPSI have given an important contribution on the use of renewable solutions (mainly solar thermal and photovoltaic) but considering other integrated solutions as geothermal or biomass in the examples documented. Furthermore, interesting retrofit solutions has been gathered to better explain how to achieve net zero energy and high efficient solutions, also in historical buildings.

The work done within Subtask B on the revision of the European standard EN 16883, to better contribute to the development of energy policies in the euro area and abroad is of interest for an international comparison on the practical usability and on how it would be better to integrate this approach with others already in use. The contribution of experts in different fields (i.e. technical, energy efficiency, construction, conservators and planners) has proved necessary in adapting and revising the standard, in order to carry out the activities to complete or improve it in the future. Until now, the EN 16883 it is voluntary in other European countries but has not yet been applied in practice in Switzerland. However, it provides guidelines for sustainably improving the energy performance of historic buildings, e.g. historically, architecturally or culturally valuable buildings. It has been proven that also in historic buildings respecting their heritage significance and preserving them by increasing energy efficiency is not necessarily a contradiction.

With the ambition of realizing zero-energy buildings and built environments, also considering the sustainable refurbishment of history buildings, a continuation of the Task is important to have a continuity in the topics undertaken, to overcome issues and accelerate the use of renewable energies towards the future vision and to bring ahead an international coordination on the main challenges and potentials. The work started by SUPSI within IEA-SHC Annex 76 / IEA-SHC Task59 could support the National Baukultur policies[3], established the in Switzerland in 2020 by the federal government following the Davos Declaration and process[4]. Following this approach, buildings and heritage sites worthy of protection could be carefully maintained and developed avoiding indesiderable abandonment. As seen before, can to survive only if adapted to today's living conditions based on energy efficiency and user comfort.

5 Outlook and next steps

The contents developed within IEA-EBC Annex76 / IEA-SHC Task59 are in line with the lines of research undertaken in SUPSI towards sustainable construction for an enhancement of the construction culture in Switzerland. Likewise, the compilation of detailed data on best practices (case studies and technical solutions) from each participating country, and a solid technical foundation has been put together that will allow for future expansion and improvement.

Nevertheless, to involve potential users that will promote renovation and energy efficient buildings and communities at local level (municipalities and communities), translation of contents and tools developed into the regional languages would be needed. Furthermore, new examples that involve not only individual buildings but also historic areas and municipalities that can be built with little or no impact on the climate can be necessary. Historical city cores, solutions for the community and new contents related this topic could be expanded, considering sustainable living, social inclusion together with energy efficiency and living quality and to support Swiss *Baukultur* policy.

However, nowadays awareness of work done is still missing to empower all the countries involved to carry out an effective dissemination work for a real use and implementation. There should be a later task in this regard and to further expand the work just started as it will be supported by current post-Covid-19 energy policies in all European countries and in Switzerland. An extended Task work is expected to be undertaken. SUPSI has already expressed its interest, in the case of being able to obtain financing to support their participation.

Some possible contents can be highlighted to consider new lines of research to be funded, also highlighted by Task59 expert during the final meeting (Figure 26):

- Increase the number of local examples and case studies and further expand the contents; Only 10 case studies from Switzerland has been documented in detail. However, it has proven that there

[3] Swiss Baukultur policies to promote high-quality *Baukultur*: https://www.bak.admin.ch/bak/en/home/baukultur/konzept-baukultur/erklaerung-von-davos-und-davos-prozess/nationale-baukultur-strategien.html (assessed 30 June 2021).

[4] https://www.bak.admin.ch/bak/en/home/baukultur/konzept-baukultur/erklaerung-von-davos-und-davos-prozess.html (assessed 30 June 2021).

are many other interesting examples that could be documented as example of good energy retrofit implementation in Historic Buildings. For example, at least about 15 other best cases documented in the solar group by SUPSI, could be studied in depth and the retrofit solutions documented in detail) to show how it is possible to adapt to the specific local contexts - i.e. materials, crafts, architecture and archetypes, etc. - and climate areas in Switzerland. Technical innovation is not the focal point in this case, as indicated in the recent conference on June 9, 2021 "Constructive Alps" conference on Alpine Baukultur. The Constructive Alps conference has been focus on practice, to discuss how buildings can be built with little or no impact on the climate in the Alps, as climate-friendly building - in harmony with social aspects - is a key to a future with a high quality of life.

- Check the usability and effectiveness of using the databases created at national and local level;
- Regarding the tools already developed, it could be possible to manage and add other types of possible actions such as providing digital models and BIM or audio-visual content to these databases and web platforms of best practices examples. Virtual tours to the buildings, videos, podcast, and interviews with users, owners or architects could be foreseen;
- Promote the results at the local level, fostering dissemination and information through books, guidelines, handbooks, dedicated conferences or workshops with professionals and interested local stakeholder. It would be very important to ensure the use of the developed tools and to ensure knowledge by professionals and property owners of similar characteristics. Industry and local companies also considered as a reference audience target;
- Main focus in RES integration and considering solar energy together with other aspect today highlighted as weak points, as information on LCA/footprint, daylighting, cost implementation and monitoring of results to check effectiveness;
- Self-sufficiency and proper spatial development are new topics to be further developed also for their importance linked to solar energy implementation. It would be important to support new tools for territorial planning considering the “visibility and acceptance” of solar systems in the historical city cores and in the landscape to ensure greater implementation. Besides, urban-scale solutions in historical and protected contexts become important and being able to document new solutions in successful practice at this scale would be of great interest to follow suit (e.g. positive district, district heating, biomass, etc.). Many examples are now in progress and can be a model for others (e.g. district heating in the municipality of Airolo, Ascona or Carona, ISOS city cores in Ticino)
- Lastly, would be necessary to consider, on a new Task, the objectives of the Davos Declaration 2018 (Conference of Ministers of Culture Davos 2018), towards a culture of quality construction in Europe, the *Baukultur* policies. The Davos Declaration considers that building is culture and creates space for culture. This is reflected in their names, which range from "architectural policy" via “Landscape” to “shaped environment”. Energy efficiency and built heritage is a cornerstone of the construction culture, worthy of conservation and protection. This should bind the built heritage not only to a sustainable approach and to quality-oriented procedures and new technologies, but also included a social economic part for a debate where everyone can contribute to shaping a better common living.

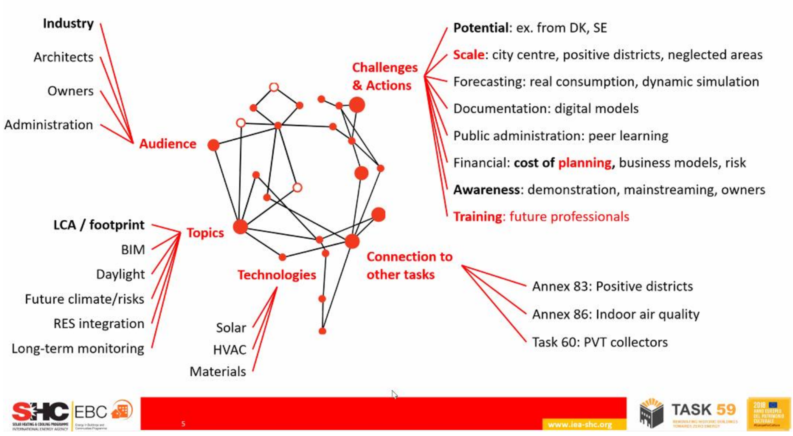


Figure 26. Potential new lines of research discussed among experts of IEA-EBC Annex 76 / IEA-SHC Task 59, during last expert meeting in June 2021.

6 National and international cooperation

At local level, the cooperation with local authorities concerning conservation and safeguard of historical and cultural assets and representatives of cantonal offices that implement the energy efficiency and RES energy measures policies it has remained constant throughout this time.

An example has been the preparation of an online session to inform relevant stakeholders concerned with historic monuments and cultural heritage about the related topics developed within the task activities. The online event dedicated to local public administrations and municipalities will take place on 2 December 2020. This briefing session for public administrations, was attended by other parties interested in the discussion (e.g. local SMEs, representatives of Municipalities, and members of trade associations and for the protection of heritage). Solar integration was presented as a necessary intervention to support other energy rehabilitation measures of the historic building. During the online event, ICT was used to check the interest in the first outcomes of the research in progress. "Padlet" tool has been used as a real-time collaborative web platform where users to actively participate in the discussion on various topics to debate (Figure 27).

Public administrations have highlighted the importance of facilitating the implementation of these measures with specific advice and training, while municipalities and municipalities have stressed the positive value - of a direct relationship with public administrations and the importance of having technical documentation to support and to enhance local examples and make them known by promoting demonstration pilot projects in the area. Guided tours of these model cases can be very useful for all actors (professionals, public administrations and municipal representatives, industries) and specific guidelines for municipalities on how to intervene. The need to move from discussion to implementation actions and find new business models was highlighted as strengths for companies in the sector (technicians and industries) and for the associations of categories, and the importance of relating different partners / stakeholders. While the weaknesses and shortcomings are still the lack of communication between the different actors. Although if there is the awareness of many authorities of the need to allow, at least in part, also in buildings and protected areas, to participate in energy, climate and lifestyle changes, the long timelines of real action were highlighted on the framework instruments (laws, territorial plans, guidelines). On the contrary, as keys to success for industries, there is the need to promote the use of new innovative, available and competitive products and the networking of new technologies is underlined.

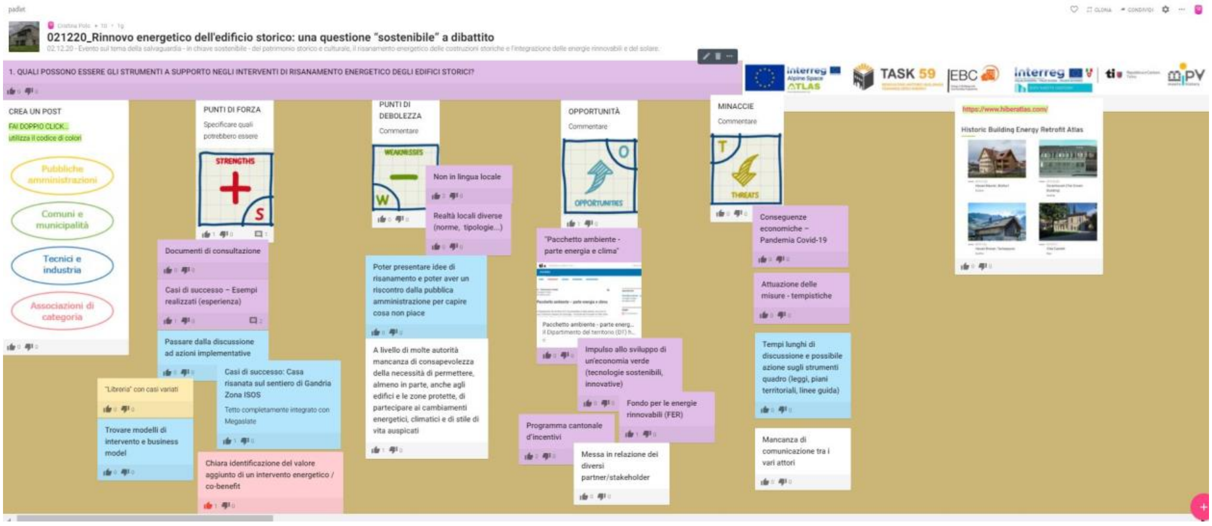


Figure 27. Informative session for public bodies, representatives of Municipalities, local SMSs and members of trade associations.

The collaboration at international level with other experts in different multidisciplinary fields provision for cooperation with well-recognized institutions in countries, which are EU members, and abroad, which provide data, information and expertise to assure the best results of excellence and similar best-practice cases, to be inspired by.

As previously reported the impacts of COVID-19 on many aspects of the project need to be stated especially with regard international cooperation. While in mid-2020 there was a pause in activities, by autumn 2020 most were familiar and active with digital means of communication. Once adopted, the change to online working for all participants has allowed a quicker and easier exchange of information, and meetings were better attended. Most of the outreach and engagement work was able to happen digitally without interruptions.

SUPSI, due the participation to ATLAS project, have cooperated with **EUSALP Action Group 9** (*EU Strategy for the Alpine Region*), as part of the activities within the ATLAS project. This cooperation include the collaboration with CESBA (Common European Sustainable Built Environment Assessment) [66] and EU experts in the definition of Performance Indicators for buildings, concerning "Key Performance Indicators for greening the Alpine infrastructure". The EUSALP "KPIs for Greening the Alpine Infrastructure" (EUSALP KPIs) is a framework of indicators and common metrics for measuring the sustainability of the built environment at building, urban and territorial scale. The EUSALP KPIs at building scale are based on the EU Level(s) systems and the CESBA KPIs. In the context of EUSALP, the AG9 intends to develop a set of common KPIs (Key Performance Indicators) to harmonize the built environment assessment systems in use in the Alpine regions and to define an Alpine space Passport. The main objective is to establish a common language of sustainability for the built environment. This common language should enable actions to be taken that can make a clear contribution to EUSALP sustainability policy objectives.

The EUSALP Report "Performance Indicators for buildings"[5] has been published the frame of the Alpine Space project "Implementing Alpine Governance Mechanisms of the European Strategy for the Alpine region" (AlpGov). This report gives practical inputs and intends to advance the thinking of how harmonised, affordable and operational assessment tools for public authorities could be developed to promote and boost sustainable and low-carbon buildings in the Alpine Space.

[5] Moro, A., Vienot, E., Berchtold-Domig, M.: EUSALP Performance Indicators for buildings, EUSALP Action Group 9, 2018.

7 Publications

Many technology transfer articles were published describing the results of the activities already done, in magazines and Web portals in Switzerland and abroad, relating to the energy, construction and cultural heritage sectors as highlighted in Subtask D activities. SUPSI has participated in various activities in the dissemination of the project and related to the integration of solar PV and BIPV systems in construction, some have also been disclosed through social channels and will be part of subsequent activities related to the Task59 newsletters previously detailed in Subtask D activities.

The advent of the pandemic Covid-19 disease has compromised the possibility of participating to multiple events during the whole period, as conferences or exhibitions. Nevertheless, Ms. Cristina Polo (researcher of SUPSI) have attended the REHABEND conference (Congress on Construction Pathology, Rehabilitation Technology and Heritage Management) that was supposed to be held the 24/27 March 2020 in Spain, but finally held online on 28-30 September 2020. The scientific article "Acceptance of Building Integrated Photovoltaic (BIPV) in Heritage Buildings and Landscapes: Potentials, Barrier and Assessment Criteria" was presented at the conference and published in the conference proceedings. The research refers to the application of integrated photovoltaic systems (BIPV) in historic buildings and in the landscape, in order to guarantee the conservation of historical, material, aesthetic and natural values, while at the same time supporting the increase of energy efficiency, of microclimatic comfort and environmental sustainability. Also in this context, another scientific paper "A conceptual framework on the integration of solar energy systems in heritage sites and buildings" was presented at the FLORENCE HERITEC 2020 international conference, which was held online on 14-16 October 2020. The paper in collaboration with Ms. Elena Lucchi (EURAC Research, Bozen, Italy), and Giovanna Franco (University of Genoa, Italy). The research aims to conduct a comprehensive review of the available literature on the integration of renewable energy sources in cultural heritage sites and buildings. The aim is to promote the conservation of their cultural and natural values, as well as the reduction of primary energy consumption, the increase in comfort levels, the minimization of environmental impacts and the improvement of technical quality and economic outlays. A common operational framework is defined to help restorers, historical conservators and energy experts, in order to facilitate the dissemination and application of renewable energy sources in cultural contexts.

This year 2021, the **Sustainable Built Heritage 2021 conference: Renovating historic buildings for a low-carbon built heritage** was successfully delivered online from the 14th to the 16th April 2021. It was a very successful event, which represented the final conference for three projects, namely Task59, ATLAS (Interreg Alpine Space) and HyLAB. IEA-SHC Task 59 and Interreg Alpine Space ATLAS projects support the conference and SUPSI has been part of the Scientific Committee of the conference.

The conference focused among other topics on urban planning and heritage conservation with thoughts about how historic buildings can be the basis of sustainable development and a more resilient world. The importance of international cooperation and conversation about this subject and the connection to the ICOMOS 2030 Sustainable Development Goals was stressed.

One part of the conference consisted of speakers introducing real life case studies as well as considerations of monitoring, outreach and new technologies (for example SOLAR). Particularly noteworthy is the focus on 'Research meets Practice', an opportunity for dialogue and discussion between academic researchers and practitioners about projects and approaches, in which there were the contribution of the Swiss architectural firm DeltaZERO SA, authors of one of the SUPSI documented best practice case studies. This ended in a roundtable discussion with experts from different countries, considering the role of historic buildings in new European policies. The full programme is available on the SBE21 Heritage website (https://sbe21heritage.eurac.edu/agenda/).

About 150 people attended the conference. Due to the conference having to be held online, networking was made possible using Airmeet. Here, participants could meet at virtual tables for discussions and questions for the speakers. This proved to be popular with many of the delegates and many wide ranging discussions were made possible.

Task59 partners submitted a number of papers to the conference. These were about a range of topics and are listed below. Particularly notable are the case studies, which introduced the best practice buildings also included in the HiBERATLAS, as well as results from the Subtask C investigations.

Conference proceedings will be published with IOP Publishing and indexed in Scopus (these articles are available on request, if necessary).

List of publications at SBE 2021 (SUPSI Contribution):

- Polo López, C.S.; Mobiglia, M. Swiss case studies examples of solar energy compatible BIPV solutions to energy efficiency revamp of historic heritage buildings. In Proceedings of the SBE21 Sustainable Built Heritage, Online. 14–16 April 2021.
- Polo López, C.S.; Bettini, A.; Khoja, A.; Davis, A.M.; Hatt, T.; Braun, M.; Kristan, M.; Podgornik, J.; Haas, F. Strategies and tools for potential assessment of Renewables (RES) in Alpine Space areas valid for historic buildings and sites. In Proceedings of the SBE21 Sustainable Built Heritage, Online. 14–16 April 2021.
- Khoja, A.; Danylenko O.; Polo López, C.S.; Essig, N. Socioeconomic Reflections on Historic Buildings Renovations: A Portrait of Rural Alpine Municipalities. In Proceedings of the SBE21 Sustainable Built Heritage, Online. 14–16 April 2021.
- Peluchetti A., Guazzi G., E Lucchi E., Dall'Orto I. and C S. Polo López, Criteria for building types selection in preserved areas to pre-assess the BIPV solar potential - The case study of Como land area. In Proceedings of the SBE21 Sustainable Built Heritage, Online. 14–16 April 2021.

Furthermore, thanks SUPSI participation in IEA EBC Annex 76 / IEA SHC Task 59 it was possible to publish some scientific articles in **Sustainability** (ISSN 2071-1050), peer-reviewed and open access journal published online by MDPI, within the Special Issue "Advances in Historic Buildings Conservation and Energy Efficiency". This special issue belongs to the section "Environmental Sustainability and Applications".

Ways to reduce historic buildings energy consumption proved to be very challenging because of the need to balance on the one hand the conservation principles and on the other hand that of providing thermal and visual comfort to the users. This special issue aims at enlarging this knowledge, and welcomes original research related to techniques, technologies and methodological approaches to the conservation of the envelope and of the indoor artifacts features, along with ways to guarantee indoor comfort conditions and reduce the energy consumption.

List of publications Sustainability Special Issue 2021 (SUPSI Contribution):

- Polo López, C.S.; Troia, F.; Nocera, F. Photovoltaic BIPV Systems and Architectural Heritage: New Balance between Conservation and Transformation. An Assessment Method for Heritage Values Compatibility and Energy Benefits of Interventions. *Sustainability* **2021**, *13*, 5107. https://doi.org/10.3390/su13095107; PDF Version: https://www.mdpi.com/2071-1050/13/9/5107
- 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 ; PDF Version: https://www.mdpi.com/2071-1050/13/9/5246/pdf
- 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

In the following pages and tables (Table 9, 10 and 11) there is a summary of all publications during the development of IEA-SHC Annex 76 / IEA-SHC Task 59 activities: conference proceedings, journal articles and trade journals.

Table 9: Contribution of SUPSI in conferences and conference proceedings.

CONFERENCE PROCEEDINGS	PARTNER TASK59	DATE	CONFERENCE
Swiss case studies examples of solar energy compatible BIPV solutions to energy efficiency revamp of historic heritage buildings	SUPSI	April 21	**Conference proceedings SBE21 Heritage Conference** Main author: C.S. Polo López (SUPSI)
Strategies and tools for potential assessment of Renewables (RES) in Alpine Space areas valid for historic buildings and sites.	SUPSI	April 21	**Conference proceedings SBE21 Heritage Conference** Main author: C.S. Polo López (SUPSI)
Socioeconomic Reflections on Historic Buildings Renovations: A Portrait of Rural Alpine Municipalities.	SUPSI	April 21	**Conference proceedings SBE21 Heritage Conference** Main author: A. Khoja (MUAS)
Criteria for building types selection in preserved areas to pre-assess the BIPV solar potential - The case study of Como land area.	SUPSI / EURAC	April 21	**Conference proceedings SBE21 Heritage Conference** Main author: A. Peluchetti (R2M Solution)

Table 10: Scientific articles published.

JOURNAL ARTICLE	PARTNER TASK59	DATE	JOURNAL/ISSUE
Acceptance of Building Integrated Photovoltaic (BIPV) in Heritage Buildings and Landscapes: Potentials, Barrier and Assessment Criteria	SUPSI / EURAC / UNIGE	Sept 20	Proc. Int. Conf. Rehabend, 24-27 September 2020, p. 1626-1644. EID:2-s2.0-85081755689, Part of ISSN: 23868198, http://www.scopus.com/inward/record.url?eid=2-s2.0-85081755689&partnerID=MN8TOARS Main author: C.S. Polo López (SUPSI)
A conceptual framework on the integration of solar energy systems in heritage sites and buildings	EURAC / SUPSI	Oct 20	IOP Conference Series: Materials Science and Engineering, Volume 949, International Conference Florence Heritech: the Future of Heritage Science and Technologies, 14-16 oct 2020, Online Edition. IOP Publishing, IOP Conf. Series: Materials Science and Engineering 949 (2020) 012113, doi:10.1088/1757-

			899X/949/1/012113949 (2020) 012113. https://iopscience.iop.org/article/10.1088/1757-899X/949/1/012113/pdf Main author: Elena Lucchi (EURAC)
Conservation-compatible retrofit solutions in historic buildings: an integrated approach in Task 59 project	Various Subtask C SUPSI	March 21	Sustainability – Special Issue https://www.mdpi.com/2071-1050/13/5/2927 Main author: Alessia Buda (Polimi)
Risk-benefit assessment scheme for renewable solar solutions in traditional and historic buildings	SUPSI / EURAC / HES	May 21	Sustainability – Special Issue https://www.mdpi.com/2071-1050/13/9/5246 Main author: C.S. Polo López (SUPSI)
Photovoltaic BIPV Systems and Architectural Heritage: New Balance between Conservation and Transformation. An Assessment Method for Heritage Values Compatibility and Energy Benefits of Interventions.	SUPSI / UNICT	May 21	Sustainability – Special Issue https://www.mdpi.com/2071-1050/13/9/5107/htm Main author: C.S. Polo López (SUPSI)

Table 11: Articles published in trade journals.

ARTICLE (TRADE JOURNALS)	PARTNER	DATE	JOURNAL/PAPER
Risanamento energetico del patrimonio storico	SUPSI	Aug 20 (004/20)	Archi magazine. Publisher: espazium. ISSN 1422-5417
Il Castello di Doragno, Restauro e sostenibilità energetica	SUPSI	Aug 20 (004/20	Archi magazine. Publisher: espazium. ISSN 1422-5417
BIPV in dialogue with history	SUPSI	Nov 20	BIPV Status Report 2020 "Building Integrated Photovoltaics: A practical handbook for solar buildings' stakeholders". 2020. SUPSI, Becquerel Institute. Editor: SUPSI https://solarchitecture.ch/wp-content/uploads/2020/11/201022_BIPV_web_V01.pdf
Pacchetto ambiente: soluzioni pratiche e tecniche per ri-costruire una società rinnovabile, sostenibile e futuribile.	SUPSI	Winter 20	Tutto Green magazine, Ed. n°2-2020 (editor: Edimen SA)

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