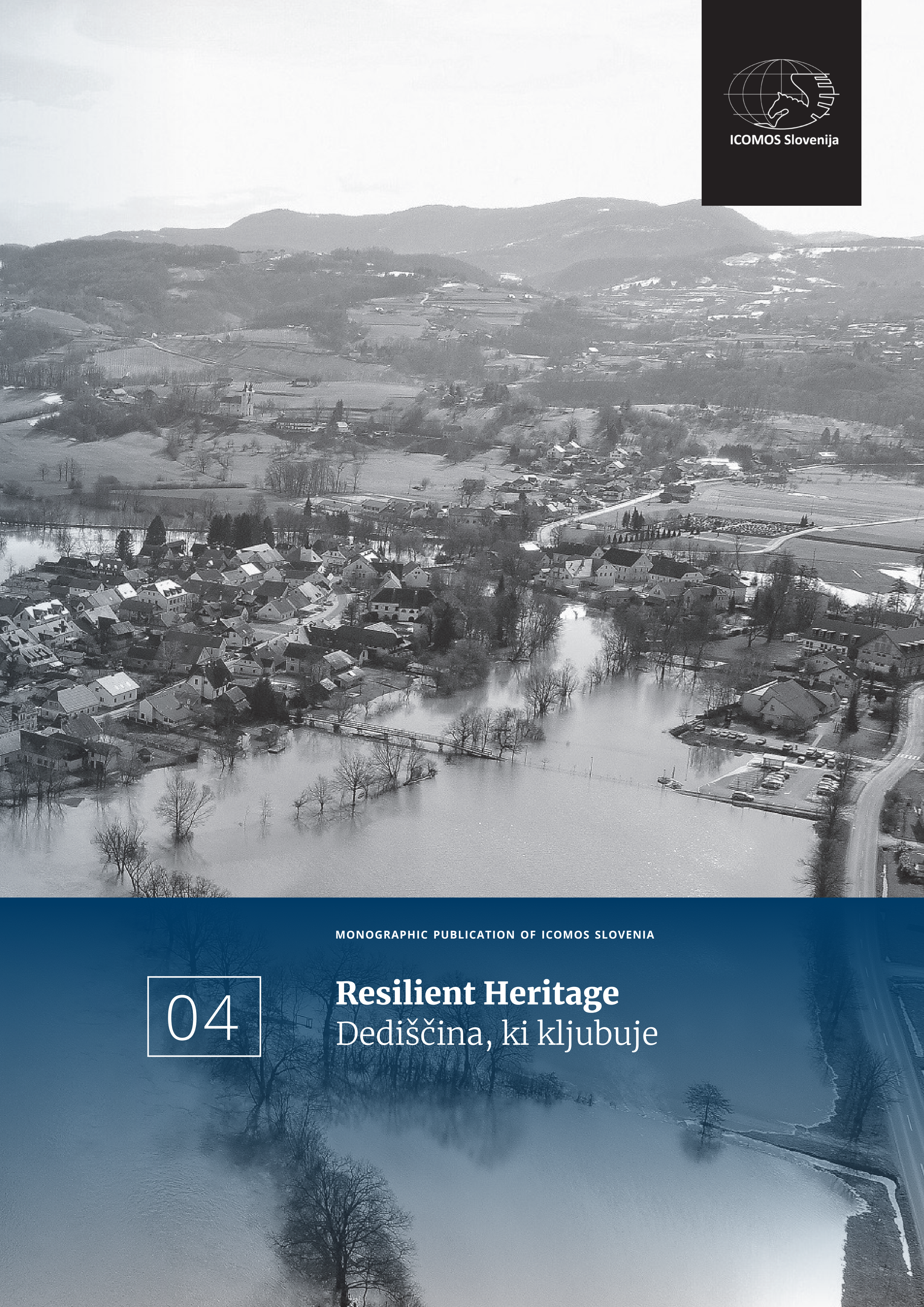

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04

Resilient Heritage
Dediščina, ki kljubuje

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SONJA IFKO

Introduction

The 4th ICOMOS Slovenia International Scientific Symposium, held in September 2021, focused on questions related to increasing the resilience of cultural heritage. This is a topic encountered practically at every turn in the current cultural heritage protection practice. The current situation calls for immediate action in the field of cultural heritage, nature, built environment, and lifestyle – in short, in all areas of our lives.

The monograph at hand presents the contributions from the symposium, addressing various themes that are directly or indirectly related to the improvement of the state of cultural heritage in the circumstances of the increasingly intense impacts of climate change and conflicts with a broad range of backgrounds. In this context, we are also confronted with the frequently overlooked contribution of cultural heritage to the Sustainable Development Goals and people's well-being – both, of individuals and various communities. This was experienced by all during the Covid-19 pandemic.

Thematically, the monograph is divided into three sections and an introductory plenary section, which highlights the comprehensive and multifaceted role of cultural heritage in ensuring greater resilience of the planet and quality of life for everyone. The transcript of the lecture by Andrew Potts, one of the world's leading experts on cultural heritage and climate change, highlights the global climate situation and the role of cultural heritage in addressing it. It also focuses on the European Cultural Heritage Green Paper.

The first section, titled "What Is the Situation and How Prepared Are We", presents the contributions that focus on analysing and listing threats to the individual heritage areas and sites due to climate change, inappropriate land use, and politically-driven urban development, as described by Andrea Triff. Tanja Hohnec's contribution sums up the Slovenian experience in dealing with climate change in the field of cultural heritage, describing the results of the international CHEERS project. It is vital that the experience with organising interdisciplinary cooperation is presented.

The second section presents the key challenges. Here, the authors focus on the various approaches to increasing the resilience of heritage and, on the other hand, balancing the investments in energy efficiency measures, which is one of the society's funadamental priorities in the current crisis.

The third section, titled Cultural Heritage as an Example, presents the experience and examples of successful implementations and projects that increase the resilience of heritage and thus its contribution to sustainable development. The authors from Madrid outline the PROCOERS Plan of protecting the collections kept in the Museo Nacional Centro de Arte Reina Sofía. The article on the development of heritage resilience in the Mae Klong river basin presents lessons learned in Thailand, while the contribution on the revitalisation of the medieval fortress of Bijela Tabija describes the efforts of the experts from Bosnia and Herzegovina.

Photo: Miha Tomšič

GAŠPER STEGNAR, STANE MERŠE, SAMO GOSTIČ,
MARJANA ŠIJANEC ZAVRL, MIHA TOMŠIČ

Balancing Investments in Energy Efficiency Measures with the Conservation of Cultural Heritage Buildings in the Light of Global Warming – A Slovenian Case Study

SUMMARY

There is a growing concern that global warming will significantly change the buildings' performance pattern in the future. In their fight against climate change, countries have already committed to reducing greenhouse gas emissions, increasing the share of renewable energy, and improving energy efficiency. In the building sector, a substantial contribution to these efforts will be made through extensive energy renovation of buildings and the restructuration of heat supply. Cultural heritage buildings present an important part of the building stock, especially in historic cities, and improving their energy efficiency can represent significant savings in the overall energy consumption.

The study investigates the effects of climate change related impacts and policies on energy use, overall investments, and the risk of neglecting important conservation features on cultural heritage buildings in Slovenia. A comprehensive assessment of any building renovation should not address merely its energy characteristics, but also the aspects of cultural heritage protection and seismic renovation, focusing on the experiences gained in previous renovations of public buildings. The study demonstrates the possible solutions for energy and seismic renovation and improvement of indoor thermal comfort that can be applied to cultural heritage buildings.

Climate change related actions cause a paradigm shift in the building renovation design, while the magnitude of climate change impact and related investments require a holistic approach to the design and planning of resources in order to comply with cultural heritage building protection rules.

Usklajevanje naložb v ukrepe za doseganje energetske varčnosti in ohranjanja stavb kulturne dediščine v luči globalnega segrevanja – slovenska študija primera

POVZETEK

Pojavlja se vse več pomislekov, da bo globalno segrevanje v prihodnosti korenito spremenilo vzorce učinkovitosti stavb. Države so se že zavezale, da bodo v okviru boja proti podnebnim spremembam zmanjšale izpuste toplogrednih plinov, povečale delež obnovljivih virov energije in izboljšale energetsko učinkovitost. Znaten prispevek gradbenega sektorja bo obsežna energetska prenova stavb in prestrukturiranje toplotne oskrbe. Stavbe kulturne dediščine so zlasti v zgodovinskih mestih pomemben del stavbnega fonda, zato je mogoče zagotoviti znaten prihranek pri skupni porabi energije, če izboljšamo njihovo energetsko učinkovitost.

Študija preučuje tudi učinke, povezane s podnebnimi spremembami, ter politike o porabi energije, skupne naložbe in tveganje, da bi pri stavbah kulturne dediščine v Sloveniji zanemarili pomembne vidike ohranjanja. V celovito oceno kakršne koli prenove stavb bi morali vključiti tako energetske značilnosti kot tudi vidike zaščite kulturne dediščine in seizmičnega načrtovanja prenove, pri čemer se je treba osredotočiti na izkušnje, zbrane pri predhodnih prenovah javnih stavb. Študija predstavlja možne rešitve za energetsko in seizmično prenovo ter izboljšanje notranjega toplotnega ugodja, ki bi jih lahko uporabili pri stavbah kulturne dediščine.

Ukrepi, povezani s podnebnimi spremembami, spreminjajo paradigmo pri načrtovanju prenove stavb, zaradi obsežnih učinkov podnebnih sprememb in s tem povezanih naložb pa je treba zagotoviti celosten pristop v zvezi s pripravo in načrtovanjem sredstev, da bi ustrezno upoštevali predpise o zaščiti stavb kulturne dediščine.

1 Introduction

In order to achieve an economically reasonable working life, buildings need to satisfy several basic requirements. They should provide a high level of safety and well-being for their occupants and operate so that their impact on the environment is as neutral as possible. When discussing their sustainability we consider environmental, economical and social aspects, and in the case of heritage buildings we also add the cultural aspect.[1] Cultural heritage buildings present a comprehensive challenge because we aim to preserve their appearance, materials and other valuable characteristics as much as possible, while recognising the need to upgrade their construction as well as their technical and functional aspects in order to make them usable for the future generations. In this sense, energy and seismic renovation are of a particular interest concerning the Slovenian cultural heritage buildings' fund.

When evaluating the possible quantitative effects of energy renovation, we cannot treat all buildings in the same manner. This is not connected merely to their different ages, the wear and tear of building elements and mechanical systems, or the technical feasibility and cost-effectiveness of the renovation, but also, for example, their possible special status arising from their cultural and historical significance. The level of protection of such buildings against a wide variety of interventions is defined by regulations and other acts in the field of cultural heritage protection.

Buildings that have recognizable building elements and are protected as cultural heritage usually cannot go through a comprehensive energy renovation without some sort of a negative impact on the protected values. Therefore, all measures that would unacceptably alter the character or appearance of the building are excluded from the list. The permitted scope of comprehensive energy renovation thus depends on the architectural and historical significance of the building, which is previously defined by the cultural protection professionals.

To put it simply, comprehensive energy renovation of cultural heritage buildings is an energy renovation that includes all – or to be more precise, only those - measures to improve energy efficiency permitted by cultural protection conditions and consent. Regardless of the fact that the restrictions of the protection regime might hinder us in carrying out a comprehensive energy renovation or achieve energy indicators that would be as favourable ("good") as for conventional buildings, the

1 Comité Européen de Normalisation. EN 16883:2017. Conservation of Cultural Heritage—Guidelines for Improving the Energy Performance of Historic Buildings. 2017. Available online: https://standards.iteh.ai/catalog/standards/cen/189eac8d-14e1-4810-8ebd-1e852b3effa3/en-16883-2017 (accessed on 27th February 2021).

results are positive. The effects are manifested, among other things, in the improvement of living comfort and reduced operational and maintenance costs.

Energy renovation also contributes to the protection of the protected building fabric and individual elements, while extending their lifespan. We can mention the improved protection against moisture, the elimination of structural and convection thermal bridges, an increase in surface temperatures and a reduced risk of mould development. Measures for the preservation of heritage and for more efficient use of energy do not have mutually exclusive goals and outcome as long as the constructive cooperation of the competent professions is secured.

As if the problems of balancing energy efficiency measures with the preservation of cultural heritage values of buildings were not enough, an additional layer of problems arise when we take into account that Slovenia is on an earthquake prone area. Most cultural heritage buildings are old, older than the contemporary seismic codes, in most cases older than any seismic codes. In the case of Slovenia, certain requirements regarding earthquake safety were introduced in 1964 (and toughened in 1981 before adopting Eurocodes in 2008). But even then, the considered earthquake (horizontal) load was small (about 1 % to 4 % of the building weight) while now it can be up to 40 % (depending on the location and type of building). Thus, most cultural heritage buildings do not possess the seismic resistance required today. Old cultural heritage buildings are mostly masonry buildings (at least in Europe). They might look solid, strong and imperishable, however, their fragility is hidden in the construction details and in old, inappropriate and weathered material. Such buildings are generally capable of resisting vertical loads, though they are vulnerable to horizontal seismic loading. During earthquakes, a sudden collapse of a part or the entire building might occur due to the overturning of the walls, collapse of the corner connections or the shear failure of masonry walls.

2 Methods

2.1 Energy efficiency first – a difficult concept to grasp when dealing with cultural heritage buildings

It is widely recognised that in order to be prepared for the future, buildings need to consume minimum energy and minimise greenhouse gas emissions while ensuring comfortable conditions in a changing climate. In 2016, Slovenia was one of the 197 countries that adopted the Paris Agreement, aiming to keep the global average temperature below 2 °C above the pre-industrial levels while pursuing efforts to limit the temperature increase to 1.5°C.[2] Slovenia's current emissions reduction targets are represented by the 2030 target to reduce emissions to 20 % below 2005 levels and to reach net zero levels in 2050.[3]

2 UNFCCC, 2016. Available online: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed on 31st August 2022).

3 National Energy and Climate action Plan (NECP), 2020. Available online: http://www.energetika-portal.si/fileadmin/dokumenti/publikacije/nepn/dokumenti/nepn_5.0_final_feb-2020.pdf (accessed on 31st August 2022).

However, as a part of the European Green Deal, the EU has set a binding goal of achieving climate neutrality by 2050 with European climate rules. Therefore, the current levels of greenhouse gas emissions must be significantly reduced over the coming decades. As an interim step towards climate neutrality, the EU has increased its climate ambitions by 2030, pledging to reduce emissions by at least 55 % by that year.[4] As a part of the "Fit for 55" package, the EU is preparing a review of its climate, energy and transport legislation that would bring the current laws in line with the 2030 and 2050 ambitions that have yet to be adopted on national levels.

Improving the efficiency of new and existing buildings is globally recognised as a good way of reducing emissions related to energy generation: energy efficiency is key to ensuring a safe, reliable, affordable and sustainable energy system for the future. Energy efficiency is the one energy resource that every country possesses and is the quickest, and least costly way, of addressing energy security, and the related environmental and economic challenges. This means that by creating a more efficient way of using resources in buildings, we can retain the same level of comfort while consuming less energy. On an annual basis, the small proportion of new-builds added to the existing building stock is low, therefore it is important to develop and implement technical solutions that would provide both cost-effective new-builds as well as cost-effective renovations. Slovenia still has a large building stock of dwellings that need to be upgraded, as every uninsulated building is wasting energy through excessive heating and is adding to the global climate change by releasing greenhouse gas emissions into the atmosphere. From a global, local and individual point of view, it makes a lot of sense to make Slovenia's built environment energy-efficient now.

The impact of inefficient buildings is not only harmful for the environment, but also for people, as the building users are affected by the consequences, either through high energy bills for heating such spaces or, when they cannot afford to heat them, having to cope with cold and unhealthy environments. Although Slovenia has a relatively mild climate, about 10 % of households are estimated to live in fuel poverty. Around 100,000 households in single family buildings deal with high heating bills, since it was recognized their building's efficiency falls in the category of energy classes F and G.[5] Most of these buildings were built before 1980.[6] The average indoor temperatures are low by international standards and occupants regularly report they feel cold, because they cannot afford to adequately heat their inefficient buildings.

The adaptation of current buildings for future needs shall consider all possible challenges and stresses that these structures might be subjected to. As renovation is defined as works done to change the performance, function or capacity of a building or an upgrade to a building to adjust to new circumstances or require-

4 Consilium Europa, 2022. Available online: https://www.consilium.europa.eu/sl/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/ (accessed on 31st August 2022).

5 From 150 to 210 kWh/m2a inclusive (F), and from 210 to 300 kWh/m2a and more (G), according to the national scale.

6 Long Term Energy Renovation Strategy (LTERS), 2021. Available online: https://www.energetika-portal.si/fileadmin/dokumenti/publikacije/dseps/dseps_2050_final.pdf (accessed on 31st August 2022).

ments,[7] renovating our most vulnerable building stock is of high importance. Internationally, the application of energy renovation strategies to historic buildings has seen intense development in research and practice, with energy efficiency policies becoming more sensitive to heritage conservation principles over the years. Until recently, energy renovation was seen as a threat to conservation, but it is gradually gaining recognition as a measure to help with the protection of heritage buildings by providing healthy indoor environments that can have a longer lifespan. Renovation in places of cultural and historical significance is often described as a balancing act between optimisation and conservation of original features.

Another challenge for the adaptation of historic buildings to current and future requirements is their seismic vulnerability. This is particularly important for historic constructions made of load-bearing masonry, organised in complex aggregates, which present an intrinsic vulnerability and are particularly susceptible to local or global collapses in case of seismic loading. Earthquake protection of the built heritage can be realised through preventive knowledge of the seismic risk, with which we can plan mitigation strategies and schedule the necessary renovation measures to reduce vulnerability. Strengthening cultural heritage structures in order to meet the requirements of contemporary seismic codes often requires invasive interventions that may not be applicable because of their impact on the heritage fabric and other limitations. The challenge of balancing safety with the maintenance of architectural and artistic features of historic structures remains a pressing issue.

Despite the fast-developing international scenario on energy renovation of historic buildings, neither Slovenia nor the European Union have a large list of renovation projects for its existing buildings and even fewer examples of energy renovation of historic buildings. On the other hand, seismic renovation of historic buildings is becoming more common in the country. The reasons for this lack of energy renovation interventions are investigated in this paper, and ways to encourage energy renovation strategies are discussed, aiming to integrate both energy and seismic upgrade efforts.

2.2 The Integration of Energy and Seismic Renovation in Cultural Heritage Buildings

The integration of energy and seismic considerations in the renovation of cultural heritage buildings aims to increase the resilience of built heritage by concurrently addressing the threats of natural disasters related to climate change and earthquakes. This integrative approach considers the long-term sustainable management of heritage, and fits within the wider concept of preventive conservation, recognising that ‘prevention is better than cure’ when safeguarding cultural heritage. According to UNESCO, disaster mitigation calls for a change in the line of thought, from post-disaster reaction to pre-disaster action,[8] so that these preventive strategies aim to address the possible issues before they occur. The main benefits of preventive measures can be found in the improved protection of heritage values, cost-effectiveness, the reduced risk for accumulating deterioration and additional damage, the prolongation of the service life of buildings and building parts and the empowerment of local communities in dealing with heritage.[9]

The links between energy and seismic renovation are multiple-fold: energy efficient renovation is useful for structural protection, while structural strengthening prevents the environmental impacts and required energy associated with damages, repairs or reconstruction. In addition, both types of interventions are generally applied to the building envelope, therefore their impact on heritage fabric can be minimised by applying strategies that work harmoniously together, rather than duplicating the use of new construction elements.

Examples of research and practice integrating energy and seismic renovation can be found in Europe, especially in Italy, after the recent earthquakes that have led to greater urgency on seismic strengthening solutions and a few studies have identified the benefits of this integrated approach. Many authors have identified that most building renovation interventions tend to focus on either energy efficiency or seismic resilience techniques, pointing out the need for greater integration and understanding across both fields. There is a disconnection among the stakeholders that arises from the development of seismic risk mitigation independently of the sustainable development goals. Calvi and Ruggeri[10] presented a proposal for an integrated assessment of energy efficiency and earthquake resilience, according to which environmental and seismic impact metrics are translated into common financial decision-making variables.

Several initiatives targeting energy and seismic renovation were developed following the 2009 earthquake in L’Aquila, Italy, as well as other cities damaged by previous earthquakes in the country. There were proposals to turn the recovery process into an opportunity to improve the energy performance of cultural heritage buildings as a part of an integrated energy and seismic renovation approach. Pilot projects developed in the villages of Caporciano and Apice Vecchia, analysed the renovation solutions for both, individual buildings as well as for the entire village. The ultimate goals of the proposed strategies were to integrate passive energy renovation actions on building envelopes, introduce structural interventions aimed at improving seismic performance and integrate or add energy systems that run with the help of renewable energy sources, such as photovoltaic systems.[11] Bournas and Davoli[12] evaluated the financial feasibility and benefits of the combined approach to seismic and energy renovation. It was shown that the payback of the interventions can be significantly reduced (i.e. by 50 to 10 years) when seismic renovation is applied concurrently with energy renovation, combining advanced construction materials, mainly due to the large savings related to labour costs.

7 European Commission. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Renovation Wave for Europe: Greening Our Buildings, Creating Jobs, Improving Lives, COM/2020/662 Final. 2020. Available online: https://ec.europa.eu/energy/sites/ener/files/swd_-_a_renovation_wave_for_climate_neutrality_and_recovery.pdf (accessed on 31st August 2022).

8 Arya et al., 2010. Guidelines for Earthquake Resistant Construction.

9 C.J. Whitman, O. Prizeman, J. Gwilliam, P. Walker, A. Shea., 2020. Energy Renovation of Historic Timber-frame Buildings-hygrothermal Monitoring of Building Fabric.

10 Calvi and Ruggeri, 2016. Energy Efficiency and Seismic Resilience: A Common Approach.

11 Belpoliti et al., 2010. La riqualificazione energetico-ambientale.

12 Boarin and Davoli, 2014. Preliminary Audit And Performance Improvement.

Overall, the literature on the integration of energy and seismic renovation of cultural heritage buildings suggests this is a growing field of study, with a potential to be further explored in many different contexts and cultures. There are calls to improve the energy efficiency of cultural heritage buildings around the world and, in the case of countries with valuable built heritage that is seismically vulnerable, a combined approach might be appropriate. Countries that could benefit from this approach include Italy, Greece, Turkey, Chile and Nepal, among many others. This integrated approach is usually attempted after earthquakes cause significant damages to built heritage and there is a need to repair and renovate concurrently; however, preventive measures before a disaster takes place would be far more effective for safeguarding cultural heritage for future generations.

2.3 Seismic strengthening – a necessary, but high expense

Various strengthening methods can be used to improve the seismic resistance of buildings with masonry walls, however, in the case of cultural heritage, the renovations are restricted by the acceptable methods. Many applicable methods are quite invasive and can significantly alter the appearance (and substrate) of the building. Listed below are some typical methods for strengthening the structure, with an indication of the problems that might occur when used for cultural heritage buildings (denoted below as CH):

1. Connecting load bearing elements (in order to prevent disintegration – an application of measures that will ensure the structure will behave as a whole, the horizontal load will be distributed to the walls according to their stiffness, and the walls will be protected against excessive rocking and possible failure in the out-of-plane direction)
    1. horizontal steel ties (but their installation impairs facades) or perfo ties (drilled inside the wall, but demand a more complex application, which is expensive)
    2. anchoring the roofing (to prevent sliding and deformation)
    3. exchange/stiffen wooden floors with reinforced concrete or planking with OSB (this method strongly interferes with the appearance of floors and ceilings and is often unacceptable in CH)
2. Strengthening the load bearing structure (to meet the current resistance requirements)
    1. cement grout injections into the stone masonry (great improvement of strength but irreversible)
    2. refill or grout injections into the cracks in masonry (if cracks have to be repaired due to structural reasons; again, an irreversible method)
    3. partial rebuilding of the brick masonry (might not be an option in CH due to aesthetic reasons or substrate preservation)
    4. reinforced concrete coating of brick masonry walls (very effective in terms of strength but almost never an option in CH)
3. Strengthening the foundations (in the case of weak foundations it is necessary to widen or deepen them, which can be achieved by constructing a reinforced-concrete tie-beam along the edge of the foundations)
4. Removing or anchoring 'loose' elements (ornaments, chimneys), however, this can be sometimes connected to restoration works (frescos, altars, stone ornaments...)

New methods are being developed in order to overcome the above stated problems of these invasive methods. One of the most promising is the reinforcement of masonry with fibre reinforced polymer (FRP) fabric on the surface of the wall (in the plaster). Its efficiency and reversibility favour this technique in the case of CH buildings. The idea of using FRP for strengthening masonry walls is not as new as it is vast in possibilities for strengthening configurations, providing new materials and a variety of underlaying inhomogeneous basic material. New materials can be engineered to match the required properties of strength, aesthetics and compatibility with the substrate.

Other methods include earthquake isolation for individual elements or for the entire building (which is extremely difficult in the case of CH buildings). One can also introduce new structural elements to dissipate the earthquake's energy: braces, dampers, or ductile connectors can be incorporated in the structure and they can be visually separated from the CH substrate (if that is required from the CH point of view).

Measures for strengthening the load bearing structure can be invasive, they can degrade the aesthetics of the building and they are very expensive due to their complexity. The costs of strengthening the building to withstand an (expected) earthquake varies dramatically, but can easily consist of 50 % or more of the total renovation costs. Nevertheless, it should be taken into consideration that all expenses on energy efficiency (or other) measures can be lost in the case of an earthquake if the structure is not sufficiently resilient. Thus, earthquake resistance must be taken into consideration and other measures should be applied (and costs incurred) only once basic earthquake resistance is ensured. Or at least the cost benefit and risk analysis are performed and an action is decided upon their results.

3 Results

3.1 Decarbonising cultural heritage buildings is not straightforward

The 2030 National Energy and Climate Plans (NECPs) present the framework for Member States to outline their climate and energy goals, policies and measures between 2021 and 2030. The short-term goal for Slovenia is to, by 2030, reduce greenhouse gas emissions in buildings by at least 70 % compared to 2005. Besides this, at least 2/3 of all energy use in buildings must derive from renewable energy sources. By 2050, the goal is to reach zero net emissions in the building sector by maintaining a high level of energy renovation of buildings with low-carbon and renewable materials and by focusing on heating methods using renewable-based technologies and remote heating systems with renewable energy sources.

The main challenges for the decarbonisation of the building stock by 2050 are to increase the current low renovation rates and the application of ambitious minimum requirements for existing buildings. Decarbonisation scenarios for the building sector are being created through energy models. The latter have been widely applied to the analysis of energy system decarbonisation in order to assess the options and costs of the transition to a low carbon supply. However, questions persist as to whether they are able to effectively represent and assess heat decarbonisation pathways for the buildings sector. This question stands out especially for the cultural heritage buildings, since in the case of inadequate addressing of their specifics, the overall energy and CO_2 savings can quickly be overestimated.

Older cultural heritage buildings are often more energy-efficient than buildings built between World War II and late 1970s. Some studies have shown that buildings constructed before 1940 require less energy for heating and cooling than houses built during the subsequent 35 years.[13] Before electricity was available, homes capitalized on natural sources of lighting, heating and ventilation because the house itself – not electric lights and heaters – was all that protected the occupants from the elements. Regardless of their level of energy efficiency, all buildings must still be maintained properly in order to function fittingly as well to offer an appropriate environment so that they serve their purpose. This means that the thermal envelope components still need to be renovated to the permitted extent and the heating and cooling system must be, if technically possible, in accordance with the national heating and cooling guidelines.

Some specific elements of older buildings - with or without heritage significance - that contribute to their noteworthy energy efficiency are: (1) thick, heat-retaining masonry walls made from stone or brick, (2) exterior balconies, porches, wide roof overhangs, rooftop ventilators, clerestories, skylights, awnings and shade trees, (3) windows often include exterior shutters, interior venetian blinds, curtains and drapes and (4) exterior walls were often painted in light colours to reflect the hot summer sun, resulting in cooler interior living spaces.

Measures for the energy renovation of cultural heritage buildings are not primarily evaluated according to the achieved energy indicators, but according to their impact on the protected heritage values. The proposed technically feasible and economically justifiable measures require cultural protection consent, and not all of them may be eligible in each individual case. In general, they can be applied in the following fields:

- Opaque building envelope (e.g. additional external or internal thermal insulation, sealing of cracks and joints)
- Windows and doors (e.g. general repair, replacement of glazing, replacement of whole elements, weatherstripping)
- Installation of energy efficient HVAC systems and components (e.g. local and central heating, connection to remote heating, hydraulic balancing of the heating system, ventilation with heat recovery, installing an energy management system)
- Installation of renewable energy systems (e.g. heat pump, biomass, solar collectors for domestic hot water, photovoltaics)

13 https://www.nachi.org/energy-efficiency-historic-buildings.htm

Organisational measures (e.g. regular maintenance and repair, installation of occupancy sensors, energy accounting)

In November 2016, the Guidelines for Energy Renovation of Cultural Heritage Buildings[14] were published in Slovenia as the first formal national document dedicated specifically to this topic. Measures as listed above are described in detail, ranked according to their potential impact on the protected heritage values, and accompanied by further explanations of their possible mutual influence and building phenomena. The guidelines serve as a practical orientation and source of knowledge for building conservation specialists, architects, engineers and investors.

The long-term goal of buildings in the public sector is energy renovation of 3 % of the total floor area, where the minimum energy efficiency requirements are achieved in accordance with the national legislation. The central government buildings in Slovenia consist of almost 500 buildings with a total floor area of 890,899 m². In the scope of the long-term energy renovation strategy by 2050 it was established that 39 % of the buildings are officially protected as a part of a protected environment or because of their special architectural or historical significance. Furthermore, according to the modelling process, 23 % of the assessed buildings do not meet the required seismic resistance according to Eurocode 8-1. The buildings were divided into cohorts according to their compliance. Based on their potential for either deep or partial energy renovation and taking into account the cultural heritage aspect, the potential energy and CO_2 savings were calculated (Table 1).

Table 1: *Energy renovation potential for central government buildings in Slovenia.*

Group	Energy efficiency	Cultural heritage	Seismic strengthening	N	Floor area	Energy savings	CO_2 savings
Unit	[compliance]	[compliance]	[compliance]	-	m²	GWh/a	kt/a
1	yes	-	-	22	55.250		
2	no	no	no	166	263.986	20,85	5,85
3	no	yes	no	59	121.982	9,64	2,70
4	no	ne	yes	21	47.723	3,77	1,06
5	no	yes	yes	34	81.539	6,44	1,81
6	no	yes	-	10	33.889	2,68	0,75
7	no	no	-	179	286.531	22,64	6,35
Sum				491	890.899	66,02	18,5.

14 Vendramin, M, et al, 2016. Smernice za energetsko prenovo stavb kulturne dediščine. Ljubljana: Ministrstvo za infrastrukturo: Ministrstvo za kulturo, 2016. ISBN 978-961-93518-6-4. Available online. http://www.energetika-portal.si/podrocja/energetika/energetska-prenova-javnih-stavb/ (accessed on 31st August 2022).

If 3 % of all central government buildings would be renovated in a deep manner, the estimated annual investment would reach approximately six million euros, if their heritage significance aspect is taken into account. If the buildings were also seismically strengthened, the overall investment would increase in the range of 27.1–52.6 million euros. This analysis highlighted several issues:

- The potential for energy renovation is substantial, but the necessary investment is high.
- A sizeable proportion of this building stock is under cultural heritage protection. Such buildings should be treated with care and separate financial funds should be allocated to this building cohort.
- The seismic aspect presents an important issue. Many buildings should be seismically strengthened before any energy renovation works take place, but the investment needed is considerably higher than that for the energy aspect. Slovenia does not allocate any grants for such works, and this presents another issue.

The results indicate that deeper knowledge of the overall building stock status is needed. Since the EU is tackling building decarbonisation by 2050, the majority of the buildings will have to be renovated and countries have to be prepared for this renovation wave. Suitable and stimulative financial instruments are necessary.

3.2 Effects of investing in energy efficiency

As indicated above, every assessment of the actual potential to improve the energy efficiency of cultural heritage buildings hides numerous pitfalls. We cannot treat them in the same way as other buildings, as their protected values and thus also permitted interventions are individually determined. We can only confidently state that this potential is less than the otherwise total technical potential. We checked how this is manifested in practice on the example of buildings owned and used by municipalities that applied for co-financing the renovation measures from cohesion funds.

As a part of the Operational Programme for Implementing the European Cohesion Policy 2014-2020,[15] the first call for co-financing comprehensive energy renovations of buildings (co-)owned and used by municipalities from cohesion funds was published in 2016.[16] Comprehensive energy renovation was defined in the tender as the coordinated implementation of measures for efficient use of energy on the building envelope (e.g. facade, roof, floor) and on the building's technical systems (e.g. heating, ventilation, air conditioning, hot water) in a way that, as far as it is technically possible, utilizes all the economically justifiable potential for energy renovation.

Up to 40 % of the eligible costs of the operation were co-financed by the funds of the European cohesion policy, of which 85% came from the Cohesion Fund and 15 % from the Slovenian participation in the cohesion policy. The criteria for selecting projects included the contribution to energy efficiency (50 %), share

15 http://www.eu-skladi.si/kohezija-do-2013/2014-2020/operativni-program-za-obdobje-2014-2020
16 https://www.uradni-list.si/glasilo-uradni-list-rs/vsebina/2016005800004/javni-razpis-za-sofinanciranje-energetske-prenove-stavb-v-lasti-in-rabi-obcin-st--4301-5201615-ob-290616

of co-financing the eligible costs by the beneficiary (35 %) and contribution to social change and raising social awareness (15 %).

Specific criteria were additionally set for cultural heritage buildings, which were derived from the principles presented in the Guidelines for Energy Renovation of Cultural Heritage Buildings. Thus, when calculating the indicator of the contribution to energy efficiency (the ratio between the annual final energy savings and the conditioned area of the building; kWh/(m^2.a)), the effects of the renovation were taken into account, including the measures that could not be implemented in full due to the protection of cultural heritage, or partially (e.g. only the facade), as if the measure had been implemented.

We obtained the first set of applications that Slovenian municipalities sent to the tender from the Ministry of Infrastructure. An integral part of the documentation consisted of the calculations of the energy indicators of the planned new state after the energy renovation, as well as the estimated financial parameters of investments needed to improve the energy efficiency. Above all, we were interested in the specific information for each individual building, whether it is protected as cultural heritage, or whether there are no cultural protection restrictions for the selection of renovation measures.

Since we received scanned original documentation, the data had to be manually transferred to an Excel file and arranged according to various parameters. Taking into account the identified variations of particular planned measures, the file comprised of over 300 columns, with each row dedicated to a particular building. With the help of filters, the data were then combined and analysed according to individual topics. We compared the technical and financial parameters of the first group of applications submitted to the above-mentioned public tender, as presented in the appendices to the applications. We were interested whether and what the differences are in the indicators for cultural heritage buildings and other buildings. We analysed 188 projects submitted for the tender, of which 59 or almost one third were buildings with a cultural heritage status. Logically, not all measures were planned for all buildings. For cultural heritage buildings and for other buildings, we calculated separately:

- the average U-value of the facade with additional thermal insulation (W/(m^2K)),
- the average U-value of the roof with additional thermal insulation (W/(m^2K)),
- the average U-value of new windows (W/(m^2K)),
- the average cost of the specific investment in the measure (EUR/m2),
- the annual total (kWh/a) and specific (kWh/(m^2.a)) energy use after renovation,
- the annual total (kWh/a) and specific (kWh/(m^2.a)) energy savings after renovation,
- the annual total (kWh/a) and specific (kWh/(m^2.a)) use of renewable energy sources after renovation.

The key findings are summarised as follows:

- Cultural heritage buildings achieved, on average, higher (worse) U-value of external walls after renovation than other buildings. (Figure 1)

- The price of energy renovation of facades in cultural heritage buildings was lower than the price in other buildings (cause: lower final U-value of external walls, less complex facade systems). (Figure 1)
- A comparison of cultural heritage buildings and other buildings did not show any significant deviation, neither in the investment prices nor in the achieved U-value of the renovated roof. (Figure 2)
- The analysis of the investment in windows showed a significant difference in price. New windows installed in cultural heritage buildings were generally more expensive, but also had slightly worse thermal characteristics compared to windows in other buildings. (Figure 3)
- With the planned renovation measures, a 10 % lower specific energy consumption was achieved for buildings that are not under the cultural protection regime, which was expected.
- The specific final energy savings following the implementation of the planned measures showed a similar expected situation; they were 28 % higher for buildings without a protection regime, while the specific use of energy from renewable sources was higher by almost one third.

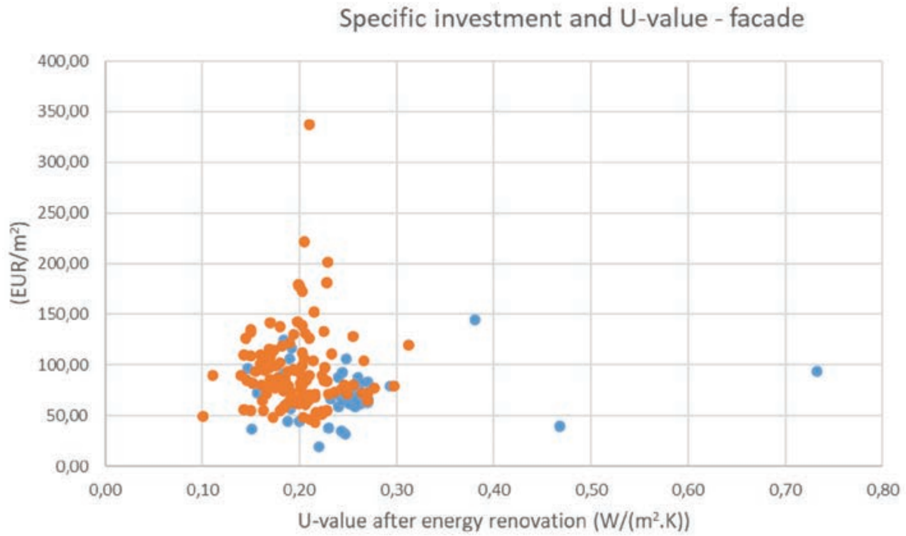

Fig. 1: *Energy renovation of facades: specific investment and U-value. The average specific investment was 71,37 EUR/m2 for heritage buildings (n=46) and 93,86 EUR/m2 for other buildings (n=123). The average new U-value was 0,25 W/(m2.K) for heritage buildings.*

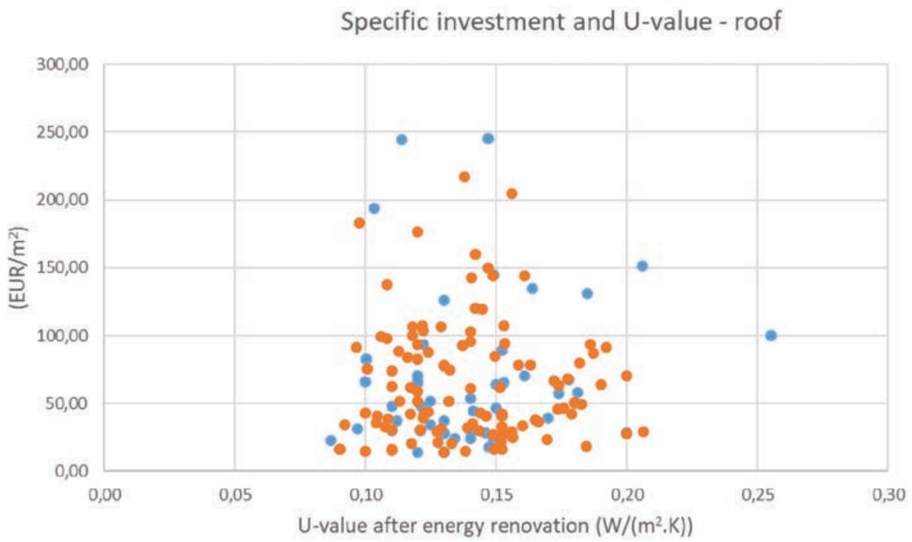

Fig. 2: *Energy renovation of roofs: specific investment and U-value. The average specific investment was 64,33 EUR/m² for heritage buildings (n=51) and 66,14 EUR/m² for other buildings (n=108). The average new U-value was 0,20 W/(m².K) for both groups of buildings.*

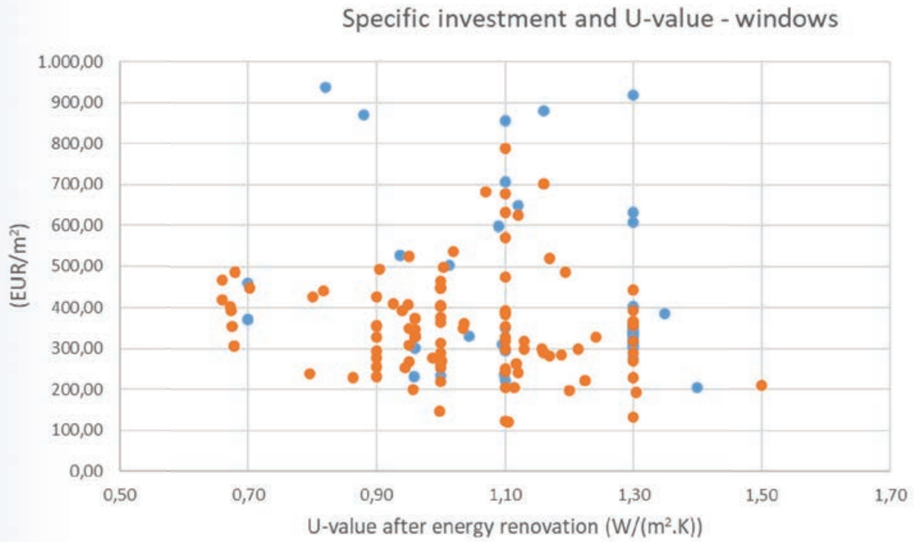

Fig. 3: *Energy renovation of windows: specific investment and U-value. The average specific investment was 412,02 EUR/m² for heritage buildings (n=54) and 349,98 EUR/m² for other buildings (n=108). The average new U-value was 1,19 W/(m².K) for heritage buildings and 1,04 W/(m².K) for other buildings.*

The results are consistent with the fact that the suitability or the permissibility of measures for the energy renovation of cultural heritage buildings is not judged by the achieved energy indicators, but primarily by the extent of their impact on the protected elements and on the building as a whole. It is precisely from this potential impact that limitations arise, whether in the choice of materials or products and systems, or in their dimensions and capacities.

We have also established that the proportion of buildings in which hydraulic balancing of the heating system, installation of thermostatic valves and installation of ventilation systems with heat recovery were planned was higher in cultural heritage buildings than in other buildings. Renovation of interior lighting was planned in approximately the same proportion, while the central control system was planned in a noticeably higher proportion in buildings without a protection regime.

The cultural heritage buildings submitted for the tender showed relatively well-planned characteristics of the thermal envelope and came fairly close to the minimum requirements of the technical regulations in force at the time for efficient energy use in buildings. We can conclude that the reason for the lower specific investment in the case of the facade and the higher one in windows was due to technical reasons related to the boundary conditions of cultural heritage protection. The specific final energy saving after the implementation of the measures was expected to be lower for cultural heritage buildings than for other buildings, but the difference was less than 25%. In the case of cultural heritage buildings, the use of solar energy such as solar collectors for the preparation of hot water and photovoltaics was expectedly not among the planned measures (although this possibility is not absolutely excluded), but renewable energy sources can also find their place in this part of the building stock, e.g. when replacing the existing fossil energy source with a renewable source.

The analysis of the buildings in question showed that the frequent general opinion that interventions (measures) to increase energy efficiency are practically not allowed in cultural heritage buildings is not true. According to the considered set of buildings, cultural heritage buildings comprised 31 % in number, and 34 % in terms of conditioned floor area of the whole. This roughly one-third share of buildings contributed 27 % of final energy savings and 26 % of energy from renewable energy sources to the overall planned result. (Table 2)

	Cultural heritage (n=59)	Other (n=129)
Total renovated conditioned area (m2)	127.249,70	245.963,40
Total final energy savings (kWh/a)	6.767.654,99	18.064.569,93
Specific final energy savings (kWh/(m2a))	53,18	73,44
Total final energy use after renovation (kWh/a)	15.317.098,83	27.309.127,84
Specific final energy use after renovation (kWh/(m2a))	120,37	111,03
Total renewable energy use after renovation (kWh/a)	2.519.442,70	6.995.179,43
Specific renewable energy use after renovation (kWh/(m2a))	19,80	28,44

Table 2: *Comparison of selected energy indicators according to planned energy renovation measures for both groups of analysed public buildings.*

On the other hand, we cannot conclude from the available data what the actual share of cultural heritage buildings is (in this case: owned or used my municipalities), in which interventions listed above would be permitted, and to what extent. It is also not known according to which key the buildings in each municipality were selected and what is the number of remaining municipal public buildings (both all buildings and cultural heritage buildings). With considerable probability, it can be concluded that for individual cultural heritage buildings, information was primarily obtained on (more numerous or more extensive) intervention options for energy efficiency and renewables. We assume that those cultural heritage buildings that had a greater potential in terms of such permitted interventions were selected to apply to the tender, therefore we cannot unconditionally generalize the stated results to the entire building heritage fund. The limitation of the possibility of generalization also stems from the “individuality” of the assessment of the cultural significance of an individual building and its associated categorization and cultural protection conditions. Finally, we must underline that the above results and comments are based on the trust in the correctness of the calculated parameters and indicators both for the existing state and planned renovation of each building, as provided by the applicants in their tender documentation.

4 Discussion

Over 20 % of the European building stock was built before 1945, with low energy performances and high energy consumption.[17] Only about 1 % of this stock is renovated each year.[18] Thus, its energy saving potential is high. Based on this data, the European Union recognizes the importance of the improvement of energy efficiency and the decarbonization of the existing building stock. These strategies permit the mitigation of climate changes and favour the energy transition while also preserving heritage values and historical characters. The European policies focus on the instruments and measures for increasing energy performance,[19] renewable energy sources,[20] building renovations, and quality of life,[21] as well as for cutting greenhouse gas emissions and generating new jobs in the green construction sector.

Each intervention on historic buildings involves physical changes and may include visual and spatial impacts, irreversibly altering their authenticity.[22] Thus, their renovation requires vast building knowledge that supports the selection of compatible retrofit solutions that balance energy efficiency, human comfort, heritage preservation, and environmental sustainability. Energy audits require the understanding of original construction techniques, heritage values, modifications over time, actual performances, problems, and renovation opportunities.

It should be emphasized that, apart from rare exceptions, we can talk about “special” materials, products or technologies that can be used for the renovation of cultural heritage buildings, as long as we do not require to use the most authentic or the same elements as the original ones. In other words, in a strictly technical sense, everything that is suitable for renovating a building that is not subject to a special protection regime is also suitable for a cultural heritage building from a comparable time period and built using a comparable construction method. The cultural protection conditions determine whether such a technical option is also permissible in practice.

A possible special protection regime for a specific building, except in rare exceptions, does not mean that it was built in a significantly different way from other – unprotected - buildings, that unique building materials and products were used, that special energy sources are required for its operation, or that it generally has significantly different (energy) properties than comparable buildings from the same periods.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Gašper Stegnar: Conceptualization, methodology, investigation, writing - original draft, writing - review & editing, supervision. Stane Merše: Methodology, investigation, writing - review & editing. Samo Gostič: Conceptualization, methodology, investigation, writing - original draft, writing - review & editing. Marjana Šijanec Zavrl: Methodology, investigation, writing - review & editing. Miha Tomšič: Conceptualization, methodology, investigation, writing - original draft, writing - review & editing, supervision.

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