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## ENERGY EFFICIENCY OF CULTURAL HERITAGE BUILDINGS – OPPORTUNITIES AND CHALLENGES

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*Keywords: energy efficiency, energy rehabilitation (reconstruction), protected building, cultural heritage buildings, possibilities and limitations*

### ABSTRACT

When talking about improving the energy efficiency of the existing building stock, which also includes buildings that have been listed, it is necessary to bear in mind that it is obligatory to act according to the conditions prescribed for that area by the competent institution, and they are generally restrictive regarding any type of architectural and construction intervention. Generally speaking, they may not carry out any works, except conservation works. Such restrictive conditions often include elements of facade joinery (windows and doors), ranging from very rigorous (that the original appearance and original material must be kept), to more liberal ones that allow the replacement of old elements with new ones, which look true to the original, but the use of new materials is allowed. How to resist such architectural challenges is the leitmotif of this work. The work does not intend to solve this problem, but rather to indicate potential challenges and possibilities of overcoming them.

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## 1. Introduction

Contemporary processes of urban-architectural and social development have imposed the need to transform the existing building stock in accordance with the principles of sustainability, environmental protection and energy efficiency. One of them is balancing the requirements of the energy transition and the principles of protection and preservation of cultural and historical heritage. In this context, buildings that are under architectural and conservation protection are a special challenge, as they at the same time have the status of both a cultural asset and a building with preserved architectural authenticity, but also the status of a building that needs to be adapted to modern standards of energy transition. The energy transition, as a global and national process, is aimed at finding a mechanism for more efficient use of energy resources and reducing greenhouse gas emissions (GHG), which implies that buildings, as the largest consumers of energy in the housing and public buildings sector, become an important segment of sustainable energy development policy. In other words, in the case of protected buildings, the application of the principles for improving energy efficiency encounters a number of limitations.

Unlike contemporary buildings, where it is possible to plan interventions in accordance with the latest technological and technical innovations, in the case of cultural heritage items of immovable property, the most important criteria are the preservation of authenticity and integrity, where any intervention aimed at their restoration is subject to strict rules of conservation and restoration. For these reasons, the energy rehabilitation of cultural property must be carefully designed, adapted and based on a multidisciplinary approach, where technical, legal and conservation aspects are intertwined. Among the main challenges are the outdated building stock, the low level of renovation rate, as well as the need for specific expertise and innovative approaches, especially when it comes to buildings that have the status of cultural heritage.

In line with global and European aspirations for sustainable development, an increasing number of contemporary initiatives and projects address the issue of adequate conservation and restoration of architectural heritage, especially through approaches that combine environmental, cultural and energy goals. One such project, in which ICUN (Innovation Center of the University of Niš) participates, is EU-REPAIR, which supports the European Green Deal and national climate strategies, with a focus on improving energy efficiency and applying the principles of circular economy, especially in the context of protected cultural heritage in countries such as the Republic of Serbia, North Macedonia, Estonia and Lithuania [1]. In this context, the Republic of Serbia, as a country that strives to harmonize its normative and strategic documents with the standards of the European Union, is faced with the challenge of creating sustainable solutions that will simultaneously respond to the requirements of energy efficiency and preservation of cultural heritage. The subject of the project's research, which in one segment deals with this paper, is to look at the possibilities and limitations in the application of energy efficiency measures on protected buildings, with special emphasis on the regulatory framework, international experiences and practical challenges that arise in the process of rehabilitation and reconstruction [2].

## 2. Energy efficiency of cultural heritage buildings

Buildings that have the status of cultural heritage buildings represent a specific category of the building stock, where all interventions must be carried out in accordance with the principles of conservation, restoration and protection of authenticity. Unlike modern buildings, where energy efficiency measures are planned more freely and integrally in the design phase, in

protected buildings the application of these measures implies a limited choice of materials, methods and technologies, so as not to violate cultural, historical and architectural values. The main specificity is the need to preserve the authentic elements of the building, such as the façade, carpentry, roof covering, decorative elements, spatial organization, which often prevents standard interventions. In this context, priority is given to “non-invasive”, reversible and adapted measures (e.g. internal thermal insulation with controlled vapour permeability, restoration of existing joinery with improvement of its thermal characteristics, replacement of heating and lighting systems with more energy-efficient solutions, application of so-called passive measures (control of insolation, ventilation, natural lighting) [2].

According to the recommendations of ICOMOS (International Council on Monuments and Sites) and UNESCO, energy interventions on cultural property must be aligned with the principles of heritage and local identity conservation, with the prior preparation of appropriate conservation studies and the consent of the relevant institutions.

The main challenge in improving energy efficiency in protected buildings is to achieve a balance between modern energy policy requirements and the obligation to preserve cultural and historical values. The most common obstacles include: legal restrictions that require the preservation of the original appearance of the building, lack of modern materials that are compatible with historical constructions, higher cost of work due to the need for a specific approach, craft techniques or manual work, insufficient research of the building and the lack of precise technical documentation, difficult implementation of energy certification, because standard measurement methods are often not applicable to historic buildings. In addition, the role of conservation institutions (e.g. the Institute for the Protection of Cultural Monuments) in planning processes is often reduced to restrictive control, rather than active orientation towards sustainable solutions, which contributes to a conservative approach and a lack of innovation. Despite numerous challenges, modern trends show that improving energy efficiency and preserving cultural heritage are not mutually exclusive goals, but that, with the right approach, they can be achieved complementarily.

The reconstruction and reuse of listed historic buildings, with the application of appropriate energy efficiency measures, requires a special approach to each historic building. In order to save energy and when conservation measures allow, it is necessary to envisage the following construction measures: install thermal insulation on the building envelope and replace and install appropriate windows and doors. In addition, when a thermal insulation shell and replacement of windows are partially or completely unacceptable, then, doors and windows can receive glazing with double-glazed windows in an extended slot of the old windows (when it has architectural value, detail and authenticity), and the thermal insulation shell may be inserted layer-by-layer and partially not into all the surrounding walls. By applying these measures, as well as using renewable energy sources in order to obtain the total annual energy required, it is possible to significantly improve the energy efficiency of the historic building [3].

The topic of energy efficiency in protected buildings is increasingly attracting the attention of the professional and scientific public, especially in the context of the EU's climate goals and national decarbonization strategies. At the international level, numerous studies indicate the need to develop the so-called Integrated Conservation and Energy Retrofit approach, which at the same time takes into account the cultural significance of the building and its energy characteristics. In the last decade, several major European projects have developed methodological guidelines and technical solutions that enable the improvement of energy efficiency while preserving cultural and historical values. One of the most important projects in this area is 3ENCULT (Efficient Energy for EU Cultural Heritage), implemented under the Seventh Framework Programme of the European Union (FP7) in the period 2010 – 2014. One of the most important contributions of the project is the development of special cooperation protocols between engineers, architects and conservators, as well as the fact that case studies

have shown the possibility of achieving energy savings of 30 – 40 % without compromising the cultural integrity of the buildings [4]. The EE-Heritage project is an initial phase (“seed money” phase) envisaged to lay the foundations for a future, more ambitious project aimed at the energy transition of public cultural heritage sites in the Danube region. The project was launched in September 2024. It is funded under the Interreg Danube Region Programme. It aims to transform public structures of cultural significance into digitally managed buildings that are energy-efficient and socially engaged. It is interesting that this approach achieves a high level of energy efficiency, while respecting conservation rules and the principles of sustainable use of cultural heritage [5, 6].

### 3. Examples of energy renovated cultural heritage buildings

This chapter will present the research of Professor Aleksandar Rajčić on the current state and a description of the interventions carried out on three culturally significant buildings in Serbia (Belgrade), with the aim of improving their energy efficiency. The paper presents the Old Palace building, the Bristol Hotel and the Main Railway Station in Belgrade. Along with the description of the interventions, an overview of the achieved results is given, including the transition of the buildings to higher energy classes [8].

#### 3.1. Energy renovation of the Old Palace building

The Old Palace building (Figure 1-left) was designed by architect Aleksandar Bugarski, and since 1961 it has been the seat of the Belgrade City Assembly. Throughout its history, the building has undergone several reconstructions, mostly due to damage caused during the war. The most recent major reconstruction was undertaken in 2013 with the aim of improving the building’s energy performance (Figure 1-right) [7].




**Figure 1. Appearance of the Old Palace in the past (image left) and today (image right) [7] – Source: [https://beogradskonasledje.rs/katalog\\_kd/zgrada-starog-dvora-2](https://beogradskonasledje.rs/katalog_kd/zgrada-starog-dvora-2) [7]**

Since the building is protected as a cultural monument, all interventions had to be done in accordance with the conservation requirements defined by the Institute for the Protection of Cultural Monuments. The exterior facade of the building preserved its authentic appearance, including the facade decorations, which meant that improvements to the thermal envelope could only be implemented in non-exposed areas, such as the interior sides of attics and roofs. Additionally, hybrid facade carpentry was introduced, where the exterior frame was retained in its original form, while the interior frame was made of modern materials with double glazing.

According to available data, the condition of the building before the implementation of energy renovation measures showed a relative annual final energy consumption for heating ( $Q_{h,rel}$ ) of 161,2 kWh/m<sup>2</sup> per year, while the specific annual heating demand ( $Q_h$ ) was 104,76 kWh/m<sup>2</sup>. After the interventions, these parameters improved to  $Q_{h,rel} = 130,6$  kWh/m<sup>2</sup> and  $Q_h = 85,34$  kWh/m<sup>2</sup> [8]. The building's energy class was upgraded from E to D, thereby improving energy efficiency within the limits set by conservation requirements (Tab. 1).

**Table 1. The building's transition to a higher energy class according to the Regulation (Regulation on the conditions, content, and manner of issuing certificates on the energy performance of buildings, "Official Gazette of RS", No. 69/2012, 44/2018 and 11/2022)**

Administrative and office buildings		New	Existing
Energy class	$Q_{H, nd, rel.} [\%]$	$Q_{H, nd} [\text{kWh}/(\text{m}^2 \cdot \text{a})]$	$Q_{H, nd} [\text{kWh}/(\text{m}^2 \cdot \text{a})]$
A+	≤15	≤8	≤10
A	≤25	≤14	≤17
B	≤50	≤28	≤33
C	≤100	≤55	≤65
 D	≤150	≤83	≤98
E	≤200	≤110	≤130
F	≤250	≤138	≤163
G	>250	>138	>163

### 3.2. Energy renovation of the Bristol Hotel

The Bristol Hotel was built between 1910 and 1912, based on a design by architect Nikola Nestorović (Figure 2-left) [7]. The building represents one of the first modern hotels in Belgrade, designed and constructed with elements and decorative motifs characteristic of the Art Nouveau style [9].



**Figure 2. Appearance of the Bristol Hotel in the past (image left) [7] and today (image right) – Source: <https://beobuild.rs/otvoren-rekonstruisan-hotel-bristol-p3216.html> [10]**

Due to the conservation restrictions, interventions on the facade facing the street of the Bristol Hotel were kept to a minimum (Figure 8-right). Accordingly, the energy upgrade of the building focused on the elements of the thermal envelope: facade walls, transparent surfaces, sloped and flat roofs, and the floors above and ceilings below unheated spaces. The walls were

constructed of solid bricks of varying thicknesses, plastered on both sides, and with decorative elements. The street-facing ground floor walls were not subject to thermal improvement, while the facade walls on the upper floors were renovated from the interior by adding an 8 cm thick layer of mineral wool insulation, over which a vapor barrier, a substructure of galvanized profiles, and a finishing layer of gypsum board panels were placed.

Unlike the street-facing facade, the walls oriented toward the atrium were not under conservation restrictions, allowing their thermal insulation to be applied externally using an ETICS system. An 8 cm thick layer of mineral wool was glued and additionally fixed with dowels, reinforced with a mesh embedded in adhesive, and finished with a thin-layer plaster coating.

The windows facing the street, although under certain protection regulations, were replaced with new wooden windows modeled after the originals, preserving their geometry and material. The new windows feature double glazing with gas filling, and the same approach was applied to the roof windows. Transparent surfaces facing the inner atrium were designed as curtain walls in an aluminum frame system with improved thermal break.


Sloped roofs were constructed using a frame system with LLD beams and rafters. The energy renovation involved adding a 24 cm thick layer of mineral wool MW between secondary beams, while the interior finish was done with gypsum boards over a vapor barrier. The exterior protection includes wooden sheathing with an additional waterproofing membrane.

Flat roofs are mostly located in the building's annexes. The roof structure consists of trapezoidal steel sheets or reinforced concrete slabs, over which layers of vapor barrier, 20 cm thick mineral wool insulation, waterproofing membrane, and a protective mechanical finishing layer were applied.

Floors above unheated spaces were retained structurally, but the upper layers were reconstructed by removing existing materials and installing 10 cm of thermal insulation, protective foil, a new reinforced concrete slab for strengthening, and the final floor finish. Ceilings below unheated spaces were designed as reinforced concrete slabs with a 12 cm thick thermal insulation layer, protective foil, and a cement screed [8].

As shown, nearly all relevant components of the thermal envelope underwent energy renovation to the extent allowed by cultural heritage protection requirements. Following the interventions, the building was upgraded from a lower energy class to Class B ( $Q_{h,rel} = 44,5 \%$ ,  $Q_h = 44,52 \text{ kWh/m}^2$ ). The minimum requirements set by current regulations were met, as the annual final energy demand for heating does not exceed the max. permitted values (Tab. 2) [8].

**Table 2. The building's transition to a higher energy class according to the Regulation (Regulation on the conditions, content, and manner of issuing certificates on the energy performance of buildings, "Official Gazette of RS", No. 69/2012, 44/2018 and 11/2022)**

Administrative and office buildings		New	Existing
Energy class	$Q_{H, nd, rel.} [\%]$	$Q_{H, nd} [\text{kWh}/(\text{m}^2 \text{a})]$	$Q_{H, nd} [\text{kWh}/(\text{m}^2 \text{a})]$
A+	$\leq 15$	$\leq 14$	$\leq 15$
A	$\leq 25$	$\leq 23$	$\leq 25$
 B	$\leq 50$	$\leq 45$	$\leq 50$
C	$\leq 100$	$\leq 90$	$\leq 100$
D	$\leq 150$	$\leq 135$	$\leq 150$
E	$\leq 200$	$\leq 180$	$\leq 200$
F	$\leq 250$	$\leq 225$	$\leq 250$
G	$> 250$	$> 225$	$> 250$

### 3.3. Energy renovation of the Belgrade Railway Station

The Belgrade Railway Station is one of the most representative examples of public architecture from the second half of the 19<sup>th</sup> century in Serbia (Figure 3-left) [7]. According to the Cultural Heritage Protection Act, the building is registered as a cultural monument of great importance, officially recognizing its cultural and architectural significance (“Official Gazette of SRS”, No. 28/83).


The project was designed by architects Wilhelm von Flattich and von Schlicht, while the technical solution was worked out by engineer Dragutin Dragiša Milutinović. The building was constructed in the spirit of classical architectural language, characteristic of European railway architecture of that era. Its architecture reflects a synthesis of stylistic and contemporary technological trends, blending elements of Neo-Renaissance, Neo-Baroque, and other styles (Figure 3-right) [9].



Figure 3. Appearance of the Belgrade Railway Station in the past (image left) [9] and today (image right) – Source: [https://beogradskonasledje.rs/katalog\\_kd/zeleznicka-stanica](https://beogradskonasledje.rs/katalog_kd/zeleznicka-stanica) [7]

Since the building has been declared a cultural monument of great importance, all reconstruction, renovation, and adaptation works must be performed strictly within the existing dimensions and volume, without compromising the original architectural values. The position and size of the facade openings must be strictly preserved. Additionally, interior decorative elements and finishes dating from the time of the building’s construction must be maintained.

Table 3. The building’s transition to a higher energy class according to the Regulation (Regulation on the conditions, content, and manner of issuing certificates on the energy performance of buildings, “Official Gazette of RS”, No. 69/2012, 44/2018 and 11/2022)

Administrative and office buildings		New	Existing
Energy class	$Q_{H, nd, rel.} [\%]$	$Q_{H, nd} [kWh/(m^2 a)]$	$Q_{H, nd} [kWh/(m^2 a)]$
A+	$\leq 15$	$\leq 10$	$\leq 12$
A	$\leq 25$	$\leq 17$	$\leq 20$
B	$\leq 50$	$\leq 33$	$\leq 38$
C	$\leq 100$	$\leq 65$	$\leq 75$
 D	$\leq 150$	$\leq 98$	$\leq 113$
E	$\leq 200$	$\leq 130$	$\leq 150$
F	$\leq 250$	$\leq 163$	$\leq 188$
G	$> 250$	$> 163$	$> 188$

The planned repurposing involves adapting the building for the needs of the Historical Museum of Serbia. Given these restrictions, external interventions on the facade are not permitted, while internal interventions are allowed only to the extent that they do not compromise the preservation of the existing interior. For this reason, the reconstruction project includes increasing the usable area on the ground floor by closing a passage and forming a hall, which requires the installation of new facade joinery for that section [8].

The usable area of the basement has also been increased, and 10 cm thick XPS insulation layer is planned on the ceiling above the basement. On the ceiling above the top floors, 20 cm thick mineral wool insulation is to be installed. Energy improvements are also planned for walls adjacent to unheated spaces, with 5 cm thick mineral wool insulation applied from the attic side. Following the completed interventions, the railway station building has been classified as energy class C (the energy required for heating  $Q_{h,an}$  is between 38 and 75 kWh/m<sup>2</sup>), which in this case is 71,51 kWh/m<sup>2</sup> (Table 3) [8].

#### **4. Conclusion**

Harmonization of the legal and strategic framework of the national level with European standards in the field of protection of cultural property and energy efficiency is a basic prerequisite for the sustainable restoration of immovable cultural property. Although there are numerous legal instruments that allow interventions in protected facilities, their implementation requires high coherence, expert supervision and multidisciplinary cooperation. Therefore, it is necessary to strengthen the capacities of the competent institutions, improve cross-sectoral coordination and ensure the availability of financial mechanisms, in order to enable the systematic, efficient and responsible implementation of energy rehabilitation measures in accordance with the principles of cultural heritage protection.

The presented examples of selected buildings show that there are examples of good practice within which elements of successfully implemented energy rehabilitation can be identified, as well as limitations arising from specific architectural solutions or levels of protection. Calculations show that the greatest potential for improvement lies in the improvement of thermal insulation layers, improvement of window and door systems, as well as modernization of heating and ventilation systems, with strict adherence to conservation standards. This confirms that it is possible to implement energy-sustainable solutions without compromising the original identity and authenticity of buildings.

The research also pointed to institutional and regulatory challenges, such as the lack of flexibility of the legislative framework in relation to the specifics of cultural property and the lack of clearly defined guidelines for the implementation of energy measures on protected buildings. This opens up space for the improvement of national regulations in the direction of harmonization with European standards and practices. Based on the conducted research and the results obtained, it can be concluded that further research orientation is necessary in three different, but interrelated directions: a) development of a methodology for identifying optimal energy rehabilitation measures that balance conservation and efficiency, b) establishment of clear guidelines and institutional support for the implementation of these measures in practice, and c) strengthening the awareness of the professional and general public about the importance of integrating sustainable solutions in the preservation of cultural heritage.

The paper confirms the importance of energy rehabilitation in the protection of cultural property and lays the foundation for further research and practical applications, which must be based on an interdisciplinary approach.

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# ЕНЕРГИЙНА ЕФЕКТИВНОСТ НА СГРАДИТЕ НА КУЛТУРНОТО НАСЛЕДСТВО – ВЪЗМОЖНОСТИ И ПРЕДИЗВИКАТЕЛСТВА

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*Ключови думи: енергийна ефективност, енергийна рехабилитация (реконструкция), защитена сграда, сгради от културното наследство, възможности и ограничения*

## РЕЗЮМЕ

Когато говорим за подобряване на енергийната ефективност на съществуващия сграден фонд, който включва и сгради, които са в защитен режим, е необходимо да се има предвид, че е задължително да се действа в съответствие с условията, предписани за тази зона от компетентната институция, и те като цяло са ограничителни по отношение на всякакъв вид архитектурна и строителна намеса. Най-общо казано, те не могат да извършват никакви дейности, освен консервационни работи. Такива ограничителни условия често включват елементи от фасадна дограма (прозорци и врати), от много строги (че трябва да се запази оригиналният външен вид и оригиналният материал), до по-либерални, които позволяват замяната на стари елементи с нови, които изглеждат верни на оригинала, но използването на нови материали е разрешено. Как да устоим на подобни архитектурни предизвикателства, е лайтмотивът на тази творба. Работата няма за цел да реши този проблем, а по-скоро да посочи потенциални предизвикателства и възможности за преодоляването им.

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