applied sciences

MDPI

Article

The Intersection of Architectural Conservation and Energy Efficiency: A Case Study of Romanian Heritage Buildings

Simona Elena Șerban [1], Tiberiu Catalina [1,2,*], Razvan Popescu [1] and Lelia Popescu [1]

[1] Faculty of Building Services, Technical University of Civil Engineering, 021414 Bucharest, Romania; lelialetitia@yahoo.com (L.P.)
[2] National Institute for Research-Development in Construction, Urbanism and Sustainable Territorial Development—INCD URBAN-INCERC, 021652 Bucharest, Romania
* Correspondence: tiberiu.catalina@gmail.com; Tel.: +40-763-915-461

Abstract: In Europe, it is estimated that 14% of existing buildings were built before 1919, whereas 26% were built before 1945. In Romania, about 31% of the buildings date from before 1961, contributing to the current stock of old buildings with historic and architectural value in the country. This paper illustrates the current state of buildings with historic and architectural value in Romania, alongside a case study of a representative administrative building in Câmpulung, Romania. The analysis of the Town Hall building in Câmpulung, Romania, demonstrates that potential energy savings of up to 47.53% can be achieved by implementing interventions such as upgrading windows, insulating the attic, and installing photovoltaic panels. The highest energy reduction is obtained by replacing the window glass with a value of 18.16% with attic insulation with a value of 16.1%. This paper also presents indoor measurements of temperature and humidity in different offices positioned in the north and the south. The study conducted on the south façade office revealed consistent temperatures ranging from 21.7 °C to 24.4 °C, with an average of 23.31 °C. However, the humidity levels fluctuated considerably, ranging from 17.1% to 39.1%, with an average of 26.89%. The sun-exposed section of the building saw relatively stable temperature conditions, but the varying humidity levels could have a detrimental impact on the quality of the indoor atmosphere and potentially decrease the effectiveness of the workforce. By contrast, the north façade office exhibited lower and more fluctuating temperatures, ranging from 19.8 °C to 23.6 °C, with an average of 21.74 °C. Additionally, it had higher and more stable humidity levels, ranging between 19.5% and 41.7%, with an average of 29.83%. A thermographic analysis was performed on the north façade of the Câmpulung Town Hall, utilizing thermal imaging technology to detect areas of heat loss, and thus identifying the energy inefficiency problems of the building's exterior. The investigation found notable variations in temperature, especially around the windows, where temperatures could be as high as 14.1 °C, highlighting the insufficiency of the building's antiquated timber-framed windows in preventing energy loss.

Keywords: energy efficiency; historic buildings; heritage conservation; thermography; energy audit

Citation: Șerban, S.E.; Catalina, T.; Popescu, R.; Popescu, L. The Intersection of Architectural Conservation and Energy Efficiency: A Case Study of Romanian Heritage Buildings. *Appl. Sci.* **2024**, *14*, 4835. https://doi.org/10.3390/app14114835

Academic Editors: David Bienvenido Huertas and Daniel Sánchez-García

Received: 18 April 2024
Revised: 6 May 2024
Accepted: 8 May 2024
Published: 3 June 2024

1. Introduction

Buildings account for approximately 40% of the European Union's total energy consumption and generate 36% of greenhouse gas emissions. In Europe, it is estimated that 14% of the existing building stock was built before 1919, and 26% was built before 1945 [1]. Heritage architecture is an element that emphasizes personality, culture, and history, being a symbol for European cultural heritage and the identity of European society, giving it an identifiable character [1]. The existing building stock thus needs to be preserved through continuous transformation and optimization while presenting the opportunity to modernize and optimize energy production in all sites of European cultural heritage, both on a large scale and locally. In this approach, the perspective is changing, and the existing building fund is beginning to be seen as a reusable resource, optimal for interventions that will provide space for contemporary activities in the future; this has also been demonstrated by the European Union's interest in and dedication to this matter [2,3].

As climate change poses a real and urgent threat to humanity and the environment [4], addressing the challenges facing architectural heritage thus becomes key to the future of European architecture [5,6], and this can be accomplished by creating specific and local guidelines, standards, and methodologies to address the modernization process and energy optimization of historic buildings [2].

In this paper, the term that is often used when referring to old building stock is buildings with historical and architectural value, which is a description that includes not only the buildings included in the National Register of Historic Monuments in each member state but also refers to buildings that have historic and architectural value that are not included in the above-mentioned lists. Currently, in Romania, there is no structured information regarding the actual number of buildings with historic and architectural value that exist; however, these buildings are widespread, and research in the field is being developed.

Heritage buildings have been elaborated through a combination of design practices, execution and design practices, techniques, and knowledge, and have been tested in a well-defined framework and adapted to local, climatic, and sociological contexts. By the same principles, buildings (the architecture of today, ultimately) must serve current needs through the development of procedures, methodologies, and practices to ensure the sustainability of architectural objects so that they can be used by future generations. Hence, there is a need to create an intervention framework to modernize and optimize the energy performance of buildings that are listed as historical monuments, which are specific cultural buildings presenting traditional construction systems that are still widely used today.

In a European context, through the most recent communiqué of the European Union, titled "A Renovation Wave for Europe—greening our buildings, creating jobs, improving lives" [2,5], a legislative framework has been proposed that supports the modernization of energy in existing building funds. Thus, in the current European context, the identification of customized solutions for energy efficiency [2,5] for the building envelopes of those considered architectural heritage buildings is a key strategy for the modernization and energy optimization of the modernist building fund, and this can be achieved by studying, diagnosing, and implementing solutions to reduce general energy consumption and CO_2 emissions for the existing building fund. Therefore, as directives and strategies to prevent climate change and protect European heritage, the European Union has proposed the Green Deal [2,6], which aims to accomplish the following goals:

- Reach the threshold of climate neutrality by 2050;
- Decouple economic growth from the use of resources;
- Ensure that no citizen or country is left behind;
- Ensure the efficient use of resources in a clean and circular economy;
- Restore biodiversity and reduce pollution.

In addition, on 14 July 2021, the European Commission adopted a set of proposals to make EU climate, energy, transport, and taxation policies adequate to reduce net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels. Achieving these emission reductions over the next decade is crucial for Europe to become the world's first climate-neutral continent by 2050 and make the European Green Agreement a reality [6]. In this context, the new proposals target sectors such as energy, transport, construction, and renovation, with the aim of having 35 million buildings renovated by 2030.

2. Heritage Buildings in Romania

A number of European countries [7–20] have started to develop various national guidelines paired with research projects aimed at specific architecture within their borders and to focus on the regeneration and energy optimization of the existing building fund.

Therefore, the importance of proposing solutions specific to each case, i.e., on a case-by-case basis, has been acknowledged, given the multiple challenges that the global building fund presents (England, Hungary, Italy, Greece, Croatia, etc.) [7–18,20–40].

In Romania, roughly 31% of buildings date from before 1961, thus forming the stock of buildings with historical and architectural value [1]. Regardless of the fact that only a few of them are listed as historical monuments, they all carry importance from a historical and architectural point of view, being directly responsible for the characteristic of the country's various regions, thus keeping alive the local identity of local communities [1]. At the same time, even if the regulations for existing buildings impose limitations in terms of energy modernization interventions, many of the heritage buildings will benefit from individual optimization through customized solutions, which is necessary if we want the goal of reducing international greenhouse gas emissions by 80% by the year 2050 to be realistically attainable.

From a legislative point of view, in Romania, the process of authorizing energy efficiency interventions on buildings with historical and architectural value requires obtaining the consent of the Ministry of Culture, according to the legislative provisions in force [41–46].

Within the national legislation of Romania, there are various categories of buildings and areas of historical and architectural importance; e.g., they may be classified as historical monuments, according to the provisions of Law no. 422/2001 [41] (in the form of individual monuments, ensembles, or sites), or they may designated protected built-up areas, according to the provisions of Law no. 350/2001 [42] on territorial development and urban planning. In accordance with the legislative framework mentioned above, at present, in Romania, there are several strategies and programs funded at the European level with the aim of highlighting the gaps in the current legislative framework and, subsequently, of developing the legislative framework at the national level and beyond [1,44,45].

Regarding energy efficiency measures, the main regulatory act in Romania is Law no. 372/2005 [43] on the energy performance of buildings, with subsequent additions and amendments, though the requirements do not apply to buildings and monuments protected by heritage legislation.

To be mentioned in this approach is a methodology developed within Reform R1.b, optimizing the legislative and normative framework to support the implementation of investments in the transition to green and resilient buildings and financed by PNRR, Pillar IV, and Component 5–Renovation Wave [2], titled "the intervention methodology for the non-invasive approach to energy efficiency in buildings with historical and architectural value" [1]. The main purpose of the methodology is to facilitate understanding of the behavior and characteristics of historic buildings in relation to energy efficiency interventions, the health of the spaces, and the increase in comfort level, as well as to establish the methodological framework for intervention in historic buildings, detailing the stages of analysis and choice of solutions within the projects in order to optimize and streamline costs in the medium and long term [1].

Currently, heritage buildings occupy an important share of the national building fund, with over 30,000 historical monuments declared in the list of historical monuments revised by the Ministry of Culture and National Identity in 2015 [46]. Their importance and value, and especially the general legal regime of the monuments' historical data and the need to protect them, require increased attention to monitor their behavior over time. Therefore, the impact of continuously increasing temperatures and climatic conditions must also be addressed, especially in the context of current climatic phenomena that can damage both the structure of a monument and any protected objects inside it.

2.1. Characteristics of Heritage Buildings in Romania

Heritage building stock, once modernized and optimized, can function as well as a new building without undergoing major interventions or incurring excessive costs. With the help of modern energy optimization technologies, as well as the involvement and education of the population regarding their impact on the general well-being of the natural and built environment, as already pointed out by European directives and by specialists in the field, we will be able to highlight and implement the essential aspects of the protection and effective use of the European architectural heritage.

In a study carried out in 2013, which analyzed the number of buildings with historic and architectural value in Europe [46], 19 European countries were analyzed. In the general ranking, Romania came in 15th place (see Figure 1) out of the 19 countries analyzed in the study. A key take away from the study was the knowledge that many of the European states that were included in the study had different criteria for classifying historical monuments, taking into consideration the country's population and territory.

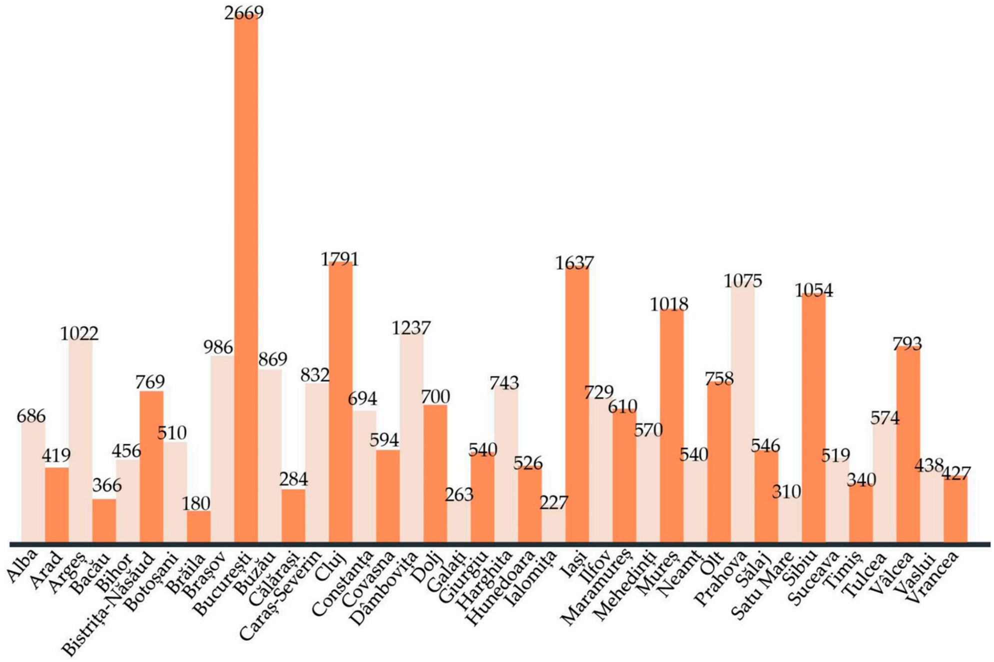

Figure 1. A visual representation of the current spread of national heritage buildings on Romanian territory. Information is provided the National Heritage Institute, Bucharest.

For example, Romania took over the wireframe method of categorizing and protecting heritage architecture monuments and sites from the French model, a state that has approximately 44,000 historical monuments, a relatively low number compared to the country's population and surface area.

As can be seen in the classification above [45], Romania has an extensive cultural heritage of great historic and architectural value, with the majority of these buildings being located in Bucharest, the country's capital city [47]. In total, there are 30,147 heritage sites included in the List of Historical Monuments and 8 sites included in the UNESCO World Heritage List [44,46].

The importance of rehabilitating these buildings thus becomes apparent, as a great number of these buildings are still in use and require urgent interventions in order to improve their interior conditions and the way in which the energy used for maintaining these conditions is employed.

The National Register of Historic Monuments in Romania [47] divided the monuments into two distinctive categories:

- Category A: Heritage monuments with national or universal value;
- Category B: Heritage monuments representative of the local cultural heritage;

As a country, Romania, on its territory, has a large number of heritage buildings (that have been indexed in the list of heritage buildings and are thus protected); however, there is also quite a high number of currently undefined buildings with historic and architectural value, i.e., buildings that have not been included in the National Register of Historic

Monuments in Romania but need to be protected and restored with the same degree of importance.

Heritage buildings are very diverse in terms of architectural style, most of them combining several styles, thus becoming unique; from fortresses to churches, from mansions to open-air museums, to administrative buildings, or private houses (residential buildings), the distribution of monuments with architectural and historical value is relatively balanced.

The counties with the largest number of buildings and sites in the category of monuments and architectural ensembles are Sibiu (840), Braşov (784), Argeş (765), Mureş (736), Prahova (737), and Iași (706) [44,46].

An important factor to be considered is that the above-mentioned buildings are not the only buildings in Romania with historic and architectural value; at present, there is an active endeavor to add more buildings to the list, and this is an ongoing process; more and more buildings are constantly being identified and added to the National Register of Historic Monument in Romania. An example of unique architecture on the Romanian territory is the Town Hall of Câmpulung town, as shown below (see Figure 2).

Figure 2. Town Hall of Câmpulung, Romania—main façade, showcasing the neo-Romanian style.

At the beginning of the 20th century, the interwar period marked an important moment in the development of Romanian architecture; through the drive of some renowned architects of the time, the quest for creating an original Romanian architectural style was on its way, and the results can be seen in the images above. Therefore, the restoration and inclusion in the National Register of Historic Monuments in Romania of these architectural and structural experiments was of great relevance and importance.

In Romania, heritage buildings are divided into several utility topologies, such as educational units (universities, schools, academies, institutes, and libraries), administrative buildings, restaurants, railway stations, hospitals, archives, and museums, each with its different regime of use and density of utilizers. Thus, it is equally necessary to study these types of buildings (schools/universities) in order to evaluate and propose energy efficiency measures since many of them are "energy-hungry". In this way, indoor climate/comfort conditions can also be improved (air quality, humidity, PMV, PPD, etc.).

The typologies of buildings with historic and architectural value serve a wide range of functions; e.g., individual housing, collective housing, administrative spaces, headquarters of institutions and social services, education and health spaces, and commercial or production spaces. If part of the existing building fund had been maintained in its original function, many heritage buildings would have been adapted for new uses, with a new set of needs and requirements for the use of space. If these transformations were made consistent with the structure and typology of historic buildings, these readjustments would allow them to extend their life [1].

2.2. Main Challenges in the Energy Optimization of Heritage Buildings in Romania

When the topic of energy efficiency measures is considered for buildings with historic and architectural value, there are a multitude of causes of damage that come into discussion; thus, the rehabilitation process needs to be conducted in a timely manner to buildings with historical and architectural value, as follows [48]:

- Constructive causes: These are observable after a long period of time after the execution of the construction and are usually accompanied by other causes.
- Improper use of construction: This is one of the main causes resulting in damage to a construction. Considering their very long lifespan, the human factor intervenes in the decision-making process with respect to intervention in historical buildings.
- Degradation of materials.
- The land connection solution.
- Humidity.
- Catastrophic actions.
- Lack of use.
- Lack of skills and experience and/or materials.
- Over-climatization.
- Lack of insulation and vapor barriers in historic buildings.
- Additional sources of moisture.
- Pollution.
- Inherent wear and tear.
- The light.
- Climatic changes.
- Effects of temperature and humidity fluctuations.
- Microbiological growth.
- Pests, i.e., vermin and insects.

As Romania is a four-season country, heritage buildings can be affected by the influence of temperatures, with major fluctuations due to low winter temperatures; in addition, fires, excessive solar radiation, and excessive precipitation have also proven to be key factors that must be taken into consideration. The implications of thermal actions are diverse; however, in the first phase of an energy efficiency project conducted on a building with historic and architectural value, the focus should definitely be on the influence of humidity and very low temperatures, since the main priorities are ensuring interior comfort and reducing energy consumption.

In addition, it is essential to consider the different structural and architectural typologies of heritage buildings, which can prove to be a good start in identifying the best solutions for these types of buildings. For example, some buildings with historic and architectural value that have used massive walls as a structural solution are able to experience delays in receiving the variation of outside temperature due to their high thermal capacity and thermal inertia. This results in fewer thermal bridges; the indoor temperature is kept longer (depending on the variation of outdoor temperatures), and the risk of overheating or excessive cooling of the interior spaces is greatly reduced.

If the renovation processes and energy optimization steps do not take into consideration the specific characteristics of the building's typology, the processes may lead to a decrease in the quality of their usage, create interior comfort problems for their inhabitants, or irreparably destroy their historic and architectural value. Thus, it is extremely important to take into consideration the built typology of the building during the pre-intervention process. The European policy regarding reducing energy consumption by 2050 makes it mandatory to optimize the energy of all buildings by 2050, including those in Romania. This initiative has increased the importance of the existing building stock on a national level, thus creating a positive context for the development of new solutions for interventions that ought to consider the specific requirements of public historic buildings.

3. Case Study: Câmpulung Town Hall Building

As case study, we have chosen a public building that is listed in the National Register of Historic Monuments in Romania, namely, the Town Hall building of Câmpulung, Romania, a B-category heritage building with the identification code: AG-II-m-B-13556. The structural typology of the building consists of massive walls that have good energetic values, with the shape of the building being a U form with an interior courtyard.

3.1. Description

The Town Hall of Câmpulung was originally created to function as the Muscel Prefecture and was built as part of the Ministry of Public Works program in order to equip the Old Kingdom with the necessary public buildings intended for county administrations. This project was carried out according to the plan of the architect Dimitrie Ionescu Berechet; it began in 1924, and was finalized in 1934, which is also the year in which the inauguration of the building took place (see Figure 3).

Figure 3. A visual representation of the Town Hall building at its inauguration in 1934.

The building was constructed with elements from the neo-Romanian, the neo-byzantine, and neo-gothic styles, and, as with many other buildings constructed in the same period, the result was a unique-looking building This was a period in Romanian history when a multitude of architectural experiments were taking place, mostly through the architects' desire to instill an architectural identity to the buildings of the time, a goal eventually achieved through several architectural experiments. Thus, in the case of the Câmpulung Town Hall building, we can observe neo-Romanian elements, such as the dimensions and decorations of the windows on the first floor, which present a neo-Gothic-style framing, as can be seen in the image below.

Architecturally, the Town Hall of Câmpulung (see Figure 4) features intricate façade carvings, high ceilings, and large windows typical of the period's style, which not only enhance its aesthetic value but also present unique challenges in terms of thermal insulation. The building's historical significance is underscored by its location in the heart of Câmpulung, making it a landmark of not only architectural but also sociocultural importance.

Figure 4. Town Hall of Câmpulung, Romania—side building façade.

3.2. Identified Building Problems before the Intervention Process

The main reason why the building needed to be optimized energetically was the fact that this heritage building has a public function, as this is the location of Câmpulung's Town Hall. In terms of problems, the building was dealing with high energy bills, unoptimized energy usage, thermal bridges, and interior spaces that could not be utilized as they had not been rehabilitated; hence, the administration decided to modernize the building, making it more accessible and user friendly while also being able to produce its own required energy.

Currently, the building faces significant energy efficiency challenges. It is primarily heated through an outdated central heating system, leading to high energy consumption and inefficiency. The building's heating system is centralized and relies on a single gas boiler located in the basement. This boiler operates at high temperatures and distributes heat through water radiators set at 80 °C. The conventional arrangement, albeit prevalent in older buildings, presents efficiency obstacles and sustainability issues due to its elevated energy usage and substantial heat dissipation.

The thermal performance of the building is compromised by several factors, including poor insulation in the attic, single-glazed windows, and significant air infiltration through aging window frames and doorways. These issues are enhanced by the building's large volume and high ceilings, which makes it difficult to maintain consistent indoor temperatures.

The thermal envelope of the structure is the main emphasis of the suggested energy optimization techniques. Among the main procedures meant to lower energy consumption while maintaining the architectural integrity of the building are replacing the window units with double-glazed panels, adding better sealing and insulating materials in the attic, and installing more-efficient heating systems. Along with enhancing the Town Hall's sustainability, these actions are supposed to act as a model for the preservation of other historic structures dealing with comparable issues.

The exterior walls of the building are made of 45 cm solid brick. The construction is provided with unheated space with a hipped roof. The floor above ground is made of concrete and does not have any thermal insulation in the soffit. The perimeter plinth is not thermally insulated. The joinery of the exterior windows and doors is made of wood. The heels are positioned on the inner face of the parapets.

The existing exterior finishes show mechanical wear at the level of the visible layers. Due to atmospheric agents, mechanical agents, and biological agents, as well as occasional rheological phenomena, the finishes have been affected up to now by dirt and discoloration caused by the action of ultraviolet rays, stains, etc. The building has no special shading elements on the façades.

As can be seen in the image above (see Figure 5), the state of the attic was unkept and no intervention was conducted to insulate the roof space, hence the occurrence of substantial heat loss and thermal bridges.

Figure 5. Image displaying the uninsulated attic.

However, because the attic had not been in its original form since the building's construction in 1934, this necessitated proper care and proper rehabilitation solutions so as not to lose the historic and architectural value of this interior space, while also enabling us to implement certain changes to the space to incorporate the HVAC elements to properly generate energy efficient results for the building.

3.3. Energy Analysis—A Pre-Intervention, Non-Invasive, Multicriterial Study

As the Town Hall of Câmpulung is a registered heritage building, the process of pre-intervention analysis had to be conducted in a non-invasive way. Thus, to analyze the current state of the building from an energy efficiency point of view, it was necessary to conducted multiple non-invasive studies:

- The energy audit of the building;
- An in situ study using measurement equipment, recording the humidity and temperatures on the south and north façade;
- A thermographic study of the building's envelope;

3.3.1. The Energy Audit

Part of the building issues presented were identified by studying the building's annual energy consumptions, as the annual heat consumption for space heating (discontinuous heating) is determined according to the Mc001/PII.1 Romanian methodology. The calculation temperature considered the fact that we have a daily variation, so the equivalent internal temperature was calculated to be 20 °C. Finally, the values based on which the building will be classified from an energetic point of view were determined. Adding up the entire energy consumption presented above results in a total annual energy consumption for heating of 714.7 MWh/year and a specific consumption of 326.7 kWh/m^2 year, respectively.

It can be observed in Table 1 above that the building's main elements do not meet the requirements needed for proper thermal insulation; thus, rehabilitation and thermal energy modernization solutions are needed in order to achieve appropriate thermal insulation and energy saving according to current requirements. It can also be observed that in this case, for example, even if the walls of the building are massive, they do not perform thermally as needed so as to form an optimal indoor climate. This highlights once again the importance of the project team's research before intervention to ensure that the right solutions have been selected in order to extend the building's (i.e., the Town Hall's) lifespan calculations.

Table 1. Results of a study conducted on the main construction elements of the studied heritage building in order to identify the current thermal resistance and determine if they meet the thermal insulation requirements for a building of this typology.

Construction Element	R′ [m^2K/W] (Calculated)	R′min [m^2K/W] (Standard Value)	Meeting the Thermal Insulation Requirements
Exterior wall	17.1	1.7	No
Floor slope over basement/terrain	1.36	2.5	No
Floor slope terrace/Sky parlor/Attic	0.28	4	No
Exterior window frame	0.38	0.5	No

The highest consumptions are related to heating and, secondly, to the lighting system; thus, the energy efficiency measures tackled these parts (see Table 2). In Romania, within the legislation, the building is compared to a reference building (same architecture) but enhanced in terms of thermal resistance and systems. The reference building in this case is calculated as in Table 3.

Table 2. Energy consumption calculations—building Town Hall.

Consumption	Heating	Domestic Hot Water	Lighting	Total
Annual consumption [MWh/year]	714.7	1.6	50.6	766.9
Specific consumption [kWh/m^2/year]	326.7	0.7	23.1	350.6
CO_2 emissions [kgCO_2/m^2/year]	78.4	0.2	18.1	96.7
Energy class-Romanian legislation	E	A	A	**D**

Table 3. Energy consumption calculations—reference Town Hall.

Consumption	Heating	Domestic Hot Water	Lighting	Total
Annual consumption [MWh/year]	208.0	1.4	60.8	275.6
Specific consumption [kWh/m^2/year]	95.1	0.7	22.0	120.2
CO_2 emissions [kgCO_2/m^2/year]	22.8	0.2	21.8	46.7
Energy class-Romanian legislation	B	A	A	**A**

It must be mentioned that for historic buildings, there is no clear delimitation for reference buildings, and exterior walls are forbidden to be thermally insulated with external insulation. In this situation, the purpose is not to reach the reference values—this would be impossible—but rather to find the best solutions to the problem of reducing energy consumption while keeping the architectural value of the building.

3.3.2. Result from the In Situ Measurements of Temperature and Humidity

To better understand the state of the building and its indoor conditions during winter/spring season, testing the relative humidity and the temperature fluctuation was a key part of the study. Following the energy audit, we were able, with the help of the Testo 174 equipment, to record and analyze the date recorded as follows: we placed the equipment, that had been set to record, in an office facing the south façade and in an office facing the north façade; this positioning of the sensors was also meant to be used for comparison as the solar gains can severely impact the indoor temperatures.

As can be observed in Figure 6, the temperatures throughout March and April of this year, during both night and day, were different, with almost daily temperature drops.

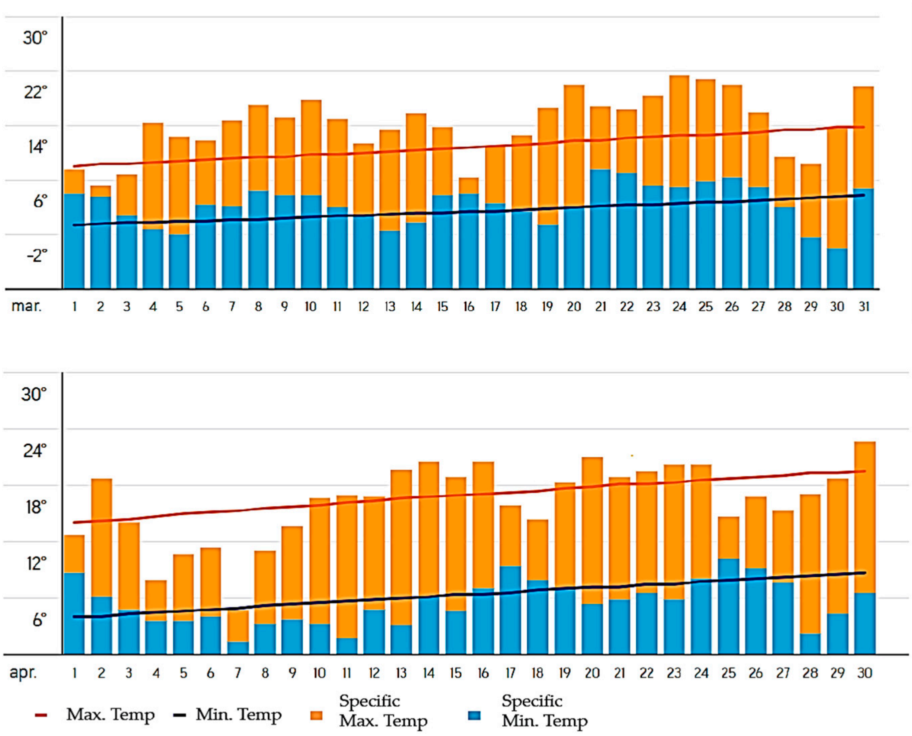

Figure 6. Exterior temperatures between March and April 2023, the period when the in situ measurements took place.

Romania is a country that experiences all 4four seasons during a year; however, in the passing years, the lines between winter and summer have been blurred and the changes are visible as little to no snow falls during the winter season. The reason why we chose to monitor the building during the end of winter and the beginning of spring was to better understand the state of a building with such characteristics.

- South Façade Office Measurements

The Testo equipment we set in one of the main offices of the building facing the south façade was positioned strategically in order to monitor the relation between the building's pre-intervention relative humidity and the interior temperatures registered. Thus, as the above Table 4 showcases, as this is the façade that was the most solar, the temperatures remained generally constant, i.e., between 21.7 and 24.4 °C, while the humidity throughout the period of the office monitoring (14 March 2023–11 April 2023), as can be seen in Figure 7, fluctuated from 17.1 to 39.1%rH. This can decrease the quality of the interior climate and reduce the work efficiency of the staff that work in the building, as the building is an administrative one.

Table 4. Results regarding the degree of relative humidity and temperature.

Parameter [1]	Min	Max	Mean Value
Humidity [%rH]	17.1	39.1	26.89
Temperature [°C]	21.7	24.4	23.308

[1] Parameters recorded between 14 March 2023 and11 April 2023, a transition period in between the cold season and a warmer one.

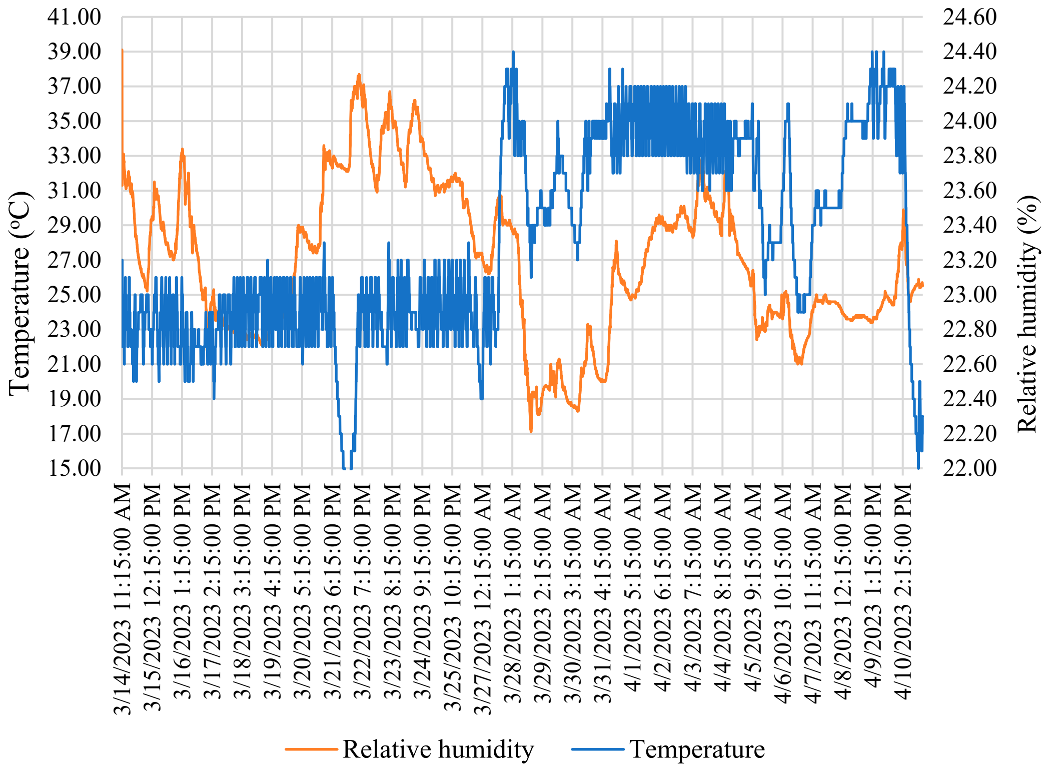

Figure 7. Results regarding the degree of relative humidity and temperature obtained from the equipment located in an office space facing the south façade of the building.

- North Façade Office Measurements

The equipment that was set to measure the relative humidity and temperatures in the main office facing the north façade was able to showcase, just as in the case of the south façade, that the monitored temperature values were more constant (see Table 5) than the humidity levels; the latter were significantly more different, taking into consideration the climate conditions at that time in Câmpulung town, as there was more humidity in the exterior air.

Table 5. Results regarding the degree of relative humidity and temperature obtained from the equipment located in a room facing the north façade of the building.

Parameter [1]	Min	Max	Mean Value
Humidity [%rH]	19.5	41.7	29.83
Temperature [°C]	19.8	23.6	21.738

[1] Parameters recorded between 14 March 2023 and 11 April 2023, a transition period in between the cold season and a warmer one.

Moreover, the failure to address this issue, particularly in the context of Romania's seasonal climate variations, poses significant concerns. Summers in Romania are characterized by high temperatures, while the transitions between colder and warmer seasons are protracted. During these transitional periods, there is a continuous exchange of air between indoor and outdoor environments. This persistent state of flux can compromise the building's usability, rendering it an unsafe workspace for prolonged durations.

Figure 8 highlights that, because of temperature changes, the interior temperatures fluctuate considerably in the period during which the equipment monitored the building. Consequently, this means more chances of thermal bridge formations appearing, and even mold can occur over time, given the change in temperatures and the lack of necessary layers for thermal insulation. All this comes as a research validation tool for the energy audit conducted, showcasing with real-time data that the construction elements do not meet the requirements of thermal insulation and energy saving.

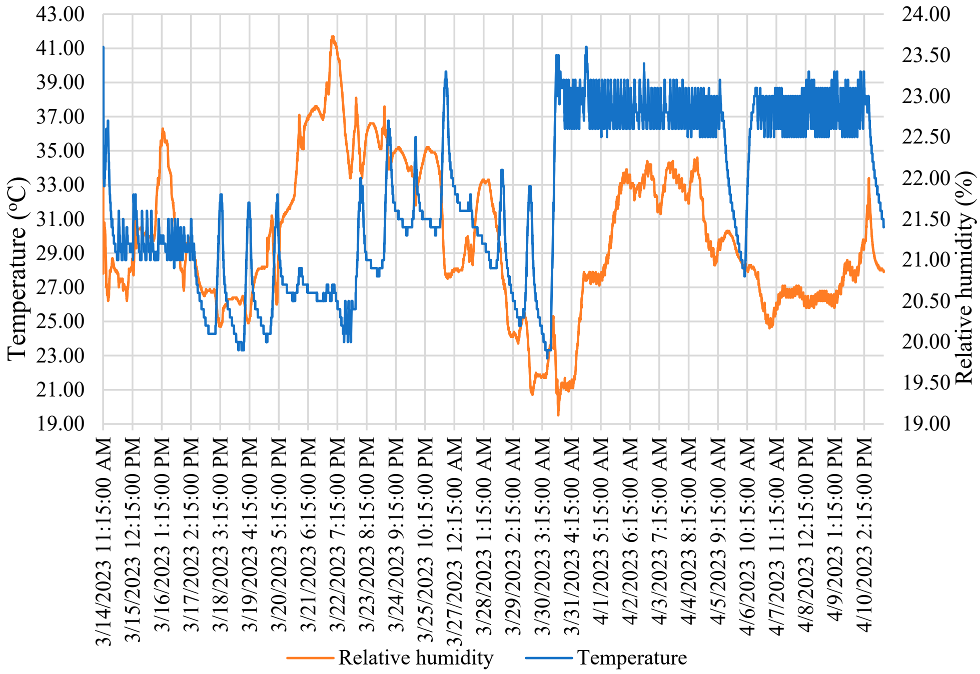

Figure 8. Results regarding the degree of relative humidity and temperature obtained from the equipment located in an office room facing the south façade of the building.

The south office room has a wider temperature range, with the lowest and highest recorded readings being 21.7 °C and 24.4 °C, respectively, with an average temperature of around 23.31 °C. In comparison, the north office room maintains a temperature range between 19.8 °C and 23.6 °C, with an average temperature of approximately 21.74 °C, which is lower. This suggests that the temperature in the south office is consistently higher than that in the north office. The humidity levels in the north office room typically exceed those in the south office room. The humidity levels in the north office range from 19.5% to 41.7%, with an average humidity of 29.83%. In comparison, the south office has humidity levels ranging from 17.1% to 39.1%, with a mean humidity of 26.89%. This indicates that the air in the north office consistently has a higher level of humidity. The north office room reveals a little more noticeable fluctuation in temperature and humidity. The north office exhibits a wider spectrum of temperature and humidity variations, which could have a more pronounced impact on thermal comfort and air quality, compared to the relatively milder south office.

3.3.3. Results from the Thermographic Study on the Building's Envelope

A thermographic study was also undertaken on the Câmpulung Town Hall, specifically examining the north façade of the structure. We have used a TESTO 872s thermal imaging camera to conduct thermographic observations of the Town Hall of Câmpulung. The weather conditions at the time of measurement were overcast, with a morning temperature of around 3 °C. The prevailing conditions were optimal for performing thermal imaging as they effectively reduced the influence of solar radiation on the thermal measurements, enabling more-precise identification of heat losses from the building's exterior. This study employed thermal imaging technology to detect regions experiencing heat losses, thus highlighting the energy efficiency problems of the building's exterior and better proving the necessity of implementing solutions. The outcomes of this assessment are crucial for planning future conservation and restoration endeavors, especially due to the Town Hall's historical significance and unique architectural requirements. The heat loss through the windows was particularly significant, with temperatures reaching up to 14.1 °C (see Figure 9). The significant difference in temperature clearly demonstrates that the windows are vulnerable areas in the building's envelope. The outdated timber-framed windows of this historic structure are evidently insufficient in mitigating energy dissipation.

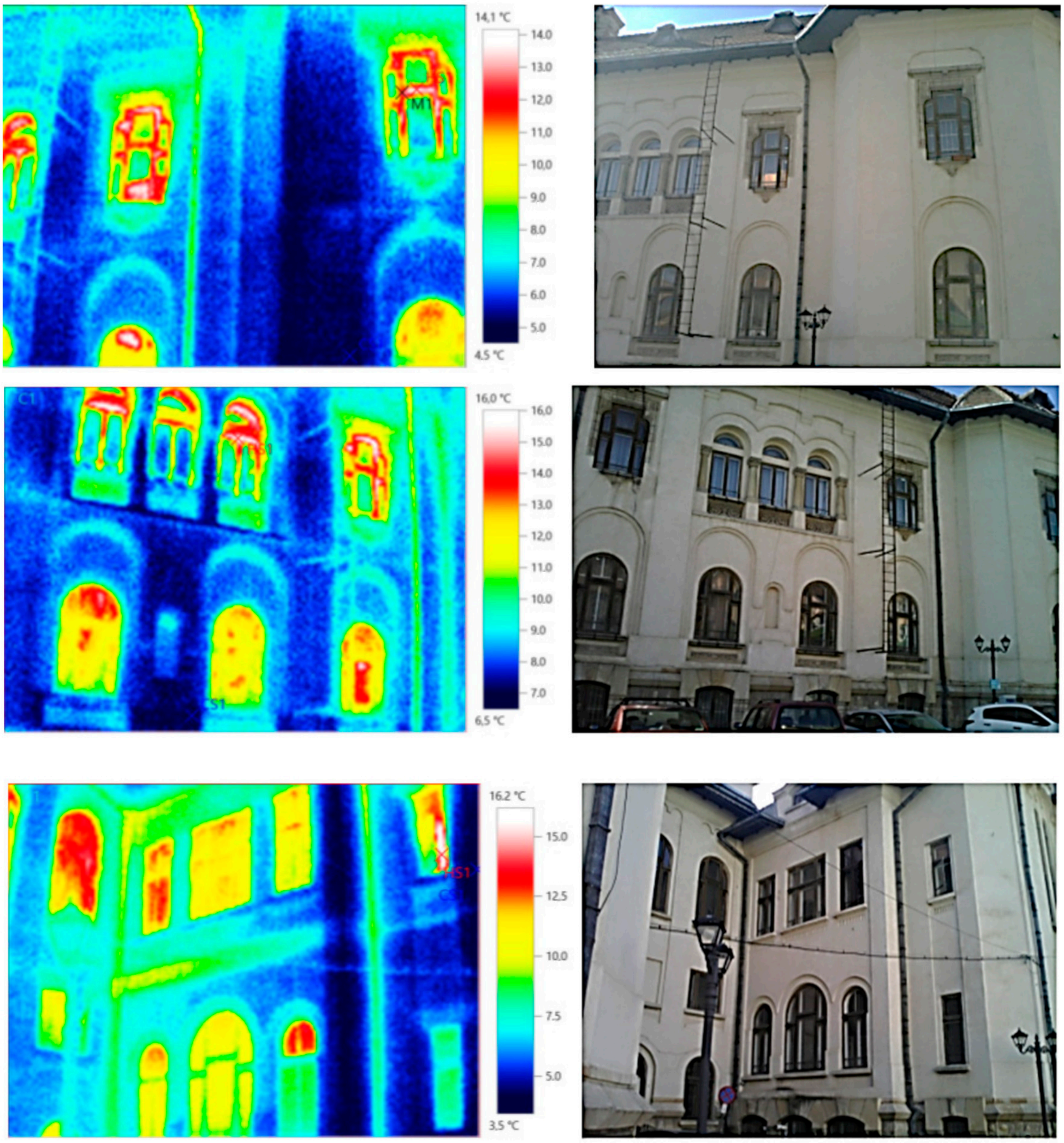

Figure 9. Multiple thermal images of the north façade of the building.

The thermographic research highlights a significant issue of energy inefficiency at the Câmpulung Town Hall, mainly caused by outdated construction materials and deteriorating architectural components. By replacing or updating the historical windows with thermally efficient alternatives that preserve the building's beauty and historical significance, energy consumption can be reduced, and the sustainability of the property can be improved. This short thermographic study provides essential evidence to support the need for investing in energy efficiency measures at the envelope level.

4. Strategies and Solutions

The strategy implemented in this project was first to study the building in a non-invasive way via the use of the above-mentioned studies (thermal calculations, indoor measurements, and thermal camera photos).

Identified Solutions

Taking into consideration the energy audit and the in situ studies, a series of solutions were identified as proper for the intervention. They are as follows:

- Proposed solution 1: Changing the entire window as a result of the minimum thermal resistances provided for the external window frame (R'min > 0.9 m^2K/W);
- Proposed solution 2: Keeping the wood frame with restoration measures but replacing the glass with a high-performance example, namely, 4-12-4 type with low-e.

After changing the windows, the following must be taken into account:

- The sealing of cold air infiltrations in the joints of carpentry contours between the skirting board and the wall gap with a sealing film on the outside (width 29 cm), and filling the remaining spaces after installing the new windows with polyurethane foam and closing the joints with plaster;
- The water-repellent sealing of the joints on the outer contour of the frame with special materials (silicone putty, exterior sealing film, hydrophobic mortars, etc.), as well as covering the joints;
- Where necessary, replacing the existing galvanized sheet joists on the external horizontal gable at the bottom of the wall gaps with aluminum gables; the slope, the existence and shape of the teardrop, the sealing against the frame (nails with a wide head at small distances), the sealing against the wall (the edge of the board raised and covered with plaster on the upper part), etc., will be ensured;
- The unclogging (or creating, if there are none) of the holes at the bottom of the skirts intended for the removal of condensed water between the sashes.

The thermal modernization of the exterior window frame is proposed to be carried out in the following manner: changing the entire glazed surface with glass of type 4-12-4 energy performance to prevent the building's cooling requirement from increasing during the hot season; the solar coefficient of the glass will be $g < 0.35$.

Adopting the solution of the total replacement of the existing windows involves sealing the interior space and drastically reducing the number of air exchanges below the value necessary to dilute the CO_2 concentration and indoor humidity. Thus, before the rehabilitation, the air exchange was partially achieved through the leaks in and around the window frames.

In addition, by providing sealing gaskets, air freshening must be conducted in other ways, namely, by installing hygro-adjustable grid systems in the color of the wooden frame. The solutions identified for the doors at the entrance of the building are to be equipped with automatic, mechanical, or electric closing systems. For the door at the main entrance, it is recommended to choose a configuration similar to the existing one, consisting of two successive doors between which a buffer space from the outside environment is created.

The rehabilitation solutions chosen for the attic slab include insulating the floor towards the unheated bridge; the heat-insulating layer will be applied to the outer face of the support layer after uncovering the ballast and/or waterproofing layers as appropriate. The hydrothermal insulation solution will be made with a layer of fireproof mineral wool of a minimum 30 cm and a maximum conductivity of 0.04 W/mK.

Regarding the modernization solutions proposed for the interior lighting, the proposed strategy was to replace the interior lighting luminaires, which currently have fluorescent lamps, with efficient LED lighting luminaires.

The increased efficiency of LED luminaires would lead to energy savings and therefore the achievement of another desired outcome. Also, their average lifetime is substantially longer than any classic source, operating for up to 30,000 h without the luminous flux diminishing. LEDs are also able to withstand variations in supply voltage without affecting their lifetime.

The main solution to the problem of creating new energy sources was the installation of a complete photovoltaic system of the "ON-GRID" type, a system with monocrystalline photovoltaic panels with a power of 25 kWp and a total area of 200 m^2. The system will be installed on the back part of the roof without affecting the building's aesthetic value.

The PV panels are installed to ensure the production of electricity for the building's own consumption, being connected to the external network, and they will consist of the following:

Monocrystalline photovoltaic panels with a power between 350 and 500 W and a total nominal power of 25 kW, mounted on a support structure made of aluminum profiled elements with a west orientation and an inclination of 30–40° compared to the inclined plane and voltage inverters with a minimum efficiency of 95%.

Regarding the mounting system for panels, the solution was to use MC4-type connectors for photovoltaic panels and a solar electric cable with a two-way energy meter (recording of energy consumed from the network and energy delivered to the network). The surface available for mounting the panels is approx. 855 m^2, and the total area of the panels is 200 m^2. The total installed power of the system is 25 kWp, with an annual electricity production of approx. 32,500 kWh (from renewable sources).

As future research directives for energy optimization projects for buildings with historic and architectural value, analyzing and creating a new category of similar buildings that are not listed in the monument category would prove useful not only to better address their problems in a controlled way but to also unveil their real number and their actual spread in the country.

5. Results and Perspectives

The results identified in the case study further highlight the need for a pre-study multicriterial analysis regarding the current state of the building alongside a heritage study. In situ studies of the building, conducted in a non-invasive way, have facilitated more in-depth knowledge of the building, thus making sure that the solutions proposed will extend the life cycle of the building. The solutions for energy reduction are presented in Table 6.

Table 6. Proposed energy efficiency solutions.

Solution	Description
S1	Keeping the wood frame with restoration measures but replacing the glass with a performant 4-12-4 type with low-e
S2	The hydrothermal insulation solution for the attic floor will be made with a layer of fireproof mineral wool of a minimum of 30 cm and a maximum conductivity of 0.04 W/mK
S3	Replacing the interior lighting luminaires, which currently have fluorescent lamps, with efficient LED lighting luminaires
S4	Installing thermostatic valves on all heating radiators
S5	Mounting 25 kW solar photovoltaic panels on the west façade
S1 + S2 + S3 + S4	Analysis of solutions 1–4
S1 + S2 + S3 + S4 + S5	Analysis of solutions 1–5–complete

The results of the simulations are summarized in Table 7.

Table 7. Results of annual consumption and energy reduction for each proposed solution.

Consumption	Heating	Domestic Hot Water	Lighting	Total
Solution S1				
Annual consumption [MWh/year]	575.4	1.6	50.6	627.6
Specific consumption [kWh/m^2/year]	263.0	0.7	23.1	286.9
Energy reduction		18.16%		
solution S2				
Annual consumption [MWh/year]	591.2	1.6	50.6	643.4
Specific consumption [kWh/m^2/year]	270.3	0.7	23.1	294.1
Energy reduction		16.1%		
solution S3				
Annual consumption [MWh/year]	714.7	1.6	31.9	748.1
Specific consumption [kWh/m^2/year]	326.7	0.7	14.6	342.0
Energy reduction		2.44%		
solution S4				
Annual consumption [MWh/year]	664.1	1.6	50.6	716.3
Specific consumption [kWh/m^2/year]	303.6	0.7	23.1	327.5
Energy reduction		6.59%		
solution S5				
Annual consumption [MWh/year]	714.7	1.6	18.1	734.4
Specific consumption [kWh/m^2/year]	326.7	0.7	8.3	335.7
Energy reduction		4.24%		
solution S1 + S2 + S3 + S4				
Annual consumption [MWh/year]	451.9	1.6	50.6	504.1
Specific consumption [kWh/m^2/year]	206.6	0.7	23.1	230.4
Energy reduction		43.29%		
solution S1 + S2 + S3 + S4 + S5				
Annual consumption [MWh/year]	419.9	1.6	0.0	421.5
Specific consumption [kWh/m^2/year]	192.0	0.7	0.0	192.7
Energy reduction		47.53%		
Final energy class	D	A	A	B

The energy efficiency solutions recommended for a building, including window upgrades and solar panel installation, have undergone comprehensive analysis to determine their individual and collective effects on energy usage. The initial solution (S1) entails enhancing the windows by installing high-performance glass, while preserving the original wooden frames. This approach results in a substantial 18.16% decrease in energy use, highlighting the crucial importance of window insulation in enhancing the overall energy efficiency of buildings, especially in historic buildings.

The second method (S2) improves thermal insulation by installing fire-resistant mineral wool on the attic floor. This method decreases energy usage by 16.1%, thus lowering the amount of heat lost via the roof, which is a prevalent source of inefficiency in older structures. By enhancing the insulation of the roof, this solution improves the building's thermal envelope and helps maintain stable inside temperatures, resulting in a more comfortable life and work environment.

The third solution (S3) centers on enhancing the lighting system by replacing outdated fluorescent lamps with energy-efficient LED luminaires. The change leads to a moderate reduction of 2.44% in overall energy consumption. However, it has a significant impact on the energy used just for lighting, which highlights the efficiency of LEDs in comparison to older lighting choices.

The fourth solution (S4) incorporates thermostatic valves on all heating radiators, enhancing the heating system's efficiency by optimizing heat distribution management. This modification results in a 6.59% decrease in energy consumption, demonstrating the advantages of contemporary heating controls in minimizing needless heating and improving the comfort of occupants.

The fifth option (S5) integrates renewable energy by installing 25 kW solar photovoltaic panels on the west façade. This not only reduces the building's dependence on external power sources by 4.24% but also promotes sustainability efforts by decreasing the carbon footprint linked to conventional energy sources.

When these ideas are implemented all together, the outcomes are notably remarkable. The integration of solutions S1 through S4 leads to a significant decrease in energy usage by 43.29%, demonstrating the synergistic impact of comprehensive building retrofits. The addition of solar panels (S1–S5) further amplifies this effect, resulting in a 47.53% reduction in energy use and raising the building's energy rating to "B". This holistic strategy not only greatly reduces operational expenses but also establishes the building as an example of sustainable retrofitting in historical structures, highlighting the feasibility of combining contemporary technologies with preservation principles. This technique not only advances environmental objectives but also preserves the cultural and historic integrity of heritage structures.

6. Conclusions

This paper presented the framework for pre-intervention studies on a heritage building, that is a building with historic and architectural value. The framework incorporated several primary non-invasive techniques, presented in detail in the paper. A key takeaway from the study was the importance of studying buildings with historic and architectural value in situ, monitoring them in periods of seasonal changes—with climate conditions that are inconsistent—in order to better assess how the buildings handle these transition periods and how to better assist them with strategic energy efficiency measures.

The proposed framework can help with providing a better understanding of the characteristics of buildings with historic and architectural value before starting the energy optimization processes, as the proposed pre-intervention studies can highlight important aspects about the building's current state and intervention possibilities.

Buildings with historic and architectural value, once modernized and energy optimized, can function as well as new buildings, meaning they will be able to accommodate proper interior comfort values for the inhabitants. As in the case of the Town Hall building, there are plenty of older buildings that are still being intensively used to this day. The proposed solution of integrating a solar panel system on the roof so as not to disrupt the general architecture of the façades but still to be able to generate energy locally could prove to be a great solution for these buildings. Ultimately, the positive outcome of consistently modernizing this building stock is that we can live more sustainably and in healthier interior climates.

Author Contributions: Conceptualization, S.E.Ș. and T.C.; methodology, S.E.Ș. and T.C.; software, T.C.; validation, T.C.; formal analysis, T.C.; investigation, S.E.Ș., T.C., R.P. and L.P.; resources, S.E.Ș. and T.C.; data curation, S.E.Ș. and T.C.; writing—original draft preparation, S.E.Ș.; writing—review and editing, S.E.Ș., T.C., R.P. and L.P.; visualization, S.E.Ș. and T.C.; supervision, T.C.; project administration, T.C. All authors have read and agreed to the published version of the manuscript.

Funding: This paper was funded by the National Research Grants of the UTCB (ARUT 2023), project number UTCB-31.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. *The Intervention Methodology for a Non-Invasive Approach to Energy Efficiency Measures for Buildings with Historical and Architectural Value/22.12.2022 2022*; Romanian Ministry Order 3568/2022; Romanian Ministry of Culture: Bucharest, Romania, 2022.
2. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. In *A Renovation Wave for Europe—Greening Our Buildings, Creating Jobs, Improving Lives*; European Commission: Brussels, Belgium, 2020.

3. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. In *A Policy Framework for Climate and Energy in the Period from 2020 to 2030*; European Commission: Brussels, Belgium, 2014.
4. World Meteorological Organization. *Annual Report Highlights Continuous Advance of Climate Change*; World Meteorological Organization: Geneva, Switzerland, 2022.
5. European Council. *2030 Climate and Energy Policy Framework*; European Council: Brussels, Belgium, 2014.
6. *Delivering the European Green Deal on the Path to a Climate-Neutral Europe by 2050*; European Commission: Brussels, Belgium, 2021.
7. Stanica, D.-I.; Karasu, A.; Brandt, D.; Kriegel, M.; Brandt, S.; Steffan, C. A methodology to support the decision-making process for energy retrofitting at district scale. *Energy Build.* **2021**, *238*, 110842. [CrossRef]
8. Nägeli, C.; Farahani, A.; Österbring, M.; Dalenbäck, J.-O.; Wallbaum, H. A service-life cycle approach to maintenance and energy retrofit planning for building portfolios. *Build. Environ.* **2019**, *160*, 106212. [CrossRef]
9. Blázquez, T.; Ferrari, S.; Suárez, R.; Sendra, J.J. Adaptive approach-based assessment of a heritage residential complex in southern Spain for improving comfort and energy efficiency through passive strategies: A study based on a monitored flat. *Energy* **2019**, *181*, 504–520. [CrossRef]
10. Dornieden, T.; Gorbushina, A.A.; Krumbein, W.E. Biodecay of cultural heritage as a space/time-related ecological situation—An evaluation of a series of studies. *Int. Biodeterior. Biodegrad.* **2000**, *46*, 261–270. [CrossRef]
11. Godwin, P.J. Building Conservation and Sustainability in the United Kingdom. *Procedia Eng.* **2011**, *20*, 12–21. [CrossRef]
12. Rodrigues, C.; Freire, F. Building retrofit addressing occupancy: An integrated cost and environmental life-cycle analysis. *Energy Build.* **2017**, *140*, 388–398. [CrossRef]
13. Huijbregts, Z.; Kramer, R.; Van Schijndel, J. Computational modeling of the impact of climate change on the indoor environment of a historic building in Netherlands. In Proceedings of the 9th Nordin Symposium on Building Physics, Tampere, Finland, 29 May–2 June 2011.
14. Coillot, M.; El Mankibi, M.; Cantin, R. Heating, ventilating and cooling impacts of double windows on historic buildings in Mediterranean area. *Energy Procedia* **2017**, *133*, 28–41. [CrossRef]
15. Litti, G.; Khoshdel, S.; Audenaert, A.; Braet, J. Hygrothermal performance evaluation of traditional brick masonry in historic buildings. *Energy Build.* **2015**, *105*, 393–411. [CrossRef]
16. Caro, R.; Sendra, J.J. Evaluation of indoor environment and energy performance of dwellings in heritage buildings. The case of hot summers in historic cities in Mediterranean Europe. *Sustain. Cities Soc.* **2020**, *52*, 101798. [CrossRef]
17. Menassa, C.C. Evaluating sustainable retrofits in existing buildings under uncertainty. *Energy Build.* **2011**, *43*, 3576–3583. [CrossRef]
18. Murgul, V.; Pukhkal, V. Saving the Architectural Appearance of the Historical Buildings due to Heat Insulation of their External Walls. *Procedia Eng.* **2015**, *117*, 891–899. [CrossRef]
19. Sugár, V.; Talamon, A.; Horkai, A.; Kita, M. Energy saving retrofit in a heritage district: The case of the Budapest. *J. Build. Eng.* **2020**, *27*, 100982. [CrossRef]
20. Ruggeri, A.G.; Calzolari, M.; Scarpa, M.; Gabrielli, L.; Davoli, P. Planning energy retrofit on historic building stocks: A score-driven decision support system. *Energy Build.* **2020**, *224*, 110066. [CrossRef]
21. Biseniece, E.; Žogla, G.; Kamenders, A.; Purviņš, R.; Kašs, K.; Vanaga, R.; Blumberga, A. Thermal performance of internally insulated historic brick building in cold climate: A long term case study. *Energy Build.* **2017**, *152*, 577–586. [CrossRef]
22. Walker, R.; Pavía, S. Thermal performance of a selection of insulation materials suitable for historic buildings. *Build. Environ.* **2015**, *94*, 155–165. [CrossRef]
23. González, A.G. Keeping the Historical Heritage Alive: Methodology for the energy renovation of the historic residential stock of the east extension in Brussels. In Proceedings of the PLEA2013—29th Conference, Sustainable Architecture for a Renewable Future, Munich, Germany, 10–12 September 2013.
24. Bernardi, A.; de Carli, M.; Pockelé, L.; Poletto, F.; Galgaro, A.; Di Sipio, E.; Castelruiz, A.; Urchueguía, J.; Badenes, B.; Pasquali, R.; et al. Shallow Geothermal Energy for existing buildings—Overview and status of project GEO4CIVHIC 2022. In Proceedings of the European Geothermal Congress 2022, Berlin, Germany, 17–21 October 2022.
25. Corrado, V.; Ballarini, I.; Paduos, S.; Primo, E. Refurbishment of the Residential Building Stock toward the Nearly-Zero Energy Target Through the Application of the Building Typology. *Energy Procedia* **2016**, *101*, 208–215. [CrossRef]
26. Ascione, F.; Bianco, N.; De Masi, R.F.; Mauro, G.M.; Vanoli, G.P. Cost-Effective Refurbishment of Italian Historic Buildings. In *Cost-Effective Energy Efficient Building Retrofitting*; Elsevier: Amsterdam, The Netherlands, 2017; pp. 553–600.
27. Smiles, M.J.; Law, A.M.; Urwick, A.N.; Thomas, L.; Irvine, L.A.D.; Pilot, M.T.; Bowman, A.R.; Walker, A.B. Next steps in the footprint project: A feasibility study of installing solar panels on Bath Abbey. *Energy Sci. Eng.* **2022**, *10*, 892–902. [CrossRef]
28. Chen, X.; Qu, K.; Calautit, J.; Ekambaram, A.; Lu, W.; Fox, C.; Gan, G.; Riffat, S. Multi-criteria assessment approach for a residential building retrofit in Norway. *Energy Build.* **2020**, *215*, 109668. [CrossRef]
29. Johansson, P.; Wahlgren, P.; Eriksson, P. *Interior Super Insulation in Heritage Buildings. Challenges and Possibilities to Conserve Heritage Values and Increase Energy Performance*; Chalmers University of Technology Report ACE 2020:2; Chalmers University of Technology: Gothenburg, Sweden, 2020.

30. Dulnewa, J.; Elvisto, T.A.; Hahn, T.; Harten, J.; Menniks, M.; Prahm, J.; Saleh, S.; Scherz, D.; Simpson, S. *Improving the Energy Efficiency of Historic Buildings: The Four Pilot Projects of Co$_2$olBricks, Stand: October 2013 Co$_2$olBricks—Climate Change, Cultural Heritage and Energy Efficient Monuments*; Denkmalschutzamt: Hamburg, Germany, 2013; Volume 7.
31. GEO4CIHIC Consortium, Adriana Bernardi, Francesa Bampa, Historic Buildings and Buildings from the Universal Heritage, GEO4CIVHIC Most Easy, Efficient and Low Cost Geothermal Systems for Retrofitting Civil and Historical Buildings. 2018. Available online: https://geo4civhic.eu/ (accessed on 7 May 2024).
32. *4RinEU Reliable Models for Deep Renovation Guidelines and Technology Concepts for Managing Building End of Life*; European Commission: Brussels, Belgium, 2019.
33. Örn., T.; Nilsson, K. Identifying Cultural Building Values—Methododlogy review for energy efficiency alterations. Part of: Cultural Heritage Preservation. In Proceedings of the EWCHP 2013. 3rd European Workshop on Cultural Heritage Preservation, Bozen/Bolzano, Italy, 18 September 2013; pp. 219–225.
34. Widström, T. *Enhanced Energy Efficiency and Preservation of Historic Buildings Methods and Tools for Modeling*; Architecture and the Built Environment; Royal Institute of Technology (KTH): Stockholm, Sweden, 2012.
35. *Energy Efficiency and Historic Buildings Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings*; HIstoric England (Ed.) English Heritage: Swindon, UK, 2011.
36. Galatioto, A.; Ricciu, R.; Salem, T.; Kinab, E. Energy and economic analysis on retrofit actions for Italian public historic buildings. *Energy* **2019**, *176*, 58–66. [CrossRef]
37. *EUR 28055 EN*; Economidou, M.; Labanca, N.; Serrenho, T.; Bertoldi, P.; Zancanella, P.; Paci, D.; Panev, S.; Gabrielaitiene, I. Assessment of the first National Energy Efficiency Action Plans under the Energy Efficiency Directive. Publications Office of the European Union: Luxembourg, 2016. [CrossRef]
38. Sun, X.; Gou, Z.; Lau, S.S.-Y. Cost-effectiveness of active and passive design strategies for existing building retrofits in tropical climate: Case study of a zero energy building. *J. Clean. Prod.* **2018**, *183*, 35–45. [CrossRef]
39. Sesana, E.; Gagnon, A.S.; Ciantelli, C.; Cassar, J.; Hughes, J.J. Climate change impacts on cultural heritage: A literature review. *WIREs Clim. Chang.* **2021**, *12*, e710. [CrossRef]
40. Franzen, C.; Dahl, T.; Wedebrunn, O.; Bräunlich, K.; Esposito, E.; Colla, C.; Pulcini, F.; Gabrielli, E.; Khalil, M.; Helbig, O.; et al. D 2.5 Report on Methodology and Checklist | Efficient Energy for EU Cultural Heritage. 2010. Available online: http://www.3encult.eu/en/project/workpackages/builtheritageanalysis/Documents/3ENCULT_2.5.pdf (accessed on 7 May 2024).
41. *Romanian Law, No. 422/2001 on the Protection of Historical Monuments, Republished, Amended and Supplemented*; Romanian Ministry of Culture: Bucharest, Romania, 2006.
42. *Romanian Law, No. 350/2001 Regarding Territorial Development and Urban Planning*; Romanian Ministry of Culture: Bucharest, Romania, 2006.
43. *Romanian Law, No. 372/2005 Regarding Modernization and Energy Optimization Interventions for Existing Buildings*; Romanian Ministry of Culture: Bucharest, Romania, 2023.
44. *Romanian Sectorial Strategy in the Field of Culture and National Heritage for the Period 2014–2020—Analysis of Capacity and Funding Needs*; Romanian Ministry of Culture: Bucharest, Romania, 2014.
45. *Romanian Strategy for Culture and National Heritage 2016–2022*; Romanian Ministry of Culture: Bucharest, Romania, 2016.
46. *Territorial Development Strategy of Romania: Foundational Studies—Services for the Development of Studies for the Implementation of Project Activities Titled 'Development of Tools and Models for Strategic Territorial Planning to Support the Upcoming Programming Period Post-2013'*; Romanian Ministry of Culture: Bucharest, Romania, 2013.
47. The National Register of Historic Monument in Romania. Available online: https://patrimoniu.ro/en/articles/lista-monumentelor-istorice (accessed on 7 May 2024).
48. Crișan, R. *Reabilitarea Patrimoniului Construit Teorie si Practica/Heritage Rehabilitation Theory and Practice*; OZALID: Bucharest, Romania, 2023.