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Installation of Photovoltaic Panels on Historic Buildings and Heritage Areas: Lessons to Learn and Consideration for North Cyprus

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Abstract
The preservation of heritage areas and historic buildings and the adoption of new technology to reduce energy losses in these buildings are simultaneously crucial. In various cities around the world, the installation of photovoltaic panels (PV panels) on historic buildings has expanded recently. This study focuses on examining the standards and guidelines for installing PV panels on historic buildings and heritage areas to investigate the key considerations and requirements that are necessary for successfully integrating PV panels into historic buildings. Furthermore, it examines the possibility of installing PV panels on historic buildings, taking into account the specific conditions of Northern Cyprus. Then some recommendations are presented for the development of a planning guide for the installation regulations of PV panels for historical buildings in Northern Cyprus to facilitate coordinated cooperation between cultural heritage areas and PV panels, ensuring the preservation of valuable historic buildings while using sustainable energy solutions for the future.
Keywords: Heritage areas; Historic buildings; Installation; North Cyprus; PV panels.

1. Introduction

Architecture acts as a cultural representation that facilitates communication across generations by reflecting traditions, cultural and historical influences, climate, and living conditions of the country(Aziz Amen & Nia, 2018, Amen & Kuzovic, 2018, Amen & Nia, 2021, Aziz Amen, 2017). As the developing world evolves and undergoes changes, buildings are directly impacted and consequently, some historic buildings may lose their original functions over time due to changes in lifestyle, technology, regulations, economics, and environment (Ozay & Ozay, 2004; Al-Sakkaf et al., 2020).

Historic buildings often have low energy performance and high energy consumption (Lucchi, 2022), which has led to the popularity of energy retrofitting for these buildings using renewable energy sources and technologies (Tsoumanis et al., 2021). The integration of renewable energy technologies into heritage sites and buildings can have several benefits, including preserving cultural and natural values, reducing primary energy consumption, increasing comfort levels, reducing environmental impacts, and improving technical quality and economic efficiency (Broström & Svahnström, 2011; Lucchi et al., 2020; De Medici, 2021; Lopez, 2020). However, the challenge of integrating renewable energy technologies in a controlled and consistent manner requires careful consideration of compatibility criteria between new technologies and historic building identity (De Medici, 2021).

Photovoltaic (PV) and BIPV (Building Integrated Photovoltaic) technologies are improving and becoming affordable, and the trend toward the installation of PV and BIPV panels on historic buildings is expected to continue (Kimberly et al., 2013). But the integration of PV systems into buildings with cultural and heritage values requires balancing technical performance such as charge values, load values, duration of use, and weather conditions to assess the effectiveness of the technology with historic preservation concerns (Broström & Svahnström, 2011; Flores-Bernardo, 2012).

Historic areas are usually subject to strict regulations regarding any changes (Formolli et al., 2022). Therefore, it is crucial to carefully consider innovative design solutions that allow the integration of PV systems without compromising the building's historic character (Lucchi et al., 2020; Flores-Bernardo, 2012). Therefore, standards have been established to monitor the installation of PV panels on historic buildings in heritage environments which promote the adoption of renewable energy systems while protecting heritage areas (Kimberly et al., 2013). However, the integration of PV panels with heritage values should be evaluated on a case-by-case basis, as each building has its unique characteristics and require special considerations (De Medici, 2021; Polo López et al., 2021).

The aim of this study is to evaluate the installation of PV panels on historic buildings and heritage areas in Northern Cyprus. The study will examine historic buildings and heritage areas and the use of PV panels in Northern Cyprus. In addition, the study reviews some relevant standards worldwide and based on the findings, makes recommendations to improve planning and installation guidelines for PV panels on historic buildings in Northern Cyprus.

2. Literature Review

In light of the related literature review, the integration of PV systems into buildings, with a particular focus on the challenging and complex relationship between the physical design of PV systems and the cultural significance of the buildings themselves has been conducted. For example, how the need to safeguard the cultural resources of cities and nations, including the visual aspects of historic structures, can drive technological innovation and their usage (Moschella et al., 2013). Considering several factors, including the condition of the building prior to the intervention, the specifics of the PV technology employed, and the aesthetic and energy-related benefits of the intervention (Polo López et al., 2021).

Certain BIPV solutions are well-suited for addressing energy efficiency issues in historical buildings. For instance, Sudimac et al. examined the energy efficiency of the Cathedral of St. Michael the Archangel in Belgrade as a case study, with the objective of identifying the most efficient method of mounting PV panels for optimal power generation. The study conducted a comparative analysis of two options for installing PV panels on the southwestern roof of the church using PVgis and PVsist V6.84 software simulations (Sudimac et al., 2020). A study was conducted by Tsoumanis et al. to implement BIPV solutions in the Historic Centre of Évora as part of the European project POCITYF. The proposed solutions aim to adhere to preservation guidelines for the historic center while meeting the positivity metrics agreed upon with the European Commission on the path towards decarbonisation of European cities [4]. To evaluate the financial feasibility of installing a roof-mounted PV system on Bath Abbey, a Grade I listed building, the system's performance and cost were simulated. The simulation was conducted using the PVsyst software package, which takes into account inputs such as the dimensions of the Abbey, historical weather data, the orientation of the roof, module azimuthal and tilt angles, and shading caused by the spire and roof features to generate the electrical output of the panels (Smiles et al., 2022).

As the installation of PV panels is increasing on historic buildings, the "Special Award for Solar Architecture in Heritage Contexts," created as part of the Interreg project "BIPV meets history," recognizes the most significant Italian-Swiss case studies of BIPV in historical buildings and heritage landscapes. The award aims to strike a balance between cutting-edge technology and design expertise to achieve the perfect equilibrium between preserving historic buildings and high-value contexts and meeting contemporary needs and lifestyles (Durante et al., 2021).

As shown in the literature review, several studies have been conducted to investigate the installation of PV and BIPV panels on historical buildings. Table 1 shows 10 historic monuments where PV panels are installed. Some of these monuments date back to before the 12th century, such as Wing All Saints' Church and Gloucester Cathedral, and some of them are Grade I listed buildings such as Dunster Castle and St. Michael with St. Mary's Church.

Table 1. Historic monuments with PV panels.

Information	Photos	Information	Photos
Wing All Saints' Church Buckinghamshire, England 8th to 11th centuries		Gloucester Cathedral Gloucester, England 11th century	
Dunster Castle Somerset, England 12th century		St. Michael with St. Mary's Church, Melbourne, England 12th century	

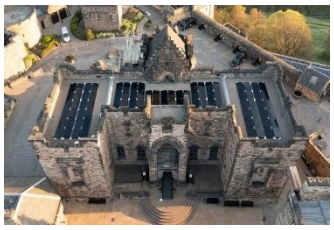
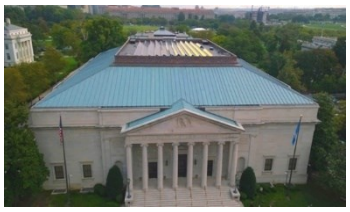
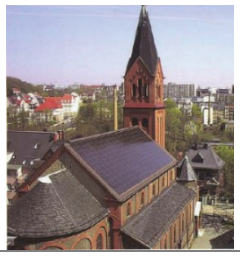
Salisbury Cathedral, Salisbury, England 13th century		Neo-Gothic church, Sarpsborg, Norway 18th century	
St. Anne's Church. London, UK 18th century		Scottish National War Memorial Edinburg, UK Early 20th century	
DAR Constitution Hall, Washington, D.C., U.S. Early 20th century		Herz-Jesu church, Plauen, Germany Early 20th century	

Table 1 shows that the trend of installing PV panels on historic buildings has affected even Grade I listed buildings and will continue more or less worldwide and affect other historic monuments, historical buildings, and heritage areas. Therefore, it is essential to ensure that the installation of PV panels on such valuable structures is done with the utmost care and compliance with established guidelines to preserve their integrity and historical values.

3. Methodology

The methodology of this study consists of three main steps: a literature review and a list of some historical buildings where PV panels have been installed, a review of related standards from different countries, and an assessment of the current situation in Northern Cyprus. Each step is explained in detail in the following.

3.1 Literature review and list of some projects

A comprehensive literature review was conducted to collect information on projects implemented in different countries where PV panels were installed on historic buildings. This review aimed to understand the benefits and limitations of integrating PV panels in historic buildings and heritage areas, particularly focusing on preserving architectural and historical significance.

3.2 Review of Related Standards

Standards and guidelines adopted by countries with successful experience in integrating PV panels into historic buildings were reviewed. This study aims to identify key principles, requirements, and considerations that ensure responsible and sustainable installation of PV panels while preserving the heritage value of historic buildings. This review covers aspects such as architectural compatibility, structural integrity, visual impact, and regulatory frameworks. The findings of this phase are used to develop recommendations tailored to the local context of Northern Cyprus.

3.3 Assessment of the current situation in Northern Cyprus

The current situation regarding the installation of PV panels on historic buildings and heritage areas in Northern Cyprus is evaluated. This involved collecting data from the Northern Cyprus Electricity Authority (KIB-TEK) and reviewing existing regulations, policies, and practices regarding the integration of PV panels into historic buildings.

The results of the literature review, review of related standards, and assessment of the current situation in Northern Cyprus formed the basis for developing recommendations for the sustainable integration of PV panels into historic buildings and heritage areas in Northern Cyprus. These recommendations aim to provide guidance for the development of regulations, guidelines, and practices that balance the benefits of solar energy with the preservation of architectural and historical significance in Northern Cyprus.

4. Standards for installing PV panels on historical buildings

Improper installation of PV panels can have a significant impact on the character-defining features of historic buildings and reduce the efficiency of PV panels. Therefore, it is essential to conduct a thorough review process to ensure the compatibility of PV panels with the architectural and cultural values of the historical building and to maintain the efficiency of the panels (Kuntz, 2008; Kandt, et al., 2011). However, not all changes to a historic building necessarily detract from its values. PV panels can be installed without adversely affecting the importance or integrity of the building (Changeworks, R. H 2009).

The standards for installing PV panels on historic buildings provide a systematic approach to guide decision-making in the unique context of each building. The aim is to preserve the importance of heritage areas and historical monuments while maximizing energy performance.

The standards mentioned in Table 2 were reviewed in this study. As the requirements for historic preservation depend on factors such as location, grade, and the building's importance, and the generation of energy and maximizing the efficiency of PV panels is influenced by geographical conditions and location, several standards have been developed for the installation of PV panels in heritage areas. Therefore, some countries like the USA and UK have established several standards to cover the installation of PV panels in different heritage areas.

Table 2. Regulations for installing PV panels on heritage buildings.

Country	Region	Name	Year
International	-	International Council on Monuments and Sites (ICOMOS)	2017
European Union	-	Guidelines on building integration of photovoltaic in the Mediterranean area	2018
		EN 16883 (Conservation of cultural heritage - Guidelines for improving the energy performance of historic buildings)	2017
USA	California	California Solar Rights Act	2021
	California (Pomona)	Guide to installing solar panels on historic buildings	2020
	North Carolina	Designation of historic districts	2013
	South Carolina (Columbia)	Solar panels and historic buildings	2016
	Washington (Olympia)	Solar Installations on Historic Properties	2022
	Guilford	Guidelines on Solar Systems in Guilford's Historic Districts	2020
	Ohio (Oberlin)	Historic Preservation Guidelines for Solar Energy Systems	2019
Scotland	Edinburg	Renewable Heritage (A Guide to Microgeneration in Traditional and Historic Homes)	2017
UK	England	Campaign to Protect Rural England	2019
	Britain	Small-scale solar electric (photovoltaics) energy and traditional buildings	2008
	Britain	BS 7913 (Guide to the Conservation of historic buildings)	2013
	Suffolk	Solar photovoltaics (PV), planning and building regulations in conservation areas or on listed buildings	
Canada	Canada	Guidelines for the Installation of Photovoltaic Technology on Heritage-Designated Properties	2018
Australia	Tasmania	Heritage and solar technology gridlines	
	Sydney	Development Application exception for solar panels in heritage conservation areas Guideline	2021

The review of these standards reveals that regulations for historic monuments become more stringent and specific as the importance of the historic monument increases to protect the historic values and particular attention is paid to listed buildings in each country. Furthermore, precise regulations are implemented to prevent glare, obstruction of views, and other negative impacts on the heritage area.

In general, based on the extensive review of the standards presented in Table 2, the items that should be considered and investigated in the installation of PV panels on historical buildings can be categorized as follows:

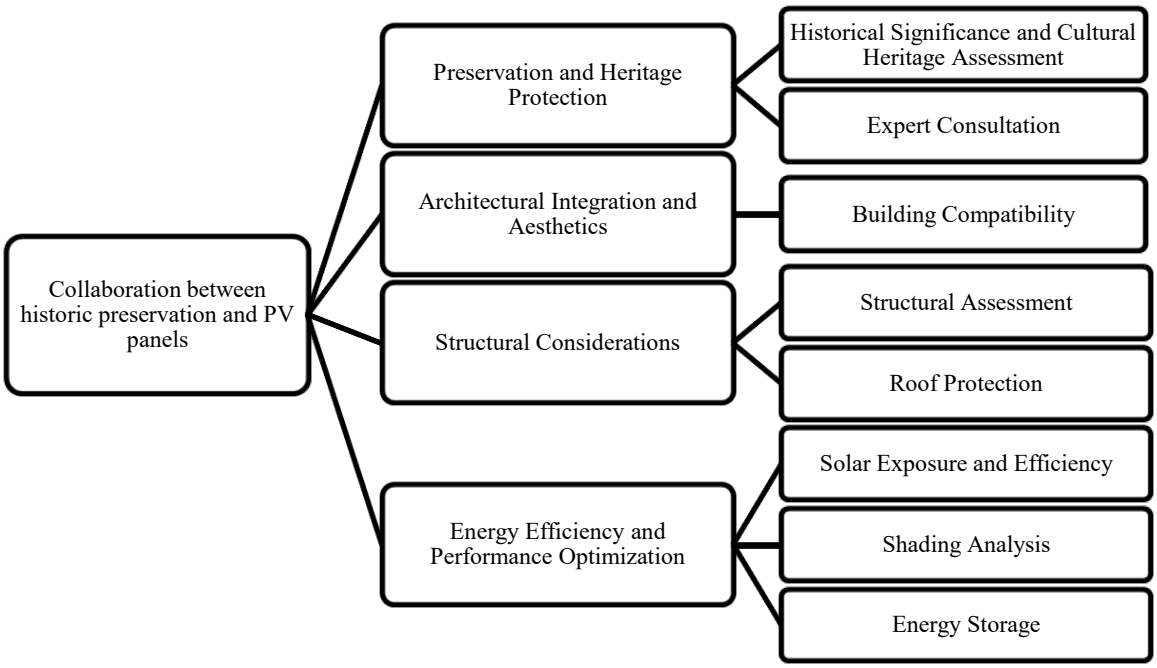


Figure 1. Collaboration between historic preservation and PV panels (Authors).

Preservation and Heritage Protection:

- Historical Significance and Cultural Heritage Assessment: Evaluate the historical value and cultural significance of the building and its surroundings.
- Expert Consultation: Seek input from historians, architects, and preservation specialists to ensure the proposed installation aligns with preservation goals.

Architectural Integration and Aesthetics:

- Building Compatibility: Ensure the PV panel installation harmonizes with the architectural style and character of the historic building in panel placement, orientation, and color to minimize visual impact and maintain architectural integrity. Explore the use of building-integrated photovoltaics (BIPV) to integrate panels seamlessly into the building's design.

Structural Considerations:

- Structural Assessment: Conduct a thorough evaluation of the building's structural capacity to support the additional weight of the panels and determine any necessary reinforcements.
- Roof Protection: Develop strategies to protect the roof during and after the installation process.

Energy Efficiency and Performance Optimization:

- Solar Exposure and Efficiency: Optimize panel placement and orientation to maximize solar exposure and energy production.
- Shading Analysis: Conduct shading analysis to identify potential obstructions and minimize energy loss.
- Energy Storage: Consider incorporating energy storage systems to optimize the use of generated electricity.

4.1 Cyprus condition

Cyprus is an island country in the eastern Mediterranean, with a rich and complex history dating back thousands of years. This island has been inhabited since prehistoric times and evidence of human habitation dates back to the Neolithic period. Over the centuries, Cyprus was ruled by various powers, including the Byzantines, the Lusinians, the Venetians, the Ottomans, and the British (Mallinson, 2011).

During the 20th century, Cyprus became a battleground for various political and ethnic groups. In 1960, the island gained independence from British colonial rule, but tensions between Greek Cypriots and Turkish Cypriots soon turned violent. In 1974, tensions rose, and fighting broke out, and as a result, the island was divided into two countries: The Republic of Cyprus in the south and the Turkish Republic of Northern Cyprus in the north (Mallinson, 2011).

As mentioned earlier, Cyprus has successfully blended different cultures and reflected them in its architecture. Over time, its architectural heritage has developed gradually, resulting in many monuments from different periods that

have been restored and adapted for various uses (Lucchi, 2022). This island has large reservoirs of natural stones, and as a result, natural stones have been the primary building material in the region since ancient times, resulting in a number of well-preserved stone masonry structures that remain in use today. However, it is worth noting that these structures are exposed to irreversible structural damage and loss due to geological changes, climate changes, pollution, increasing urbanization, and human neglect (Christou & Elliotis, 2016).

On the other hand, Cyprus experiences around 300 days of sunshine each year, receiving a total of 2600 to 3500 hours of sunlight annually. The average daily global horizontal irradiation in the country ranges from 4.80 to 5.44 kWh/m^2, making it a prime location for utilizing solar energy due to its exceptional weather conditions and distinctive geographical location (Ravari et al., 2023).

KIB-TEK reports that from 2014 to 2020, there has been a significant increase of 855% in the installation of PV panels in Northern Cyprus, and there is an increasing trend towards their installation on a daily basis (Resatoglu et al., 2022).

As discussed earlier, it has been identified that there is currently a lack of established guidelines and regulations in North Cyprus regarding the installation of PV panels on historical structures. As a result, PV panels have been installed on some historical structures in a manner that has caused detrimental effects on the integrity of the structures.

For instance, after dividing Cyprus, many churches in the north were abandoned and destroyed. But, some of these abandoned churches were later converted into mosques by the Turkish Cypriot authorities. These cases are the result of historical and political events that happened on the island. Figure 2 shows a historical monument that belongs to the religious heritage which is known as Yeşilyurt Fatih Cami (mosque). This mosque is located in the western part of Northern Cyprus, on the Lefke highway in Place Yeşilyurt (Pendaya)Village, the building was built as a church in 1961 and started to be used as a mosque in 1977 (Camilerimiz, 2023)

PV panels have recently been installed on the building to generate electricity, but their modern appearance does not blend well with the historic aesthetic of the building. Installation of PV panels not only negatively affects the appearance of the building, but due to shading issues, they do not have the necessary efficiency.

Figure 2. installation PV panels on a historic building in Northern Cyprus.

In other cases, PV panels have been installed on some other historical buildings that belong to industrial heritage and residential heritage, which are shown in Figures 3 and 4, respectively.

Figure 3. Installation of PV panels on a historic building in Northern Cyprus.

Figure 4. Installation of PV panels on a historic building in Northern Cyprus.

5. Discussion

It is anticipated that the trend of installing PV panels on historic structures may continue to grow over time. It is imperative for the country to prioritize the preservation of its historical monuments and take appropriate measures to ensure the proper installation of PV panels on such structures in the future. In order to address this issue and ensure the preservation of historical monuments, it is necessary to develop comprehensive guidelines and regulations for installing PV panels on historical structures.

After conducting a comprehensive review of the mentioned standards, several key points were extracted that appear to be beneficial in enhancing the installation process of PV panels on historic buildings and heritage areas in North Cyprus. The tips are mentioned below:

1. Thoroughly explore all installation options for PV panels and consider the possibility of installing panels in alternate locations and linking them to the property from there.
2. Consider positioning PV panels behind existing architectural features like parapets and chimneys to minimize their visibility.
3. Aim to make mechanical equipment associated with the photovoltaic system as unobtrusive as possible.
4. Choose PV panels and mounting systems that are color-compatible with the existing roof materials.
5. The visual impact of PV tiles can vary depending on the percentage of roof coverage, with 100% coverage resulting in a more uniform appearance that may be desirable in certain situations.
6. Ensure that the installation of panels is reversible and does not damage the historic integrity of the resource and district
7. Any removal of existing roof material during installation will be replaced with a matching material to maintain the original appearance of the building without any changes.

8. The proposed change will not have a negative impact on any significant historical, cultural, architectural, or aesthetic features of the property or the historic district in which it is situated.
9. The proposed change is in line with the architectural style of existing adjacent contributing structures in the historic district, ensuring compatibility.
10. The scale, massing, proportions, materials, textures, fenestration, decorative features, and details of the proposed change are in accordance with the period and/or compatible with adjacent structures in terms of architectural style and design.
11. Ensure that proper safety measures are in place for the installation of panels and provide adequate access for maintenance purposes.
12. Install the panels in a manner that maximizes their efficiency based on the existing conditions and factors such as orientation, tilt, shading, and other relevant considerations.
13. Choose the optimal energy retrofit option by considering factors such as budget, local situation, building condition, available space, and the presence of similar installations nearby.
14. Approvals are required in each region based on local regulations, and the guidelines should include information on obtaining necessary approvals in compliance with local requirements.

As highlighted in the key highlights, the relevant guidelines must encompass multiple facets, such as ensuring the structural integrity of the historical buildings and considering the overall impact on cultural heritage. Furthermore, they should provide clear instructions on the appropriate placement, angle, and orientation of PV panels to maximize their efficiency while mitigating any potential damage to the historical structures. Additionally, the guidelines should outline the procedures for obtaining necessary permits and approvals, as well as establishing regular monitoring and inspection protocols for the installed panels.

6. Conclusions

In conclusion, the installation of PV panels on historic buildings and heritage areas presents significant opportunities for promoting sustainability and reducing energy consumption. However, it is essential to carefully plan and execute the installation process to ensure the preservation of the historic value of these buildings and ensure effective and safe implementation. The findings of this study will provide valuable insights into the standards and best practices for PV panel installation on historic buildings and heritage areas, and the recommendations will be instrumental in enhancing the planning guide for PV panel installation regulations for historic buildings in North Cyprus.

When considering the installation of PV panels on a historic building, it is crucial to take multiple factors into account to safeguard the building's structural integrity and historical significance. By adhering to established guidelines and best practices, PV panel installations on historic buildings can be carried out in a manner that balances sustainability goals with heritage preservation.

Developing comprehensive guidelines for the installation of PV panels on historical structures is vital, as it not only minimizes potential adverse effects but also promotes sustainable energy practices. Such guidelines will allow the country to leverage the benefits of renewable energy while ensuring the preservation of its valuable cultural heritage for generations to come. By implementing these guidelines, a balance can be struck between sustainable energy generation and heritage conservation, creating a win-win situation for both the environment and cultural preservation efforts.

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Conflict of Interests

The authors declare no conflict of interest.

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