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CASE STUDY RESEARCH PAPER

Identifying and prioritizing energy efficiency improvement measures in historical monuments based on the impact on heritage values (Case Study: Asef Mansion, Sanandaj)

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ABSTRACT

Optimizing energy consumption in historic buildings is a complex task due to their unique physical characteristics and the necessity of preserving heritage values. In Iran, insufficient specialized knowledge and weak regulatory frameworks have sometimes resulted in interventions that harm the building fabric or heritage significance. This study aims to identify energy-efficiency measures applicable to historic buildings and to prioritize them based on their impact on the heritage values of the Asef Vaziri Mansion. Initially, through theoretical research and a qualitative descriptive analytical approach, a three level framework consisting of main strategies, systems, and 30 commonly applied measures in Iran was developed. Using the EFFESUS assessment framework and the Delphi technique to gather the opinions of 15 experts, the impacts of these measures on the mansion's heritage values were evaluated according to three criteria: physical, visual, and spatial. Data were analyzed using SPSS (version 27). The results indicate that user-behavior-related measures, due to having no negative impact (0.0% of the maximum possible negative impact), received the highest priority. Optimization of the domestic hot-water system (30.8%) ranked second. Conversely, the installation of shading devices, with a 74.1% impact, exhibited the greatest negative effect and therefore attained the lowest priority. Overall, the findings show that less visually intrusive measures cause less harm to heritage; however, the specific characteristics of each historic building may lead to different prioritization outcomes. Consequently, energy oriented interventions must be selected and prioritized according to the building's heritage values and the extent of their impact.

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INTRODUCTION

Historic buildings are resources with cultural, architectural, and identity values that must be carefully preserved, utilized, and managed to remain sustainable over the long term (Buda et al., 2021, p. 1). The continuous use of these buildings, alongside energy efficiency, is essential for their sustainability. This is not only important for the preservation of the buildings themselves but also for the reuse of embodied energy in their materials and structures, which is a key factor in sustainability (Alasmar et al., 2024, p. 6086). However, the use of non-durable materials and structures during construction, coupled with inadequate maintenance over time, has led these buildings not only to experience poor thermal comfort and high energy consumption but also to emit significant amounts of carbon dioxide (CO₂) (Jamal et al., 2024, p. 43). On the other hand, improving energy efficiency in historic buildings is a complex and challenging task (Felius et al., 2023, p. 1) because these buildings differ from modern buildings in two main aspects:

Physical characteristics:

- These buildings may have complex and irregular geometries; envelope structures without insulation or vapor barriers; traditional construction methods and non-standard natural materials that create heterogeneity in the structure; and non-mechanical internal climate management strategies such as thermal mass, humidity buffering, and natural ventilation through wall or window openings.

The necessity of heritage conservation:

The retrofitting of historic buildings is influenced by established conservation principles and practices and requires the protection of the historical fabric and distinctive heritage features of the building (Webb, 2017, p. 749)

These factors often result in energy efficiency improvement strategies conflicting with building maintenance processes, potentially causing damage to historic buildings (Hegazi et al., 2021, p. 2). Consequently, energy perfor-

mance in heritage buildings has become a focal point for researchers and specialists, with the number of studies related to energy efficiency improvement in these buildings increasing steadily (Lidelöw et al., 2019, p. 231).

However, in the limited domestic studies, most research has focused on introducing uncommon measures derived from foreign sources, without considering the impact of these measures on the heritage values of buildings. Moreover, Chapter 19 of the National Building Regulations, as the most important legislation governing energy optimization in buildings, applies only to newly constructed buildings, and historic buildings are exempt. This knowledge gap and the lack of applicable regulations in Iran have led to interventions aimed at compensating for environmental comfort deficiencies, which often cause damage to the building fabric and heritage values. Therefore, what is needed today is a comprehensive approach that can provide the most effective and practical energy efficiency improvement measures for historic buildings in Iran, in a way that preserves their heritage values and prevents personal preferences from guiding energy related interventions. In line with this goal, the following research questions are posed: 1. Which common and practical measures in historic buildings, structured within a systematic framework, lead to improved energy efficiency? 2. How can these measures be prioritized based on their impact on the heritage values of Asef Vaziri Mansion in Sanandaj? Accordingly, the aim of this study is to identify and organize energy efficiency improvement measures in historic buildings within a structured framework and to prioritize them based on their impact on the heritage values of Asef Vaziri Mansion in Sanandaj.

MATERIALS AND METHODS

Approaches to Improving Energy Efficiency in Historic Buildings

Energy efficiency, or energy productivity, refers to the ratio of output, whether performance, services, goods, or energy to energy input. In the context of efficient energy use or energy optimization, energy is consumed in a manner that maximizes benefits (European Parliament, 2015, p. 2; Nair et al., 2022, pp. 3–20). A building is considered energy-efficient if it provides more services for the same energy input or delivers the same services with lower energy consumption (IEA, 2015). Improving energy efficiency in historic buildings has always been challenging due to their physical characteristics and the need to preserve their heritage values (Pianezze, 2012, p. 99). Most historic buildings were constructed without adherence to specific standards. Therefore, retrofitting approaches differ from one building to another (Sodangi & Salman, 2024, p. 11). Additionally, there are concerns regarding improper energy retrofit measures, which may lead to mold formation, structural damage, aesthetic degradation, or potential harm to the building interior and artworks (Nair et al., 2022, p. 13). As historic buildings are considered part of the existing building stock, they share similar approaches to energy efficiency improvement as other existing buildings. However, the implementation of these measures is challenging due to existing conditions and conservation requirements (Pavlović et al., 2022, p. 824), and it is necessary to carefully consider specific characteristics of these buildings, such as cultural heritage values and the performance of traditional construction systems, during subsequent stages (Flores, 2013, p. 67). Energy efficiency improvement measures in existing buildings can be classified according to various approaches, such as the number of systems selected for improvement, the amount of energy saved, the type of building system, cost per square meter, methods used for energy saving, and payback time (Chunduri, 2014, p. 12). Classification based on application is the most common type of categorization in studies related to building energy assessment, and it

is therefore employed in the present research. Although researchers have proposed different classifications in this field, certain overlaps and commonalities can still be identified despite differences in terminology (Fasna & Gunatilake, 2019, p. 312). For example, energy efficiency improvement measures related to the building envelope are classified in some studies as “passive strategies” (Fernandes et al., 2021, p. 8), while in most studies they are simply categorized under “building envelope” (Ahmed et al., 2025, p. 7; Xiaoting Chen et al., 2024, p. 7; Hong et al., 2019, p. 11). In other classifications, these measures are placed under the “structure” category (Carapeto et al., 2016, p. 4). Similarly, active strategies, which relate to building energy equipment (Austin et al., 2022, p. 5), are sometimes considered under the framework of building systems or equipment (Chung-Camargo et al., 2024, pp. 10–14; Xu et al., 2010, p. 443). With the introduction of renewable energy production as an effective strategy for improving energy efficiency in existing buildings, the framework for energy efficiency improvement has expanded. Researchers have categorized three groups building envelope, building systems, and renewable energy technologies as the main strategies for energy efficiency improvement (Aranda et al., 2017, p. 4.;, 2020, p. 13; Madushika et al., 2023). Nevertheless, in some studies, each of these strategies may be treated as a subgroup of other strategies. For instance, Mejjouli (2022), proposing a different classification, created two main strategies: energy production measures and “energy consumption reduction measures, placing building envelope and building systems under the consumption reduction subgroup and renewable energy technologies under the energy production subgroup (Mejjouli, 2022, p. 2) Tab1. Presents a summary of the classifications identified in recent studies on energy efficiency improvement strategies in existing buildings.

Table 1: Comparison of the framework of energy-efficiency improvement strategies in existing buildings. (Source: Authors)

Reference	Majavali, 2022	Sadini et al., 2011	Gu, 2019	Madoshika et al., 2023	Zhou et al., 2010	Al-Khatib & Abuhejleh, 2019	Austin et al., 2022	Ahmed et al., 2025	Hong et al., 2019
framework	Energy Consumption Reduction	Passive Strategies	Passive Strategies	Passive Strategies	Building Envelope	Passive Strategies	Passive Strategies	Building Envelope	Building Envelope
		Active Strategies	Active Strategies	Building Systems	Building Systems	Active Strategies	Active Strategies	Lighting - Heating, Ventilation, and Air Conditioning (HVAC) - Water Heating	Systems and Equipment
	Energy Production	-		Energy Generation Systems	-	-	Renewable Energy	On-Site Energy Generation	Renewable Energy
	-	-		-	Improvement of Energy Management Systems	-	-	Building Smart Control and Management Systems	Energy Management and Control Systems
	-	-		-	-	User Behavior	User Behavior	-	User Behavior

Energy Efficiency Improvement Measures in Historical Buildings

In ASHRAE Guideline 34, recommendations for energy efficiency improvement measures are categorized into four main groups: building envelope, energy and environmental control systems, heating, ventilation, and air-conditioning HVAC systems, and lighting. Measures related to the building envelope include internal and external insulation of walls, roofs, and floors, cavity and joint insulation, thermal bridge mitigation, sealing, moisture and water control at

foundations, roofs, and walls, door and window sealing and improvement, as well as the use of blinds and adhesive films on glazing. Recommendations in the energy and environmental control systems category include the installation or upgrading of energy management and control systems and the selection of efficient energy sources compatible with renewable energy integration. For HVAC systems, measures include the use of variable refrigerant flow (VRF) systems, upgrading existing systems, and seasonal adjustment of heating and cooling temperatures. Finally, lighting recommendations include the

use of energy efficient lamps, dimming systems, and occupancy sensors (ASHRAE Guideline 34, 2019). Notably, the guideline largely overlooks hot water heating systems and user behavior strategies. Posani et al. (2018), in a review focusing primarily on the building envelope, organized energy efficiency improvement interventions including walls, roofs, floors, windows, sealing, thermal bridges, and shading devices based on their frequency of use in the literature. They found that among wall interventions, expanded polystyrene (EPS) insulation, thermal plaster, and mineral wool were most common for both internal and external insulation. For floors, the addition or replacement of cellulose, hemp, or wood fiber insulation was most frequent. Roof interventions most commonly involved mineral wool or cellulose insulation, and window interventions mainly involved the replacement with double- or triple-glazed units and sealing. Complementary measures, such as sealing, thermal bridge mitigation, and shading devices, were less frequent (Posani et al., 2018: 3–7). Nair et al. (2022) conducted a comprehensive review, classifying energy efficiency measures into seven groups: sealing, windows, insulation, ventilation, heating, photovoltaic panels, and phase change materials. They examined technical challenges and the potential applicability of measures in each group. The study highlighted the lack of general measures and emphasized more specialized interventions suitable for addressing technical, conservation, and cost-related challenges (Nair et al., 2022: 3–20). In most studies related to energy efficiency optimization, user behavior-based measures have either been overlooked or limited to system interaction and information provision, without addressing physical interventions. Therefore, the following review focuses specifically on user behavior and related measures. While many earlier studies mainly addressed window, shading, and blind control (Fabi et al., 2012: 192–193), more recent research has examined behavioral habits that influence the

effective (or inefficient) use of comfort-control devices. These include thermostat adjustments, switching lights on and off, clothing choices, movement between spaces, and even drinking fluids or metabolic variations (Feng et al., 2024: 2; Harputlugil & de Wilde, 2025: 2; T. Hong et al., 2016: 695; Yan et al., 2023: 2).

Assessment of the Impact of Interventions on the Heritage Values of Historical Buildings

Impact assessment (IA) is defined by the International Association for Impact Assessment (IAIA) as a process for identifying the future consequences of a current or proposed action (IAIA, 2009). Among various types of impact assessments, Environmental Impact Assessment (EIA) is recognized as a comprehensive tool and forms the foundation for other impact assessment instruments (Morgan, 2012: 6). Within EIA frameworks, cultural heritage is identified as a sensitive component, and its assessment has consistently been recognized as a challenging task (ICOMOS, 2011). Sagnia emphasizes the need to evaluate “cultural aspects of the environment and to perform a balance of-impacts analysis” in environmental impact assessments, noting that cultural impact assessment has not been fully integrated into planning, policy making, decision-making processes, and project cycles” (Sagnia, 2004: 38). In response, ICOMOS developed the Heritage Impact Assessment (HIA) guidelines in 2011 within the EIA framework (ICOMOS, 2011: 1). These guidelines classify impacts into positive and negative categories and evaluate them on five scales: major, moderate, minor, negligible, and neutral (ICOMOS, 2011: 9). Another HIA framework, developed collaboratively by ICCROM, WHITRAP-Shanghai, the Asian Academy for Heritage Management (AAHM), and the University of Hong Kong, has been widely adopted across Asia. Experts and stakeholders, including ICOMOS and UNESCO, have contributed to its development (Khaskheli et al., 2023: 38). This framework outlines seven sequential steps: Preliminary review, scoping,

and task assignment. Establishing baseline conditions. Heritage impact assessment significance evaluation. Threat and risk analysis. Impact assessment. Monitoring and mitigation. Reporting and archiving (WHITRAP & ICCROM, 2012). Tools for assessing impacts on heritage properties include checklists, matrices, flowcharts, networks, maps, Geographic Information Systems (GIS), quantitative statistical methods, and professional judgment. It is not necessary to rely on a single assessment method; a combination of approaches can be used. For example, a simple checklist may identify key impacts, which can then be further analyzed through matrices for predicting secondary and cumulative effects using qualitative and quantitative approaches. Collected data can subsequently be mapped to illustrate the characteristics and impacts on heritage properties. Finally, GIS or matrix analysis can be employed to quantify the significance of the assessed impacts (Ashrafi et al., 2021: 12).

Methodology

The present study is descriptive-analytical in terms of methodology and applied in terms of purpose. Data collection methods included both library-based and field studies, and the primary data collection tool was a questionnaire. The development of the framework for energy efficiency improvement measures was carried out through a review of library-based studies using a descriptive qualitative analysis approach. Subsequently, to evaluate the impact of these measures on the heritage values of Asef Vaziri Mansion, the assessment framework provided by the European EFFESUS project (2014) was employed. Furthermore, the Delphi technique was used to gather expert opinions regarding the impact of each intervention. The survey data were analyzed using descriptive statistics, including mean, standard deviation, and inter-quartile range IQR, within SPSS software (version 27).

Case Study Evaluation

Asef Mansion, also known as Asef Divan, Asef

Vaziri, or the House of Kurd, is one of the prominent historical buildings remaining from the Qajar era in Sanandaj. The original structure of the complex was established during the Safavid period, and additional sections were added during the early Pahlavi era. The last restoration and conservation works were carried out in 2003 (1382 SH). This monumental building has been registered as a national heritage site under the number 1822 and currently functions as the Kurdistan Anthropology Museum under the ownership of the General Directorate of Cultural Heritage. The complex comprises four distinct courtyards: the main outer courtyard, the kitchen courtyard, the inner courtyard, and the servants' courtyard. In the northern part of the main outer courtyard, the primary hall of the building is located, featuring a wooden columned porch and muqarnas-decorated capitals dating back to the Safavid period. On both sides of the main hall, corridors with triple interconnected doors across two floors have been designed. Interior ceilings are constructed with timber beams in the traditional Sanandaji framework style. The selection of this mansion as the case study for the present research is based on its high heritage value, continuous utilization, and the existing challenges related to energy efficiency and environmental comfort within the building. (Fig.1)

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By reviewing the literature on energy efficiency improvement approaches in existing buildings, a preliminary framework for enhancing energy performance in historic buildings can be proposed based on the main strategic approaches. Through a systematic analysis of previous studies and with the aim of covering all possible levels of energy interventions from passive, low-cost measures to active systems and energy generation the primary energy efficiency strategies are classified into six main categories: passive strategies, active strategies, on-site renew-

able energy generation, energy management and control systems, and user behavior. In Iran, building energy management systems (BMS) have been scarcely implemented due to high installation costs, lack of technical knowledge, outdated infrastructure, and weak enforcement of incentive policies. Therefore, considering the research objective of providing practical measures for improving energy performance in historic Iranian buildings, BMS is not included in the proposed framework. Within the domain of energy efficiency improvement in historic buildings, each primary strategy is further divided into subgroups, or systems, to enable independent implementation of interventions (Flores, 2013: 72) and to provide a foundation for subsequent analysis and evaluation. In the passive strategy category, the systems include exterior walls, roofs, floors, doors, and windows (EFFESUS, 2014: 17–43; Eriksson, 2021: 60; Herrera-Avellanosa et al., 2024: 1001–1004; Pavlović et al., 2022: 827). Active strategies are subdivided into cooling, heating, and HVAC systems, domestic hot water systems, and lighting systems (Etxepare et al., 2020: 6–7; Posani et al., 2018: 3–7). Renewable energy production systems include photovoltaic panels, solar thermal collectors, wind turbines, biomass reactors, and geothermal heat pumps (Etxepare et al., 2020: 6–7; Johansson et al., 2021: 6). Considering

that solar energy offers the highest priority, advantages, and applicability for urban areas and buildings in Iran (Qaemi & Heravi, 2012: 1969), and among solar energy utilization methods, photovoltaic panels are the most accessible and widely available option in the Iranian construction market (Talebi et al., 2023: 3), only photovoltaic panels are included in the renewable energy subgroup. One notable gap in previous studies is the lack of detailed subgroups within the user behavior category that could encompass implementable actions. Therefore, in the current framework, the user behavior strategy is divided into systems related to user behaviors regarding heating cooling, windows, lighting systems, and behavioral adaptations such as clothing choices (Fabi et al., 2012: 190; Maghsoudi Nia et al., 2022: 8).

Thus, by identifying the main strategies and the corresponding sub-systems for each, a framework for improving energy efficiency in historical buildings was developed. This framework, after being aligned with the measures extracted from the literature, served as the basis for the preparation of a table that, while confirming the proposed framework, presents a set of effective and feasible actions for enhancing energy efficiency in historical buildings (Tab.2).

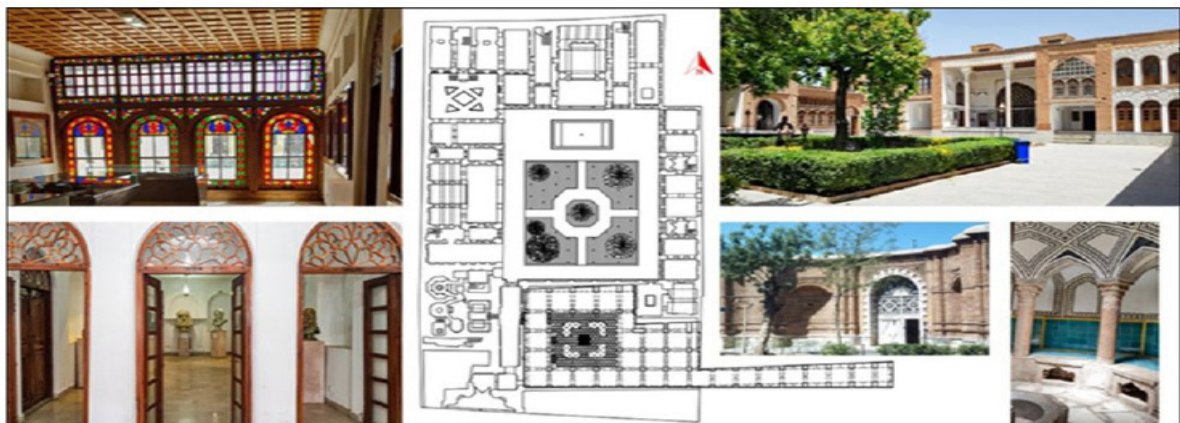


Figure1: Asef Mansion, Sanandaj. (Source: Photographs by the authors; plan from the Kurdistan Provincial Cultural Heritage Archive, 2025)

Table 2: Framework of Energy Efficiency Improvement Measures in Historical Buildings.

Framework		Actions	Resources
Strategies	Systems		
	Walls	Internal insulation	(3ENCULT, 2014: 9)
		External insulation	(Şahin et al., 2015: 135)
	Roof	Internal insulation	(Historic England, 2024: 22)
		External insulation	(STBA, 2025)
	Floor	Insulation	(Felius et al., 2023: 4)
		Floor replacement	(Herrera-Avellanosa et al., 2024: 1002)
	windows	Installing efficient doors	(ASHRAEGuideline34, 2019: 21)
		Door renovation	
		Sealing around doors	(Nair et al., 2022: 3)
	windows	Installing low-emissivity (Low-E) glass	(Posani et al., 2018: 7)
		Using light-filtering adhesive film	(IEA & EBC, 2021: 16)
		Installing new double or triple glazed windows	(Eriksson, 2021: 60)
		Window renovation	
		Installation of awnings, shutters and external	(Turgut, 2020: 8)
	Caulking around windows	(Nair et al., 2022: 3)	
Active strategies	Cooling, heating and air conditioning systems	Installation of efficient systems	(ASHRAEGuideline34, 2019: 22-23) (3ENCULT, 2014: 16) (Kumtepe & Ayçam, 2025: 29)
		Optimization of existing systems	
	Water heating system	Installation of energy-efficient lighting system	(STBA, 2025)
		Optimization of existing systems	(Kumtepe & Ayçam, 2025: 33)
	Lighting systems	Installation of energy-efficient lighting system	(Thravalou et al., 2023: 6)
		Optimization of existing lighting system	(STBA, 2025)
Use of light sensors		(EFFESUS, 2014: 11)	
Energy production	Photovoltaic panels	Installation of photovoltaic panels	(Johansson et al., 2021: 6)

User behavior	Heating and cooling systems	Reducing thermostat temperature in cold seasons	(Moon & Han, 2011: 345)·(Galatioto et al., 2017: 12)
		Increasing thermostat temperature in hot seasons	
	Windows	Closing windows when the heating and cooling system is operating	(Vasseur & Marique, 2019: 6)·(Pan et al., 2017: 2235)
		Opening windows and turning off the air conditioning system when the outside temperature is within the comfort range	(Heebøll et al., 2018: 626)
	Lighting	Turning off the lights when you are not present.	(Lundberg et al., 2019: 7)
	Cover	Wearing cooler clothes in hot seasons	(Galassi & Madlener, 2018: 525)
Wearing warmer clothes in cold seasons		(Bonte et al., 2014: 19)	

Table 3: Definitions of Criteria Used for Assessing the Impact of Interventions on Heritage (Source: EFFESUS, 2014: 140)

Impact Criteria	Description	Key Question
Physical	Material type and physical characteristics of the building or its fabric	Is carrying out the intervention acceptable if it maintains only the visual similarity with the original, but uses different materials or fabric?
Visual	Appearance, aesthetics, and proportionality of the building	Is carrying out the intervention visually acceptable without considering the original materials?
Spatial	Layout, spatial organization, and the experiential quality created by different parts of the building	Is carrying out the intervention acceptable in terms of alterations to spatial layout and experiential quality?

Table 4: Scoring Scale for Assessing the Impact on Heritage (Source: EFFESUS, 2014: 140)

Level of Impact	Scale
No negative impact	0
Minor negative impact	1
Moderate negative impact	2
High negative impact	3
Severe negative impact	4

Prioritization of Measures Based on Their Impact on the Heritage Values of Asef Mansion
 As mentioned in the research methodology, the assessment of interventions' impact on the heritage values of Asef Mansion was conducted based on the evaluation framework provided

by the EFFESUS project. Within this framework, through expert surveys, the extent of the interventions' impact on heritage values is determined according to three criteria: physical, visual, and spatial. A five-point scale is used, where a higher score indicates a greater negative impact on the heritage values of the building. Definitions related to the evaluation criteria and scoring scale are presented in (Tab.3) and (Tab.4).

Considering the methodological framework of the EFFESUS project and the judgment-based nature of assessing the impact of energy-related interventions on heritage values (Ashrafi et al., 2021: 11), the Delphi technique was employed in this study to collect expert opinions. This technique is a structured method for achieving consensus among experts on complex issues

and is based on a systematic analysis of viewpoints (Phichetkunbodee, 2023: 410), and it is regarded as a reliable approach for evaluating the effects of interventions on historical heritage. Accordingly, data collection at this stage was conducted using the Delphi method.

Delphi Method

To determine the impact of interventions on the heritage values of the Asef Mansion, it was first necessary to assign weights to the evaluation criteria (physical, visual, and spatial). For this purpose, a Delphi survey was conducted with the participation of 15 conservation and architectural heritage experts. In this survey, experts were asked to rate the importance of each criterion on a scale of 1 to 9 (Tab 5). Among the 15 participants, 11 held doctoral degrees in architecture (3 in conservation, 8 in architecture), and 4 held master's degrees in architecture (1 in conservation, 3 in architecture). In this study, the criteria for achieving expert consensus were defined based on an interquartile range (IQR) ≤ 1 and a standard deviation (SD) < 1 (Geist, 2010: 150). Furthermore, Kendall's coefficient of concordance was used to test the level of agreement and stability of the criteria, with a threshold value greater than 0.5 (Hajizadeh et al., 1403: 318). Once the conditions for expert consensus were met, the mean scores assigned to each criterion were calculated. The final weight of each criterion was obtained by dividing the mean score of that criterion by the sum of all mean scores. Accordingly, the weighting coefficients for the physical, visual, and spatial criteria were derived such that their total equals one, representing the relative contribution of each criterion in assessing the impact of energy efficiency interventions on heritage.

In the next step, after presenting comprehensive studies on the architecture and heritage values of Asef Mansion using plans, photographs, and written information, 23 energy efficiency interventions were evaluated by the experts across the three criteria (physical, visual, and

spatial), comprising a total of 69 variables. It should be noted that seven interventions related to user behavior were excluded from the survey due to their lack of impact on heritage. After completing the questionnaires and achieving expert consensus, the final score for each intervention was calculated using a weighted mean approach, in which the mean score of each criterion was multiplied by its corresponding weight, and the sum of these three values formed the final score of the intervention.(Tab. 5)

Table 5: Scoring Scale for Determining the Weight of Criteria
(Source: [Guyen et al., 2022, p. 294](#))

Importance Level	Scale
Least Important	0
Medium Important	2-3
Highly Important	4-5
Very Important	7-6
Extremely Important	9-8

Determination of Weights for Evaluation Criteria

The findings of the first round of the Delphi survey for determining the weights of the criteria indicate that, although Kendall's coefficient was 0.75 typically representing a strong level of agreement two of the three evaluated criteria, namely the visual and spatial criteria, did not meet the consensus requirements due to a standard deviation ≥ 1 and an interquartile range > 1 . Since the Delphi process requires the use of identical questionnaires in at least two rounds to achieve expert consensus (Wang et al., 2024: 5), a second round of the Delphi survey was conducted. In the second round, Kendall's coefficient improved to 0.81; however, the physical criterion, with a standard deviation of 1.73 and an interquartile range of 3, still failed to reach consensus. Finally, in the third round, consensus was achieved for all criteria, with Kendall's coefficient reaching 0.72, indicating a strong level of agreement. Consequently, the visual criterion

received the highest weight of 0.41. The physical and spatial criteria followed with weights of 0.31 and 0.28, respectively, ranking second and third. (Tab.6)

Table 6: Results of the Three Rounds of the Delphi Survey for Determining the Weights of Impact Evaluation Criteria. (Source: Authors)

Third round of Delphi					Second round of Delphi					First round of Delphi				
Relative weight of the criterion	Interquartile range	Standard deviation	Average	Number	Relative weight of the criterion	Interquartile range	Standard deviation	Average	Number	Relative weight of the criterion	Interquartile range	Standard deviation	Average	Number
0.31	1	0.88	6.53	15	0.38	3	1.73	7.00	15	0.37	4	1.71	6.73	15
0.41	0	0.26	8.93	15	0.45	1	0.83	8.40	15	0.44	2	1.39	8.07	15
0.28	1	0.88	6.07	15	0.17	1	0.86	3.20	15	0.19	1	1.06	3.53	15

Determining the Impact of Interventions on the Heritage of Asef Vaziri Mansion

In the first round of the Delphi survey regarding the assessment of the impact of interventions on the building’s heritage, 15 participants took part. Among the 23 interventions evaluated from the physical, visual, and spatial perspectives, 12 interventions, comprising 17 variables, did not reach consensus. This means that at least one of the three criteria for these interventions had a standard deviation ≥ 1 or an interquartile range >1 . Among the interventions without consensus, two interventions application of light-filtering adhesive film and internal wall insulation had the highest level of disagreement, as none of the three criteria reached the necessary agreement conditions. Furthermore, the Kendall’s W coefficient was 0.45, indicating a low level of agreement. Therefore, a second round of the Delphi survey was conducted. In the second round, experts were asked to evaluate all 23 interventions again. In addition to the questionnaire, the results from the first round were provided so that participants could consider the opinions of others and revise their responses if necessary. In this round, Kendall’s W increased slightly to 0.47, but agreement remained weak. Moreover,

11 interventions, comprising 11 variables, still did not meet the consensus criteria. Tab 7 presents the statistical results of the first and second rounds of the Delphi survey.

Fig (2) shows the percentage of negative impact of energy efficiency improvement measures on the heritage of Asif Mansion. These values are calculated based on the ratio of the negative impact of each measure to the maximum possible negative impact. Also, the relative contribution of physical, visual, and spatial criteria in the overall combination of negative impact of each measure is shown as a percentage. After measures related to user behavior, which were ranked 1st with a score of 0, optimization of water heating systems is ranked second with an impact of 30.8%. On the other hand, installing awnings has the highest negative impact on heritage with an impact of 74.1% and is ranked last. Also, evaluating the distribution of the impact of the criteria in all measures shows that the visual criterion has the highest share (41%), followed by the physical (31%) and spatial (28%) criteria. This alignment of the results with the coefficients obtained from the first stage of the Delphi survey confirms the accuracy and validity of the initial determination of the weight of the criteria at that stage

Table 7: Results of the first and second rounds of the Delphi survey for determining the impact of interventions on the heritage of Asef Mansion. (Source: Authors)

Interventions	Delphi Round 1											Delphi Round 2										
	Physical			Visual			Spatial			Interquartile Range	Physical			Visual			Spatial			Final Mean		
	Mean	Standard Deviation (SD)	Interquartile Range	Mean	Standard Deviation (SD)	Interquartile Range	Mean	Standard Deviation	Interquartile Range		Mean	Standard Deviation (SD)	Interquartile Range	Mean	Standard Deviation (SD)	Interquartile Range	Mean	Standard Deviation	Interquartile Range			
Optimization of existing water heating systems	0.93	0.80	1.75	1.67	0.62	1.00	1.07	0.59	0.75	1.27	1.27	0.88	1.00	1.47	0.83	1.00	0.87	0.74	1.50	1.24		
Optimization of existing HVAC systems	0.67	0.62	1.00	2.20	1.01	1.75	1.20	0.56	1.00	1.44	0.67	0.82	1.00	2.00	1.07	1.50	1.27	0.96	1.00	1.38		
Optimization of existing lighting systems	1.53	0.52	1.00	1.73	0.59	1.00	0.73	0.59	1.00	1.39	1.27	0.70	1.00	1.47	0.74	1.00	1.00	0.38	0.00	1.27		
Use of occupancy sensors for lighting control	1.47	0.52	1.00	1.73	0.59	1.00	1.33	0.49	1.00	1.54	1.00	0.76	1.50	2.00	0.65	1.00	1.20	0.68	1.00	1.47		
Sealing around doors	1.93	0.59	0.00	2.07	0.70	0.75	1.67	0.82	1.00	1.91	1.73	0.59	1.00	2.33	0.98	0.50	1.53	0.83	1.00	1.92		
Sealing around windows	1.67	0.82	1.00	2.60	0.63	1.00	1.53	0.64	1.00	2.01	1.80	0.86	1.00	2.60	0.74	1.00	1.53	0.83	1.00	2.05		
Use of light-filtering adhesive films	1.40	1.18	2.00	2.20	0.86	1.75	2.20	1.21	2.50	1.95	1.67	0.98	1.50	2.53	0.64	1.00	1.67	1.23	1.50	2.02		
Installation of high-efficiency water heating systems	1.67	0.62	0.75	2.13	1.13	1.00	1.60	0.91	1.00	1.84	1.80	0.77	1.00	2.00	0.93	1.00	1.80	0.77	1.00	1.88		
Installation of low-emissivity glazing	1.60	0.51	1.00	2.47	0.74	1.00	2.15	0.80	0.75	2.11	1.47	0.74	1.00	2.73	0.70	1.00	1.87	0.92	1.00	2.10		
Installing high-efficiency lighting systems	1.53	0.64	1.00	1.47	0.83	1.00	1.67	0.90	1.00	1.54	1.33	0.90	1.50	1.67	0.62	1.00	1.87	0.64	1.00	1.62		
Installing high-efficiency HVAC systems	1.87	0.99	1.00	2.07	0.46	0.00	1.80	1.01	1.50	1.93	1.60	1.18	1.00	1.93	0.70	0.00	1.93	0.80	1.00	1.83		
Renovation of Existing Doors	2.53	1.06	1.75	2.53	0.83	0.75	1.87	0.74	1.00	2.35	2.33	0.90	0.50	2.27	1.03	2.00	1.60	0.83	1.00	2.10		
Renovation of Existing Windows	1.33	0.90	1.00	1.80	1.21	2.50	1.40	0.51	1.00	1.54	1.60	0.51	1.00	1.54	1.19	2.00	1.13	0.64	1.00	1.69		
External Roof Insulation	2.47	0.83	1.00	2.20	0.94	1.75	1.47	0.52	1.00	2.08	2.80	0.77	1.00	2.33	0.98	1.00	1.27	0.70	1.00	2.18		
Internal Roof Insulation	1.73	0.46	0.75	2.80	0.56	1.00	2.40	0.51	1.00	2.36	1.60	0.51	1.00	2.53	0.92	1.00	2.47	0.64	1.00	2.23		
Internal Wall Insulation	2.13	0.74	1.75	2.53	1.13	1.75	2.00	1.20	2.50	2.26	2.40	0.63	1.00	2.40	1.35	0.50	2.27	0.88	1.00	2.36		
Installation of Photovoltaic Panels	2.13	1.36	1.75	2.80	0.68	0.75	2.67	0.62	1.00	2.56	2.33	0.82	1.00	2.93	0.70	0.50	2.80	0.56	0.50	2.71		
Installation of High-Efficiency Doors	2.57	0.65	1.00	3.00	0.53	0.00	1.33	0.90	2.00	2.40	2.80	0.77	1.00	3.00	0.53	0.00	1.40	0.83	1.50	2.49		
Installation of New Multi-Glazed Windows	2.60	0.83	1.00	3.33	0.49	1.00	1.60	1.12	1.00	2.62	2.40	0.63	1.00	3.27	0.70	1.00	1.87	0.83	1.00	2.61		
Floor Insulation	1.87	0.64	0.75	3.07	0.59	0.75	2.33	0.90	0.00	2.49	1.73	0.88	0.50	3.20	0.68	1.00	2.21	0.80	0.00	2.47		
External Wall Insulation	3.20	0.77	1.00	3.33	0.49	0.75	1.47	0.64	1.00	2.77	3.07	0.70	0.50	3.20	0.56	1.00	1.33	0.82	1.50	2.64		
Floor Replacement	2.93	0.59	0.75	3.33	0.72	1.00	2.27	0.46	1.00	2.91	3.14	0.66	1.00	3.47	0.74	1.00	2.47	0.52	1.00	3.09		
Installation of Awnings	2.29	0.61	1.00	3.40	0.63	1.00	3.13	0.52	0.00	2.98	2.00	0.65	0.50	3.27	0.59	1.00	2.93	0.46	0.00	2.78		

Table 8: Results of the third and fourth rounds of the Delphi survey for determining the impact of interventions on the heritage of Asef Mansion. (Source: Authors)

Interventions	Delphi Round3											Delphi Round4											Final Ranking
	Physical			Visual			Spatial			Interquartile Range	Physical			Visual			Spatial			Final Mean			
	Mean	Standard Deviation	Interquartile Range	Mean	Standard Deviation (SD)	Interquartile Range	Mean	Standard Deviation	Interquartile Range		Mean	Standard Deviation	Interquartile Range	Mean	Standard Deviation	Interquartile Range	Mean	Standard Deviation	Interquartile Range				
Optimization of Existing Water Heating Systems	1.53	0.64	1.00	1.80	0.56	1.00	1.13	0.52	0.50	1.53	1.13	0.92	0.25	1.60	0.74	1.00	0.80	0.56	0.25	1.23	1		
Optimization of Existing HVAC Systems	0.87	0.83	1.00	1.73	0.96	1.00	0.93	0.80	1.00	1.24	0.93	0.80	1.00	1.80	0.86	0.25	1.00	0.76	0.25	1.31	2		
Optimization of Existing Lighting Systems	1.20	0.77	1.00	1.73	0.59	0.50	0.93	0.46	0.00	1.34	1.00	0.85	0.50	1.87	0.35	0.00	0.93	0.46	0.00	1.34	3		
Use of Occupancy Sensors for Lighting Control	1.00	0.85	1.50	1.80	0.41	0.50	1.40	0.51	1.00	1.44	1.07	0.70	1.00	1.93	0.46	0.00	1.33	0.49	1.00	1.50	4		
Sealing Around Doors	1.53	0.64	1.00	2.07	0.80	0.50	1.20	0.86	0.50	1.66	1.53	0.52	1.00	2.13	0.74	0.25	1.07	0.70	0.00	1.65	5		
Sealing Around Windows	1.67	0.72	1.00	2.29	0.47	1.00	1.40	0.74	1.00	1.85	1.53	0.64	1.00	2.20	0.41	0.25	1.13	0.74	0.25	1.69	6		
Application of Light-Filtering Adhesive Film	1.73	0.88	0.00	2.20	0.41	0.00	1.53	0.99	1.50	1.87	1.67	0.82	1.00	2.20	0.68	1.00	1.00	0.65	0.25	1.70	7		
Installation of High-Efficiency Water Heating Systems	1.53	0.64	1.00	2.13	0.64	1.00	1.87	0.52	0.50	1.87	1.40	0.74	1.00	1.80	0.86	0.25	2.00	0.53	0.00	1.73	8		
Installation of Low-Emissivity Glass	1.67	0.49	0.50	2.53	0.52	1.00	1.47	0.83	1.00	1.97	1.20	0.68	1.00	2.07	0.46	0.00	1.87	0.52	0.25	1.74	9		
Installation of High-Efficiency Lighting Systems	1.53	0.99	1.00	1.93	0.70	1.00	1.80	0.68	1.00	1.77	1.47	0.74	1.00	2.00	0.65	0.25	1.93	0.59	0.25	1.82	10		
Installation of High-Efficiency HVAC Systems	1.40	1.12	1.50	2.20	0.41	0.00	1.93	0.46	0.00	1.88	1.80	0.41	0.25	2.27	0.59	1.00	1.93	0.46	0.00	2.03	11		
Renovation of Existing Doors	2.07	0.70	1.00	2.80	0.56	1.00	1.47	0.74	1.00	2.20	1.93	0.96	0.50	2.73	0.88	1.00	1.20	0.86	0.25	2.06	12		
Renovation of Existing Windows	1.80	0.56	1.00	2.57	0.94	1.00	1.33	0.62	1.00	1.99	2.00	0.65	0.50	2.80	0.41	0.25	1.27	0.59	1.00	2.12	13		
External Roof Insulation	2.67	0.72	1.00	2.53	0.74	1.00	1.60	0.83	1.00	2.31	2.80	0.68	1.00	2.47	0.74	1.00	1.40	0.63	1.00	2.27	14		
Internal Roof Insulation	1.87	0.52	0.50	2.80	0.68	1.00	2.29	0.47	1.00	2.37	1.80	0.56	1.00	2.67	0.62	1.00	2.33	0.49	1.00	2.30	15		
Internal Wall Insulation	2.27	0.46	0.50	3.00	0.53	0.00	2.53	0.52	1.00	2.64	2.13	0.35	0.00	2.87	0.52	0.25	1.87	0.83	1.00	2.36	16		
Installation of Photovoltaic Panels	2.13	0.64	0.50	2.80	0.68	1.00	2.40	1.12	1.00	2.48	2.07	0.88	1.00	2.33	0.82	1.00	2.93	0.80	0.25	2.42	17		
Installation of High-Efficiency Doors	2.60	0.63	1.00	2.73	0.88	0.50	1.67	0.49	1.00	2.39	2.47	0.52	1.00	3.00	0.53	0.00	1.80	0.41	0.25	2.50	18		
Installation of New Multi-Glazed Windows	2.20	0.68	1.00	3.00	0.65	1.00	1.60	0.51	1.00	2.36	2.33	0.49	1.00	3.14	0.53	0.25	1.80	0.41	0.25	2.52	19		
Floor Insulation	2.07	0.59	0.00	2.93	0.80	1.00	2.00	0.65	0.00	2.40	2.93	0.70	0.00	3.20	0.56	1.00	1.60	0.51	1.00	2.67	20		
External Wall Insulation	3.00	0.65	0.50	3.20	0.56	1.00	1.60	0.51	1.00	2.69	2.20	0.41	0.25	3.40	0.63	1.00	2.20	0.86	0.25	2.69	21		
Floor Replacement	3.00	0.85	1.00	3.47	0.74	1.00	2.47	0.52	1.00	3.04	3.00	0.76	0.25	3.33	0.72	1.00	2.27	0.59	1.00	2.93	22		
Installation of Awnings	2.00	0.65	0.50	3.33	0.49	1.00	2.80	0.41	0.50	2.77	2.27	0.59	1.00	3.47	0.52	1.00	3.00	0.53	0.00	2.96	23		

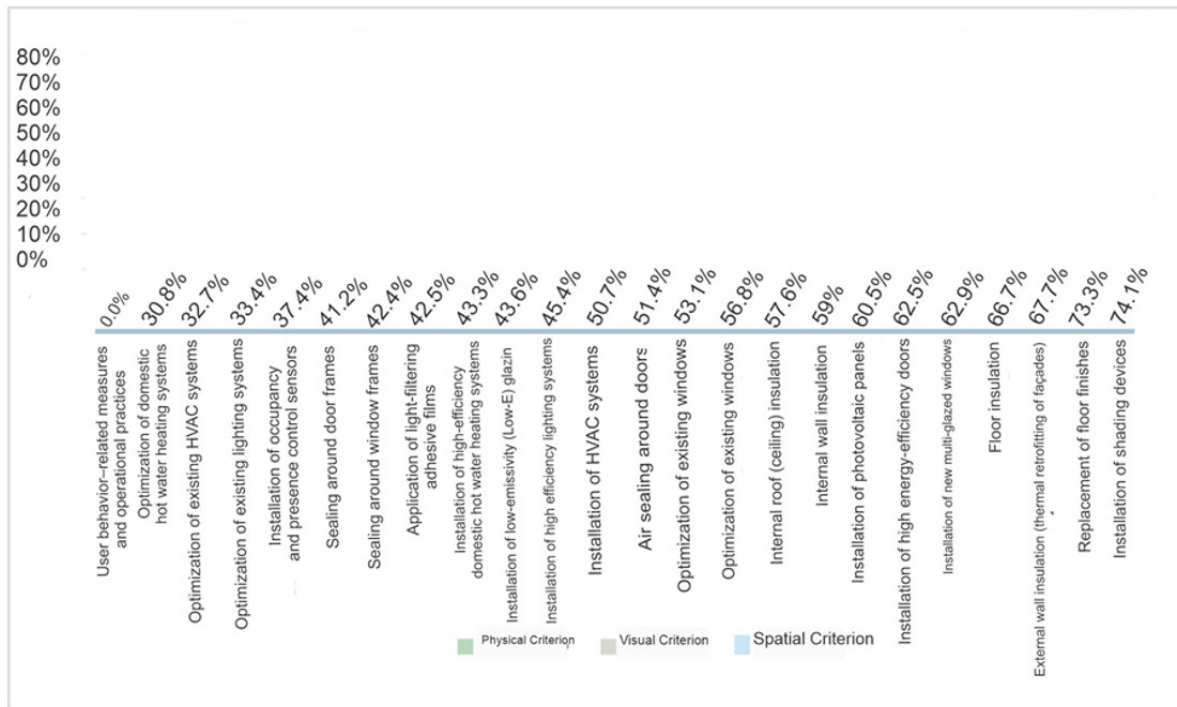


Figure 2: Percentage of negative impact of energy efficiency improvement measures on the heritage of Asif Mansion and their prioritization. (Source: Authors)

CONCLUSION AND RESULTS

In Iran, improving energy efficiency in historic buildings presents a major challenge for conservationists, architects, and urban managers, as it requires the simultaneous assessment of energy performance and the preservation of the historical identity and appearance of the structures. This study first identified a comprehensive list of common and practical energy efficiency measures applicable to historic buildings in Iran and reorganized them within a structured framework consisting of three levels: main strategies, systems, and actions. Subsequently, by selecting Asef Mansion in Sanandaj as the case study, the impacts of the identified measures on the heritage values of the building were evaluated using the EFFESUS project assessment framework and based on expert opinions collected through two rounds of the Delphi method. The findings highlight experts' strong emphasis on preserving the authentic visual appearance of historic buildings compared to other aspects, such as physical

characteristics, material qualities, and spatial experience, when encountering energy related interventions. Therefore, measures that remain concealed and do not affect the visible appearance of the historic fabric such as optimizing existing systems (heating, lighting, HVAC) leave the least negative impact on heritage. In contrast, actions such as floor replacement or installing shading devices, which directly alter the physical appearance of the building, cause the highest negative impact and thus fall into lower priority categories. Although visual impact was often the most decisive factor in evaluating heritage effects, the specific characteristics of each historic building may shift the dominance toward other evaluation dimensions. For instance, in Asef Mansion, installing solar water heating systems and photovoltaic panels had the most adverse impact from a spatial perspective, whereas external roof insulation had the highest negative impact from a physical perspective. Conversely, a single measure may impose dominant nega-

tive impacts from a different dimension in another building. For example, while photovoltaic panels at Asef Mansion have the highest spatial impact, in buildings with roofs exposed to public view or located within sensitive urban landscapes, their main negative effect would be visual. Therefore, energy-related interventions in historic buildings must be prioritized and selected based on the building's unique heritage values and the magnitude of impact that each measure imposes on these values. In other words, there is no universal solution or fixed prioritization applicable to all buildings. Beyond these results, measures related to user behavior consistently occupy the highest priority because they impose no negative impacts on heritage. This indicates that such measures being low-cost and nonintrusive can serve as a safe and effective starting point for improving energy efficiency in heritage buildings. In this regard, actions such as user training on equipment operation or employing smart control systems can significantly enhance energy performance at minimal cost. As one of the first attempts of its kind in the country, this study introduces a transparent method for quantifying the impact of energy efficiency measures on the heritage values of historic buildings, enabling the development of a targeted list of interventions that simultaneously address energy considerations and the preservation of heritage significance. In subsequent stages, measures that fail to meet conservation criteria should be removed, ultimately resulting in a concise list of actions suitable for enhancing energy efficiency. Ultimately, when performed with care and sensitivity, energy retrofitting in historic buildings can not only reduce energy consumption but also serve as an effective tool for safeguarding these structures and contributing to the broader goals of sustainable development.

Suggestions for Future Research

Given the complexity of energy-efficiency interventions in historic buildings, it is recom-

mended that future studies incorporate more comprehensive analyses—such as assessments of improvements in energy performance, implementation costs, and life cycle assessment (LCA)—with a particular focus on the specific physical and heritage characteristics of these buildings. To achieve integrated and multidimensional decision-making, the incorporation of these analyses within the framework of multi-criteria decision-making (MCDM) methods, such as AHP or TOPSIS, appears essential. This approach would allow economic, environmental, energy-performance, and heritage-value dimensions to be evaluated simultaneously when selecting intervention options. Adopting such a methodology can not only ensure a more accurate prioritization of alternatives but also help balance architectural conservation objectives with the requirements of sustainable development.

REFERENCES

- 3ENCULT. (2014). *Final report summary – 3ENCULT (Efficient Energy for EU Cultural Heritage)*. Italy.
- Ahmed, E. K. A., Dewidar, K. M., El-Hakeem, Y. A., & Guirguis, M. N. (2025). *An integrated framework for sustainable retrofitting of existing university buildings*. *Discover Sustainability*, 6(1), 38. <https://doi.org/10.1007/s43621-024-00703-7>
- Alasmar, R., Anaç, M., & Bakan, M. K. (2024). *Evaluating the effect of adaptive reuse in the energy performance of historic buildings: A case study from Türkiye*. *Heritage*, 7(11), 6085–6100. <https://doi.org/10.3390/heritage7110285>
- Alkhateeb, E., & Abu-Hijleh, B. (2019). *Potential for retrofitting a federal building in the UAE to net zero electricity building (nZEB)*. *Heliyon*, 5(6), e01971. <https://doi.org/10.1016/j.heliyon.2019.e01971>
- Aranda, J., Zabalza, I., Conserva, A., & Millán, G. (2017). *Analysis of energy efficiency measures and retrofitting solutions for social housing*

- buildings in Spain as a way to mitigate energy poverty. *Sustainability*, 9(10), 1869. <https://doi.org/10.3390/su9101869>
- ASHRAEGuideline34. (2019). *Energy Guideline for Historic Buildings*.
- Ashrafi, B., Neugebauer, C., & Kloos, M. (2022). A conceptual framework for heritage impact assessment: A review and perspective. *Sustainability*, 14 (1), 27. <https://doi.org/10.3390/su14010027>
- Austin, M. C., Carpino, C., Mora, D., & Arcuri, N. (2022). A methodology to identify appropriate refurbishment strategies towards zero energy buildings in a hot and humid climate. *Journal of Physics: Conference Series*, 2385(1), 012020. <https://doi.org/10.1088/1742-6596/2385/1/012020>
- Balali, A., Hakimelahi, A., & Valipour, A. (2020). Identification and prioritization of passive energy consumption optimization measures in the building industry: An Iranian case study. *Journal of Building Engineering*, 30, 101239. <https://doi.org/10.1016/j.jobe.2020.101239>
- Ben, H., & Steemers, K. (2020). Modelling energy retrofit using household archetypes. *Energy and Buildings*, 224, 110224. <https://doi.org/10.1016/j.enbuild.2020.110224>
- Bonte, M., Thellier, F., & Lartigue, B. (2014). Impact of occupant's actions on energy building performance and thermal sensation. *Energy and Buildings*, 76, 219–227. <https://doi.org/10.1016/j.enbuild.2014.02.068>
- Buda, A., de Place Hansen, E. J., Rieser, A., Giancola, E., Pracchi, V. N., Mauri, S., ... Polo López, C. S. (2021). Conservation-compatible retrofit solutions in historic buildings: An integrated approach. *Sustainability*, 13(5), 2927. <https://doi.org/10.3390/su13052927>
- Carapeto, T., Coelho, D., & Oliveira, C. (2016). Assessment of energy efficient retrofitting measures in the residential building sector. Paper presented at the 2016 51st International Universities Power Engineering Conference (UPEC).
- Chen, X., Qu, K., Calautit, J., Ekambaram, A., Lu, W., Fox, C., ... Riffat, S. (2020). Multi-criteria assessment approach for a residential building retrofit in Norway. *Energy and Buildings*, 215, 109668. <https://doi.org/10.1016/j.enbuild.2019.109668>
- Chen, X., Vand, B., & Baldi, S. (2024). Challenges and strategies for achieving high energy efficiency in building districts. *Buildings*, 14(6), 1839. <https://doi.org/10.3390/buildings14061839>
- Chunduri, S. (2014). Development of planning and design phases of an integrative building lifecycle process model for advanced energy retrofit projects [Doctoral dissertation, The Pennsylvania State University]. Penn State Electronic Theses and Dissertations for Graduate School. <https://etda.libraries.psu.edu/catalog/22849>
- Chung-Camargo, K., González, J., Chen Austin, M., Carpino, C., Mora, D., & Arcuri, N. (2024). Advances in retrofitting strategies for energy efficiency in tropical climates: A systematic review and analysis. *Buildings*, 14(6), 1633. <https://doi.org/10.3390/buildings14061633>
- EFFESUS. (2014). *Energy Efficiency in European Historic Urban Districts A Practical Guidance*. Retrieved from https://build-up.ec.europa.eu/sites/default/files/link-files/effesus_booklet_final-version.
- EN16883. (2017). Conservation of cultural heritage - Guidelines for improving the energy performance of historic buildings. In: Brussels.
- Eriksson, P. (2021). Balancing building conservation with energy conservation: Towards differentiated energy renovation strategies in historic building stocks. Maney Publishing. <https://doi.org/10.1179/1756750514Z.00000000054>
- Ettxepare, L., Leon, I., Sagarna, M., Lizundia, I., & Uranga, E. J. (2020). Advanced intervention protocol in the energy rehabilitation of heritage buildings: A Miñones Barracks case study. *Sustainability*, 12(15), 6270. <https://doi.org/10.3390/su12156270>
- European Parliament. (2015). *Understanding energy efficiency*.
- Fabi, V., Andersen, R. V., Corgnati, S., & Olesen, B. W. (2012). Occupants' window opening be-

- haviour: A literature review of factors influencing occupant behaviour and models. *Building and Environment*, 58, 188–198. <https://doi.org/10.1016/j.buildenv.2012.07.009>
- Fasna, M. F. F., & Gunatilake, S. (2019, November). Energy retrofits to enhance energy performance of existing buildings: A review. In *Proceedings of the 8th World Construction Symposium* (pp. 8–10). Colombo, Sri Lanka.
- Felius, L. C., Brandser, A., & Smits, F. (2023, December). Practical solutions for building envelope retrofitting of historic buildings in cold climates. In *Journal of Physics: Conference Series*, 2654(1), 012005. <https://doi.org/10.1088/1742-6596/2654/1/012005>
- Feng, K., Chokwitthaya, C., & Lu, W. (2024). Exploring occupant behaviors and interactions in buildings with energy-efficient renovations: A hybrid virtual-physical experimental approach. *Building and Environment*, 265, 111991. <https://doi.org/10.1016/j.buildenv.2023.111991>
- Fernandes, J., Santos, M. C., & Castro, R. (2021). Introductory review of energy efficiency in buildings retrofits. *Energies*, 14(23), 8100. <https://doi.org/10.3390/en14238100>
- Flores, J. A. D. M. (2013). *The investigation of energy efficiency measures in the traditional buildings in Oporto World Heritage Site* [Doctoral dissertation, Oxford Brookes University]. Oxford Brookes University Research Archive.
- Galassi, V., & Madlener, R. (2018). Shall I open the window? Policy implications of thermal-comfort adjustment practices in residential buildings. *Energy Policy*, 119, 518–527. <https://doi.org/10.1016/j.enpol.2018.05.031>
- Galatioto, A., Ciulla, G., & Ricciu, R. (2017). An overview of energy retrofit actions feasibility on Italian historical buildings. *Energy*, 137, 1–25. [doi:10.1016/j.energy.2016.12.103](https://doi.org/10.1016/j.energy.2016.12.103)
- Gayen, P., Hajela, A., & Kumar, J. (2022). An approach for assessing the modern architectural heritage of India. *Conservation of Architectural Heritage (CAH): Embodiment of Identity*, 287–300. Springer.
- Geist, M. R. (2010). Using the Delphi method to engage stakeholders: A comparison of two studies. *Evaluation and Program Planning*, 33(2), 147–154. <https://doi.org/10.1016/j.eval-progplan.2009.07.006>
- Goh, C. S. (2019). *Energy: Current approach*. Butterworth-Heinemann.
- Grytli, E., Kværness, L., Rokseth, L. S., & Ygre, K. F. (2012). The impact of energy improvement measures on heritage buildings. *Journal of Architectural Conservation*, 18(3), 89–106.
- Harputlugil, T., & de Wilde, P. (2025). Building occupant energy labels (OEL): Capturing the human factors in buildings for energy efficiency. *Sustainability*, 17(3), 1216. <https://doi.org/10.3390/su17031216>
- Heebøll, A., Wargocki, P., & Toftum, J. (2018). Window and door opening behavior, carbon dioxide concentration, temperature, and energy use during the heating season in classrooms with different ventilation retrofits—ASHRAE RP1624. *Science and Technology for the Built Environment*, 24(6), 626–637.
- Hegazi, Y. S., Shalaby, H. A., & Mohamed, M. A. (2021). Adaptive reuse decisions for historic buildings in relation to energy efficiency and thermal comfort—Cairo citadel, a case study from Egypt. *Sustainability*, 13(19), 10531. <https://doi.org/10.3390/su131910531>
- Hernández, D., Hernández-Callejo, L., Zorita-Lamadrid, A., Duque-Pérez, O., & García, F. S. (2021). A review of strategies for building energy management system: Model predictive control, demand side management, optimization, and fault detect & diagnosis. *Journal of Building Engineering*, 33, 101692.
- Herrera-Avellanosa, D., Rose, J., Thomsen, K. E., Haas, F., Leijonhufvud, G., Brostrom, T., & Troi, A. (2024). Evaluating the Implementation of Energy Retrofits in Historic Buildings: A Demonstration of the Energy Conservation Potential and Lessons Learned for Upscaling. *Heritage*, 7(2), 997–1013.
- Historic England. (2024). *Adapting Historic Buildings for Energy and Carbon Efficiency*.
- Hong, T., Taylor-Lange, S. C., D'Oca, S., Yan, D., &

- Corgnati, S. P. (2016). Advances in research and applications of energy-related occupant behavior in buildings. *Energy and Buildings*, 116, 694–702. <https://doi.org/10.1016/j.enbuild.2015.11.052>
- Hong, Y., Ezeh, C. I., Deng, W., Hong, S.-H., & Peng, Z. (2019). Building energy retrofit measures in hot-summer-cold-winter climates: A case study in Shanghai. *Energies*, 12(17), 3393. <https://doi.org/10.3390/en12173393>
- IAIA. (2009). what is Impact Assessment? Retrieved from <https://www.iaia.org/publicdocuments/special>.
- ICOMOS. (2011). *Guidance on Heritage Impact Assessments for Cultural World Heritage Properties*. A publication of the International Council on Monuments and Sites.
- IEA. (2015). Retrieved from <http://www.iea.org>
- IEA, & EBC. (2021). *Conservation compatible energy retrofit technologies: Part II: Documentation and assessment of conventional and innovative solutions for conservation and thermal enhancement of window systems in historic buildings*.
- Jamal, K. A. A., Harun, S. N., & Said, S. Y. (2024). A Review and Comparative Study of Retrofit for the Energy Efficiency of Malaysian Heritage Buildings. *Insights on Resiliency and Urban Development*, 42-58.
- Johansson, D., Hamid, A. A., Bagge, H., Eriksson, P., Farsäter, K., Fransson, V., & Kristofferson, J. (2021). Prioritize the right energy measures in historic buildings—approach and measure selection. Paper presented at the IOP Conference Series: Earth and Environmental Science.
- Khaskheli, R., Zhang, W., Marvi, H., & Bhutto, A. (2023). Heritage Impact Assessment (HIA) as an Alternative Evaluation Tool for Historical Built Heritages in Lahore, Pakistan. *Journal of World Architecture*, 7(6), 36-44.
- Kumtepe, E., & Aycam, . (2025). Approach Proposal for Energy-Efficient Retrofit of Historic Buildings with Comparative Analysis of EU Research Projects. *Kent Akademisi*, 18(1), 21-52.
- yritsi, E., Philokyprou, M., Kyriakidis, A., Michael, A., & Michopoulos, A. (2023). Energy retrofitting of heritage buildings: An integrated methodology. *IOP Conference Series: Earth and Environmental Science*, 1196(1), 012108. <https://doi.org/10.1088/1755-1315/1196/1/012108>
- Lidelöw, S., Örn, T., Luciani, A., & Rizzo, A. (2019). Energy-efficiency measures for heritage buildings: A literature review. *Sustainable Cities and Society*, 45, 231–242. <https://doi.org/10.1016/j.scs.2018.09.029>
- Lundberg, D. C., Tang, J. A., & Attari, S. Z. (2019). Easy but not effective: Why “turning off the lights” remains a salient energy conserving behaviour in the United States. *Energy Research & Social Science*, 58, 101257. <https://doi.org/10.1016/j.erss.2019.101257>
- Ma, Z., Cooper, P., Daly, D., & Ledo, L. (2012). Existing building retrofits: Methodology and state-of-the-art. *Energy and Buildings*, 55, 889–902. <https://doi.org/10.1016/j.enbuild.2012.08.018>
- Madushika, U., Ramachandra, T., Karunasena, G., & Udakara, P. (2023). Energy retrofitting technologies of buildings: A review-based assessment. *Energies*, 16(13), 4924. <https://doi.org/10.3390/en16134924>
- Maghsoudi Nia, E., Qian, Q. K., & Visscher, H. J. (2022). Analysis of occupant behaviours in energy efficiency retrofitting projects. *Land*, 11(11), 1944. <https://doi.org/10.3390/land11111944>
- Mejjiaoui, S. (2022). Toward ZEB: A mathematical programming-, simulation-, and AHP-based comprehensive framework for building retrofitting. *Applied Sciences*, 12(4), 2241. <https://doi.org/10.3390/app12042241>
- Moon, J. W., & Han, S.-H. (2011). Thermostat strategies impact on energy consumption in residential buildings. *Energy and Buildings*, 43(2–3), 338–346. <https://doi.org/10.1016/j.enbuild.2010.10.027>
- Morgan, R. K. (2012). Environmental impact assessment: The state of the art. *Impact Assessment and Project Appraisal*, 30(1), 5–14. <https://doi.org/10.1080/14615517.2012.661557>

- Nair, G., Verde, L., & Olofsson, T. (2022). A review on technical challenges and possibilities on energy efficient retrofit measures in heritage buildings. *Energies*, 15, 7472. <https://doi.org/10.3390/en15207472>
- Pan, S., Wang, X., Wei, S., Xu, C., Zhang, X., Xie, J., & De Wilde, P. (2017). Energy waste in buildings due to occupant behaviour. *Energy Procedia*, 105, 2233–2238. <https://doi.org/10.1016/j.egypro.2017.03.638>
- Pavlovi, J., Šabanovi, A., & ukovi -Ignjatovi, N. (2022). Energy efficiency improvement in industrial brownfield heritage buildings: Case study of “Beko.” Paper presented at the International Conference on Technological Imagination in the Green and Digital Transition.
- Phichetkumbodee, N., Chantrawutikorn, M., Sundaranaga, C., Chaichana, C., Pholporton, K., Ayuthaya, T. K. N., & Rinchumphu, D. (2023). Using the Delphi method for selecting energy efficiency indicators in the Thailand context. *Energy Reports*, 9, 408–414. <https://doi.org/10.1016/j.egy.2022.12.025>
- Pianezze, F. (2012). L'obiettivo del miglioramento dell'efficienza energetica nel processo di conservazione del costruito storico. *Politecnico di Milano*. https://www.politesi.polimi.it/bitstream/10589/56723/1/2012_03_PhD_Pianezze.pdf.
- Posani, M., Veiga, M., & Freitas, V. (2018). Historic buildings resilience: A view over envelope energy retrofit possibilities. Paper presented at the 8th International Conference on Building Resilience, Lisbon, Portugal.
- Qaemi, M., & Heravi, G. (2012). Sustainable energy performance indicators of green building in developing countries. Paper presented at the Construction Research Congress 2012: Construction Challenges in a Flat World.
- Sadineni, S. B., Madala, S., & Boehm, R. F. (2011). Passive building energy savings: A review of building envelope components. *Renewable and Sustainable Energy Reviews*, 15(8), 3617–3631. <https://doi.org/10.1016/j.rser.2011.07.014>
- Sagnia, B. K. (2004). Framework for cultural impact assessment. International Network for Cultural Diversity (INCD).
- ahin, C. D., Arsan, Z. D., Tunçoku, S. S., Broström, T., & Akkurt, G. G. (2015). A transdisciplinary approach on the energy efficient retrofitting of a historic building in the Aegean Region of Turkey. *Energy and Buildings*, 96, 128–139. <https://doi.org/10.1016/j.enbuild.2015.02.044>
- Sodangi, M., & Salman, A. (2024). Analyzing the critical impediments to retrofitting historic buildings to achieve net zero emissions. *The Open Construction & Building Technology Journal*, 18, 14–11. <https://doi.org/10.2174/1874836802418010014>
- STBA. (2025). Responsible retrofit guidance wheel. Retrieved from <https://responsible-retrofit.org/greenwheel>
- Talebi, M., Jahangiri, M., & Riahi, R. (2023). Finding the best station to use buildings integrated photovoltaics (BIPVs) in eight different climates of Iran: Effect of wind speed and photovoltaic modules type. *International Transactions on Electrical Energy Systems*, 2023(1), Article 4213468. <https://doi.org/10.1155/2023/4213468>
- Thralvalou, S., Michopoulos, A., Alexandrou, K., & Artopoulos, G. (2023). Energy retrofit strategies of built heritage: Using Building Information Modelling tools for streamlined energy and economic analysis. Paper presented at the IOP Conference Series: Earth and Environmental Science.
- Turgut, T. (2020). Challenges and opportunities of energy efficiency retrofitting in historic buildings, Santiago de Compostela.
- Vasseur, V., & Marique, A.-F. (2019). Households' willingness to adopt technological and behavioral energy savings measures: An empirical study in the Netherlands. *Energies*, 12(22), 4294. <https://doi.org/10.3390/en12224294>
- Wang, Y.-F., Hsu, Y.-F., Fang, K.-T., & Kuo, L.-T. (2024). Gamification in medical education: Identifying and prioritizing key elements through Delphi method. *Medical Education Online*, 29(1), 2302231. <https://doi.org/10.108>

[0/10872981.2023.2302231](https://doi.org/10.1016/j.rser.2023.2302231)

Webb, A. L. (2017). Energy retrofits in historic and traditional buildings: A review of problems and methods. *Renewable and Sustainable Energy Reviews*, 77, 748–759. <https://doi.org/10.1016/j.rser.2017.04.021>

WHITRAP & ICCROM. (2012). Introduction to the HIA framework. Paper presented at the International Training Course on Heritage Impact Assessments, Lijiang, China.

Xu, P., Chan, H. W. E., & Ying, X. (2010). An assessment framework for sustainable building energy retrofit (BEER) project under energy performance contracting (EPC) mechanism based on balanced card. Paper presented at the 15th Annual Symposium on Advancement of Construction Management and Real Estate: Towards Sustainable Development of International Metropolis, CRIOCM 2010.

Yan, B., Yang, W., He, F., & Zeng, W. (2023). Occupant behavior impact in buildings and the

artificial intelligence-based techniques and data-driven approach solutions. *Renewable and Sustainable Energy Reviews*, 184, 113372. <https://doi.org/10.1016/j.rser.2023.113372>

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