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Case Report

Evaluating the Effect of Adaptive Reuse in the Energy Performance of Historic Buildings: A Case Study from Türkiye

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Abstract: The building sector accounts for 30% to 40% of total energy consumption, and historic buildings play an important role in this proportion. Historical buildings that do not meet the required comfort conditions for the residents are adaptively reused, with various revisions. Recognizing the energy design of a historical building in its original condition and comparing the current situation can help create future solutions. This study examines the changes that a historic house in a hot climate zone in Türkiye experiences, from its original state up until the current situation. Energy analyses of the pre- and post-restoration situation are carried out, and the effect of adaptive reuse decisions on the energy performance of the building is investigated. A dynamic thermal simulation created with DesignBuilder was used to identify the energy use, carbon emissions, and thermal comfort. TM59 adaptive thermal comfort was used for the pre-restoration and the Fanger model for the post-restoration phase. This building, which was repurposed from a three-block residence, consists of a four-block hotel. Although the preservation of its original value is at the forefront, various structural changes were observed. The analysis demonstrates a higher occurrence of discomfort hours during summer compared to winter, consistent across both phases. Furthermore, energy consumption increased significantly, predominantly for heating, representing a doubling of energy use during the post-restoration phase. This is attributed to the building's conversion into a hotel and the use of mechanical systems. Future research is required to develop strategies to reduce the energy consumption, carbon emissions, and discomfort hours while maintaining the value of the historic building and its materials.

Keywords: adaptive reuse; energy performance; historical buildings; thermal comfort; carbon emissions

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1. Introduction

The construction sector has a crucial role in meeting societal needs, improving quality of life, and reflecting social and economic characteristics. Nevertheless, it also engenders carbon emissions, environmental damage, and a surge in global warming because of the utilization of natural resources and energy consumption [1]. The building sector has the largest percentage of energy consumption, constituting about 40% worldwide [2] and 32% of the total share of energy consumption in Turkiye [3]. The energy efficiency of the building sector has significant potential to contribute to reducing greenhouse gas (GHG) emissions. Houghton [4] and Moran et. al. [5] state that historical buildings account for 25% of the buildings in the European stock. According to TUIK (the Turkish Statistical Institute) [6], approximately 47.4% of Türkiye's buildings were built between 2000 and 2020, whereas the percentage of buildings constructed before 1980 is 12.4%. In addition, 62% of the civil architecture in Türkiye consists of immovable cultural heritage [6]. Hence it is important not to neglect these in studies on energy efficiency. Heritage Counts' research on two case studies shows that retrofitting and refurbishing historic buildings can reduce carbon emissions by more than 60% by the year 2050 [7]. This situation cannot be underestimated in terms of the retrofitting, reuse, and energy utilization of historical buildings. Most energy efficiency studies of historic buildings are aimed at continual usage and provide appropriate technological solutions for increasing energy efficiency while conserving historic building values [8]. The International Energy Agency has described energy efficiency as "a method of effectively managing and limiting the increase in energy consumption" [9]. Implementing energy efficiency measures in buildings presents crucial prospects for mitigating greenhouse gas emissions and global warming impacts [10,11]. The sustainability of heritage buildings requires energy efficiency [8] and continual usage [12]. Also, this is significant for both the preservation of buildings [13] and the reuse of embodied energy [14], which are important sustainability factors.

It has become quite common to reuse the existing building stock to avoid additional energy and cost expenditures. Adaptive reuse involves modifications that include both functional and physical aspects, bringing in the concepts of "adaptation" and "reuse" [15]. Adaptive reuse refers to the process of modifying a building's original purpose to fulfill the requirements of the new or current owners [16]. Adaptive reuse has crucial environmental, social, economic, and cultural benefits. By decreasing the materials used, energy consumed, and transportation energy, adaptive reuse can extend a building's life span and improve sustainability [17,18]. Adaptive reuse, as a method, has the potential to promote local culture, create new housing and commercial opportunities, and attract investments due to its flexibility and freedom of application [19]. Although this approach has a lot of potential, it should also consider the compatibility of the new function with the original use of the building. The study conducted in Gaziantep [20] evaluated adaptive reuse projects involving a museum, hotel, café, and public building in terms of the relationship between the conservation and energy efficiency of historical buildings. It shows that the hotel has the highest rate of changing the original features, which is one of the most important parameters affecting the heritage value, among the museum, hotel, café, and public building functions. Hotels need more changes compared to other functions due to their characteristics. On the other hand, it is stated that the hotel function is the most likely to adapt to energy-efficient systems. This reveals the energy efficiency potential of this type of building. However, while making these changes, a balance should be established by considering the heritage value of the building. According to [21], sustainable adaptive reuse should foster inclusion in society, environmental sustainability, innovation-based economic growth, and cultural and social identity. Various methodologies (STBA, EN16883, 3ENCULT, EFFESUS) have been developed that emphasize the need for a holistic approach to energy efficiency solutions for historic buildings. Although a wide range of factors are highlighted, it is emphasized that the heritage value and current condition of the building should be carefully assessed before any recommendations are implemented. The evaluation criteria in the methodologies relate to the internal and external environment, technical compatibility, energy efficiency, cost, and heritage value. These are aimed at preserving the authenticity of the building in terms of energy efficiency, thermal comfort, costs of the retrofitting, interventions, and the reuse of historical buildings. When dealing with these buildings, it should be taken into consideration that each historical building has unique heritage value [22–25].

Gaziantep province, renowned for its abundant historical structures, stands as a significant city within Türkiye. Upon careful examination of the traditional architectural style of Gaziantep, it is clear that the choice of building materials, arrangement of exteriors, spatial alignment, and even the layout of spaces have been greatly impacted by the region's natural resources, cultural characteristics, and technological capabilities. These characteristics collectively have a noticeable impact on the energy efficiency aspects of the building [26,27]. The building sector in Gaziantep has experienced an increase in demand as a result of a substantial surge in immigration to the province. Historic buildings have been reused and added to used building stock. The case of Gaziantep was selected to examine the pre- and post-restoration conditions of the building, considering thermal comfort and energy efficiency factors in the reuse of historic buildings. When we look at the restoration studies of historic buildings in Gaziantep, it is seen that energy efficiency is not a priority, and the current approach is to preserve the originality and physical integrity of the building. On the other hand, energy efficiency studies of historic buildings in the existing literature mostly focus on the energy efficiency and thermal comfort conditions of the existing condition of a single building [8,14,28]. In this study, it is believed that considering the original condition of the building along with the current situation will provide important evidence. Current "sustainable city" models tend to focus on the present and future, and they struggle to include the past in their plans for sustainability [28]. In this context, this study aims to track the development of a historical building in Türkiye and evaluate the effect of adaptive reuse on the energy performance of the historic building. In this context, this study analyzed the characteristics of the selected historical building and the changes it has undergone over time. Then, the energy performance of the original building and the current state of the building are analyzed. The energy usage of these two stages was compared. Historical buildings are seen as an essential part of modern society. Thus, understanding historic buildings and their energy performances will significantly contribute to sustainability solutions.

2. Materials and Methods

The study develops a three-level approach to assess the energy performance, adaptive reuse, and circularity of a 19th century historic building in Gaziantep, Turkiye. This building was originally built as a residence, was renovated in three different periods, and was finally reused as a hotel after restoration. Firstly, through the case study reflecting the Gaziantep traditional building typology, the initial condition of the building and the stages affecting the final appearance of the building are detailed. Then, energy and thermal comfort analysis for the original state of this building were analyzed. In addition, the current state of energy and thermal comfort analysis was determined. Finally, for the case study, the results of the analyses for the initial situation and the final situation were compared and evaluated within the scope of circular economy and adaptive reuse. Suggestions are presented with a critical point of view for the improvement and correction of the results obtained (Figure 1).

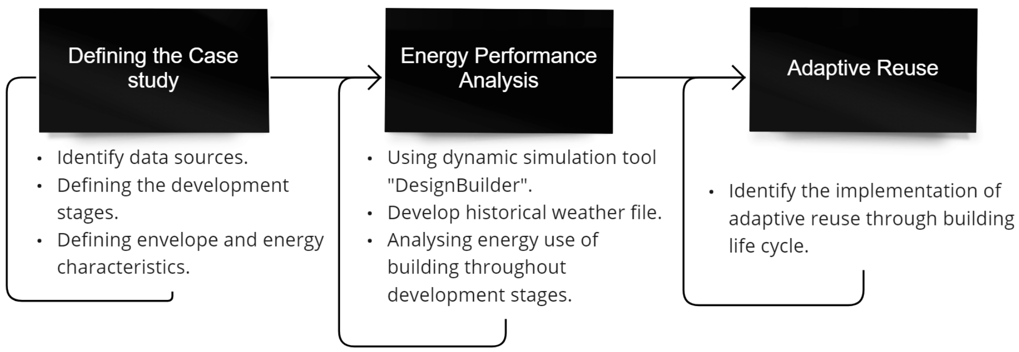


Figure 1. A three-level approach for evaluating the energy performance, carbon emissions, thermal comfort, and adaptive reuse of a 19th century building in Turkiye.

2.1. Case Study: 19th Century Construction in Gaziantep

Gaziantep's location between Mesopotamia, which hosted the first civilizations, and the Mediterranean Sea, and its location at the intersection of the roads from the Mediterranean Sea to the east, north, and west has enabled it to maintain its importance throughout historical processes. At the same time, the fact that Gaziantep is also on the historical trade route has increased the importance and vitality of the province [29]. The city has a hot summer Mediterranean climate, with hot and dry summers and cool and snowy winters. In January, the average minimum temperature of city is -0.6 °C, while in July, the average maximum temperature is 35.3 °C [30]. In July, the average minimum relative humidity is 38%, while the average highest relative humidity is 74%, in January [31].

The first Conservation Development Plan for the historic city center of Gaziantep was adopted in 1980 [29]. Following that, in 1983, the responsibility for conservation transferred to the local level, so an approach of dual tracking was implemented [32]. Gaziantep has areas designated as conservation areas, which consist of historical buildings that are largely original in terms of characteristic structure. In time, due to the change in lifestyle and user needs, new buildings were built and historical buildings changed their functions [33].

Religious beliefs played a major role in the physical structuring of the neighborhoods in the historical development of the city. Firstly, religious buildings were built in the neighborhoods and streets, and then the settlement developed around these religious buildings [34,35]. The relationship of Gaziantep houses with the street is in the form of walls, with deaf walls on the lower floors and walls with windows on the upper floors, like traditional Anatolian Turkish houses. The privacy perception of Turkish society is one of the most important reasons for using this approach in design. The buildings are not in a straight line due to the narrow streets and uneven terrain, depending on the climate [36]. When considering the plot location and topographical features of the residential buildings, it is challenging to distinguish the designed houses according to their plan outlines. When the general characteristics of Gaziantep traditional residential buildings are analyzed, it is seen that they have high walls and courtyards [37]. History, beliefs, culture, tradition, geographical conditions, and economy are some factors that affected the shape of these houses [38]. According to various studies, one of the important factors in the formation of the urban texture is the climatic characteristics of the region. Due to the hot climate of the region, the streets are narrow, and the houses are designed inward, aiming to create shade in the courtyard and to ensure the comfort of daily life [39].

Gaziantep houses generally consist of two buildings in a large garden context. One of these buildings is orientated to the north and the other to the south [39,40] (Figure 2). While the building-orientated north is used in summer and spring, the building-orientated south is used in winter and autumn, providing an effective use of the building according to the climate [40–42].

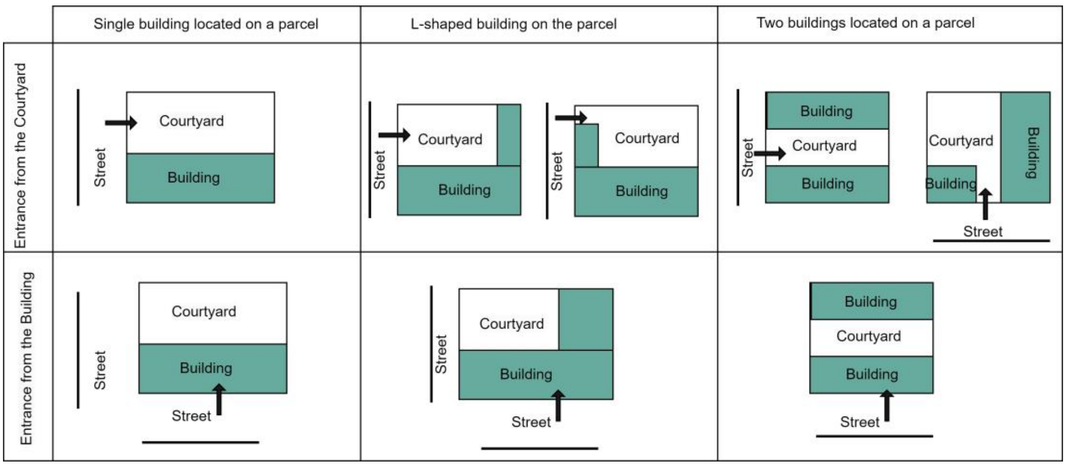


Figure 2. Gaziantep courtyard house building typology.

2.2. Energy Performance Analysis and Circularity

A dynamic simulation using the DesignBuilder tool was used to analyze the energy performance of the historical building in two phases of its life cycle: during the first stage of construction and the current state of the building. The energy performance analysis consists of heating, cooling, and lighting as major sources of energy consumption of the building. The effect of a change of function of the building throughout the life cycle is addressed. Meteonorm is a global database that provides both historical and typical meteorological year weather data. It covers most Middle Eastern countries and can generate specific historical weather files based on actual recorded data.

This software allows for the customization of weather files based on specific locations and years [43]. Meteonorm 8 was used to develop historical weather data based on the current weather conditions.

2.3. CIBSE TM59 and PMV Fanger Model Analysis

The CIBSE TM59 [44] provides a comprehensive methodology for assessing the risk of overheating in naturally ventilated buildings, particularly focusing on residential structures. This guidance aims to ensure thermal comfort for occupants while minimizing the reliance on mechanical cooling systems, aligning with sustainable design principles. TM59 establishes two primary criteria, denoted as Criteria A and B, to evaluate overheating risk. Criteria A evaluates the number of hours during which indoor temperatures exceed a specified threshold, typically set at 28 °C, within key living spaces like living rooms, kitchens, and bedrooms. On the other hand, Criteria B considers the extent to which indoor temperatures surpass the outdoor ambient temperature by a predefined margin, typically around 5 °C, during occupied hours [44].

The Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) model, developed by Ole Fanger, is a widely used method for assessing thermal comfort in built environments. The PMV model predicts the mean thermal sensation vote of a large group of people on a seven-point thermal sensation scale, ranging from cold (−3) to hot (+3). It takes into account six primary factors: air temperature, mean radiant temperature, air velocity, humidity, clothing insulation, and metabolic rate. The PPD index, derived from the PMV, estimates the percentage of people likely to feel thermally uncomfortable in a given environment. This model is fundamental in HVAC design and environmental engineering as it provides a quantitative basis for creating indoor environments that enhance occupant comfort and productivity. According to ASHRAE Standard 55, the PMV-PPD model is integral to defining acceptable thermal conditions for human occupancy, emphasizing its importance in ensuring energy efficiency and occupant well-being [45].

3. Results

3.1. Defining the Phases of Development

Gaziantep traditional houses have unique typologies. The general characteristics of this typology are that the buildings are designed with high courtyard walls, the buildings are in the courtyard, and there is a use of traditional materials. This study uses the building "Aynur Hanım Konağı" to represent this typology. The building has been changed throughout its life cycle due to the user's needs, the development of technologies, the aesthetic perception, and other parameters. For these reasons, "Aynur Hanım Konağı" is analyzed in five chronological stages: the first phase (1890–1940) is named "1. Restitution", the second phase (1940–1970) is named "2. Restitution", the third phase (1970–2005) is named "3. Restitution", with the survey of the building taken in 2005 and it being subsequently restored (Figure 3). The changes of the building over time includes the architectural plan, structural materials, building elements, the number of users, and the number of buildings in the courtyard.

Aynur Hanım konağı was built in 1890. The building originally consisted of three blocks: an accommodation building, a coal cellar, and a bathroom, connected by a courtyard. The building named BN1 is the building constructed by the users for accommodation purposes. The outer walls of the building were constructed of masonry made of keymık stone, which is the traditional construction material of Gaziantep, and the inner walls were built of Havara stone. According to the literature, it has been proven that the mechanical properties of Keymık and Havara stone are similar to Urfa stone [46]. The wall thickness between the Keymık and Havara stone was filled with rubble, with a total wall thickness of 64 cm. Traditional Gaziantep stones are 27 cm in depth, defined as nine fingers by local people, 27 cm wide, and vary in length. This measurement system is the determinant of the door and window sizes on the facades. The floors of the building were constructed as traditional wooden beam floors. The roof is a wooden construction hipped roof, and the roof cover is Marseille-type tiles.

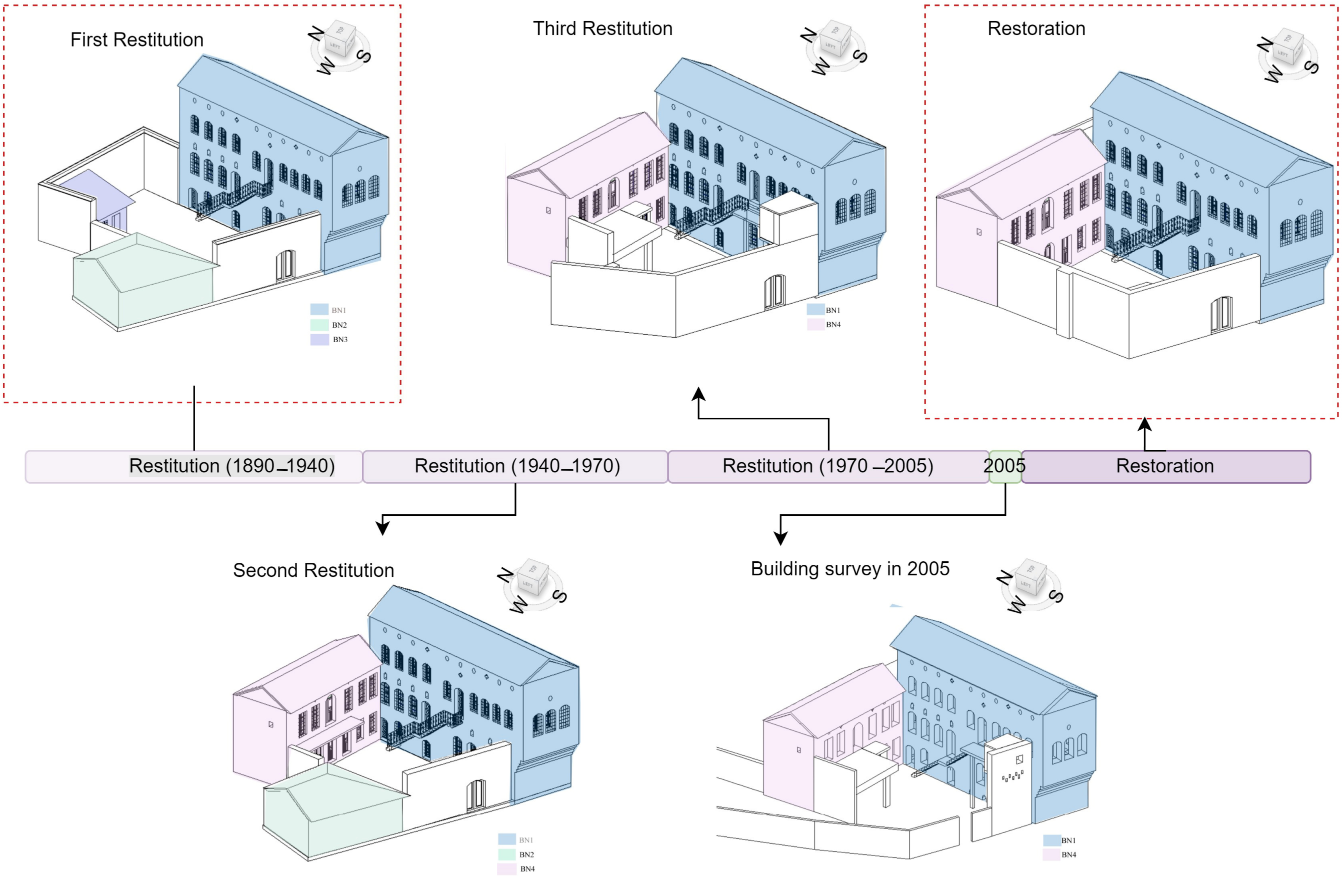


Figure 3. Building restitution, survey, and restoration processes.

In the buildings added after the first construction of the building, it is seen that the windows are concentrated on the facades facing the inner courtyard, that is, on the south facade. This is an explanation of Gaziantep's cultural perception of privacy. When the facades of the buildings in the parcel are examined, the windows of the first building are arched, while the windows of the latter building are flat. Due to the technical requirements of the material used at that time, regardless of the shape of the window, the width of the window is approximately 80–84 cm, while the depth of the space where the window is placed in the wall is 27 cm. In addition to normal windows, Gaziantep houses also have ventilation windows. A typical value for older, unsealed buildings might be around 5.0 to 7.0 ACH for housing units' spaces of heavyweight construction [47]. The assumption of infiltration rate for the restitution building is 6.00 ACH, following the Turkish Energy Performance in Buildings Regulation (BEP TR). The geometry of the ventilation windows can be different shapes, according to the beliefs and aesthetic perceptions of the user. These ventilation windows are located at a higher level than normal windows and are smaller in size than normal windows. Doors in Gaziantep houses are designed in a way to complete the geometry of the windows. If the windows are arched, the doors are arched; if the windows are flat, the doors are also built flat. One of the elements that make up the aesthetic perception in Gaziantep houses is the specially shaped wrought iron on the stairs, in front of the windows, or on the door tops (Figure 4).

Figure 4. The view of Aynur Hanım mansion around the 1900s and in 2024.

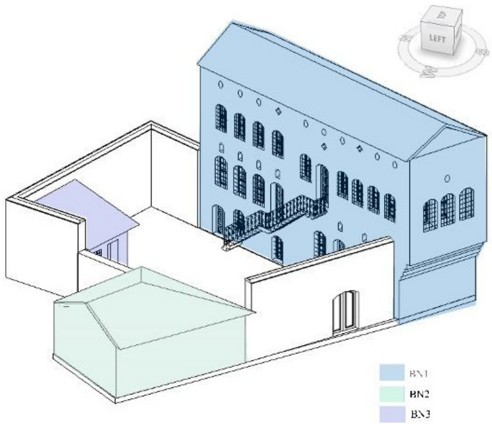
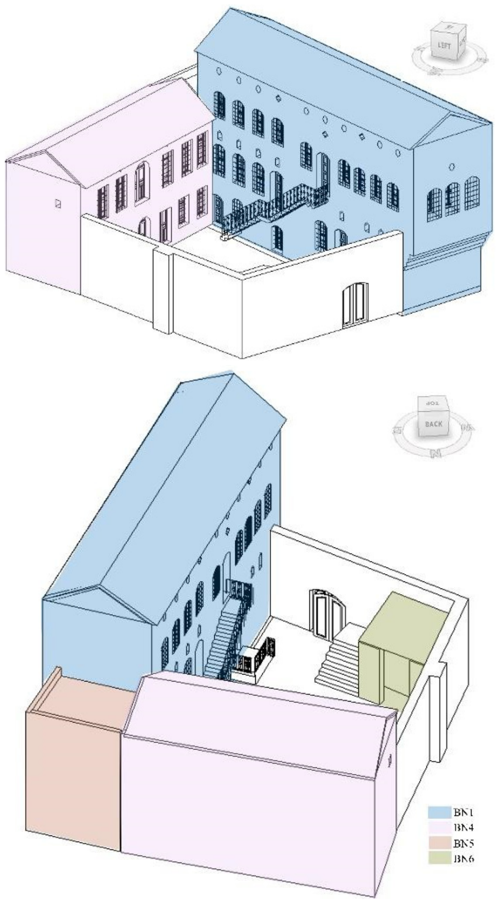
Gaziantep has a culturally extended family structure. In this extended family model, when the male children of the house get married, they live with their families. When the houses cannot accommodate the number of people, a new building is added within the same parcel. Traces of a similar process (extended family) are seen in the building used in the study. In other words, new buildings were added to the existing building over time, and the buildings within the parcel were expanded. In 1940, a new building was added to the parcel. The wall materials are mostly original; there are differences from the first building in terms of flooring material, staircase position, and door and window geometry. This situation can be associated with the construction techniques that developed over time.

Between 1970 and 2000, Gaziantep received a lot of migrants due to socio-economic conditions, trade, urban growth, demographics, household factors, etc. [44]. This situation also affected the architectural structure of the city. In order to meet the functional needs, uncontrolled and unconscious additions were applied to the existing buildings. Uncontrolled and unconscious additions are additions made without the permission of local administrations, disrupting the traditional building appearance, with materials different from the traditional building materials. Aynur Hanım Konağı was also affected by this change. From the third period onwards, the building underwent a serious transformation process, and unqualified additions were made to the building. As presented in Figure 3, some parts of the building were demolished; the walls delimiting the courtyard were demolished, and a wall was built with rubble stones instead.

In the restoration project, it was aimed to preserve the original values of the building in terms of design, architectural features, construction system, and material use, and the study was based on the third-period restitution data. It was aimed to preserve the original material in situ, and as a principle of restoration, it was the intention not to intervene more than necessary. However, in cases of necessity, the deteriorated original material was replaced with new material. As can be seen in Figure 3, in the restoration project of the building, the unqualified additions to the building in the historical process and that negatively affected the building in terms of visual and structural aspects were removed. Architectural elements such as doors, windows, rickety workmanship, and wrought iron were added in accordance with the original.

Although the transformations of the building are basically divided into five periods, in this study the first construction phase of Aynur Hanım Konagi and its post-restoration status were evaluated (Table 1). The first phase of Aynur Hanım Konagi consists of three blocks: BN1 accommodation, BN2 bathroom, and BN3 storage (Table 1). There is no heating and cooling in the buildings used for bathroom and storage. The building built for accommodation is heated with coal, and a natural ventilation method is used for cooling. When the window orientations are analyzed, the window density on the surface facing the courtyard is higher than the other directions. When analyzed in terms of window openings, it is seen that the proportion of windows on the west facade is 20%, on the south facade 8%, and on the east facade 6%, while the north facade consists of walls without windows.

Table 1. The first construction and restoration of Aynur Hanım Konagi.

Phases and Dates		Characteristics and Changes
Aynur Hanım Konağı first Restitution		Aynur Hanım Konağı was built in 1890. The building consists of 3 blocks: BN1 accommodation, BN2 bathroom and BN3 storage. The building material of all the buildings is the traditional building material of Havara and Keymik stone.
Aynur Hanım Konağı final restoration		BN2 and BN3 blocks do not exist in the current state of the hotel. BN4, BN5, and BN6 structures were added during the restoration of the building. The walls are made of Keymik and Havara stone. But the floors were built in concrete. The BN4 is a hotel, BN5 is used as a bathroom with access from the hotel rooms, and BN6 is used as a common toilet.

When the condition of the building after the restoration is examined, it is seen that it was aimed to preserve the original material in situ, and as a principle of restoration, it was the intention not to intervene more than necessary. However, in cases of necessity, the deteriorated original material was replaced with new material. The unqualified additions that were added to the building during the historical process and that negatively affected the building visually and structurally were removed. Architectural elements like doors, windows, rotten workmanship, and wrought iron were added as per the original. The first building is faithful to the original structure, and there is no change in the material and geometry of the building components. For the other accommodation structure added, it is seen that the walls are similar to the first structure and the floor is constructed of reinforced concrete. When the window sizes of the later building are evaluated, it is seen that the windows are concentrated in the courtyard direction. Thus, 19% of the south facade and 1% of the west facade consists of windows, while the north and east facades are spaceless. In all processes after the restoration, heating is done with natural gas, and cooling is done with air conditioning, with electricity as an energy source.

3.2. Evaluation of Thermal Comfort, Energy, and Carbon Performance

Table 2 outlines the building materials used in the construction of Gaziantep building components, considering the material's energy characteristics, such as heat conduction coefficient and heat capacity and density.

Table 2. Building construction materials used in Gaziantep.

ID	Material	Density (g/m^3)	Heat Conduction Coefficient (W/mK)	Heat Capacity	Thickness	Resource
M-01	Iron	7870	8.020	3.520		[48]
M-02	Urfa Stone	2570	1.420	1.410	64 cm	[49]
M-03	Marble	2360	3.140	8.700	4 cm	[50]
M-04	Limestone	2600	2.100	9.200	6 cm	[50]
M-05	Wood (Poplar)	4100	0.088	0.226	7.5 cm	[51]
M-06	Glass (Single clear)	2500	1.160	7.950	3 mm	[52]
M-07	Roof Tile	1900	0.840	8.000	12 cm	[52]
M-08	White plaster	1682	0.819	8.370	3 cm	[52]
M-09	Black plaster	1726	0.836	8.670	X	[53]
M-10	Lime Plaster	1820	0.800	8.639	X	[54]
M-11	Brick	2025	0.600	8.000	X	[50]
M-12	Zinc coating	7140	1.160	3.890	X	[52]
M-13	Bulk Concrete	2100	1.400	8.400	X	[52]
M-14	Soil	2180	1.490	8.400	X	[49]

The development of building materials for each building component of wall, floor, and windows throughout the life cycle of the building during the four main development phases is presented in Table 3. The BN1, BN2, and BN3, representing the first phase of restitution, and BN1, BN4, BN5, and BN6, of the restoration phase, are analyzed to compare the difference of energy performance of the building in two periods and using different construction materials and mechanical energy systems for heating, cooling, and lighting.

Heating represents the predominant energy consumption component across both phases, constituting the highest proportion of total energy use. This finding holds true despite the absence of cooling energy requirements in the initial phase. However, cooling and DHW consumption significantly increase during the restoration phase compared to the restitution phase due to functional differences. In the restoration phase, the building primarily functions as a hotel, whereas in the restitution phase, it serves as a house. Additionally, mechanical systems utilizing electricity were introduced during the restoration phase.

There is a significance difference in energy consumption between the restoration and restitution phases. This reflects the difference in function and modern demands such as heating, cooling, and the increased use of electrical appliances as illustrated in Figure 5. It is seen that the energy used for DHW increased, and the lighting energy slightly decreased with reuse. The energy consumed for lighting should be higher when changing the function to a hotel. However, one of the main reasons for this decrease is that the lighting type is changed, despite the continuous use in each area of the building as a hotel. It is thought that this decreasing amount of energy can be further reduced with developing technologies.

Table 3. Building construction materials and energy systems in Gaziantep in the DesignBuilder model.

1. Restitution (1890–1940)				**4. Restoration**			
Block	**BN1**	**BN2**	**BN3**	**BN1**	**BN4**	**BN5**	**BN6**
Function	Home	Storage	WC	Hotel	Hotel	Bathroom	Toilet
Operating schedule	Operating hours: 24 h	Factor 1		Operating hours:24 h		Factor 0.50	
Material of walls	M-01 M-02	M-01 M-02	M-01 M-02	M-01 M-02	M-01 M-02	M-01 M-02	M-01 M-02
Material of windows	M-05 M-06	M-05 M-06	M-05 M-06	M-05 M-06	M-05 M-06	M-05 M-06	M-05 M-06
Material of floors	M-02 M-04 M-05	M-14	M-14	M-02 M-04 M-05	M-05 M-13	M-05 M-13	M-05 M-13
Material of roof	M-05 M-07	M-05 M-07	M-05 M-07	M-05 M-07	M-05 M-07	M-05 M-07	M-05 M-07
Infiltration							
HVAC	-	-	-	air-con	air-con	air-con	
Lighting	incandescent light	incandescent light	incandescent light	LED light	LED light	LED light	LED light

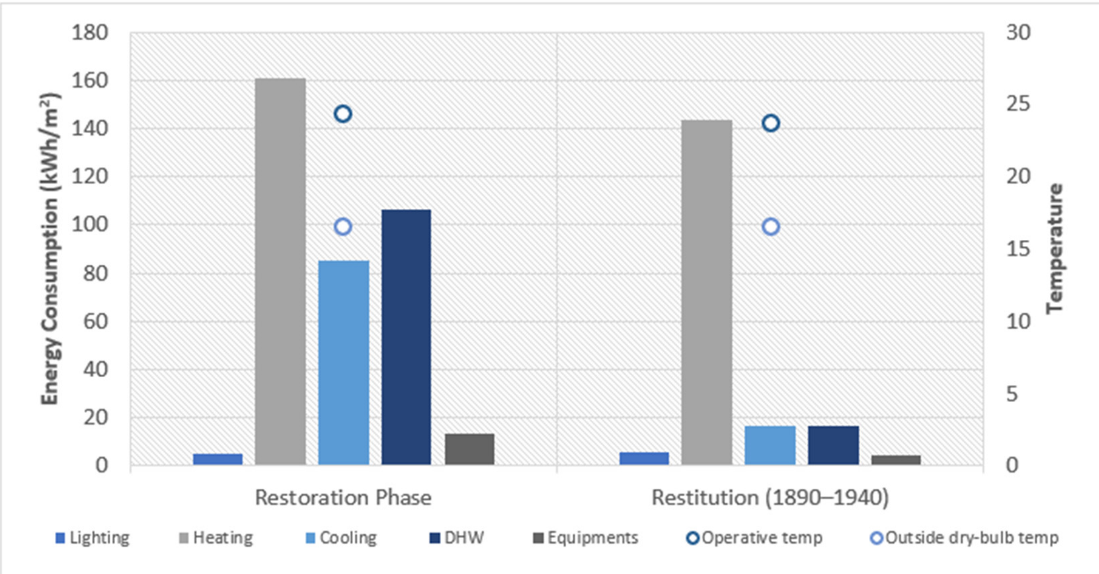


Figure 5. The analysis of annual energy use of the building in restoration and restitution phases in comparison to the outside dry-bulb temperature.

The total energy consumption disparity between the restitution (1890–1940) and restoration phases, along with the operational carbon emissions, is depicted in Figure 6. The analysis was conducted utilizing DesignBuilder software V7, with the model parameters outlined in Table 3, detailing the construction envelope specifications and energy systems employed during both operational phases. Carbon emissions were calculated based on the total energy consumption, applying the carbon emission factor derived using Equation (1).

$$\textit{Carbon emissions}\ (\mathrm{kg\ CO_2}) = \textit{Energy consumption}\ (\mathrm{kWh}) \times \textit{Carbon intensity}\ (\mathrm{kgCO_2/kWh}) \quad (1)$$

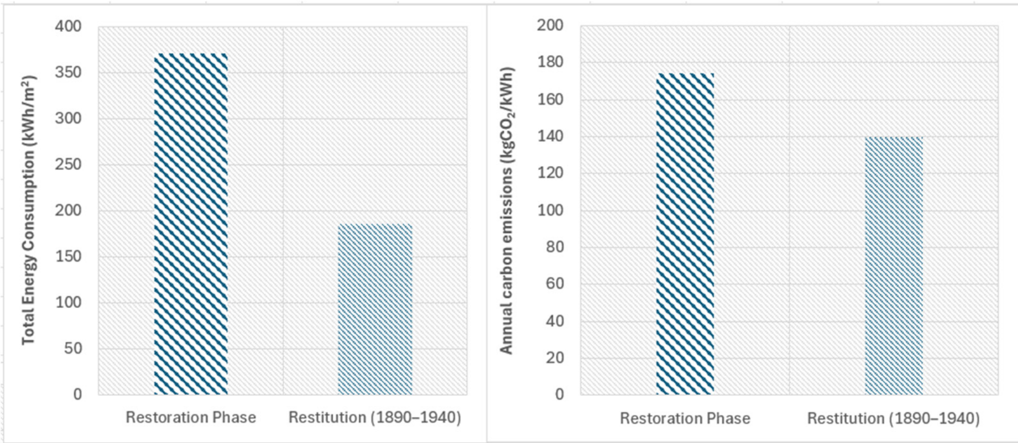


Figure 6. A comparison of energy use and carbon emissions between restitution (1890–1940) and restoration phases.

Figure 6 illustrates a notable contrast in energy consumption, approximately 200 kWh/m^2, compared to the difference in carbon emissions, which is approximately 30 kgCO_2/kWhm^2, between the restitution and restoration phases. The reduced discrepancy in carbon emissions can be attributed to the carbon emission factor of the fuels employed for operational purposes. During the restitution period, coal exhibited a carbon emission factor of 0.8 kgCO_2/kWh, whereas electricity demonstrated a lower factor of 0.4 kgCO_2/kWh.

For the restoration phase, an assessment of thermal comfort was conducted utilizing the Fanger Predicted Percentage of Dissatisfied (PPD) and Fanger Predicted Mean Vote (PMV). Figure 7 illustrates the findings, indicating mild weather conditions from May to October (20%–27%). Conversely, a PMV value of -0.5 to -1 indicates that the predicted thermal sensation is slightly cool in the building during the months from November to April in wintertime.

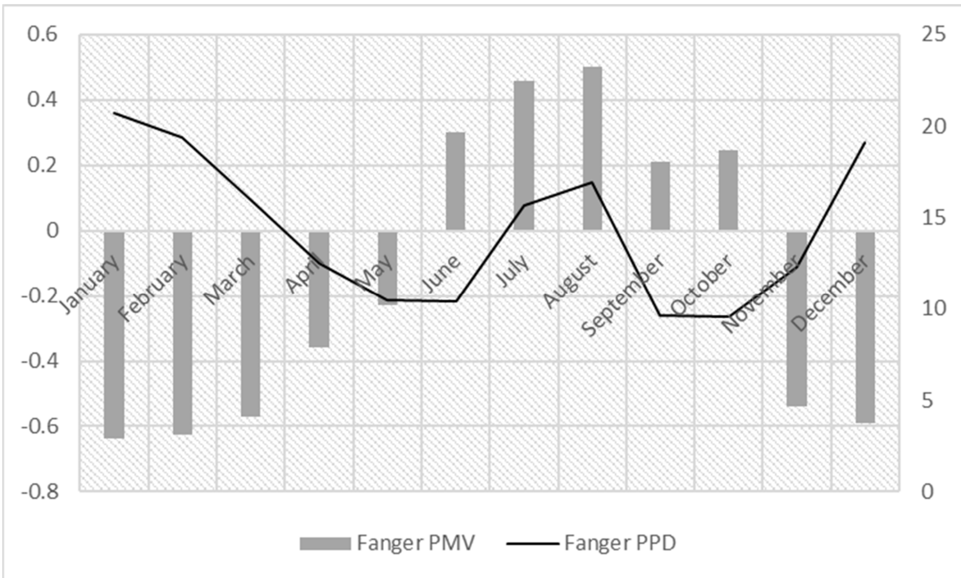
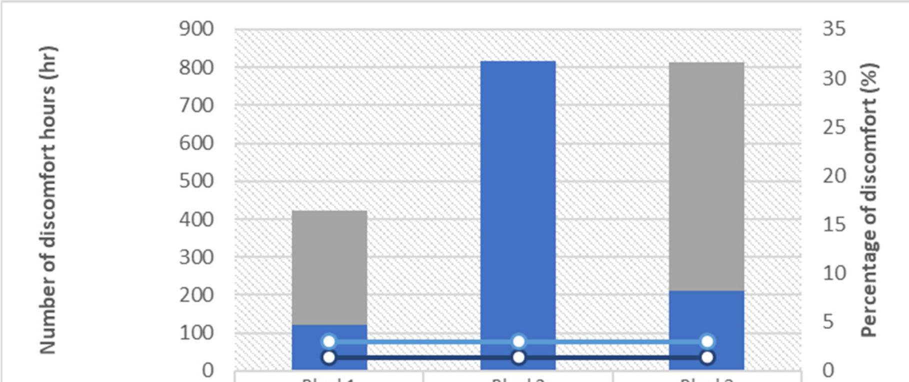


Figure 7. Thermal comfort analysis of the building in the restoration phase.

It is important to note that the PMV model predicts the average thermal sensation of a population and does not account for individual preferences. Some people might find conditions with a PMV of -0.5 comfortable, while others might prefer warmer conditions. Additionally, the model assumes a standard person with average clothing and activity levels; deviations from these standards can affect individual thermal comfort.

During the restitution phase (1890–1940), the building relies on natural ventilation without the use of mechanical cooling systems. Thermal comfort analysis is conducted using CIBSE TM59. Figure 8 illustrates the results of this analysis, indicating that all three zones fail to meet thermal comfort Criteria A and B. Among the zones, Zone A exhibits the highest level of discomfort, characterized by elevated discomfort hours and a substantial percentage of discomfort. Block 1, Block 2, and Block 3 represent BN1, BN2, and BN3, respectively. Criterion B is used for the thermal comfort analysis of the bedrooms; this is the reason why Block 2 (BN2) is analyzed following Criterion A and shows a high level of discomfort.



	Block1	Block2	Block3
Criterion B (hr)	423.3	767.5	813
Criterion A (%)	4.77	31.74	8.14
Criterion B	36	36	36
Criterion A	3	3	3

Figure 8. Thermal comfort analysis in restitution phase (1890–1940) using TM59 ASHRAE.

Figure 9 provides a visualization of the total discomfort hours experienced. Interestingly, there is a greater number of discomfort hours observed during summer compared to winter, both in the restitution phase (1890–1940) and the restoration phase. Notably, the restitution phase exhibits higher discomfort hours throughout the entire year compared to the restoration phase due to the increase of outdoor temperature as a result of global climate change. The summer discomfort hours are slightly higher than the winter discomfort hours due to the severe hot climate conditions in summer.

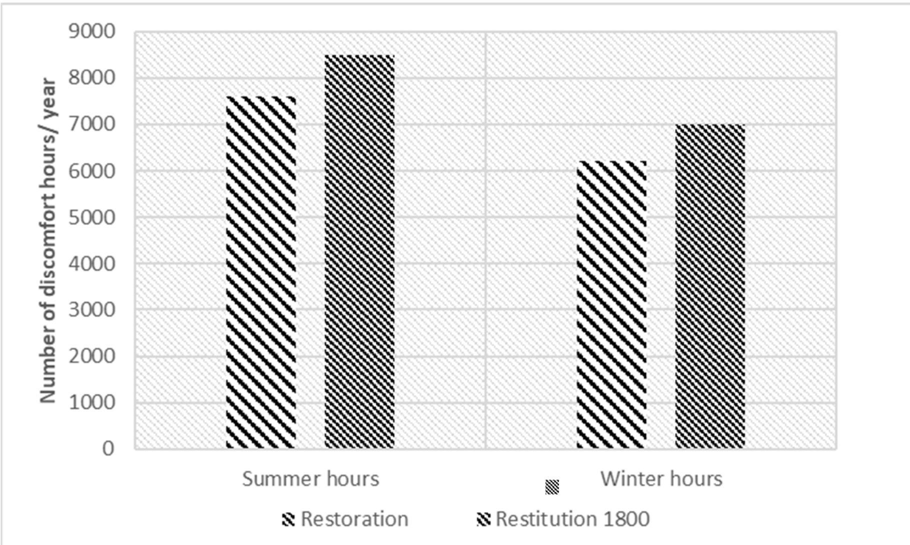


Figure 9. Time the building is not thermally comfortable based on ASHRAE 55–2004 during restoration phase and on TM59 in restitution (1890–1940) phase.

For this reason, these buildings developed many passive strategies, such as caves and courtyards, to cope with the hot weather at the time they were built. Today, however, these features are not sufficient for the thermal comfort of the users with the changing conditions. Today, mechanical systems are used to provide thermal comfort.

4. Discussion

Within the scope of this study, the energy use of a building, whose first use was a house, was evaluated over time, considering its restoration and subsequent change in function. The change in energy use resulting from the change of function of a historic building in the study is striking, in line with the climate change over time.

The utilization of dynamic thermal modelling techniques offers a valuable tool for predicting overheating risks in naturally ventilated buildings. This predictive capability empowers designers to proactively implement effective mitigation strategies aimed at enhancing thermal comfort while concurrently reducing energy consumption. Passive design measures in historic buildings [27], including natural ventilation pathways and strategic placement of shading devices, emerge as pivotal strategies to temper indoor temperatures and alleviate overheating concerns. Also, thermal comfort in historic buildings plays a key role in balancing energy efficiency and heritage conservation [55].

However, the integration of mechanical systems in response to changing operational requirements and functions can lead to escalated energy demands. To counterbalance this trend, it is imperative to devise strategies aimed at curbing energy consumption associated with heating, cooling, and DHW usage. Implementing energy-efficient technologies, optimizing system operations, and incorporating renewable energy sources can effectively mitigate these heightened energy demands, fostering sustainability and reducing environmental impacts.

In the context of historical buildings, adopting a circular economy approach holds immense potential for promoting sustainable reuse and preservation. Strategies such as adaptive reuse, material recycling, and heritage conservation contribute to minimizing waste generation and environmental degradation while preserving cultural heritage. By leveraging circularity principles, historical buildings can be transformed into vibrant, functional spaces that meet contemporary needs without compromising their intrinsic value and historical significance [44]. Embracing circularity not only enhances the sustainability credentials of historical building projects but also fosters resilience and longevity, ensuring their continued relevance and contribution to the built environment.

By employing dynamic thermal modeling techniques, TM59 facilitates the prediction of overheating risk and enables designers to implement appropriate mitigation strategies, such as passive design measures and shading devices, to enhance thermal comfort and reduce energy consumption in naturally ventilated buildings. On the other hand, as determined in the analyses of this building, the discomfort hours intensified in the summer, which led the users to design passive strategies for thermal comfort [27]. In addition, although the discomfort hours seem to be higher in summer periods, one study [55] shows that the perceived thermal comfort of the users in the same region is higher in the summer period due to the passive strategies that these historical houses use. This shows that technical solutions and approaches will not be sufficient for these buildings; the perceptions and approaches of historical building users should also be a parameter that is included in this process.

The case study shows that energy and sustainability concepts are not taken into consideration in the restorations and retrofitting of historical buildings. There are currently unclear design guidelines governing the retrofitting of historic structures in accordance with their historic values. The fact that every heritage structure is unique is the primary cause of this lack of clarity. Different components and values are involved in each case, and they need to be assessed and protected. As a result, energy retrofit activities for buildings with historical significance should protect both tangible and intangible heritage values in addition to achieving the targeted level of energy efficiency [56]. This study emphasizes that historic buildings need to be sustainable, taking into account the heritage values of the building, the materials and techniques used in construction, and the methods for energy conservation during renovation and retrofitting. Ignoring energy and comfort data reduces the usability of historic buildings and causes them to become unusable in the future. Unused buildings, on the other hand, become obsolete over time and deteriorate due to a lack of maintenance and environmental impacts. This results in restoration works not achieving their purpose. The reuse of historic buildings, integrated with their potential passive strategies, provides energy efficiency [57]. Consequently, in a successful heritage conservation process, heritage values and energy actions should be considered in an integrated manner.

5. Conclusions and Future Work

In conclusion, the analysis reveals significant insights into thermal comfort, energy consumption, and carbon emissions across the restitution and restoration phases of the building. Notably, the analysis demonstrates a higher occurrence of discomfort hours during summers compared to winters, consistent across both phases, with the restitution phase exhibiting higher discomfort levels throughout the year. During the restitution phase, reliance on natural ventilation necessitates compliance with the rigorous guidelines set by the CIBSE TM59, emphasizing sustainable design principles to ensure occupant comfort. However, despite efforts to mitigate overheating risks, all zones fail to meet criteria A and B, particularly Zone A, marked by elevated discomfort levels. In the restoration phase, thermal comfort assessment using Fanger's methods reveals mild conditions during certain months but discomfort during others. Furthermore, energy consumption, predominantly for heating, increases significantly during the restoration phase, attributed to the building's conversion into a hotel and the use of mechanical systems. This transition also impacts carbon emissions, indicating a notable disparity in emissions per unit of energy consumed between the two phases. Overall, these findings underscore the complex interplay between building function, thermal comfort, energy usage, and environmental impact, informing future design strategies for sustainable and comfortable living environments.

Considering the results of the analysis, the evaluation of energy and thermal comfort parameters in the restoration, reuse, change of function, or repair of historical buildings is as important as the preservation of their original values for future use.

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References

1. Anaç, M.; Arun, G. HBIM destekli arşiv modeli. *J. Fac. Eng. Archit. Gazi Univ.* **2024**, *39*, 443–459. [CrossRef]
2. UNEP. *Emissions Gap Report 2018*; United Nations Environment Programme: Nairobi, Kenya, 2018.
3. Atmaca, A.; Atmaca, N. Comparative life cycle energy and cost analysis of post-disaster temporary housings. *Appl. Energy* **2016**, *171*, 429–443. [CrossRef]
4. Houghton, J.T. Climate change and sustainable energy. *Weather* **2006**, *60*, 179–785. [CrossRef]
5. Moran, F.; Blight, T.; Natarajan, S.; Shea, A. The use of Passive House Planning Package to reduce energy use and CO_2 emissions in historic dwellings. *Energy Build.* **2014**, *75*, 216–227. [CrossRef]
6. TUİK. *Bina ve Konut Nitelikleri Araştırması*; TUİK: Çankaya, Türkiye, 2021. Available online: https://data.tuik.gov.tr/Bulten/Index?p=Survey-on-Building-and-Dwelling-Characteristics-2021-45870 (accessed on 20 August 2024).
7. *Heritage Count: There's No Place Like Old Homes-Re-Use and Recycle to Reduce Carbon*; Historic England Archive: Swindon, UK, 2020.

8. Martínez-Molina, A.; Tort-Ausina, I.; Cho, S.; Vivancos, J.-L. Energy efficiency and thermal comfort in historic buildings: A review. *Renew. Sustain. Energy Rev.* **2016**, *61*, 70–85. [CrossRef]
9. IEA. Available online: https://www.iea.org/ (accessed on 25 May 2024).
10. Şahin, C.D.; Arsan, Z.D.; Tunçoku, S.S.; Broström, T.; Akkurt, G.G. A transdisciplinary approach on the energy efficient retrofitting of a historic building in the Aegean Region of Turkey. *Energy Build.* **2015**, *96*, 128–139. [CrossRef]
11. Todorović, M.S.; Ećim-Đurić, O.; Nikolić, S.; Ristić, S.; Polić-Radovanović, S. Historic building's holistic and sustainable deep energy refurbishment via BPS, energy efficiency and renewable energy—A case study. *Energy Build.* **2015**, *35*, 130–137. [CrossRef]
12. Webb, A.L. Energy retrofits in historic and traditional buildings: A review of problems and methods. *Renew. Sustain. Energy Rev.* **2017**, *77*, 748–759. [CrossRef]
13. Changeworks. *Energy Heritage: A Guide to Improving Energy Efficiency in Traditional and Historic Homes*; Changeworks: Edinburgh, UK, 2008.
14. Lidelöw, S.; Örn, T.; Luciani, A.; Rizzo, A. Energy-efficiency measures for heritage buildings: A literature review. *Sustain. Cities Soc.* **2019**, *45*, 231–242.
15. Plevoets, B.; Cleempoel, K.V. Adaptive Reuse of the Built Heritage. In *Concepts and Cases of an Emerging Discipline*; Routledge: London, UK, 2019. [CrossRef]
16. Bullen, P.A.; Love, P.E. Adaptive reuse of heritage buildings. *Struct. Surv.* **2011**, *19*, 411–421.
17. Yung, E.H.; Chan, E.H. Implementation challenges to the adaptive reuse of heritage buildings: Towards the goals of sustainable, low carbon cities. *Habitat Int.* **2012**, *36*, 352–361. [CrossRef]
18. Mısırlısoy, D.; Günçe, K. Adaptive reuse strategies for heritage buildings: A holistic approach. *Sustain. Cities Soc.* **2016**, *26*, 91–98. [CrossRef]
19. Rock. Guidelines for sustainable adaptive reuse for CH. *Regeneration and Optimization of Cultural Heritage in Creative and Knowledge Cities.* 2017. Available online: https://www.fuelpovertylibrary.info/sites/default/files/EAGA41%20(2008)%20GUIDANCE%20Energy%20Heritage%20-%20A%20guide%20to%20improving%20energy%20efficiency%20in%20traditional%20and%20historic%20buildings.pdf (accessed on 25 May 2024).
20. Bakan, M.K.; Fouseki, K.; Altamirano, H. Heritage conservation and energy efficiency in adaptive reuse projects the case of Gaziantep, Türkiye. *J. Cult. Herit. Menag. Sustain. Dev.* 2024, *ahead-of-print*. [CrossRef]
21. Hegazi, Y.S.; Shalaby, H.A.; Mohamed, M.A.A. Adaptive Reuse Decisions for Historic Buildings in Relation to Energy Efficiency and Thermal Comfort—Cairo Citadel, a Case Study from Egypt. *Sustainability* **2021**, *13*, 10531. [CrossRef]
22. 3ENCULT. *Energy Efficiency Solutions for Historic Buildings: A Handbook*; 3ENCULT: Birkhäuser, Basel, 2015.
23. EFFESUS Consortium. *Energy Efficiency in European Historic Urban Districts: A Practical Guidance*; EFFESUS Consortium, Fraunhofer Center for International Management and Knowledge Economy: Leipzig, Germany, 2016. Available online: https://www.effesus.eu/wp-content/uploads/2016/06/EFFESUS_Booklet_Final-Version (accessed on 20 August 2024).
24. *BSI Standards Publication*; EN 16883; Conservation of Cultural Heritage–Guidelines for Improving the Energy Performance of Historic Buildings. CEN: Brussels, Belgium, 2017.
25. May, N.; Griffiths, N. *Planning Responsible Retrofit of Traditional Buildings*; Sustainable Traditional Buildings Alliance (STBA): London, UK, 2015.
26. Bakan, M.K.; Altamirano, H.; Fouseki, K. The effect of underground chambers on the moisture balance of historical buildings in a hot and dry climate. In Proceedings of the 2nd International Conference on Moisture in Buildings 2023 (ICMB23), London, UK, 3–4 July 2023.
27. Anaç, M.; Cuce, P.M.; Cuce, E. Passive sustainability strategies in traditional Gaziantep residences: A critical report on historical development. *Int. J. Low-Carbon Technol.* **2024**, *19*, 245–256. [CrossRef]
28. Fouseki, K.; Guttormsen, T.; Swensen, G. *Heritage and Sustainable Urban Transformations: Deep Cities*; Routledge: London, UK, 2019; ISBN 9780429462894.
29. *Gaziantep Valiliği, Gaziantep İli Kültür Envanteri*; Merinos yayıncılık: Gaziantep, Türkiye, 2005.
30. T. S. M. Service. Extreme Maximum, Minimum and Average Temperatures Measured in Long Period (°C). 2024. Available online: https://www.mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=undefined&m=GAZIANTEP (accessed on 24 May 2024).
31. Weather and Climate. 2023. Available online: https://weatherandclimate.com/turkey/gaziantep (accessed on 24 May 2024).
32. Anaç, M.; Arun, G. HBIM supported archive model. *J. Fac. Eng. Archit. Gazi Univ.* **2024**, *39*, 443–469.
33. Günaydın, A.S.; Altunkasa, M. Tarihî kent merkezlerinin koruma ve geliştirme stratejilerinin belirlenmesi: Gaziantep örneği. *Bingöl Üniversitesi Sos. Bilim. Enstitüsü Derg.* **2019**, *9*, 51–70. [CrossRef]
34. Günel, E.; Çolak, A. Mimarlıkta bağlam ve bağlam kriterleri; Gaziantep Bey mahallesi geleneksel evleri örneği. *Çü Fen Ve Mühendislik Bilim. Derg.* **2019**, *38*, 54–66.
35. Kasapbaşı, E. *Gaziantep 1960–1980 Dönemi Kent Konutu Mekan Kurgusunun Analizi*; Çukurova Üniversity: Adana, Türkiye, 2017.
36. Kuban, D. *Türkiye'de Kentsel Koruma Kent Tarihleri ve Koruma Yöntemleri*; Tarih Vakfı Yurt Yayınları: İstanbul, Türkiye, 2021.
37. Akın, G. *Doğu ve Güneydoğu Anadoludaki Tarihsel Ev Tiplerinde Anlam*; Istanbul Technical University: Istanbul, Türkiye, 1984.
38. Kanalıcı, A.K. *Geleneksel Gaziantep Evleri Yapı Üretim Analizi*; Near East University: Lefkoşa, Cyprus, 2012.
39. Yıldırıö, E.G.; Çağdaş, G. Gaziantep Geleneksel Mimari Dokusunun Sosyo-Kültürel Bağlamda. *Gaziantep Univ. J. Soc. Sci.* **2018**, *17*, 508–532.

40. Deringöl, T. *Sürdürülebilir Çağdaş Konut Tasarımında Gaziantep'in Yerel Mimarisinden Öğrenilenler*; Selcuk University: Konya, Türkiye, 2015.
41. Ünal, Z. *Bilgisayar Destekli Tarihi Çevre Koruma Bilgi Sistemi Oluşturulması ve Gaziantep Kentsel Sit Alanında Örneklenmesi*; Yıldız Technical University: Istanbul, Türkiye, 1998.
42. Atalar, A. *Osmanlı Dönemi Antep Evleri*; Merinos: Gaziantep, Türkiye, 2004.
43. Meteonorm. Introduction to Meteonorm. Available online: https://meteonorm.com/en/ (accessed on 15 September 2024).
44. CIBSE, TM59. *Design Methodology for the Assessment of Overheating Risk in Homes*. 2017. Available online: https://www.cibse.org/knowledge-research/knowledge-portal/technical-memorandum-59-design-methodology-for-the-assessment-of-overheating-risk-in-homes (accessed on 19 July 2024).
45. *ANSI/ASHRAE Standard 55-2017*; Thermal Enviromental Conditions for Human Occupancy. American Society of Heating, Refrigerating and Air-Conditioning Engineers, American National Standards Institute: Atlanta, GA, USA, 2017.
46. Kürşat, B. Gaziantep'in Geleneksel Taş Evlerinde Enerji Verimliliği. Master Thesis, Hasan Kalyoncu University, Gaziantep, Türkiye, 2023.
47. Thompson, S. *Impacts of Variable Air Infiltration Rates and Insulation Installation on Residential Energy Performance*; Sustainability House: Edwardstown, Australia, 2013.
48. Çengel, Y. *Heat Transfer: A Practical Approach*; McGraw-Hill: New York, NY, USA, 1998; pp. 177–192, ISBN 0-07-115223-7.
49. Demirbas, M.F. Thermal energy storage and phase-change materials: An overview. *Energy Sources Part B Econ. Plan. Policy* **2006**, *1*, 85–95. [CrossRef]
50. Durmuş, G.; Görhan, G. Doğal Taş Plakaların Isıl İletkenlik Bakımından Termografik Görüntülerinin İncelenmesi. *Selcuk Univ. J. Eng. Sci.* **2009**, *8*, 48–57.
51. Bozkurt, Y. Ağaç malzeme ve ısı münasebetleri. *J. Fac. For. Istanb. Univ.* **2014**, 73–88.
52. Materials for Thermal Calculation Property Tables and Charts. 2016. Available online: https://cecs.wright.edu/people/faculty/sthomas/htappendix01.pdf (accessed on 25 May 2024).
53. IZODER, Izoder TS 825 Hesap Programı, Türkiye. 2007. Available online: https://www.izoder.org.tr/hesap-makinesi/ts_825_yardim.pdf (accessed on 25 May 2024).
54. Walker, R.; Pavía, S. Thermal and hygric properties of insulation materials suitable for historic fabrics. In Proceedings of the III International Congress on Construction and Building Research, Madrid, Spain, 14–16 December 2015.
55. Bakan, M.K.; Fouseki, K.; Altamirano, H. Investigating the Role of Thermal Comfort Perception on Negotiating Heritage Conservation and Energy Efficiency Decisions through System Dynamics. *Buildings* **2024**, *14*, 1800. [CrossRef]
56. Kyritsi, E.; Philokyprou, M.; Kyriakidis, A.; Michael, A.; Michopoulos, A. Energy retrofitting of heritage buildings: An integrated methodology. *IOP Conf. Ser. Earth Environ. Sci.* **2023**, *1196*, 012108. [CrossRef]
57. Balçık, S.; Yamaçlı, R. Mimarlık Mirası Yapıların İşlevlendirilmesi ve Enerji Verimliliği. *Inonu Univ. J. Art Des.* **2022**, *12*, 29–40.