

## Article

# An Approach to Identifying Factors Affecting Residential Energy Consumption at the Urban Block Scale: A Case Study of Gaziantep

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## Abstract

Previous studies on building energy performance have focused on single buildings or theoretical scenarios, remaining largely at the building scale and emphasizing envelope parameters. This study addresses this gap by systematically examining morphological parameters at the urban block scale through a five-step framework derived from the historical zoning evolution of Gaziantep (Turkiye), a city in a hot-dry climate. Four representative neighborhoods, reflecting different planning periods, were modeled in DesignBuilder v6.1 under a standardized envelope defined by national regulations. The analysis considered building orientation (15° vs. 45°), number of storeys (5–15), inter-building distance, and number of apartments per floor. Simulation results indicate that cooling energy demand is significantly higher than heating, with potential savings of up to 22% in total energy consumption depending on urban fabric parameters. The Alleben neighborhood, characterized by the oldest planned fabric, consumed 30% less cooling energy compared to the other regions. Orientation alone increased cooling demand by up to 12%. At the same time, compact urban forms reduced loads through mutual shading, while higher apartments per floor increased energy use due to the larger façade area and internal gains. By linking historical zoning evolution with block-scale simulations, this study provides a transferable framework that highlights the decisive role of planning parameters and offers practical guidance for climate-sensitive urban development.

**Keywords:** sustainable architecture; housing design; energy simulation; DesignBuilder; sustainable development



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## 1. Introduction

Population growth has led to the expansion of urban areas globally [1]. The desire for collective living drives people to cities in search of resources, opportunities, and social connections. Cities have a positive impact on human life and the economy, but they also pose threats to land, the environment, resources, and the climate [2]. Cities consume 70% of the world's energy and are a significant source of resource use and greenhouse gas emissions [3]. By the 2010s, over half of the world's population lived in cities [4]. By 2050, it is estimated that 70% of the population will live in and around cities [5,6].

Cities with the highest population and energy consumption are major carbon emitters [7]. City areas, covering only 3% of the globe, are responsible for 75% of carbon

emissions [2]. Energy and carbon are hard to distinguish because global energy systems rely on fossil fuels [8]. Over 80% of global energy consumption depends on fossil fuels [9]. However, the intensive use of fossil fuels poses a threat to sustainability. There is widespread support for carbon-neutral future planning [10]. Intensive energy use, carbon emissions, GHG, and fossil fuels are closely related and have similar impacts. The main reason for climate change is GHGs [11]. Cities and the construction sector are significant contributors to GHGs. The building sector and construction activities are challenging to mitigate. Technology advancements, urban population growth, and climate change raise comfort demands [12]. This results in higher energy consumption and triggers increased carbon emissions [13,14]. Globally, 46% of heat energy is used for heating and cooling in buildings [15], making them among the most energy-intensive activities [1].

Residential buildings are the most common in urban areas [16]. Strategies for residential buildings are crucial for energy management. The findings of this research are important for achieving sustainable development and enhancing energy efficiency. Reducing natural resource use minimizes environmental damage from buildings. Energy efficiency is a crucial indicator of the monetary value of residential buildings—energy-efficient housing benefits long-term real estate investments. Determining the design factors that affect energy consumption in residential buildings using the study's approach highlights the importance of the research.

The factors analyzed in this research relate to national and international energy policies. Although energy savings in residential buildings may be modest per unit, they can be significant on an urban and regional scale. Implementing these principles and associated legal measures will be the focus of future studies. Literature reveals that heating and cooling energy in residential buildings is a significant global energy consumer. The United Nations has established a roadmap for sustainable development, comprising 17 international goals for 2030. Two of these goals are directly related to the research findings. These are 'Goal 11: Sustainable Cities and Communities' and 'Goal 13: Climate Action' from the Sustainable Development Goals (SDGs). SDG 11 targets sustainable settlements, while SDG 13 focuses on climate change. The research outputs align with SDG 11.3 target "By 2030, enhance inclusive and sustainable urbanization. . . sustainable human settlement planning. . .". It also aligns with SDG 13 target "13.2 Integrate climate change measures into national policies, strategies and planning" [17].

Rapid and unplanned urbanization has made energy efficiency in residential buildings a significant global issue. Major savings can be achieved through passive design strategies. These strategies are explained in the methodology section. Lack of consideration for passive design strategies in housing increases energy consumption. These strategies must be tailored to the specific building type and climate. Disregarding passive design strategies due to uncontrolled urbanization can lead to increased energy consumption. This issue is the central problem of this paper. Previous studies on passive strategies and energy saving are presented later in this section. The problem indirectly leads to various issues.

This paper examines Gaziantep's historical development as the study area. The study identifies variations in urban texture within the city center through chronological analyses. The relationship between design parameters in urban fabric and energy consumption is analyzed. Energy optimization in design is predicted through the identified parameters. Energy analyses use computer simulations. Regional-scale design proposals can be applied to different settlements. The relationship between optimization and energy consumption is tested through heating and cooling energy simulations. The data will enable new research cases by modifying parameters such as building type, equipment type, and design site. Researchers can compare their results with previous data to assess consistency. The study's approach constitutes a contribution to the field.

This research aims to identify factors that affect design at the building block scale, to develop local passive design strategies for residential buildings. Five targets have been established for this purpose. These five objectives constitute the study's methodology and are explained in detail in the methods section.

This study examines the impact of layout angle, number of floors, inter-building distance, and apartments per story on energy consumption. The main finding of this study is that these parameters affect energy consumption. The combined and individual effects of these factors are the subject of future studies; this study focuses on the current situation. These design parameters are determined by local administrations at neighborhood and urban scales. Therefore, these variables should be taken into consideration when preparing zoning plans. Additionally, deviations from these parameters due to profit motives should be regulated by legal obligations.

Aksoy & Demirci [18] utilized DesignBuilder to analyze the thermal load of rural residential buildings and determined that these buildings perform more efficiently than modern houses. Rural houses have lower CO<sub>2</sub> emissions. The study does not attempt to determine the reasons for this difference. This paper explores these reasons. Ali et al. [19] conducted an analysis using DesignBuilder to assess the effects of parameters such as orientation, form, setback distance, and the height of adjacent buildings on detached houses. It has been demonstrated that setback distance and building height influence thermal comfort and natural lighting, and that energy consumption can be reduced. The method has not been tested on condominiums. Apartment buildings were assessed in this study.

Kerestecioglu et al. [20] analyzed the heating and cooling loads, as well as CO<sub>2</sub> emissions, of four residences in Istanbul using the IES VE software. They achieved a 72% reduction in heating energy, a 24% reduction in cooling energy, and a 62% reduction in CO<sub>2</sub> emissions by adjusting variables such as window-to-wall ratio, insulation, building materials, and shading elements. Performance optimizations are at the building scale; recommendations at the building block scale are excluded from the limitations. In this research, the building block scale was studied. Syed & Abdou [21] investigated the savings potential through thermal load analysis using DesignBuilder. Passive and active strategies were comparatively analyzed in the context of a residential building. A 17% reduction in annual energy consumption was observed due to factors related to building materials, roof, and insulation. The research approach should be applied at the inter-building scale within passive systems. In this paper, buildings are modeled with their immediate surroundings. Valitabar et al. [22] examined vertical shading elements in terms of view and energy consumption using Grasshopper and Ladybug software. The results demonstrated the potential for energy savings. A similar approach should be applied to shading interactions between dwellings.

Manriquez & Sills [23] simulated the annual energy loss in stilt houses on Chiloé Island, Chile, using DesignBuilder and reported a 65% potential savings in heating energy. The energy loss is attributed to air and thermal insulation. This approach should be adapted to the building block scale. Hachem-Vermette [24] measured the solar energy performance of residential buildings at the neighborhood scale using TRNSYS. The impact of adjacent structures on the energy performance of different scenarios was assessed, and an integrated design approach was developed. Factors affecting energy consumption were identified as building materials, shading elements, positioning, and road and block layout. This approach will be utilized by altering the study area. Bustamante et al. [25] used DesignBuilder to analyze the energy performance of renovation interventions in selected residences in Chile across three scenarios. The study developed strategies that provide energy savings of 13 to 33% in heating and cooling. Factors affecting energy consumption

include climate, insulation, materials, user habits, and building conditions. The study does not consider the effects on urban fabric. Caldas & Santos [26] utilized Gene\_Arch software to develop energy-efficient housing scenarios based on traditional housing strategies, concluding that a potential 60% reduction in energy consumption could be achieved by decreasing cooling demands. The study should be applied to 20th-century houses ranging from traditional to contemporary styles across different regions. Ren et al. [27] analyzed the form and orientation parameters of residences in western Sichuan, Tibet, using EnergyPlus. A 36% saving potential in heating and cooling energy was identified. A design framework was established for Western China, using optimal values from the study's findings. The parameters of this approach should be expanded and adapted for different regions. Dub & Yannas [28] examined the relationship between design factors and energy consumption in selected residences in Buenos Aires, Argentina. Using Rhino and ENVI-met software, energy conservation strategies were formulated for low- and medium-density residential areas. Parameters should be expanded and tested across various climatic zones. The examined studies are listed in Table 1 for comparison.

**Table 1.** Comparative summary of previous studies.

Study	Parameters	Tools	Scale	Focus
Aksoy & Demirci (2022) [18]	Roof, building material, door/windows, construction system	DesignBuilder	Building	A comparative analysis of traditional rural architecture and modern interventions regarding energy performance and CO <sub>2</sub> emissions.
Ali et al. (2024) [19]	Setback distances, adjacent building height, orientation, and building geometry.	DesignBuilder	Building	Examining the effects of building regulations on indoor environmental quality (IEQ) and occupant satisfaction.
Kerestecioğlu et al. (2016) [20]	Window, roof, insulation thickness, air infiltration, shading, and landscaping.	IESVE	Building	Investigating the potential for reducing heating and cooling loads through building envelope enhancements in existing residential buildings.
Valitabar et al. (2021) [22]	Vertical shading elements (angles, spacing)	Grasshopper, Ladybug (EnergyPlus, Radiance)	Room	Optimizing dynamic vertical shading systems to enhance views, visual comfort, and operational energy performance.
Hachem-Vermette (2015) [24]	Layout and road system, building form, orientation, BIPV, mutual shading, building height	EnergyPlus, Sketchup, TRNSYS	Neighborhood	Optimizing neighborhoods as holistic entities through the integrated design of solar energy-powered communities.
Ren et al. (2023) [27]	Orientation, shape, solar radiation, and latitude.	EnergyPlus	Building	Developing an optimization method for building orientation and form based on geographic and meteorological parameters.

Table 1. Cont.

Study	Parameters	Tools	Scale	Focus
Ayçam et al. (2020) [29]	Courtyard types, settlement layout, street texture/width.	DesignBuilder	Building	Investigating the applicability of traditional residential settlement patterns to contemporary housing in terms of energy performance.
Shao et al. (2022) [30]	Building orientation, insulation thickness, window width and type, and interior design temperature.	EnergyPlus + MOBO	Building	Achieving multi-objective optimization across energy consumption, thermal comfort, and economic performance.
Noohian & Mahmoudi (2023) [31]	Insulation, shading, comfort temperature, hot water, PV panel	DesignBuilder	Building	Analyzing the potential of green building strategies for reducing energy consumption and greenhouse gas emissions.
Al-Hashim et al. (2024) [32]	Construction system (materials, thermal mass), settlement density, orientation, and courtyards.	DesignBuilder	Building	Evaluating the sustainable features of traditional architecture and its efficiency in terms of thermal comfort and energy performance.
Sobhy et al. (2017) [33]	Insulation	TRNSYS.	Building	Analyzing the effects of insulation strategies on thermal behavior and energy savings.
Kaihoul et al. (2021) [34]	Envelope materials, wall thickness, courtyards, Window–Wall Ratio (WWR), shading, and orientation.	EnergyPlus	Building	Evaluating the impact of passive design strategies derived from traditional architecture on energy demand.
Zeynali et al. (2024) [35]	Orientation, central courtyard form, burial in the ground, and materials.	DesignBuilder, ClimateConsultant	Building	Analyzing how passive design techniques minimize energy consumption using courtyards and ground coupling.
Syed & Abdou (2016) [21]	Materials, roof, insulation (passive and active strategies).	DesignBuilder	Building	Comparing passive and active design strategies for near-zero energy homes (NZEHS).
Manriquez & Sills (2019) [23]	Air and heat insulation.	DesignBuilder	Building	Evaluating the energy performance of houses on wooden piles and their potential savings in heating energy.
Bustamante et al. (2018) [25]	Climate, insulation, materials, and user habits.	DesignBuilder	Building	Analyzing the energy performance of renovation strategies in social housing under different climatic conditions.

Table 1. Cont.

Study	Parameters	Tools	Scale	Focus
Caldas & Santos (2012) [26]	Courtyard, orientation, location, form.	Gene_Arch	Building	Developing energy-efficient housing scenarios based on traditional strategies to reduce cooling demand.
Dub & Yannas (2018) [28]	Design factors for urban blocks (density, height/width ratio).	Rhino, ENVI-met	Block	Formulating energy conservation strategies by comparing current building regulations with existing construction practices.

In this section, previous studies were reviewed, and the methodological distinctions of this study were outlined. Most previous studies have primarily focused on the building scale, and there remains a lack of a comprehensive approach that addresses the interplay between urban development and buildings. This study systematically examines morphological parameters at the block scale and analyzes them using a five-step framework derived from the city's historical development. Consequently, the impact of urban development phases on energy performance is revealed, providing a novel perspective for the literature. Within the framework developed in this paper, the design parameters of the existing urban fabric were analyzed, and influencing factors were identified. This ensures that the recommendations are practical and actionable. While it is theoretically possible to propose more efficient suggestions, implementing the solution will be challenging if not feasible. Therefore, the study relied on data from the existing urban fabric for all design parameters. For instance, the observed orientations in the urban fabric are 15° and 45°, and the number of storeys ranges from 5 to 15. Thus, the simulations did not include a 30° angle or 20-storey buildings. This constraint is the main reason for the study's underlying limitations. Since the study focuses on factors within the urban fabric, reference buildings were modeled with their immediate surroundings, and visuals from the models were provided. Unlike previous studies, this study considered the interaction of buildings within the existing urban fabric. The most significant contribution of this study is that the developed approach is presented as a framework adaptable to different regions. In the Conclusions, integrated recommendations for energy consumption were created for architects, urban planners, local administrations, and relevant authorities. It has been determined that the problems cannot be resolved solely by architects and that the profit motives of contractors and property owners are one of the most significant barriers to addressing this issue.

## 2. Materials and Methods

The methodology consists of five stages, explained from general to specific:

Target 1: Determination of the Study Area

The approach needed to be tested on a sample area to validate the hypothesis. To proceed, comprehensive analyses should be conducted in a chronologically examined urban center. Factors will be examined by identifying pilot areas based on the existing settlement fabric. It is essential to locate an area where the evolution of urban fabric can be identified.

Target 2: Development Analysis of the Settlement Fabric of the Study Area

Examining the components that form the city and its subregions is necessary for energy comparisons. Starting from the city's historical development, planned housing and expansion areas should be analyzed. The settlement fabric must be analyzed to select a reference region and building for comparison. After examining the settlement fabric and

zoning plans, the next phase is selecting reference zones for energy analysis. The indicator required to complete Target 2 is the identification of the development of urban fabric in the study area.

#### Target 3: Identifying the Distinctive Urban Fabric

After examining the urban development of the study area, it is necessary to identify the fabric forming the city. These variations in the fabric are significant for explaining differences in energy consumption. The next phase targets identifying zones clustered by similar parameters, likely influenced by historical differences and zoning regulations. The achievement indicator for Target 3 is identifying multiple sub-regions within the housing fabric of the study area.

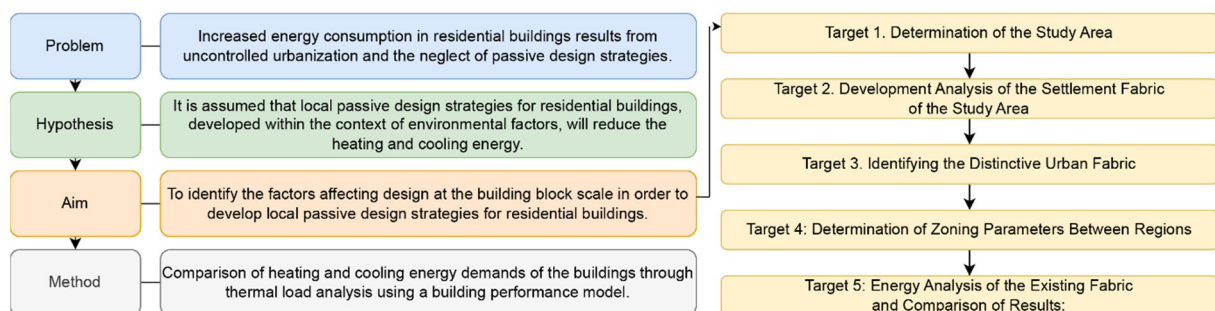
#### Target 4: Determination of Zoning Parameters Between Regions

To identify the reasons for differences in energy analysis, the zoning parameters shaping the urban fabric must be determined. Satellite images, zoning plans, and site details will be used. The final step is to list these factors provisionally and test them through analysis. To complete Target 4, differences between fabrics must be identified as zoning parameters.

#### Target 5: Energy Analysis of the Existing Fabric and Comparison of Results

The final objective is to test variables presumed to cause differences in consumption through energy analyses. The indicator required to complete this phase is the consistency of the heating and cooling data for reference buildings.

Once all targets are completed, consistent heating and cooling data will identify the intended factors. The research workflow is defined in Figure 1.



**Figure 1.** Research workflow, aim, and targets.

Strategies for managing building energy consumption are classified into two categories. Active strategies require an initial investment to achieve energy savings. Passive systems utilize natural resources and operate without requiring external energy. Photovoltaic systems and solar thermal equipment are active systems, whereas using daylight for lighting and heating is a passive system [36]. Active systems require a more integrated approach [37], whereas passive applications focus on parameters such as ventilation and the building envelope [38]. Factors like initial investment cost, awareness, and the need for tailoring to individual buildings may hinder the adoption of active systems. However, passive strategies are suitable for implementation at building and settlement levels and require no fixed lifespan or specialized knowledge. Since no investment is required, users will favor passive strategies.

Computer software is used to identify appropriate energy-saving strategies. The planning and design phase is critical for determining the proper strategy in architectural design. Building performance models predict building performance through simulations. The simulations focus not only on climate, building equipment, and the building envelope but also on parameters such as function, user habits, and occupancy [39]. These simulations can only measure output such as lighting, energy performance, and thermal comfort [40].

BPM tools provide architects with feedback on design decisions [36]. Mendes et al. [41] examined the three most used simulation methods:

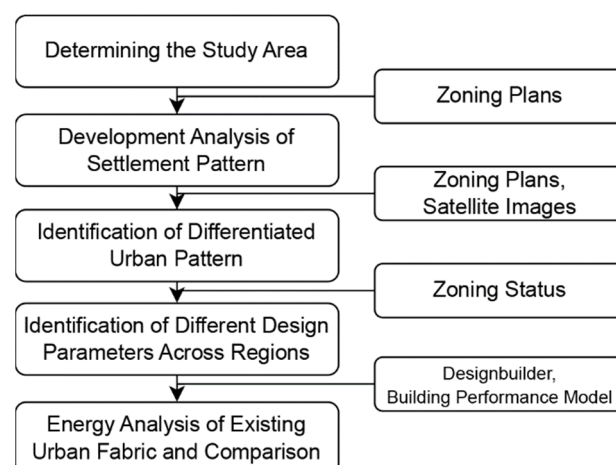
- Thermal load method.
- Degree hour/degree day method.
- Design days method.

Thermal load simulations measure buildings' heating and cooling energy consumption [42]. The desired temperature interval is determined using the degree-hour/degree-day method, and the difference is calculated through simulations. This threshold temperature is referred to as the base temperature [43]. Design day analysis employs simulations that statistically estimate climatic conditions for selected days of the year [44]. This method facilitates design by considering the extreme temperatures of different seasons.

DesignBuilder is the most frequently used tool among software options [41]. The software offers rapid results for structures with simple geometries and supports various file and drawing formats. Therefore, DesignBuilder version 6.1 (DesignBuilder Software Ltd., Stroud, UK) powered by EnergyPlus (U.S. Department of Energy, Washington, DC, USA) was chosen for this research. The program can conduct various analyses, including thermal load calculations, computational fluid dynamics (CFD) simulations, cost analysis, and carbon emissions assessment.

#### *Urban Development in Gaziantep*

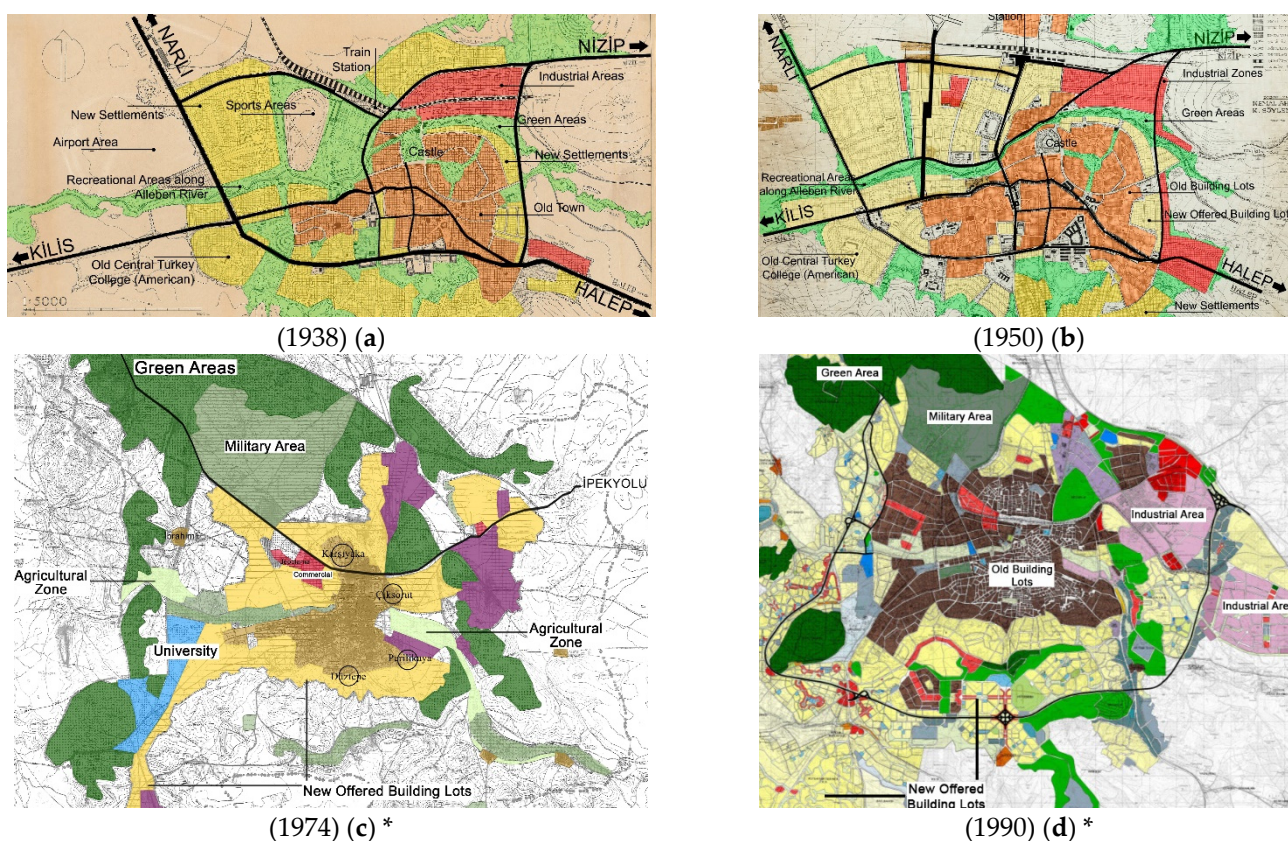
After determining the study's methodology, the next step is to identify the study area, as defined by Target 1. Gaziantep was initially investigated for access to field data. Zoning plans were analyzed to identify the city's chronological development. Zoning plans from 1938, 1950, 1973, and 1990 were retrieved for Gaziantep. Housing and growth areas were analyzed within these plans. The zoning plans were compared with current neighborhood conditions. The obtained data allows for the observation of urban fabric's development. The necessary indicator has been obtained, marking the achievement of Target 1. The methodological framework and the auxiliary materials to be used are shown in Figure 2.



**Figure 2.** Methodological framework.

The first zoning plan for Gaziantep, prepared by Herman Jansenn in 1938, was shaped by railroads and roadways. Settlement in the new housing areas outlined in this plan began in the 1950s. Four- to five-story apartment buildings and green spaces were prominent. The first signs of transitioning from a single-centered urban model to an industrial city are evident. Migrations due to industrial area development required new city planning. Kemal Ahmet Aru and Hamit Kemali Söylemezoğlu prepared a new city plan in 1950. While the monocentric structure was preserved, industrial and residential areas expanded. As parcels

expanded, five- to six-storey residences were planned. In 1974, Zühtü Can developed a new plan in response to the growing population. This plan facilitated a complete transition to an industrial city. Industrial areas constituted 20% of the plan. Residential parcels expanded, and the number of stories increased to six or seven. Due to the impacts of unregulated urbanization and migration, Oğuz Aldan developed the fourth zoning plan in 1990 [45]. In this plan, both the number and width of roads increased. The size of industrial areas, residential parcels, and the number of stories increased. Four zoning plans are shown in Figure 3.



**Figure 3.** Zoning plans for Gaziantep (a,b) [46] (c,d) [47]. \* The images were translated by the author (MSS).

After examining the plans, four sub-regions constituting the city were identified (Figure 3). The similarities and differences in these regions emerged as part of chronological development. The status quo for objective two has been achieved. The next step is identifying clusters of regions with similar parameters. The residential expansion zones of each zoning plan were analyzed, and commonalities were identified. Accordingly, four neighborhoods were selected from the specified areas. The four selected regions represent residential areas in each zoning plan chronologically. A single building block was chosen from the development areas added in each new plan. The study aimed to observe changes in energy consumption as the city expanded. The four selected zones represent the chronological development pattern of Gaziantep. These zones include various morphological parameters. Four distinct development phases can be identified based on zoning plans and expansion areas. One representative zone has been selected for each of the four periods. This selection also enables testing different urban density scenarios, as density evolves with city expansion. The goal is to draw generalizable inferences from these four zones. (The selected regions represent the chronological development of Gaziantep. The areas contain different morphological parameters. Four distinct periods are observed

based on zoning plans and expansion areas. One area has been selected for each of these four periods. This selection also enables testing different urban density scenarios, as density changes as the city expands. The purpose is to derive broad inferences based on these four regions). These neighborhoods, in chronological order, are:

1. Alleben.
2. Degirmiçem.
3. Batıkent.
4. Akkent.

Below are satellite images of the selected regions (Figure 4) and zoning information (Table 2).

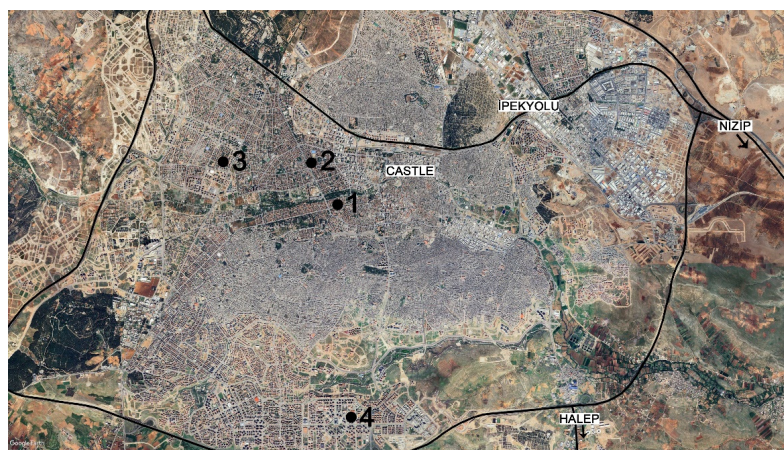



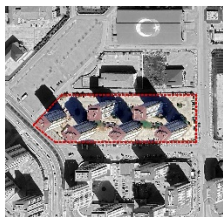


Figure 4. Location of selected areas.

Table 2. Information for the selected areas.

	1. Alleben	2. Değirmiçem	3. Batıkent	4. Akkent
Satellite				
District	Şahinbey	Şehitkamil	Şehitkamil	Şahinbey
Construction Period	1960–1980	1980–2000	2000–2010	2010–
Number of Storey	5	5	6	15
Ground Floor Area	~240 m <sup>2</sup>	~500 m <sup>2</sup>	~650 m <sup>2</sup>	~3000 m <sup>2</sup>
Parcel Area	~600 m <sup>2</sup>	~1000 m <sup>2</sup>	~1250 m <sup>2</sup>	14,375 m <sup>2</sup>
Road Width	9 m	8 m	14 m	40 m
Floor Area Ratio	- *	0.40	0.35	- *
Units Per Storey	2	2	2	4
Units Per Building	10	10	12	60
Units Per 1000 m <sup>2</sup>	16	10	10	25
Layout Angle	15°	15°	15°	45°
Coordinates	37.0612:37.3653	37.0725:37.3601	37.0727:37.3329	37.0175:37.3692

\* The floor area ratio is not specified in the zoning plan for regions 1 and 4.

The building envelope was modeled in accordance with the minimum requirements of the national insulation standard, featuring a window-to-wall ratio of 30%. The heating system consists of gas combi boilers and radiators in all zones, while the cooling system uses split-type air conditioners. The floor-to-floor height was set at 3.5 m according to zoning regulations. Domestic hot water is supplied by natural gas. These assumptions aim to isolate the effects of morphological parameters on energy performance by excluding variations in architectural design. Square-shaped residential buildings were frequently observed in the planned residential areas between 1960 and 2010. The buildings in the four regions also exhibit forms close to a square. No shading elements are incorporated into the buildings. Gaziantep is in a hot-dry climate zone, characterized by long, hot summers and cold winters. This climate exhibits significant temperature differences between days and seasons, accompanied by intense solar radiation. Figure 5 presents the average, extreme, minimum, and maximum temperature values for Gaziantep since 1940 [48].

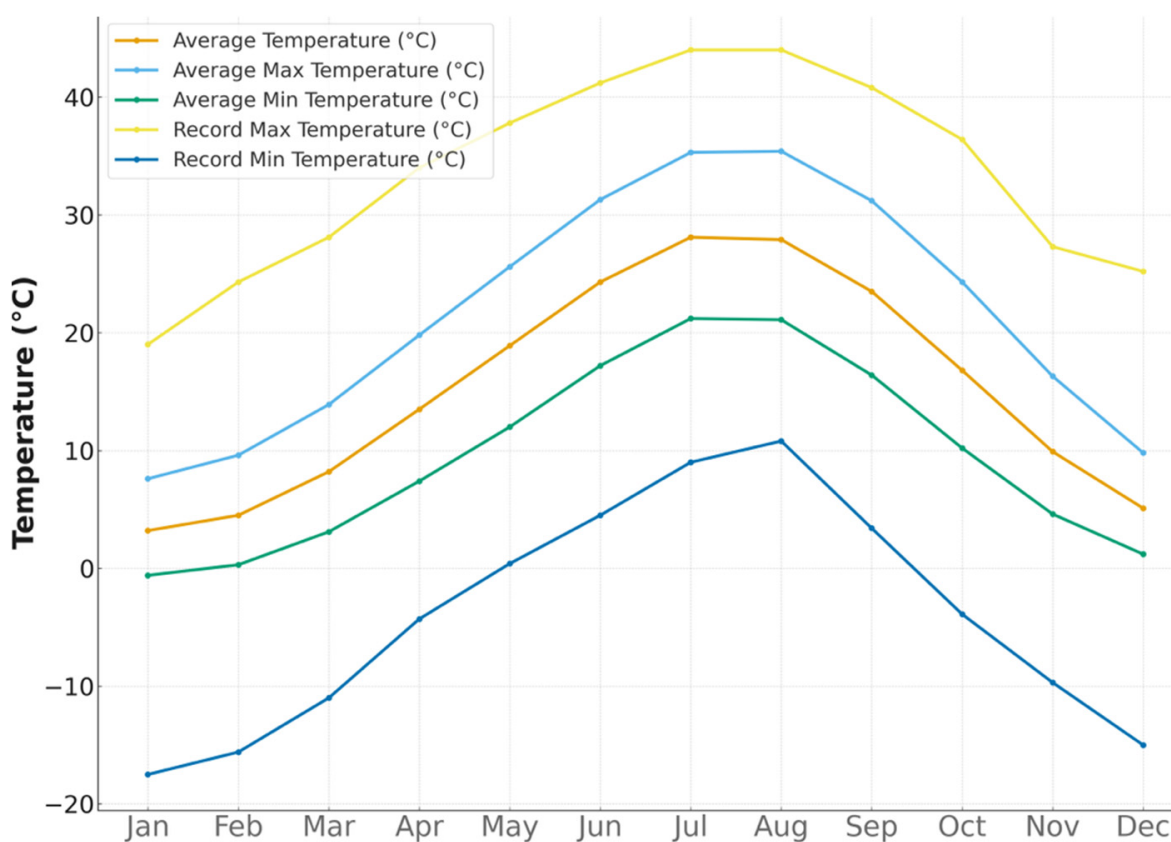


Figure 5. Annual temperature values of Gaziantep.

### 3. Results and Discussion



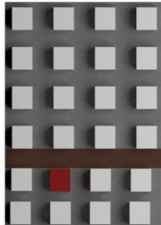
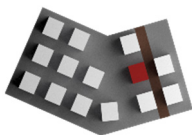
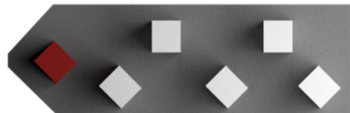

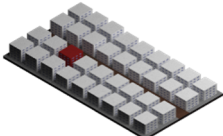
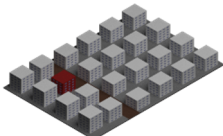
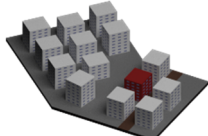
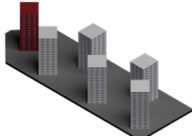
Four reference buildings from the selected neighborhoods and their surroundings have been modeled in DesignBuilder. The minimum requirements specified in the Turkish Standard 825 Thermal Insulation Rules for Buildings (TS 825 Turkish Standards Institution, Ankara, Türkiye) have been complied with for the building envelope. The building materials used are listed in the table (Table 3). As the layers and U-values of the materials are defined within the program, verifying simulation results with measurements is not required.

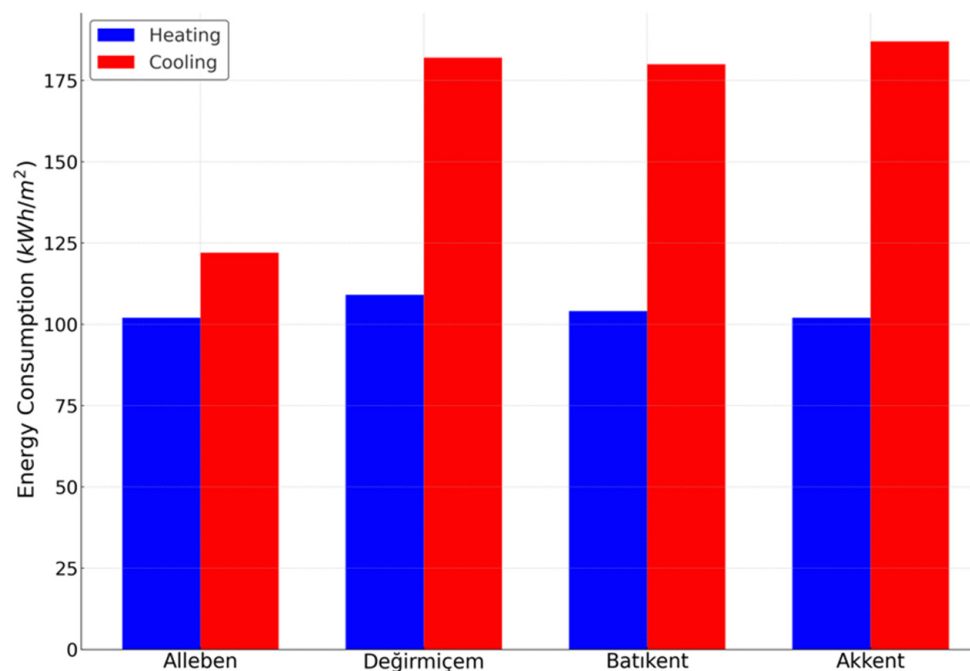
**Table 3.** Construction materials used in the simulations.

External Walls	0.6 cm inorganic exterior plaster +5 cm stone wool +3 cm cement-based plaster +19 cm brick +2 cm gypsum plaster	U-Value 0.57 W/m <sup>2</sup> -k
Ground Floor	100 cm reinforced concrete +3 cm leveling concrete +4 cm XPS +4 cm protective concrete +5 cm Screed +1 cm parquet	U-Value 0.53 W/m <sup>2</sup> -k
Roof	Gravel +2 cm felt +8 cm XPS + bituminous membrane +4 cm protective concrete +14 cm reinforced concrete +2 gypsum plaster	U-Value 0.38 W/m <sup>2</sup> -k

All buildings have a standard wall-to-window ratio and are heated by radiators using a natural gas combi boiler. The wall-to-window ratio is set at 30% for all buildings and façades. This isolates the impact of building design on urban factors. The study aims to identify factors on the building block scale. The building envelope was kept constant across all buildings for the same reason. Other factors include the 1960s requirements and challenges in identifying building materials on-site. The building envelope components presented in Table 3 are defined based on the minimum thermal insulation requirements specified in the TS 825 standard [49] and are kept constant across all regions to isolate the effects of urban morphological parameters. The cooling system uses electrically powered air conditioners. No ventilation system is present in the buildings. Heating is set at 20 °C, with a setback of 13 °C. Cooling is set at 26 °C, with a setback of 32 °C. Occupant numbers and user habits were kept constant in all dwellings. The objective is to assess the direct impact of urban-level design parameters. Annual heating and cooling simulations have been conducted using DesignBuilder. Annual consumption values are divided by the total construction area, and energy consumption per square meter is presented in the table in kilowatt-hours (kWh). Therefore, an energy comparison of varying-sized residences was performed (Table 4 and Figure 6).

**Table 4.** Energy consumption for the selected areas.

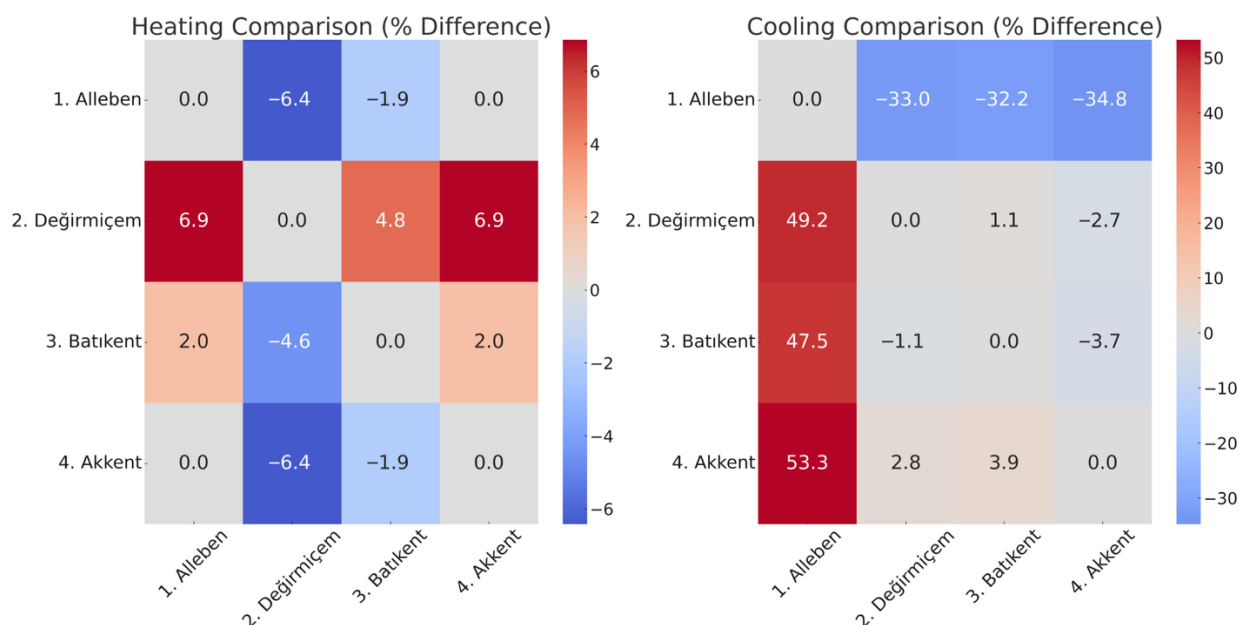
Area	1. Alleben	2. Değirmişem	3. Batıkent	4. Akkent
Plan 				
Layout 				
Heating	102 kWh/m <sup>2</sup>	109 kWh/m <sup>2</sup>	104 kWh/m <sup>2</sup>	102 kWh/m <sup>2</sup>
Cooling	122 kWh/m <sup>2</sup>	182 kWh/m <sup>2</sup>	180 kWh/m <sup>2</sup>	187 kWh/m <sup>2</sup>
Total	224 kWh/m <sup>2</sup>	291 kWh/m <sup>2</sup>	284 kWh/m <sup>2</sup>	289 kWh/m <sup>2</sup>



**Figure 6.** Energy Consumption by Region.

The simulation results compare the annual heating and cooling performance of buildings. The Alleben neighborhood showed the best results in all analyses. No significant difference exists between regions in heating energy consumption. The highest energy consumption (Zone 2—Değirmişem) is 7% higher than the lowest value. However, a noticeable difference in cooling energy is observed. This is due to Gaziantep’s location in a hot, dry climate zone. The Alleben neighborhood had 30% lower cooling energy consumption than the other three regions (Table 4). Zone 4 (Akkent), which has the highest cooling energy consumption, uses 53% more energy than Zone 1 (Alleben). Based on these data, Zone 1 (Alleben, 224 kWh/m<sup>2</sup>) demonstrates the highest energy performance, providing a 22% potential energy savings compared to the building with the lowest performance (291 kWh/m<sup>2</sup>). The number of storeys, the distance between buildings, the apartments per storey, and the layout angle are key factors in this difference. Heating and cooling energy consumption were compared in a matrix for all reference buildings. In Figure 7, “red” indicates a higher value, “blue” a lower value, and “white” denotes equality. For example, in the first row, “1 blue 2” means heating demand of “1 < 2”. Figure 7 provides a concise visual comparison of relative differences in heating and cooling demand across regions, complementing the numerical data presented in Table 4.

Zone 4 has the buildings with the most storeys. Compared to Zone 4, 15-storey buildings in the other zones consistently underperform in cooling energy efficiency. However, the same Conclusions cannot be drawn for heating energy. Zone 3, with a six-storey reference building, needs more cooling energy than Zone 1 but less than Zone 2, which has a five-storey reference building. A definitive conclusion cannot be reached with the current data. Increasing the number of floors to 15 affects consumption.



**Figure 7.** Heating and cooling demand comparison matrix.

Cooling energy demand rises as the distance between buildings expands. From smallest to largest, the distances between the buildings differ between the 1st, 3rd, 2nd, and 4th regions. Cooling energy consumption follows this order. In Zone 1, the average building distance is 6 m, both vertically and horizontally; in Zone 3, it ranges from 8 to 12 m; in Zone 2, it is 15 m; and in Zone 4, it is 30 m or more. Heating energy shows the same trend in the first three regions; however, region 4, which is expected to consume more energy, uses the same energy as region 1. In hot-dry climates, cooling energy demand is directly affected by the interaction between buildings, solar exposure, and wind conditions, and increased inter-building distance results in façades being exposed to higher levels of solar radiation. This significantly increases the cooling load. Detailed simulations are needed to understand this phenomenon.

In the first three zones, there are two housing units per floor. In zone 4, this increases to four. Zone 4's cooling energy is compared with other zones and consistently shows higher values. Cooling energy increases as the number of apartments per floor reaches four. An increasing number of apartments per floor leads to an expansion of the building's floor area and façade surface. This results in a higher level of heat exchange with the external environment. The results indicate that the growing internal volume, higher occupancy, and enlarged façades negatively affect the cooling load.

Buildings in the first three regions are placed at 15-degree angles. In Zone 4, the reference building is positioned at a 45-degree angle. Zone 4's cooling energy is consistently higher than that of buildings with a 15-degree angle. The 45-degree building consumes equal or less heating energy than the others. Changing the building angle affects both heating and cooling energy. 15° and 45° are specific angles observed in the regions. The most likely scenario is that a 45-degree building orientation would benefit more from passive cooling under prevailing northwesterly wind conditions. An important passive cooling strategy involves orienting façades with larger surface areas toward the prevailing wind and enhancing the wind-corridor effect through the building layout. However, with a 45° orientation angle, Gaziantep—located in the Northern Hemisphere—is more exposed to solar radiation from the southwest, the dominant direction of sunlight in summer. Compared to wind influence, the results indicate that the intensified effect of solar radiation significantly increases the cooling load.

The variations in energy consumption across the four zones are related to their morphological characteristics and development stages. For instance, the high building density in Zone 1 Alleben corresponds to a lower cooling demand, while the low density in Zone 4 Akkent leads to a higher cooling load. Another parameter that stands out in Zone 4 (Akkent) is road width. As road width increased to 40 m, the gradual rise in the number of floors over time caused the façades to receive higher solar exposure. Naturally, this condition also has a significant effect on the cooling load. The contribution of the selected regions to this study lies not only in observing chronological development but also in comparing energy loads across different morphological parameters. This enhances the generalizability of the results, particularly in similar climatic conditions.

The first three zones share similar characteristics regarding the number of floors, orientation angle, number of apartments, and road width. However, the compact urban fabric of Zone 1 (Alleben), combined with factors such as high building density, smaller façade surfaces, proximity to adjacent buildings, a 15° orientation angle, reduced base area, and small plot sizes, enhances the shading effect. This reduces solar exposure, resulting in a significant decrease in cooling demand. Each development period was represented by one typical block, which illustrates historical evolution but limits statistical generalization.

Base and parcel areas increase progressively from Zone 1 to Zone 4. However, heating and cooling energy consumption does not follow this pattern. Zones 2 and 3 disrupt this pattern in energy consumption. Thus, no consistent inference about building base and parcel areas can be made.

The number of storeys, the distance between buildings, the number of apartments per storey, and the layout angle affect energy consumption in quadruple and pairwise comparisons. This tendency is not observed in the base and parcel areas. However, it cannot be concluded that these variables always increase or decrease outcomes. Existing analysis cannot determine if these parameters, individually or combined, lead to this trend in energy consumption. The only clear inference is that these parameters affect energy consumption. The impact of individual parameters on energy consumption may vary. Some parameters may individually reduce energy consumption, but their combined effect with other factors may increase total energy consumption. Several scenario-based simulations should be conducted to test the correlation between parameters accurately. These analyses should include sufficient scenarios to test each parameter individually and all combinations collectively. For instance, all buildings should be tested at angles of 15° and 45°, and their energy consumption should be compared.

Figure 7 illustrates that cooling energy in the region needs to be optimized, and Zone 1 data suggests this can be achieved through wind, sun, and shading control based on Gaziantep's environment. There is no significant difference in heating energy consumption. Immediate building-scale adjustments include sun-shading elements, modifying window-to-wall ratios, and increasing insulation layers. Since the urban plan determines variables like building density, height, setback distance, and road widths, their optimization depends on zoning regulations. For instance, the distance between buildings is crucial, as building heights create a wind corridor effect. Ground and elevation conditions are also significant for determining building bases and roads. The road design dictates the direction and shape of building blocks. Generally, building orientation is determined by the zoning plan, and architects cannot make changes in this regard. Landowners and contractors prioritize profit-maximizing designs over those efficient for the block, limiting building designers' flexibility. Optimizing the height-to-width ratio between buildings is highly effective. Findings from Zone 1 show that optimizing the h/w ratio and layout angle to minimize solar exposure can significantly reduce cooling energy use. However, these arrangements will have the opposite effect in winter, as restricting sunlight increases heating energy

demand. Considering heating and cooling rates, prioritizing cooling energy savings can lead to more significant reductions in total energy consumption.

For Gaziantep, orienting buildings at a 45° angle aligns them with the prevailing northwest wind. Setback distances and inter-building spacing also affect wind and solar exposure on façades. The prevailing wind is a passive design strategy to reduce cooling energy demand. The number of storeys affects sunlight and wind exposure. In hot climates, increased solar exposure on façades raises cooling energy demand. Increasing the number of flats per storey changes sunlight exposure, affecting façades and floor areas.

The findings indicate that the examined parameters cannot be evaluated in isolation. An increase in the number of floors leads to a larger façade area and a higher cooling load. However, it also increases the solar gain on adjacent buildings, thereby partially offsetting the expected rise in energy consumption. Similarly, an orientation angle of 45 degrees increases solar gain, thereby elevating the cooling load. It has been observed that higher building density exerts a positive effect through shading. However, increased density modifies the influence of both the number of floors and building orientation. An increase in the number of apartments per floor enlarges the façade surface, while changes in the width-to-height ratio modify the inter-building distance and, consequently, influence solar exposure. This paper suggests that morphological factors should be evaluated in conjunction with scenario-based approaches. In block planning, building height, setback distance, orientation angle, road width, and positioning should be evaluated as interrelated variables rather than independent ones. Another key finding is that these parameters vary across distinctive design cases. Each building block requires context-specific decisions regarding the morphological parameters. Therefore, while the interactions among parameters should be considered in the development of scenarios, each variable should also be isolated to observe its individual effects.

The consumption data in this study for apartment buildings with 5 to 15 floors are supported by previous studies. Studies also show that energy consumption decreases with changes in features such as courtyards and detached houses, and that passive strategies vary for these types. However, these cases are excluded due to this study's limitations. Studies in similar climate zones and cities (in Türkiye) and their energy consumption are presented in Table 5. Studies on detached houses [32,35,50] have shown lower total energy consumption. However, in all studies, cooling energy remains consistently high due to the hot climate. Studies [33,51,52] found that heating energy is lower in humid regions than in dry regions. The presented data are consistent with this paper.

**Table 5.** Simulation results obtained in previous studies.

Reference	Location	Climate Zone	Heating Energy	Cooling Energy
[31]	Kashan, Iran	Hot-dry	78.9 kWh	138.8 kWh
[34]	Ouled Djellal, Algeria	Hot-dry	64.5 kWh/m <sup>2</sup>	75.3 kWh/m <sup>2</sup>
[35]	Kashan, Iran	Hot-dry	240.44 kWh/m <sup>2</sup> (Heating + Cooling)	
[32]	Al Batinah, Oman	Hot-dry	244 kWh/m <sup>2</sup> (Heating + Cooling)	
[29]	Diyarbakır, Türkiye	Hot-dry	87.48 kWh/m <sup>2</sup>	115.94 kWh/m <sup>2</sup>
[50]	Kairouan, Tunisia	Hot-dry	53.50 kWh/m <sup>2</sup>	118.77 kWh/m <sup>2</sup>
[51]	Izmir, Türkiye	Hot-Humid	42 kWh/m <sup>2</sup>	108 kWh/m <sup>2</sup>
[52]	Hatay, Türkiye	Mediterranean	17,697.1 kWh	127,450 kWh
[33]	Marrakech, Morocco	Hot-Semi Arid	32 kWh/m <sup>2</sup>	87 kWh/m <sup>2</sup>

The low energy consumption of detached houses shows that sunlight and wind are key parameters influenced by building height. While the simulations in this study used actual data on location, climate, and building materials, Table 5 was used to enhance the reliability

of the results. Although field verification was not conducted, the building envelope was modeled using the U-values specified in the TS 825 standard, and the obtained results are consistent with previous studies conducted in hot-dry climates. This finding strengthens the validity of the model. All simulations employ Gaziantep's actual climatic conditions (latitude 37.08°, longitude 37.37°, elevation 701 m; ASHRAE climate zone 3B-American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, GA, USA) and use the IWEC (International Weather for Energy Calculation, developed by ASHRAE and U.S. Department of Energy, Atlanta, GA, USA and Washington, DC, USA) file in DesignBuilder to represent environmental data. The IWEC data are derived from long-term daily and annual averages of actual meteorological measurements (temperature, relative humidity, wind speed, solar radiation, etc.), thereby ensuring accurate representation of environmental inputs in the model. The simulations were conducted with a daily step covering the period from 1 January to 31 December.

Simulation results show that layout angle, number of storeys, interbuilding distance, and apartments per storey are key parameters influencing energy consumption in hot-dry climates. Simulation studies on block-scale factors from previous research are presented in Table 6 and support this study's findings. Changes in the h/w ratio alter building distance, setbacks, environmental interactions, and density, directly affecting wind and sunlight. The number of floors determines building height and is a variable of the h/w parameter. Building and block orientation define the layout. Parameters like shading, surrounding relationships, and location are directly interrelated. The criteria in Table 6 align with this study's parameters and are derived from one another.

**Table 6.** Criteria from previous studies influencing energy consumption.

Reference	Criteria
[18]	Wind Direction, Building Material, Building Position
[19]	Setback, Building Height
[20]	Building Orientation, Site Selection, Surrounding Relations
[24]	Shading, Location, Layout
[30]	Building Orientation
[27]	Building Orientation, Building Height
[28]	Block Orientation, Building Density, Building Height/Width
[19]	Building Height/Width
[22]	Shading
[26]	Building Density

Ren et al. [27] demonstrated that building orientation and form are generalizable parameters affecting energy performance. Kaihoul et al. [34] stated that orientation constitutes a critical design strategy in hot-dry climates. Hachem-Vermette [24] emphasized the influence of road and parcel layout on solar potential, highlighting the mutual shading effects between buildings. Simulation outcomes and findings from the literature indicate that building orientation is not merely an architectural parameter but should also be evaluated at the urban scale. Evidence from Canada demonstrates that the impact of urban density on energy consumption parallels the patterns observed in Gaziantep.

The findings indicate that Zone 1 (Alleben), which has the highest building density, demonstrated better energy performance. This suggests that closely spaced, low-rise buildings reduce the cooling load by mitigating solar gain. However, this situation cannot be fully verified for Gaziantep, which was selected based on the available data. Specific scenarios should be developed to investigate this situation in more detail. Al-Hashim et al. [32] indicated that in Oman's hot-dry climate, the compactness of the urban fabric constitutes one of the major bioclimatic strategies. In Oman, densely populated traditional areas out-

performed modern districts in terms of cooling energy performance. A similar pattern was observed in Gaziantep. Ayçam et al. [29] reported that in Diyarbakır, located 300 km from Gaziantep and within the same climatic zone, reducing the distance between buildings in the traditional urban fabric improved cooling performance.

Sobhy et al. [33] in Morocco, Kaihoul et al. [34] in Algeria, and Noohian & Mahmoudi [31] in Iran reported that the cooling load predominates over the heating load in hot-dry climate zones. In contrast, Öztürk Keresticioğlu et al. [20] found that heating energy demand exceeded cooling energy demand in their study conducted in Istanbul (Turkey), which is in a temperate climate zone. These results highlight the influence of climate on thermal loads and support the overall findings of this study. The five-step framework provides an assessment not only for the local context but also for cities in different geographical and climatic regions, yielding results consistent with international literature. The findings confirm the generalizability and applicability of the framework. The results indicate that zoning and building regulations can play a crucial role in shaping energy performance.

#### 4. Conclusions

The simulation demonstrates a clear contrast between energy types: cooling energy consumption varied by up to 53% across the neighborhoods analyzed, while heating energy consumption differed by only 7%. Results show that cooling energy is up to 90% greater than heating energy in the hot-dry climate zone. Consumption data for selected districts reveals 22% of potential savings in total consumption through passive design factors. The study's approach identifies layout angle, number of stories, interbuilding distance, and apartments per story as the factors affecting energy consumption at the building block scale. In the hot-dry climate zone, the layout angle affects heating and cooling energy, while the number of storeys, the distance between buildings, and the flats per floor influence cooling. However, due to study limitations, it was not possible to determine which of these variables had a more significant impact. Additionally, scenarios should be developed for each variable and tested in combination to determine their individual or collective effect on energy consumption. These issues will be the focus of future studies.

To test the relationship between energy consumption and parameters, all buildings should be simulated as 4-flats-per-storey variants, limited to two options in the regions. All areas should be simulated as low-, medium-, and high-rise buildings, with storeys ranging from 5 to 15 in the tested areas. According to Table 2, the layout angles are 15° and 45°. To assess the angle's direct effect on energy consumption, all buildings should be simulated at these angles in separate scenarios. The h/w ratio should be fixed and varied in each region based on observed variables to determine the minimum simulation scenario. This method should first determine on-site variables and adapt them to all regions. The 30% wall-to-window ratio should also be modified and included in the scenarios.

This paper identified factors influencing energy consumption by analyzing the historical development of urban fabric rather than through trial and error or predictions. The significant contribution is that it eliminates uncertainty about the applicability of results, as it starts with factors already implemented. Optimal design parameters can theoretically be tested through simulations, but their effectiveness depends on their applicability. This represents the approach's unique contribution and provides a framework that is applicable to various areas. The results for Gaziantep indicate that energy optimization needs a holistic approach with participation from multiple stakeholders.

Parameters like road widths, alignments, setbacks, and building heights are defined in the zoning plan. Local administrations should consider these conditions when preparing zoning plans, as focusing only on factors influencing energy consumption is insufficient.

Legal measures against profit-oriented policies should be implemented and supervised by ministerial control mechanisms to ensure optimal design. This mechanism should be part of the building permit process, and housing construction and occupancy should require compliance with local design requirements. Following these steps, the designer can determine the most appropriate design using passive strategies. Otherwise, academic studies will remain mere recommendations. This study makes a unique contribution by presenting an evaluation framework that links urban development processes with energy performance at the building-block scale, distinguishing it from studies conducted solely at the building scale. The paper reveals the impact of morphological parameters on energy performance. Future research is recommended to broaden the scope by exploring various scenarios (orientation, number of floors, inter-building distance, number of apartments, density, floor area, building footprint, etc.) and incorporating parameters such as shading elements, window-to-wall ratio, and building envelope characteristics into the model. The proposed five-step framework can be adapted to various settlement contexts. Scenario generation and parametric design processes can be integrated into this framework by adjusting the parameters and case study context. Thus, this approach contributes to a more comprehensive understanding of the effects of morphological parameters on energy performance.

The results indicate that parameters such as orientation, number of floors, and building density have a direct and significant impact on energy performance. This highlights the necessity for architects to consider passive design strategies, local conditions, and zoning regulations at multiple scales in the initial stages of design. Road width, plot layout, block orientation, settlement pattern, and climatic conditions are identified as key factors influencing thermal loads. Urban planners should address parameters that significantly affect architectural design in a climate-sensitive manner throughout the planning process. Regulatory and control mechanisms focusing on energy performance and climate adaptation are of critical importance for policymakers.

The results of the study revealed that the morphological parameters are key factors influencing thermal loads. These findings demonstrate that zoning plans and urban design regulations are crucial not only for spatial planning but also for achieving energy efficiency. Building orientation and layout angles should be determined to maximize energy efficiency during the preparation of zoning plans. Inter-building distance, setbacks, and road width are essential parameters affecting solar gain in hot climates, as they directly influence the solar exposure of buildings. Zoning regulations should be formulated in accordance with climatic conditions. Building height and density should be evaluated in relation to energy performance, considering both heating and cooling loads. The optimal values of these parameters can be regionally determined through simulation scenarios developed using the proposed five-step framework.

#### *4.1. Limitations*

This study modeled only the current status of the residences and compared the consumption results. Occupant numbers (4 individuals based on Gaziantep's average), occupancy schedules, user habits, building materials, internal design, wall-to-window ratios, lighting, and equipment gains, and ventilation rates were kept constant for all modeled buildings and 92 units. Changes to the buildings' designs are beyond the limitations of this study, and scenario generation was excluded from the methodology. Cases with further generated scenarios are the subject of future work. Relevant factors were identified to develop passive design strategies, and their optimal values need to be evaluated through simulation scenarios.

#### 4.2. Additional Information

This paper is derived from the PhD thesis “A Design Proposal for the Positioning of Residential Buildings Based on Energy Analysis: The Case of Gaziantep” [53], with reference number 10654239, at Hasan Kalyoncu University, Turkiye.

**Author Contributions:** Conceptualization, M.S.S., M.S.Y. and F.D.A.; methodology, M.S.S., M.S.Y. and F.D.A.; software, M.S.S.; validation, M.S.S.; formal analysis, M.S.S.; investigation, M.S.S.; resources, M.S.S.; data curation, M.S.S.; writing—original draft preparation, M.S.S.; writing—review and editing, M.S.S.; visualizations, M.S.S.; supervision, M.S.Y. and F.D.A. All authors have read and agreed to the published version of the manuscript.

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