

**BIOCLIMATIC ARCHITECTURE AND ADVANCED
IMPROVEMENT STRATEGIES TOWARDS HIGH ENERGY
EFFICIENCY AT DISTRICTS LEVEL**

A Thesis

by

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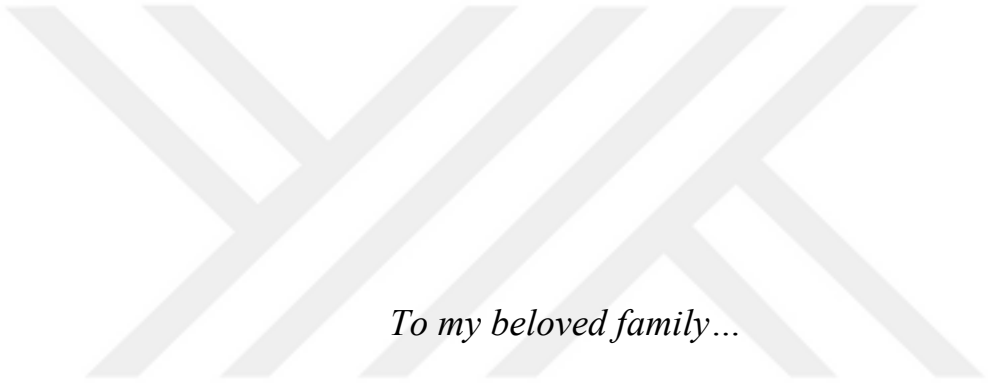
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To my beloved family...

ABSTRACT

Today's construction sector is taking a major part in worldwide energy consumption and its contribution to climate change. It is crucial to take proactive measures in architecture to mitigate the harmful effects of carbon emissions and pollution on our planet. Architectural strategies should focus on reducing energy consumption to align with this objective.

In the context of climate change and unpredictable weather patterns, it is crucial to minimize reliance on active systems in architecture. By integrating passive design strategies, we can achieve a more sustainable approach. Active systems have their limitations, while passive systems offer greater flexibility and environmental friendliness. Bioclimatic architecture refers to the design of buildings that align with local climate conditions, aiming to enhance energy efficiency and reduce environmental impact. Implementing bioclimatic design on a larger scale, such as at the district level, has the potential to significantly increase energy efficiency.

Bioclimatic architecture strategies have a substantial positive impact on districts' energy efficiency. Energy consumption and carbon emissions can be lowered by designing buildings according to the local climate conditions. Moreover, bioclimatic architecture may provide the residents with more comfortable living and working conditions, which can also positively impact health. The strategy of bioclimatic architecture in generating energy-efficient districts is determined by several parameters such as building geometry, materials, and district scale methods.

The thesis aims to guide future district designs by providing assumptions towards ecologically sustainable and resilient neighborhoods using the assistance of bioclimatic strategies and advanced improvement strategies. The research investigates the districts' energy performance levels by integrating passive and advanced strategies to the buildings towards energy-efficient neighborhoods in the hot-humid and cold climate regions of Turkey. In order to assess the influence of bioclimatic parameters on district-level energy efficiency in two specific locations, a district energy model is created using Grasshopper and Rhinoceros. The district energy simulation results are obtained and analyzed. The bioclimatic and passive design variations' impacts under different climate conditions are discussed and compared in detail.

ÖZETÇE

Günümüz yapı sektörü, dünya çapındaki enerji tüketiminde göz ardı edilemez büyüklükte bir paydayı kapsamaktadır. Bu nedenle, karbon emisyonlarının ve kirliliğin Dünya üzerindeki zararlı etkilerini önlemek için mimaride alınabilecek önlemler hayati önem taşımaktadır. Mimari stratejiler de bu fikir doğrultusunda enerji tüketimini düşürme yönünde gelişebilir.

Binaların enerji performansının analizinde, pasif tasarım stratejilerinin mimariye entegrasyonu ile aktif sistem bağımlılığı mümkün olduğunca azaltılmalıdır. Binaların enerji verimliliğini artırmak ve çevresel etkiyi azaltmak için yerel iklim koşullarına göre tasarlanması biyoklimatik mimari olarak bilinir. Biyo-iklimsel tasarım, bina ölçeğinden daha büyük ölçekte uygulandığında bölge enerji verimliliğini artırma potansiyeline sahiptir.

Biyo-iklimsel mimarlık stratejileri, enerji açısından verimli bölgeler üzerinde önemli bir etkiye sahip olabilir. Binalar yerel iklim koşullarına göre tasarlanarak enerji tüketimi ve karbon emisyonları azaltılabilir. Ek olarak, biyo-iklimsel mimari, konut sakinlerine daha konforlu yaşam ve çalışma koşulları sağlayabilir ve bu da sağlık üzerinde olumlu bir etkiye sahip olabilir. Biyoklimatik mimarinin enerji verimli mahalleler oluşturma stratejisi, bina geometrisi, malzemeler ve bölge ölçeğindeki yöntemler gibi çeşitli parametrelerle belirlenir.

Bu tez, biyo-iklimsel stratejiler ve gelişmiş iyileştirme stratejilerinin yardımıyla ekolojik olarak sürdürülebilir ve esnek mahallelere yönelik değerli bilgiler ve varsayımlar sağlayarak gelecekteki bölge tasarımlarına rehberlik etmeyi amaçlamaktadır. Araştırma,

Türkiye'nin sıcak nemli ve soğuk iklim bölgelerinde enerji verimli mahallelere yönelik binalara pasif ve gelişmiş stratejiler entegre ederek ilçelerin enerji performans düzeylerini araştırmaktadır. Grasshopper, Rhinoceros programında, biyoklimatik parametrelerin iki lokasyonda bölge düzeyinde enerji verimliliği üzerindeki etkisini kanıtlamak için bir bölge enerji modeli oluşturulmuştur. Alınan simülasyonlar ile birtakım sonuçlar elde edilmiş ve analiz edilmiştir. Son olarak, pasif tasarım varyasyonlarının farklı iklim koşulları altındaki etkileri tartışılıp ayrıntılı olarak karşılaştırılmıştır.



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CHAPTER I

INTRODUCTION

The term sustainability entered our lives quite a while ago. Any new term starts to lose popularity over time, whereas “sustainability” is becoming more important day by day since we can clearly testify to our crucial impacts on Earth. Sustainability’s “basic principles and concept are balancing a growing economy, protection for the environment, and social responsibility.” [1]. It is a wide and multidisciplinary concept.

“Protection for the environment” is the main aim of sustaining the Earth’s resources in architecture. These resources are described by Yeang and Woo (2010), as “A state of an ecosystem where resource production, resiliency, and ecological diversity remain stable across time.” following the definition, we need to maintain the Earth’s resources for the next generations’ use. In architecture, the sustainability concept's ideology and applicability is a significant necessity. An individual building’s lifecycle starts from processing the raw materials to the ending: demolishing the building. Each step of a building's life cycle requires energy to proceed. Therefore, the construction sector consumes and demands a high amount of energy. As architects, we are responsible for shaping future buildings into more livable, efficient, and sufficient living spaces.

There are a variety of approaches for maintaining resources under the concept of sustainability. One of the most effective design guidelines for buildings is the bioclimatic architecture concept. The concept constitutes the lessons learned from the history of building architectural systems. Traditional architecture maintains passive strategies

against the exterior impacts of a building's surrounding environment. We, as architects, may have solutions against the new climatic conditions with climate change, to future architecture, by combining traditional strategies with the latest innovative building technology.

Another concept, which is a relatively new subject to the area of sustainability, is positive-energy neighborhoods/blocks. "Positive energy" can be described as "the generation of more electricity, by a neighborhood, than it consumes." in the context of a neighborhood (or district/blocks). To achieve a great impact of the sustainability strategies, it is necessary to upgrade the building scale to a comparatively larger scale, in this case, neighborhoods [2].

1.1 Problem Statement

From a global perspective, the construction sector occupies over one-third, approximately 40%, of energy consumption worldwide [3]. Therefore, the design of future buildings has a significant impact on the reduction of the natural resources considering the estimation of the future conditions. Nowadays, the world is facing the effects of climate change, global warming, and pandemics. These crises are going to affect our habits and living space conditions. Therefore, the building design criteria are going to be reshaped. Since the global pandemic has affected the heating/ventilating/cooling systems used in interior spaces, energy use is going to change.

On the other hand, climate change is an undeniable catastrophe that affects our environment more day by day, it is likely to impact many aspects of life in the future, worsening existing economic difficulties such as aging and failing infrastructure, strained ecosystems, and economic inequalities. The increase in global temperatures is going to cause a high demand for energy for the cooling need of our buildings, and the damage to

the ecosystem is going to cause a lack of resources. We need to take serious precautions starting from today to prevent the increase in future energy use and the reduction of energy resources [4].

The Energy Performance of Buildings Directive (EPBD) 2010 is the European Union's energy efficiency directive that corresponding to these problems [5]. According to the EEA, the European Union (EU) has developed a long-term strategy based on three milestones to mitigate climate change and reduce carbon emissions: lowered Greenhouse Gas emissions (GGH) by 20% in 2020, 40% in 2030, and 80-95% in 2050, compared to 1990 emission levels. This strategy relies heavily on the Energy Performance of Buildings Directive (EPBD). It modernizes the existing regulatory framework to reflect higher objectives and more pressing requirements in climate and social action [6].

In Turkey, rapid population expansion has resulted in a considerable increase in energy demand during the previous two decades. Turkey's economy is still fueled by fossil fuels, heavily relying on imports, principally oil and gas (93% and 99%, respectively). Consequently, Turkey's innovations and policies have emphasized domestic production and liberalization. Turkey has prioritized growing local exploration and production to reduce its dependency on imported oil and gas. Considering the limits on upstream supply and the need to cut emissions, Turkey should concentrate on low-cost demand-side activities such as improvements in efficiency [3].

Turkey still needs to pursue even more significant renewable energy growth goals, in electricity, heating and other energy demands for buildings. Furthermore, Turkey's commitment to meeting its consumption requirements with more domestic energy resources may conflict with efforts to decarbonize the energy sector, particularly in light of the government's goal of using more low-quality domestic lignite in power generation.

In a similar vein, as many countries around the world strive to achieve net-zero greenhouse gas emissions by the middle of the century, Turkey should consider the impact of its energy policy, particularly its reliance on coal-fired power, on investor confidence, local air pollution, and the direction of the long-term emission of movement [3].

In response to Turkey's energy issues, the "National Energy and Mining Policy" establishes the groundwork for long-term energy strategies aimed at maximizing Turkey's domestic resources' efficiency. The strategy's main goal, based on three key elements: supply security, increased use of local resources, and predictable markets, is to implement efforts to ensure that domestic resources are utilized as efficiently as possible while lowering reliance on imported energy. The National Energy Efficiency Action Plan (NEEAP) is initialized in this policy scope. According to the national gazette, the plan targets to develop sustainable financial mechanisms, enhance awareness of energy efficiency, support local production, locate smart cities and plants, expand the regional heating systems and retrofitting of existing buildings in the period 2017-2023 [7]. The energy efficiency studies on districts should be emphasized in the Turkish literature for Turkey's future energy policies on lowering the reliance on imported energy and encouragement on construction sector to prevent energy crisis.

1.2 Importance of the Study

Worldwide energy and health issues such as global warming, climate change, urban heat island effect (UHI) and lack of resources affect the society's economy and the citizens' welfare and comfort. These major concerns need to be addressed by each country's policies in immediate action to become immediately climate-adaptive, carbon-neutral, zero energy and/or surplus energy cities. The planned actions and government

policies may contribute to balancing the energy economy and ensuring healthy living circumstances.

Corresponding to the mentioned concerns, great interest has emerged in literature on studies of climate-friendly neighborhoods. Despite this fact, in academic papers and worldwide projects, there is a lack of concrete information on positive energy neighborhoods (PEN) [8]. Indeed, only a few studies have addressed the issues associated with passive and active energy-driven urban design, such as the connections between urban form and urban power generation systems [9].

Such potential can be integrated into building design and urban planning brought by our country's geological position, such as the passive urban approaches and the use of sustainable resources. In this context, the demand for imported energy in our country may be reduced when city planning is done by considering the necessary design criteria.

1.3 Aim and Scope of the Study

Bioclimatic architecture is a sub-concept of sustainability. Its fundamental structure is based on a vernacular architecture that uses natural sources as materials and implements the building strategies as passive systems since there was a lack of technology. Therefore, the concept aims to generate architecture suitable for its climatic conditions by using renewable energy sources and integrating passive systems for the thermal comfort of the occupants.

Positive energy neighborhoods (PEN) are energy-efficient city regions or blocks of buildings that emit no greenhouse gases and effectively produce a yearly regional surplus of renewable energy. Assessing the environmental impact of the neighborhood/district/block size is critical for creating sustainable cities since neighborhoods are the building blocks of cities [8].

This dissertation aims to lead future neighborhood designs with the assistance of bioclimatic strategies and the advancement of building blocks' energy performances by integrating passive and advanced strategies to the buildings towards positive energy neighborhoods (PEN), with providing crucial knowledge on bioclimatic architecture, energy-efficient districts, and the intersection of these two concepts, passive strategies on district scale. The methodology contains ecologically sustainable and resilient neighborhoods in two different climatic regions of Turkey, Antalya and Erzurum at blocks scale.

1.4 Thesis Structure

The thesis structure constitutes five main chapters.

Chapter I covers the introduction to the topic, explaining the aim and scope of the thesis, problem statement, and methodology followed.

Chapter II discusses the literature review on three main topics: bioclimatic architecture, specifically passive strategies for two different climatic regions, positive energy neighborhoods and intersection of the two concepts, passive strategies' impacts on districts.

In chapter III, the thesis methodology is explained with the analysis and tools.

In chapter IV, the obtained results of the method are discussed in terms of scenarios' impacts comparison and the impacts' differentiation under two different climatic conditions.

Chapter V includes the conclusion by summarizing the results and discussion.

CHAPTER II

LITERATURE REVIEW

The theoretical framework of the literature review is illustrated (Figure 1). First, the objectives are defined with the aim and scope of thesis. Secondly, for the literature review, the bioclimatic architecture concept is defined, its relationship with environmental control strategies, and the climate regions' design requirements are analyzed. For environmental data input the climatic regions' features are collected. In this context, the environmental parameters' effects on buildings are investigated. In the following step, bioclimatic architecture theory, its roots and the design principles are gathered on building and neighborhood scale. The Positive Energy Blocks/Neighborhoods (PEB/PEN) are explained with building design criteria, neighborhood-scale positive energy methods and renewable energy usage's vitality in designing PEBs. In the last step of the literature review, both two main concepts of the

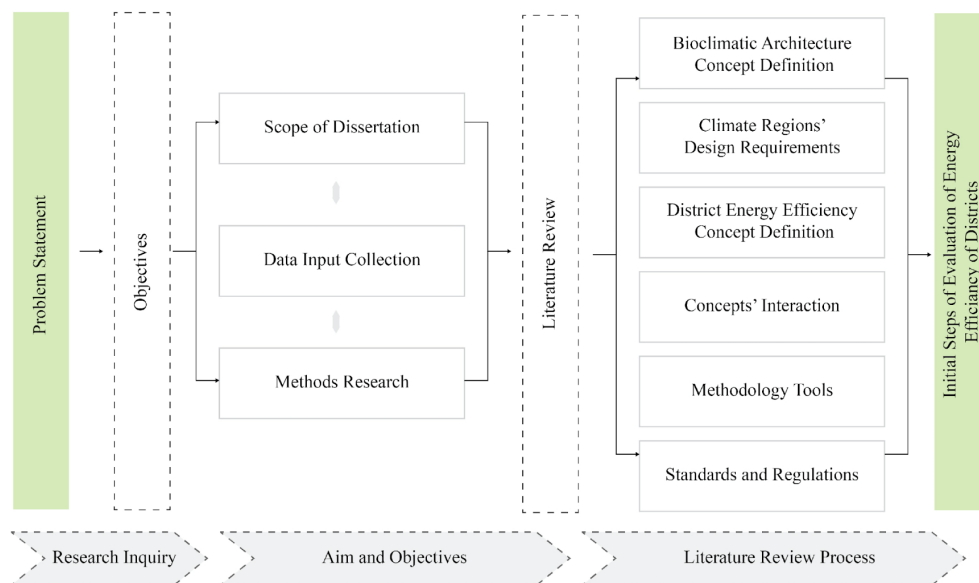


Figure 1: Theoretical framework of literature review

thesis are discussed. The cross-section is explained as bioclimatic architecture principles' necessity in Positive Energy Neighborhoods and passive design parameters on a larger scale.

2.1 Bioclimatic Architecture Concept

Bioclimatic design also known as “passive mode design” is an environmental design approach that focuses on low-energy-consumption solutions that use the local climate. Passive mode design focuses on following strategies;

- i. energy efficient design by minimizing active system usage,
- ii. buildings' adaptability to the local climate and the site's environmental conditions by its geometry and materials,

Passive mode design tactics include proper physical form configuration and orientation, interior spatial arrangement, exterior design, including opaque-to-transparency ratio, insulation, and color, utilization of building mass, greenery, and natural ventilation. As a low-energy design, passive mode design aims to optimize natural and ambient energy sources while reducing the use of nonrenewable energy sources. Instead of motorized heating and cooling systems that require external energy sources, this can be accomplished by using radiation, conduction, and convection [1] [10].

The bioclimatic strategy to architecture considers the project's entire surrounding factors. The temperature and location, as well as the environmental occurrences of the site, influence, but do not define, the type of design for the built form. The design is based on the current climate and seasons throughout the year. Designs for temperate and cold climates, for example, must be different, much as the topography and neighbors of the specific site influence the design. The location's sun path, usage of natural ventilation,

use of vegetation, proper façade design, sun shading, and other related issues all influence the building's shape and orientation. The local climate influences bioclimatic design and results in structures that are more suited to a certain location. Therefore the sustainable architectural study should include the other field's collaborations such as; climatology, biology and advanced systems [1] [11] [12] [13] (Figure 2).

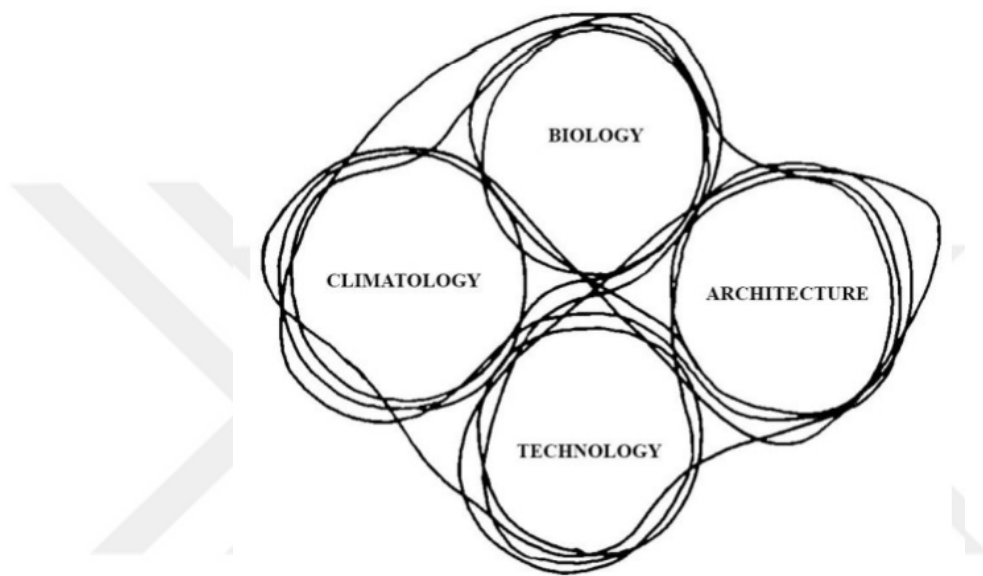


Figure 2: Disciplines' intersections [13]

Bioclimatic architecture has been developed over a period to address the problems that come with structures. Our ancestors discovered practical techniques to deal with the various climatic conditions in various parts of the world through trial and error. People have tried adapting their constructions to the environment throughout history to provide better living conditions [14].

The evaluation of climatic conditions has been studied in various methods, and two types of assessment are addressed. The negative impacts of climate on man are described in one approach as tension, agony, sickness, and even death. The second is a set of circumstances in which man's performance, wellness, and physiological energy are at their peak. In describing acceptable or disagreeable atmospheric and thermal

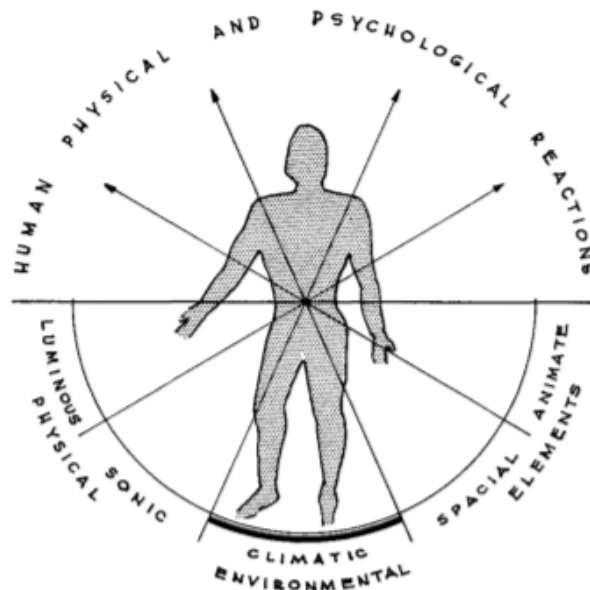


Figure 3: Man as the central measure in architecture [15]

conditions, both methodologies can be utilized to highlight coincident and complementary correlations. In light of this evaluation, studies have shown that human comfort levels may vary in different locations, such as summertime may correspond to the optimum need of a human in the UK whereas the wintertime may ensure the maximum level of comfort for humans in the Mediterranean region [15] [16] [17]. Therefore, architecture must be shaped around the needs of occupants of the space to achieve thermal comfort (Figure 3).

The primary ideas that can be recognized in vernacular architecture are to develop a building according to its environmental conditions in terms of building orientation, shading systems, and construction materials to ensure indoor thermal comfort. It is critical to apply bioclimatic design ideas influenced by vernacular architecture to future structures to improve their energy efficiency [18].

Bioclimatic architecture must improve total energy efficiency, achieve thermal occupancy comfort, employ renewable energy sources and local materials, safeguard the environment while keeping costs low. Local environmental considerations significantly

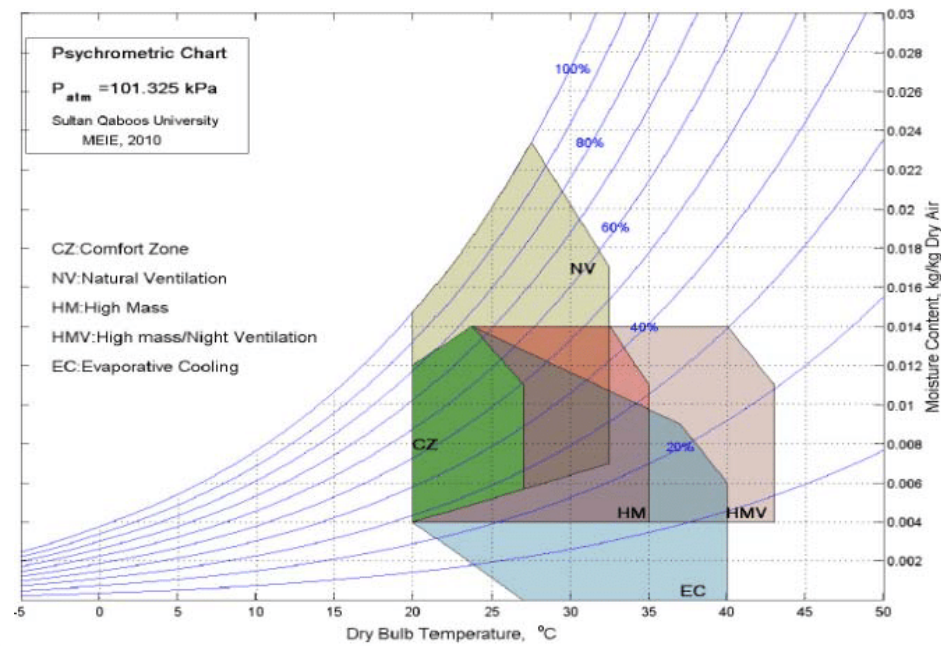


Figure 4: Givoni's bioclimatic chart [21]

impact the application of passive thermal design solutions for buildings. Bioclimatic charts can be used to determine whether the technique is suitable for the specific location [19].

The bioclimatic charts for buildings depict the relationship between climate and thermal comfort. These charts guide the required architectural solutions to attain thermal comfort in any specific location [20] [21] (Figure 4). The application of bioclimatic architectural concepts to structures entails a study of the climatic area and topographical constraints of the site. In this regard, each climatic location has unique peculiarities to consider in the early design stages before beginning construction.

2.1.1 From Vernacular to Contemporary Bioclimatic Architecture

The common definition of today's understanding of a building is closely linked to expectations of durability and consistency of the construction and the interior thermal comfort conditions, which resists natural environmental variations. In the past, when the technology was not developed, a traditional building envelope was used as a prevention block between the controlled interior area and the external environment in this scenario

[22]. Numerous cities worldwide will lose their unique perspectives, allowing them to be independent and consistent in the past. Settlements and structures were two pre-modern human innovations that resulted from climate and structural constraints on the one hand, and collective beliefs on the other. Vernacular architecture is a type of architecture that is focused on local building materials and necessities. Vernacular architecture has evolved to represent regional traditions by drawing on a local, cultural, technological, and historical context. Today's architecture is different from vernacular architecture; nonetheless, traditional architecture is not vernacular architecture, and there are some similarities between the two [23] [24] [25].

Contrary to traditional vernacular architecture, which frequently uses local climatic conditions, such as daylight and solar thermal radiation, modern buildings that generally have extensively glazed façades, heavily rely on artificial heating, cooling, and ventilation (HVAC) systems to maintain the highest level of interior comfort. The dependency on active building systems influences building energy performance throughout operation, accounting for nearly 90% of total energy spent during a structure's lifecycle [22]. Vernacular architecture can minimize the need for HVAC systems' assistance in heating and cooling the buildings.

In 1991, Özdeniz conducted a bioclimatic study on traditional Turkish dwellings in Turkey. This research can be utilized to define diverse climatic zones in Turkey, as well as historical approaches and principles of Turkish vernacular buildings [18]. The architecture of Sardinia's vernacular is studied as a case study of the Mediterranean climate in the literature for the hot-humid climate region; each microclimate variant's vernacular types are investigated, the efficacy of multiple bioclimatic methods are reviewed, and the relationship between them and architectural details had been highlighted [26].

*“The main difference between vernacular and bioclimatic building lies in the ability to select the technological solution most appropriate to the climate”
(Widera B., 2014) [27]*

The similarities between vernacular and bioclimatic architecture are apparent. First and primary, both concepts are distinguished by suitable architectural adaptation to local climate conditions. The second factor is dwelling in harmony with nature, which might be seen in vernacular houses and is intentionally developed in bioclimatic structures. The bioclimatic approach necessitates a thorough grasp of the ecosystem's diversity and sensitivity. In both architectural occurrences, there is also regard for the cultural legacy of the location where the building is created. Nevertheless, regarding the amount of applied technology, vernacular and bioclimatic construction differ significantly. Vernacular houses are generally built on knowledge established in a certain region worldwide and passed down through the generations as heritage (Figure 5-a). Modern bioclimatic architecture integrates traditional techniques with innovative technology (Figure 5-b). Moreover, the effective combination of passive and active measures is crucial in this approach [27] .

The learnings from vernacular architecture have inspired today's sustainable architecture. With the assistance of technology, today's buildings aim to ensure thermal comfort of interiors as well as reduce the high energy demand by active building systems.

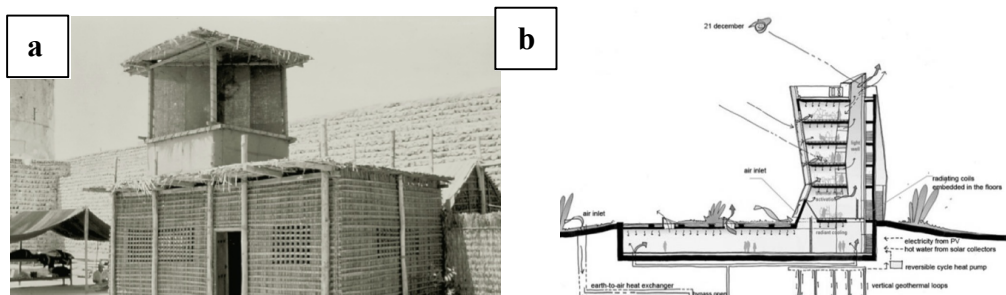


Figure 5: a) A traditional dwelling in Dubai aiming to maximize ventilation [20] b) A modern bioclimatic building with a double skin façade to maximize ventilation [37]

Therefore, integrating passive thermal systems and innovative design solutions into the buildings is significant. These passive systems integration on different climate and locations. Most studies focus on cold climate and hot-humid climate conditions since there are more distinctive strategies adapted from traditional architecture to adapt in challenging environmental conditions. Yet, there are studies of architecture in temperate climates. On the other hand, some studies discuss the bioclimatic innovative solutions effectiveness on building energy efficiency. The reviewed literature is presented with descriptions (Table 1).

Table 1 The reviewed sources and descriptions on bioclimatic architecture.

Reference	Title	Description
[28]	Passive Cooling of Buildings in Warm Climates by Means of the Barra-Costantini System: Thermal Dynamics and Performance Evaluations.	Concrete (with high thermal mass) is used for ceiling materials. The ceiling canal system is used as passive cooling strategy.
[29]	Passive Heating & Cooling of Buildings.	The vernacular passive systems are explained in detailed.
[30]	Guidelines for bioclimatic housing design in Greece.	This study developed a guideline for Greece by investigating and simulating different passive strategies.
[31]	Bioclimatism in vernacular architecture.	Vernacular architecture and bioclimates' relation are explained.
[32]	Energetic aspects of bioclimatic buildings in the Mediterranean area: a comparison between two different computation methods	The energy need in well-insulated buildings can be reduced in 50% by passive solar installations.
[33]	Building bioclimatic charts for non-domestic buildings and passive draught evaporative cooling.	To determine if passive evaporative cooling in conjunction with night ventilation may provide thermal comfort in an office building in Southern Europe, the Givoni building bioclimatic charts are employed.
[34]	Bioclimatic housing: innovative designs for warm climates.	The purpose of this book is to describe the term "bioclimatic" and the relationship between climate and people, with an emphasis on nations where housing temporarily needs cooling.

Table 1 The reviewed sources and descriptions on bioclimatic architecture.

[35]	Elaboration of a bioclimatic house in the humid tropical region: Case of the town of Douala-Cameroon.	To assess the building's energy efficiency and discover a way to lower the thermal load in accordance with the assessment of the humid environment made by meteorological data, bioclimatic design parameters are simulated.
[19]	Development of Bioclimatic Chart for Passive Building Design.	In this research, Givoni's zones based on TMY data are utilized to create a bioclimatic chart for Muscat, which is presented as a case study.
[36]	Thermal Energy Impact of Bioclimatic Techniques Applied to Low-income Housing in a Hot Dry Climate.	The effects of bioclimatic methods on thermal comfort in hot regions are analyzed. Louvers, a ventilated courtyard, and cooling systems are suggested.
[37]	Bioclimatic Architecture.	This article's goal is to explore the history of the idea of bioclimatic architecture as well as some of today's applications.
[38]	Achieving Energy Efficiency in Accordance with Bioclimatic Architecture Principles.	Through the promotion of bioclimatic principles, energy efficiency in all economic sectors will be increased in Pristina and Kosovo.
[26]	Bioclimatic lessons from Mediterranean vernacular architecture: The Sardinian case study,	The Mediterranean climate is studied through an analysis of Sardinia's traditional architecture. Analyses are done on the vernacular kinds associated with each climatic variety.
[39]	Management and assessment of performance risks for bioclimatic buildings	A residence in a tropical region is evaluated for thermal comfort using meteorological data and bioclimatic design techniques.
[40]	Bioclimatic Design Approach in Dayak Traditional Longhouse.	To evaluate the local bioclimatic home design technique on traditional wooden dwellings, another study is conducted in Malaysia.
[41]	Towards Adaptive Residential Buildings Traditional and Contemporary Scenarios in Bioclimatic Design.	The research analyzes the evolution of bioclimatic design standards as well as the vernacular architectural solutions used in Syria.

Table 1 The reviewed sources and descriptions on bioclimatic architecture.

[42]	A bioclimatic approach to develop spatial zoning maps for comfort, passive heating, and cooling strategies within a composite zone of India.	To estimate comfort levels in India, another study reproduced passive heating and cooling systems and produced a bioclimatic chart.
[43]	Design and thermal evaluation of a social housing model conceived with bioclimatic principles and recycled aggregates.	By using bioclimatic techniques, novel envelope techniques are employed to replicate the thermal performance of a single-family home in a tropical area.
[44]	Comparative bioclimatic approach for comfort and passive heating and cooling strategies in Algeria.	In this study, the effectiveness of bioclimatic design solutions is assessed by a climatic analysis of eight Algerian cities using a combination method integrating psychometric chart analysis and building energy efficiency simulation.
[45]	Analysis tool for bioclimatic design strategies in hot humid climates.	By developing a bioclimatic comfort model, a design guideline for climate is provided.
[46]	Geo-climatic potential of direct evaporative cooling in the Mediterranean Region: A comparison of key performance indicators.	The geo-climatic potential of several low-energy cooling strategies is calculated in the study.
[47]	Comparative analysis of user comfort and thermal performance of six types of vernacular dwellings.	The assessment of local architecture (passive cooling solutions) in western Sub-Saharan Africa provided the foundation for a sustainable, bioclimatic, and affordable housing idea.
[48]	Impact of climate change on future bioclimatic potential and residential building thermal and energy performance in India.	Future residential structures in tropical locations may see a 50%–60% yearly cooling load reduction in case of the implementation of passive techniques.

2.1.2 Bioclimatic Architecture Strategies

Optimizing building energy performance has been increasingly important. Bioclimatic design can also be defined as “passive-mode design”. By implementing

effective passive system solutions on buildings, several approaches exist to lower the construction sector's excessive energy consumption. These passive system solutions for heating and cooling buildings reduce the demand for active systems. It's also critical to employ renewable energy sources rather than fossil fuels to avoid pollution and to build with locally sourced materials. These methods are based on vernacular architecture, which helps to define bioclimatic architecture [49] [50] [18].

Bioclimatic architecture has already evolved over a period to address the problems that come with structures. Our forefathers discovered practical techniques to deal with the different environmental conditions in various parts of the world through trial and error. People have tried adapting their houses to the environment throughout history to provide better living standards [51]. According to Givoni (1981), various design aspects affect indoor thermal comfort (Figure 6).

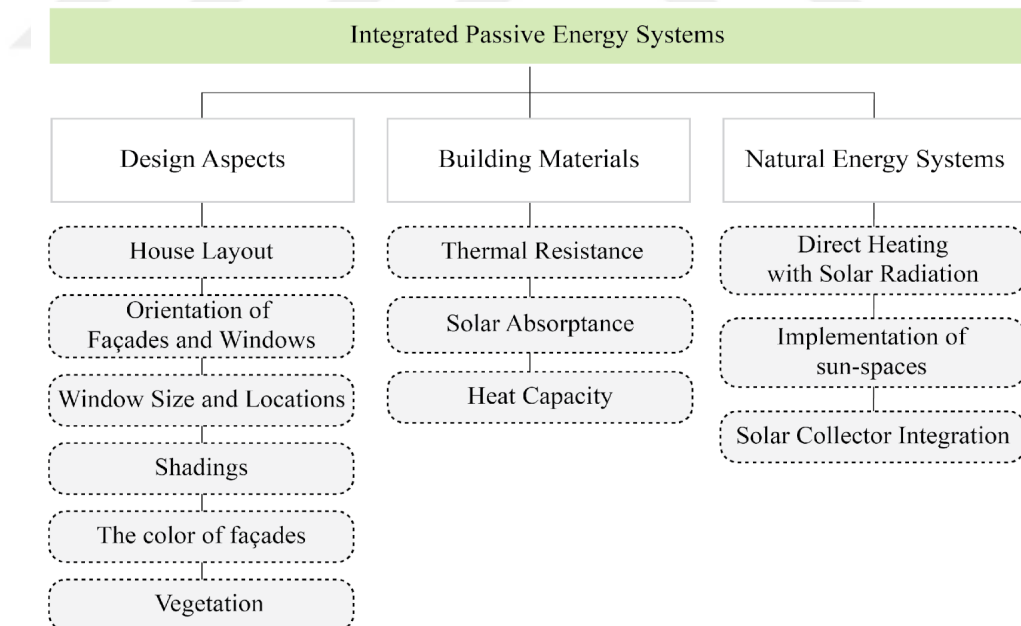


Figure 6: Integrated passive energy systems (Adapted from Givoni, 1981) [21]

The primary ideas recognized in vernacular architecture are to develop a building according to its environmental conditions in terms of building orientation, shading

systems, and construction materials. It is critical to apply bioclimatic design ideas influenced by vernacular architecture to future structures to improve their energy efficiency [18].

2.1.2.1 Climate Conditions in Antalya and Passive Cooling Strategies

The Mediterranean climate in Turkey is specified as a hot-humid climatic region according to TS 825 Standard [52], (Figure 7). The maximum average temperature is 34.1 C in June and July. In contrast, the minimum temperature is 6 degrees in January. The annual average humidity is approximately 65%, according to the meteorological data from 1930 to 2020 [53].

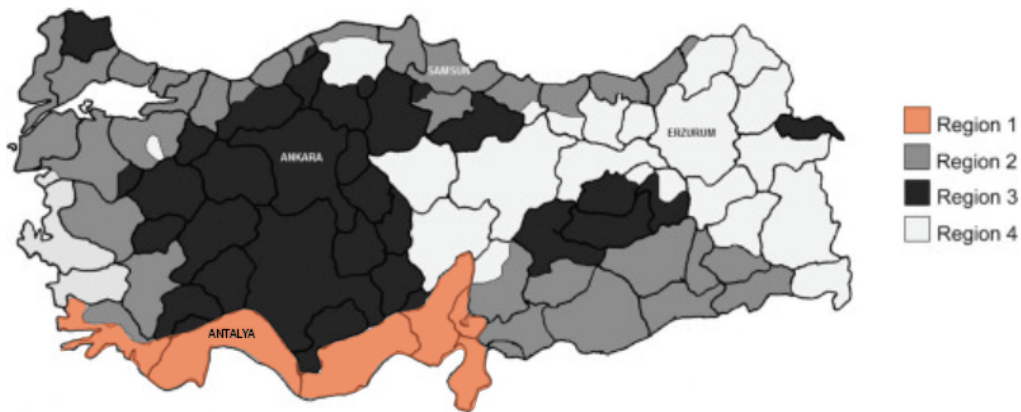


Figure 7: Turkey's hot-humid climatic region (Region 1) according to TS 825 Standard [52]

Wind systems near the coastline can be implemented to ventilate the buildings in hot and humid climates. During the summer, the cooling and dehumidifying energy demands are the most important variables, notably in the northern hemisphere and along the east coasts of open oceans. The high absolute humidity and frequently high outside air temperatures limit window ventilation. Dew point difficulties have an impact on surface cooling systems. Natural ventilation is possible during transitional periods,

especially at high latitudes. Heating energy demand is low in regions outside the tropics during the winter, while humidifying energy demand is nearly nonexistent. By simply glancing at the site, it is impossible to determine the amount of energy consumption with any precision [54] [55].

Heat avoidance is the first level of strategy for passive cooling. At this stage, the building must be designed to keep the heat gain minimal. The design should constitute strategies such as proper use of shadings on windows, building orientation, façade and roof color choices, insulation materials and thicknesses, as well as getting optimum daylight interior. Since avoiding heat only would not provide enough cooling for interiors during the summer, passive cooling measures should be implemented as well. A combination of heat avoidance and passive cooling may not be able to maintain thermal comfort in some locations. Therefore, the last step (third tier), mechanical equipment, may be sufficient for interior thermal comfort (Figure 8). This equipment must cool just what heat avoidance and passive cooling could not achieve in a sustainable design process. Suppose the first two tiers are performed efficiently. In that case the mechanical equipment will be relatively compact and require very little energy, still saving both money and the environment [20].

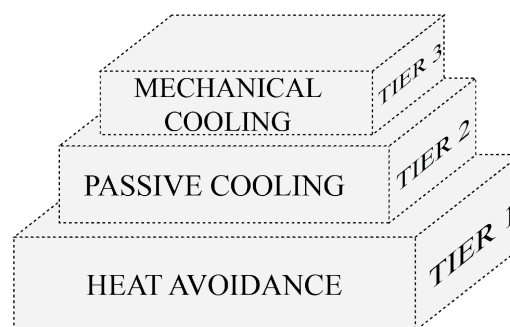


Figure 8: Three tier design approach (Adapted from Lechner, 2014) [20]

Negative pressure in the bottom half of space, positive pressure in the upper section, and zero pressure in the middle are caused by the stack effect [56] (Figure 9-a). If that was a multistory building's atrium, the heated air would rise to the top stories. The neutral axis must be raised to avoid this problem by increasing the height of the atrium, employing wind [20].

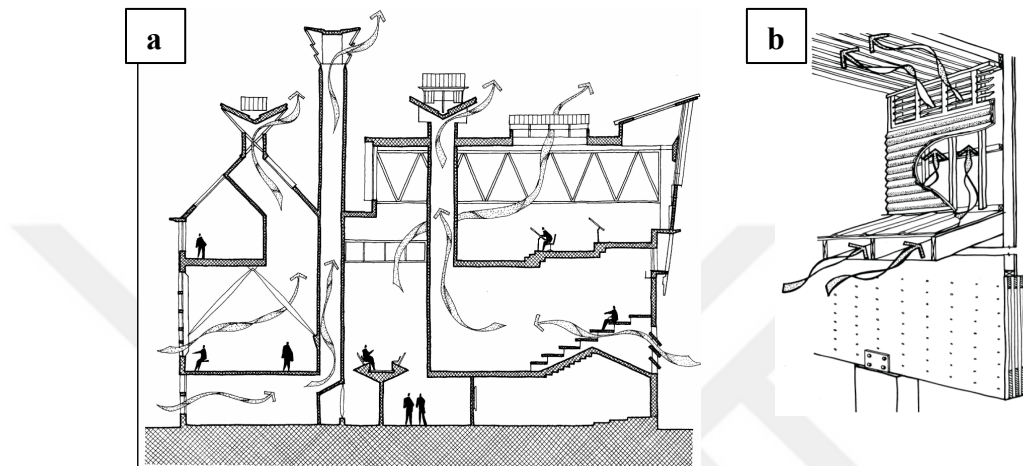


Figure 9: a) Stack effect in building [56] b) Vented wall and roof system [57]

According to DeKay & Brown (2014), five invariable passive cooling strategies can be implemented in hot climates for passively conditioned buildings:

- I. Creating shaded outdoor spaces such as porches, terraces, and balconies. This way, the direct wind getting interior increases while avoiding direct sunlight.
- II. Placing rooms that would not be affected by the heat or sun, as tampon areas between outside and living spaces.
- III. Planning the interior in consideration of thermal zoning and placing the rooms that need cooling in one part of the building may reduce the demand for more energy.
- IV. Stack ventilation is a gravity-driven system that enhances indoor air change (Figure 9-a). The warm air inside rises and exits from the chimneys or roof top

openings. Therefore, the hot air is changed with fresh cooler air entering from the below floors.

- V. Horizontal shades are beneficial since noon is the most heated time throughout the day. On the east and west façades double skin materials should be chosen for shading and permeability (Figure 9-b) [57].

A double-skin façade is formed by two building layers separated by a vented space. The cavity's primary goal is to improve the building's performance by altering the façade's features in all seasons. An unheated thermal buffer zone occurs between the heat-insulated internal wall and the external surface, which can be vented if necessary and include operable solar shading devices. Double-skin facades are intended to respond to changing environmental circumstances and to compensate for periodical climate variations. Heat, cold, light, and wind are thus adjusted to achieve optimum comfort without using advanced equipment or energy [55] [58].

Table 2 Hot-humid climate bioclimatic strategies

Passive Cooling Systems	Envelope Features
Sun-shading devices / louvers / eaves / shutters/ vegetation/ canopy / overhang	Wall thickness & material (low thermal mass)
Natural / cross ventilation	Flat roof / green roof / ventilated gable roof
Stack effect	Glazing units (low e / filmed)
Roof pond	Lightweight structures
Ventilated courtyard / atrium	Large windows
Color of the external façades	High ceilings
Building Orientation	Light color painted roof & walls
Large openings	Light insulation
Wind tower	Double skin façades
Solar chimney	Radiant cooling (concrete roof)
Night-flush cooling	High opening/wall ratio

To avoid humidity and related discomfort, buildings in hot-humid climates must benefit from ventilation mostly. In addition to the listing above, courtyards may be used to increase cross ventilation. The building form must be shaped to maximize the exterior surface area [59]. To summarize, the passive cooling strategies from the reviewed literature are listed [36] [45] [47] [55] [60] [61] (Table 2).

2.1.2.2 *Climate Conditions in Erzurum and Passive Heating Strategies*

The city Erzurum located in the eastern region's climate is specified as a cold region of Turkey [52] (Figure 10). The maximum average temperature is 27.2 C in August. In contrast, the minimum average temperature is -14 C in January, according to the meteorological data measured from 1930 to 2020 [53].

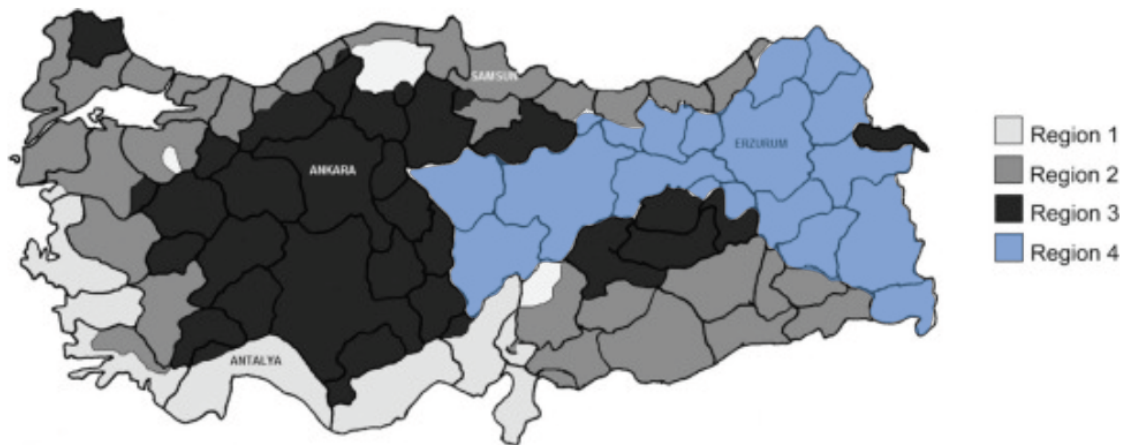


Figure 10: Turkey's cold climatic region (Region 4) according to TS825 Standard [52]

Cold winters and hot to warm summers define this region. During the winter, the primary energy need is for heating and humidification. These needs may increase in the higher and more northern locations. In the winter, the lower outside air temperatures severely limit the natural ventilation of the buildings. In the summertime, windows may offer most of the ventilation, and night ventilation may also be an option. In continental regions, temperature swings between different seasons are dramatic, and the conditions

get harsher as you get further away from the sea. Temperature variations within a single day are much larger in the summer than in the winter. Precipitation occurs throughout the year. In the winter, the continental plates chill significantly, forcing cold air to condense and sink. Winter precipitation falls mainly as snow [54]. Since Erzurum is in a cold, dry region of Turkey, the bioclimatic conditions of this region have been a significant concern [62].

The most significant issue for the livability of buildings in cold climates is keeping the heat stored indoors. As a result, compact forms with minimum surfaces are exposed to the exterior to prevent heat loss [31]. According to Lechner (2014), there are three main approaches before designing in a cold climate;

- I. Storing the heat inside in wintertime,
- II. Avoiding the winter wind,
- III. Benefiting of the sun

Water, concrete, bricks, stone, and PCM can be used as high thermal mass. In addition to the building form and materials, passive heating systems that use solar heat gain are efficient. Solar gain management is an integral aspect of any building's basic design idea for reducing the energy required for interior heating. Optimal orientation of the building, high-performance glazing, and thermal mass employment are examples of passive heating methods. Using specialized solar collectors to heat interior air can contribute much more to thermal comfort during cold weather [63].

The integration of thermal walls is one of the core strategies. This method is simply a south-facing double- or triple-glazed window that allows sunlight to fall on a large wall made of masonry, in-situ concrete, or water tanks. The south-facing side of the wall is often painted black. However, a low-emissivity, high-absorbency material like

metal foil can considerably improve performance. The heat the wall absorbs during the day is released in the evening [63] (Figure 11).

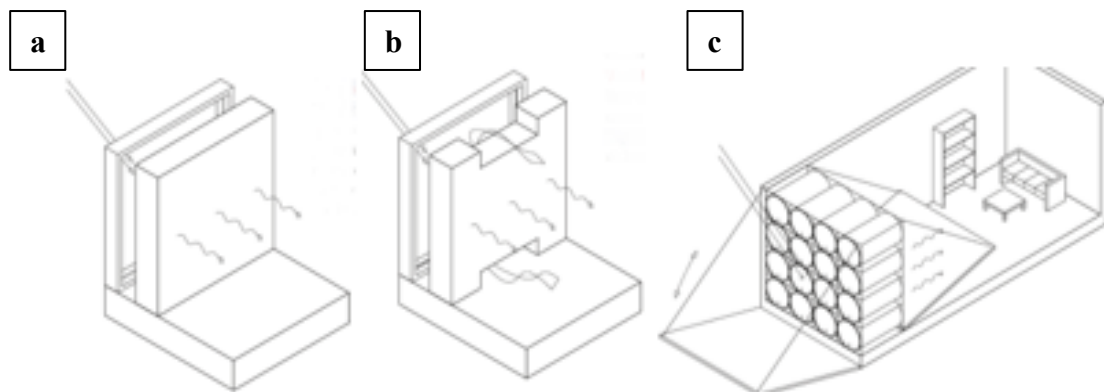


Figure 11: a) Simple trombe wall b) Ventilated trombe wall c) Trombe wall with water barrels[64]

Trombe wall creates the greenhouse effect, which is the simplest basic collector wall. Short-wave light penetrates south-facing wall's glass panes and strikes a dark absorbent layer. It is absorbed and converted into heat radiation with a long wavelength. Heat is transferred from the space between the façade layers to the inside via the wall. The heat gained can be expelled rapidly or over a lengthy period, even into the evening hours, depending on its storage capacity. The heat differential inside the gap causes the room air to circulate if there are holes at the top and bottom of the wall. Cold air is sucked into the bottom gap, heated, and pushed out into the area behind it [64].

Another passive heating system is the glass-enclosed sunspace which faces a south wall and ceiling to capture solar radiation. With the integration of sunspaces (greenhouse) into the building, short-wave radiation permeates a glass pane and then is converted to long-wave radiation, which is then absorbed by the floor or walls of a room (Figure 12). This thermal emission is subsequently distributed to the interior. The temperature changes in the living space are considerably reduced, and interior rooms are kept in a comfortable setting. The glass wall and roof are covered with insulation at night to keep

the heat gained during the day contained. Longwave heat radiation, unlike short-wave solar radiation, cannot pass through the glass, allowing the space to warm up [64] [65].

The tactics in cold climate regions may require passive heating system integration or improvement in building envelope layers. In most cases, both may be necessary. To summarize the passive heating strategies, the systems and envelope properties are listed [63] [20] [65] [66] [67] (Table 3).

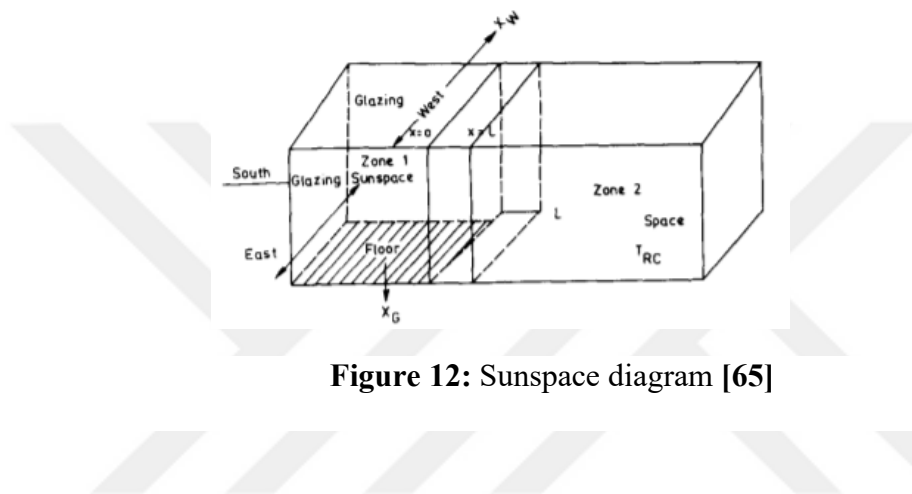


Figure 12: Sunspace diagram [65]

Table 3 Bioclimatic strategies in cold climate

Passive Heating Systems	Envelope Features
Trombe wall	Large glazing units (double-glazed)
Sunspace	Wall thickness
Vertical water tubes	Material
Water tanks	High Thermal Mass
Orientation	Roof system
Direct gain	Insulation thickness
Reflectors	Clerestory windows
Roof pond	Dark colored walls
Thermosiphon system, connective loop	Inclined south facing glazing
Roof radiation trap system	PCM (Phase change materials)

2.2 Positive Energy Blocks/Districts (PEB/PED)

2.2.1 Sustainable Urban Planning

The building industry must develop large-scale, high-performance buildings in response to climate change. Buildings that produce energy and are energy-efficient are known as Net Zero Energy Buildings (NZEB). NZEBs use high resource efficiency techniques and renewable energy systems to manage quality and enhance the performance of buildings. NZEB can help societies' economic transitions to be healthier and sustainable [68].

To disentangle and overcome the urbanization problems, newly invented ways of urban thinking centered, multidisciplinary strategy and long-term perception concerning the planning and development of the constructed, infrastructural, operational, and functional forms of cities are required. Accordingly, innovative solutions and advanced techniques must be integrated into urban planning and development [69]. The concept of nearly zero energy buildings (nZEB) is one of the goals of the EPBD. To upscale the concept of nZEB, the energy supply and generation must be adjusted. It is necessary to innovate energy networks and promote interaction between them and facilities in order to scale up NZEB and achieve its most robust market, environmental, and welfare advantages [70].

In recent years, the concept of zero energy districts (ZED) has become widespread on the transition from building scale to campus scale in studies on energy performance. In this context, passive strategies for building design and use of renewable energy should be analyzed to reduce building energy consumption.

The "smart city" can be defined as "efficient and intelligent utilization of the city." The smart city ideology will enhance urban methods and growth, especially with the rapid

development of technology and sustainable development, which began in the 1990s and continues today. It's a method that focuses on the technology adaptation process. In a growing world of ecological concerns, communication technologies, automation, and building materials technologies assist nature-sensitive development techniques. Many organizations, companies, and initiatives around the globe are working in this direction to present a vision for the future of cities [71].

Numerous innovative technologies are being researched and used in the field of smart sustainable urban planning and development in response to the pressing need to deal with the complexity of the knowledge needed for enhancing, employing, and combining urban systems and allowing cooperation between urban contexts [72].

Sustainable urban development, which has been developed since the early 1990s with similar concerns, essentially envisions the effective use of a settlement and is presented with similar or different key elements. In selecting smart city concepts, city planning techniques are a factor to be considered. The main emphasis features of all of these techniques may be used to establish the development principles of a smart settlement phenomenon [71].

Settlement form, building materials and types, integrating renewable energy systems into districts, energy efficiency, energy conservation, and energy production are some of the typical topics covered by planning and design concepts. Globally, distributed energy generation is growing rapidly. A significant portion of these distributed generating units rely on renewable energy sources, which, when coupled with rising electrical demand, creates serious challenges for maintaining network efficiency and balancing the energy supply while also ensuring overall system stability. As a result, better infrastructure for consumer communication and information is needed. Districts can be

seen as fully functional, populated units that manage local energy sources and have the ability to buy energy in case local generation is insufficient or sell excess energy to the surrounding grid. Meeting climate targets ultimately depends on developing a practical and innovative strategy for "Positive Energy Blocks" (PEB), a system-level idea in which a neighborhood creates more energy than it consumes, with the excess being stored locally or exported [73].

As part of their Strategic Energy Technology (SET) initiative, several European countries have agreed to build 100 Positive Energy Districts (PEDs) by 2025. Towards that goal, a wide framework definition of PEDs has been established; Urban areas referred to as Positive Energy Districts aggressively manage an annual local or regional surplus of renewable energy and attain net zero emissions of greenhouse gases while being resource-efficient and adaptable. To achieve social, financial, and environmental sustainability, they necessitate the integration of various infrastructures and systems as well as the relationship of structures, people, local energy, and mobility. The PEDs must be implemented with a comprehensive assessment of the city's context, regulations, aspirations, initiatives, resources, and alternatives. For planning PEDs, knowledge of technology and governance is required. Additionally, a holistic approach of energy demand, supply and storage should be considered for energy balance in PEDs [74] (Figure 13).

To achieve yearly net zero energy imports, annual net zero CO₂ emissions, and annual local renewable energy surpluses, the Set Plan Action 3.2 underlines the need of incorporating district-scale creative techniques. Below are some of the factors that must

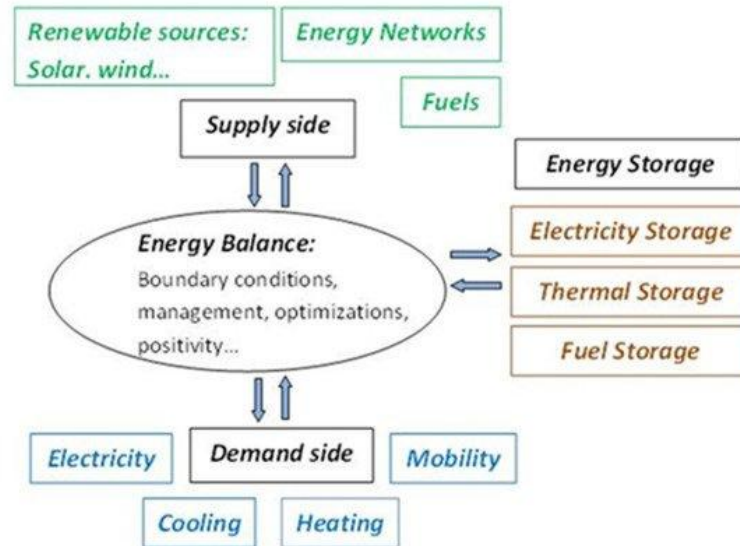


Figure 13: Interrelation of PEB's key elements [74]

be considered when calculating a district's overall energy balance, both geographically and seasonally:

- I. Power generation is driven by available natural resources such as renewables.
- II. The typology of the district (population, settlement type, architecture, and context).
- III. Control systems and infrastructures that can be employed to predict energy component exchanges.
- IV. Possible connections between renewable energy systems and other power systems.
- V. Guidelines and rules for managing operations are in place to maintain the system's stability, accessibility, and adaptability [75].

In order to reach an optimal system of energy balance in PEB, the thermal, electrical and gas streams and their effects on each other must be analyzed in detail [76]. The environment, management system, optimistic calculations, and regulatory limits all impact on effective system operation. To be able to accurately measure the global energy

balance and impact on the environment of an innovative urban system, a consistent methodology and set of metrics for performance are essential [77].

2.2.2 Renewable Energy Systems and Advanced Building Systems in Positive Energy Districts

Today's designs must undoubtedly go further than vernacular design. The usage of non-renewable energy in buildings must be minimized or avoided. Architecture should begin with bioclimatic considerations, optimizing and expanding all passive-mode design possibilities. Therefore, it should move on to a stage of blended options as an intermediate step. The next level of adaptation of bioclimatic architecture will be supported with advanced building systems. The active systems should be considered where the passive system implementation does not correspond to the thermal comfort levels. It eventually leads to a "productive mode" (where the built system generates its energy) using renewable energy sources, as in ecosystem eco-mimicry, where the energy source is renewable and comes from the sun. Today's design goal is to develop "net-zero energy buildings," which are energy-efficient structures in which the total energy consumed roughly equals the amount of renewable energy generated on the site [15]. Positive energy buildings, which can be isolated or integrated at the neighborhood scale, can help the area and provide surplus power to buildings with trouble in achieving their net zero energy goals.

Conventional energy is obtained from restricted resources such as coal, oil, and natural gas. On the other hand, renewable energy is derived from sustainable resources, such as solar, wind, biomass, etc. Various renewable energy systems transform one type of energy into the other. In power generation from renewables, mainly, the final product of energy is electricity [78].

In grid-connected settings for residential and office buildings, implementing a renewable energy-sourced system should always come first for energy efficiency improvements, low-carbon emissions, and cost-efficiency. These efficient renewable energy systems such as solar thermal, ground or water source heat pumps (GHSP), air source heat pumps (AHSP), solar photovoltaics, wind turbines, and hydro turbines. Most of the existing buildings do not have equal access to all renewable energy sources, such as use of solar radiation, wind, stream, rivers, or locally accessible biomass. Installing a ground-sourced heat-pump is the most carbon and cost-efficient alternative and is necessary to access to a sufficient ground [79]. The surplus energy district model can be described as a central spot where numerous energy carriers meet. According to demand requirements, corresponding energy flows can be appropriately converted, conditioned, stored, and distributed [80].

Solar energy can be used for heating the interior space and domestic hot water (DHW). In most cases, solar thermal systems are complex and permanently installed systems that incorporate specifically designed absorbers/collectors, electric pumps, and plumbing into a building's heat distribution system. Some of these systems include additional hot water tanks. These systems' solar panels are generally roof-integrated, mounted on a part of the building's surface. The installation of such systems is budget friendly compared to electricity or natural gas-sourced heating [79].

Geothermal energy is the heat energy of the earth. Using geothermal energy in heating systems is a renewable system [81]. This heating system is also called a geothermal heat pump or geo-exchange system. The chiller exchanges heat with a fluid circulating via an earth connection device in a heat pump (ground or groundwater). Depending on the ground temperature, the fluid is enclosed in several loop arrangements. Loops can be placed horizontally, vertically, or submerged in water. Geothermal heat

pumps, which transmit heat between the home and the earth, attain higher efficiencies and have low operating costs since they take advantage of relatively consistent ground temperatures [1].

Photovoltaic systems operate by directly converting sunlight into electrical energy. The conversion occurs in a solar or photovoltaic cell, which is typically constituted of silicon, though alternative materials are being explored. PV cells must be enclosed and wired together into a bigger DC electrical unit known as a module. A PV array is a collection of solar modules [82]. According to Roberts and Guariento (2009), the PV installment types are as follows:

- I. stand-alone, off-grid, including storage for battery
- II. on the ground and connected to the grid (e.g., solar farms)
- III. on building roofs, connected to the grid
- IV. building integrated (BIPV), connected to the grid

Building integrated photovoltaics' (BIPV) assistance is an innovative approach of using renewable energy. BIPV can significantly help with the Green Deal's goals, to accelerate the emission reductions of the EU's building stock [83]. Given the highly inventive and substantial commercial potential, this technology has the potential to become a benchmark for the EU sector. BIPV technologies have already had notable cost reductions and a better level of technical maturity over the past ten years, which have been reinforced with a more competitive worldwide market. BIPV may become a popular construction method in Europe, given the need for industrial competitiveness and innovative manufacturing techniques. This direction must have the proper backing to attain the climate-neutrality targets by 2050 [84].

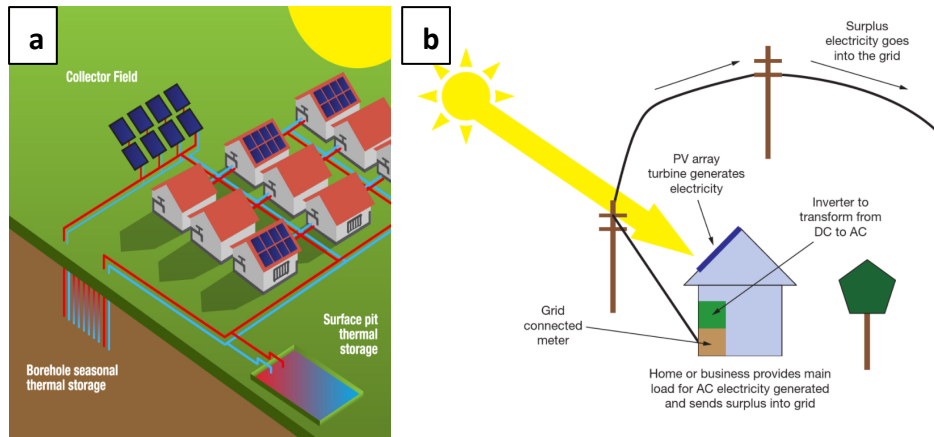


Figure 14: a) Solar district heating [140] b) Photovoltaic panels integrity to the city-grid [79]

Panels' dimensions are typically 1-2 m² and can be linked together to form arrays producing power (1,000 W-1,000 kW). PV collectors are frequently found on the roofs of buildings, positioned towards the sun's path (the way that they can have the maximum possible sunlight). Solar collectors absorb heat, while PV modules generate power. In the PED concept, the role of power generation is significant. The grid-connected photovoltaic system of the housing units provides surplus electricity power to the city grid. If the power generation is insufficient for the building energy demand, the grid provides power to the buildings [79] (Figure 14).

The CHP (combined heat and power) system has been integrated into the power grid in some countries to produce electricity and usable heat, and significantly increases profits while reducing emissions from burning fossil fuel sources. This is done by capturing a portion or all of the by-product heat, which lowers operational costs for power generation. Combined heat and power systems (CHPs), which produce heat and power with excellent efficiency, have recently attracted a lot of attention. Due to their capacity to quickly change their electrical load to reduce or enhance the thermal output, small-

scale CHPs, also known as domestic (dCHP) or Micro CHPs (MCHPs), have discovered markets in residential and commercial applications [85].

The advantages and difficulties of power-to-heat alternatives in power systems with significant proportions of variable renewable energy sources are starting to become apparent, but the literature is still segmented: both different innovations and extensions of existing power systems. Cogeneration produces heat and electricity power together in the same system. This method of two energy forms' generation is more efficient than producing in separate ways. In a simple system, the gas turbines can only replace 30-40% of its electricity power consumption. In the cogeneration systems, the thermal waste loads can also be turned into power. Hence, 70-90% of the input energy can be provided to the system again. This cogeneration technique is also called “combined heat-power systems” (CHP) [86].

2.2.3 Positive Energy Districts Standards and Regulations

The building sector was responsible for 20% to 38% of global GHG emissions in 2019 according to the fifth assessment report of the Working Group III for the Mitigation of Climate Crisis [87]. Of this amount, 57% of indirect CO₂ emissions came from off-site electricity and heat generation, with the remaining 24% of CO₂ produced on-site and 18% from the cement and steel industry for building construction. According to the regional interactive atlas of the IPCC WPI, regional climate change will cause temperature increases to be magnified in the future, and increased urbanization will worsen the predicted air temperature rise in cities. Therefore, a top priority for achieving national goals and targets is the decarbonizing of the built environment [88].

The Strategic Energy Technology (SET) Plan is concentrated on ten specific action fields. One of these fields is under Action 3.2, which aims to support the planning,

implementing, and replicating of 100 Positive Energy Districts by 2025 for sustainable urban planning. This energy technology strategy was endorsed by the European Union countries in 2008 [89].

According to PED program partners, the PED guideline provides a standard foundation in all nations while still maintaining flexibility in terms of locational circumstances for PEDs. Hence, the idea of PEDs is developing and must be improved upon, progressed, and updated to be verified and used. The fundamental concept and targets of energy performance analysis must be defined to account for the various types of district-related data that are now accessible. To do this, a set of categorization metrics must be specified. These goals cover both substantive and procedural aspects of the social, economic, and environmental facets of sustainability [90].

The PEDs must be implemented by properly assessing and considering the cities' environmental conditions, regulations, objectives, approaches, and resources. Planning, constructing, implementing, and monitoring PEDs as well as their replication and mainstreaming, need knowledge, skills, and technology. Even though many European cities are leading the transition to low-carbon energy, there is currently no shared definition, roadmap, or rules to guarantee the practical viability of PED designs. This is mainly because cities are still in the planning or early implementation stages. In this respect, it is still necessary to identify the fundamental requirements for putting PEDs into practice and comprehend how these needs work in concert with one another [74]. To make PEDs accessible for a wide variety of potential methods, criteria for determining the physical and virtual borders of PEDs are currently being discussed in partnership with other initiatives (e.g. EERA Joint Program Smart Cities) [91].

2.2.4 Turkish Standards and Regulations

According to the energy performance regulation in buildings of Turkey, buildings reaching a minimum construction area of 2000 m² or greater must be constructed by nZEB regulations. These buildings' architectural, mechanical, and lighting projects should comply with the regulation guidelines. Additionally, these nZEB buildings must have an energy performance class of B or above on their Energy Performance Certificates, and at least 10% of their primary energy requirements must be satisfied by renewable energy sources [92].

In buildings with a 60% or above window-to-wall ratio, the thermal transmittance coefficient of the window system in buildings should not be higher than 2.1 W/m²K to prevent heat loss through the building envelope. This building construction is accepted if the thermal transmittance coefficients of the sections are guaranteed to be 25% lower than the values suggested, and the insulation properties must comply with the TS 825 Standard [93].

In Turkey, Sustainable Development Plans Report, proposes objectives for future sustainable energy plans. The Ministry of Energy and Natural Resources, Ministry of Industry and Technology, Ministry of Environment and Urbanization and related institutions had prepared strategy documents and different policies. One of these documents, the 9th Development Plan, focuses on liberalization in the electricity and natural gas sectors. In the period of the 9th Development Plan, the integration of renewable energy systems and power plants into the electricity transmission distribution system has accelerated [94].

Renewable systems such as heat pumps (air, soil or water sourced), cogeneration, and micro-cogeneration may correspond to the heating, cooling, ventilation, domestic hot

water, electricity, and lighting demand of the new constructions covering larger area than 20.000 m². Renewable energy resources usage and system details are analyzed during the project planning phase; the application of renewables' budget should be at least 10% of the total construction budget. For the general requirements of solar thermal panels and photovoltaic panel applications on buildings, the standards TS EN 12975-1 and TS 3817 must be followed [92].

An article reviews the sustainable urbanization approaches that have become widespread worldwide. The research's findings, provided in the paper as principles and models for the design of ecologically sustainable cities, will assist Turkish policymakers in planning for the development of eco-city projects as well as the ecological transformation of existing urban areas [95].

2.3 Bioclimatic Architecture Strategies' Impacts on Positive Energy Blocks' Energy Performance

2.3.1 Passive Urban Design Strategies

At both the building and district scales, a holistic approach to integrated urban energy planning and design can improve overall energy efficiency, the use of renewable energy sources, and bioclimatic methods to reduce the energy footprint [96]. To support the holistic approach covering these two main issues and develop the literature review for the thesis, positive energy districts (PED) and bioclimatic architecture concepts' intersection is discussed. The bioclimatic principles and PEDs' common highlighted subject areas are building energy performance, climatic conditions, and thermal comfort.

Numerous research has indicated that climatic parameters (temperature, humidity levels, air velocity, and solar irradiance) significantly impact buildings' energy usage and thermal comfort. The region's temperature fluctuations through the seasons are one of the

most vital climate characteristics since it affects the buildings' heating and cooling energy demands. High humidity levels may cause occupancy thermal discomfort as well as mold problems in building layers and may require ventilation (passive or active) solutions. Solar radiation is connected to building energy use and is considered an important renewable energy provider; consequently, its usage at the urban block level is crucial to provide surplus energy to the grid [97] [98] [99] [100] [101].

In a city layout, the patterns and features important in determining single-building units can be discovered on a larger scale. Since it is affected by the same impulses, its texture reflects not only mass-building tendencies on a bigger scale but also an aggregation of distinct shapes. The density of a city layout will vary depending on whether the climate is pleasant [15] (Figure 15).

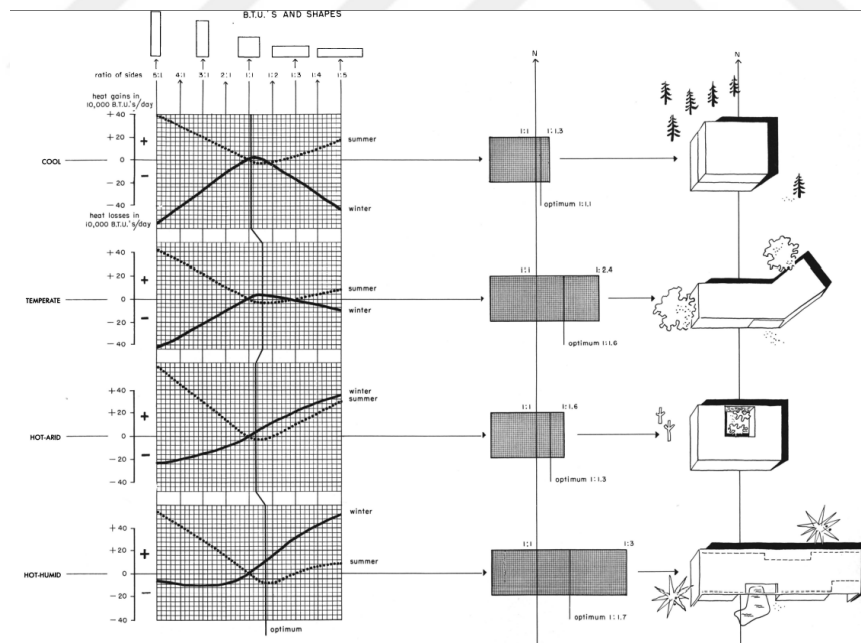


Figure 15: Building forms under different climate types [15]

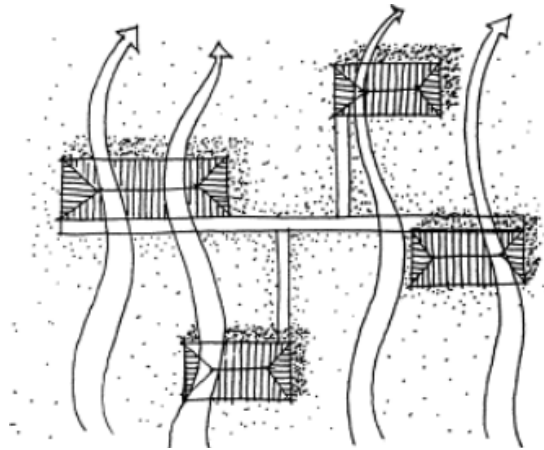


Figure 16: Settlements in hot-humid climate regions [31]

Humidity is an important factor in hot climates. The thesis is focused on the hot-humid climate. Because the fluctuations in outside temperature in the daily and annual cycle are minimal, the thermal inertia of the buildings provides no benefit. Furthermore, due to the high radiation intensity, it is critical to provide the best possible protection from its effects by attempting to halt both direct and diffuse radiation. In hot-humid climates, the ventilation strategy plays an important role. It is critical for dissipating heat and reducing humidity in interior spaces. As a result, the buildings have wide sun-protected apertures. In contrast, traditional building implantation uses long narrow forms that are independent and separate from one another, seeking to avoid creating barriers for breezes between the structures [31] (Figure 16).

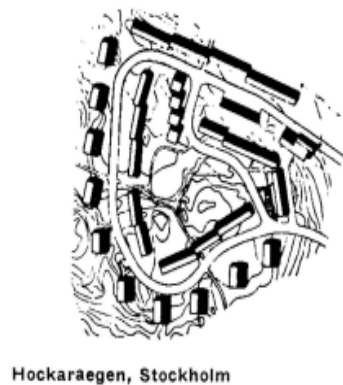


Figure 17: Settlement layout under cold climatic condition [15]

In cold climatic regions, the arrangement attempts to give wind protection. Large building units are flexibly clustered and positioned to benefit from the sun's advantageous thermal benefits. Houses need to be connected to reduce the amount of surface area exposed to heat loss. The settlement is laid out in a dense, solitary pattern [15] (Figure 17).

2.3.2 Energy Performance Evaluation of Positive Energy Districts

As individual buildings' energy conservation has been intensively researched and studied, the low-energy design regulations and standards have been published and applied. Nowadays, the energy conservation and efficiency of urban buildings have peaked. Since the urban structure of today's huge cities increase day by day, the operational energy usage of urban buildings also increases. Although a single building's effect may be minor, the sum of effects at the district scale can be much more impactful. Hence, it is critical to use proper instruments for modeling urban building energy for low-energy urban design [102].

The scale of an urban design may vary from 10 to 1000 building blocks. Furthermore, to study on this scale (blocks/neighborhood/district), an urban building energy modeling (UBEM) methodology has been developed recently. In accordance with the reviews for the UBEM tools, there are both possibilities and challenges. Even though the method is a promising approach, there are need for technical improvements to determine urban thermal effects [103].

While researching the urban climate characteristics, it is proposed that urban form and energy performance from the perspective of architecture and urban design should be analyzed to find the most efficient and sustainable strategies for urban block design [104].

The thermal comfort and energy efficiency of settlements are concerning different urban design aspects. According to Shi et al. (2017), these effective measures are as follows:

- I. Building forms
- II. Density of the blocks
- III. The layout
- IV. Orientation
- V. Window/wall ratio

According to the result of a review article on PEDs, while creating future possibilities for neighborhood energy systems, the building improvements (such as window, wall, and foundation retrofitting etc.) must be planned for the blocks not just infrastructure upgrades with various energy carriers. In this case, the selected neighborhoods may achieve improve overall efficiency in the future constructions [80].

2.3.2.1 UBEM Tools

Several different UBEM approaches and tools offer information on the building stocks' (city or district scale) energy consumption, including improvement scenario evaluations, analyses of peak loads and energy trends, etc. The main objective of UBEM is the energy modeling of the building blocks, which can then be utilized as input for the proper design and optimization of energy systems [105].

Swan and Ugursal (2009), review numerous modeling approaches for simulating the energy usage of the residential sector and assert that there are two methods: top-down and bottom-up. The top-down strategy ignores specific end uses and assumes the residential sector as an energy drain. The energy consumption of the housing stock is regressed as a function of top-level factors such as macroeconomic indicators, energy prices, and the overall environment using historical aggregate energy values. The bottom-

up approach, which combines statistical and engineering methods, extrapolates the estimated energy consumption of a sample group of individual buildings to district and city scales. Each method uses a different degree of input data, employs various computation or simulation methods, and yields outcomes with various applicability levels [106] (Figure 18).

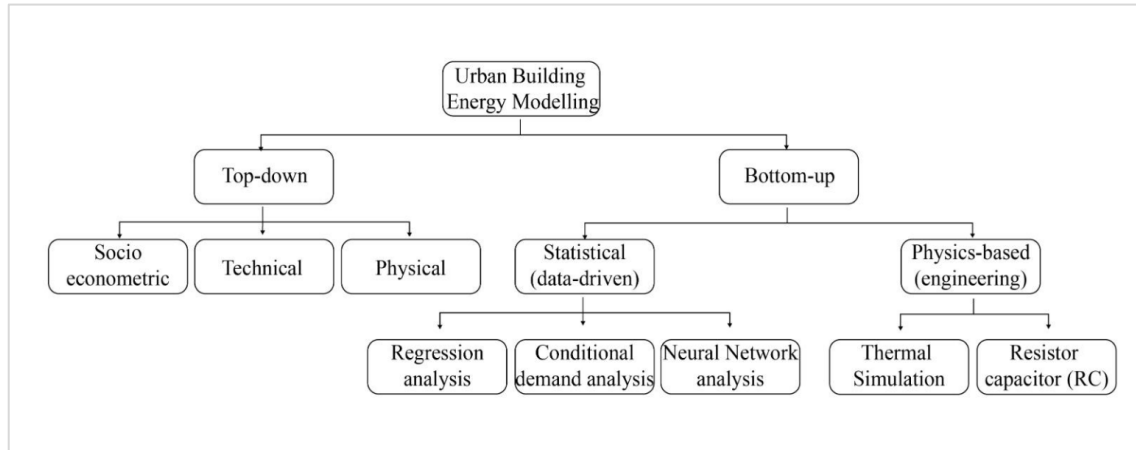


Figure 18: Urban building energy modeling sub-categories diagram (Adapted from Ferrando et al., 2020) [105]

Figure 19 represents the timeline of bottom-up physics-based UBEM tools' release dates. This dissertation methodology uses UrbanOPT (Urban Renewable Building and Neighborhood Optimization), an OpenStudio-based platform providing energy assessments on district-level energy modeling.

In literature, the mentioned above UBEM tools and simulation engines are used in various ways (Table 4). Abdollahzadeh & Bitoria (2022) conduct a multi-objective study with an optimization procedure of district energy modeling and thermal analysis. The urban energy simulation is created using a parametric method to identify the optimal layouts. The used technique follows a methodology of passive design parameters that can be implemented in districts by designers in the early design phases. The study also

proposes renewable systems, such as PVs, to lower the energy demand of urban districts [107].

Another research by Evola et al. (2020), follows a different workflow. It provides both the dynamic thermal load of the buildings and the parameters needed to quantify the outdoor comfort felt by pedestrians by matching the indoor and outdoor thermal fields in an urban case in Italy [108].

The paper by Vartholomaïos (2017), offers the findings of a parametric examination of how three urban typologies are affected by urban layout. The study of residential energy use is conducted to fulfill the requirements for heating and cooling. The result support the assertion that the methods of high urban compactness and passive solar architecture work together and may be attained at various urban concentrations [109].

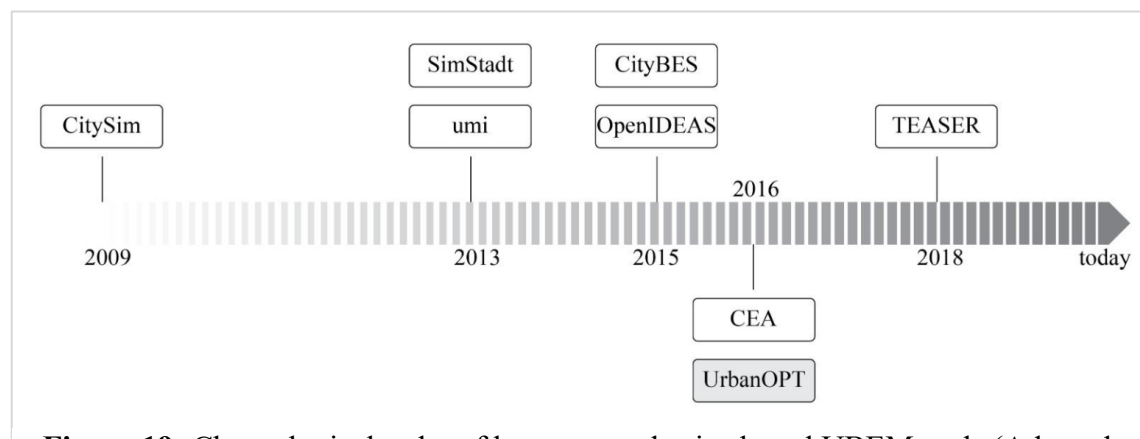


Figure 19: Chronological order of bottom-up physics-based UBE tools (Adapted

from Ferrando et al., 2020) [105]

Table 4 Urban energy modeling tools used in literature

Year	Title	Tools	Reference
2017	A parametric sensitivity analysis of the influence of urban form on domestic energy consumption for heating and cooling in a Mediterranean city	Ladybug, Honeybee, EnergyPlus	[110]
2018	Comparison of dynamic urban building energy models (UBEM): Sigmoid energy signature and physical modelling approach.	IDA ICE	[111]
2020	Urban mitigation and building adaptation to minimize the future cooling energy needs	Weather Research and Forecasting model (WRF), EnergyPlus	[112]
2020	Energy-driven urban design at the district scale for tropical high-density cities.	Grasshopper	[113]
2020	A novel comprehensive workflow for modelling outdoor thermal comfort and energy demand in urban canyons: results and critical issues	Grasshopper, Ladybug, Honeybee, Dragonfly	[114]
2020	Analysis of Open Urban Design as a tool for pedestrian thermal comfort enhancement in Moroccan climate	ENVI-met	[115]
2020	Modeling the influences of layouts of residential townhouses and tree-planting patterns on outdoor thermal comfort in Bangkok suburb	ENVI-met, BioMET	[116]
2021	Using urban building energy modelling (UBEM) to support the new European Union's Green Deal: Case study of Dublin Ireland.	Tabula, EnergyPlus	[117]
2022	Urban microclimate and energy consumption: A multi-objective parametric urban design approach for dense subtropical cities.	Grasshopper, Ladybug, Honeybee	[118]
2022	UBEM's archetypes improvement via data-driven occupant-related schedules randomly distributed and their impact assessment	Grasshopper	[119]
2022	How close are urban scale building simulations to measured data? Examining bias derived from building metadata in urban building energy modeling	AutoBEM, OpenStudio, EnergyPlus	[120]

2.3.2.2 *Challenges in UBEM*

Due to the limited data and computational resources available, dynamic urban simulations frequently confront three key challenges: creating virtual 3d settlements, developing architectural typology, and incorporating the effects of urban microclimates [121]. Geometric data can be obtained at the building scale by measured data. However, for the modeling of urban contexts, the buildings' geometric data gathering is difficult due to the sheer number of buildings in a settlement, and it is challenging to apply the principles on larger scales [122].

Since a neighborhood is considered a single unit with demand, local supply, and storage, it is critical to establish a distinct boundary of the blocks. To better understand demand-supply matching, it is crucial to treat demand and supply simultaneously than sequentially. When using storage systems to impose some flexibility on the system, modeling time intervals is a big challenge. Defining limits for correctly establishing performance evaluation techniques is one of the major issues of moving from the building to the urban level. The difficulty and architectural limitations associated with the urban setting that affects energy performance increase as the scale of the operation also increases [123].

The amount and precision of the data inputs are necessary for a successful UBEM. Nonetheless, two major obstacles to the development of UBEM are the scarcity of current information and the difficulty in interpreting unpredictable data [122]. Shi et al. (2017) discovered the general limitations of urban design through an analysis of contemporary morphological methods. The findings suggest that an urban design prototype, including the location, roads, layouts, dwellings and building programs, should be created for the methodology of an urban study [9]

CHAPTER III

METHODOLOGY

The thesis framework is presented in Figure 20. The bioclimatic architecture design principles, PED strategies, and the intersection areas of the study areas are analyzed critically. This thesis chapter includes the definition and the practice of district energy model generation and proposes renovation strategies subsequently.

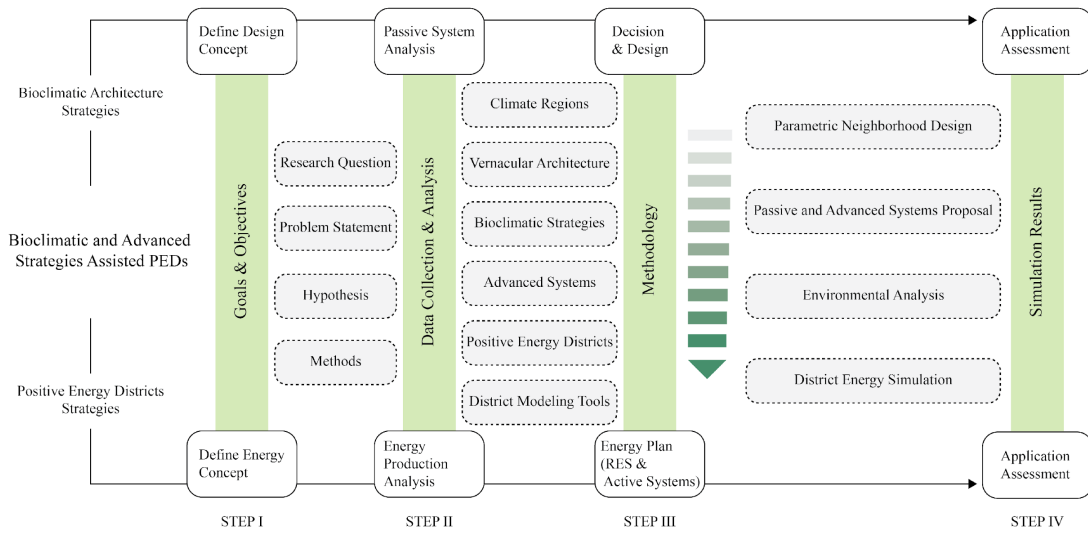


Figure 20: Thesis framework overview

3.1 Research Method

In this study, building typologies, heating and cooling systems, orientation and other distinctive parameters are examined according to climate type to evaluate the energy consumption and carbon dioxide emissions of buildings belonging to positive energy neighborhoods. To assess the passive and advanced systems/tactics impacts on PEDs, Urban Building Energy Modeling (UBEM) is essential for applications that require urban energy performance analysis.

In this dissertation's methodology, Rhinoceros 7, Grasshopper software is used for the building modeling metrics interface. For the district energy calculations, in addition to Dragonfly and Honeybee plug-ins, URBANopt open-source software is used [124]. The grasshopper script, including URBANopt parameters, for district energy simulation is obtained from the referenced website, which is a public open source [125] (Figure 21). The simulation engine is EnergyPlus. The script is edited and enhanced for coherence to the thesis.

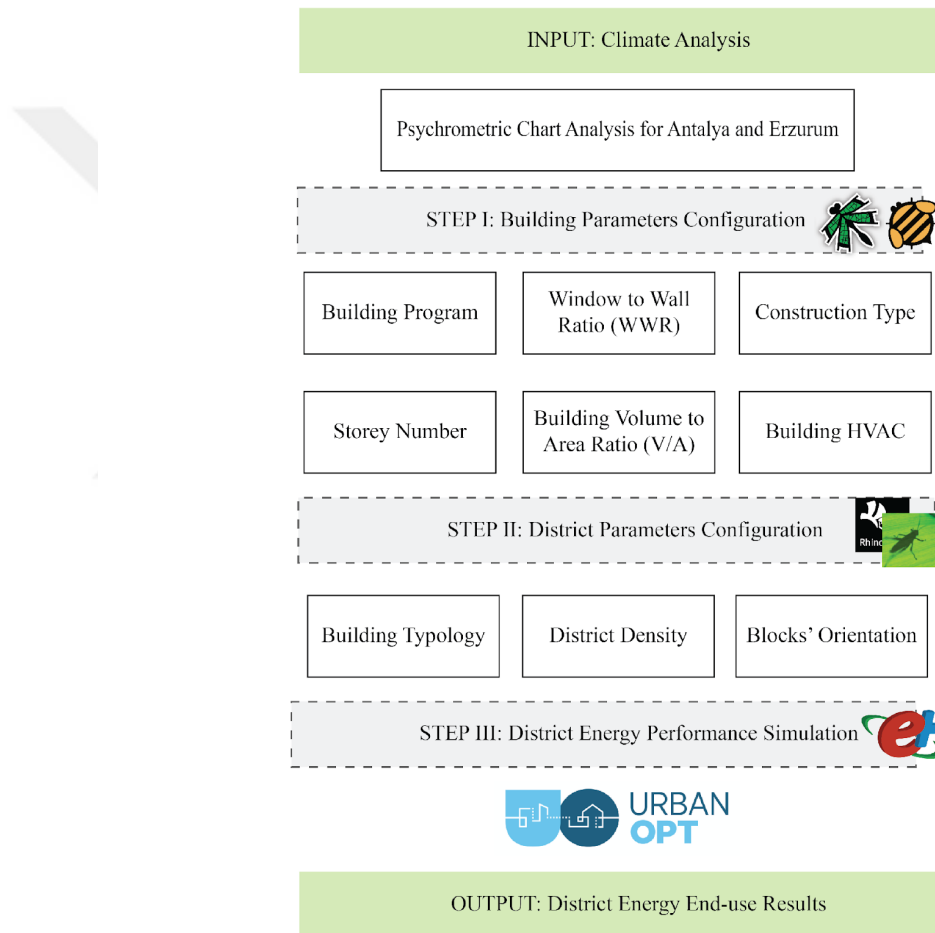


Figure 21: Methodology diagram

Base scenarios are created for two different climatic regions. The detailed building-related data from the software library and, accordingly, datasets are determined to represent a sample district to test variation simulations. Passive and advanced building scale and district scale scenarios are configured to obtain district energy end-use results.

3.1.1 District Energy Model

The first step of the methodology is to generate urban blocks. Initially, a base energy model is needed to analyze the environmental effects of different climatic conditions throughout the year. Therefore, an urban block typology is generated with a simple layout of 12 buildings with surrounding buildings (Figure 22). Next, the context buildings are defined to calculate the shadow impacts on the generated district. The heights are determined as the district buildings' heights to not over affect energy calculations. An avenue located on the South side of the district is modeled with the linked roads separating the urban blocks. The generated neighborhoods' buildings have different functions to represent a settlement; mixed-used buildings, residential, and office buildings. Building programs are selected from the software library.

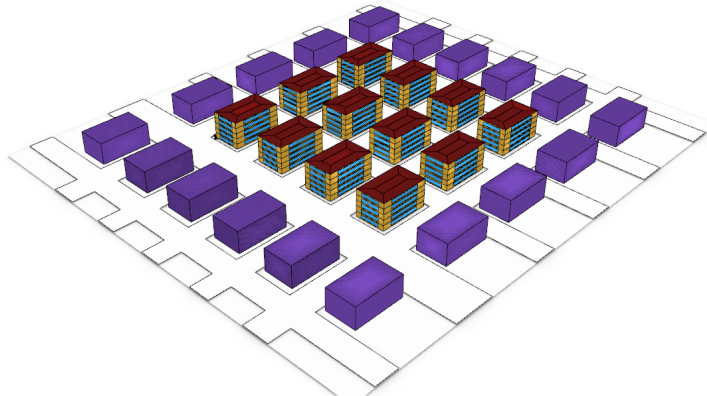


Figure 22: Rhinoceros 7, Grasshopper, Honeybee district energy model

As the third step, the construction set is defined for the district buildings. The building envelope materials are subdivided into; ExteriorSubset, SubfaceSubset, GroundSubset and WindowConstr components. These components are linked to OpaqueMat and WindowMat to define sublayers. Opaque material sublayers' thickness, conductivity, density and specific heat values are determined from the Turkish Standard, TS 825 [93]. The base scenario construction set does not include thermal insulation layers

to test the thickness variations of insulations' impacts on different climatic region scenarios.

The HVAC is defined as Variable air volume (VAV) with a chiller for cooling and a boiler for heating in commercial buildings. In residential buildings, packaged thermal air conditioner (PTAC) is defined for the cooling demand and a boiler with baseboards for the heating consumption.

3.1.2 District Locations and Climatic Condition Analysis

This study investigates how passive strategies and renewable energy integration in hot and cold climates affect the energy performance of energy districts. Accordingly, the climate and location data are obtained for Antalya and Erzurum, Turkey, from the website <https://climate.onebuilding.org/>.

To define the geoJSON data for the district energy model, the latitude and longitude information for Antalya and Erzurum are obtained from the TMY weather files (epw). These data inputs, time zones and elevation of the location from sea level (m) are linked to the ConstrLoc component.

First, the climatic region 1 and 4 [52] conditions are examined in ClimateConsultant 6.0 software for the climatic condition analysis. The program is an interface to present hourly climate data for a specific location and visualize climate characteristics. For comfort models, ASHRAE Standard 55 is selected [126]. One of the advanced elements of Climate Consultant is the Psychrometric Chart, which presents the comfort zone in chosen climate. The chart's dots represent one of the yearly hours' temperature and humidity data. On this graphic, particular zone reflect various Design Strategies. An approximate estimate of the most efficient passive heating or cooling strategies can be obtained from the percentage of hours that fall into each of the 16 Design

Strategy Zones. The distribution of this psychrometric data in each Design Strategy zone is examined by Climate Consultant to produce a particular set of Design Guidelines for a specific site [127]. This data is used for creating geoJSON files to conduct energy simulations in further steps.

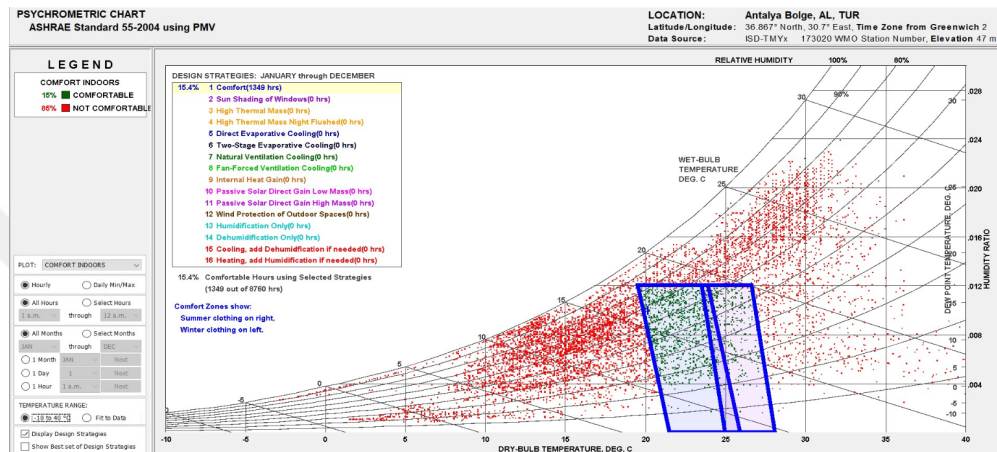


Figure 23: Psychrometric chart of Antalya, hot-humid climate (Region 1)

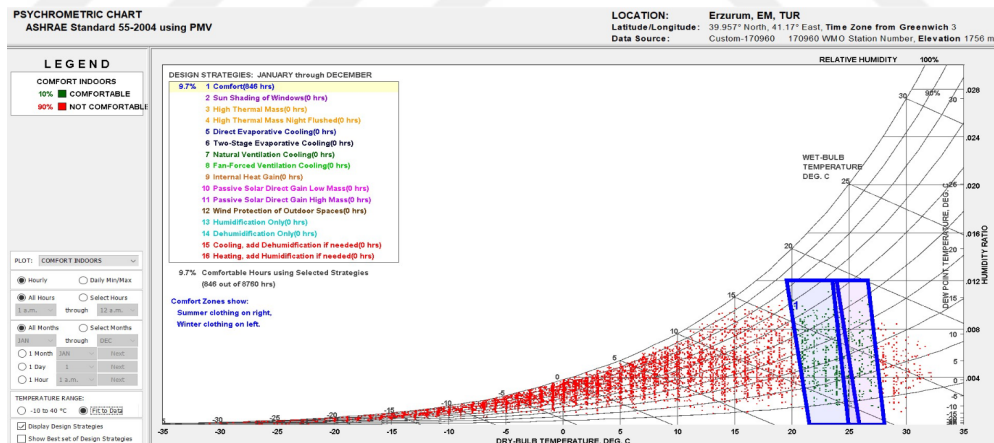


Figure 24: Psychrometric chart of Erzurum, cold climate (Region 4)

The Mediterranean region's climate (Region 1) hot-humid climatic region's comfort level over a year is 15.4%. According to the graph, the high humidity with high-temperature levels creates discomfort (Figure 23). Additionally, even though the region is classified as hot climate, there are accumulated dots on low temperatures that also cause

discomfort. When the sun hours are evaluated, it is seen that there is a high potential for getting direct sunlight and heat gain during winter.

Erzurum is in a cold climate (Region 4). This climatic region's comfort level over a year is 9.7%. As expected, low temperature levels are the most impactful factor on discomfort (Figure 24).

3.1.3 District Energy Simulation

To test bioclimatic strategies effects on the energy performance of PEDs, a set of building scale and neighborhood scale parameter variations are determined:

- I. Building volume-to-area ratio
- II. Building window-to-wall ratio
- III. Insulation material
- IV. Block density
- V. Building typology/form
- VI. Blocks orientation/rotation
- VII. Building storey height differences
- VIII. Photovoltaic power

The district energy scenarios are applied to two different locations of Turkey: Antalya, hot-humid climate region (H0, H1...) and Erzurum, cold climate region (C0, C1...). The abbreviated scenarios and the parameters for each scenario variation is given in Table 5.

Table 5 Simulation scenario variables and abbreviations

Scenario	Abbreviations	Parameters
Antalya Base Scenario	H0, H1...	Building Storey Height: 2.7 Meters Window to Wall Ratio: 0.4 Geometry: Rectangle (15x25 m) Envelope Insulation: None
Erzurum Base Scenario	C0, C1...	Orientation: Gridal Settlement District Density: 15 m Road width Building Storey Heights: Equal Renewable System: None
Building Volume-to-Area Ratio Impact Scenario	V1	Block Volume/Area 25% Increase Building Storey Height: 3.37 m
Block Window to Wall Ratio Impact Scenario	W1	Block Window/Wall 20% Increase Window to Wall Ratio: 0.6
	W2	Block Window/Wall 20% Increase Window to Wall Ratio: 0.2
Building Insulation Material Impact Scenario	M1	Wall Insulation: 0.04 m EPS Roof Insulation: 0.15 m Rockwool
	M2	Wall Insulation: 0.20 m EPS Roof Insulation: 0.25 m Rockwool
District Density Impact Scenario	D1	District Density: 7.5 m Road width
Building Geometry Impact Scenario	H0, T1	Geometry: Courtyard in Antalya
	C0, T1	Geometry: Compact (Square) in Erzurum
District Orientation Impact Scenario	R1	Orientation: Scattered Settlement
District Storey Heights Impact Scenario	S1	Building Storey Heights: Increasing towards South
District Solar Power Impact Scenario	PV1	Renewable System: District solar farm
	PV2	Renewable System: Photovoltaic panels mounted on building roofs

3.1.3.1 Base Scenario

The district consists of 5-storey height 12 buildings: office buildings, mixed-used buildings, and residential. The first and second row from the South covers commercial buildings, whereas the last row locates residential buildings. Each building's dimensions

are 15x25 meters. The street (two-lane roads) widths are 15 meters which is also the maximum building height.

In the base scenario (H0, C0), building storey heights are set to 2.7 meters. The window-to-wall ratio set is set to 0.4. The HVAC definition for commercial buildings is VAV with chiller and boiler, and PTAC and boiler for residential.

The generated base district energy model's building envelope materials are selected from TS 825 Standard [93]. The U-values of the opaque and glazing materials as well as with their conductivity, specific heat capacity and density values are listed in Table 6.

All HVAC, lighting, equipment and occupancy schedules are selected from Modelika library for the district energy model, in UrbanOpt [128]. However, some parameters are adapted for coherence of the thesis. The HVAC specifications for residential and commercial buildings of the generated district energy model is selected from ASHRAE, "Energy Standard for Buildings Except Low-Rise Residential Buildings" [129]. The residential buildings' heating operation system is boiler with radiators since it is the most typical heating type in Turkey. The cooling system is selected as PTAC for living rooms and bedrooms in residential buildings. The commercial buildings in the generated district have VAV with chiller for heating and cooling demand of the buildings. Additionally, the lighting operations are set as manual-on with occupant sensors and daylight dimming controls in commercials and residential (Table 7).

Table 6 Base district energy model buildings' envelope materials

Building Features	Construction Details	Conductivity (W/m-k)	Specific Heat Capacity (J/kg-K)	Density (kg/m³)
External Walls Uvalue: 0,400 (W/M2-K)	0,013 m Gypsum Plastering	0,4	1000	1000
	0,2 m Aearated Concrete Blocks	0,49	1600	2000
	0,03 m External Rendering	0,5	1000	1300
Internal Walls Uvalue: 2,929 (W/M2-K)	0,025 m Gypsum Plasterboard	0,25	1000	900
	0,01 m Air Gap	-	-	-
	0,025 m Gypsum Plasterboard	0,25	1000	900
Flat Roof Uvalue: 0,591 (W/M2-K)	0,005 m Roofing Felt	0,19	837	960
	0,025 m Clay Tile (Roofing)	1	800	2000
Floors Uvalue: 0,426 (W/M2-K)	0,2 m Aerated Concrete Slab	0,16	840	500
	0,03 m Floor Screed	0,41	840	1200
	0,004 m Plywood (Lightweight)	0,15	2500	560
Ground Floor Uvalue: 0,426 (W/M2-K)	0,03 m Epoxy Resin	0,2	1400	1200
	0,05 m Floor Screed	0,41	840	1200
	0,1 m Cast Concrete	1,13	1000	2000
	0,13 m Urea Formaldehyde Foam	0,04	1400	10
Glazing Units	Double Glazing 2,5mm/6mm Air, clear	Uvalue (W/m2k)	Solar Heat Gain Coefficient	Visible Transmittance
		2,9	0,75	0,81

Table 7 Base district energy model buildings' HVAC & lighting system details

HVAC type	Building Functions	Zones	Efficiency
Radiator Heating	Residentials	Living Room & Kitchen & Bedrooms	0.8
Boiler DHW	Residentials	Central System	0.8
PTAC	Residentials	Living Room & Bedrooms	3.3 COP
VAV with Chiller	Commercials	Offices & Administrative & Common Areas	10.8 EER 12.7 IEER 14.4 IEER
Lighting type	Building Functions	Zones	Controls
Ceiling Mounted & Recessed	Residentials & Commercials	All zones	manual-ON occupant sensors, and continuous daylight dimming controls

3.1.3.2 Simulation Scenarios

The first parameter (H1, C1) (V1) is combined to evaluate the building volume's impact on building energy performance. In this scenario, the Floor-to-floor (m) component is used to vary the buildings' Volume/Area (V/A) ratio. Building V/A ratios are enhanced by 25%.

The second scenario (H2, C2) (W1) is created to evaluate the impact of the window to -to-wall ratio on building energy performance. A list of ratios is linked to SimpleRatioPar and ApplyFacadePar components. In this scenario, window to wall ratio set is set higher, which is 60%. In the third scenario (H3, C3) (W2), window to wall ratio set is set lower, which is 20%.

For the fourth scenario (H4, C4) (M1), an insulation test was carried out for the building envelope and roof. For the exterior walls' insulation layer, 4 cm EPS is applied. For the roof insulation, a 15 cm rockwool layer is also defined. All material properties

are selected from TS 825 standard. The Passivhaus design guideline is followed for the fifth scenario (H5, C5) (M2). For the exterior walls' insulation layer, 20 cm EPS is applied. For the roof insulation, a 25 cm rockwool layer is set up.

The sixth scenario (H6, C6) (D1) is combined to compare the high and low building block density's impact on building energy performance. In this scenario, the street with dimensions is set to half the dimensions at the base scenario, to 7.5 m, making a high-density neighborhood.

In the seventh scenario (H7) (T1) is created to analyze the impact of building typology/form on building energy performance. For the hot-humid climate region scenario (location of Antalya), buildings with courtyards are generated [15] (Figure 25). The floor areas remained the same.

On the other hand, in (C7) (T1), a more compact form with the same building area is tested in the cold climate region scenario (Figure 26).

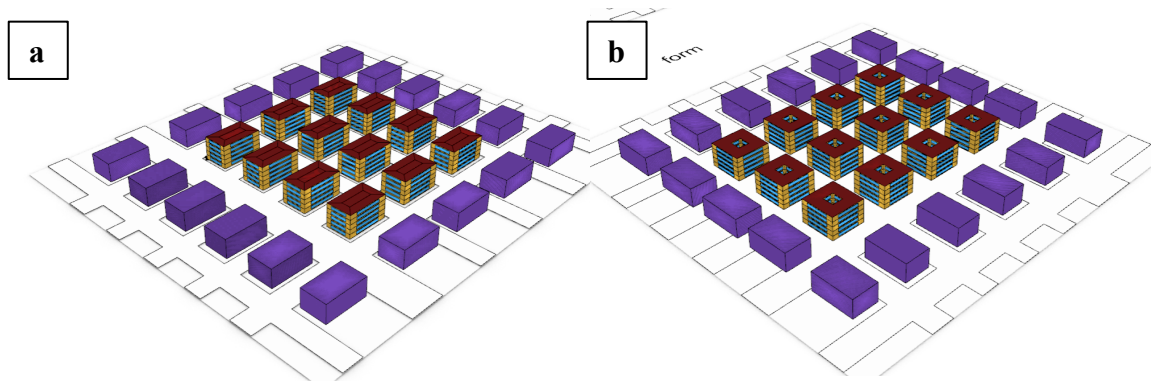


Figure 25: a) base district energy model building forms b) generated courtyard building geometries in hot climate scenario.

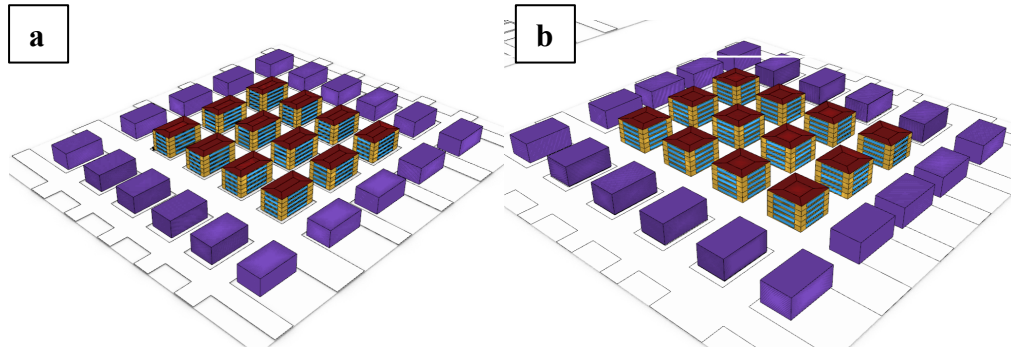


Figure 26: a) base district energy model building forms b) generated compact building geometries in cold climate scenario

The eighth scenario (H8, C8) (R1) is defined to evaluate the building orientation and location's impact on district energy performance. In this scenario, the district block's location patterns are scattered.

In the ninth scenario (H9, C9) (S1), building height differences are created among the rows of the district, from South to North. The first row of the district buildings' storey numbers is reduced to 3. The second-row buildings are set to 4 storeys, and the last row (residential) remains the same as 5 storeys. In this case, it is expected to reduce shadow impact by lowering the building height towards the South, and the energy performance is analyzed (Figure 27).

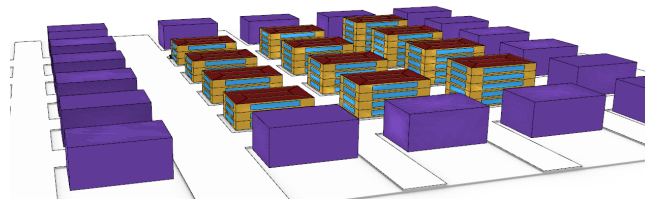


Figure 27: Building height variation scenario modeling

The renewable energy assistance on PEDs is investigated in the tenth scenario variation (H10, C10) (PV1). This scenario consists of a district solar farm with 200 solar panels integrated ground mounted, located on the first row of the district. The panels' dimensions are modeled as 2mx1m. In the eleventh scenario (H11, C11) (PV2), photovoltaic panels are mounted on each buildings' roof. It is aimed to compare the

efficacy of these two implementation types on a district scale. In total, 22 variation scenarios are tested on the generated on the energy district model.



CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, the simulation result outputs are presented, compared, and discussed regarding the building/district energy performance. The determined variation scenarios whose variables are defined are applied on the locations, Antalya, and Erzurum.

Initially, the hot climate region, Antalya (H0), and cold climate region, Erzurum (C0) scenarios have been compared separately to observe each variation measure's impact under different environmental conditions. The variation scenarios are compared with the base scenario by heating, cooling and total primary energy end uses. Sequentially, variation scenarios are compared under two climatic conditions. In this regard, it is aimed to evaluate different measures' performance in hot-humid climate and cold climate.

- I. The base scenario applied to two different climate regions are compared with each other by the energy end-use subcategories.
- II. Building volume/area ratio (V1), window/wall ratio (W1, W2), insulation thickness (M1, M2) results are compared to the base simulation to evaluate the building scale measure changes' impacts on districts' heating and cooling demands.
- III. Building typology (T1), orientation (R1), district density (D1), height difference (S1) scenarios' results are compared against the base simulation to observe district scale changes impact on building/district energy consumption.

- IV. The photovoltaic panel integration (P1, P2) on building scale and district scale are compared with the base scenario to assess the advanced system's impacts on district energy performance.

4.1 Results

It is observed that the heating primary energy use in the H0 scenario is 29.69 kWh/m², whereas the cooling primary energy use is 142.39 kWh/m² of the district. In total the primary energy use is 214.24 kWh/m² in the hot climate base scenario (H0). In comparison with this case, the C0 scenario has resulted with a higher heating primary energy use with 218.46 kWh/m², lower cooling primary energy use with 29.10 kWh/m². In total the primary energy use of C0 base scenario is 301.67 kWh/m² for the cold climate district energy consumption.

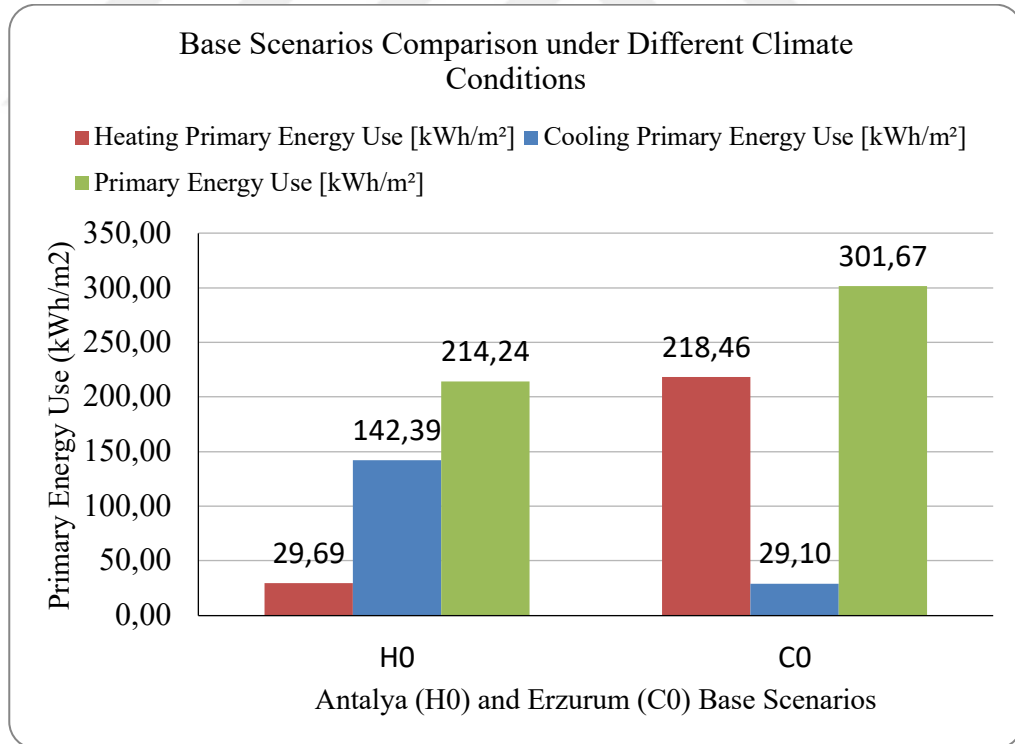


Figure 28: Base scenarios' energy use end results for Antalya and Erzurum

The base scenarios comparison show that the cooling energy is the major demand for Antalya region whereas the heating demand is the dominant consumption in Erzurum region (Figure 28) (Figure 29).

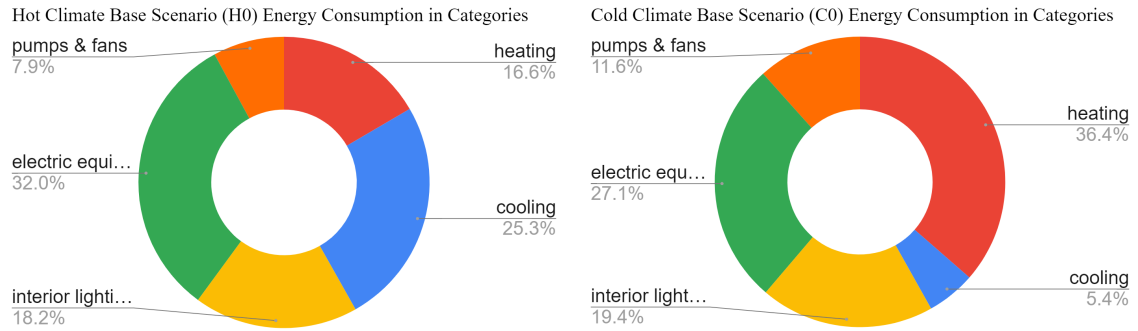


Figure 29: District energy consumption sub-categories in Antalya and Erzurum

4.1.1 Antalya Simulation Results

The (H1, V1) scenario has resulted in 160.73 kWh/m² cooling, 38.81 kWh/m² heating, and in total 235.71 kWh/m² primary energy use. Compared to the Antalya base scenario (H0), the cooling demand is increased 12.88%, the heating demand is increased 30.70% when the volume/area ratio in the neighborhood buildings is enhanced by 25%. Additionally, the primary energy use in total has increased by 10.02% compared to H0. The CO₂ emission increase in this scenario comparing to base scenario by 9.78%.

The scenario of (H2, W1) has led to a cooling requirement of 179.18 kWh/m², a heating requirement of 34.43 kWh/m², and a primary energy usage of 246.27 kWh/m². When compared to the hot climate base scenario, H0, increasing the window to wall ratio by 20% has resulted in a 25.84% increase in cooling demand and a 14.95% increase in total primary energy consumption. Under this scenario, CO₂ emissions are up 14.94% from the base case.

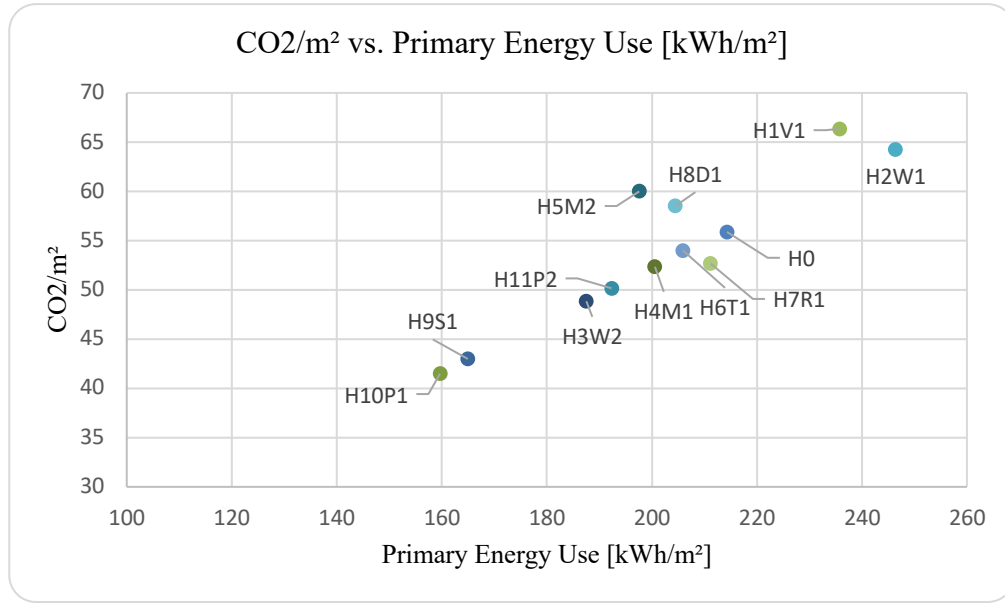


Figure 30: Carbon dioxide emissions and primary energy end uses under different scenarios.

The (H3, W2) scenario consumes a total of 187.48kWh/m² of primary energy, with 105.39 kWh/m² being used for cooling and 28.91 kWh/m² for heating. When compared to the hot climate base scenario, H0, decreasing the window to wall ratio by 20%, resulted in a 25.98% decrease in cooling demand and a 12.49% decrease in total primary energy use. The CO₂ emissions decrease in this scenario comparing to base scenario by 12.60%.

In the (H4, M1) scenario, there is a cooling demand of 134.43 kWh/m², a heating demand of 18.59 kWh/m², and a total primary energy use of 200.53 kWh/m². When compared to the H0 scenario, which is the hot climate base scenario, adding 4 cm EPS insulation layer to exterior walls, and 15 cm rockwool insulation to the roof layers, resulted in a 5.59% decrease in cooling demand and a 37.39% decrease in heating primary energy use. In total primary energy use decreased by 6.40%. The CO₂ emissions are decreased in this scenario comparing to base scenario by 6.04%.

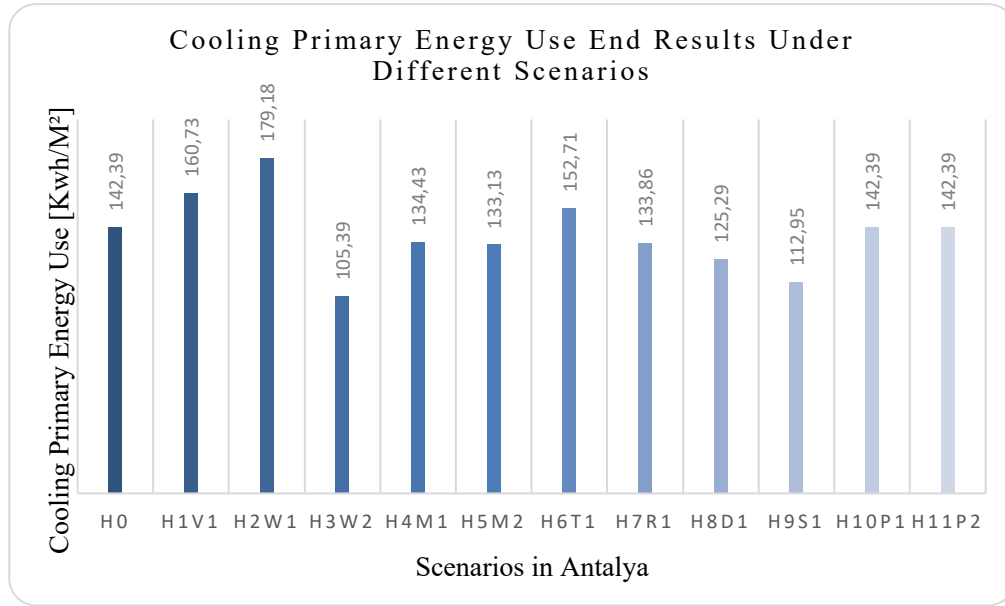


Figure 31: Cooling primary energy use end results in Antalya under different scenarios.

The (H5, M2) variation has resulted with the cooling demand of 133.13 kWh/m², heating demand of 16.26 kWh/m², and overall primary energy usage of 197.55 kWh/m². Compared to the hot climate base scenario, the Passivhaus standard insulation improvement on the building envelope, 20 cm of EPS insulation to exterior walls and 25 cm of rockwool insulation to the roof layers, there is a 6.50% decrease in cooling demand and a 45.25% reduction in primary energy used for heating. Overall, the primary energy usage decreases by 7.79%, and the CO₂ emissions decrease by 7.35% when compared to the base scenario.

The scenario of (H6, T1) has led to a cooling requirement of 152.75 kWh/m², a heating requirement of 28.15 kWh/m², and a primary energy usage of 205.87 kWh/m². When compared to the hot climate base scenario, H0, the building form variation from base model to atrium model, has resulted in a 7.28% decrease in cooling demand and a 5.19% decrease in heating demand. In total primary energy consumption, there is a decrease of 3.91%. Under this scenario, CO₂ emissions are down by 3.90% from the base case.

The (H7, R1) scenario has resulted in 133.86 kWh/m² cooling, 29.79 kWh/m² heating, and in total 211.14 kWh/m² primary energy use. Compared to the hot climate base scenario (H0), the cooling demand is decreased 5.99% when the settlement orientation is converted to a scattered district model. Hence, the primary energy use in total has slightly decreased compared to H0.

The (H8, D1) scenario has resulted in 125.29 kWh/m² cooling, 31.23 kWh/m² heating, and in total 204.43 kWh/m² primary energy use. Compared to the hot climate base scenario (H0), the cooling demand decreased by 12.01%. Hence, the primary energy use in total has decreased by 4.85% compared to H0, since the heating demand is increased by 5.70%. The CO₂ emission increase in this scenario comparing to base scenario by 4.70%. In this scenario, the high-density neighborhood has created potential building shadows on neighboring buildings. In this case, the cooling demand decreased as expected. However, this shadow impact from the high-density neighborhood, cause increase in heating demand since the buildings block the direct sunlight getting interior spaces.

The (H9, S1) scenario has resulted in 112.95 kWh/m² cooling, 24.38 kWh/m² heating, and in total 164.92 kWh/m² primary energy use. Compared to the hot climate base scenario (H0), the cooling demand decreased 20.67% when the district building storey count increases towards the North. On the other hand, energy consumption for heating demand decreased by 17.89%. In this regard, all buildings in the rows are more able to get direct sunlight. Hence, the primary energy use in total has decreased by 23.02% compared to H0. The CO₂ emissions decrease in this scenario comparing to base scenario by 23.08%.

The (H10, P1) scenario has resulted in 159.63 kWh/m² total primary energy use. In this scenario all consumption values are kept equal with the base hot climate scenario. The photovoltaic power generation (kwh) is substituted from the electricity end use. Power conversion of the photovoltaic panels are also considered in this calculation. In the end, the primary energy use in total has decreased by 25.49% compared to H0, when photovoltaic panels are integrated on building roofs. The CO₂ emissions decrease in this scenario comparing to base scenario by 25.78%.

The (H11, P2) scenario has resulted in 192.28 kWh/m² total primary energy use. In this scenario all consumption values are kept equal with the base hot climate scenario. The photovoltaic power generation (kwh) is substituted from the electricity end use. Power conversion of the photovoltaic panels are also considered in this calculation. In the end, the primary energy use in total has decreased by 10.25% compared to H0, when a row in the district is left for solar farm. The CO₂ emissions decrease in this scenario comparing to base scenario by 10.34%.

When all parameters impact on district heating demand, cooling demand, primary energy and carbondioxide emissions, the differences are presented in percentage (Table 8). The parameters are analyzed and categorized according to whether they reduce the heating or cooling energy consumption, or in total, the primary energy consumption and carbon dioxide emissions. Some parameters affected the district energy dramatically, whereas some did not affect significantly. These results are discussed below:

- I. The cooling demand was the major energy consumption in the generated energy district in Antalya. The most impactful parameters that reduced the cooling energy consumption are Scenario 3 (H3 W2), decreasing the WWR by 20% and Scenario 9 (H9 S1), storey height variations in the district buildings.

- II. The heating demand is the most decreased when applying insulation on the district buildings' envelope materials in the Scenario 4 (H4 M1), Scenario 5 (H5 M2), by 37.39% and 45.25% respectively. However, the primary energy consumption rates do not change in the same impact.
- III. On the other hand, the primary energy consumption is the most decreased in Scenario 9 (H9 S1) and with Scenario 10 (H10 P1) by PV panel integration on district roofs. All in all, the storey height variation scenario is the most impactful scenario in terms of reduction of cooling and total energy consumption and carbon dioxide emissions.
- IV. The least impactful scenarios are Scenario 5 (H6 T1), changing the building forms to atriums and Scenario 7 (H7 R1), change in the building orientations in the district. Both variation types affect the district energy consumption by approximately 6%.

Table 8 Antalya scenarios' comparison to the base scenario in percentage

Scenarios in Hot Climate Location Antalya	Cooling Demand Comparison to the Base Scenario	Heating Demand Comparison to the Base Scenario	Primary Energy Consumption Comparison to the Base Scenario	Carbondioxide Emissions Comparison to the Base Scenario
Scenario 1 (H1 V1) Block Volume/Area 25% Increase Impact	12.88%	30.70%	10.02%	9.78%.
Scenario 2 (H2 W1) Block Window/Wall 20% Increase Impact	25.84%	15.96%	14.95%	14.94%
Scenario 3 (H3 W2) Block Window/Wall 20% Decrease Impact	-25.98%	12.62%	-12.49%	-12.60%
Scenario 4 (H4 M1) Building Envelope Insulation Impact	-5.59%	-37.39%	-6.40%	-6.04%
Scenario 5 (H5 M2) Building Envelope Insulation Impact	-6.50%	-45.25%	-7.79%	-7.35%
Scenario 6 (H6 T1) Building Atrium Form Impact	-7.28%	-5.19%	-3.91%	-3.90%
Scenario 7 (H7 R1) District Orientation Impact	-5.99%	consistent	consistent	consistent
Scenario 8 (H8 D1) District Density Impact	-12.01%	5.70%	-4.85%	4.70%
Scenario 9 (H9 S1) Storey Height Impact	-20.67%	-17.89%	-23.02%	-23.08%
Scenario 10 (H10 P1) Photovoltaic Integration on Building Roofs Impact	-	-	-25.49%	-25.78%
Scenario 11 (H11 P2) Photovoltaic Solar Farm Impact	-	-	-10.25%	-10.34%

4.1.2 Erzurum Simulation Results

In Erzurum scenario results, the (C1, V1) scenario has resulted in 262.06 kWh/m² heating, 33.86 kWh/m² cooling, and in total 343.23 kWh/m² primary energy use. Compared to the cold climate base scenario, C0, the heating demand increased by 19.96%

when the volume/area ratio is enhanced by 25%. Additionally, primary energy use in total has increased by 13.78%. The CO₂ emission increase in this scenario comparing to base scenario by 13.39%.

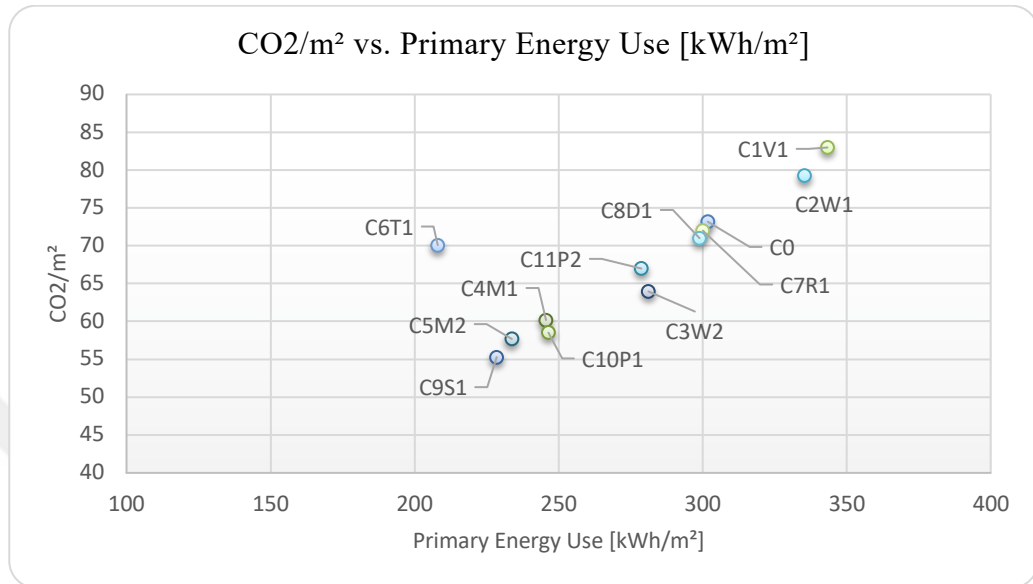


Figure 32: Carbon dioxide emissions and primary energy end uses under different scenarios.

The scenario of (C2, W1) has led to a heating requirement of 219.19kWh/m², a cooling requirement of 42.45 kWh/m², and a primary energy usage of 335.29 kWh/m². When compared to the cold climate base scenario, C0, increasing the window to wall ratio by 20% consequences not a noticeable difference in heating demand. On the contrary, the cooling demand increased by 45.84%. In total, primary energy use increased 7.82%. Under this scenario, CO₂ emissions are up 8.29% from the base case.

The (C3, W2) scenario consumes a total of 281.09 kWh/m² of primary energy, with 219.18 kWh/m² being used for heating and 16.66 kWh/m² for cooling. When compared to the cold climate base scenario, C0, decreasing the window to wall ratio by 20 consequences not a noticeable difference in heating demand. Despite, cooling demand

decreased by 42.75%. Overall, there is a 6.82% decrease in total primary energy use. The CO₂ emissions decrease in this scenario comparing to base scenario by 7.25%.

In the (C4, M1) scenario, there is a heating demand of 141.85 kWh/m², a cooling demand of 29.44 kWh/m², and a total primary energy use of 245.56 kWh/m². When compared to the C0 scenario, which is the cold climate base scenario, adding 4 cm EPS insulation layer to exterior walls, and 15 cm rockwool insulation to the roof layers, resulted in a 35.06% decrease in heating demand and a 1.15% increase in cooling primary energy use. In total primary energy use decreased by 18.60%. The CO₂ emissions are decreased in this scenario comparing to base scenario by 17.55%.

The (C5, M2) variation has resulted with the heating demand of 169.81 kWh/m², cooling demand of 30.38 kWh/m², and overall primary energy usage of 233.70 kWh/m². Compared to the hot climate base scenario, the Passivhaus standard insulation improvement on the building envelope, 20 cm of EPS insulation to exterior walls and 25 cm of rockwool insulation to the roof layers, there is 43.71% reduction in heating demand and a 4.39% increase in primary energy used for cooling. Overall, the primary energy usage decreases by 22.53%, and the CO₂ emissions decrease by 21.18% when compared to the base scenario.

The scenario of (C6, T1) has led to a heating requirement of 132.13 kWh/m², a cooling requirement of 30.75 kWh/m², and a primary energy usage of 208.01 kWh/m². When compared to the hot climate base scenario, H0, the building form variation from base model to compact form model, has resulted in a 12.14% decrease in heating demand and a 7.91% decrease in cooling demand. In total primary energy consumption, there is a decrease of 4.22%. Under this scenario, CO₂ emissions are down by 4.24% from the base case.

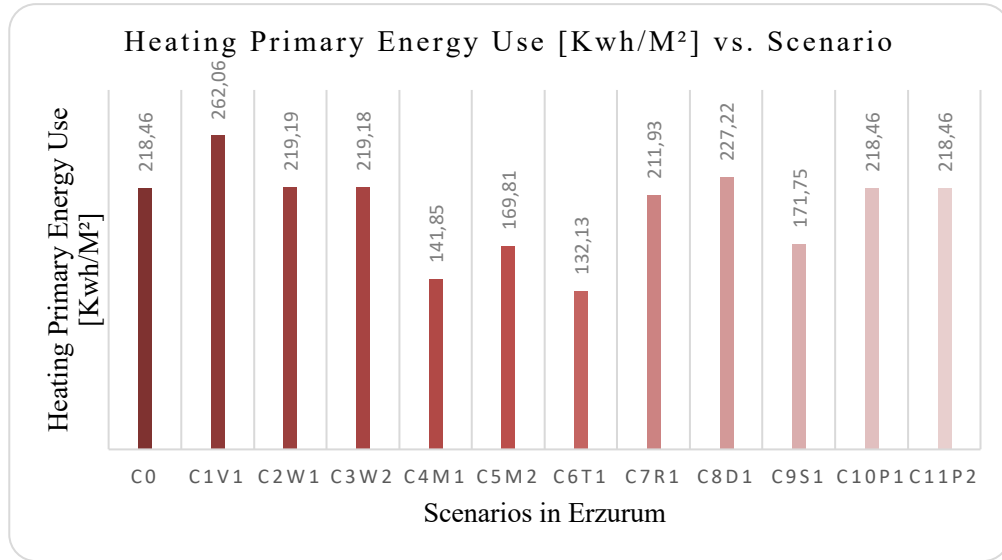


Figure 33: Heating primary energy end use in Erzurum under different scenarios

The (C7, R1) scenario has resulted in 211.93 kWh/m² heating, 30.87 kWh/m² cooling, and in total 300.16 kWh/m² primary energy use. Compared to the cold climate base scenario (C0), the heating demand decreased by 2.99% whereas the cooling demand increased 6.07% when the settlement orientation is converted to a scattered district model. Hence, the primary energy use in total has slightly decreased compared to C0.

The (C8, D1) scenario has resulted in 227.22 kWh/m² heating, 22.66 kWh/m² cooling, and in total 298.86 kWh/m² primary energy use. Compared to the cold climate base scenario (C0), the heating demand increased by 5.01%, the cooling demand decreased dramatically, by 22.15%. In total, the primary energy use, and the CO₂ emission are not significantly changed compared to H0. Similar to the hot climate scenario, in this cold climate scenario, the high-density neighborhood has created potential building shadows on neighboring buildings. In this case, the cooling demand decreased as expected. However, this shadow impact from the high-density neighborhood, cause increase in heating demand since the buildings block the direct sunlight getting interior spaces.

The (C9, S1) scenario has resulted in 171.75 kWh/m² heating, 21.46 kWh/m² cooling, and in total 228.45 kWh/m² primary energy use. Compared to the cold climate base scenario (C0), the heating demand decreased 21.38% when the district building storey count increases towards the North. On the other hand, energy consumption for cooling demand also decreased by 26.25%. In this regard, all buildings in the rows are more able to get direct sunlight. In conclusion, the primary energy use in total has decreased by 24.27% compared to H0. The CO₂ emissions decrease in this scenario comparing to base scenario by 24.46%

The (C10, P1) scenario has resulted in 246.40 kWh/m² total primary energy use. In this scenario all consumption values are kept equal with the base hot climate scenario. The photovoltaic power generation (kwh) is substituted from the electricity end use. Power conversion of the photovoltaic panels are also considered in this calculation. In the end, the primary energy use in total has decreased by 18.32% compared to H0, when photovoltaic panels are integrated on building roofs. The CO₂ emissions decrease in this scenario comparing to base scenario by 20.03%.

The (C11, P2) scenario has resulted in 278.64 kWh/m² total primary energy use. In this scenario all consumption values are kept equal with the base hot climate scenario. The photovoltaic power generation (kwh) is substituted from the electricity end use. Power conversion of the photovoltaic panels are also considered in this calculation. In the end, the primary energy use in total has decreased by 7.63% compared to H0, when a row in the district is left for solar farm. The CO₂ emissions decrease in this scenario comparing to base scenario by 8.34% (Figure 37) (Figure 38).

Table 9 Erzurum scenarios' comparison to the base scenario in percentage

Scenarios in Cold Climate Location Erzurum	Cooling Demand Comparison to the Base Scenario	Heating Demand Comparison to the Base Scenario	Primary Energy Consumption Comparison to the Base Scenario	Carbondioxide Emissions Comparison to the Base Scenario
Scenario 1 (C1 V1) Block Volume/Area 25% Increase Impact	16.35%	19.96%	13.78%	13.39%
Scenario 2 (C2 W1) Block Window/Wall 20% Increase Impact	45.84%	consistent	7.82%	8.29%
Scenario 3 (C3 W2) Block Window/Wall 20% Decrease Impact	-42.75%	consistent	-6.82%	-7.25%
Scenario 4 (C4 M1) Building Envelope Insulation Impact	-1.15%	-35.06%	-18.60%	-17.55%
Scenario 5 (C5 M2) Building Envelope Insulation Impact	4.39%	-43.71%	-22.53%	-21.18%
Scenario 5 (C6 T1) Building Compact Form Impact	-7.91%	-12.14%	-4.22%	-4.24%
Scenario 7 (C7 R1) District Orientation Impact	6.07%	-2.99%	consistent	consistent
Scenario 8 (C8 D1) District Density Impact	-22.15%	5.01%,	consistent	consistent
Scenario 9 (C9 S1) Storey Height Impact	-26.25%.	-21.38%	-24.27%	-24.46%
Scenario 10 (C10 P1) Photovoltaic Integration on Building Roofs Impact	-	-	-18.32%	-20.03%
Scenario 11 (C11 P2) Photovoltaic Solar Farm Impact	-	-	-7.63%	-8.34%

When all parameters impact on district heating demand, cooling demand, primary energy and carbondioxide emissions, the differences are presented in percentage (Table 9). The parameters are analyzed and categorized according to whether they reduce the heating or cooling energy consumption, or in total, the primary energy consumption and carbon dioxide emissions. Some parameters affected the district energy dramatically, whereas some did not affect significantly. These results are discussed below:

- I. The heating demand was the major energy consumption in the generated energy district in Erzurum. The most impactful parameters that reduced the heating energy consumption are Scenario 4 (C4 M1) and Scenario 5 (C5 M2), by approximately 35% and 44% respectively.
- II. The cooling demand is the most decreased when the WWR is decreased by 20%, Scenario 3 (C3 W2). However, primary energy consumption decreases only 7%.
- III. On the other hand, the primary energy consumption is the most decreased in Scenario 9 (C9 S1) and with Scenario 10 (C10 P1) by PV panel integration on district roofs. All in all, the storey height variation scenario is the most impactful scenario in terms of reduction of heating and total energy consumption and carbon dioxide emissions.
- IV. The least impactful scenario is Scenario 7 (C7 R1), change in the building orientations in the district.

4.1.3 Parameter Impacts' Comparison under Different Climatic Conditions

The selected bioclimatic and advanced parameters' impacts are discussed under different climatic conditions. The results are varied in different selected locations, Antalya, and Erzurum.

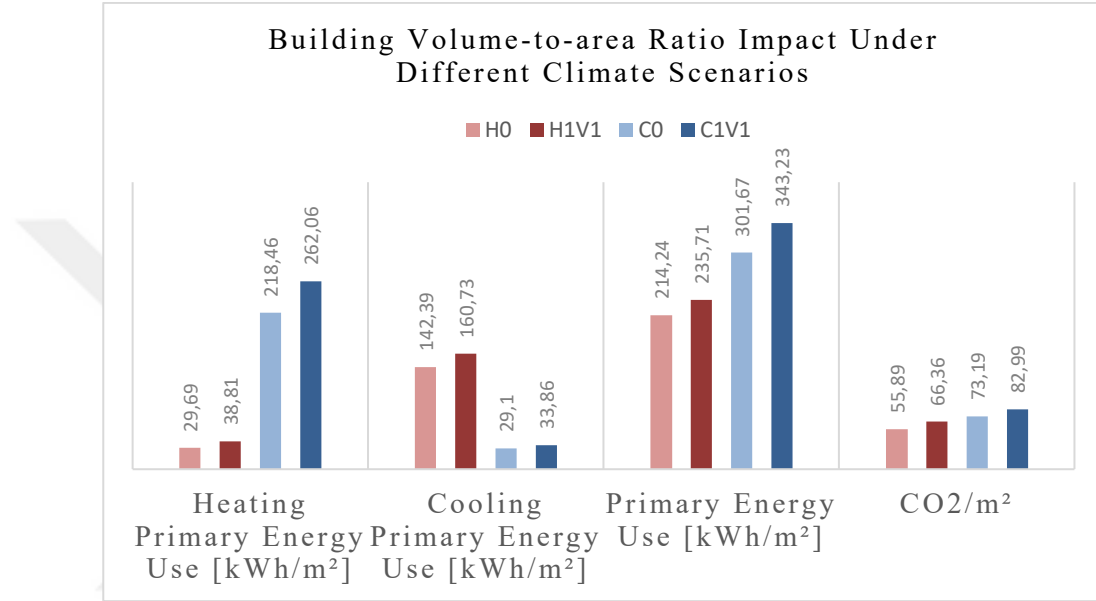


Figure 34: Building volume-to-area ratio impacts on district primary energy use and CO2 emissions under different climate scenarios

The first variation of the variation scenarios (V1) is changing the district buildings' volume to area ratios. In this scenario, this ratio is enhanced by 25% in both climate conditions. In the district energy model of Antalya, the cooling demand increased by 12.88%. The result was expected since there occur more volumes to be conditioned by PTACs during the summertime. In the district energy model of Erzurum, the heating consumption increases by 19.96% as the demand for heating appears when there are more building volumes. The total primary energy end use increases approximately by 10% and 14% respectively in these scenarios. When two scenarios are compared, it can be said that

the increase in volume is more impactful in cold climate rather than hot climate. This assumption is more dominant in conditioning demands for the districts (Figure 34).

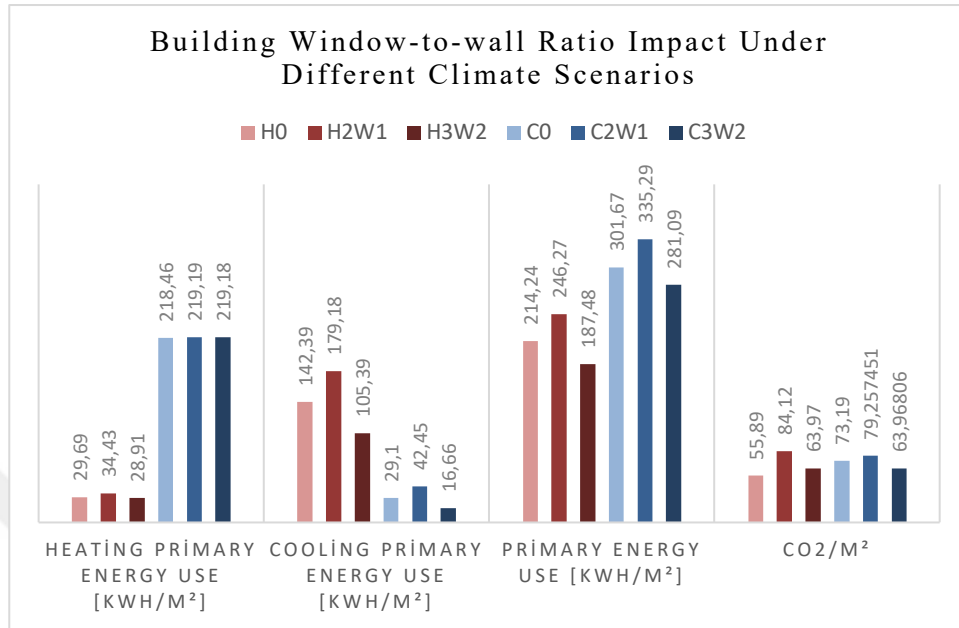


Figure 35: Building window-to-wall ratio impact on district primary energy use and CO2 emissions under different climate scenarios

The second parameter of the variation scenarios (W1, W2) is the change in window to wall ratios (WWR) of the district buildings. In these scenarios, this ratio is increased and decreased by 20% to test the transparency ratio impact. In Antalya district energy model, the change in WWR caused a 26% increase/decrease in cooling consumption. On the other hand, the same parameter changes in Erzurum district energy model, the heating consumption is not changed noticeably. Conversely, the cooling consumption increased by 46%. The primary energy end use varies approximately $\pm 15\%$ in Antalya, and $\pm 8\%$ in Erzurum. In conclusion the change in WWR only impacts the cooling consumption, dominantly in cold climate. On the contrary, the parameter affects the primary energy end use in hot climate more significantly (Figure 35).

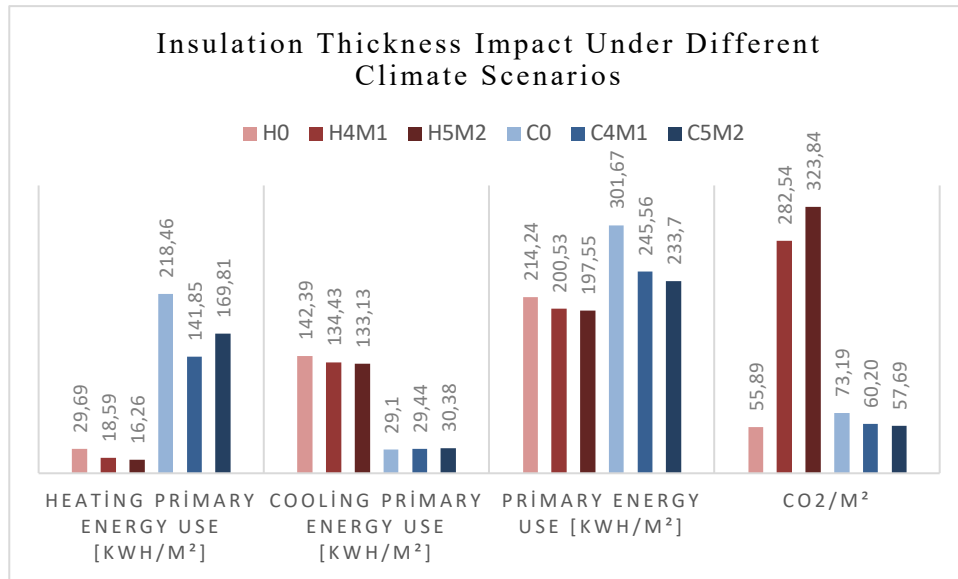


Figure 36: Insulation thickness variations' impact on district primary energy use and CO2 emissions under different climate scenarios

The third variation in the scenarios (M1, M2) is the insulation thickness input to the district energy buildings envelope layers. In M1 scenario the wall and roof insulations are added according to the TS825 standard [52] to the construction layers. In M2 scenario the Passivhaus [130] standard is implemented on the building envelope insulation features. According to the first insulation thickness scenario, in both climate conditions, presents a similar decrease in the heating consumption approximately 37% and 35% respectively. This ratio increases 8% in both climate scenarios applying the Passivhaus standardized insulation layers. It can be assumed that the improvement in insulation layers shows similar tendency in both climate districts' energy results (Figure 36).

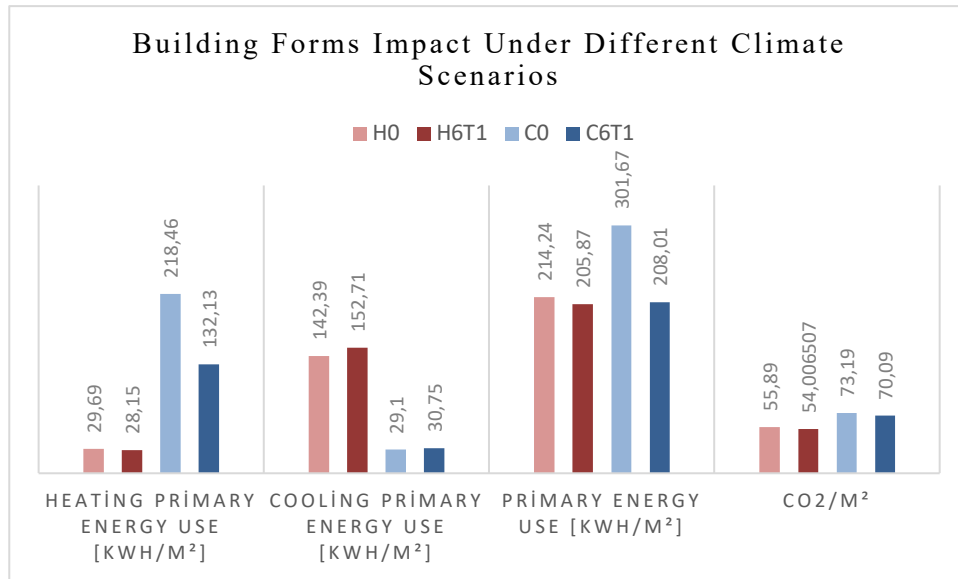


Figure 37: Building geometry variations' impacts on district primary energy use and CO2 emissions under different climate scenarios

The fourth variation in the scenarios (T1) is the variation in district buildings' geometries. For the two different climatic region cases, the form recommendations from literature are considered. In the case of Antalya, the base case scenario is converted with the courtyard buildings with the same storey amount and floor areas. On the other hand, the building forms converted into compact forms in Erzurum district case.

The change in building geometries resulted in a 7% decrease in cooling demand for Antalya and a 12% decrease in heating demand for Erzurum. The primary energy end values for both climate cases resulted with a similar percentage, 4% approximately which is not a major impact (Figure 37).

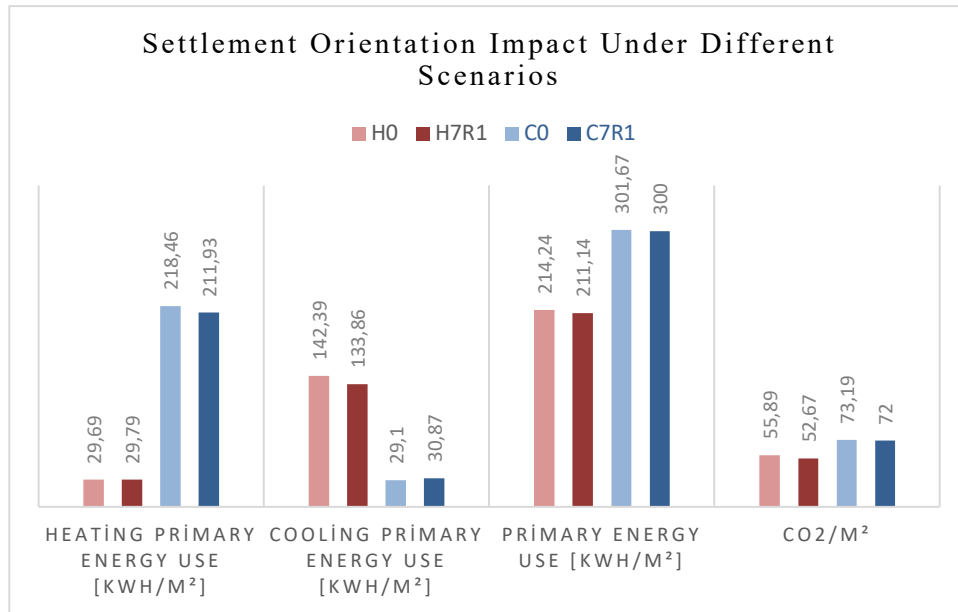


Figure 38: Settlement orientation variation impact on district primary energy uses and CO2 emissions under different climate scenarios

The fifth parameter for variation scenarios (R1) is the district buildings' settlement orientation change. In this model, the buildings are oriented in scattered layout rather than grid system. In Antalya scenario, the cooling demand decreased by 6% whereas the heating demand in Erzurum district decreased by only 3%. Unexpectedly the cooling demand in Erzurum increased by 6%. The reason behind this result might be that the district buildings are more exposed to direct sunlight, preventing neighboring buildings' shadows. Hence, it can be inferred that the scattered orientation is beneficial in hot climates for ventilation opportunities, whereas it can be disadvantageous in cold climates (Figure 38).

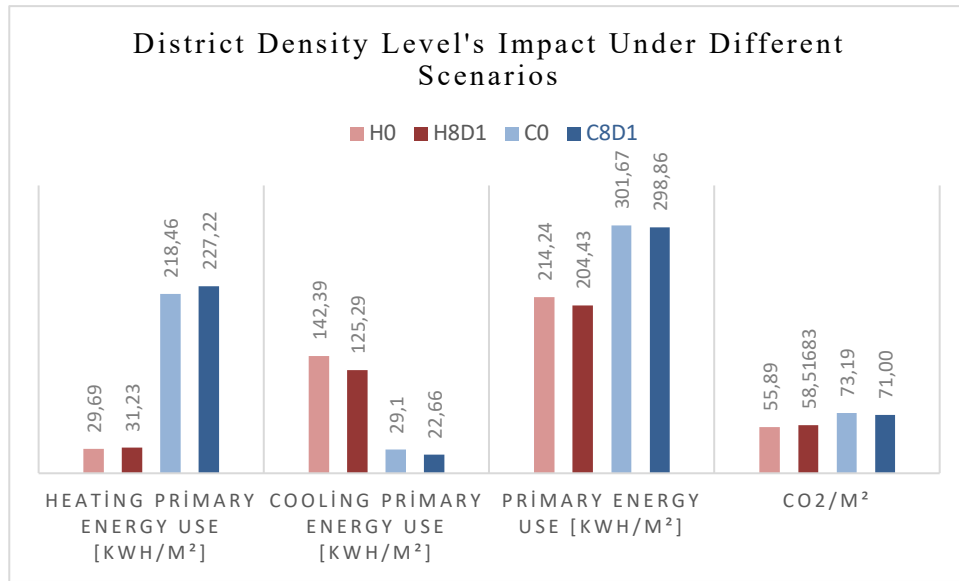


Figure 39: District density level's impact on district primary energy use and CO2 emissions under different climate scenarios

The sixth scenario of the scenarios (D1) is the parameter of changing the density of the energy district models. In these models, the street width dimensions are lessened. The high-density district energy model simulations resulted in an increase of 12% in Antalya region's cooling demand whereas this value is more impactful, with 22% in Erzurum. The heating consumption in both regions increased by 5% approximately. Building shadows on nearby structures could be a result of the neighborhood's high density. The cooling requirement in this instance fell as anticipated. Yet, because buildings restrict direct sunlight from entering interior spaces, the shadow effect from the dense neighborhood increases the need for heating. In conclusion, the increase in district density affects the cooling consumption more impactful in the cold climate region (Figure 39).

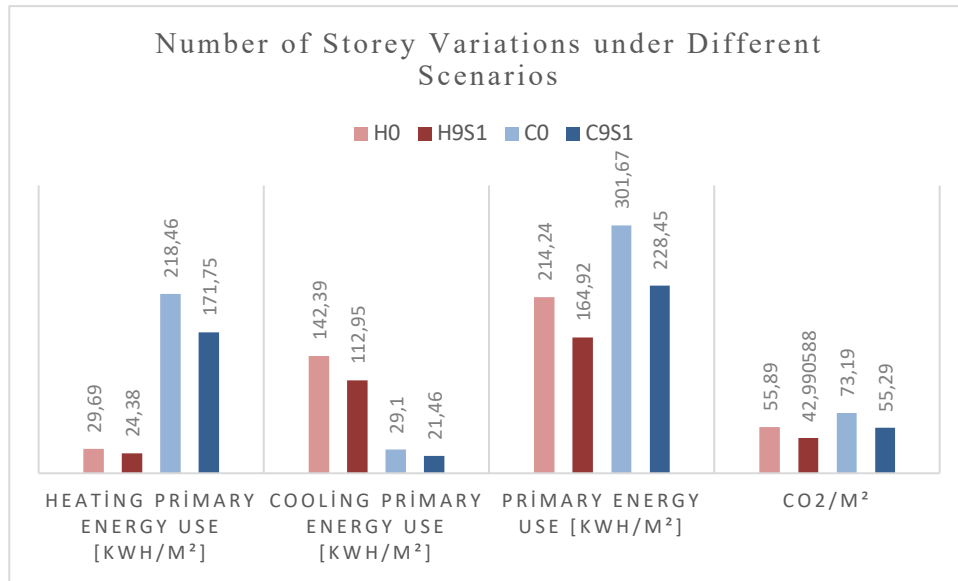


Figure 40: The storey count variation' impact on district primary energy use and CO2 emissions under different climate scenarios

In the seventh scenario (S1), the number of storeys in the district's buildings increases to the north. In this way, the potential of every building in the rows to get direct sunlight is improved. The cooling consumption in Antalya district, and the heating consumption in Erzurum districts decreased dramatically, approximately by 21% in both cases. On the other hand, the heating consumption of Antalya district also decreases by 18%. The reason behind this result might be the improvement of getting direct sunlight. Additionally, the cooling consumption of Erzurum also decreases significantly, by 26%. In this regard, it can be assumed that this strategy is equivalently impactful on heating demand of Erzurum and cooling demand of Antalya. However, the most consequential result is seen on the cooling consumption decrease in cold climate region district (Figure 40).

Finally, the eighth variation (P1, P2), includes photovoltaic power generation scenarios. The first scenario (P1) is the implementation of the PV panels on district buildings' roofs. The primary energy use result decreases 25% approximately in Antalya

region whereas in Erzurum region, this reduction is 18%. On the other hand, the second scenario (P2) includes a solar farm placed on a row of the district energy model. In this scenario, primary energy consumption decreases by 10% in the Antalya region, and 8% in Erzurum region. The PV panels generate more power as expected in Antalya region in both implementation cases. When comparing these two different PV implementation scenarios, the solar farm model performs less impactful, since the roof surface area is larger than the area left for solar farm implementation (Figure 41).

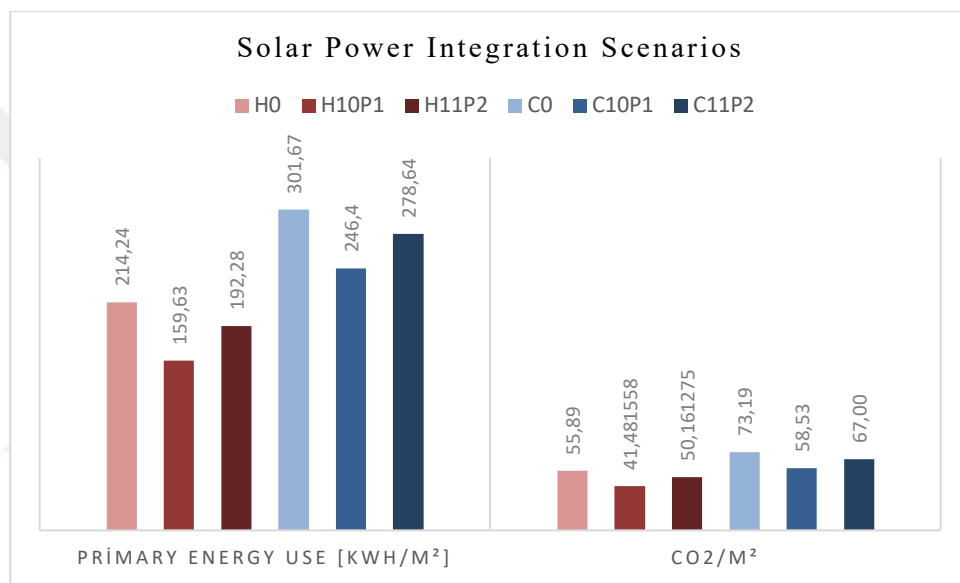


Figure 41: Different solar power integration scenarios under different climate scenarios

To summarize, the most impactful scenarios in Antalya and Erzurum are Scenario 9 (S1), storey height variation in the district and Scenario 10 (P1) photovoltaic integration on building roofs. These parameters decreased the primary energy consumption 23.02% and 25.49% respectively in Antalya and 24.27% and 18.32% in Erzurum. Additionally, Scenario 1 (V1) block volume/area increase has similar effect on Antalya and Erzurum's primary energy consumption by 10.02% and 13.78%. On the other hand, some parameters present contrast impact in both climate conditions. Scenario 2 (W1) block WWR increase has significant impact with 14.95% reduction in Antalya, whereas the

reduction in Erzurum is less significant. Scenario 4 (M1, M2) building envelope insulation reduces the primary energy consumption in Erzurum dramatically by 18.60% and 22.53% whereas this variation as not significantly decreasing in Antalya (Table 10).

Table 10 Antalya and Erzurum Simulation Results' Primary Energy Consumption Comparison to the Base Scenario

Primary Energy Consumption Comparison to the Base Scenario	Antalya	Erzurum
Simulation Scenarios		
Scenario 1 (C1 V1) Block Volume/Area 25% Increase Impact	10.02%	13.78%
Scenario 2 (C2 W1) Block Window/Wall 20% Increase Impact	14.95%	7.82%
Scenario 3 (C3 W2) Block Window/Wall 20% Decrease Impact	-12.49%	-6.82%
Scenario 4 (C4 M1) Building Envelope Insulation Impact	-6.40%	-18.60%
Scenario 5 (C5 M2) Building Envelope Insulation Impact	-7.79%	-22.53%
Scenario 5 (C6 T1) Building Compact Form Impact	-3.91%	-4.22%
Scenario 7 (C7 R1) District Orientation Impact	consistent	consistent
Scenario 8 (C8 D1) District Density Impact	-4.85%	consistent
Scenario 9 (C9 S1) Storey Height Impact	-23.02%	-24.27%
Scenario 10 (C10 P1) Photovoltaic Integration on Building Roofs Impact	-25.49%	-18.32%
Scenario 11 (C11 P2) Photovoltaic Solar Farm Impact	-10.25%	-7.63%

CHAPTER V

CONCLUSION

This thesis aims to guide future neighborhood designs by providing assumptions towards ecologically sustainable and resilient neighborhoods using the assistance of bioclimatic strategies and advanced systems. The research investigates the districts' energy performance levels by integrating passive and advanced strategies to the buildings towards energy efficient neighborhoods in Antalya and Erzurum, Turkey. A set of building and district scale parameters are simulated with Antalya and Erzurum climate conditions. According to the results, some assumptions are made.

In Antalya simulations, the most impactful parameters that reduced the cooling energy consumption are decreasing the window-to-wall ratio and storey height variations in the district buildings. The most significant decrease in heating demand is achieved by applying insulation to the envelope materials of district buildings. Scenario 4 (H4 M1) and Scenario 5 (H5 M2) show reductions of 37.39% and 45.25%, respectively. Scenario 9 (H9 S1), which involves variations in storey heights of district buildings, and Scenario 10 (H10 P1), which integrates PV panels on district roofs, lead to the most significant reductions in primary energy consumption in Antalya. Scenario 5 (H6 T1), which involves changing building forms to atriums, and Scenario 7 (H7 R1), which focuses on changing building orientations in the district by 6%, have the least impact on energy consumption. However, it should be noted that only energy consumption is conducted. This form may reduce the internal heat gain by cross ventilation. Proper CFD

(computational fluid dynamics) analysis should be conducted to test the atrium form effects in Antalya on further studies.

The most significant reductions in heating energy consumptions of Erzurum are achieved in Scenario 4 (C4 M1) and Scenario 5 (C5 M2), with approximate reductions of 35% and 44%, respectively. The most substantial decrease in cooling demand occurs when the Window-to-Wall Ratio (WWR) is reduced by 20% in Scenario 3 (C3 W2). However, this reduction in cooling demand only leads to a 7% decrease in primary energy consumption. Scenario 9 (C9 S1), which involves specific parameter changes not mentioned in the given data, and Scenario 10 (C10 P1), which integrates PV panels on district roofs, result in the most significant reductions in primary energy consumption. The scenario with the least impact on energy consumption is Scenario 7 (C7 R1), which focuses on changing the building orientations in the Erzurum district.

5.1 Limitations and Challenges

Moving from building scale to district level scale has a variety of challenges, since this scope of studies is relatively new and less common in the relative literature. One of the major challenges in conducting energy simulations for districts is the integration of proper performance evaluation systems. Since the size of the operation additionally expands, the complexity and architectural constraints related to the urban environment that impact energy performance also increase. Therefore, the UBEM tools are analyzed in literature reviewing.

This thesis uses UrbanOPT as simulation tool for district energy analysis and calculations. The methodology follows bioclimatic architecture parameters and solar power system's impacts on final energy consumption and carbon dioxide emissions. The study is restricted in terms of testing district energy systems due to the limitations of the

software. The first study restriction pertaining to the use of the tool for energy simulations is the absence of district energy systems in UrbanOpt. As of the knowledge cut-off date of September 2021, the UrbanOpt documentation [128], states that district energy systems are not released and still in progress.

On the district scale, the use of district heating & cooling systems, and power generation play a substantial role in the analysis of primary energy calculation. Furthermore, the types of research issues that can be addressed using this tool may be constrained by UrbanOpt's unavailability of district energy systems and integrity of renewable energy systems besides solar power. Without these expansions in the software, it may be more challenging to conduct research on the potential advantages of district energy systems for reducing emissions of greenhouse gases or increasing energy efficiency.

Another issue on the new energy simulation tools is the lack of compatibility and convertibility between different district energy modeling tools. There are many simulation tools available that are made to model the many components of district energy systems. However, because these software and programs typically use distinct input and output formats. Therefore, it may be challenging to transfer data between them. One energy model in a program may not be transferred into another program with its modeled features and parameters. As a result, it may not be possible to model various aspects and parameters of a district energy model using a variety of programs.

On the other hand, despite the general building energy simulations, which only analyses an individual building, district energy simulations depict the energy production and consumption of multiple buildings on different scales, from neighborhoods to cities [131]. Hence, district energy modeling needs more time to enter, process, and analyze

data. It also needs more thorough data about each structure and how they impact other buildings' energy efficiency.

District energy simulations must account for the energy distribution systems, such as district heating and cooling networks, and their related control systems in addition to simulating the energy generation and consumption of each building of the district. This method demands advanced simulation models and more data input on neighborhoods [132] [133] [134]. In this regard, compared to individual building simulations, district energy simulation is a more involved and time-consuming procedure, but it can offer insightful information on community-wide energy efficiency and cost savings.

There is usually some uncertainty present in energy simulations. A few of the factors that could affect this uncertainty are the accuracy of the input data, the complexity of the model, and the assumptions that were made throughout the simulation process. This uncertainty may limit the accuracy and trustworthiness of the simulation results [135]. One of the difficulties that have been highlighted is the lack of validation and calibration methods for district energy models. In developing district energy models, the widespread use of generic data and oversimplified assumptions, which could lead to inaccuracy in simulation results [136] [137].

5.2 Recommendation and Future Studies

Modeling bioclimatic factors in energy programs is essential to ensuring that buildings are built and operated in a way that increases occupant comfort while managing the optimal cost. In this dissertation methodology, only the energy efficiency analysis is conducted. However, it may be strengthened with further study on thermal comfort and cost analysis.

As mentioned, there are government incentives on energy efficiency of larger scales due to the increasing energy crisis worldwide. Therefore, it is crucial to level up the energy studies on larger scales. This thesis proposed a set of bioclimatic architecture parameters and advanced design strategies on analysis of district scale energy efficiency.

Through this in-depth analysis, it is presented that some parameters have significant impacts on district energy efficiency. However, due to the limitations of the district energy calculation software, some essential parameters such as renewable energy and district energy systems' integration to the energy modeling simulation were not available. In future studies, these parameters may be added for the proposal of improvement into the energy efficiency of the districts. Additionally, these parameters may be analyzed in terms of thermal comfort levels in the district.

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