COMPARISON OF ARCHITECTURAL DESIGN PARAMETERS IN TRADITIONAL BUILDINGS IN TERMS OF ENERGY PERFORMANCE FOR FUTURE HOUSING DESIGN

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Dedicated to the memory of my mother, Semiha Coşkun, and my father, Mustafa Coşkun who always gave their endless love and support to me. You are gone but your belief in me has made this study possible.

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ABSTRACT

COMPARISON OF ARCHITECTURAL DESIGN PARAMETERS IN TRADITIONAL BUILDINGS IN TERMS OF ENERGY PERFORMANCE FOR FUTURE HOUSING DESIGN

Architectural studies re-orient through traditional architecture because of the energy crisis. The purpose of this study is to examine the architectural design parameters of traditional dwellings in terms of energy efficiency for future housing design in a hot humid climate.

The case of this study is the 19th Century İzmir Houses. Two base case buildings with two and single-story were determined. Onsite measurements were taken from these buildings to identify the building material properties and to understand their thermal behavior. They were modeled and simulated with the DesignBuilder energy simulation program. The calibration and validation processes were conducted on these models.

Two and single-story 114 types of İzmir Houses were modeled using the base drawings of the actual examples of these types and the validated material properties of the base case buildings in two different settlements where they are most frequently seen. The energy consumptions of these models were simulated. The statistical analyses were applied to examine the relationship between the source energy consumption per square meter and the design parameters of İzmir Houses.

The design parameters such as the location of the hall, plan type, the existence of the basement, window to wall ratio, wall to floor ratio, window to floor ratio, total building area, wall to volume ratio, settlement pattern were found effective on the building energy performance. The least energy-consuming two-story İzmir houses type has a basement and side hall plan while the single-story house has a basement and central hall plan.

ÖZET

GELECEKTEKİ KONUT TASARIMLARI İÇİN GELENEKSEL YAPILARDA MİMARİ TASARIM PARAMETRELERİNİN KARŞILAŞTIRILMASI

Mimari çalışmalar, enerji krizi nedeniyle geleneksel mimariye yönelmektedir. Bu çalışmanın amacı sıcak ve nemli iklimdeki geleneksel konutların enerji etkinliğe ilişkin mimari tasarım parametrelerini gelecekteki konut tasarımları için irdelemektir.

Bu çalışmanın örneği 19. Yüzyıl İzmir Evleri'dir. İki ve tek katlı iki temel örnek bina tespit edilmiştir. Yapı malzemelerinin özelliklerini belirlemek ve bu tür binaların termal davranışlarını anlamak için bu binalardan yerinde ölçümler alınmıştır. Bu binalar Design Builder enerji simülasyon programı ile modellenmiş ve simüle edilmiştir. Bu modellerde kalibrasyon ve validasyon işlemleri gerçekleştirilmiştir.

İki ve tek katlı 114 tip İzmir Konutu en çok görüldükleri iki farklı yerleşimde, bu tiplerin gerçek örneklerinin temel çizimleri ve temel örnek binaların valide edilmiş malzeme özellikleri kullanılarak modellenmiştir. Bu modellerin enerji tüketimi simüle edilmiştir. Metrekare başına düşen kaynak (birincil) enerji tüketimi ile İzmir Evleri'nin tasarım parametreleri arasındaki ilişkiyi incelemek amacıyla istatistiksel analizler yapılmıştır.

Holün konumu, plan tipi, bodrumun varlığı, pencere duvar oranı, duvar taban oranı, pencere-taban oranı, toplam bina alanı, duvar hacim oranı, yerleşim düzeni gibi tasarım parametreleri bina enerji performansı üzerinde etkili bulunmuştur. En az enerji tüketen iki katlı İzmir ev tipi bodrum ve yan hollü plana sahipken, tek katlı İzmir evi bodrum ve merkezi hollü plana sahiptir.

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CHAPTER 1

INTRODUCTION

1.1. Theoretical Perspective

The first half of 20th-century architecture had left passive design strategies of traditional architecture until 1970 when studies re-orient through the traditional architecture because of the energy crisis (Manzano-Agugliaro et al. 2015). Since the 1970's the reduction of energy and CO_2 emissions had become a critical issue for architecture worldwide regarding their deep impacts on environmental disasters (Fernandes and Mateus 2012; IPCC 2014; UNEP 2009). In the '90s, contemporary architects preferred to use high technology materials and systems to provide clean and renewable energy. The sustainable architecture was regenerated by the 21. Century (Fernandes and Mateus 2012). In recent decades, residential buildings with approximately 30 % of global energy consumption are one of the leading actors which threat the environment and cause health problems (Allouhi et al. 2015).

Therefore, researching architectural design strategies of traditional dwellings has become a crucial concern in respect to decreasing energy consumption of contemporary residential buildings while regenerating recent sustainable architecture by reminding the past knowledge (Dabaieh 2013; Fernandes and Mateus 2012) There are several studies which validate the energy efficiency of traditional buildings (Hooi, Toe, and Kubota 2015; Li et al. 2012; 2013; Ozay 2005). Traditional architecture, which provides the fundamental need for a comfortable shelter, is shaped by geography, climate, availability of natural resources and materials, economy, social, history, and culture. (Fernandes and Mateus 2012; Shanthi Priya et al. 2012) According to the studies which investigate different traditional dwelling types in different regions and climate zones, traditional architecture encompasses several design strategies such as sustainability and climate responsiveness, etc. which are closely related to each other.

While testing the energy performance of several design parameters of each strategy, there are various types of design tools used by practitioners providing qualitative and quantitative information. Some of the researchers make in situ analysis while others use simulation methods or both. In situ analysis includes measurements, drawings, photographing of existing buildings. Building energy simulation models use hypothetic models and evaluate numerous variables at the same time to find an optimum model that can be validated by in situ measurements in such a short time with a limited budget.

The traditional architecture is strongly dependent on its context, while it includes common universal strategies, so it is important to develop a holistic view of it. On behalf of current issues, it is significant to analyze architectural design parameters of traditional buildings in terms of energy efficiency for future designs in each settlement by proposing a methodology generated according to its local, universal, and intrinsic factors.

1.2. Problem Statement

Buildings have substantial potential for reducing energy consumption in Turkey as in Europe, with the 35% rate of primary energy use (Şahin et al. 2015). Turkey officially started to deal with the energy efficiency problem of buildings with the standard of TS825, Thermal Insulation Requirements for Buildings in 2000. It is obligatory for buildings built after 2000 to decrease the overall heat transfer coefficient of building's envelope components according to The Directive on Building Energy Performance (BEP Directive 2008)

Some serious critics have been done to BEP TR software, which is used to prepare energy certificates due to TS825 (UCTEA 2011). For instance, heat insulation has less impact on the energy efficiency of buildings than the heat storage capacity of the envelope in a hot-dry climate. However, Istanbul and Mardin are in temperate-humid and hot-dry climatic zones, respectively. The Turkish standard is considering them in the same zone by using a degree-day concept for heating energy conservation (Yılmaz 2007).

The main objective of the energy certificate program BEP TR is saving energy from the final primary-conventional energy consumption of residential buildings. Today's tendency of the building designers to reduce the energy consumption of new or existing buildings is using insulation materials because of the BEP TR standard, which directs them to solve the energy problem through the envelope. However, insulation has a negative effect on buildings cooling loads in summer. Also, during winter, the thick insulation layer causes a low level of infiltration, so ventilation is needed. Because of ventilation heating load increases.

Traditional and vernacular residential buildings mostly evaluated according to their exterior shell/envelope in the restoration practice of Turkey. For example, in Turkey, there is a Law of Conservation of Cultural and Natural Property numbered 2863, which protects traditional and vernacular buildings as well. Superior and Regional Council for the Conservation of Cultural and Natural Properties under the Ministry of Culture and Tourism is authorized to take the necessary measures. Traditional and vernacular residential buildings are categorized as examples of civil architecture according to the law. “Street rehabilitation projects and implementations” is one of the project categories of the law that identifies the restitution, restoration, urban design projects and all kinds of projects to be done in engineering branches and their applications for the preservation and documentation of immovable cultural assets required to be protected and other structures in the streets together with all the items that define the original street texture in conservation sites and zones. This implementation is managed by the municipality or ministry of culture and tourism. Mostly due to the financial problems, these institutions rehabilitate the elevations of the buildings that face the streets in accordance with limited restrictions of the law. Unfortunately, these implementations are not permanent and do not go beyond makeup.

Besides, preparing restoration projects in a building scale by restoration specialist is not obligatory in Turkey. Architects who did not take any conservation and restoration training can also prepare restoration projects for presenting to the conservation councils. Some of the architects care only about the exterior skin of the buildings rather than design parameters regarding interior organizations and draw their projects according to this vision. Also, inappropriate re functioning decisions of these buildings force architects to underestimate the interior design parameters of the existing buildings. This approach causes to damage the architectural integrity and authenticity of these buildings. Unfortunately, examples of registered/listed civil architecture that encapsulates traditional and vernacular residential buildings constitute one of the most seen kinds of these buildings. Apart from these, there are various unregistered traditional and vernacular residential buildings that can be transformed without any obligatory processes.

According to Law No. 2863, conservation councils’ representatives are elected by the Ministry of Culture from among those specializing in archeology, art history, law, architecture, and urban planning disciplines. However according to the Directive of Energy Performance: the opinions of the conservation councils should be considered regarding the measures and practices for increasing energy efficiency and to make energy efficiency enhancement applications in the buildings which are registered as cultural assets to be protected and in view of this opinion the implementation of energy efficiency-enhancing practices that do not affect the external appearance and the feature of the buildings should be done. But the conservation and restoration projects of traditional and vernacular buildings are not evaluated in terms of energy performance because of the lack of engineering discipline in the conservation councils.

As stated in the Delhi Declaration of ICOMOS 2017, "Appropriate conservation and management of living heritage is achievable through the intergenerational transfer of knowledge and skills in cooperation with communities and facilitated by multidisciplinary expertise." The energy consumption in residential buildings is affected by "socioeconomic development, architectural design, geography, and climate" (Allouhi et al. 2015). Architectural design strategies are the only variables that depend on designers' decisions among these factors. Furthermore, several studies have argued that energy efficiency of buildings is mostly achieved with appropriate early design stage decisions (English Heritage Publications 2012; Jeong and Yoon 2012; Kazanasmaz et al. 2014; Morrissey, Moore, and Horne 2011; Omidfar, Weissman, and Georgoulias 2012; Ralegaonkar and Gupta 2010; Yildiz and Arsan 2011; Yildiz et al. 2012). When architectural design strategies are to be studied to achieve energy efficiency for the reduction of energy and Co2 emissions, it is proper to reconsider the features and benefits of traditional and vernacular architecture (Dabaieh 2013; Fernandes and Mateus 2012). For example, the aim of climate responsiveness defines the adaptation to the climatic conditions by using passive design techniques with the appropriate form, orientation, and materiality (Dabaieh 2013; Gou et al. 2015; Soleymanpour, Parsaee, and Banaei 2015). In fact, the determination of parameters about climate-responsive, sustainable, environment-friendly, etc. design strategies of traditional and vernacular dwellings are crucial in terms of exploring future design techniques, which lead to decrease dependency of insulation and similar technological materials (Bouillot 2008).

The consideration is that the energy efficiency knowledge of traditional and vernacular houses can inspire the design and construction of future contemporary houses even when the whole technological advancements continue to rise. It is necessary to refresh our knowledge about their impact on the energy efficiency of dwellings.

1.3. The Significance of the Study and the Limitations

The variations of a building type architectural design parameters (internal space arrangement, building form, facade organization, settlement pattern, orientation, etc.) will be evaluated together and determined correspondingly under different design scenarios, so; an integrated approach would be proposed.

Heating and cooling loads were considered in building energy simulations.

The effects of the inherent architectural design parameters of the 19^{th} Century İzmir Houses regarding energy consumption haven't been investigated before. Only the thermal effects of the massive exterior walls of this kind of buildings were investigated.

In addition, this study has some limitations, such as:

- Different simulation tools could be used to prepare the model and to compare the results.
- Field study measurements have been taken for a certain time (day and hour).
- The measured base case buildings are not the actual samples of the most seen types of İzmir houses, so; the base samples of these types were found from literature in order to model and simulate.

Consequently, the focus of the outcome would be the optimum values of the architectural design parameters of İzmir Houses in terms of energy efficiency. In this context, this study will be a guide for new designers to provide new information about energy-efficient design strategies indigenous to the climate and geography.

1.4. The Purpose Statement

The purpose of this study is to examine the architectural design strategies of traditional dwellings in terms of energy efficiency for future designs of residential buildings in a hot, humid climate in İzmir. Typologies of 19^{th} Century İzmir Houses' internal space arrangement, building form, facade organizations, settlement pattern, and orientation will be analyzed. Variations of such parameters would lead us to determine numerical values of impact rates.

It is aimed to find out the least energy-consuming house type of 19th Century İzmir Houses and the design parameters' impact rates on energy consumption. To achieve this, several scenarios were examined by the DesignBuilder simulation program.

1.5. Research Questions and Hypothesis

The research questions to be examined in this study are listed below

- Why is traditional architecture important regarding energy efficiency?
- What are the design strategies and parameters of traditional architecture?
- How do the internal space arrangement, building form, facade organization, settlement pattern, and orientation affect the energy performance of traditional dwellings?
- How do design parameters of traditional dwellings affect each other?
- How can future housing design benefit from traditional housing design strategies?
- Is it possible to overcome the insulation and similar technological material dependency of contemporary dwellings by traditional design techniques?

The first hypothesis is to assume traditional architecture as a model of sustainable, climate-responsive, energy-efficient design for the future with its inherent and timeless knowledge.

The second hypothesis is to analyze the traditional buildings' energy performance just according to their exterior shell cause improper practices. Thinking of traditional buildings as solely a qualitative shell gives damages irreversibly to these buildings during the restoration, such as demolishing interior spaces, etc.

The third hypothesis is to reduce the dependency on insulation or similar technological materials in terms of energy efficiency by using design parameters appropriately.

The fourth hypothesis is to assume a building energy simulation tool as an effective way of exploring the energy consumption of buildings in a limited time and budget.

1.6. The framework of the Thesis

This thesis is composed of five chapters, of which the first one is the 'Introduction.' The significance of the design parameters of the traditional buildings on future design regarding energy consumption was briefly explained. Then, the purpose and hypothesis of this research were presented.

The second chapter presents the literature review about the importance of the traditional buildings' knowledge regarding their objectives, strategies, and design parameters. Also, the earlier studies were explained about this subject. The 19th Century İzmir Houses and the dynamic simulation modeling tools were described.

In the third chapter, the methodology used in this study was clarified. At first determination of base case buildings and 19th Century İzmir Houses variations and onsite measurements were explained. The dynamic simulation modeling of these buildings and the energy simulation settings were described then. At the end of this chapter, the statistical analysis methods used in this study, such as ANOVA, T-Test, and Pearson Correlation, were presented.

In the fourth chapter, the results of the on-site measurements, building energy simulations, and their statistical analyses were explained. The results of the simulations and the significant architectural design parameters in terms of energy performance regarding statistical analysis were discussed.

The fifth and the last chapter is the 'Conclusion'. In this chapter, the concluding remarks of this research and recommendations for future housing design and studies were presented. The main structure of this study can be seen in Figure 1.1.

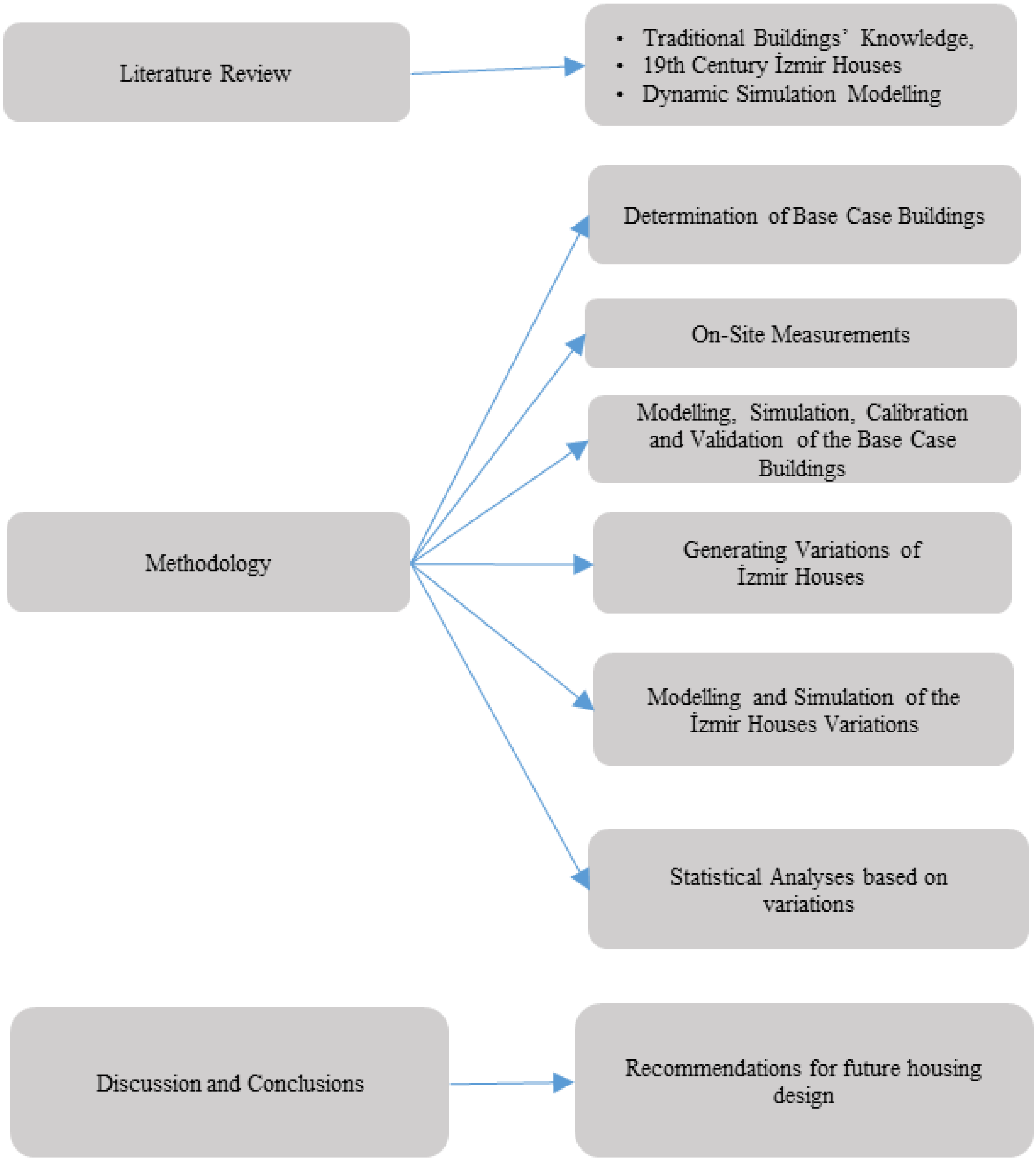


Figure 1.1 The main structure of the thesis

CHAPTER 2

LITERATURE REVIEW

Traditional architecture knowledge is based on trial and error methods. It is a reflection of the environmental context and cultural heritage (Fathy 2010; Hooi, Toe, and Kubota 2015; Shanthi Priya et al. 2012). The researchers agree that traditional dwellings are the consequences of the accumulated construction intelligence through ages which optimize the use of locally available natural resources are adapted to the local climate without using artificial systems (Gou et al. 2015; Oikonomou and Bougiatioti 2011; Shanthi Priya et al. 2012)(Gou et al. 2015; Shanthi Priya et al. 2012). What is the relationship between traditional and vernacular architecture? Both traditional and vernacular architecture are the outcomes of knowledge shaped with social, cultural, economic, defensive or religious, the available natural resources, climatic factors (Coch 1998; Manzano-Agugliaro et al. 2015; Nguyen et al. 2011). Naseer M.A. (2013)claimed that the traditional, cultural, and climatic differences between regions contribute to the generation of diverse vernacular architecture. (Osasona and Ewemade (2009) described the vernacular architecture as a product of traditional architecture that reflects the lifestyle of the individuals cited Amole, who defines the vernacular architecture as the 'post-traditional'. Therefore, it can be deduced that the traditional architecture encapsulates the vernacular architecture so as Gou et al. (2015) used the phrase "traditional vernacular dwellings" while describing the evolution of vernacular architecture. Why is it important? In 1999 International Council on Monuments and Sites (ICOMOS) presented Charter on Built Vernacular Heritage which identifies that "The built vernacular heritage is important; it is the fundamental expression of the culture of a community, of its relationship with its territory and at the same time, the expression of world's cultural diversity" Even Dabaieh (2013) evaluate the vernacular buildings as "an example of intelligent buildings". At the more abstract level, all these descriptions of vernacular architecture above mentioned have a common emphasis on time, place, and culture (Rapoport 2006). It is "based on the repetition and improvement of solutions over successive generations" (Fernandes and Mateus 2012). For instance, (Vestergaard 2015) explained how the knowledge of traditional architecture was embedded in contemporary buildings with his comparative study about energy performances of a 300-year-old vernacular house and a contemporary suburban passive house.

In traditional and vernacular architecture, the main aim is to design comfortable shelters irrespective of the outdoor environmental conditions, especially climatic for humans. Thus, passive design techniques in response to environmental parameters have been used while designing vernacular buildings (Hooi, Toe, and Kubota 2015; Naseer M.A. 2013). Due to the lack of sophisticated technologies, the traditional and vernacular architecture is based on the passive design techniques that consider factors such as: “geographic characteristics, insolation; orientation; geometry; shape; materials” (Fernandes and Mateus 2012; Rapoport 2006).

2.1. The Effects of the Industrial Revolution on Architecture

Industrial Revolution “broke the line of vernacular knowledge,” and the Modern Movement emerges in the 20th century (Fernandes and Mateus 2012). The modern architects escaped from the constraints of traditions and change living habits of each population with this belief (Lindsay and Marcel 2006; Rudofsky 1964)They assumed “that all humans have the same need” so that “the rationalistic forms and space are universal and applicable to any place on the Earth” (Fernandes and Mateus 2012). Further, they considered that architecture must homogenize the living standards by attenuation of cultural and social differences for the more livable world. Function and shape are the major concepts rather than traditional knowledge based on environmental, cultural, social, and economic factors (Manzano-Agugliaro et al. 2015). They are in favor of the fast construction process, cost-efficiency. As a result, building designs independent of its contexts to meet the needs of an idealized inhabitant types were emerged all over the world (Fernandes and Mateus 2012).

Industrialization led the standardization of material such as glass cement steel and homogenized the architectural building types (Lindsay and Marcel 2006). In the first half of the 20th Century, by the discovery of mechanical air conditioning technics and new oil wells, the architecture left passive design strategies of vernacular architecture and declared its independence from the context. Utilization of the industrialized materials and ignoring the local conditions led the buildings to become dependent on artificial systems like mechanical ventilation heating and cooling and artificial lighting (Cantin et al. 2010; Coch 1998; Fernandes and Mateus 2012).

In 1973 with the announcement of the global energy crisis, it is understood that the natural resources are limited and began to deplete. Scientific studies on re-orientation through the vernacular architecture began in 1977, mostly in India, Greece, Spain, and Brazil. In the 1980's the environmental damage produced by the building sector realized and the concept of sustainability increased (Manzano-Agugliaro et al. 2015). In the 90s, architecture deals with the high technology solutions to provide "formal quality and optimal use of energy resources, based on clean and renewable energy" (Fernandes and Mateus 2012). And now, in the 21st century, it is necessary to reduce CO2 emissions and regenerate sustainable architecture (Cantin et al. 2010; Fernandes and Mateus 2012; Lawrence 2006; Manzano-Agugliaro et al. 2015).

2.2. Revisiting the past

When the reduction of energy and Co2 emissions became an urgent issue of architecture worldwide, it is very appropriate to revisit the traditional and vernacular architecture for cleaner energy and more sustainable, climate-responsive buildings. There are various comparative studies which investigate the traditional, vernacular and contemporary architecture design strategies and concluded with the assumption of "Learning from past" (Andreou 2014; Bodach, Lang, and Hamhaber 2014; Bouillot 2008; Dabaieh 2013; Fernandes and Mateus 2012; Indraganti 2010; Ozay 2005; Rapoport 2006).

Traditional and vernacular architecture can be a model of sustainable design for the future if we use the "inherent and timeless knowledge" of it ((Dabaieh 2013). Although traditional buildings do not always meet the modern lifestyle within their designs and techniques, they create a rich knowledge base that should not be abandoned completely.

(Bodach, Lang, and Hamhaber 2014). It is important to integrate today's advanced technical capability with low-tech sustainable solutions of traditional and vernacular architecture rather than copying its architectural forms (Asadi, Fakhari, and Sendi 2016; Coch 1998; Dabaieh 2013; Dili, Naseer, and Varghese 2010; Shanthi Priya et al. 2012; Soleymanpour, Parsaee, and Banaei 2015). The synthesis of traditional and modern architecture can be achieved by linking “intelligent materials with traditional materials” and seeking “new aesthetics and functional concepts” (Fernandes and Mateus 2012). Therefore, the energy efficiency will be provided via reducing the dependency on artificial equipment, using renewable energy resources and biomass energy (Dong and Jin 2013; Shanthi Priya et al. 2012). Furthermore, the current comfort standards can be achieved by optimization of the traditional and vernacular design strategies (Fernandes and Mateus 2012).

2.3. Objectives, design strategies and parameters of traditional buildings

Many studies have been conducted to analyze the objectives, architectural design strategies, and parameters of traditional and vernacular buildings all over the world. In fact, it is very important not to interweave the objectives with the strategies. Strategies are sub-terms of objectives. Because objectives are permanent regardless of time, space, meaning, and communication, whereas strategies are related to the context. From the general to the specific, the terms of vernacular architecture can be arranged as objective, strategy, and parameters.

The traditional and vernacular architectural design gives different answers to solve the same climatic complexities. Thus, traditional and vernacular architecture is a very rich, modest kind of architecture with its flexibility and adaptability (Coch 1998; Hooi, Toe, and Kubota 2015). It is not always possible to conclude on a single objective for a building design while evaluating traditional and vernacular architecture because all the aims mentioned above are closely related to each other. For example, the design concepts of vernacular Harran houses are described as ‘‘flexible building’’, ‘‘reusable building materials’’, ‘‘environmentally friendly building’’, ‘‘climatic building design’’ and ‘‘sustainable habitation’’(Özdeniz et al. 1998). As another example, Shanthi Priya et al. (2012) determined the traditional houses in Nagapattinam, Tamilnadu, İndia as eco-friendly and climate responsive. Dabaieh (2013) determined the main objectives for vernacular architecture as being energy efficient and comfortable, using passive design techniques, being cost-effective, using available resources. Climate responsiveness, sustainability and ecologic are the other objectives of traditional and vernacular buildings taken part in the literature (Baran, Yıldırım, and Yılmaz 2011; Fernandes and Mateus

2012; Gou et al. 2015; Soleymanpour, Parsaee, and Banaei 2015). For example, Fernandes and Mateus (2012) present traditional and vernacular architecture as the basis of a sustainable approach that uses local natural resources effectively with minimum waste and which is adapted to the surrounding natural environment. According to these studies, the communities acquired the empirical notion that welfare is provided by living in harmony with the surrounding environmental conditions.

Several case studies proved the energy efficiency of traditional and vernacular buildings. Some of these studies also compare the energy performances of these buildings with contemporary ones (Hooi, Toe, and Kubota 2015; Li et al. 2012; 2013; Ozay 2005; Vestergaard 2015). These studies mostly follow holistic approaches to analyze the design strategies of vernacular dwellings because of the complexity of the energy issue, which is dependent on both quantitative and qualitative measures.

Fernandes and Mateus (2012) discussed energy-efficient design strategies to reach sustainability in vernacular buildings in Portugal as “appropriate urban planning, adequate natural ventilation, reducing solar gains in summer, capturing solar gains in winter, reducing heat loss for promoting heat gains, efficient management of resources”.

Yılmaz (2007) determined energy-efficient architectural design strategies of traditional buildings as low transparency ratio of the building envelope, the high time lag for the hot, dry climatic region, and appropriate thermal insulation and facade organization due to the sun a for the temperate humid climatic region in Turkey. The parameters to progress these strategies were found out in the hot, dry climatic region as low transparency ratio of the building envelope, high thermal mass with thick walls, high time lag, and small windows and in the temperate humid climatic region as thermal insulation, large openings on the south facade protected from shading, protected north facade.

Ulu (2018) determined the retrofit strategies for energy efficiency in traditional buildings in İzmir, Turkey. Besides, the relationship between design parameters and building energy consumptions of case buildings was evaluated. The most effective design parameters on energy consumption were determined as the ratio of total surface area to conditioned volume and usable ground floor area to conditioned volume ratio,

As mentioned above, climate responsiveness is one of the goals for traditional and vernacular architecture which defines the adaptation to the climatic conditions by using passive design techniques with the appropriate form, orientation and materiality (Dabaieh 2013; Gou et al. 2015; Soleymanpour, Parsaee, and Banaei 2015). Climate responsive strategies can provide buildings to be environmentally friendly, low-energy consuming, comfortable, healthier and sustainable (Gou et al. 2015; Naseer M.A. 2013; Ozay 2005). Bodach, Lang, and Hamhaber (2014)

(Bodach, Lang, and Hamhaber 2014) determined climate responsive strategies of vernacular houses in Nepal in four different climate zones, such as subtropical, warm temperate, temperate, and Alpine climates. As an example, for the warm temperate climate, design strategies are: “passive solar heating for winter, protection from the cold and rain, high thermal mass, enhanced air movement and medium-sized windows with shading in summer”. (Bodach, Lang, and Hamhaber 2014) figured out the design parameters regarding the strategies mentioned above as “settlement pattern, building form and orientation, building stories and internal space arrangement, design and construction materials of walls, roof, foundation, floors, ceilings, and openings”.

Nguyen et al. (2011) figured out climate responsive design strategies for traditional buildings in Vietnam as natural ventilation, appropriate building orientation shape, and solar shading. The design parameters of these buildings to achieve this aim were determined as village location, building layout and orientation, internal space settings, openings design, the buffer space, the double layer envelope, the raised ventilated floor, use of vegetation, and water.

Due to the qualitative analysis of (Gou et al. 2015) climate responsive design strategies of traditional dwellings in hot summer and cold winter regions of China are natural ventilation, sun shading, and thermal insulation of the building envelope. The design parameters to manage these strategies were determined as the location of the settlement, the compact building form, orientation regarding the prevailing wind direction, the street pattern, the interior space setting, window arrangement, utilization of buffer spaces, and vegetation for shading.

Gautam (2008) also determines climate responsive strategies of the vernacular houses in Jharkhand İndia. The climate zone of Jharkhand has extreme conditions in summer, monsoon and winter, and normal conditions in spring and autumn. For instance, in this study, the strategies determined for the summer season which is hot during the day and cold at night are “using evaporative cooling, protecting against summer heat gain, keeping the sun out in summers to reduce heat gain and glare, flattening day-to-night temperature swings to reduce cooling in summers, using vegetative cover to prevent reflected radiation and glare, expanding use of outdoor spaces during the night, nighttime flush ventilation to cool thermal mass" (Gautam 2008). The building envelope, window to wall ratio, and utilization of attic space were detected as the design parameters.

(Ozay 2005) determined the design strategies to achieve the climatically responsive buildings in the hot climate of Cyprus as "reducing energy consumption, using natural resources instead of the artificial ones such as mechanical systems and providing more comfortable, healthier, and sustainable living spaces." The design parameters were determined, such as orientation according to the sun and the prevailing wind direction, construction materials and techniques, plan layout, and building elements proportions and characteristics such as windows and doors.

(Baran, Yıldırım, and Yılmaz 2011) conducted a study in Diyarbakır and revealed that the traditional architecture has ecological aim with design strategies as "renewable energy, waste assessment, climatic comfort, landscape, and conservation of natural resources". The design parameters for reaching this goal regarding physical environments were concluded as topography and climate while the parameters regarding structural environments as "building form, spatial organization, landscape and planting, building envelope (material), technical infrastructure".

According to the study of (Manioğlu and Yılmaz 2008), held in the hot, dry climate region of Turkey to figure out the design strategies and parameters to achieve sustainability and energy efficiency, the optical and thermophysical building envelope is the most important design parameter for providing indoor thermal comfort. The orientation of the building, the distance between buildings, and the building form are the other design parameters to achieve energy conservation among the site.

One of the major aims for traditional and vernacular building design is to provide comfortable living spaces regarding thermal performance (Shanthi Priya et al. 2012). Environmental factors in achieving thermal comfort conditions are "air temp, surrounding surface temp, air humidity and air velocity", whereas psychological factors to achieve thermal comfort conditions are "clothing, activities, age and sex" (Manzano-Agugliaro et al. 2015). However, thermal comfort in these buildings cannot always be achieved for a whole year without the help of mechanical systems, especially in extreme climate conditions (Gou et al. 2015; Sun and Leng 2015). Besides, Gautam's (2008) survey results showed that the universal approach for defining comfort conditions fails because the occupants feel comfortable in conditions which defined as uncomfortable by ASHRAE and Nicol.

Other than these, occupants' behaviors are also very effective in energy consumption of the dwellings such as heating system usage, ventilation patterns, setpoint temperature, or closing the window shutters at night. The overall discussion is needed to understand the thermal performance of buildings (Cantin et al. 2010; Terés-Zubiaga et al. 2013). For example, Li et al. (2012) conducted a comparative study of the energy consumptions of Tulou buildings and normal rural buildings in China in hot summer warm winter climate zone. The residents in Tulou buildings experienced better thermal comfort; however, they consume less cooling energy than normal rural buildings. The most likely reason for better thermal comfort in Tulou buildings may be due to the difference in their building envelope, which involves thick rammed earth walls with effective thermal insulation and large thermal mass.

Besides, Soleymanpour, Parsaee, and Banaei (2015) studied the architectural design strategies of vernacular houses in different climate zones in Iran and determined parameters for achieving climate comfort in future designs for four different climatic regions. For example, for hot and humid climates, the parameters were determined as extending gable roof over balconies and protecting the walls, ground floor's slab upper than the ground level, buildings should be oriented with the longer facade toward south spread open and wide settlement pattern, plan proportions.

Cantin et al. (2010) compared architectural design and thermal characteristics of historical dwellings and modern dwellings in France in terms of thermal comfort. The design strategies to achieve thermal comfort were determined as optimized management of occupants, combining the reduction of solar gains during daytime and cooling at night. The design parameters of historical dwellings were detected as "openings windows ratios adapted to the orientation of the facades, crossing distribution of the indoor environment, the high thermal mass of the built unit, various devices allowing natural ventilation" (Cantin et al. 2010).

Due to several studies, vernacular buildings have open systems, which means they are closely related to their environment and site (Cantin et al. 2010; Nguyen et al. 2011; Terés-Zubiaga et al. 2013). Their outdoor and indoor conditions are like each other. For instance, Cantin et al. (2010) found out that in France, the average correlation coefficient between the indoor and outdoor temperature of historical buildings are %60 while the modern dwellings are only %10. Therefore, the modern dwelling is thought to have a closed, insulated, and mechanically controlled system.

Because the high energy consumption rates worldwide microclimate conditions of the traditional settlements are trendy topics in past decays (Andreou 2014). There are several studies investigated design parameters of the vernacular settlements related to the energy performance of the built environment.

For instance, Indraganti (2010) analyzed the climate appropriateness of the vernacular settlement Marikal in India that has composite climatic region according to the design parameters such as landform and topography, morphological development, form and site planning of the settlement, cluster planning, streets, alleys and courtyards, construction methods and materials, openings color and texture. These parameters influence thermal comfort in open spaces and the energy performance of buildings.

In an urban setting, solar access is a challenging factor for indoor and outdoor spaces. Andreou (2014) analyzed and compared the shading performance of a traditional and contemporary settlement in Tinos Island in Greece. Solar access and shading conditions are microclimate issues of urban canyons concerning "street pattern, canyon geometry, the height of buildings/street width ratio, street orientation" (Andreou 2014).

(Van Esch, Looman, and De Bruin-Hordijk 2012) determined passive solar heating strategies for the urban canyon in temperate climate as appropriate orientation, optimization of street vegetation, evaporative cooling, using sun shading elements with optimized angles, using a pitched roof, improving glazing thermophysical properties and adding thermal shutters, sunspaces, thermal storage walls or solar collectors. Street width and orientation were examined as urban design parameters while roof shape, building envelope were evaluated as building design parameters in this study.

2.4. Generation of the 19th Century İzmir Houses

The case of the study is 19th Century İzmir Houses. İzmir Houses were mostly built in the last quarter of the 19th Century and rarely in the first quarter of 20. Century (Çıkış 2009; Özkut 1997; Uçar and Uçar 2013). İzmir had become an important port for the world trade in the 19th Century so, migration to the city raised. These immigrants are Muslims, Rums, Armenians, Jews, and Levantines. By the population growth, the housing need occurred. Besides, the earthquakes and fires also had a great impact on the generation of new housing stock.

According to Çıkış (2009), the oldest prototypes of 19th Century İzmir houses can be found in Alsancak (old Punta). She claimed that finding the oldest prototypes of İzmir Houses in Alsancak is not a coincidence where Aydın-İzmir railway ended nearby. The decision of the construction of the railway led to the generation of land speculation. Then, a local zoning plan was produced, and row houses type was chosen to build by English financier who was used to type of rowhouse construction technique (Çıkış 2009). Moreover, Çıkış (2009) cited to (Yücel 1996) that row house type was found suitable for also Turkish family traditions by governments. Çıkış (2009) claimed that local labor adapted their experiences gained from large scale constructions to these houses' constructions. Neo-Classic style of public buildings or Eclectic, Neo-Classic, or Art Nuova styles of big mansions affected the styles of 19th Century İzmir Houses styles by local laborers who adapted their experiences from one to another.

Therefore, in the 19th Century, a huge amount of house was built across the city. Variations of these houses can still be seen all around the city such as Alsancak, Kemeraltı, Buca, Mithatpaşa, Karşıyaka (Akkurt 2004; Akyüz 1985; 1994; 1993; Ballice 2004; Çıkış 2009; Uğurel 2006).

2.4.1. **Architectural design parameters of 19th Century İzmir Houses**

Akyüz (1993) evaluated planimetric characteristics of İzmir Houses mainly due to different plan scheme orders such as a plan with the side and central hall. These buildings have orthogonal plan types. The halls relate to generally square shape rooms. After the main plan scheme categorization Akyüz (1993) examined the variations of İzmir Houses according to the number of stories. These houses are mostly built with two or single-story all around the city. Besides, the building blocks have mostly the basement floors. The plan scheme of İzmir Houses consists of three parts, the main block, service space, and garden.

The settlement pattern varies due to the district that the houses are located in. For instance, İzmir houses built in Punta, which generally have two stories, with orthogonal plan type, have a row house settlement type. They have only a backyard. On the other hand, the single-story İzmir Houses seen in Buca district are settled in detached or semidetached order. They have both side and backyard.

The construction system elements as the walls, floors, roofs, and the facade elements as windows and doors are the effective parameters on energy consumption. The walls of the houses are constructed with three different techniques, such as half infill, infill with cladding, and massive. Rubble stone or brick or both of them are used in these wall structures. Lime plaster is used to cover these walls. Half infill walls are composed of wooden frames filled with the materials mentioned above. The half infill walls are directly covered with lime plaster while the infill and cladding walls are first coated with Baghdadi strips then covered with lime plaster. The half infill and infill and cladding walls are generally used in the ground and upper floors. Massive walls are generally used in basement floors. According to the utilization of the space, they are plastered with lime or not plastered (Akyüz 1993; Moral 1990; Ulu 2018). The external walls at the ground level are coated with stone in some examples. Also, there are examples that the external walls are covered with lime plaster.

The construction of the floors is changing due to the floor they belong to. The basement floor ground material can either be compacted earth or tile. The ground floor construction system differs due to zone utilization. The hall of the ground floor is covered with white and black marble or Karosiman tile. The construction beneath these materials can be brick arch or cast concrete. The rooms on the ground floor are covered with wooden. The zones on the upper floors are covered with wood. The wooden beams underneath the upper floors are covered with Baghdadi Strips and then lime plaster. This constitutes the ceiling of the rooms below (Akyüz 1993; Moral 1990; Ulu 2018).

The oriel is an extension of the main facade at the first-floor level. In the early examples of the İzmir Houses, the oriel is connected to the room different from the latter examples effected from Turkish traditions, which Akyüz (1993) called interaction houses that have oriels connected to the rooms. These semi-open spaces may have been formed to meet the need to widen the viewpoint of the street and gaining more daylight inside. Iron beams are used in load-bearing systems of their wooden coated floors.

The attic floor utilization is generally seen in two-story İzmir Houses. They are constructed with wooden beams covered with pine wood floor planks on the top and Baghdadi strips and then lime plaster on the bottom. The wooden beams can also be covered with pine wood ceiling cover on the bottom (Ulu 2018).

The construction of the roofs is composed of wooden beams covered with wooden lats and Turkish style tile. They generally have narrow eaves with the 20-30 cm width. The roof of the oriel is separated from the main building block. It is lower than the main roof and covered with metal cladding. The roof of the service block also separates from the main building block. It is a flat roof constructed with concrete or brick arch and covered with tile. It is mostly used as a terrace, and it can be reached from the main building block. (Akyüz 1993; Ulu 2018).

The proportions of the windows of İzmir houses change due to the floor they are stated. The basement floor windows are mostly square-shaped. The windows of the ground and upper floors are rectangle-shaped, with the proportion of 1/1.5 and 1/2 mostly. The ground floor windows can be a little higher than the windows of the upper floors. All the windows are constructed with wooden frames. Both the double casement or sash window types can be seen on İzmir houses facades. They have mostly stone jambs and rarely brick jambs. The window shutters are mostly made of cast iron but sometimes especially on the upper floor facades they can be wooden (Akyüz 1993; Bilginperk 1999; Çıkış 2009).

The external doors are divided into two, as main entrance and garden doors or sometimes secondary entrance. These doors are mainly made of cast iron and wood. The external doors are separated into three-part such as completely massive, massive bottom, semi-translucent body on top, and completely semi-translucent. The entrance doors are composed of three-section as iron railing, glass, and iron or wooden wings inwards. This section detail is beneficial for using different purposes of the doors at different times of the day, such as natural ventilation, gaining daylight, or both. Internal doors are mostly massive and wooden framed (Akyüz 1993; Bilginperk 1999; Çıkış 2009; Moral 1990). They can have both double or single wing varying due to the function and proportions of the room they open.

Fast-growing housing construction in İzmir, the 19th Century, caused the generation of concepts of standardization and mass production to decrease the cost and construction period and to constitute the quality standards of construction materials. The overhangs of oriels, iron shutters, entrance doors, floor tiles, and door handles are the standard local construction materials used in İzmir Houses as well as standard import construction materials like iron beams, bricks, roof tiles. Standardization of the construction materials of these houses caused the space forms and sizes to be standard. Also, the facade elements standardization affected the solid voice ratios and view of facades similarly (Bilginperk 1999; Çıkış 2009; Erpi 1987). Because of standardization and mass production, the variations of İzmir Houses occurred around the city. But these commonly featured houses started to lose their connections with their context (Çıkış 2009).

2.4.2. **Classification of 19th Century İzmir Houses**

Various substantial studies categorize 19. Century İzmir houses differently (Akkurt 2004; Akyüz 1993; 1985; 1994; Ballice 2004; Bilginperk 1999; Çıkış 2009; Erpi 1987; Eyüce 1999; Özkut 1997; Tosun 1983; Uçar and Uçar 2013). These categories can be grouped around two ideas. Mostly researchers identify these houses as a kind of traditional type of buildings such as Greek House, Levantine, House, West Anatolian House, Interaction House, etc. while the others describe them as the samples of "alternative modern" buildings those meet local needs. Apart from that, there is shared wisdom that local factors shape these houses. Several studies were categorized İzmir houses mostly according to their facade design because the plan schemes of these houses are mostly homogenized (Akyüz 1993; 1994; Bilginperk 1999; Erpi 1987). Also, some researchers studied variations of plan organizations of these houses (Çıkış 2009; Uçar and Uçar 2013).

Akkurt (2004), named 19. Century Houses as Levantine Houses. She claimed that Levantines were role models of westernization movement in social life and physical environment with their lifestyle and architectural intelligence. According to Akkurt (2004), in the houses in Punta, there is a combination of the western culture that shapes the organization of the space and the facade order, and the local expression displayed by the oriel, which is one of the main characters of the facade. She categorized Levantine settlements in two groups. The former group contains the settlements in the north of the city center as Frank Quarter, Pier, Alsancak (old Punta) and the latter group involves the settlements in the suburbs as Buca, Bornova, Hacılar, Işıklar, Karşıyaka, Kokluca, Mersinli, Narlıköy, Pınarbaşı, Seydiköy.

Akyüz (1985; 1993; 1994), classified the traditional house types of İzmir in three categories like "Traditional Turkish House", "Levantine and Greek Houses" and "Interaction Houses". Interaction Houses were explained as 19th Century İzmir Houses, which were formed by the interaction between Western culture and vernacular architecture and sometimes traditional Turkish architecture. According to Akyüz interaction houses, the type can be stated as "İzmir House" as a typical city house. She stated that these houses in the suburbs be seen in Turkish Quarters like Arapfırını, Tilkilik, Dönertaş, İkiçeşmelik, Karantina, Greek Quarter like Alsancak, Jewish Quarters like Kemeraltı, Mezarlıkbaşı, Keçeciler, Karataş.

Ballice (2004), was agreed with Akyüz (1993) about the classification of "Traditional İzmir House". Besides, she stated that these houses were preferred by every different ethnic and religious group lived in İzmir.

Bilginperk (1999) studied houses in Buca that were built by local Greek people. He insisted that the architectural typology of Buca was occurred predominantly by Greek. According to Bilginperk (1999), these houses are not like the interaction houses which were affected by multicultural values. He held opinion with Erpi (1987) that Buca houses are kinds of functional, rationalist, and simple architectural types.

Çıkış (2009), was in favor of the latter idea and called these buildings the 19th Century İzmir Houses. According to her, the oldest examples of İzmir Houses can be found in Alsancak (old Punta). The other variations of this house type can be seen in different quarters where different religious and ethnic groups lived in such as Turks, Greeks, Jews, Armenians. For instance, these houses can be seen in Basmane, an old Armenian quarter and Namazgah, an old Turkish quarter. She claimed that houses in Buca and Bornova are also a kind of İzmir Houses, which are formerly classified as Buca and Levantine Houses in different studies (Akkurt 2004; Akyüz 1993; 1994; Erpi 1987).

Çıkış (2009) stated that evaluating these houses just due to their "formal analogies" rather than "conceptual concerns" lead to classify İzmir Houses as a solely traditional type. The 19th Century İzmir Houses contains the standardization, pervasiveness, and reflexivity concepts of modernity. Hence, the vernacular aspect of this common attitude brings it a quality of "alternative modernity," according to Çıkış (2009). Moreover, she cited Asatekin (2005), that it is not appropriate to categorize the buildings according to ethnicity. Asatekin proved how different ethnic and religious groups used houses in different cities built with the same construction techniques and spatial order by giving examples from different regions of Anatolia.

Erpi (1987), evaluated the 19. Century İzmir Houses in Buca as a variation of Chios style Greek Houses. He emphasized the local factors that influence these buildings' forms and called them Buca House. Apart from that, he described Buca House as a pioneer of the 20th Century Rationalist movement in the 19th Century not only for their architectural view but also for their architectural intelligence as the standardization of the facade elements ordered geometrical shapes and simplicity. He determined some typologies of Buca Houses according to their facade orders.

Tosun (1983) studied houses in Alsancak (in 1453 and 1482 Streets) and in Kemeraltı (in 842 Street). He classified these houses as “Traditional Western Anatolia”. He mentioned the influence of different ethnic groups on Ottoman architecture. However, he thought that 19. Century İzmir Houses were constructed by Turkish craftsmen.

Uçar and Uçar (2013) evaluated the types and facade typologies of traditional houses on the skirts of Kadifekale in Kemeraltı. She argued that these houses are a product of traditional Greek houses seen in West Anatolian coastline and hinterland because of their similar facade elements and orders.

2.4.3. **Assumptions of This Study About 19th Century İzmir Houses**

The “Levantine Houses” and the “Interaction Houses” types determined in the Ph.D. thesis of Akyüz (1993) and the Buca Houses are evaluated as 19th Century İzmir Houses in this study. The term “traditional” is preferred for the 19th Century İzmir Houses, which was not spontaneously constructed by its inhabitants according to their needs but was instead built by master-builders and tradesmen using specific draft drawings and model plans. Rapoport (1969; 2006) uses the term “pre-industrial vernacular” to describe this category of buildings identifying it with the term “traditional”.

It is explained because determining conceptual concerns, enables to discover intrinsic knowledge, production, architectural design elements from which were derived from local needs. As Rapoport (1969; 2006) suggested that we should learn from traditional design, considering it as a model system rather than copying it. So, these houses, which formed by the problem-oriented, comparative, integrative, and conceptual method, are very important samples for future housing designs.

2.5. Dynamic Simulation Modelling

Several studies revealed that the most important design decisions concerning building sustainability, energy efficiency should be made in the early design stages, by architects or building designers (English Heritage Publications 2012; Jeong and Yoon

2012; Kazanasmaz et al. 2014; Martín, Mazarrón, and Cañas 2010; Morrissey, Moore, and Horne 2011; Omidfar, Weissman, and Georgoulias 2012; Ralegaonkar and Gupta 2010; Yildiz and Arsan 2011; Yildiz et al. 2012). However, “analysis of various parameters during the design stage can increase design time and therefore cost” it is the most influential way for providing desired building qualifications and measures ((Morrissey, Moore, and Horne 2011). Besides, using dynamic simulation models for the analysis of design parameters in the early design stage for buildings is beneficial for overcoming the complexity of calculations and cost-effective (Kazanasmaz et al. 2014; Manioğlu and Yılmaz 2008; Omidfar, Weissman, and Georgoulias 2012; Yang et al. 2012).

The simulation tools are not only used in early design stages but also design, construction, operation, maintenance, and management processes. For instance, building performance simulation (BPS) tools are used in analyzing existing building performance and, evaluating alternative retrofit options, ensuring comfort conditions for the users, designing the building due to the local standards and regulations, operating cost analysis and providing the energy verification (Hong, Chou, and Bong 2000; Ulu 2018).

BPS tools provide detailed thermal simulations based on input and output files. They “contain mathematical and thermodynamic algorithms that are used to calculate the energy performance according to the underlying model of the engine” (Maile, Fischer, and Bazjanac 2007).

Wang, Yan, and Xiao (2012) classified the dynamic simulation for the energy calculation process in three main steps, inputs, simulation engine, and outputs. The input data includes the parameters as weather conditions, building description, system description, and component descriptions. Weather conditions contain the dry and wet bulb temperature of outdoor air, solar radiation intensity, wind speed, etc. Building description data contains location, design and construction data, thermal zones, internal heat gain, infiltration and usage profiles, etc. System description refers to system types and sizes, control schedules, outdoor air requirements. The component descriptions are related to HVAC systems and their detailed components. Wang describes the second step of the dynamic simulation which is the simulation engine as the core part. The simulation engine includes thermal (building) loads calculation, system simulation and central plant analysis. Buildings loads are calculated by using the building description and weather data Then system descriptions are used for system analysis, and component descriptions are used for plant central plant analysis Wang, Yan, and Xiao (2012). After the simulation phase, the CO2 emission, the heating/cooling load of the building, and each thermal zone is gained.

However, a graphical user interface of the program is easy to use the knowledge of limitations of the programs, and thermal processes gain importance while analyzing and discussing the results (Maile, Fischer, and Bazjanac 2007). (Omidfar, Weissman, and Georgoulias 2012) gave the example of Heelis National Trust Central Office in Swindon, UK, simulated by using Ecotect, which needs more electric lighting than its model. They claimed that the miscalculation technique used by the lighting engine of Ecotect simulation program leads this problem

CHAPTER 3

METHODOLOGY

The methodology of this thesis can be divided into four steps. The first step includes the preparations before the building energy simulation model analyses. The detailed structure of this step can be seen in the following Figure 3.1. The second step includes the building energy simulation model analyses' detailed structure (Figure 3.2).

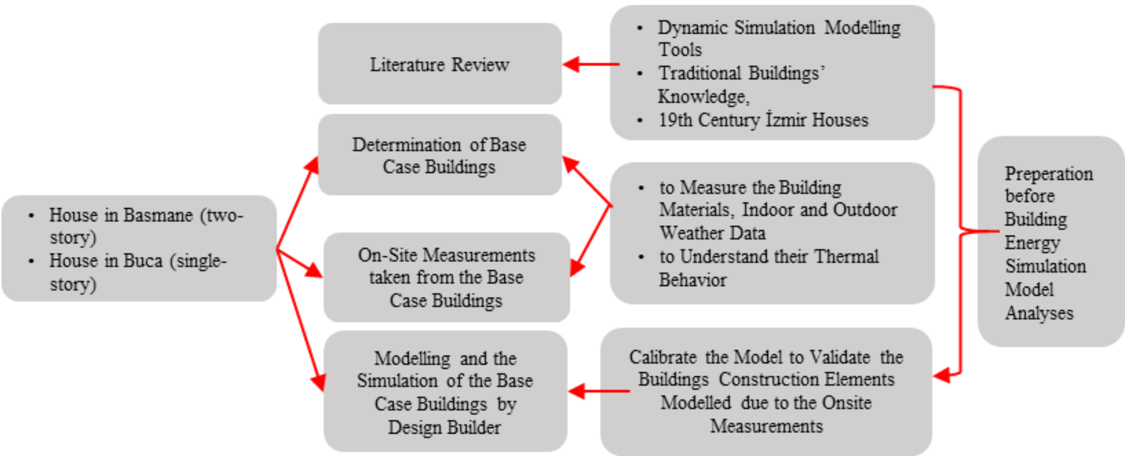


Figure 3.1. The first step of the flowchart

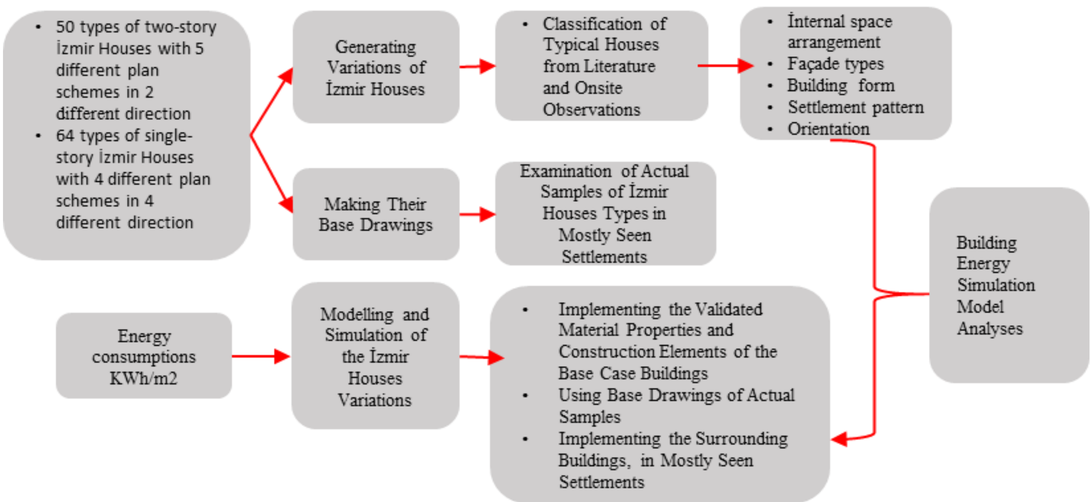


Figure 3.2 The second step of the flowchart

The analyses of the building energy simulation results are explained in the third step. The detailed structure of this step can be seen in

Figure 3.3.

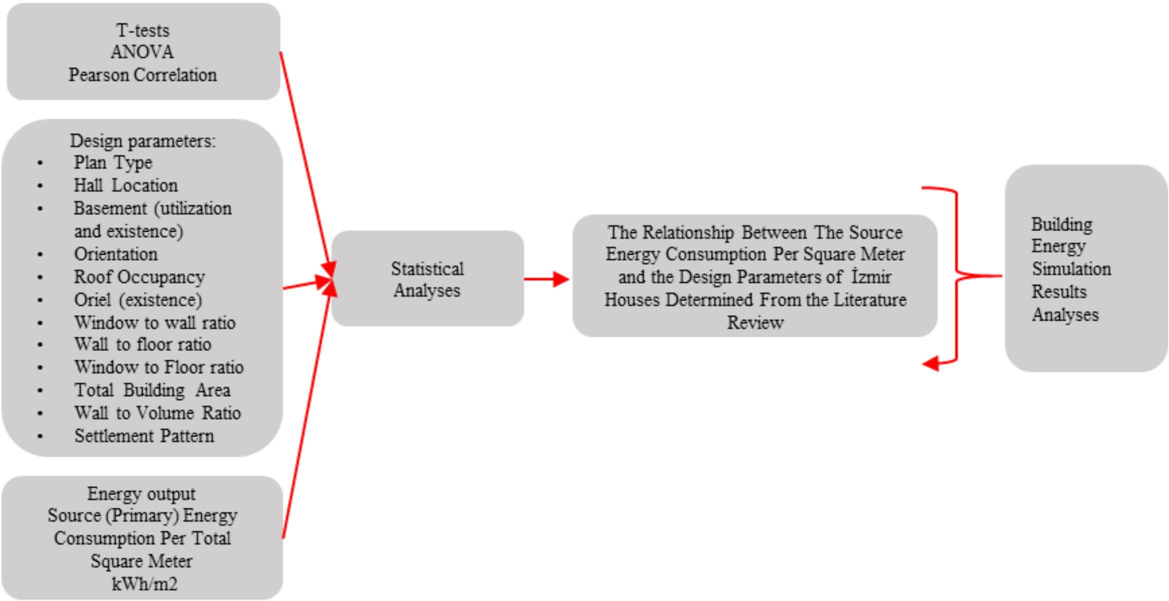


Figure 3.3. The third step of the flow chart

The last step encapsulates the studies before reaching the concluding remarks, such as results and discussions. The detailed structure of this step can be seen in Figure 3.4.

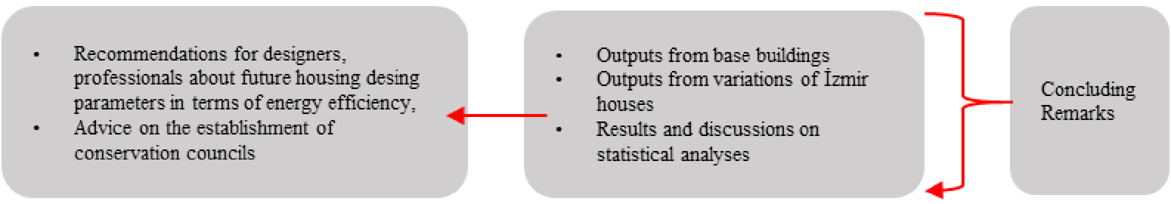


Figure 3.4. The fourth step of the flowchart

3.1. Determination of Base Case Buildings

Two base case buildings were chosen from Basmane and Buca districts to take daylighting, temperature, relative humidity, and material property measurements for understanding the behavior of these existing buildings.

3.1.1. House in Basmane

The first base case building is in Pazaryeri neighborhood of Basmane district of İzmir where the historic city center of İzmir, which was the commercial center of İzmir when the Levantine population highly existed between the beginning of the 17^{th} Century up to the end of 19^{th} Century. The survey drawings and analyses, restitution and restoration projects, reports, and photograph albums of this building, which were approved by the Regional Council for the Conservation of Cultural Property of İzmir, were taken from İzmir Metropolitan Municipality archives and prepared by restoration specialists architects Nurçe Düzalan and Özge Açan in NDOA Architecture Restoration Design Ltd Co. The area reflects representative examples of the 19^{th} Century İzmir Houses. The streets of Basmane district through Kadifekale have organic shapes with different sizes and slopes. The buildings are settled mostly in a detached order. The house in Basmane is placed on 1550 block 15 plot shown in (Figure 3.5). It is an interaction house type according to the classification of Akyüz (1993). The building is located at 38°25' N latitude and 27°8' E longitude and oriented in north-south. It is situated on a corner plot and attached to another building on the west side. The nearly square planned buildings' south facade is angularly connected to the east facade because of the shape of the parcel.

Figure 3.5. Location of the house in Basmane
(Source: Google Earth)

Figure 3.6. North facade of the house in Basmane

There are two building blocks attached in the same parcel as the main block located on the east side and annex block located on the west side of the parcel. It was thought that the annex building was built after the main block according to their construction systems and integration (Düzalan and Açan 2016). The measurements were taken in the main block, which has approximately 144 square meters of usage area.

The main entrance of the main block is located on the north facade, and the secondary entrance is located opposite it (Figure 3.6). The building has a central hall plan type, two stories, and a basement. It has an L shaped basement floor plan under the rooms of the ground floor faced north and south facade given in (Figure 3.7)The ladder of the basement is reached through the lid on it. And there is an opening that connects the basement to the garden on the basement floor wall. This opening is thought to be an unoriginal building element. There are three rooms with a nearly square plan connected to the central hall on the elevated ground floor; two of them are placed on the north, and one of them is placed on the south-west side. The staircase is situated on the south-east corner of the ground floor directly connected to the hall (Figure 3.8). There are three rooms on the first floor with the same plan scheme of the ground floor shown in (Figure 3.9).

The two-storied annex is connected to the main building on both floors by doors. The annex located in the north-south direction has a long thin trapezoidal plan. There is storage, kitchen with a toilet extension on the elevated ground floor, and another kitchen and a toilet on the first floor of the annex. It has a mezzanine floor reached from the first floor above the garden situated in the northwest of the parcel.

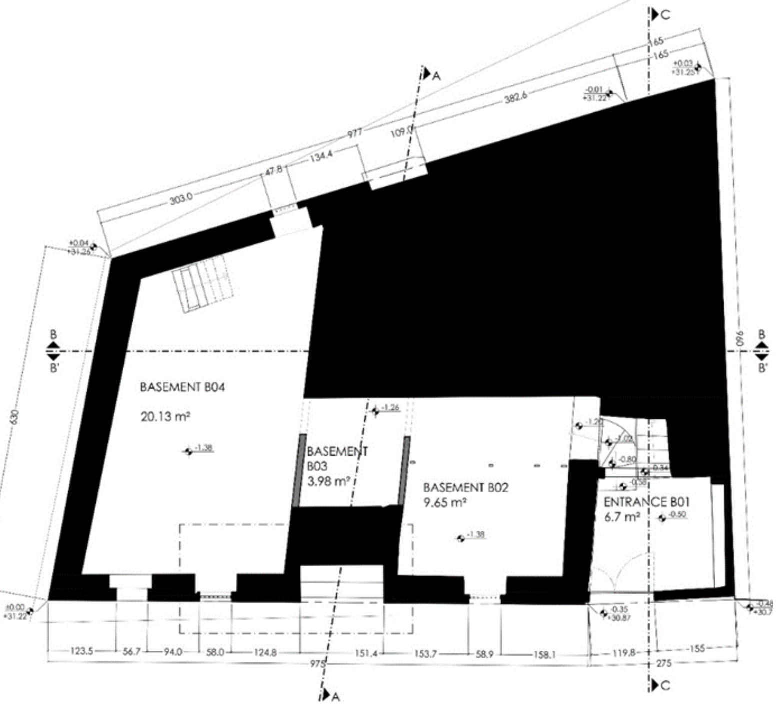


Figure 3.7. Basement floor plan of the house in Basmane
(Source: Düzalan and Açan, 2016)

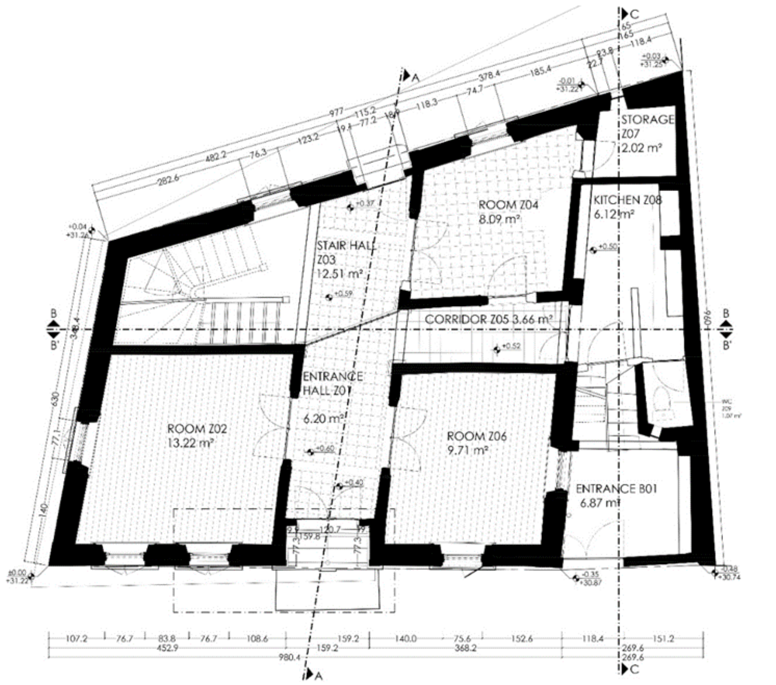


Figure 3.8. Ground floor plan of the house in Basmane
(Source: Düzalan and Açan, 2016)

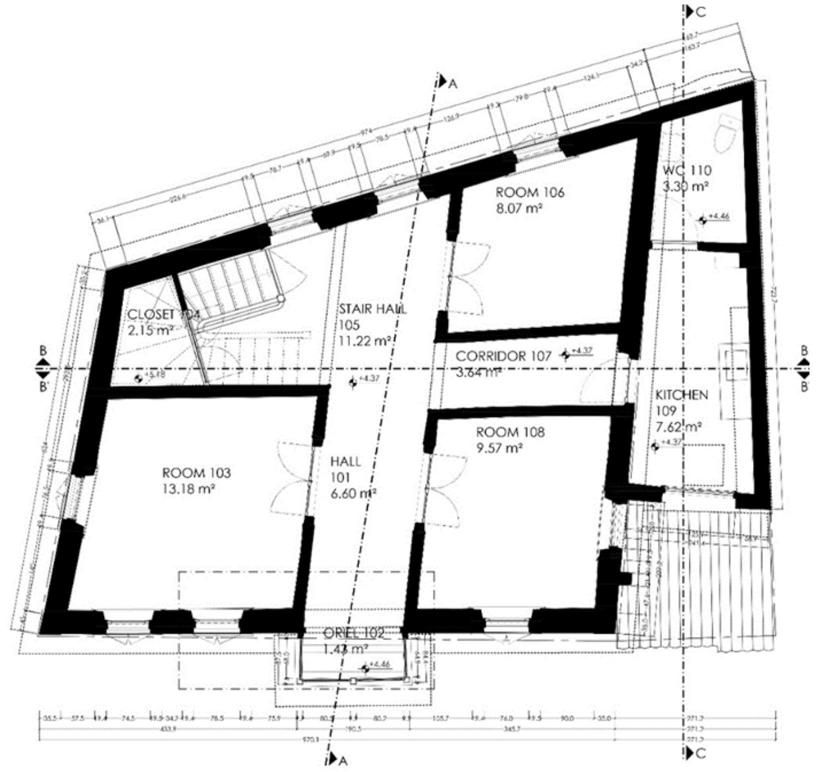


Figure 3.9. First floor plan of the house in Basmane
(Source: Düzalan and Açan, 2016)

The rooms on the ground floor of the main block are 3.5 m height while the height of the halls and the corridor is 3.58 m. The height of the rooms, hall and the corridor on the first floor is 3.17 m while the height of the oriel is 2.55 m. The height of the basement floor is 1.84 m, shown in Figure 3.10 and Figure 3.11.

The height of the annex's ground floor is 3.56 m, and the first floor is 2.66 m. The height of the mezzanine floor is 2.52 m. and the entrance hall below it is 3.12 m.

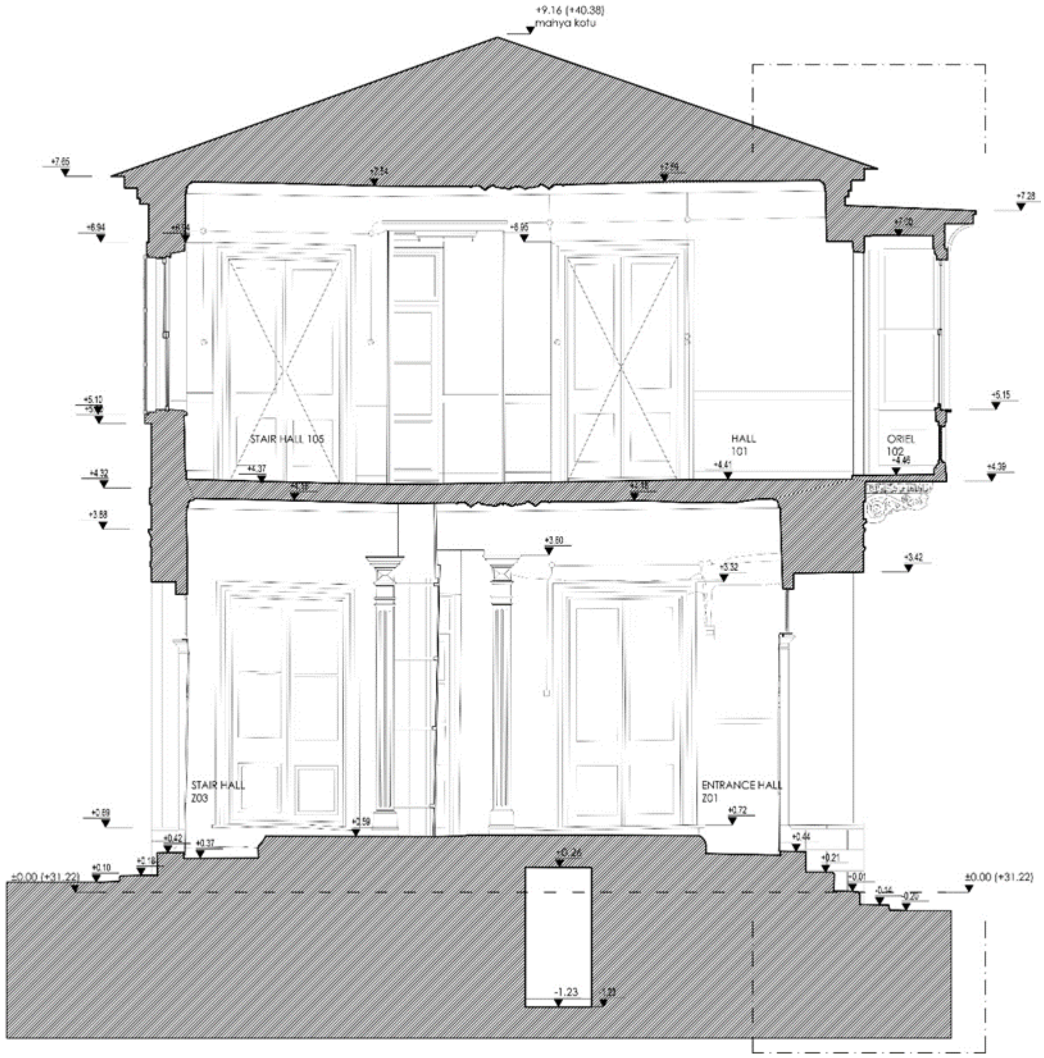


Figure 3.10. A-A section of the house in Basmane
(Source: Düzalan and Açan, 2016)

Figure 3.11. B-B section of the house in Basmane
(Source: Düzalan and Açan, 2016)

The main building has a symmetrical facade order on all sides. The main entrance door of the building on the north facade is situated on the niche inside of the main block and nearly in the middle of the facade. The elevated ground floor is reached by four steps situated in this niche (Figure 3.12). The secondary entrance of the building is situated on the south facade and reached by a step because of the difference in levels in the field. There is an oriel above the main entrance extended from the exterior wall line. There is a window on the west side of the entrance and two windows on the east side of the entrance on each floor. There is only one window on the east facade because of the staircase inside (Figure 3.14, Figure 3.13). There is a window on each side of the secondary entrance at different distances due to the interior plan scheme of the building. The windows have rectangular shapes at a ratio of 1 to 2.

The annex building has two narrow facades in the north and south directions. In the north facade, it has a door reached by 5 steps from the garden and a toilet extension with a small rectangular ventilation window on the elevated first-floor level. On the second-floor level, it has a nearly square window in the center of the facade. In the south facade, it has a small rectangular ventilation window and a circular chimney outlet on the elevated first-floor level and a square-shaped window on the first-floor level.

Figure 3.12. North facade of the house in Basmane
(Source: Düzalan and Açan, 2016)

Figure 3.13. South facade of the house in Basmane
(Source: Düzalan and Açan, 2016)

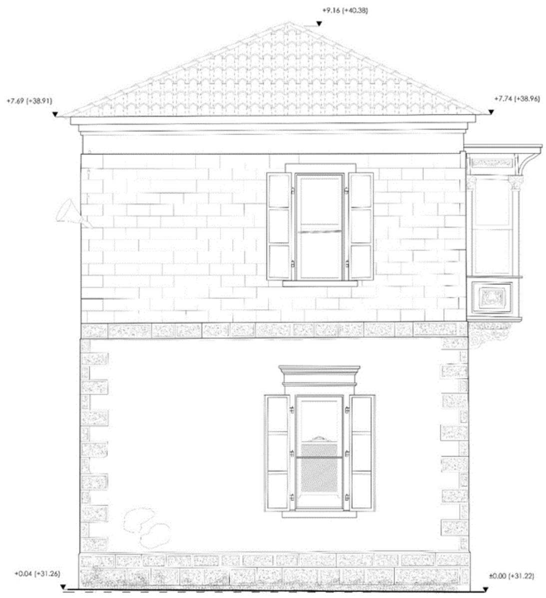


Figure 3.14. East facade of the house in Basmane
(Source: Düzalan and Açan, 2016)

The main building has a composite structure with its massive stone exterior walls with wooden studs and beams. It has wooden structured interior walls filled with stones and wooden structured slab. The entrance hall on the ground floor and the room Z04 is covered with cement tile (karosiman). All the other rooms are covered with wooden floors. The basement floor of the main block is used as a ventilation space for the rooms that have wooden floor coverings. The basement floor is covered with compacted soil. The building has a wooden structured pitched roof covered with tile. The exterior and interior walls are respectively covered with plaster including lime, soil, tow, and brick ballast. Between the street level and the elevated ground-floor level, the facade of the basement is covered with stones.

The reinforced concrete annex building does not have a wall adjacent to the main building. It has a 40 cm thick first floor and a 24 cm thick terrace floor. The storage, kitchen, and toilet of the first floor are respectively covered with screed, terrazzo, and ceramic. The toilet and the kitchen of the second floor are respectively covered with ceramic and terrazzo tile. All interior and outer walls of the annex are plastered and painted also thought to be constructed with brick.

3.1.2. **House in Buca**

The second base case building is in Kasaplar Square of Buca district of İzmir, where this kind of house was concentrated until the beginning of the 21st Century. The survey drawings and analysis, restitution and restoration projects, reports, and photograph albums of this building, which were approved by the Regional Council for the Conservation of Cultural Property of İzmir, were taken from İzmir Metropolitan Municipality archives and prepared by the restoration specialist architect Özge Başağaç in Yerdeniz Architecture Restoration Design Ltd Co. All of the buildings at the square were collapsed except 3 of them, including the base case building of this study; nevertheless, the neighboorhood still reflects representative examples of the 19th Century İzmir Houses. The streets of Buca district have a grid plan with gentle slopes. The buildings are settled mostly in a detached order. The house in Buca is located on 7338 blocks plot 4, shown in (Figure 3.15). It is a Levantine house type according to the classification of (Akyüz (1993). The building is located at 38°23' N latitude and 27°10' E longitude. The building is oriented northwest-southeast (Figure 3.16).

Figure 3.15. Location of the house in Buca (Source: Google Earth)

Figure 3.16. The north-west facade of the house in Buca

According to the restitution project, there was the main building block and an annex block that was constructed separately on the southeast corner of the parcel, in the garden. The main building was adjacent to another building in the northeast direction. There was a garden in the southwest of the parcel seen in Figure 3.17. Because of the collapsed buildings today, the building is situated on a detached plot. The measurements were taken in the main block, which has approximately 84 square meters of usage area.

Figure 3.17. The north-west facade of the house in Buca in 2001
(Source: Regional Council for the Conservation of Cultural Property Archive)

Today there are two building blocks with different construction techniques connected, which form an L shaped building in the parcel. The main building has a single floor with an elevated entrance and a basement. It has a square plan with three rooms, an entrance hall, and a kitchen on the ground floor. The basement floor of the main block which is used as a ventilation space for the rooms that have wooden floor coverings has nearly the same plan scheme with the ground floor (Figure 3.18).

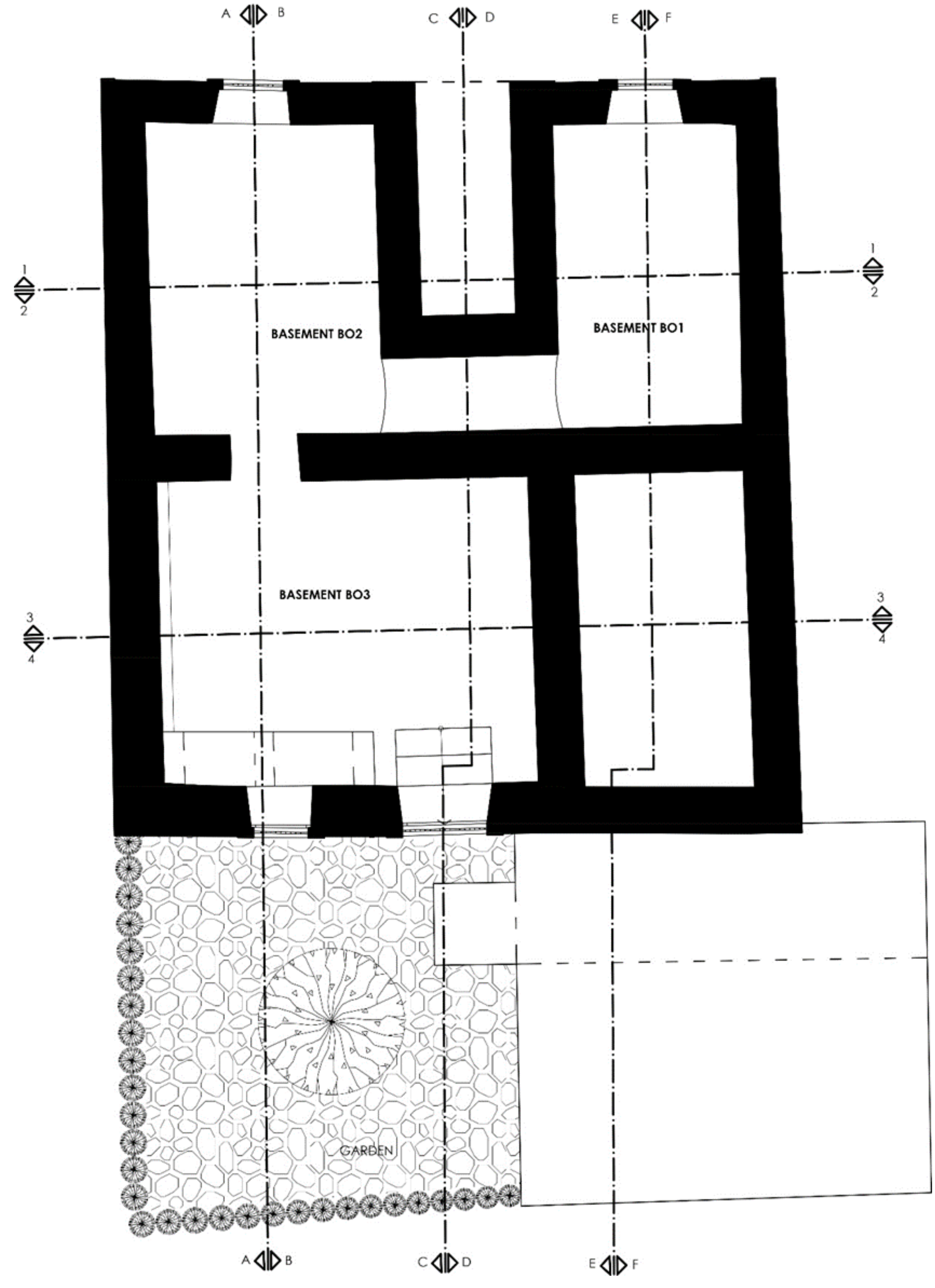


Figure 3.18. Basement floor plan of the house in Buca (
(Başağaç, 2012)

A corridor connects the annex, and the main block closed with aluminum framed glass doors and panels built in the restoration process. The annex has a single story and rectangular shape plan within 3 toilet units (Figure 3.19).

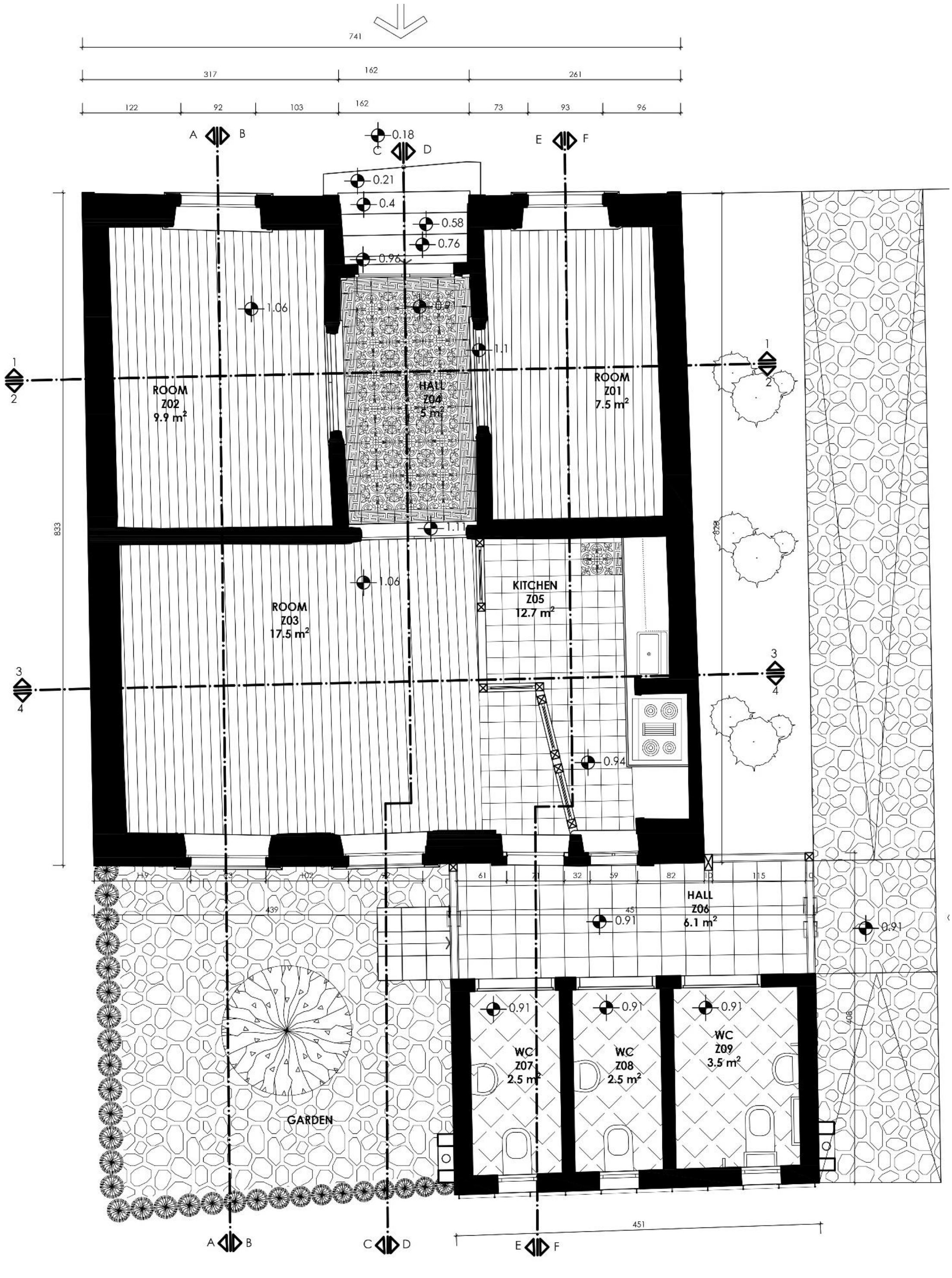


Figure 3.19. The elevated ground floor of the house in Buca
(Başağaç, 2012)

The rooms on the elevated ground floor are 3.52 m height while the height of the entrance hall is 3.64 m. The height of the rooms on the basement floor is 1.48 m, shown in Figure 3.20. The annex is 3.42 m height.

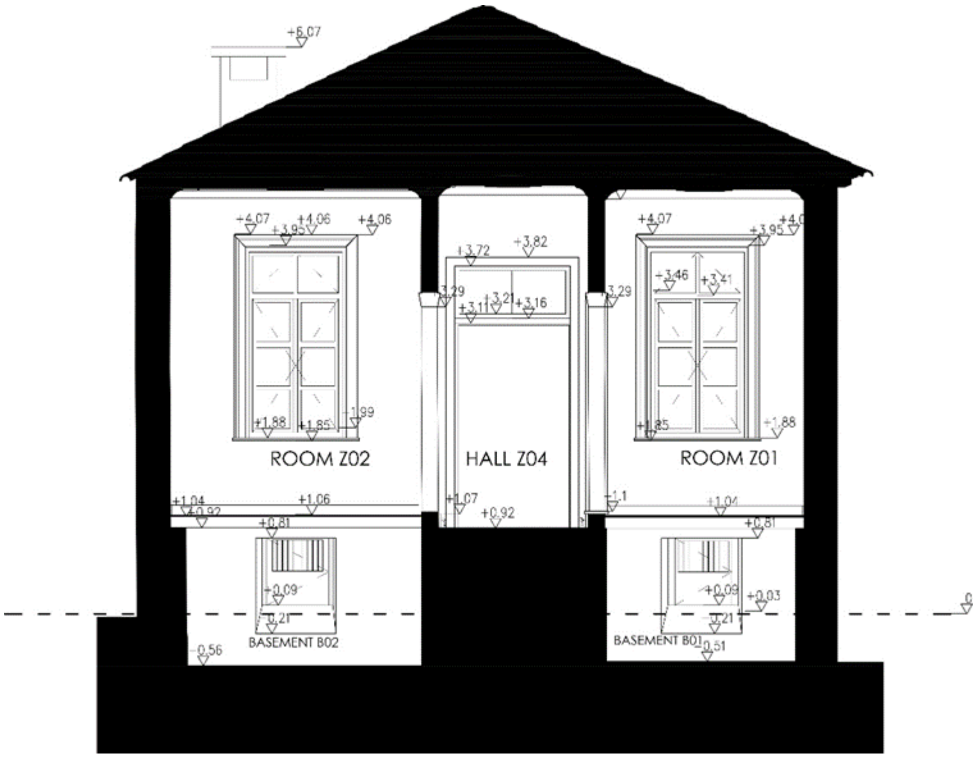


Figure 3.20. 1-1 Section of the house in Buca (Source: Başağaç,) (Başağaç, 2012)

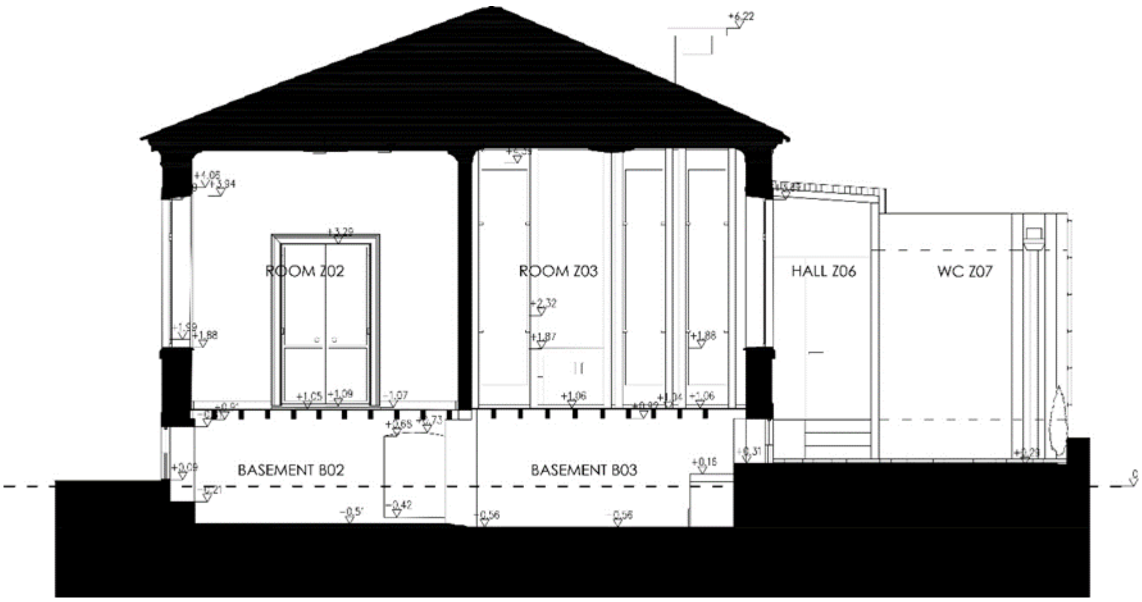


Figure 3.21. B-B Section of the house in Buca
(Başağaç, 2012)

The main building has a symmetrical facade order on the northwest facade. The main entrance door of the building on the northwest facade is situated on the niche inside of the main block and in the middle of the facade (Figure 3.22). The elevated ground floor is reached by four steps situated in this niche. The secondary entrance of the main building is on the southeast facade. The southeast facade has an asymmetrical facade order (Figure 3.23. There is a window on the east side of the door, and there are two windows on the west side of it. The northeast and southwest facades have no openings because of the old layout of the house seen in a photograph taken in 2001(Başağaç 2012). The windows have rectangular shapes at a rate of ½, except the window opening to the kitchen on the southeast facade. The double wing-door has ornamented barred windows on each wing; also, there is a window above this door. There are two square-shaped openings with a grab rail on the basement level for ventilation.

Figure 3.22. Northwest facade of the house in Buca
(Başağaç, 2012)

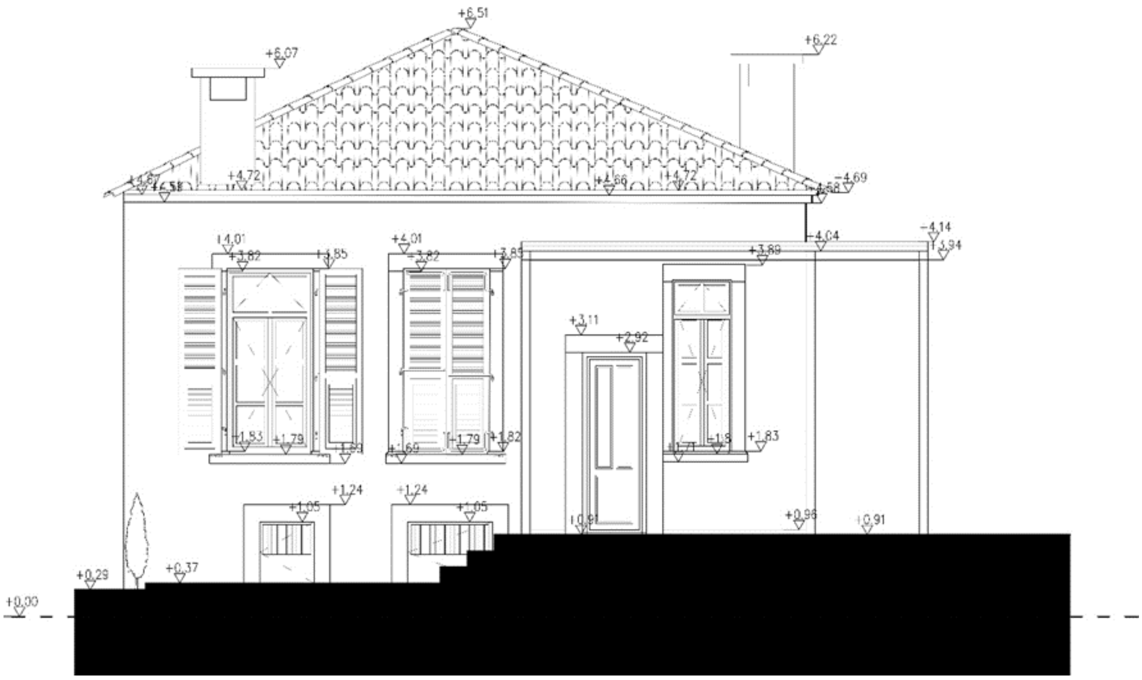


Figure 3.23. Southeast facade of the house in Buca
(Başağaç, 2012)

There are no openings beyond the three windows on the south-eastern side, as the annex building has toilet function.

The main building has a composite structure with its massive stone exterior walls with wooden studs and beams. It has wooden structured interior walls filled with stones and wooden structured slab. The entrance hall Z04 on the ground floor and the kitchen Z05 is covered with cement tile (karosiman). All the other rooms are covered with wooden floors. The basement floor was covered with compacted earth lining but changed with cement finish in restoration. The building has a wooden structured hipped roof covered with tile. The exterior and interior walls are respectively covered with lime plaster.

The structural system of the annex building is reinforced concrete. It has a ceramic tile floor covering. All the interior and the exterior brick walls of the annex are plastered and painted. The building has a flat roof.

3.2. Determination of the 19th Century İzmir Houses Variations

The most frequently seen types of 19th Century İzmir Houses were selected from literature to analyze their architectural parameters in terms of energy consumption. Therefore, two and one story İzmir Houses with different plan schemes and facade orders were selected. The plan schemes and the facade orders of these types of buildings are differentiated according to their hall and staircase positions, oriel and balcony, respectively. And the building heights of these buildings are changing according to the height of their basement. The orientation of the buildings is also differentiated. As a result of this diversification, 114 types of buildings were modeled in two different test areas.

The neighborhoods of the two-story and single-story building types were separated. Alsancak 1453 street and Buca 83 street and close circles were modeled as test fields because the earliest and the most common samples of two and single-story İzmir Houses are seen in these districts, respectively. In addition, the environmental factors affecting samples in terms of energy consumption, such as wind and shadow, are changing significantly in these settlements. However, the parcels where the buildings were placed were kept constant for both areas.

3.2.1. **Two-story İzmir Houses**

The design parameters of the most common types of two-story İzmir Houses types were determined due to the basic characteristic properties also evaluated in previous studies in literature review chapter to understand these buildings intrinsic value in respect to energy consumption (Akyüz 1985; 1993; Bilginperk 1999; Çıkış 2009; Erpi 1987; Özkut 1997; Tosun 1983). Because Alsancak was chosen as the test field the common features of the earliest samples of the İzmir Houses located there was effective in determination of these parameters (Akyüz 1985; 1993; Çıkış 2009; Moral 1990; Özkut 1997; Tosun 1983). In addition, the common architectural parameters were also chosen from the other studies about the energy consumption of the buildings.

The first parameter of the houses is the location of the halls in the houses. The halls of the buildings can be seen either at the side or at the center of the plan scheme.

The staircase location of the hall is another parameter that shaped the variations of İzmir Houses models. It changes the form of the hall when it is situated longitudinal or latitudinal.

The third important characteristic property selected as the parameter of these buildings is the basement floor. These types of buildings have either a basement floor used as a room for depot or a ventilation space or do not have a basement. The height of the basement determines the function of the basement. However, both basements are not occupied in each case.

The fourth parameter is the oriel, which is one of the most common features of İzmir Houses. The oriel is a kind of extension that has a light structure enclosed with windows. The buildings with oriel or balcony instead were chosen for variations in this study.

While analyzing the drawings of the street rehabilitation projects of Alsancak district, it is observed that the roof of the houses is used as rooms. It is thought to be the fifth parameter that should be evaluated within the scope of energy consumption. Therefore, the roofs are evaluated in two cases as heated or unheated. In both cases, the height of the roof kept constant because of the clarity of the outputs.

In Alsancak, the streets where two-story İzmir Houses are located generally extend perpendicular to the sea. The 1453 street chosen as the test field is in the northwest-southeast direction. The buildings on this street are mostly attached, such as row houses and are located southwest-northeast direction perpendicular to the streets. Hence their entrance directions are either northeast or southwest. These directions were chosen as the sixth parameters of the variations of İzmir Houses.

The first two parameters determine the space organization and form the plan. As a result of the combination of these parameters, 50 types of two-story İzmir Houses with 5 different plan schemes in two different directions were evaluated in this study (Appendix-A).

The base sample of the first plan type of the two-story İzmir houses is formed with a side hall and a staircase in the middle of the house perpendicular to the adjacent wall. Also, its basement is used as a room. It has an oriel. The roof of the house is a heated zone. Its main entrance facade directs to the southwest.

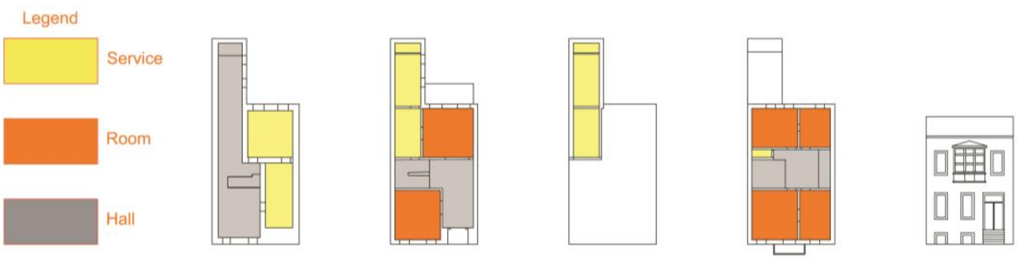


Figure 3.24. The base sample of the two-story İzmir Houses with plan type 1

The base sample of the second plan type of the two-story İzmir houses is formed with the side hall and a staircase at the corner of the main building parallel to the adjacent wall. Its' basement is used as a room. It has an oriel. The roof of the house is an unheated zone. Its main entrance facade directs to the southwest.

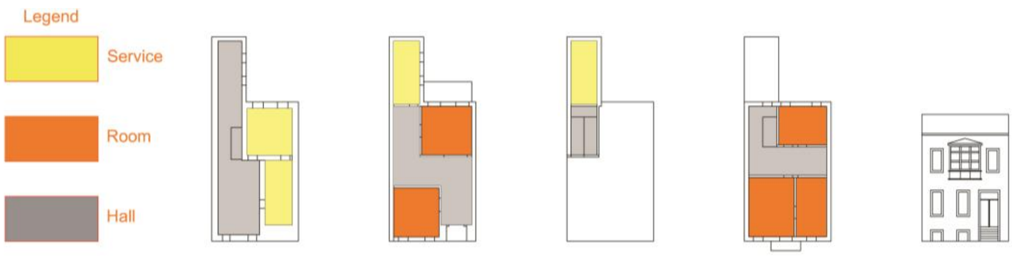


Figure 3.25. The base sample of the two-story İzmir Houses with plan type 2

The base sample of the third plan type of the two-story İzmir houses is formed with the side hall and a staircase in front of the entrance door parallel to the adjacent wall. Its' basement is used as a room. It has an oriel. The roof of the house is an unheated zone. Its main entrance facade directs to the southwest.

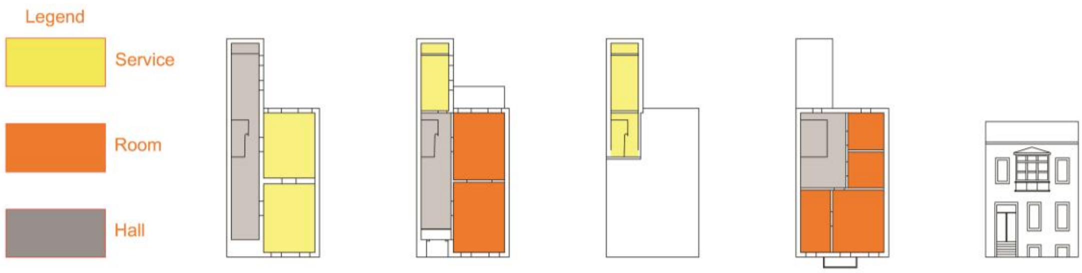


Figure 3.26. The base sample of the two-story İzmir Houses with plan type 3

The base sample of the fourth plan type of the two-story İzmir houses is formed with the central hall and a staircase in front of the entrance door. Its' basement is used as a room. It has an oriel. The roof of the house is an unheated zone. Its main entrance facade directs to the southwest.

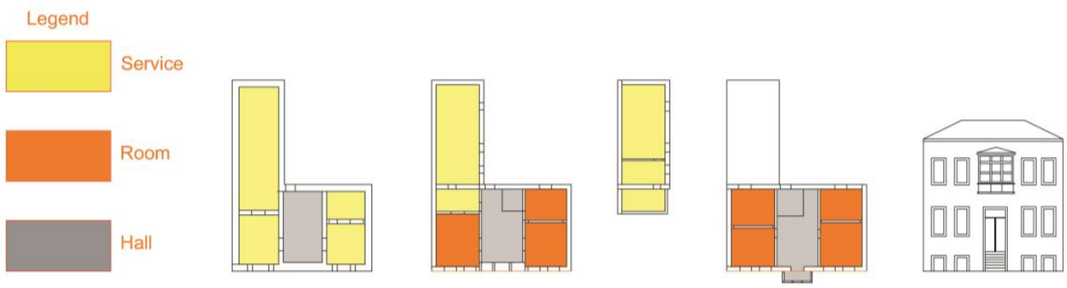


Figure 3.27. The base sample of the two-story İzmir Houses with plan type 4

The base sample of the fifth plan type of the two-story İzmir houses is formed with the central hall and a staircase in the middle of the house perpendicular to the adjacent wall. Its' basement is used as a room. It has an oriel. The roof of the house is an unheated zone. Its main entrance facade directs to the southwest.

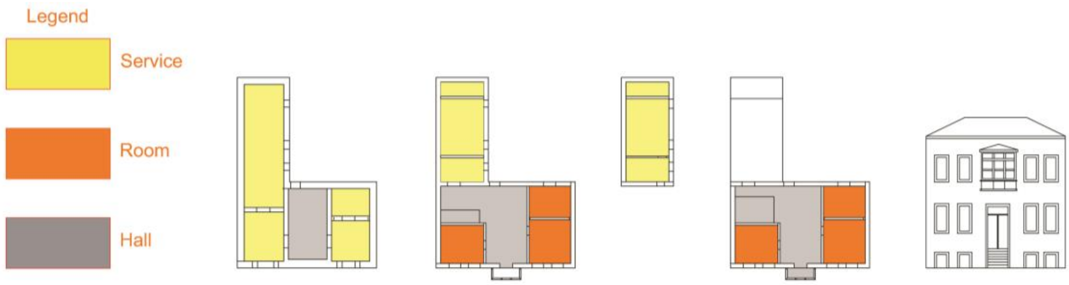


Figure 3.28. The base sample of the two-story İzmir Houses with plan type 5

3.2.2. **Single-story İzmir Houses**

The design parameters of the most common types of single-story İzmir Houses types were determined in previous studies in the literature review as in one story İzmir Houses evaluation (Akyüz 1993; 1994; Bilginperk 1999; Erpi 1987).

The first parameter of the houses is the location of the halls in the houses the halls can be seen either in the side or in the center of the plan scheme as same as in two-story houses

The second important parameter is the function of basement floors as in two-story houses. Also, the height of the basement determines the function of the basement, whether it is used as a depot or a ventilation space.

In Buca, different from Alsancak İzmir Houses are mostly located detached or attached on one side. Thus, the settlement pattern of the plot was determined as the third parameter.

The surrounding area of 83 street in Buca district has a grid street plan where Izmir houses are located. Therefore, the houses in this area provide facades in four directions. These four directions were selected as the fourth parameter of single-story İzmir Houses.

As a consequence of the combination of these parameters, 64 types of single-story İzmir Houses with 4 different plan schemes in four different directions were evaluated in this study (Appendix-A).

The base sample of the first plan type of the single-story İzmir houses is formed with the central hall. It has an asymmetrical entrance facade order with 3 windows and an entrance door between these windows. The basement of the building is used as a room. Its main entrance facade directs to the northeast. It is a detached building.

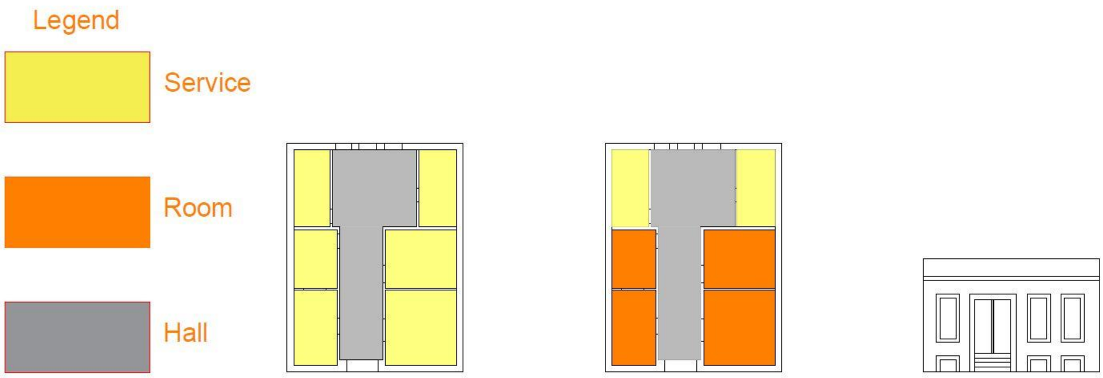


Figure 3.29. The base sample of the single-story İzmir Houses in with plan type 1

The base sample of the second plan type of the single-story İzmir houses is formed with the central hall. It has an asymmetrical entrance facade order with 5 windows and an entrance door between these windows. The basement of the building is used as a room. Its main entrance facade directs to the northeast. It is a detached building.

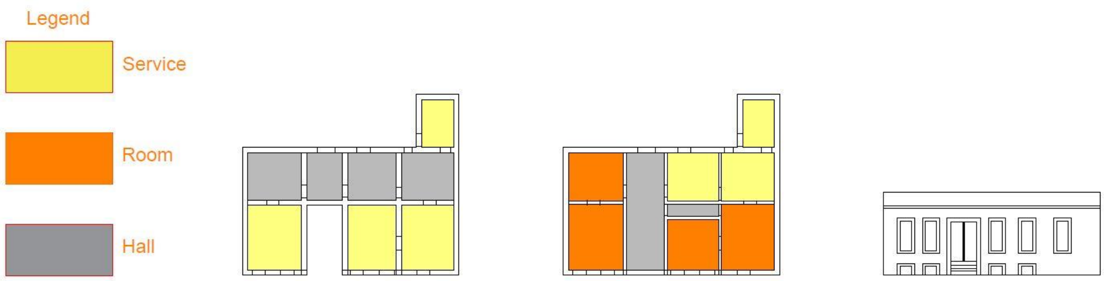


Figure 3.30. The base sample of the single-story İzmir Houses with plan type 2

The base sample of the third plan type of the single-story İzmir houses is formed with the side hall. The service space makes an extension from the main building. It has an asymmetrical entrance facade order with 2 windows and an entrance door. The basement of the building is used as a room. Its main entrance facade directs to the northeast. It is a detached building.

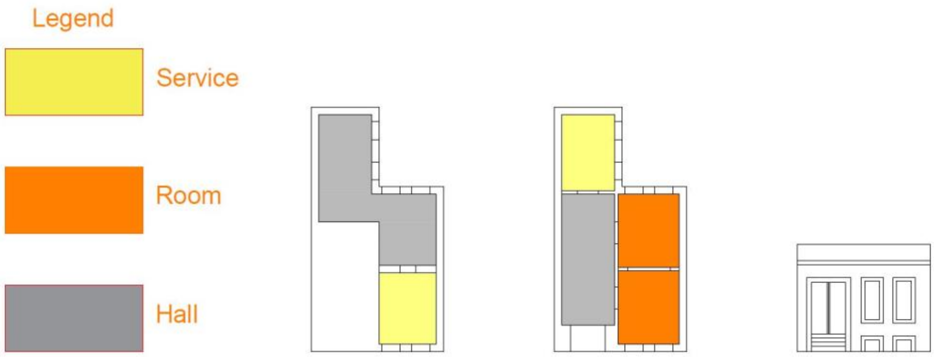


Figure 3.31. The base sample of the single-story İzmir Houses in with plan type 3

The base sample of the fourth plan type of the single-story İzmir houses is formed with the side hall. Different from the plan type 3, it has a compact rectangular building form. It has an asymmetrical entrance facade order with two windows and an entrance door. The basement of the building is used as a room. Its main entrance facade directs to the northeast. It is a detached building.

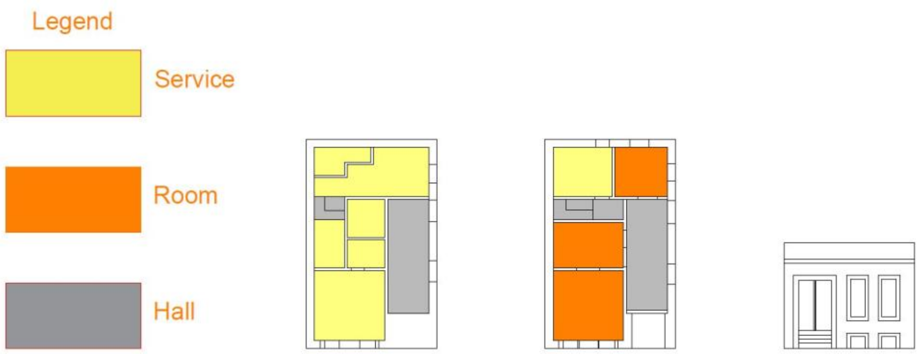


Figure 3.32. The base sample of the single-story İzmir Houses in with plan type 4

3.3. Onsite Measurements

Onsite measurements were taken from the base case buildings located in Basmane and Buca districts to understand the thermal performance of the existing building types of 19th Century İzmir Houses. These measurements are included daylight, indoor, and outdoor weather data collection.

3.3.1. Material Properties

The material properties of the models can be set in the DesignBuilder program. Within this scope, the house in Basmane was suitable for taking a sample of original building material such as stones, plaster, cement tile (karosiman), and wood to analyze. Density, thermal conductivity, and specific heat analysis were applied to these materials.

The density analyzes of the materials were carried out on the precision scale with the Archimedes principle. The temperature of the water used in the measurement is 25 °C, and the density is 0.99 g'cm^3.

Thermal conductivity λ (W/mK) analysis was conducted using a Quick Thermal Conductivity Meter (KEM QTM 500). It uses a hot wire measuring method with the measuring range of 0.023 to12 W/mK. The precision -is ±5% reading value per reference plate. The temperature range of the instrument is -10 to 200 °C.

Specific heat Cp (J/gK) capacity measurements were performed using a modulated differential scanning calorimeter (DSC Q10 V9.4 Build 287). Measurements were carried out in the temperature range from -10.00 °C to 45.00 °C with a ramp of 10.00 °C/min (Figure 3.33).

a b c

Figure 3.33. Material properties measurements (a) Density (b) Thermal Conductivity, (c) Specific Heat

The house in Buca was yet restored in this period, so it was not possible to take a sample from there. Therefore, the material properties of the house in Basmane were used in the model of the house in Buca

3.3.2. **Daylight Measurements**

Considering the parameters affecting the natural lighting in building design is fundamental to benefit from daylighting as much as possible to minimize lighting energy consumption (International Energy Agency 2000).

Lighting in residential buildings consumes 12% of total energy in Turkey and %11 of total energy in OECD countries (Ashrafian 2016).

Daylight measurements of the base cases were evaluated according to illuminance (E) and uniformity (U) standards. According to the different standards, the required illuminance level was accepted for the residential spaces were between 50 lx and 750 lx (Leoindustries 2017; Pioneerlighting 2017; Panasonic 2017). Uniformity values for interior daylight should satisfy the equations below, according to DIN 5034 (Bayram 2015).

$$U_1=E_{min}/E_{avg}>0.50$$

$$U_2=E_{min}/E_{max}>0.67$$

Daylight measurements were taken in Lux with Lutron LX-1108 light meter in two base case buildings (Figure 3.34). The measurements were taken nearly 80 cm high above the floor. Direct sunlight is avoided while measuring the daylight. Measurements were taken on the points in a grid plan with nearly 60cm units that are shaped nearly 60 cm far from the walls of the rooms. Measurements were taken in weeks of winter, summer solstice and autumnal, vernal equinoxes between April 2016 and March 2017 were chosen to understand the yearly daylight performance of the buildings. Both base case buildings were empty. The interior doors of each room were closed during the measurements.

Figure 3.34. Lutron LX-1108 light meter

All the rooms except the basement, annex, and room Z04 were chosen to measure the daylight of the house in Basmane. However, the daylighting analysis of the house in Basmane was done in limited physical conditions. For instance, the window shutter of room Z04 could not be opened, so no measurements were taken from there. Two of the 3 window shutters of the room Z02 could not be opened, but the measurement was still taken. One of the 3 windows at the west facade room Z06, is largely blocked by unlicensed construction of the annex block above the garden. The window shutter and the door of the staircase hall Z03 also could not be opened, but the measurement was still taken. The shutters at the north facade of the room Z02 and the door at the south facade of the room of the house in Basmane were closed during the measurements. And there was a lattice both at the south opening of the hall Z03 and at the east opening of the room Z02. The measurements were taken three times a day as morning noon and afternoon on 21 June 2016, 21 September 2016, 21 of December 2016, 21 March 2017.

All the rooms except the basement, annex, and kitchen were chosen to measure the daylight of the house in Buca. The kitchen's original stone walls were changed with translucent glass material in restoration implementation. This room would not show its original daylight performance, so; it was neglected for daylight measurement. As in the house in Basmane, the measurements were taken three times a day, on 21 June 2016, 21 September 2016, 21 of December 2016, 21 March 2017.

3.3.3. **Indoor and Outdoor Weather Data**

Indoor dry-bulb air temperature and relative humidity measurements were taken respectively in ˚C and RH% with Hobo U12 012 Data Loggers in two base case buildings. Data loggers were installed to the mid-height of the inner walls. It is avoided to install the data loggers to the exterior walls of the rooms. Measurements were taken four times between April 2016 and March 2017. Each measurement took nearly a month to understand the yearly thermal performance of the buildings. During these months, Hobo Data Loggers were set up for 10 minutes interval. Both base case buildings were empty. The window shutters, and the interior doors of each room were closed during the measurements.

The outdoor air temperature, relative humidity, air velocity, etc. of the house in Basmane were measured with Vantage Pro2 weather station. It was installed on the flat roof of the annex building. The outdoor air temperature and relative humidity of the house in Buca are measured with Hobo Data Loggers U-12 012 because there was only one weather station to use at the measurement period (Figure 3.35).

a

b

Figure 3.35. Weather Data Measurements (a)Vantage Pro2 weather station on the roof (b) Hobo Data Logger U12 012 on the interior wall

All the rooms except annex were chosen to measure the air temperature and humidity of the house in Basmane. The window shutters of the room Z06 are missing. There was no window profile at the openings of the basement, but the measurement was still taken. The measurements were taken in between 23 June to 20 July, 23 September to 22 October, 08 January to 08 February of 2016, 24 March to 23 April of 2017.

All the rooms except annex and kitchen were chosen to measure the temperature and humidity of the house in Buca. There was no window profile at the openings of the basement, but the measurement was still taken. The measurements were taken between 25 June to 20 July, 27 September to 26 October, 15 January to 15 February of 2016, 23 March to 22 April of 2017.

3.4. Analyses of the Onsite Measurements

The daylight, indoor, and outdoor weather data measurements' analyses methods are described in this section separately.

3.4.1. **Daylight Measurement Analyses**

The daylighting measurements were analyzed using two different ways. First of which is analyzing the daylight measurements in a specific time by generating daylighting spatial distribution. The second one is analyzing the daylight measurements' relations regarding the spatial properties of the buildings holistically on a table.

The daylighting spatial distributions of the onsite measurements were generated by using a surface interpolation tool of Geographical Information System (GIS) by using ArcGIS 10.5 Desktop software. The surface interpolation tool is used to generate a continuous or prediction surface for all locations in an output raster dataset from sampled point values at strategically dispersed sample locations. Input points can be planned randomly or regularly. Also, they can be based on a sampling scheme (Briggs 1974; Terzopoulos 1988).

Deterministic and geostatistical methods are the basic categories of interpolation tools. The method chosen for the daylight analysis is the Kriging method that is a geostatistical method of interpolation (Smith and Wessel 1990).“The geostatistical methods are based on statistical models that include autocorrelation (the statistical relationship among the measured points). Because of this, geostatistical techniques not only have the capability of producing a prediction surface but also provide some measure of the certainty or accuracy of the predictions” (Environmental Systems Research Institute Inc. 2019) The Kriging analysis was applied between the value 0 and 750 Lux for generating daylighting spatial distribution. These distributions were compared according to seasonal and diurnal periods.

The daylight measurements' relations with window to wall ratio, window to floor ratio depth, width, and height were analyzed. Since they are thought to be effective in the distribution of the daylight. The outputs of this table are the maximum, minimum, average values and the first and second category uniformities of the daylight measurements

3.4.2. **Indoor and outdoor weather data calibration and analysis**

There are two main steps in analyzing indoor and outdoor weather data. The first step is the calibration of the measured data due to the measurement instruments calibration equations. The hobo data loggers and weather station were sent to the Chamber of Mechanical Engineers Calibration Laboratory and Meteorology Training Center to calibrate. The calibration was applied to the dry-bulb temperature and relative humidity sensors of the hobo data loggers and weather station. After the calibration, the laboratory prepared certificates for each equipment, which shows the accuracy of them (Appendix-B). An equation was found for each equipment measurement validation. These equations were used to find out the real value.

The second step is editing the measured data both in numerical and graphical format. At first, the measured dry bulb temperature and relative humidity data taken in the 10-minute interval were converted to hourly data for utilizing in the simulation and calibration processes of the base case buildings' BES models. Because the BPS program used in this study, DesignBuilder software, generates the output data in an hourly format. Then the measured dry bulb temperature and relative humidity data with a 10-minute interval converted to monthly daily average data to understand the buildings' thermal behavior for all the measurement periods. In the end, 2d line graphics, calculation of the maximum, minimum, average, standard deviation values of this data were done. All these analyses were performed using Excel.

3.5. Modelling and Energy Simulation

DesignBuilder student version 5.5.2.007 dynamic simulation tool has been used to generate 3D BPS models of base case buildings and the variations of the 19th Century İzmir Houses types. DesignBuilder simulation software is used to make building energy consumption, daylighting and CO2, thermal comfort performance, cost, Computational Fluid Dynamics (CFD) analysis, and optimization alongside 3D building modeling. The Energy Plus simulation engine is used by DesignBuilder for calculating the energy performance of the building. "Energy Plus is developed by U.S. Department of Energy's (DOE) Building Technologies Office (BTO) (EnergyPlus 2019).

The selection of a location and the corresponding weather data file in EPW format is the first step of the input data process in the DesignBuilder program. Then the generation of the building model geometry process comes, which can be done by drawing tools within simulation software or by the footprints of the imported DXF files. Following the creation of the model geometry, the detailed templates and their schedules need to be selected such as building activity related data (occupancy, comfort, and equipment), construction types, openings (windows and doors), lighting, and HVAC systems for calculating the building thermal loads. It is possible to choose these templates from the DesignBuilder ready-made material library or create case-specific new ones. After the selection of all input parameters, simulation can be run with different interval options as annual, monthly, daily, hourly, and sub-hourly (Maile, Fischer, and Bazjanac 2007). DesignBuilder contains an evaluation of facade options, daylighting analysis, visualization of site layouts and solar shading, thermal simulation of natural ventilation, and sizing of HVAC equipment and systems (DesignBuilder Software Ltd. 2019).

3.5.1. **Modeling of the Base Case Buildings**

Modeling of the base case buildings will be explained under 4 subtitles, location and weather data, generation of building model geometry, templates and schedules, and simulation process.

3.5.1.1. Location and Weather Data

The base case building in Basmane is located in Latitude 38.25 Longitude 27.08. The other base case building in Buca located in Latitude 38.38 Longitude 27.17

In this study, specific climate data indigenous to the case areas were created. At first, İzmir 172180 The International Weather for Energy Calculation (IWEC) file data taken from energyplus.net was edited according to the measured and calibrated; outdoor dry bulb air temperature, relative humidity, measured; dew point temperature, atmospheric pressure, wind direction, wind speed liquid precipitation depth in Basmane. The İzmir IWEC data was also edited according to the measured and calibrated outdoor dry-bulb air temperature and relative humidity in Buca. As mentioned in Chapter 3.3.3, those measured data taken with both Hobo Data Logger and weather station had 10-minute intervals. Before editing the weather data these data were transformed into hourly data.

3.5.1.2. Generation of Building Geometry

The approved restoration projects of the base case buildings were taken from the İzmir Metropolitan Municipality archive. The survey drawings of the house in Basmane were done architects Nurçe Düzalan and Özge Açan by using the total station as a measurement tool. The survey drawings of the house in Buca were done by restoration specialist architect Özge Başağaç by using laser scanner as a measurement tool. The survey drawings are complex due to their functions, so they are not suitable to be an effective base drawing for easy modeling. For this reason, before starting modeling the base case buildings with DesignBuilder, survey drawings were simplified in line with the purpose of the study: Then, the base case buildings and their annexes were modeled as building blocks with these simplified survey drawings base. All the rooms are divided into separate zones, including basement floor rooms. All the internal and external openings such as windows doors and holes, were modeled. The staircases were modeled as holes on the floors. During the modeling process, not so many assumptions and limitations for the geometry of case buildings occurred. Just the decoration elements such as balustrades, reliefs, and door and window jambs on the facades of the base case buildings were not modelled, because these details are not related to the aim of this study. The material properties of the plaster, stone, and wood, tile (karosiman) was taken from the results of the analysis explained in chapter 3.3.1. The other materials' thermophysical properties were taken from the study of Ulu (2018). Both the material properties and the layers of the architectural elements such as walls floors, roof covering, etc., can be found in Appendix-D.

The neighborhoods of the base case buildings, including buildings, trees, sunshades, were also modeled as component blocks. The surface materials of the component blocks were also set to observe the shading effects on solar gain calculations. The cadastral and base maps taken from İzmir Metropolitan Municipality were used for neighborhood modeling (Figure 3.36, Figure 3.37).

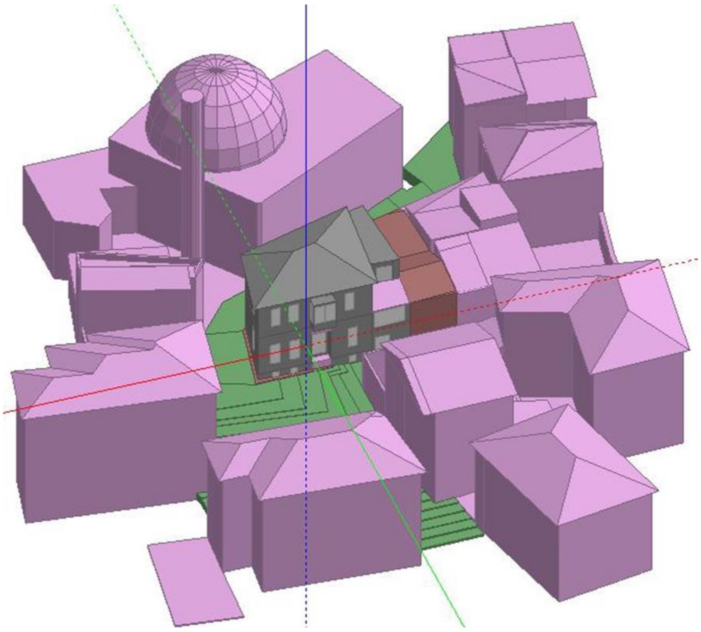


Figure 3.36. Axonometric View of the Base Case Building Model in Basmane

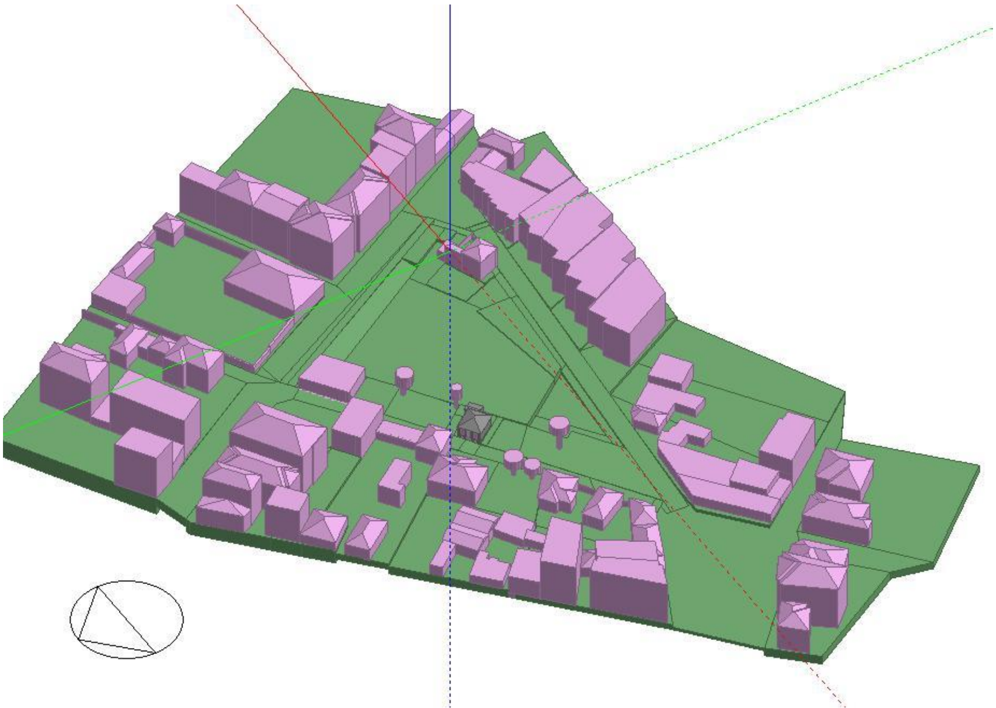


Figure 3.37. Axonometric View of the Base Case Building Model in Buca

3.5.1.3. Templates and Schedules

Annual, daily, and hourly energy simulations were done for the base case building models. The simulation of the base case buildings was done in order to validate and calibrate the building models in terms of their material properties and construction systems. The zones are included in both thermal and Radiance daylight calculations. The base case buildings were unoccupied buildings, so the activity templates of these models were identified as unoccupied in the simulation process. The lighting and HVAC templates of both buildings were chosen none.

3.5.1.4. Simulation

Annual, daily, and hourly energy simulations from 1 January to 31 December were done for the base case building models. Within the calculation options, time steps per house were selected 4, and the temperature control was selected air temperature. Regarding the solar calculations, all buildings included in shading calculations. Model reflections and shading of ground reflected solar option was selected. The full exterior option is selected for solar distribution. Average over days in frequency option was selected for the solar calculation method. Simple sky diffuse modeling was selected for sky diffuse modeling algorithms.

3.5.2. **Validation and Calibration of the Simulated Models**

The iterative calibration method was followed during the calibration and validation process of the building energy simulation (BES) models. Acceptable tolerances based on mean bias error (MBE) and coefficient of variation of root-mean-squared error (CV(RMSE)) for calibration of the BES model was checked due to the Ashrae Guideline 14. According to the guideline, when hourly data considered, models are assumed to be calibrated if MBE and CV(RMSE) are within ±10% and ±30%, respectively. The simulations didn’t correspond to these terms at first, so parameters causing discrepancy were identified and adjusted. Then simulations were run again. These process repeated several times until the calibration finalized according to the ASHRAE Guideline standards. The results of the calibration process can be found in Appendix-C.

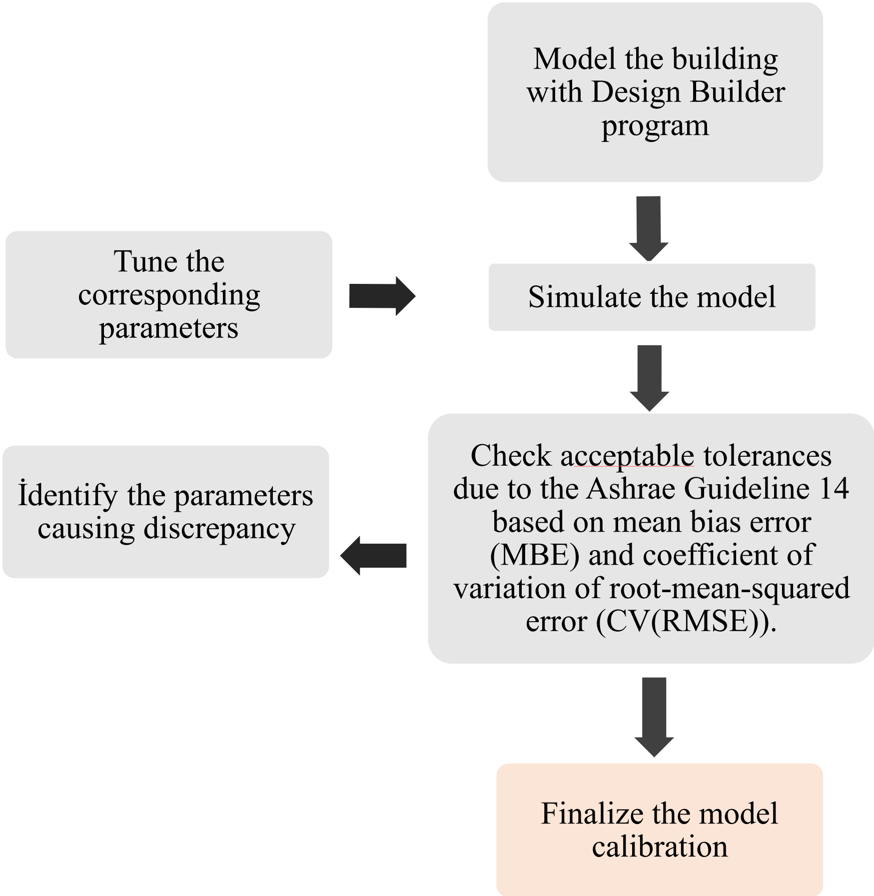


Figure 3.38. Flowchart on the iterative calibration process

3.5.3. **Modeling of the 19th Century İzmir Houses Variations**

Modeling of the 19th Century İzmir houses variations will be explained under 4 subtitles, location and weather data, generation of building model geometry, templates and schedules, and simulation process.

3.5.3.1. Location and Weather Data

The selected plot for the two-story İzmir houses located in Alsancak Latitude 38.43 Longitude 27.14. The other selected plot for the single-story İzmir houses located in Buca Latitude 38.38 Longitude 27.17.

At the begining of the modeling, İzmir 172180 IWEC file data taken from energyplus.net was selected for simulations rather than the measured yearly data of base case buildings. Because the measured data only covers partially annual data while IWEC files are derived from up to 18 years of DATSAV3 hourly weather data originally archived at the National Climatic Data Center.

3.5.3.2. Generation of Building Geometry

The base maps of Alsancak and Buca districts were taken from İzmir Metropolitan Municipality and used for the site models. The street rehabilitation project of 1453 and 1482 streets made by architects Dr. Ahmet Küçük, and Berna Küçük those were taken from Konak Municipality were used to determine the height and surface materials of neighboring buildings and grounds while Alsancak district was modeling. Also, the cbs panorama program of the İzmir Metropolitan Municipality was used for the same purpose to model the Buca district.

Although the old settlement texture of these places was intended to be modeled, this decision was abandoned because the annual data used in the simulation was from the current settlement.

Since the base case buildings are not the most common examples of the 19th Century İzmir Houses, other studies on these buildings were used for the modeling of the variations. For instance, Architect Boygar Özlen's restoration projects were used as a base for two storied types of İzmir Houses variations modeling because the case of the restoration projects were the representatives of the most common İzmir Houses in Alsancak. In addition to the drawings of Boygar Özlen, the drawings of Akyüz (1985), Moral (1990), and Tosun (1983)were used in the modeling of these buildings. One of them is in 1482 st. No:7 the other one is in 1482 st No 4. The building located in No 7 is the sample of the buildings with side halls. The other building in No 4 is the sample of the buildings with a central hall (Appendix-D,). These buildings' variations were modeled and simulated in the parcel chosen in 1453 st. in Alsancak. The interior space organizations that mean plan types of these buildings were changed by keeping their exterior dimensions constant and the numbers of the variations increased to analyze their design parameters effects on energy consumption.

For the modeling of single-story İzmir Houses, the survey drawings of three different İzmir Houses made by restoration specialist architect Cem Bilginperk within his master's thesis were used as bases for modeling the variations These buildings located in 83 St. No. 64, 113 St. No. 32, Atadan Ave. Besides, the base plan of another type of building located in 83 St. No:77 was drawn according to the building measurements, and photographs were taken by the cbs panorama program and the measurements taken on the base map. And these buildings' variations were modeled and simulated in the parcel chosen in 83 st.in Buca.

In order to ensure accuracy and clarity during the comparison of the parameters, a serious assumption was made when modeling. These assumptions are listed below:

- As in the base case modeling, all the rooms were divided into separate zones.
- Basement floor, circulation zones like hall and staircase, and in some cases, toilet and roof were defined as unheated zones while the rest of the zones defined as heated.
- Lighting was not defined for any zone simulation.
- All the zones were defined as unoccupied.
- The height of the thermal zones for two-storied and one-storied buildings was separately standardized according to the building dimensions of the samples chosen from the archives mentioned above.
- The basement was modeled with two different heights in each type of house to understand its effect on energy consumption.
- The material properties of the architectural elements such as walls floors, roof covering, etc., of the buildings were standardized in each model according to both the measurements taken from the house in Basmane and the study of Ulu (2018). The thermophysical properties of the materials can be found in Appendix-D.
- The construction systems of the architectural elements such as walls floors, roof covering, etc., of the buildings were standardized in each model according to the base case buildings and the building dimensions of the samples chosen in

Alsancak 1482 street and Buca 83 street. The layer properties of the architectural elements can be found in Appendix-D.

- The sizes of the openings at the two and one-storied buildings were separately standardized according to the building dimensions of the samples chosen from the archives.
- Neighboring buildings, the trees, balconies, and sunshades were assumed as component blocks.
- Staircases were assumed as wholes on the floors.
- Shutters were not modeled in the simulation model of variations.
- Balustrades, reliefs, and door and window jambs on the facades of the buildings were not modeled, because such details were out of the aim of this study.
- The window details of the entrance doors could not be modeled with the program.

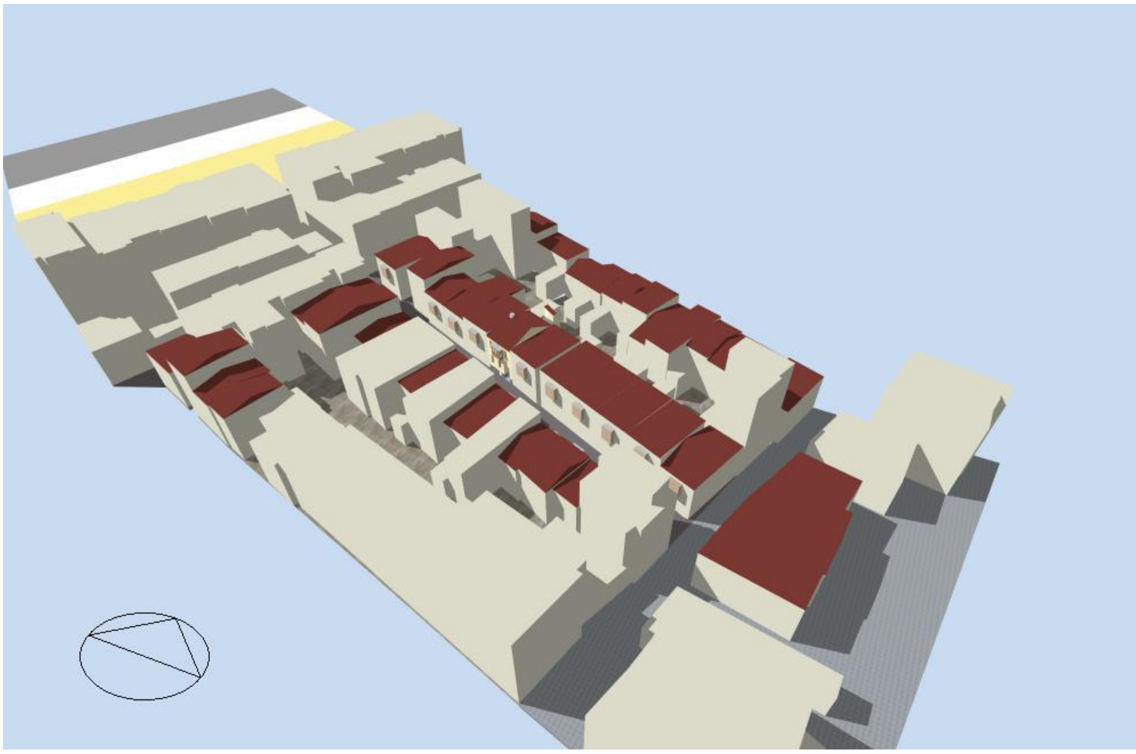
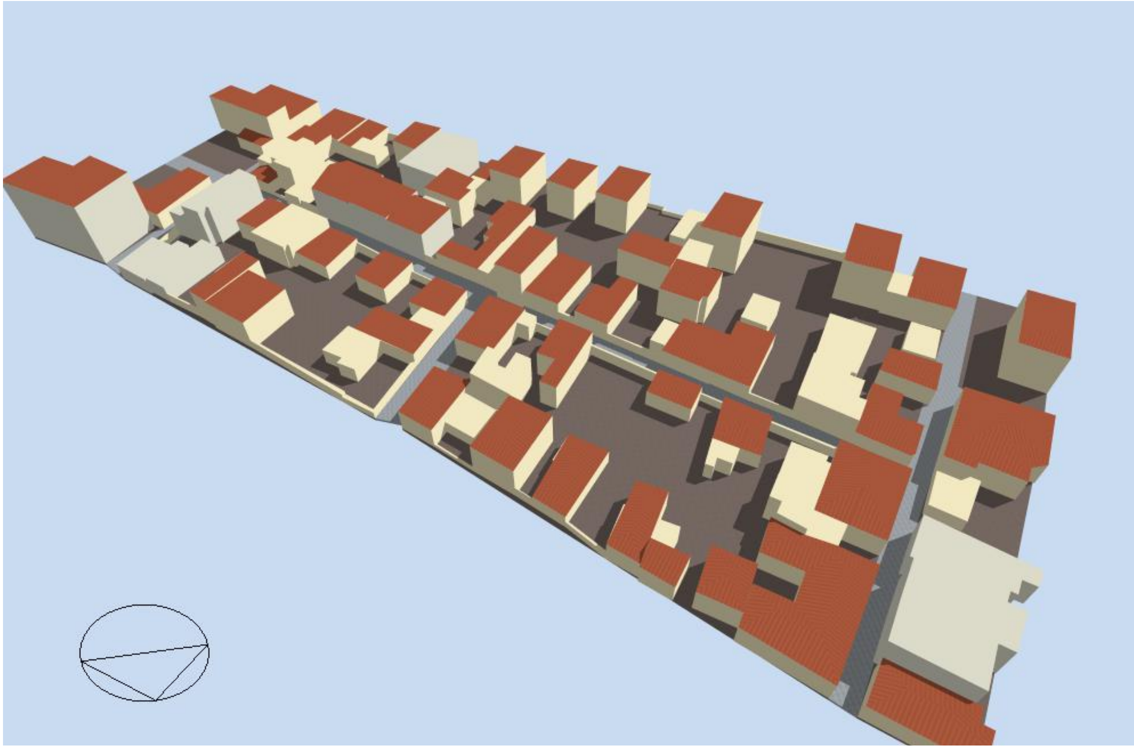


Figure 3.39. The site model of 1453 Street and its' surrounding in Alsancak



.
Figure 3.40. The site model of 83 Street and its' surrounding in Buca

3.5.3.3. Templates and Schedules

The activity templates of these models were identified as unoccupied in the simulation process. The zones are included in both thermal and Radiance daylight calculations. Within the heating setpoint temperature heating was determined 21 °C and heating set back was determined 18 °C. Within the cooling setpoint, temperature cooling was determined 26 °C, and cooling set back was determined 28 °C (Ulu 2018). The lighting systems were defined as off. Natural Gas fuel type with heating system seasonal CoP 0.5 was selected for a heating system with a schedule of 7/24 on. Electricity with cooling system seasonal CoP 4.5 was selected for a cooling system with a schedule of 7/24 on. The air change per hour for all the zones in two-story İzmir Houses were set 0.7. The air change per hour for all the zones except roof in single-story İzmir Houses were set 0.7 while the air change per hour of the roof was set 1.

3.5.3.4. Simulation

Annual, daily, and hourly energy simulations from 1 January to 31 December were done for the base case building models. Within the calculation options, time steps per house were selected 4, and the temperature control was selected air temperature. Regarding the solar calculations, all buildings included in shading calculations. Model reflections and shading of ground reflected solar option was selected. The full exterior option is selected for solar distribution. Average over days in frequency option was selected for the solar calculation method. Simple sky diffuse modeling was selected for sky diffuse modeling algorithms.

3.6. Statistical Analysis of the 19th Century İzmir Houses Variations

ANOVA, T-test, and Pearson Correlation were used to analyze the simulation results of the 19th Century İzmir Houses variations in this study.

3.6.1. ANOVA

Single-factor (one way) Analysis of Variance (ANOVA) method was conducted in Excel to test the null hypothesis that means there is no statistically significant difference between groups. The alternative hypothesis assumes that there is at least one significant difference between the groups. This method performs a simple analysis of variance on data for two or more samples. A probability value (p value) of less than 0.05 was required for significance. If the p value is smaller than 0.05, and the F critic value is less than the F value, the null hypothesis is rejected.

$H0: \mu 1 = \mu 2 = \mu 3$

H1: at least one of the means is different.

3.6.2. **T-Test**

T-test assuming both equal and unequal variances were conducted to the design parameters to ensure the accuracy of the analysis. in Excel. This analysis was used to determine significance of the differences between groups. A probability value (p value) of less than 0.05 was required for significance. If the p value is smaller than 0.05, the null hypothesis is rejected.

3.6.3. **Pearson Correlation**

Correlation analysis was chosen to measure the strength of the association between design parameters and total source energy consumption per square meter. Correlation is a bivariate analysis that has four types as Pearson correlation Kendall rank correlation Spearman correlation and Point Biserial correlation. For this study, the Pearson correlation was selected above these four, which is used to determine the degree of the relationship between two linearly related variables Bobko, 2001 and Cohen,2003). Pearson correlation coefficient is described with ‘r’. The following formula was used to calculate the Pearson r correlation in Excel:

The correlation coefficient value changes between +1 and -1, which indicates positive and negative relationships, respectively. The degree of association between the two variables will be weaker when the correlation value goes from ±1 (perfect degree) to 0. Cohen’s standard was used to determine the strength of the relationship as follows (Cohen, 2003).

No correlation: $r = 0$

Low degree: $\pm 0.1 \leq r \leq \pm 0.29$

Moderate degree: $\pm 0.3 \leq r \leq \pm 0.49$

High Degree: $\pm 0.5 \leq r < \pm 1$

Perfect: $r = \pm 1$

CHAPTER 4

RESULTS

Firstly, the results of the onsite measurements with three subsections, namely daylighting measurements, indoor and outdoor weather data is presented in this chapter. Then the simulation results of the two-story and single-story houses are presented in the separate subsections. The results of the statistical analyses which were performed to compare the significant relationship between the 19th Century İzmir Houses' architectural design parameters and the energy consumption per square meter simulated by using Designbuilder are presented and discussed in each subsection. The results of these analyses were also defined and discussed for each parameter separately.

4.1. Onsite Measurements Results of the Base Case Buildings

Onsite measurements, which include material properties daylight, indoor and outdoor weather data taken from the base case buildings located in Basmane and Buca, are presented in this chapter, respectively.

The temperatures measured with hobo data loggers changed approximately less than 1°C while the humidity changed less than %1.5. The temperatures measured with weather station changed 1°C while the humidity changed nearly %3.

4.1.1. Material Properties of the House in Basmane

The density measurements can be seen in Table 4.1. Due to the small gaps in the stones, while taking measurements in the water, the weight increased rapidly. Probably the water was filling in the voids inside. Therefore, two measurements were taken for these materials. The first measurement was taken immediately after the material was immersed in water with some air gap, and the other after the material was shaken and absorbed. As a result, the mean density value of these materials was used in the study. When stone T3 and brick TU1 were put into the water, they were dispersed, so;

measurements were taken when the materials absorbed the water and showed some stability.

Table 4.1. Density measurements

	weight in air g/cm3	**weight in water g/cm3**	**density before the absorption of the water g/cm3**	**density after the absorption of the water g/cm3**	**mean density g/cm^3**
KARO1	4.09	2.04	**1.99**	**2.00**	**2.00**
T1	7.13	4.22	**2.45**	**2.45**	**2.45**
T2	5.51	2.95	**2.14**	**2.28**	**2.21**
T3	5.31	3.10	**2.39**		
TU1	2.38	1.31	**2.21**		
water temperature @25 °C water density 0.99					

The thermal conductivity measurements can be seen in Table 4.2. The measurements were taken three times for both fronts and rear faces of the materials, and the average of these calculations was used in the study.

Table 4.2. Thermal conductivity measurements

Type	**Code**	**I (Watt)**	**Measurement location**	**Data type**	**Measurement 1**	**Measurement 2**	**Measurement 3**
Stone	T1	3	Front face	λ (W/mK)	1,82	1,87	1,91
				T_m (°C)	31	29	31
			Rear face	λ (W/mK)	1,92	1,92	1,91
				T_m (°C)	31	32	32
			Average (W/mK)		**1,8903**		
Cement Tile	K1	2	Front face	λ (W/mK)	1,24	1,26	1,27
				T_m (°C)	30	31	32
			Rear face	λ (W/mK)	1,18	1,21	1,21
				T_m (°C)	31	32	33
			Average (W/mK)		**1,2272**		

(cont. on next page)

Table 4.3. (cont.)

Type	Code	I (Watt)	Measurement location	Data type	Measurement 1	Measurement 2	Measurement 3
Brick	TU1	0,63	Front face	λ (W/mK)	0,48	0,41	0,43
				T_m (°C)	32	31	32
			Rear face	λ (W/mK)	0,56	0,55	0,56
				T_m (°C)	33	33	33
			Average (W/mK)		**0,4979**		
Stone	T2	1	Front face	λ (W/mK)	0,20	0,19	0,20
				T_m (°C)	24	26	28
			Rear face	λ (W/mK)	0,19	0,17	0,19
				T_m (°C)	29	29	31
			Average (W/mK)		**0,1902**		
Stone	T3	1	Front face	λ (W/mK)	1,01	0,96	0,96
				T_m (°C)	29	30	30
			Rear face	λ (W/mK)	1,21	1,21	1,24
				T_m (°C)	32	32	33
			Average (W/mK)		**1,0982**		
Stone	T4	1	Front face	λ (W/mK)	1,04	1,01	1,03
				T_m (°C)	29	29	29
			Rear face	λ (W/mK)	1,09	1,00	1,06
				T_m (°C)	29	29	29
			Average (W/mK)		**1,0379**		
Timber	T4	0,25	Front face	λ (W/mK)	0,12	0,11	0,14
				T_m (°C)	31	32	34
			Rear face	λ (W/mK)	0,13	0,10	0,12
				T_m (°C)	35	36	37
			Average (W/mK)		**0,1206**		

The specific heat measurements can be found in Figure 4.1. The specific heat values of the materials were calculated due to the 20 °C in the study. The coefficient of determination R^2 is close to 1, which means the linear association between x and y *is strong.*

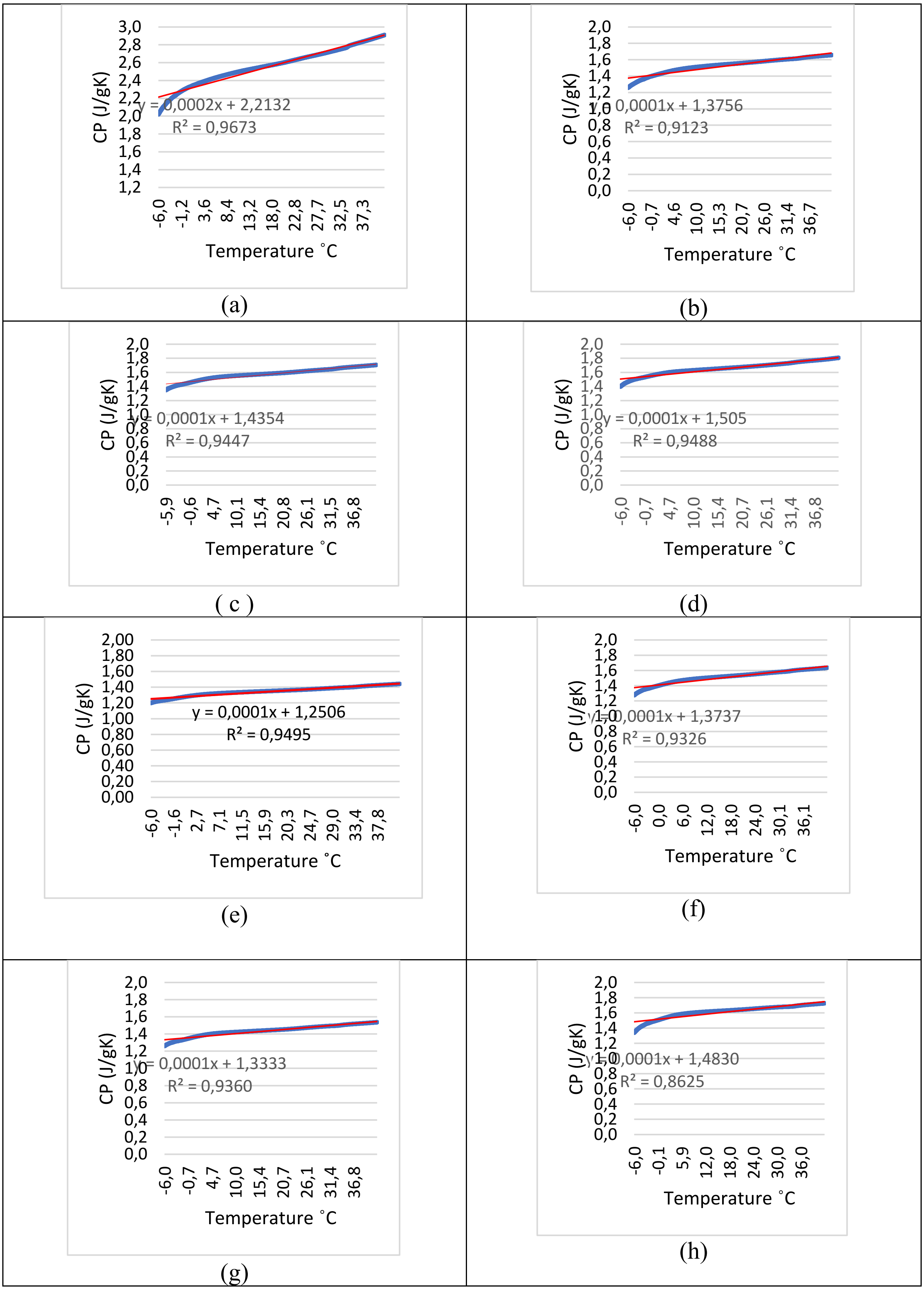


Figure 4.1. Specific heat measurements of the materials of house in Basmane (a) Wood (b) Brick (c) Plaster 1 (d) Plaster 2 (e) Stone 1 (f) Stone 2 (g) Stone 3 (h) Stone 4

4.1.2. **Daylighting of the Base Case Buildings**

The daylight measurements due to the different seasons of the houses in Basmane and Buca are presented respectively in this section. Then the relationship between the results and the spatial properties of the base case buildings are discussed.

The seasonal daylight spatial distributions of the house in Basmane are presented in the following table 4.4 and table 4.5. The diurnal daylight spatial distribution tables and the table of the results according to the spatial properties are presented in Appendix-E.

As mentioned in chapter 3.3.2, although Z02 room of the house in Basmane is unable to receive light from 1 of the 3 windows of the room, measurements have been made, and these measurements have been reflected on the maps. However, this situation was misleading and prevented comments on the room.

All the interior spaces of the house in Basmane except the corridor 107 satisfy the recommended illuminance for residential spaces in June. Besides, there is an excessive amount of bright areas especially in the entrance hall Z01 and in the rooms, 101,102,108 during the day. Daylight distribution was not balanced in the house during the day. Despite this, the room Z06 had the highest uniformity values of the year at noon. However, it did not satisfy the second category of uniformity value. Only the oriel had the required uniformity values of both. But it exceeds the required illuminance value. The highest average illuminance level of the oriel was found 3034 lx at noon.

The measurement day is cloudy, so the measurements were changing due to the cloud's movement momentarily in September. An excessive amount of bright areas was found in rooms 103, 108, the hall 101, and the entrance hall Z01 during the day. The room Z06 satisfies the required illuminance value during the day except in the afternoon. The room 106 exceeded the required illuminance value in the morning and noon. In the afternoon, it satisfied the required illuminance value, and it had the highest uniformity value of the first category during the year. None of the interior spaces had enough uniformity values except the corridor and the oriel. The corridor 107 had enough uniformity during the day but low illuminance value. However, the highest average illumination value was found at 115.54 in the afternoon. The oriel exceeds the required illumination value but satisfies the required uniformity value. The average illumination level of the oriel was more than 1906 lx during the day (table).

The measurement day is very cloudy in December. The rooms 103, 108, the hall 101, the oriel, and the entrance hall Z01 satisfy, and the rest of the rooms did not satisfy the recommended illuminance values at noon. None of the rooms except the oriel satisfy the recommended uniformity values in the morning and afternoon. The oriel exceeds the required illumination value but satisfies the required uniformity value. The average illumination level of the oriel was more than 721 lx during the day (table). Corridor 107 had an average illuminance value below 17 lx during the day. But it had the highest uniformity value at night. Sun patches, which cause visual discomfort, occurred at the hall 101 and in room 106 through the south facade at noon.

Measurement day is a sunny day in March. Daylight distribution of the house in March is more balanced than the other measurement days. The entrance hall Z01 had the highest uniformity value in the afternoon. The rooms 103, 108, and the oriel 102 had the highest uniformity values of the year at noon. Despite this, the oriel 102 was the only space that satisfied both categories of uniformity. The other spaces mentioned before satisfied just the first category of uniformity. Even the hall 101 had the highest uniformity level of the year; still, it could not satisfy both of the required values. Hall 101, the oriel 102, the entrance hall Z01 had an excessive amount of bright areas during the day while the room 106 had these areas at noon.

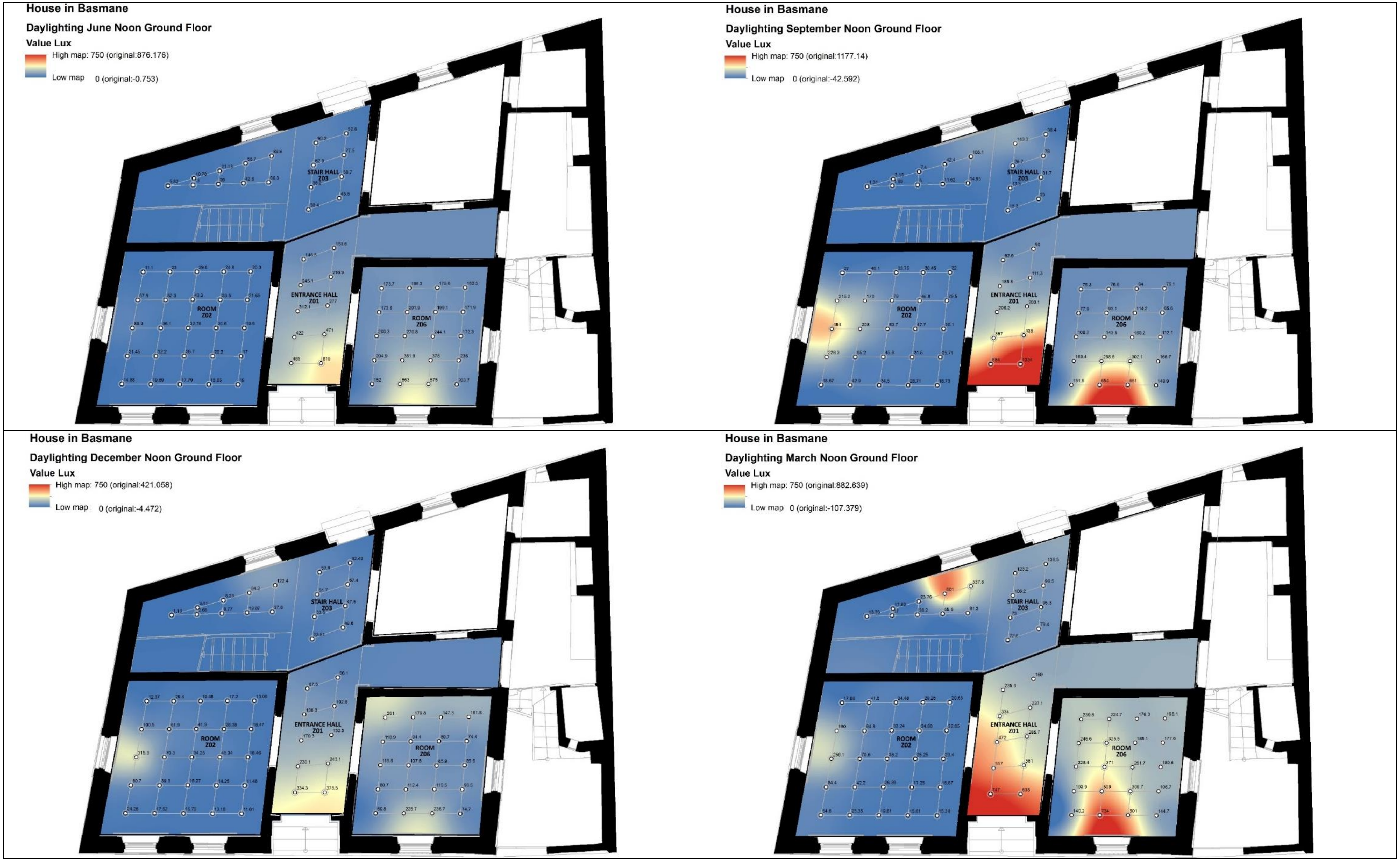


Figure 4.2. Seasonal Daylighting of the Ground Floor of the House in Basmane

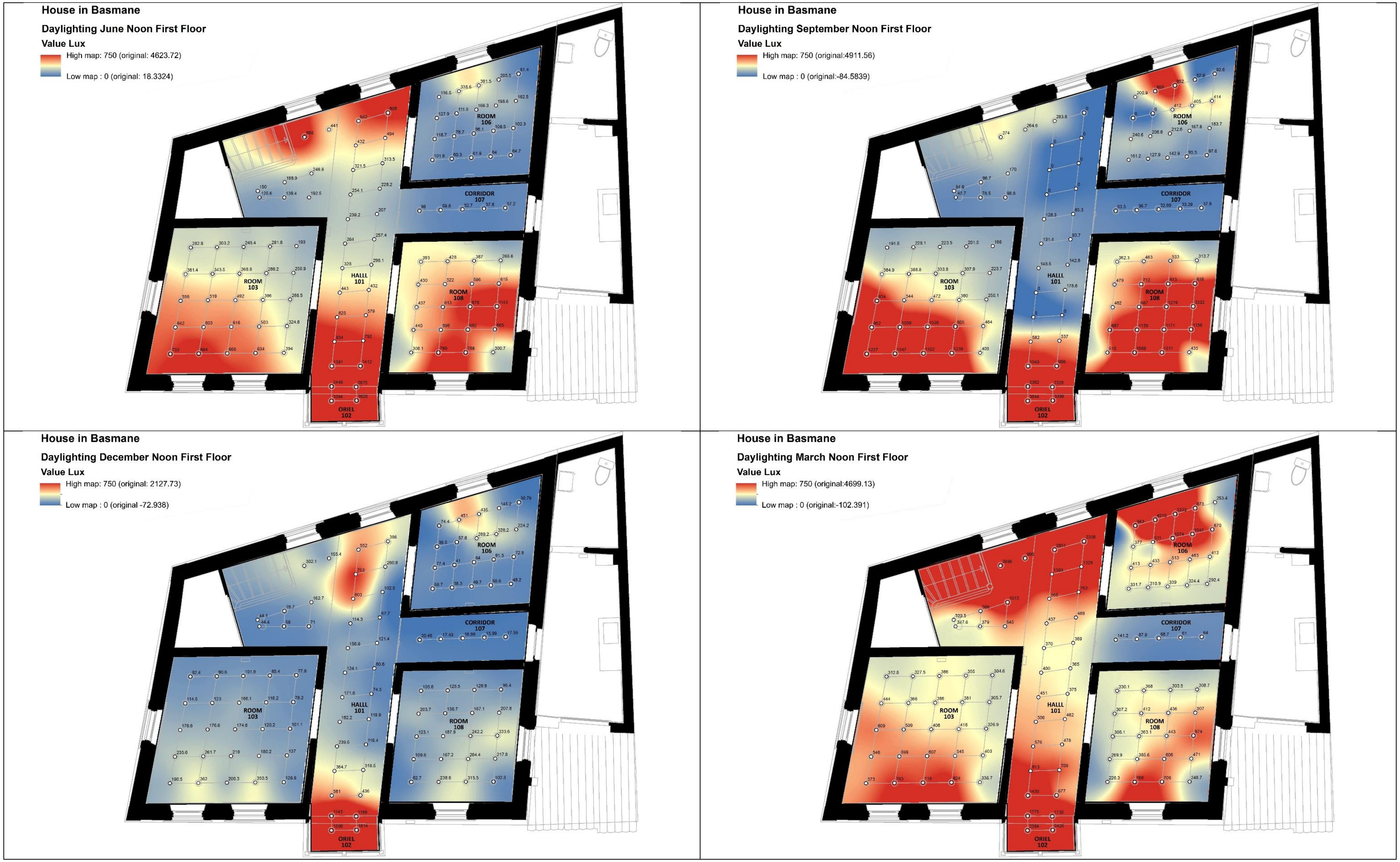


Figure 4.3. Seasonal Daylighting Analysis of the First Floor of the House in Basmane

The seasonal daylight spatial distributions and the diurnal daylight spatial distributions in June of the house in Buca are presented in the following table 4.6. The diurnal daylight spatial distribution tables of the other periods and the table of the results according to the spatial properties are presented in Appendix-E.

All the rooms of the house in Buca satisfy the recommended illuminance for residential spaces in June. Besides, there are excessive amounts of bright areas in the house. Especially in the room Z03 and the hall Z04 the average daylight illuminance exceeds approximately 1000 lx during the day. All the measured interior spaces satisfy the required first category uniformity value in June. But none of the rooms' uniformity values for interiors daylight satisfies the second category. Daylight distribution is most balanced in June, especially in room Z03, which faces the South East facade because of the right angle of the sun rays.

All the rooms and the hall satisfy the recommended illuminance values for residential spaces in September. Also, there are excessive amounts of bright areas in the house. Especially in the room, Z03 average daylight illuminance exceeds approximately 1000 lx in the morning and noon. The room Z03 has the most illuminance level while it has the lowest uniformity value in September. Uniformity level of the rooms (Z01, Z02) and the hall (Z04), which faces northwest direction, is better than the uniformity level of the room (Z03) which faces South East direction due to the direct sunlight. The rooms, Z01, Z02, and the hall Z04 satisfy the required first category uniformity value. But none of the rooms' uniformity values for daylight interiors satisfies the second category. Illuminance and uniformity levels of the interior spaces are higher in morning hours due to sun rays coming at a right angle.

The measurement day is very cloudy, so the measurements were changing due to the movement of the clouds momentarily in December. The lowest and inadequate illuminance levels in the house were measured at especially December noon and afternoon. Their values were below 30 lx. The illuminance levels of the house in the morning were sufficient for residential daylighting standards (ref). The sun rays come with the maximum oblique angle, and sun patches can reach the rear wall in the morning in the room Z03. As a result, the visual comfort conditions have been negatively affected.

Measurement day is a sunny day in March. All the rooms except room Z03 satisfy the first category uniformity level. The room Z03 exceeds the required illuminance level during the day while the rooms looking to the northwest direction exceeds only in the afternoon. The room Z01 has the most balanced daylighting distribution at noon in March.

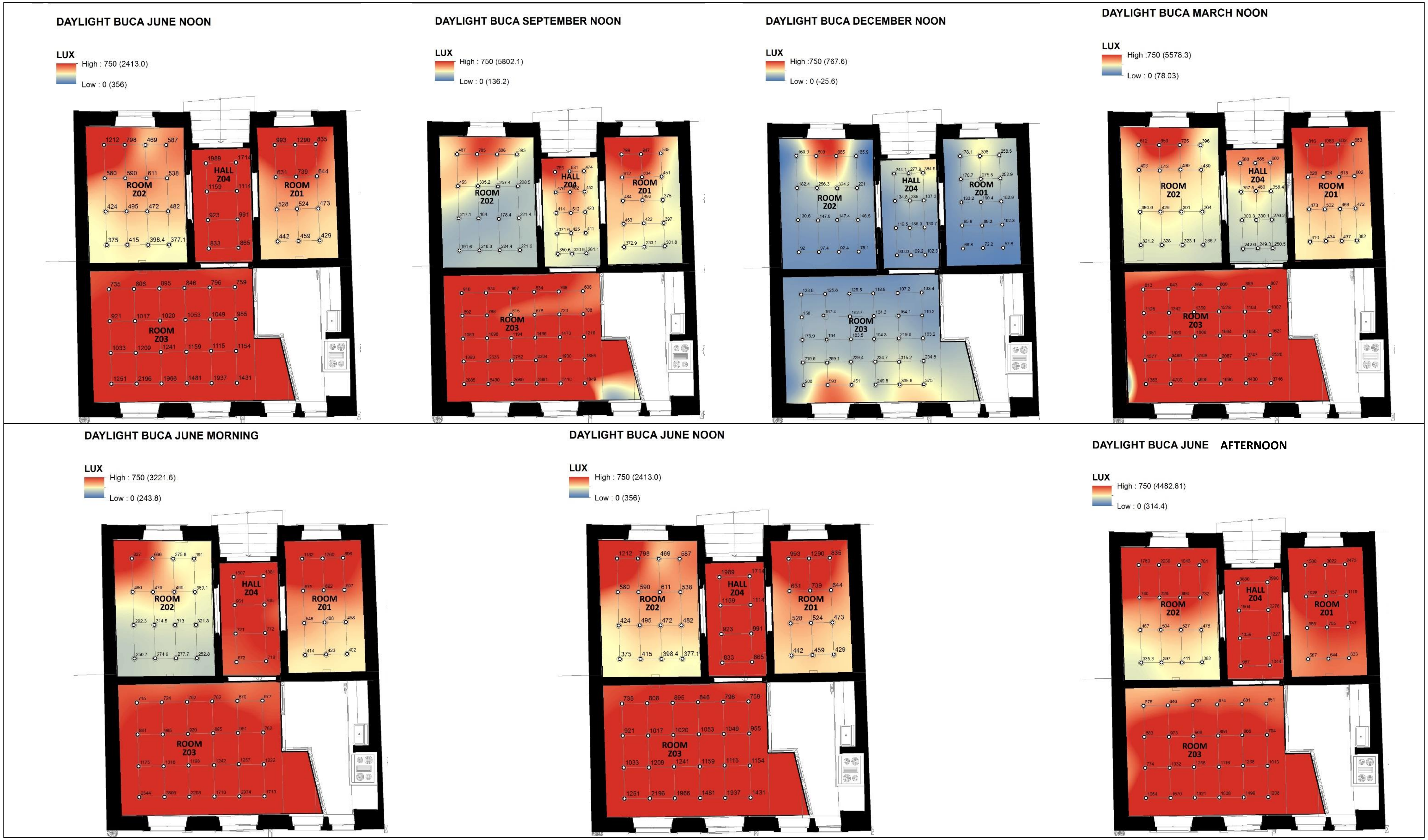


Figure 4.4. Seasonal and Diurnal Daylighting of the House in Buca

4.1.3. **Thermal Behavior of the Base Case Buildings**

The indoor and outdoor dry bulb air temperature, relative humidity measurements of the base case buildings are presented and discussed in this chapter to understand their thermal behavior. At first, the indoor and outdoor dry bulb air temperature, relative humidity measurements of the house in Basmane collected between 23rd of June and 20th of July in 2016 as monthly daily average data are presented in

Figure 4.5 and

Figure 4.6. The rest of the graphics which display the results of the other measurement periods in daily monthly average format can be found in Appendix-F.

The maximum monthly daily average air temperature is 35.13 °C, while outdoor relative humidity is 57.75%. The prevailing wind direction between June and July is West with a maximum speed of 3.6 m/s. and North-East with a maximum speed of 2.2 m/s. The maximum and average solar radiations were found 1028 W/square meter and 311 square meters respectively on these days. The maximum and average UV indexes were found 11 and 3, respectively. There was no rain during that period.

The graphs show a higher outdoor diurnal temperature difference than inside of the house. The temperature difference outside the house was 8.64°C, with a standard deviation value of 2.99. The internal temperatures remained more stable with a maximum standard deviation of 0.85 and did not follow the external temperature curve. The graph shows a time lag that the temperature inside the house remained lower during the day and higher at night than the outside temperature. The intervals of heat transfer change in each interior space according to their location and spatial properties.

In terms of humidity, there is a higher outdoor diurnal relative humidity difference than the indoor of the house as it in temperature changes. The monthly daily average relative humidity difference outside the house was 17.57 %, with a standard deviation value of 6.04. The monthly daily average indoor relative humidity's maximum standard deviation was 1.40. The graph also shows that in most of the interior spaces except the basement and the rooms 101 halls, 103, 108, the monthly daily average outdoor relative humidity remained higher between noon and afternoon and lower at the rest of the day than outside. The intervals of these changes for each interior spaces vary according to their location and spatial properties like it in temperature changes.

According to the monthly daily average analysis of the basement, the dry bulb temperature remained stable and lower than outdoor temperature all day with a maximum of 25.57 °C and a standard deviation of 0.14. The maximum and minimum monthly daily average relative humidity was 68.25% and 64.60 %. The basement has the lowest standard deviation ratio of the dry-bulb air temperature among the other zones. Unlike the other zones of the house, in the basement, the indoor relative humidity remained higher than the outdoor relative humidity all day.

The rooms on the ground floor were showing similar thermal characteristics with minor differences. According to the monthly daily average analysis table, the average temperature at the ground floor was approximately 30 °C in the measurement days. The graph also shows that the outdoor air temperature was higher than the internal air temperature from approximately 9:20 am in the morning till 10:50 pm at night and then lower till the morning on the ground floor. But the hall Z03 had a 1-hour shorter interval than the rest of the ground floor. The figure shows a more stable diurnal indoor temperature difference at the rooms Z02, Z04, Z06 and the entrance hall Z01 than the stair hall Z03 with the standard deviation 0.67. The airflow through the upstairs at the hall is thought to be the reason for this difference. It was seen on the table that the average humidity at the ground floor was approximately 47% except for room Z06 with the average value of %50.41. The adjacent building physical conditions and the prevailing wind directions are thought to be the reason for this difference. The graph also shows that the indoor relative humidity was higher than the internal relative humidity from approximately 11:00 am in the morning till 9:20 pm at night and then lower till the morning which means a shorter interval than the temperature changes. But the hall Z03 had a 1-hour shorter interval than the rest of the ground floor as the temperature change. The graphs show a higher diurnal indoor relative humidity difference at the halls Z01, Z03 with the standard deviation of 0.56, and 1.13 respectively, because of the high air infiltration rate of the spaces. There is no basement under the room Z04 which is facing south. And there are vegetations over the street attached to the facade of this building. Therefore, room Z04 at the south had a higher standard deviation (0.61) than the other rooms.

The interior spaces on the first floor were showing different thermal characteristics from the ground floor. The diurnal temperature differences were showing a swinging graphic which means higher differences and standard deviations than the ground floor. This is because of the rising heated air and the roof’s thermal mass effect.

The highest diurnal temperature differences were found in the hall 101 with a standard deviation of 1.40. It is thought to be the fact of the air infiltration from the staircase. However, the hall 101 had the lowest average temperature. One of the darkest places 107 corridors is directly related to the 101 halls. The interior spaces of the first floor, except room 108, the indoor air temperature was lower than the outdoor air temperature approximately between 10:50 am to 8:00 pm. But the room 108 looking at both north and west had a distinctive rise at the temperature graphic different than the other interior spaces on the first floor approximately between 5:00 to 7:50 pm. This is because of the direct sun rays coming at that period which can be seen in the daylighting graphics. Besides, the highest relative humidity differences were seen in the hall 101 with a standard deviation of 0.85. The air infiltration from the staircase and cross ventilation through the old window joineries may cause this. Due to the monthly daily average graphics unlike the ground floor, the diurnal relative humidity at the hall 101, the rooms 103 and 108 were found lower than the outdoor relative humidity during the day. At room 106 relative humidity was found higher approximately between 1:00 pm to 7:00 pm. The rooms 103 and 108 looking north had a similar temperature and relative humidity values. Their temperatures were found approximately 1°C higher, and relative humidities were found approximately 2.5% lower than room 106 looking south.

Secondly, the indoor and outdoor dry bulb air temperature, relative humidity measurements of the house in Basmane were collected between 22nd of September and 22nd of October in 2016. The maximum and minimum outdoor monthly daily average air temperatures are 25.99 °C and 17.45 °C, while the maximum and minimum outdoor relative humidity are 65.74% and 45.84%, respectively.

As expected, there is a higher outdoor diurnal temperature difference than inside of the house. The standard deviation value of the outdoor temperature is 2.77, while the internal temperatures remained more stable with a maximum standard deviation of 0.60. The temperature inside the house remained lower during the day and higher at night than the outside temperature, as same as in June and July periods. The intervals change in each interior space according to their location and spatial properties.

In terms of humidity, there is a higher outdoor diurnal relative humidity difference than the indoor of the house as it in temperature changes. The monthly daily average relative humidity difference outside the house was 19.9 %, with a standard deviation value of 6.38. The monthly daily average indoor relative humidity's maximum standard deviation was 0.85. In all the interior spaces, the monthly daily average relative humidity remained higher between noon and afternoon and lowered at the rest of the day than outside. The intervals of these changes for each interior space vary according to their location and spatial properties, like the temperature changes.

When the analysis was evaluated due to each interior space, the basement was seen more stable in September than June in terms of relative humidity with a standard deviation of 0.62. However, it was seen more fluctuating in terms of temperature in this period, with a standard deviation of 0.25.

The rooms on the ground floor were showing similar thermal characteristics with minor differences. According to the monthly daily average analysis table, the average temperature at the ground floor was approximately 21.83 °C in the measurement days. The outdoor air temperature was higher than the internal air temperature from approximately 10:30 am in the morning till 20:30 pm at night and then lower till the morning at the ground floor. The room Z02 has the most stable diurnal indoor temperature with a standard deviation of 0.19 while the hall Z03 has the most fluctuating diurnal temperature with a standard deviation of 0.48. The average humidity at the ground floor was approximately 53%. The indoor relative humidity was higher than the outdoor relative humidity from approximately 11:30 am in the morning till 19:00 pm at night and then lower till the morning. The hall Z03 has the most stable diurnal indoor relative humidity with the standard deviation 0.39, while room Z04 has the most fluctuating diurnal indoor relative humidity with the standard deviation 0.85.

The interior spaces on the first floor were showing different thermal characteristics from the ground floor. The diurnal temperature differences were showing a swinging graphic which means higher differences and standard deviations than the ground floor as in between June and July. The highest diurnal temperature differences were found in the hall 101 with a standard deviation of 0.60 and the maximum temperature difference of 1.89 °C. The interior spaces of the first floor except room 106 the indoor air temperature was lower than the outdoor air temperature approximately between 10:30 am to 19:30 pm. The highest relative humidity differences were seen in the hall 106 with the standard deviation 0.59, and the maximum relative humidity difference 2.31%. Due to the monthly average graphics, the diurnal relative humidity on the first floor except the room 106 was higher than the outdoor relative humidity between 12:30 am to 18:00 pm during the day. Relative humidity was found higher between 15:00 to 17:00 pm in room 106.

Thirdly, the indoor and outdoor dry bulb air temperature, relative humidity measurements of the house in Basmane have collected between the 8^{th} of January and the 8^{th} of February in 2017. The maximum and minimum outdoor monthly daily average air temperatures are 11.24 °C and 6.21 °C, while the maximum and minimum outdoor relative humidity are 74.02% and 61.34%, respectively.

There is a higher outdoor diurnal temperature difference than inside of the house. The standard deviation value of the outdoor temperature is 1.68, while the internal temperatures remained more stable with a maximum standard deviation of 0.38. The temperature inside the house remained lower during the day and higher at night than the outside temperature as same as in June, July, September, and October periods.

In terms of humidity, there is a higher outdoor diurnal relative humidity difference than the indoor of the house as it in temperature changes. The monthly daily average maximum relative humidity difference outside the house was 12.7 %, with the standard deviation value of 4.17. The monthly daily average indoor relative humidity's maximum standard deviation was 0.86. In each interior space, the monthly daily average relative humidity remained higher than outside in different periods of the day.

Both the temperature and relative humidity of the basement was more stable in January and February than the rest of the other measured periods with the standard deviation of 0.14 and 0.70, respectively. This is because the outdoor monthly daily average temperature and relative humidity standard deviation are the least of all the measurement periods.

The rooms on the ground floor were showing similar thermal characteristics with minor differences. According to the monthly daily average analysis table, the average temperature at the ground floor was approximately 7.47 °C in the measurement days. The outdoor air temperature was higher than the internal air temperature from approximately 10:00 am in the morning till 21:30 pm at night and then lower till the morning at the ground floor. The room Z02 and Z04 have the most stable diurnal indoor temperature with the standard deviation 0.13 while the hall Z03 has the most fluctuating diurnal temperature with a standard deviation of 0.26. The average humidity at the ground floor was approximately 72%. The indoor relative humidity was higher than the outdoor relative humidity at most of the day, different than the other periods explained above. The room Z02 has the most stable diurnal indoor relative humidity with the standard deviation 0.48 while the room Z04 has the most fluctuating diurnal indoor relative humidity with the standard deviation 1.02.

The diurnal temperature differences of the first floor were showing the most stable graphic than the other measurement periods. The highest diurnal temperature differences were found in the hall 101 with the standard deviation 0.38 and the maximum temperature difference 1.16°C. The interior spaces of the first floor, except room 106, the indoor air temperature was lower than the outdoor air temperature approximately between 09:30 am to 22:30 pm. The highest relative humidity differences were seen in the hall 106 with a standard deviation of 0.86 and the maximum relative humidity difference of 1.97%. Due to the monthly average graphics, the diurnal relative humidity on the first floor was higher than the outdoor relative humidity at most of the day, different than the other periods explained above. The relative humidity of the room 106 was found lower just between 01:00 am to 10:30 pm.

Finally, the indoor and outdoor dry bulb air temperature, relative humidity measurements of the house in Basmane have collected between the 24th of March and 23rd of April in 2017. The maximum and minimum outdoor monthly daily average air temperatures are 21.10 °C and 13.04 °C while the maximum and minimum outdoor relative humidity are 68.25% and 46.85%, respectively.

There is a higher outdoor diurnal temperature difference than inside of the house. The standard deviation value of the outdoor temperature is 2.70, while the internal temperatures remained more stable with a maximum standard deviation of 0.66. The temperature inside the house remained lower during the day and higher at night than the outside temperature, as same as in the rest of the other measurement periods.

In terms of humidity, there is a higher outdoor diurnal relative humidity difference than the indoor of the house as it in temperature changes. The monthly daily average maximum relative humidity difference outside the house was 12.7 %, with the standard deviation value of 4.17. The monthly daily average indoor relative humidity's maximum standard deviation was 0.86.

The basement measurements could not be taken of this period because of an error in the Hobo Data Logger.

According to the monthly daily average analysis table, the average temperature at the ground floor was approximately 16.36 °C in the measurement days. The indoor air temperature was lower than the outdoor air temperature from approximately 09:30 am in the morning till 22:00 pm at night and then higher till the morning on the ground floor. The room Z04 has the most stable diurnal indoor temperature with a standard deviation of 0.20, while the hall Z03 has the most fluctuating diurnal temperature with a standard deviation of 0.47. The average humidity at the ground floor was approximately 60%. The indoor relative humidity was higher than the outdoor relative humidity from approximately 10:0 am in the morning till 21:00 pm at night and then lower till the morning. The room Z02 has the most stable diurnal indoor relative humidity with the standard deviation 0.50 while the room Z04 has the most fluctuating diurnal indoor relative humidity with the standard deviation 0.79.

The highest diurnal temperature differences were found in the hall 101 with the standard deviation 0.66 and the maximum temperature difference 2°C. The indoor air temperature of the interior spaces of the first floor was lower than the outdoor air temperature approximately between 10:00 am to 19:00 pm and higher at the rest of the day. The highest relative humidity differences were seen in the hall 101 with the standard deviation 1.47, and the maximum relative humidity difference 4.52%. Due to the monthly average graphics, the diurnal relative humidity on the first floor was higher than the outdoor relative humidity between 11:30 am to 19:00 pm during the day.

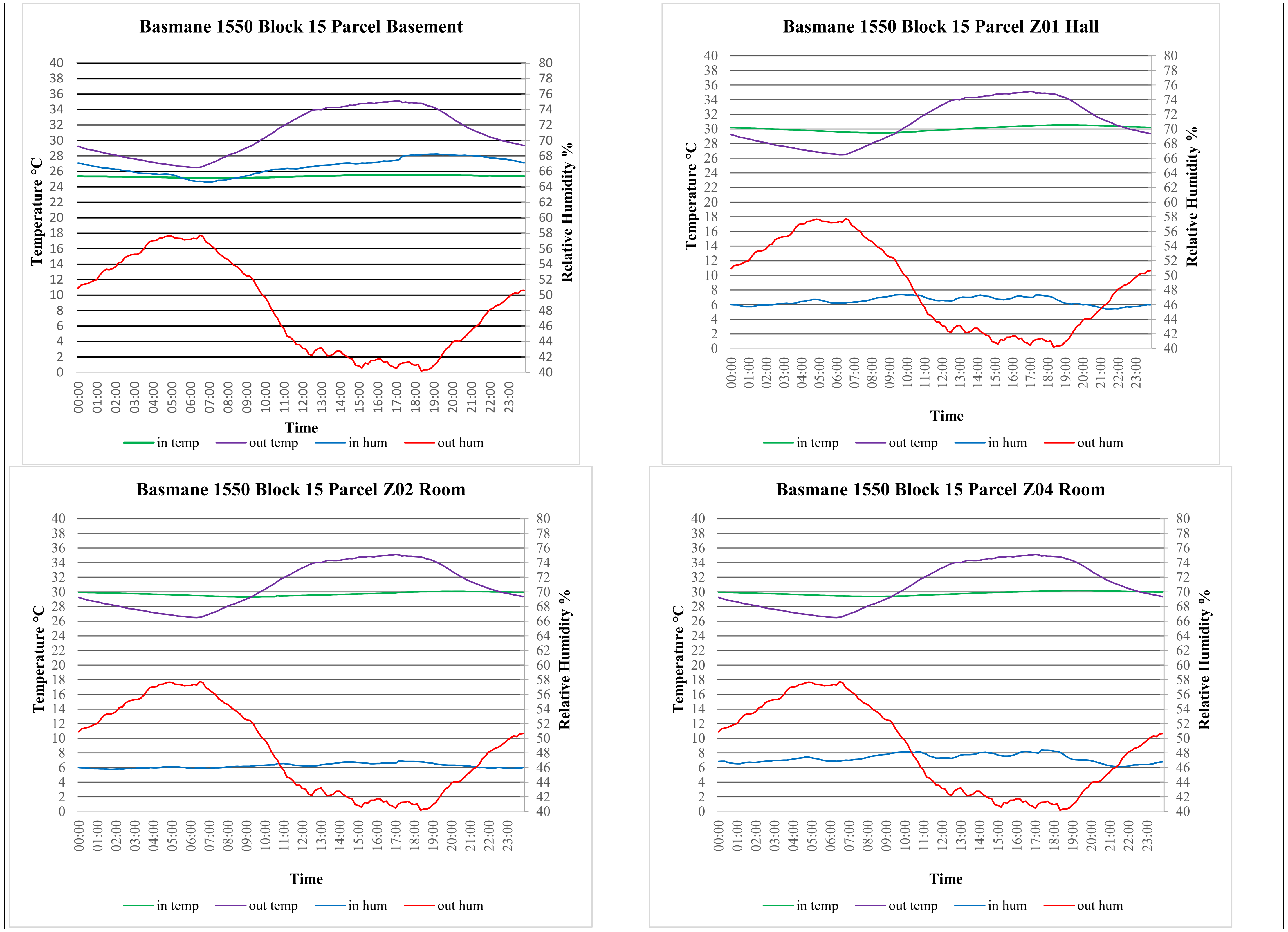


Figure 4.5. Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Basmane 23.6.2016-20.7.2016

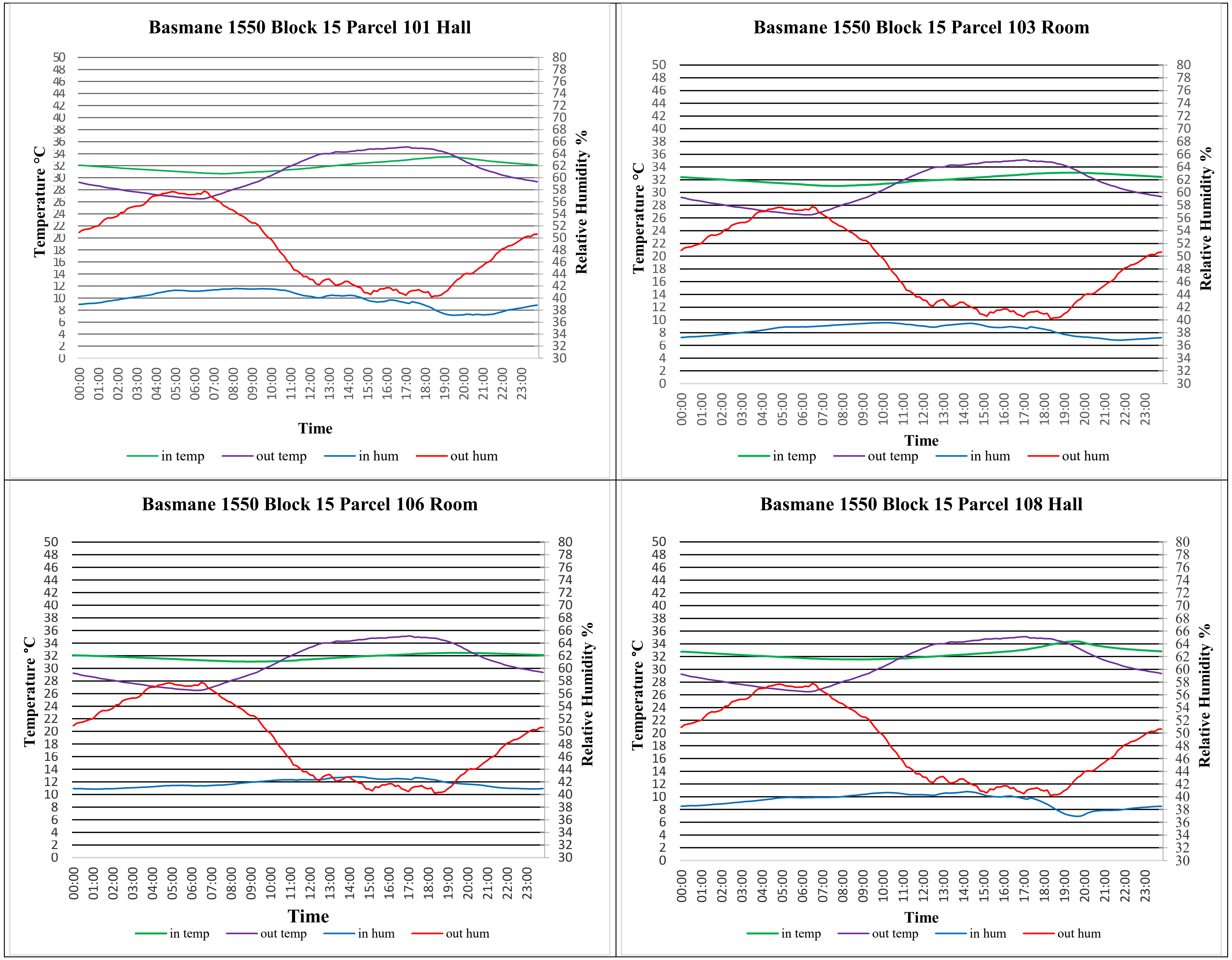


Figure 4.6. Dry bulb temperature and relative humidity monthly daily average graphics of the first floor of the house in Basmane 23.6.2016-20.7.2016

The measurements were taken in four different periods in the base case building in Buca between the years 2016 and 2017, as same as in Basmane. At first, the indoor and outdoor dry bulb air temperature, relative humidity measurements of the house in Buca collected between 25th of June and 20th of July in 2016 as monthly daily average graphics are presented in Figure 4.7. The rest of the graphics which display the results of the other three measurement periods in daily monthly average format can be found in Appendix-F. The maximum and minimum outdoor monthly daily average air temperatures are 40.62 °C and 24.57 °C while the maximum and minimum outdoor relative humidity are 58.86% and 24.55%, respectively.

There is a higher outdoor diurnal temperature difference than inside of the house. The standard deviation value of the outdoor temperature is 4.90, while the internal temperatures remained more stable with a maximum standard deviation of 1.04 in the basement. The temperature inside the house remained lower during the day and higher at night than the outside temperature.

In terms of humidity, there is a higher outdoor diurnal relative humidity difference than the indoor of the house. The monthly daily average maximum relative humidity difference outside the house was 34.31 %, with the standard deviation value of 11.01. The monthly daily average indoor relative humidity's maximum standard deviation was 3.01 in basement.

According to the monthly daily average analysis table, the average temperature at the ground floor and basement were approximately 30.22 °C and 27.08 °C, while the outdoor average temperature was 30.19 °C. The indoor air temperature was lower than the outdoor air temperature from approximately 10:00 am in the morning till 20:00 pm at night and then higher till the morning on the ground floor. The room Z02 has the most stable diurnal indoor temperature with a standard deviation of 0.23 while the hall Z04 has the most fluctuating diurnal temperature with a standard deviation of 0.46. The average humidity at the ground floor was approximately 45%. The indoor relative humidity was higher than the outdoor relative humidity from approximately 10:00 am in the morning till 21:00 pm at night and then lower till the morning. The room Z02 has the most stable diurnal indoor relative humidity with the standard deviation 0.37, while the hall Z04 has the most fluctuating diurnal indoor relative humidity with the standard deviation 1.04.

Secondly, the indoor and outdoor dry bulb air temperature, relative humidity measurements of the house in Buca collected between the 27th of September and the 26th of October in 2016. The maximum and minimum outdoor monthly daily average air temperatures are 25.17 °C and 17.31 °C while the maximum and minimum outdoor relative humidity are 64.07% and 38.37%, respectively.

There is a higher outdoor diurnal temperature difference than inside of the house. The standard deviation value of the outdoor temperature is 2.55, while the internal temperatures remained more stable with a maximum standard deviation of 0.63 in the basement. The temperature inside the house remained lower during the day and higher at night than the outside temperature.

In terms of humidity, there is a higher outdoor diurnal relative humidity difference than the indoor of the house. The monthly daily average maximum relative humidity difference outside the house was 25.7 %, with the standard deviation value of 8.46. The monthly daily average indoor relative humidity's maximum standard deviation was 1.82 in the basement.

According to the monthly daily average analysis, the average temperature at the ground floor and basement were approximately 21.61 °C and 21.74 °C, while the outdoor average temperature was 20.81 °C. The indoor air temperature was lower than the outdoor air temperature from approximately 11:00 am in the morning till 19:00 pm at night and then higher till the morning on the ground floor. The room Z01 has the most stable diurnal indoor temperature with a standard deviation of 0.14, while room Z03 has the most fluctuating diurnal temperature with a standard deviation of 0.28. The average humidity at the ground floor was approximately 53%. The indoor relative humidity was higher than the outdoor relative humidity from approximately 11:00 am in the morning till 21:00 pm at night and then lower till the morning. The room Z02 has the most stable diurnal indoor relative humidity with the standard deviation 0.26, while the hall Z04 has the most fluctuating diurnal indoor relative humidity with the standard deviation 0.59.

Thirdly, the indoor and outdoor dry bulb air temperature, relative humidity measurements of the house in Buca collected between the 15^{th} of January and 15^{th} of February in 2017. The maximum and minimum outdoor monthly daily average air temperatures are 11.38 °C and 6.02 °C, while the maximum and minimum outdoor relative humidity are 71.84% and 52.64%, respectively.

There is a higher outdoor diurnal temperature difference than inside of the house. The standard deviation value of the outdoor temperature is 1.76, while the internal temperatures remained more stable with a maximum standard deviation of 0.27 in the basement. The temperature inside the house remained lower during the day and higher at night than the outside temperature.

In terms of humidity, there is a higher outdoor diurnal relative humidity difference than the indoor of the house. The monthly daily average maximum relative humidity difference outside the house was 19.2 %, with the standard deviation value of 6.36. The monthly daily average indoor relative humidity's maximum standard deviation was 0.27 in basement.

According to the monthly daily average analysis, the average temperature at the ground floor and basement were approximately 8.40 °C and 9.09 °C, while the average outdoor temperature was 8.14 °C. The indoor air temperature was lower than the outdoor air temperature from approximately 09:30 am in the morning till 19:00 pm at night and then higher till the morning on the ground floor. The room Z03 has the most stable diurnal indoor temperature with the standard deviation 0.14 while the room Z01 and Z02 have the most fluctuating diurnal temperature with the standard deviation 0.25. The average humidity at the ground floor and basement were approximately 70% and %67 while the outdoor average relative humidity was 64%. The relative humidity in the basement, room Z02, Z03, and Z04, were higher than the outdoor relative humidity in the different periods of the day and lower at night. But the relative humidity at the room Z01 was lower just between 7:00 am and 9:0 am than the outside. The room Z02 has the most stable diurnal indoor relative humidity with the standard deviation 0.60, while the hall Z04 has the most fluctuating diurnal indoor relative humidity with the standard deviation 1.02.

Finally, the indoor and outdoor dry bulb air temperature, relative humidity measurements of the house in Buca collected between 23rd of March and 22nd of April in 2017. The maximum and minimum outdoor monthly daily average air temperatures are 21.54 °C and 13.15 °C, while the maximum and minimum outdoor relative humidity are 64.36% and 37.94%, respectively.

There is a higher outdoor diurnal temperature difference than inside of the house. The standard deviation value of the outdoor temperature is 2.81, while the internal temperatures remained more stable with a maximum standard deviation of 0.64 in the basement. The temperature inside the house remained lower during the day and higher at night than the outside temperature.

In terms of humidity, there is a higher outdoor diurnal relative humidity difference than the indoor of the house. The monthly daily average maximum relative humidity difference outside the house was 26.42 %, with the standard deviation value of 9.63. The monthly daily average indoor relative humidity's maximum standard deviation was 2.07 in the basement.

According to the monthly daily average analysis, the average temperature at the ground floor and basement were approximately 16.91 °C and 16.52 °C, while the outdoor average temperature was 17.02 °C. The indoor air temperature was lower than the outdoor air temperature from approximately 08:00 am in the morning till 19:00 pm at night and then higher till the morning on the ground floor. The room Z02 has the most stable diurnal indoor temperature with a standard deviation of 0.18, while room Z03 has the most fluctuating diurnal temperature with a standard deviation of 0.29. The average humidity at the ground floor and basement were approximately 58% and %58 while the outdoor average relative humidity was 53%.

The indoor relative humidity was higher than the outdoor relative humidity from approximately 11:00 am in the morning till 21:00 pm at night and then lower till the morning. The room Z02 has the most stable diurnal indoor relative humidity with the standard deviation 0.26, while the hall Z04 has the most fluctuating diurnal indoor relative humidity with the standard deviation 0.59. The relative humidity in the basement, room Z02, Z03, and Z04, were higher than the outdoor relative humidity in the different periods of the day and lower at night. But the relative humidity at the room Z01 was lower just between 3:00 am and 8:00 am than the outside. The room Z02 has the most stable diurnal indoor relative humidity with the standard deviation 0.18, while the hall Z03 has the most fluctuating diurnal indoor relative humidity with the standard deviation 0.29.

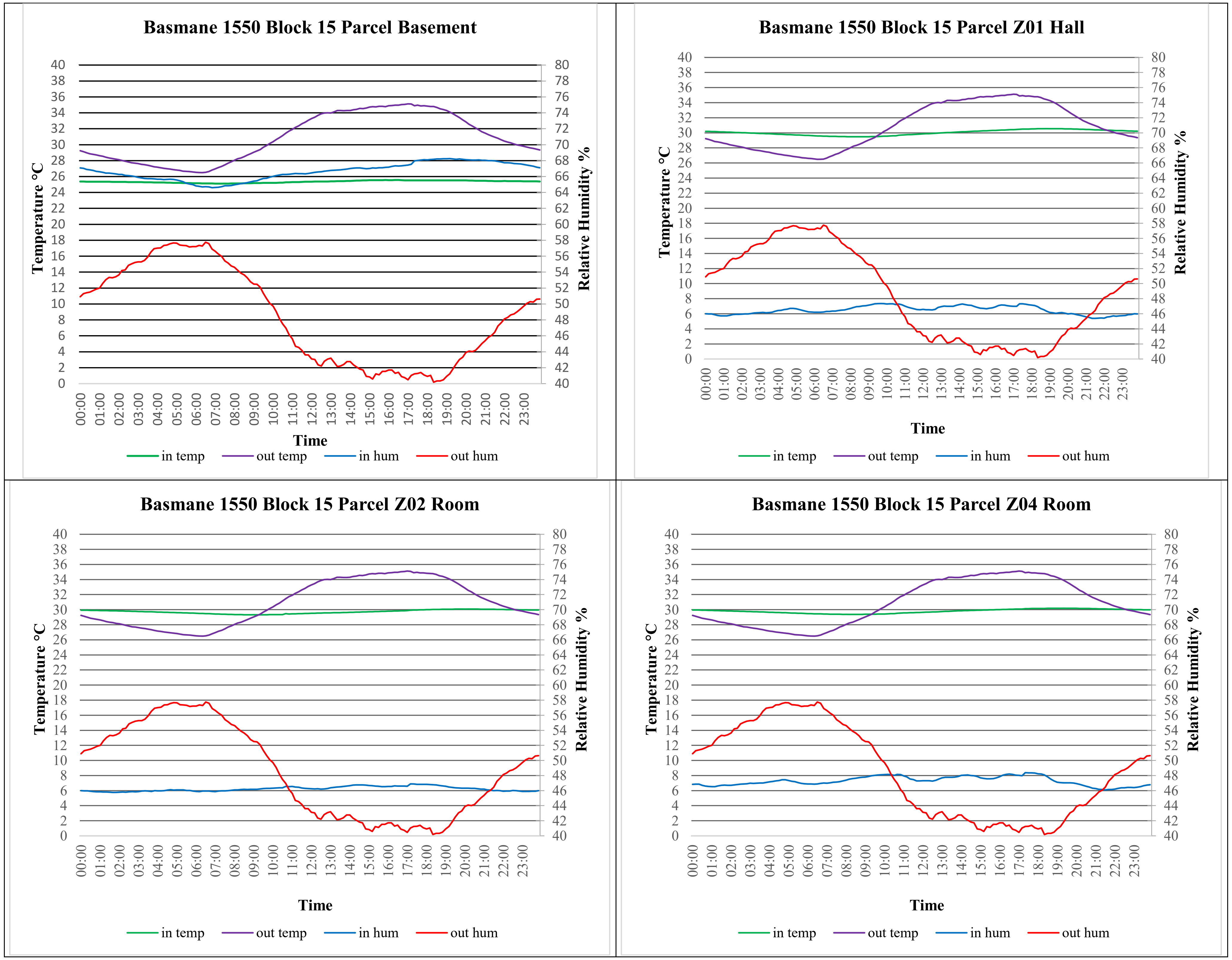


Figure 4.7. Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Buca 25.6.2016-20.7.2016

4.2. Energy Consumption Results of the 19th Century İzmir Houses Variations

The BES energy consumption results of the two and single-story İzmir houses types are presented and compared respectively in this section to understand their thermal behavior and the effects of the design parameters on these buildings' energy performance. Furthermore, statistical analyses' results regarding the significance of these design parameters and the degree of their relationship between energy consumption will be presented in the following section

It was observed that the heating load of İzmir houses is much higher than the cooling load. Thus, the design parameters that lead to the reduction of the heating load have a positive effect on the energy performance of the houses. The simulation results and the design parameters details of all the BES models analyzed in this study can be seen in Appendix-G.

The comparison between the two-story İzmir houses types average energy consumption showed that the buildings with side hall plan type consume 66 kwh/m2 less energy than the buildings with central plan type when the average values of design parameters, window to floor ratio remained stable while wall to floor, window to floor and wall to volume ratios were increasing and total building area and volume were decreasing.

Table 4.4 The average energy consumptions and average values of some of the design parameters of the two-story İzmir houses the main types

Building type	Average Gross Window to Wall Ratio	Average Gross Wall to Floor Ratio	Average Gross Window to Floor Ratio	Average Total Building Area m2	Average Volume m3	Average Wall to Volume Ratio	Average Source Energy Consumption per total Building Area kWh/m2
Model 1	0.12	0.64	0.08	323.24	926.48	0.22	246.17
Model 2	0.13	0.66	0.08	316.05	929.20	0.22	210.08
Model 3	0.12	0.65	0.08	315.93	926.97	0.22	218.03
Model 4	0.12	1.07	0.13	276.99	869.07	0.34	302.30
Model 5	0.12	1.08	0.13	275.47	870.42	0.34	279.15

In addition, among the houses with side hall plan type, the buildings which have stairs parallel to the adjacent exterior wall and perpendicular to the L shaped hall consumes less energy than the other buildings examined. This stairs location leads the L shaped hall form at the ground floor became zig-zag, and the rectangular-shaped hall form on the first floor became L shaped. However, the average values of design parameters of the two-story houses with side hall such as window to wall ratio, wall to floor ratio, window to floor ratio, total building area wall to volume ratio doesn't change so much the average energy consumptions change. It was found out that the average least energy consuming building types among these were Model 2 that has zig zag form hall at the ground floor mentioned above.

Besides, among the two-story İzmir houses with central hall plan type, model 5 which has staircase perpendicular to the adjacent wall and lead the hall shape at the ground and first floors became L shaped from rectangular consumes less energy than the buildings with rectangular shaped. As mentioned above, however, the average values of the other design parameters of the two-story houses with central hall don't change so much the energy consumption changes. The reduction of the energy consumption in both house types with side and central hall plan can be caused by more homogenous airflow in these houses provided by the articulated forms of the halls between the rooms (heated zones).

Another important result is that the two-story buildings with basements consume less energy than the buildings without a basement. When the annual heating and cooling energy consumptions per square meter graphics were examined, it was observed that the buildings without the basement are showing more fluctuating graphics (Appendix-G). As mentioned in the section 4.1.3 thermal behavior of the base case buildings, the basement stabilizes the temperature and relative humidity fluctuations. So, it affects the energy consumption results.

The average energy consumptions of the houses with the oriel are approximately 20 kWh/m2 more than the houses with balcony. As mentioned in section 4.1.3, the oriel serves as a light source. The direct sunlight reaches to the depths of the hall space. However, the effect of oriel on heating and cooling energy consumption was not found much it would have a significant effect on lighting energy consumption.

The houses with roofs heated consume approximately 20-40 kwh more energy than the houses with unheated roofs. The energy performance of the houses with side halls was more affected by the heating system of the roof. It can be related to the differences between the floor area of the roofs of the houses.

The comparison between the single-story İzmir houses types average energy consumption showed that the buildings with side hall plan type consume 55 kwh/m2 more energy than the buildings with central plan type when the average values of design parameters, window to floor ratio remained stable while wall to floor, window to floor and wall to volume ratios were increasing and total building area and volume were decreasing.

Table 4.5. The average energy consumptions and average values of some of the design parameters of the single-story İzmir houses main types

Building type	Average Gross Window to Wall Ratio	Average Gross Wall to Floor Ratio	Average Gross Window to Floor Ratio	Average Total Building Area m2	Average Volume m3	Average Wall to Volume Ratio	Average Source Energy Consumption per total Building Area kWh/m2
Model 1	0.11	1.19	0.13	176.13	495.68	0.41	304.83
Model 2	0.08	1.26	0.10	203.39	567.56	0.44	350.35
Model 3	0.10	2.20	0.22	82.54	236.76	0.76	385.01
Model 4	0.10	1.45	0.15	113.48	317.68	0.51	325.26

Furthermore, among the houses with central hall plan type Model 2, which have a larger wall to floor and wall to volume ratios, consumes more energy than Model 1. Also, Model 1 was found out as the least energy consuming building type among all the single-story houses examined. The houses with side hall plan type have a larger wall to floor and wall to volume ratio than the houses with a central hall. Among the houses with side hall plan type, Model 3 with the highest wall to floor, window to the floor, wall to volume ratios, and the least total building area have the worst energy performance.

Another important result is that the single-story buildings with basements consume less energy than the buildings without a basement. When the annual heating and cooling energy consumptions per square meter graphics were examined, it was observed that the buildings with central hall plan type and without basement are showing a more fluctuating heating energy consumption graphics. The cooling energy consumption graphics show more stabilize graphics. However, the buildings with side hall plan type and without basement have more fluctuating graphics of both cooling and heating energy consumption (Appendix-G). As mentioned above, the wall to floor and wall to volume ratio of the side hall plan type houses are larger than the central hall plan type. This can cause the cooling energy consumption graphics differences between these types of buildings.

The houses settled in detached order consumes 30-50 kwh/m2 more energy than the houses in semidetached order. The rising wall area ratio exposed to the outdoor microclimatic conditions can be the reason for this situation. The figures at the Appendix-G showed that the semidetached houses have the least heating and cooling energy consuming and fluctuating graphics.

The average energy consumption of the two-story house in Alsancak was figured out 90 kwh/m2 more than the single-story house in Buca. The house in Buca is semidetached to another building while the house in the Alsancak is settled in a row.

So, the exterior walls of the basement of the house in Buca exposed to the outdoor climatic conditions more than the house in Alsancak. In addition, the heating and cooling energy consumption graphics of the two-story İzmir houses show more fluctuation than the single-story houses in Buca. This difference is similar to the differences between the thermal behaviors of the two and single-story base case buildings mentioned in section 4.1.3.

4.2.1. **Statistical Analyses Results**

The results of the architectural design parameters' statistical analyses are presented in different subsections. Since the two and single-story Izmir houses were modeled in two different regions as Alsancak and Buca, statistical analyses were performed separately. Thus, the results of the houses with the two-story and single-story are explained separately and respectively in each subsection.

Also, in this study, a total of 114 BES models were prepared, 50 of which contain two-story houses and 64 of which contain single-story houses. Some of these buildings have basement utilizing as a ventilation space, some have basement utilizing as a ventilation space and some don't have a basement. In the statistical analysis of İzmir Houses especially in the single-story houses, the existence of basement space has a large impact on energy consumption, thus suppressing the impact of other architectural parameters. In order to understand the real impacts of the other architectural parameters, the statistical analyses of both two and single-story İzmir houses were done in two alternatives for each parameter. One of these alternatives consists of a total of 114 BES models simulation results for the analysis of 50 two-story and 64 single-story buildings with and without basements. The other alternative consists of a total of 88 BES models simulation results for the analysis of 40 two-story and 48 single-story buildings with basements. The results of these two analyses alternatives for each parameter were explained respectively.

4.2.2. **Relationship Between İnterior Space Organization and The Total Energy Consumption Per Square Meter**

The relation between interior space organization and the total source energy consumption per square meter of the two-story İzmir Houses with and without basement was analyzed by two different parameters. One of them is the location of the hall space, which is one of the basic characteristic properties of İzmir Houses. The other parameter is the plan type, which is formed by both the integration of the location of the hall and the staircase.

T-tests based on two samples assuming both unequal and equal variances were conducted to compare side hall and central hall locations within total energy consumption at a 5% level of significance. (α=0.05) The null hypothesis $H0:\tau i=0$; there is no relation among energy consumption according to interior space organization. Regarding the t-test (unequal variances) analysis result, there was a significant difference in the scores for side hall (M=224.76) and central hall (M=290.73) locations; t Stat (30)=-5.68, t Critical two-tail=2.04, p = 3.46379E-06 (Table 4.6). The -t Stat is less than t critical two tail and the P two-tail value is less than a 5% level of significance, so the null hypothesis was rejected. These results suggest that the location of the halls really does have an effect on total energy consumption. It was observed that the total energy consumption of İzmir houses with central hall plans is higher than the houses with side hall plans. Also, this t-test assuming unequal variances was consistent with the t test assuming equal variances for the same parameters. Regarding the t-test (equal variances) analysis result, there was also a significant difference in the scores for side hall and central hall locations; t Stat (48) =-6.14, t Critical two-tail=2.01, p = 1.50917E-07 (Appendix-H).

Table 4.6. T-test analysis (unequal variances) of energy consumption per square meter based on the location of the hall space of the two-story houses

	Side Hall	Central Hall
Mean	224.7576667	290.727
Variance	922.0754461	2087.378675
Observations	30	20
Hypothesized Mean Difference	0	
df	30	
t Stat	-5.675534067	
P(T<=t) one-tail	1.7319E-06	
t Critical one-tail	1.697260887	
P(T<=t) two-tail	3.46379E-06	
t Critical two-tail	2.042272456	

A single factor (one way) ANOVA was conducted for the parameters of 5 different plan types regarding total energy consumption based on the null hypothesis H0:τi=0; there is no relation among energy consumption according to interior space organization. The mean square between groups is 15523.56, and the mean square within groups is 1256.215. Means of groups are respectively 246.17, 210.08, 218.03, 302.30 and 279.15 (Table 4.7). Due to the analysis F critic (α=0.05, 4, 2.57874 for 45).is less than F value, 12.3574. The P-value, 7.30783E-07 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that plan type varies significantly according to energy consumption. Briefly, it was observed that plan type is an effective parameter on total energy consumption per square meter.

Table 4.7. Variance analysis of energy consumption per square meter based on plan types of the two-story houses

Groups	Count	Sum	Average	Variance		
TYPE 1	10	2461.65	246.17	1178.26		
TYPE 2	10	2100.78	210.08	413.29		
TYPE 3	10	2180.3	218.03	580.67		
TYPE 4	10	3023.04	302.30	2378.18		
TYPE 5	10	2791.5	279.15	1730.66		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	62094.25	4	15523.56	12.357	7.30783E-07	2.579
Within Groups	56529.56	45	1256.215			
Total	118623.82	49				

Besides understanding the strength of the relationship between interior space organization and the source energy consumption per total square meter, Pearson correlation analyses were conducted. The correlation factor between the hall locations and total energy consumption per square meter is 0.66, which means there is a high degree of a positive relationship between these variables according to Cohen’s standard. The relationship between these variables is positive, which indicates that as hall location changes from side to center, the energy consumption increases. In addition, the correlation factor between the building types and total energy consumption per square meter is 0.45 which means there is a moderate degree of positive relationship between these variables according to Cohen’s standard. The relationship between these variables is positive, which indicates that the buildings with side hall have less energy consumption than the buildings with center hall.

As mentioned in section 4.2.1, the t-test, the single factor ANOVA and Pearson correlation analyses were repeated only for buildings with basements. According to the results of these statistical analyses, it was understood that the interior space organization does have a significant effect on energy consumption. There is a strong positive relationship between these variables.

Also, the relation between interior space organization and the total energy consumption per total square meter of the single-story İzmir Houses with and without basement was analyzed regarding hall space location.

T-tests based on two samples assuming both unequal and equal variances were conducted to compare side hall and central hall locations within total energy consumption at a 5% level of significance. (α=0.05) The null hypothesis H0:τi=0; there is no relation among energy consumption according to interior space organization. Regarding the t-test (equal variances) analysis result, there was not a significant difference in the scores for side hall (M=355.13) and central hall (M=327.59) locations; t Stat (62)=1.07, t Critical two-tail=1.99, p = 0.28 (Table 4.8). The t Stat is lower than t critical two-tail, and the P two-tail value is higher than the 5% level of significance, so the null hypothesis was accepted. These results suggest that the location of the halls does not have an effect on total energy consumption for both the buildings with and without a basement. Also, this t-test assuming equal variances was consistent with the t test assuming unequal variances for the same parameters. Regarding the t-test (unequal variances) analysis result, there was not a significant difference in the scores for side hall and central hall locations; t Stat (62) =1.07, t Critical two-tail=1.99, p = 0.28 (Appendix-H).

Table 4.8. T-test analysis (Equal Variances) of energy consumption per square meter based on the location of the hall space of the-single story houses

	Side Hall	Central Hall
Mean	355.1321875	327.591875
Variance	10718.17091	10093.5184
Observations	32	32
Pooled Variance	10405.84466	
Hypothesized Mean Difference	0	
df	62	
t Stat	1.079916523	
P(T<=t) one-tail	0.14218124	
t Critical one-tail	1.669804163	
P(T<=t) two-tail	0.28436248	
t Critical two-tail	1.998971517	

Furthermore, a single factor (one way) ANOVA was conducted for the parameters of 4 different plan types regarding total energy consumption based on the null hypothesis H0:τi=0; there is no relation among energy consumption according to interior space organization. The mean square between groups is 19091.45, and the mean square within groups is 10000.39. Means of groups are respectively 304.83, 350.35, 385.01, and 325.26 (Table 4.9). Due to the analysis F critic (α=0.05, 3, 2.7581 for 60) is less than the F value of 1.9091. The P-value, 0.13774, is higher than the 5% level of significance; thus, the null hypothesis is accepted. Briefly, it was observed that plan type is not an effective parameter on total energy consumption per square meter for buildings with and without a basement.

Table 4.9. Variance analysis of energy consumption per square meter based on plan types of the single-story houses

Groups	Count	Sum	Average	Variance		
TYPE 1	16	4877.31	304.83	8274.4541		
TYPE 2	16	5605.63	350.35	11480.3797		
TYPE 3	16	6160.13	385.01	9910.0394		
TYPE 4	16	5204.1	325.26	10336.6943		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	57274.36	3	19091.45	1.9091	0.137742346	2.7581
Within Groups	600023.51	60	10000.39			
Total	657297.87	63				

Besides, to understand the strength of the relationship between the location of the hall and the total energy consumption per total square meter, Pearson correlation analysis was conducted. The correlation factor between the hall locations and total energy consumption per square meter is 0.13 which means there is a low degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that, as hall location changes from center to side the energy consumption increases.

As mentioned in section 4.2.1, the t-test, the single factor ANOVA and Pearson correlation analyses were repeated only for buildings with basements. Regarding the t-test (equal variances) analysis result, there was a significant difference in the scores for side hall (M=299.87) and central hall (M=273.13) locations; t Stat (46)=2.85, t Critical two-tail=2.01, p = 0.006(Table 4.10). The t Stat is higher than t critical two tail and the P two-tail value is lower than the 5% level of significance, so the null hypothesis was rejected. These results suggest that the location of the halls have an effect on total energy consumption for both the buildings with basement. Also, this t-test assuming equal variances was consistent with the t test assuming unequal variances for the same parameters. Regarding the t-test (unequal variances) analysis result, there was not a significant difference in the scores for side hall and central hall locations; t Stat (41) =2.85, t Critical two-tail=2.01, p = 0.006 (Appendix-H).

Table 4.10. T-test analysis (Equal Variances) of energy consumption per square meter based on the location of the hall space of the-single story houses with basement

	Side Hall	Central Hall
Mean	299.87375	273.1370833
Variance	1417.439998	689.5696998
Observations	24	24
Pooled Variance	1053.504849	
Hypothesized Mean Difference	0	
df	46	
t Stat	2.853511421	
P(T<=t) one-tail	0.003230382	
t Critical one-tail	1.678660414	
P(T<=t) two-tail	0.006460763	
t Critical two-tail	2.012895599	

Furthermore, a single factor (one way) ANOVA was repeated for the parameters of 4 different plan types, including buildings with basement regarding total energy consumption based on the null hypothesis H0:τi=0; there is no relation among energy consumption according to interior space organization. The mean square between groups is 12795.73 and the mean square within groups is 423.91. Means of groups are respectively 255.33, 294.03, 330.29 and 269.46 (Table 4.11). Due to the analysis F critic (α=0.05, 3, 2.8165 for 44) is less than F value, 30.1847. The P-value, 9.32627E-11 is higher than the 5% level of significance; thus, the null hypothesis is rejected. Briefly, it was observed that plan type is an effective parameter on total energy consumption per square meter for buildings with a basement.

Table 4.11. Variance analysis of energy consumption per square meter based on plan types of the single-story houses with basement

Groups	Count	Sum	Average	Variance		
TYPE 1	12	3064.01	255.33	536.5095		
TYPE 2	12	3491.28	290.94	213.8042		
TYPE 3	12	3963.47	330.29	445.8120		
TYPE 4	12	3233.5	269.46	499.5315		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	38387.19	3	12795.73	30.1847	9.32627E-11	2.8165
Within Groups	18652.23	44	423.91			
Total	57039.42	47				

Besides, to understand the strength of the relationship between the location of the hall and the total energy consumption per total square meter, Pearson correlation analysis was repeated. The correlation factor between the hall locations and total energy consumption per square meter is 0.39, which means there is a moderate degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that, as hall location changes from center to side the energy consumption increases.

According to the results of these statistical analyses, it was understood that the interior space organization statistically has a significant effect on energy consumption for the buildings with the basement. It can be concluded that in terms of energy consumption, the effect of the basement was very strong, which statistically suppressed the influence of the interior space organization. Also, in both types of statistical analyses implied to the single-story houses; however the interior space organization found out as significant or not, it was observed that total energy consumption of İzmir houses with side hall plans is higher than the houses with central hall plans.

4.2.3. **Relationship Between The Basement and The Total Energy Consumption Per Square Meter**

The two-story İzmir Houses' relation between the utilization of basement as a room or a ventilation space and the absence of basement space with the total energy consumption per total square meter, was analyzed by using single-factor ANOVA, T-test assuming equal and unequal variables and Pearson correlation methods.

A single factor (one way) ANOVA was conducted for the existence of the basement regarding total energy consumption based on the null hypothesis $H0:\tau i=0$; there is no relation among energy consumption according to the basement. The mean square between groups is 40651.55, and the mean square within groups is 77972.27. Means of groups are respectively 236.07, 239.41, and 308.11. (Table 4.12). Due to the analysis F critic ($\alpha=0.05$, 2, 3.1951 for 47).is less than F value, 12.2519. The P-value, 5.2186E-05 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that the utilization of the basement varies significantly according to energy consumption. Briefly, it was observed that the existence of the basement is an effective parameter on total energy consumption per square meter.

Table 4.12. Variance analysis of energy consumption per square meter based on the basement of the two-story houses

Groups	Count	Sum	Average	Variance		
Basement as a room	30	7082.03	236.07	1068.4223		
Basement as a ventilation space	10	2394.1	239.41	1342.6274		
Absence of basement	10	3081.14	308.11	3878.2637		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	40651.55	2	20325.78	12.2519	5.2186E-05	3.1951
Within Groups	77972.27	47	1658.98			
Total	118623.82	49				

In addition, to understanding the strength of the relationship between the existence of the basement and the total source energy consumption per total square meter, Pearson correlation analysis was performed. The correlation factor between these variables is 0.52, which means there is a high degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that the energy consumption increases when the basement does not exist.

Furthermore, t-test assuming unequal and equal variances and Pearson correlation analyses were conducted only for two-story buildings with basements to understand the different utilization of the basement spaces' effect on energy consumption. According to the results of these statistical analyses, it was understood that the basement utilization differences due to the volumetric differences do not have a significant effect on energy consumption. There is not any relationship between these variables.

The single-story İzmir Houses' relation between the use of the basement as a room or a ventilation space or the absence of basement and the total energy consumption per total square meter was analyzed by using t-test and Pearson correlation methods.

A single factor (one way) ANOVA was conducted for the utilization of basement spaces regarding total energy consumption based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to interior space organization. The mean square between groups is 290688.82, and the mean square within groups is 1244.59. Means of groups are respectively 280.38, 298.76, and 505.93. (Table 4.13). Due to the analysis F critic ($\alpha=0.05$, 2, 3.1478 for 61).is less than F value, 233.561. The P-value, 2.56541E-29 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that the utilization of the basement varies significantly according to energy consumption. Briefly, it was observed that the utilization of the basement is an effective parameter on total energy consumption per square meter.

Table 4.13. Variance analysis of energy consumption per square meter based on the utilization of the basement of the single-story houses

Groups	Count	Sum	Average	Variance		
Basement as a room	32	8972.16	280.38	1330.462897		
Basement as a ventilation space	16	4780.1	298.76	812.8716917		
Absence of basement	16	8094.91	505.93	1498.853816		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	581377.6	2	290688.82	233.5611651	2.56541E-29	3.1478
Within Groups	75920.23	61	1244.59			
Total	657297.9	63				

Besides analyzing the strength of the relationship between the use of the basement and the source energy consumption per total square meter, Pearson correlation analysis was performed. The correlation factor between these variables is 0.85, which means there is a high degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that as the basement use changes from room to ventilation space, the energy consumption increases.

In addition, t-test assuming unequal and equal variances and Pearson correlation analyses were conducted only for single-story buildings with basements to understand the different utilization of the basement spaces' effect on energy consumption. Due to the t-test (unequal variances) analysis result, there was a significant difference in the scores for the utilization of the basement as a room (M=280.38) and as a ventilation space (M=298.75) locations; t Stat (37)=-1.91, t Critical two-tail=2.02, p = 0.06(Table 4.14). The -t Stat is higher than -t critical two tail and P two-tail value is higher than 5% level of significance, so the null hypothesis was accepted. These results suggest that the different utilization of the basement does not affect the total energy consumption. Also, this t-test assuming equal variances was consistent with the t test assuming equal variances for the same parameters. Regarding the t-test (equal variances) analysis result, there was not a significant difference in the scores for side hall and central hall locations; t Stat (46) =-1.76, t Critical two-tail=2.01, p = 0.08 (Appendix-H).

Table 4.14. T-test analysis (Unequal Variances) of energy consumption per square meter based on the utilization of the basement of the-single story houses

	Basement as a room	Basement as ventilation space
Mean	280.38	298.75625
Variance	1330.462897	812.8716917
Observations	32	16
Hypothesized Mean Difference	0	
df	37	
t Stat	-1.91189709	
P(T<=t) one-tail	0.031828445	
t Critical one-tail	1.68709362	
P(T<=t) two-tail	0.063656889	
t Critical two-tail	2.026192463	

Besides, in order to analyze the strength of the relationship between the different utilization of the basement due to the volumetric reasons and the total energy consumption per total square meter, Pearson correlation analysis was performed. The correlation factor between these variables is 0.25, which means there is a low degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that, as the basement utilization changes from room to ventilation space the energy consumption increases.

According to the results of these statistical analyses based on energy consumption for single-story İzmir Houses, it was examined that the absence of the basement is more effective than the different utilization of the basement.

4.2.4. Relationship Between Orientation and The Total Energy Consumption Per Square Meter

The two-story İzmir Houses' relation between the orientation and the total energy consumption per total square meter, was analyzed by using t-test and Pearson correlation methods. The main entrance facing Southwest and Northeast were chosen as the parameters because these are the most common directions seen in Alsancak.

T-tests based on two samples assuming both unequal and equal variances were conducted to compare the orientation within total energy consumption at a 5% level of significance. (α=0.05) The null hypothesis $H0:\tau i=0$; there is no relation among energy consumption according to orientation. Regarding the t-test (equal variances) analysis result, there wasn't a significant difference in the scores for entrance facing Southwest (M=254.77 kWh/square meter) and Northeast (M=247.52 kWh/square meter) locations; t Stat (48)= 0.52, t Critical two-tail=2.01, p = 0.60 (Table 4.15). The t Stat is less than t critical two tail and the P two-tail value is higher than the 5% level of significance, so the null hypothesis explained above is accepted. Also, this t-test assuming equal variances was consistent with the t test assuming unequal variances for the same parameters. Regarding the t-test (unequal variances) analysis result; t Stat (48) =0.52, t Critical two-tail=2.01, p = 0.60, there is no relationship among these variables. (Appendix-H).

Table 4.15. T-test analysis (Equal Variances) of energy consumption per square meter based on the orientation of the two-story houses

	Entrance Facing Southwest	Entrance Facing Northeast
Mean	254.7716	247.5192
Variance	2428.966956	2486.297699
Observations	25	25
Pooled Variance	2457.632328	
Hypothesized Mean Difference	0	
df	48	
t Stat	0.517223561	
P(T<=t) one-tail	0.303687743	
t Critical one-tail	1.677224196	
P(T<=t) two-tail	0.607375486	
t Critical two-tail	2.010634758	

Furthermore, for analyzing the strength of the relationship between the orientation and the total energy consumption per total square meter, Pearson correlation analysis was performed. The correlation factor between these variables is -0.07, which means there is no relationship between these variables.

Besides, the t-test assuming unequal and equal variances and Pearson correlation analyses were repeated only for buildings with basements in order to analyze their orientations' effect on energy consumption. According to the results of these statistical analyses, it was observed that there is no relationship between the orientation of the building and the total source energy consumption per square meter.

The single-story İzmir Houses' relation between the orientation and the total energy consumption per total square meter, was analyzed by using ANOVA and Pearson correlation methods. The main entrance facing Southwest, Northeast Northwest, and Southeast were chosen as the parameters because these are the most common directions seen in Buca.

A single factor (one way) ANOVA was conducted for the parameters of 4 different plan orientations regarding total energy consumption based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to interior space organization. The mean square between groups is 651.54, and the mean square within groups is 10922.39. Means of groups are respectively 333.07, 348.60, 341.48, and 342.30 (Table 4.16). Due to the analysis F critic ($\alpha=0.05$, 3, 2.7581 for 60) is higher than

F value, 0.0597. The P-value, 0.980725, is higher than the 5% level of significance; thus, the null hypothesis is accepted meaning that there is no relation among total energy consumption per square meter according to orientation.

Table 4.16. Variance analysis of energy consumption per square meter based on the orientation of the single-story houses

Groups	Count	Sum	Average	Variance		
Entrance Faces Southwest	16	5329.06	333.07	11179.20		
Entrance Faces Northeast	16	5577.67	348.60	10606.77		
Entrance Faces Northwest	16	5463.64	341.48	11333.25		
Entrance Faces Southeast	16	5476.8	342.30	10570.33		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1954.63	3	651.54	0.0597	0.980725	2.7581
Within Groups	655343.24	60	10922.39			
Total	657297.87	63				

Besides understanding the strength of the relationship between the orientation and the source energy consumption per total square meter, Pearson correlation analysis was performed. The correlation factor between these variables is -0.03, which means there is no relationship between these variables.

Furthermore, a single factor ANOVA and Pearson correlation analyses were repeated only for two-story buildings with basements to understand the effect of orientation on energy consumption. According to the results of these statistical analyses, it was understood that the orientation does not have a significant effect on energy consumption. There is not any relationship between these variables.

4.2.5. **Relationship Between The Roof Occupancy and The Total Energy Consumption Per Square Meter**

The two-story İzmir Houses' relation between the occupancy of the roof, which determines the roof heating and the total energy consumption per total square meter, was analyzed by using the t-test and Pearson correlation methods.

T-tests based on two samples assuming both unequal and equal variances were conducted to compare the use of the basement within total energy consumption at a 5% level of significance. (α=0.05) The null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to the occupancy of the roof. Regarding the t-test (unequal variances) analysis result, there was a significant difference in the scores for the roof occupied (M=249.55 kWh/square meter) and roof unoccupied (M=230.09 kWh/square meter) locations; t Stat (36)= 2.05, t Critical two-tail=2.03, p = 0.047 (Table 4.17). The t Stat is higher than t critical two tail and the P two-tail value is lower than the 5% level of significance, so the null hypothesis is rejected. But this t-test assuming unequal variances was not consistent with the t test assuming equal variances for the same parameters. Regarding the t-test (equal variances) analysis result; t Stat (38) =1.81, t Critical two-tail=2.02, p = 0.07, there is no relationship among these variables. (Appendix-H).

Table 4.17. T-test analysis (Unequal Variances) of energy consumption per square meter based on the roof occupancy of the two-story houses

	Roof occupied heated	Roof unoccupied unheated
Mean	249.5492857	230.0938462
Variance	557.8310071	1298.215841
Observations	14	26
Hypothesized Mean Difference	0	
df	36	
t Stat	2.053335105	
P(T<=t) one-tail	0.023680089	
t Critical one-tail	1.688297714	
P(T<=t) two-tail	0.047360179	
t Critical two-tail	2.028094001	

In addition, to understanding the strength of the relationship between the occupancy of the roof and the total energy consumption per total square meter, Pearson correlation analysis was performed. The correlation factor between these variables is -0.05, which means there is not a relationship between these variables.

Besides, the t-test assuming unequal and equal variances and Pearson correlation analyses were repeated only for the buildings with the basement to analyze the heating of the roof's effect on energy consumption. According to the results of these statistical analyses, it was examined that there is no significant relationship between the roof heating and the total source energy consumption per square meter.

Since the occupancy of the roof is not observed in single-story İzmir Houses, the effect of this parameter on energy consumption has not been examined within the scope of the mentioned buildings.

4.2.6. **Relationship Between Existence of Oriel and The Total Energy Consumption Per Square Meter**

The two-story İzmir Houses' relation between the existence of the oriel and the total energy consumption per total square meter, was analyzed by using t-test and Pearson correlation methods.

T-tests based on two samples assuming both unequal and equal variances were conducted to compare the use of the basement within total energy consumption at a 5% level of significance. (α=0.05) The null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to the occupancy of the roof. Regarding the t-test (unequal variances) analysis result, there was a significant difference in the scores for the oriel exists (M=255.17 kWh/square meter) and oriel does not exist (M=235.06 kWh/square meter) locations; t Stat (21)= 1.50, t Critical two-tail=2.08, p = 0.14 (Table 4.18). The t Stat is less than t critical two tail and the P two-tail value is higher than the 5% level of significance, so the null hypothesis explained above is accepted. Also, this t-test assuming unequal variances was consistent with the t test assuming equal variances for the same parameters. Regarding the t-test (equal variances) analysis result; t Stat (38) =1.15, t Critical two-tail=2.02, p = 0.25, there is no relationship among these variables. (Appendix-H).

Table 4.18. T-test analysis (Unequal Variances) of energy consumption per square meter based on the existence of the oriel of the two-story houses

	Oriel Exist	Oriel Not Exit
Mean	255.1665	235.061
Variance	2700.192054	1120.275432
Observations	40	10
Hypothesized Mean Difference	0	
df	21	
t Stat	1.500526006	
P(T<=t) one-tail	0.07418213	
t Critical one-tail	1.720742903	
P(T<=t) two-tail	0.148364261	
t Critical two-tail	2.079613845	

Furthermore, for analyzing the strength of the relationship between the existence of the oriel and the total energy consumption per total square meter, Pearson correlation analysis was performed. The correlation factor between these variables is -0.17, which means there is a low degree of negative relationship between these variables. The relationship between these variables is negative, which indicates that as the oriel exists, the total energy consumption per square meter increases.

Since there is no oriel at the single-story İzmir Houses, the effect of this parameter on energy consumption has not been examined within the scope of the mentioned buildings.

Besides, the t-test assuming unequal and equal variances and Pearson correlation analyses were repeated only for the buildings with the basement to analyze the effect of oriel on energy consumption. Due to the results of these statistical analyses, it was examined that there is no significant relationship between the oriel and the total source energy consumption per square meter.

4.2.7. **Relationship Between Gross Window to Wall Ratio and The Total Energy Consumption Per Square Meter**

The first analysis to determine the relationship between gross window to wall ratio and the energy consumption per total square meter for both two and single-story İzmir

Houses with and without basement was the Pearson correlation method. Then the scatter charts of these parameters were drawn to understand the effective groups. After that, ANOVA analyses were performed for these groups' relation within the total energy consumption per square meter.

The correlation factor of the two-story İzmir houses between gross window to wall ratio and total energy consumption per square meter is 0.41, which means there is a moderate degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that the energy consumption increases when, window to wall ratio increases.

The window to wall ratios were grouped as .0.10, 0.11, 0.12, 0.13, 0.14, 0.15 according to the scatter chart (Figure 4.8). A single factor (one way) ANOVA test conducted for these variables was based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to the gross window to wall ratio. The mean square between groups is 12802.87, and the mean square within groups is 1241.12. Means of groups are respectively 219.74, 240.64, 212.55, 254.08, 325.05 and 240.36 (Table 4.19). Due to the analysis F critic (α=0.05, 5, 2.4270 for 44).is less than F value, 10.3155. The P-value, 1.36812E-06 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that gross window to wall ratio varies significantly according to energy consumption. Briefly, it was observed that gross window to wall ratio is an effective parameter on total energy consumption per square meter.

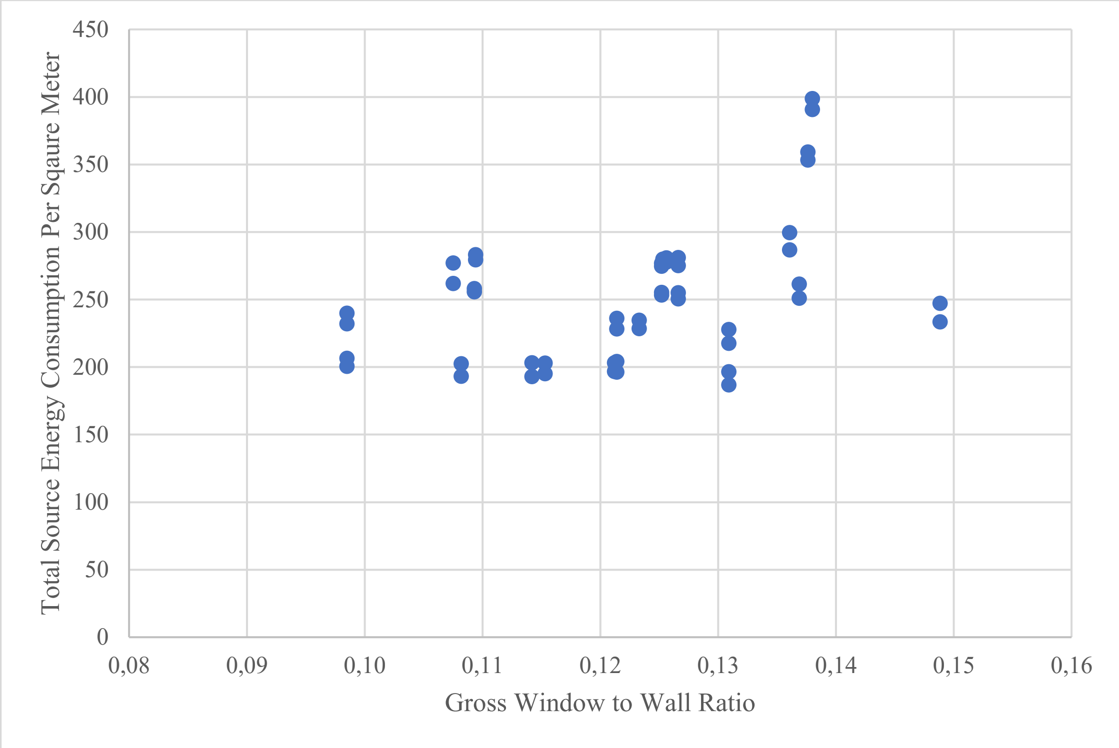


Figure 4.8. The distribution of the total energy consumption per square meter based on the window to wall ratio of the two-story houses

Table 4.19. Variance analysis of energy consumption per square meter based on the gross window to wall ratio of the two-story houses

Groups	Count	Sum	Average	Variance		
wwr 0.10	4	878.97	219.74	366.8002		
wwr 0.11	10	2406.43	240.64	1445.9427		
wwr 0.12	10	2125.47	212.55	290.5034		
wwr0.13	16	4065.26	254.08	963.5471		
wwr0.14	8	2600.42	325.05	3333.1160		
wwr0.15	2	480.72	240.36	96.0498		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	64014.34	5	12802.87	10.3155	1.36812E-06	2.4270
Within Groups	54609.48	44	1241.12			
Total	118623.82	49				

Besides, single-factor ANOVA and Pearson correlation analyses were repeated only for the two-story buildings with basement to examine the effect of the window to wall ratio on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is positive, which indicates that the energy consumption increases when, window to wall ratio increases. But different than the analyses implied all the 50 BES models, there is a low degree relationship between the energy consumption and the window to wall ratio. Also, the ANOVA analysis result shows a significant relationship between these variables.

The correlation factor of the single-story İzmir houses between gross window to wall ratio and total energy consumption per square meter is 0.08, which means there is no relationship between these variables.

However, the window to wall ratios were grouped as 0.05-0.08, 0.09- 0.1, 0.11, 0.13 according to the scatter chart (Figure 4.8) and a single factor (one way) ANOVA test conducted for these variables was based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to gross window to wall ratio. The mean square between groups is 58655.37, and the mean square within groups is 7164.01. Means of groups are respectively 299.05, 406.73, 297.43, 407.65, and 227.44 (Table 4.20). Due to the analysis F critic (α=0.05, 4, 2.5279 for 59) is less than F value, 8.1875. The P-value, 2.54143E-05 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that gross window to wall ratio varies significantly according to energy consumption. Briefly, it was observed that gross window to wall ratio is an effective parameter on total energy consumption per square meter.

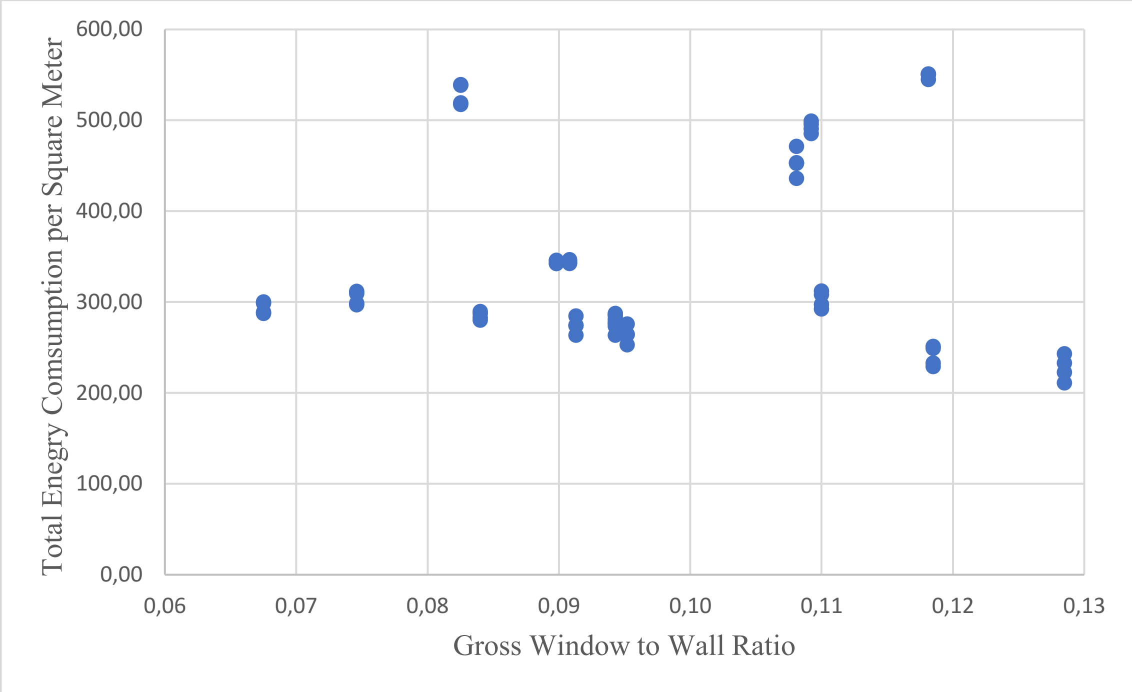


Figure 4.9. The distribution of the total energy consumption per square meter based on the window to wall ratio of the single-story houses

Table 4.20. Variance analysis of energy consumption per square meter based on the gross window to wall ratio of the single-story houses

Groups	Count	Sum	Average	Variance		
wwr 0.07	8	2392.39	299.05	73.5564		
wwr 0.08	8	3253.86	406.73	17038.5982		
wwr 0.09-0.10	24	7138.24	297.43	1205.6110		
wwr 0.11-0.12	20	8152.92	407.65	14452.4361		
wwr 0.13	4	909.76	227.44	188.6524		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	234621.5	4	58655.37	8.1875	2.54143E-05	2.5279
Within Groups	422676.4	59	7164.01			
Total	657297.9	63				

Besides, single-factor ANOVA and Pearson correlation analyses were repeated only for the single-story buildings with basement to examine the effect of the window to wall ratio on energy consumption. But different than the analyses implied all the 50 BES models of single-story İzmir Houses, there is a high degree (-0.56) a negative relationship between the energy consumption and the window to wall ratio, which indicates that the energy consumption increases when, window to wall ratio decreases. Also, the ANOVA analysis result again shows a significant relationship between these variables.

According to the results of these statistical analyses, it was understood that the window to wall ratio statistically has a significant effect on energy consumption for the buildings with or without basement in different level of impacts. Also, it can be concluded that in terms of energy consumption, the effect of the basement was very strong, which statistically suppressed the influence of the window to wall ratio.

4.2.8. **Relationship Between Gross Wall to Floor Ratio and The Total Energy Consumption Per Square Meter**

The analysis process to determine the relationship between gross wall to floor ratio and the energy consumption per total square meter for both two and single-story İzmir Houses is same as the analysis process of the window to wall ratio parameter.

The correlation factor of the two-story İzmir houses with and without the basement between gross wall to floor ratio and total energy consumption per square meter is 0.73, which means there is a high degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that the energy consumption increases when the gross wall to floor ratio increases.

The wall to floor ratios were grouped as 0.61-0.68, 0.95-1.08, 1.19-1.20, according to the scatter chart (Figure 4.10). A single factor (one way) ANOVA test conducted for these variables was based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to the gross wall to floor ratio. The mean square between groups is 44053.51, and the mean square within groups is 649.29. Means of groups are respectively 211.48, 227.44, 243.51, 280.20 and 280.77 (Table 4.21). Due to the analysis F critic ($\alpha=0.05$, 2, 3.1951 for 47) is less than F value, 67.8484. The P-value, 1.39196E-14 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that gross wall to floor ratio varies significantly according to energy consumption. Briefly, it was observed that the gross wall to floor ratio is an effective parameter on total energy consumption per square meter.

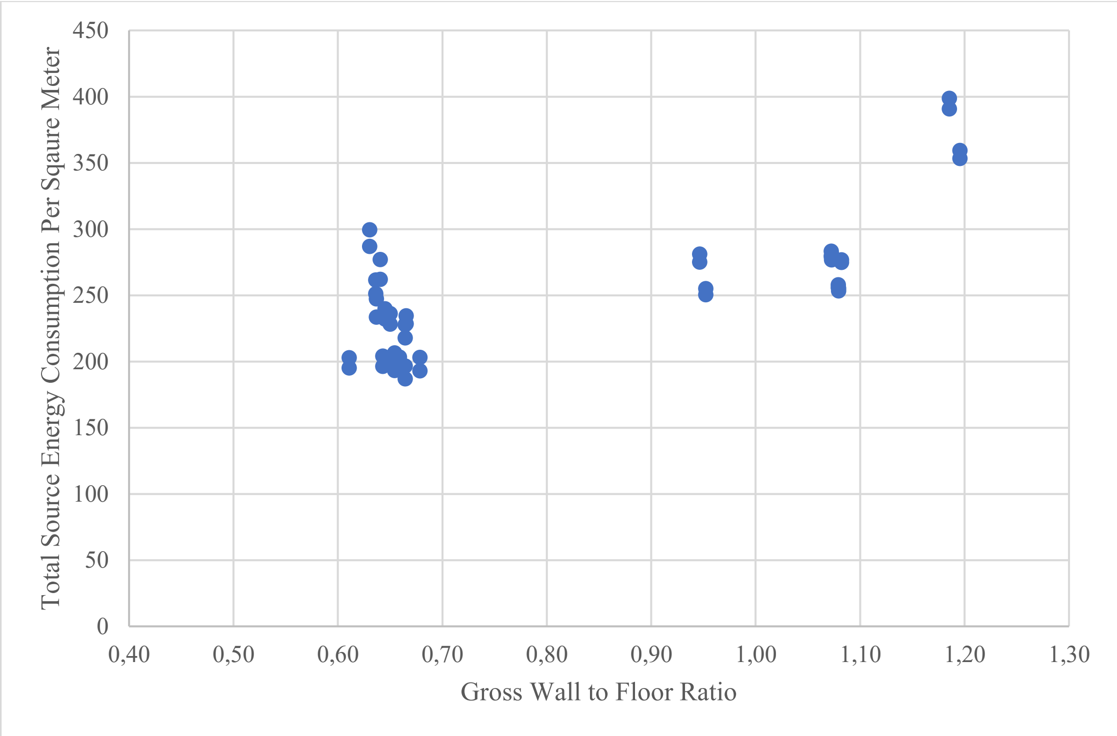


Figure 4.10. The distribution of the total energy consumption per square meter based on wall to floor ratio of the two-story houses

Table 4.21. Variance analysis of energy consumption per square meter based on gross wall to floor ratio of the two-story houses

Groups	Count	Sum	Average	Variance		
wafr 0.61-0.68	30	6742.73	224.76	922.0754		
wafr 0.95-1.08	16	4312.77	269.55	149.9563		
wafr 1.19-1.20	4	1501.77	375.44	509.0904		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	88107.01	2	44053.51	67.8484	1.39196E-14	3.1951
Within Groups	30516.80	47	649.29			
Total	118623.82	49				

Besides, single-factor ANOVA and Pearson correlation analyses were repeated for only the two-story buildings with basement to analyze the effect of the wall to floor ratio on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is high degree positive, which indicates that the energy consumption increases when, wall to floor ratio increases. Also, the ANOVA analysis result shows a significant relationship between these variables.

The correlation factor of the single-story İzmir houses with and without the basement between gross wall to floor ratio and total energy consumption per square meter is 0.54, which means there is a high degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that the energy consumption increases when the gross wall to floor ratio increases.

The wall to floor ratios were grouped as 0.98-1.32, 1.37-1.51, 1.58, 1.84, 1.93-2.05, 2.3-2.51, according to the scatter chart (Figure 4.11). A single factor (one way) ANOVA test conducted for these variables that was based on the null hypothesis H0:τi=0; there is no relation among energy consumption according to the gross wall to floor ratio. The mean square between groups is 103389.74, and the mean square within groups is 648.41. Means of groups are respectively 270.29, 490.96, 284.88, 492.65, 323.34, 549.17 and 344.18 (Table 4.22). Due to the analysis F critic (α=0.05, 6, 2.2625 for 57) is less than F value, 159.4510 The P-value, 9.51747E-34 is less than 5% level of significance; thus, the null hypothesis is rejected meaning that gross wall to floor ratio varies significantly according to energy consumption. Briefly, it was observed that the gross wall to floor ratio is an effective parameter on total energy consumption per square meter.

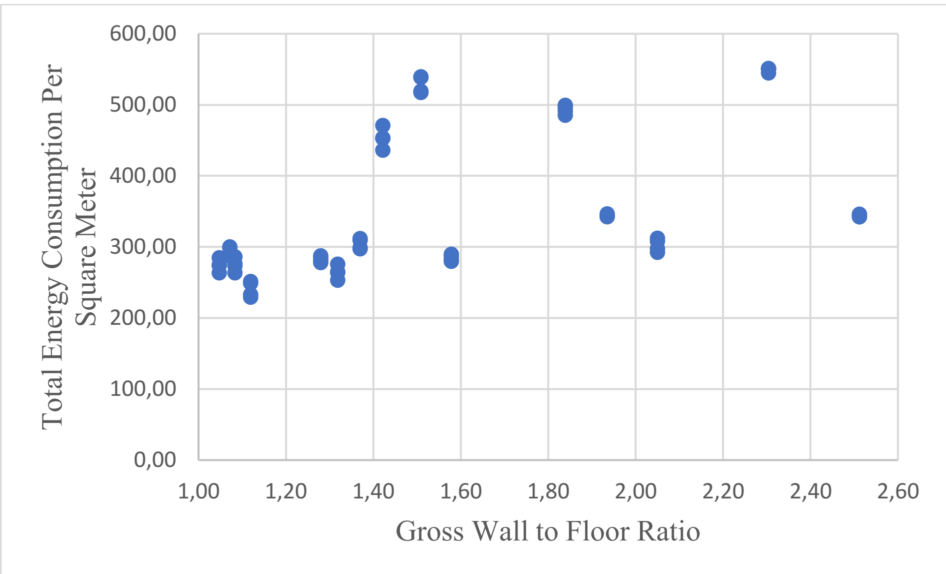


Figure 4.11. The distribution of the total energy consumption per square meter based on wall to floor ratio of the single-story houses

Table 4.22. Variance analysis of energy consumption per square meter based on gross wall to floor ratio of the single-story houses

Groups	Count	Sum	Average	Variance		
wafr 0.98-1.32	32	8649.28	270.29	666.1418		
wafr 1.37-1.51	8	3927.65	490.96	1766.8330		
wafr 1.58	4	1139.51	284.88	18.7376		
wafr 1.84	4	1970.6	492.65	37.3359		
wafr 1.93-2.05	8	2586.75	323.34	533.4717		
wafr 2.3	4	2196.66	549.17	8.9228		
wafr 2.51	4	1376.72	344.18	3.9662		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	620338.45	6	103389.74	159.4510	9.51747E-34	2.2625
Within Groups	36959.42	57	648.41			
Total	657297.87	63				

Besides, single-factor ANOVA and Pearson correlation analyses were repeated for only the single-story buildings with basement to analyze the effect of the wall to floor ratio on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is high degree (0.79) positive, which indicates that the energy consumption increases when, wall to floor ratio increases. Also, the ANOVA analysis result shows a significant relationship between these variables.

4.2.9. Relationship Between Gross Window to Floor Ratio and The Energy Consumption Per Total square meter

The analysis process to determine the relationship between gross window to floor ratio and the energy consumption per total square meter for both two and single-story İzmir Houses is same as the analysis process of the window to wall ratio parameter.

The correlation factor of the two-story İzmir houses with and without the basement between gross window to floor ratio and total energy consumption per square meter is 0.80, which means there is a high degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that the energy consumption increases when the gross window to floor ratio increases.

The window to floor ratios were grouped as 0.06-0.09, 0.12-0.14, 0.16, according to the scatter chart (Figure 4.12). A single factor (one way) ANOVA test conducted for these variables was based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to the gross window to floor ratio. The mean square between groups is 44053.51, and the mean square within groups is 649.29. Means of groups are respectively 224.76, 269.55 and 375.44 (Table 4.23). Due to the analysis F critic ($\alpha=0.05$, 2, 3.1951 for 47) is less than F value, 67.8484. The P-value, 1.39196E-14 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that gross window to wall ratio varies significantly according to energy consumption. Briefly, it was observed that gross window to floor ratio is an effective parameter on total energy consumption per square meter.

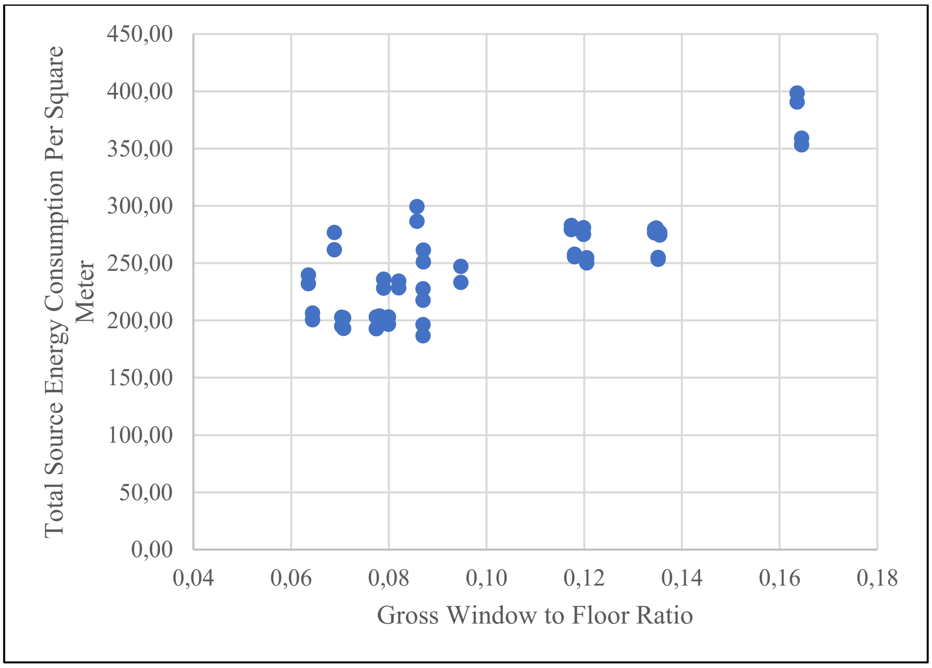


Figure 4.12. The distribution of the total energy consumption per square meter based on the window to floor ratio of the two-story houses

Table 4.23. Variance analysis of energy consumption per square meter based on the gross window to floor ratio of the two-story houses

Groups	Count	Sum	Average	Variance		
wfr 0.06-0.09	30	6742.73	224.76	922.0754		
wfr 0.12-0.14	16	4312.77	269.55	149.9563		
wfr 0.16	4	1501.77	375.44	509.0904		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	88107.01	2	44053.51	67.8484	1.39196E-14	3.1951
Within Groups	30516.80	47	649.29			
Total	118623.82	49				

In addition, t-test assuming unequal and equal variances and Pearson correlation analyses were conducted only for the two-story buildings with basement to understand the effect of the wall to floor ratio on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is high degree positive, which indicates that the energy consumption increases when, wall to floor ratio increases. Also, the t-test analyses show a significant relationship between these variables.

The correlation factor of the single-story İzmir houses with and without the basement between gross window to floor ratio and total energy consumption per square meter is 0.54, which means there is a high degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that the energy consumption increases when the gross window to floor ratio increases.

The window to floor ratios of these houses were grouped as 0.07-0.1, 0.12-0.13, 0.15, 0.18, 0.20, 0.23, 0.27 according to the scatter chart (Figure 4.13). A single factor (one way) ANOVA test conducted for these variables that was based on the null hypothesis H0:τi=0; there is no relation among energy consumption according to the gross window to wall ratio. The mean square between groups is 66144.51, and the mean square within groups is 4568.96. Means of groups are respectively 286.74, 304.81, 453.33, 344.18, 492.65, 323.34, 549.17 (Table 4.24). Due to the analysis F critic (α=0.05, 6, 2.2625 for 57) is less than F value, 14.4769. The P-value, 5.95894E-10 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that gross window to wall ratio varies significantly according to energy consumption. Briefly, it was observed that gross window to floor ratio is an effective parameter on total energy consumption per square meter.

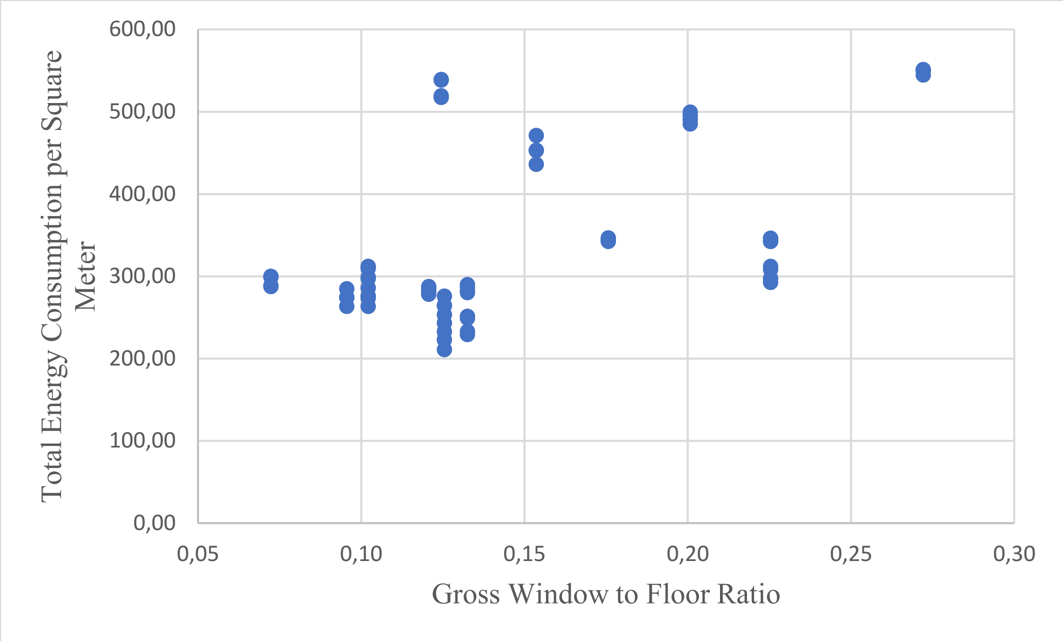


Figure 4.13. The distribution of the total energy consumption per square meter based on the window to floor ratio of the single-story houses

Table 4.24. Variance analysis of energy consumption per square meter based on the gross window to floor ratio of the single-story houses

Groups	Count	Sum	Average	Variance		
wfr 0.07-0.1	16	4587.78	286.74	228.0979		
wfr 0.12-0.13	24	7315.36	304.81	10978.7082		
wfr 0.15	4	1813.30	453.33	204.6991		
wfr 0.18	4	1376.72	344.18	3.3715		
wfr 0.20	4	1970.60	492.65	37.3359		
wfr 0.23	8	2586.75	323.34	533.7266		
wfr 0.27	4	2196.66	549.17	8.9228		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	396867.04	6	66144.51	14.4769	5.95894E-10	2.2625
Within Groups	260430.83	57	4568.96			
Total	657297.87	63				

In addition, single-factor ANOVA (one way) and Pearson correlation analyses were conducted only for the single-story buildings with basement to understand the effect of the window to floor ratio on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is high degree positive (0.51), which indicates that the energy consumption increases when, wall to floor ratio increases. Also, the t-test analyses show a significant relationship between these variables.

4.2.10. Relationship Between Total Building Area and The Energy Consumption Per Total Square Meter

The analysis process to determine the relationship between total building area and the energy consumption per total square meter for both two and single-story İzmir Houses is same as the analysis process of the window to wall ratio parameter.

The correlation factor of the two-story İzmir houses with and without the basement between total building area and total energy consumption per square meter is -0.84, which means there is a moderate degree of negative relationship between these variables. The relationship between these variables is negative, which indicates that the energy consumption decreases when the total building area increases.

The total building areas were grouped as 291-295, 328-339, 345, according to the scatter chart (Figure 4.14). A single factor (one way) ANOVA test conducted for these variables was based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to the total building area. The mean square between groups is 26409.41, and the mean square within groups is 288.58. Means of groups are respectively 375.44, 263.23, 269.55, 210.20 and 269.43 (Table 4.25). Due to the analysis F critic (α=0.05, 4, 2.5787 for 45) is less than F value, 91.5146. The P-value, 5.09837E-21 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that total building area varies significantly according to energy consumption. Briefly, it was observed that the total building area is an effective parameter on total energy consumption per square meter.

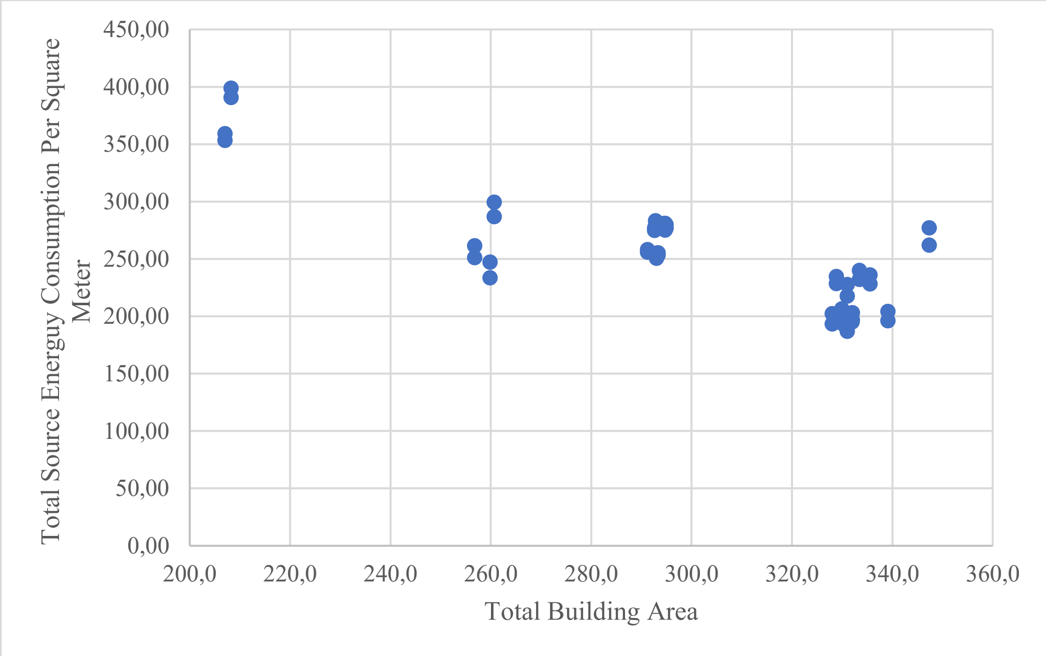


Figure 4.14. The distribution of the total energy consumption per square meter based on total building area of the two-story houses

Table 4.25. Variance analysis of energy consumption per square meter based on a total building area of the two-story houses

Groups	Count	Sum	Average	Variance		
building area 207-208	4	1501.77	375.44	509.0904		
building area 256-261	6	1579.37	263.23	631.2511		
building area 291-295	16	4312.77	269.55	149.9563		
building area 328-339	22	4624.5	210.20	282.7943		
building area 348	2	538.86	269.43	114.6098		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	105637.66	4	26409.41	91.5146	5.09837E-21	2.5787
Within Groups	12986.16	45	288.58			
Total	118623.82	49				

Furthermore, single-factor ANOVA and Pearson correlation analyses were repeated for only the buildings with basement to analyze the effect of total building area on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is high degree negative (-0.83), which indicates that the energy consumption increases when the total building area decreases. Also, the ANOVA analysis result shows a significant relationship between these variables.

The correlation factor of the single-story İzmir houses with and without the basement between total building area and total energy consumption per square meter is -0.61, which means there is a high degree of negative relationship between these variables. The relationship between these variables is negative, which indicates that the energy consumption decreases when the total building area increases.

The total building areas were grouped as 55, 70, 92, 112, 128, 197, 228, according to the scatter chart (Figure 4.14). A single factor (one way) ANOVA test conducted for these variables that was based on the null hypothesis $H0:\tau i=0$; there is no relation among energy consumption according to the total building area. The mean square between groups is 72670.69, and the mean square within groups is 3882.00. Means of groups are respectively 549.17, 492.65, 330.29, 453.33, 334.24, 255.33, and 290.94 (Table 4.25). Due to the analysis F critic ($\alpha=0.05$, 6, 2.2625 for 57).is less than F value, 18.7199. The P-value, 6.85167E-12 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that total building area varies significantly according to energy consumption. Briefly, it was observed that the total building area is an effective parameter on total energy consumption per square meter.

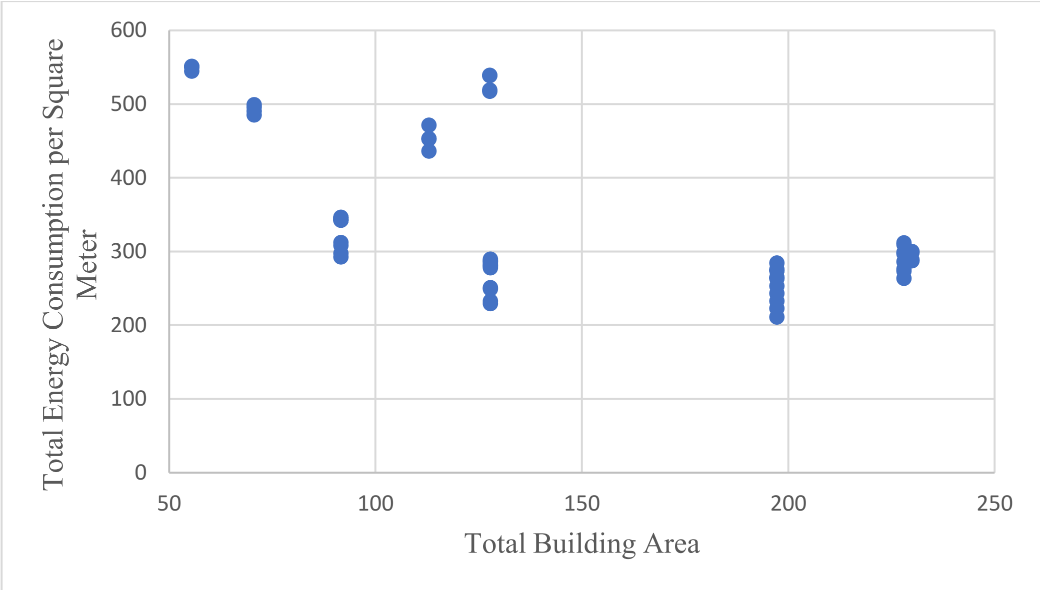


Figure 4.15. The distribution of the total energy consumption per square meter based on a total building area of the single-story houses

Table 4.26. Variance analysis of energy consumption per square meter based on a total building area of the single-story houses

Groups	Count	Sum	Average	Variance		
55m2	4	2196.66	549.17	8.9228		
70m2	4	1970.60	492.65	37.3359		
92 m2	12	3963.47	330.29	445.8120		
112 m2	4	1813.30	453.33	204.6991		
128 m2	16	5347.85	334.24	13824.2312		
197 m2	12	3064.01	255.33	536.5095		
228m2	12	3491.28	290.94	213.8042		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	436024.14	6	72670.69	18.7199	6.85167E-12	2.2625
Within Groups	221273.72	57	3882.00			
Total	657297.86	63				

In addition, single-factor ANOVA and Pearson correlation analyses were repeated for only the buildings with basement to analyze the effect of total building area on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is moderate degree negative (-0.44), which indicates that the energy consumption increases when the total building area decreases. Also, the ANOVA analysis result shows a significant relationship between these variables.

4.2.11. Relationship Between Gross Wall to Volume Ratio and The Energy Consumption Per Total Square Meter

The analysis process to determine the relationship between gross wall to volume ratio and the energy consumption per total square meter for both two and single-story İzmir Houses is same as the analysis process of the window to wall ratio parameter.

The correlation factor of the two-story İzmir houses with and without the basement between gross wall to volume ratio and total energy consumption per square meter is 0.61, which means there is a high degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that the energy consumption decreases when the gross wall to volume ratio decreases.

The gross wall to volume ratio were grouped as 0.20, 0.22-0.25, 0.33-034, according to the scatter chart (Figure 4.16). A single factor (one way) ANOVA test conducted for these variables was based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to the gross wall to volume ratio. The mean square between groups is 31661.69, and the mean square within groups is 1176.61. Means of groups are respectively 263.23, 215.14, and 290.73 (Table 4.27). Due to the analysis F critic ($\alpha=0.05$, 2, 3.1951 for 47).is less than F value, 26.9094. The P-value, 1.626E-08 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that gross wall to volume ratio varies significantly according to energy consumption. Briefly, it was observed that the total building area is an effective parameter on total energy consumption per square meter.

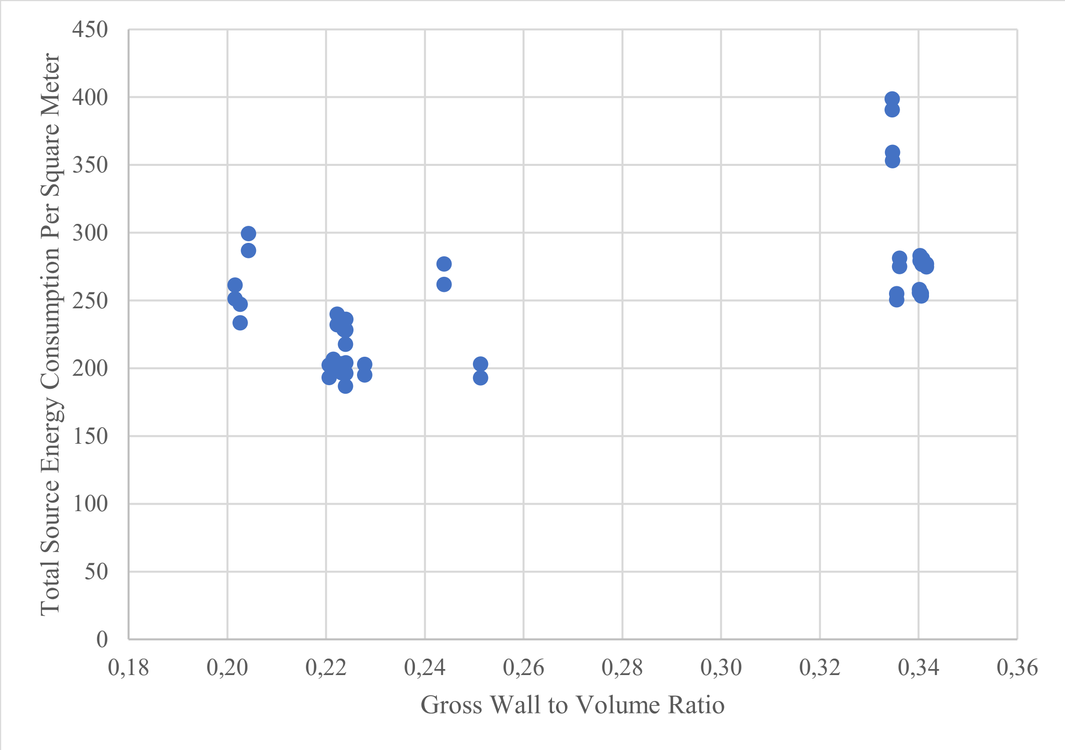


Figure 4.16. The distribution of the total energy consumption per square meter based on the gross wall to volume ratio of the two-story houses

Table 4.27. Variance analysis of energy consumption per square meter based on the gross wall to volume ratio of the two-story houses

Groups	Count	Sum	Average	Variance		
wavr 0.20	6	1579.37	263.23	631.2511		
wavr 0.22-0.25	24	5163.36	215.14	542.7822		
wavr 0.33-0.34	20	5814.54	290.73	2087.3787		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	63323.38	2	31661.69	26.9094	1.626E-08	3.1951
Within Groups	55300.44	47	1176.61			
Total	118623.82	49				

In addition, single-factor ANOVA and Pearson correlation analyses were repeated only for the buildings with the basement to examine the effect of the wall to volume ratio on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is high degree positive, which indicates that the energy consumption increases when, wall to volume ratio increases. Also, the ANOVA analysis result shows a significant relationship between these variables.

The correlation factor of the single-story İzmir houses with and without the basement between gross wall to volume ratio and total energy consumption per square meter is -0.22, which means there is a low degree of positive relationship between these variables. The relationship between these variables is positive, which indicates that the energy consumption increases when the gross wall to volume ratio increases.

The gross wall to volume ratio were grouped as 0.34-0.39, 0.41-0.44, 0.46-0.48, 0.53, 0.54-0.56, 0.67, 0.71-0.87 according to the scatter chart (Figure 4.14). A single factor (one way) ANOVA test conducted for these variables that was based on the null hypothesis $H0{:}\tau i=0$; there is no relation among energy consumption according to the gross wall to volume ratio. The mean square between groups is 84040.17, and the mean square within groups is 2685.21. Means of groups are respectively 247.58, 418.68, 287.51, 492.65, 283.90, 549.17 and 330.29 (Table 4.25). Due to the analysis F critic ($\alpha=0.05$, 6, 2.2625 for 57).is less than F value, 31.2975. The P-value, 2.47661E-16 is less than a 5% level of significance; thus, the null hypothesis is rejected meaning that the gross wall to volume ratio varies significantly according to energy consumption. Briefly, it was observed that the gross wall to volume ratio is an effective parameter on total energy consumption per square meter.

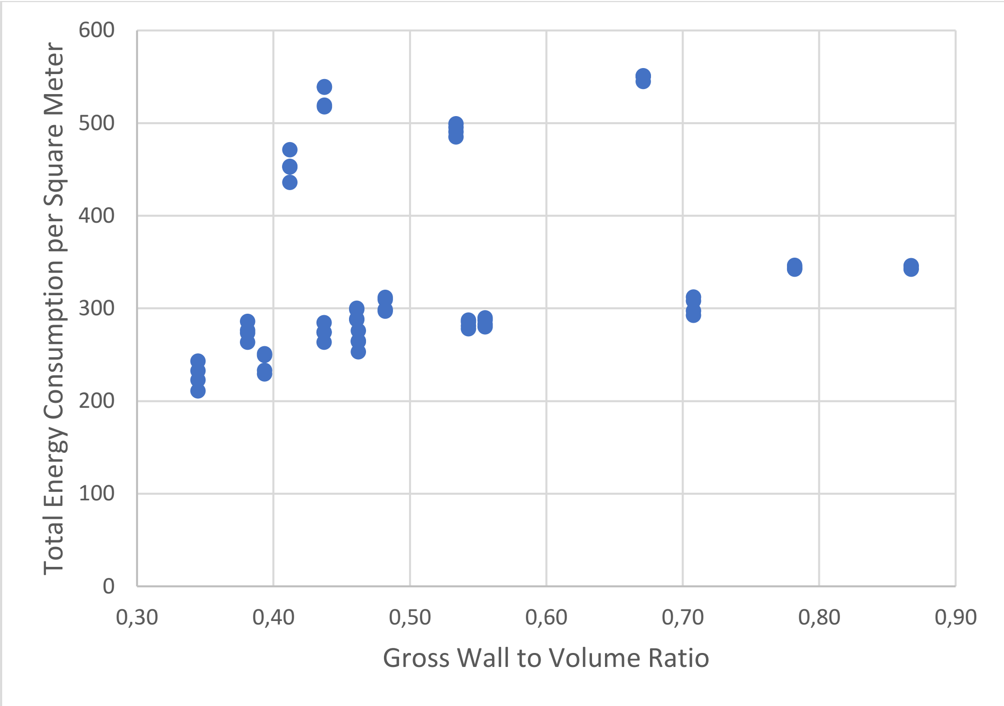


Figure 4.17. The distribution of the total energy consumption per square meter based on the gross wall to volume ratio of the single-story houses

Table 4.28. Variance analysis of energy consumption per square meter based on the gross wall to volume ratio of the single-story houses

Groups	Count	Sum	Average	Variance		
wavr 0.34-0.39	12	2970.98	247.58	542.3365		
wavr 0.41-0.44	12	5024.15	418.68	12542.2421		
wavr 0.46-0.48	12	3450.14	287.51	360.6775		
wavr 0.53	4	1970.6	492.65	37.3359		
wavr 0.54-0.56	8	2271.17	283.90	16.6181		
wavr 0.67	4	2196.66	549.17	8.9228		
wavr 0.71-0.87	12	3963.47	330.29	445.8120		
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	504241.02	6	84040.17	31.2975	2.47661E-16	2.2625
Within Groups	153056.85	57	2685.21			
Total	657297.87	63				

In addition, single-factor ANOVA and Pearson correlation analyses were repeated for only the buildings with basement to analyze the effect of the gross wall to volume ratio on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is high degree positive (0.86), which indicates that the energy consumption increases when, wall to volume ratio increases. Also, the ANOVA analysis result shows a significant relationship between these variables. Besides, it was understood that the basement effect is so strong it suppresses the effect of the wall to volume ratio.

4.2.12. **Relationship Between Settlement Pattern and The Energy Consumption Per Total Square Meter**

The analysis to determine the relationship between settlement pattern and the source energy consumption per total square meter was conducted only for the single-story İzmir Houses with and without basement since the settlement pattern of the Alsancak district is mostly formed by attached buildings.

T-tests based on two samples assuming both unequal and equal variances were conducted to compare the use of the basement within total energy consumption at a 5% level of significance. ($\alpha=0.05$) The null hypothesis $H0:\tau i=0$; there is no relation among energy consumption according to settlement pattern. Regarding the t-test (unequal variances) analysis result, there was a significant difference in the scores for detached (M=368.04 kWh/square meter) and semidetached (M=261.31 kWh/square meter) settlement pattern; t Stat (62)= 6.30, t Critical two-tail=1.99, p = 3.53037E-08 (Table 4.29). The t Stat is higher than t critical two tail and the P two-tail value is less than a 5% level of significance, so the null hypothesis is rejected. These results suggest that the settlement pattern really has an effect on total energy consumption. It was observed that the total energy consumption of single-story İzmir houses in the detached order is higher than the houses in the attached order. Also, this t-test assuming unequal variances was consistent with the t test assuming equal variances for the same parameters. Regarding the t-test (equal variances) analysis result, there was also a significant difference in the scores for detached and attached İzmir Houses Stat (62) =4.03, t Critical two-tail=1.99, p =0,00015(Appendix-H).

Table 4.29. T-test analysis (Unequal Variances) of energy consumption per square meter based on the existence of the oriel of the single-story houses

	Detached	Semidetached
Mean	368.045	261.313125
Variance	10751.70886	1017.81573
Observations	48	16
Hypothesized Mean Difference	0	
df	62	
t Stat	6.29352697	
P(T<=t) one-tail	1.76518E-08	
t Critical one-tail	1.669804163	
P(T<=t) two-tail	3.53037E-08	
t Critical two-tail	1.998971517	

Besides, the correlation factor of the single-story İzmir houses between settlement patterns and total energy consumption per square meter is -0.46, which means there is a moderate degree of negative relationship between these variables. The relationship between these variables is negative, which indicates that the energy consumption increases when the semidetached settlement pattern of the house changes to detached.

In addition, T-tests based on two samples assuming both unequal and equal variances and Pearson correlation analyses were repeated for only the buildings with the basement to analyze the effect of settlement pattern on energy consumption. Due to the results of the correlation analysis, the relationship between these variables is high degree negative (-0.52), which indicates that the energy consumption increases when the semidetached settlement pattern of the houses changes to detached. Also, T-tests results based on two samples assuming both unequal and equal variances were consistent with the previous analyses that there was a significant relationship between the settlement pattern and the total source energy consumption per square meter.

CHAPTER 5

DISCUSSIONS AND CONCLUSION

This study proposes a method for finding out the significant relation between architectural design parameters and energy consumption of traditional building types for future housing design. The 19th Century İzmir Houses was selected as the case.

Firstly, two base case buildings were chosen from Basmane and Buca districts for understanding the behavior of these existing buildings before modeling and simulating the other variations.by taking daylighting, temperature, relative humidity, and material property measurements.

5.1. Daylighting of Base Case Buildings

It was evaluated that nearly all the measured and evaluated zones of the base case houses satisfy the recommended illuminance value, but much of the zones could not satisfy the uniformity. However, these zones reach the highest uniformity value, neither with their highest nor lowest illuminance values. They reach their highest illuminance values with their medium illuminance values. The average illuminance and uniformity values of the house in Buca are higher than the house in Basmane. And these values were changing according to some factors explained below such as window to wall ratio, window to floor ratio, the direction of the space, the shape of the space, the plan layout of the building, the material properties of the interior walls, the form and location of the openings.

The window to wall ratio and the window to floor ratio are one of the main parameters that affect the daylight performance of the interior spaces. When the rooms of the house in Buca looking at the same direction with nearly the same height such as Z01, Z02, and Z04 were compared, it was seen that the hall Z04 with the biggest window to wall ratio and window to floor ratio was evaluated as the most uniform space. But even these values of the hall Z04 are still not enough for a required second category uniformity. It is the same for the house in Basmane. For instance, the rooms 103 and 108 are facing to the north. Both have a nearly square shape plan layout. Room 103 has a higher window to wall ratio, window to floor ratio, and uniformity values than room 108. The window to wall ratio of the

The form and the location of the openings are the other important factor for daylight analysis. The narrow window openings with a ratio of 1 to 2 and without shading and daylight redirecting system cause sun patches and unbalanced daylighting distribution. However, the window to wall ratios of the rooms are not enough for the required uniformity values. The form of the windows that widening through interior space supports the balance of the distribution of the light in both of the houses. The location of the windows changes visual performance. The window to wall ratios and window to floor ratios of the rooms which have windows in different directions of the house in Basmane is higher than the rooms with windows at the one facade of the house in Buca. However, because of the effects of other factors mentioned above, the uniformity levels of the house in Buca is higher. The analysis is getting complex when a room has windows in different directions. In the rooms with openings in one direction understanding of the daylighting behavior is easier than the rooms which have windows in different directions. So the spatial analysis is needed to understand.

The direction of the rooms is another important factor that affects the uniformity and the brightness of the room. The room Z03 of the house in Buca has a bigger window to wall ratio than the room Z02, but it has less daylight uniformity because of the excessive amount of direct sunlight coming from the southeast direction.

The shape of the rooms is also effective in the daylight distribution inside. The room Z03 of the house in Buca with nearly square shape is most uniform in June noon because of the right angle of the sun rays. However, window to wall ratio and window to floor ratio of the room Z01 is bigger than room Z02 it doesn’t mean that Z01 has more illumination and uniformity value in all the measurement periods during the year. Because both room’s values are not so much different, and both rooms are in a rectangular shape. So, the uniformity values of the rooms were changing due to the sun angles. For instance, the plan of the room Z02 is more like a square, and this affect lighting distribution positively in the days with more direct sun angles. And the room Z01 is most uniform in December morning, while the room Z02 and the hall Z04 is most uniform in September morning because of the mean oblique angle of the sun rays. Sun patches and unbalanced daylighting distribution occurred in the rooms with a rectangular shape. When the house in Basmane was evaluated, it was also understood that the rectangular shape interior spaces such as the entrance hall Z01, the hall 101 had the highest uniformity values when the incidence angle of the sun rays was low in March. The depth of the hall 101 is bigger than the depth of the entrance hall Z01. And, an excessive amount of light is coming through north by the oriel windows and by the windows on the south facade. The entrance door ratio of 1 to 2.3 and the three partied section with windows have a significant role at the brightness of the long and narrow entrance hall. Because of these reasons the hall Z01 had a higher amount of uniformity value than hall 101.

The plan layout is another important factor for the evaluation of the daylight performance of the house. While there is almost no environmental factor to prevent sunlight coming into the base case building in Buca, it is quite high in Basmane. The building in Buca is in a detached order. All the rooms have a direct relationship with the direct sunlight except the hall Z04 of the house in Buca. The areas close to the windows in the rooms were very bright when compared to the rear area. It was seen that there was an unbalanced daylight distribution during the day due to the direct sunlight inside the room. The hall Z04 setbacks 0.85 meters from the northwest facade, and this prevents the interior space from direct sunlight. In addition to the highest window to wall ratio and window to floor ratio, the plan layout of the hall Z04 effects the uniformity values positively. At the south-east of the house in Buca, there is a garden paved with slates and a big square paved with granite stones. Besides, there are a secondary entrance space and a restroom space at the southeast corner of the house in Buca which obstructs the sunlight coming to room Z03. It also affects the distribution of daylight in this room. At the northwest of the house in Buca, there is a 5m width granite stone-paved road. On the other side of the road, there is a front garden of a two-story building. The building in Basmane is at the corner and in a semidetached order. The rooms at the north facade of the house in Basmane are brighter than the rooms at the south facade due to the narrower street widths, closer and higher buildings around. In addition, the rooms on the north side of the plan layout have more openings on different sides. The rooms at the north facade of the house in Basmane are brighter than the rooms at the south facade due to the different street widths and different heights of the buildings around. Besides, the rooms on the north side of the plan layout have more openings on different sides. The oriel window serves as a light source for the hall 101with a ratio of 1 to 2.16. In all the seasons, there are excessive amounts of light in oriel that have windows at the three facades with a %46 window to wall ratio. The oriel has the highest uniformity value in the house. Also, it is the only zone that satisfies both first and second category uniformity.

The material properties of the interior walls are effective factors in the daylight distribution of the inner spaces. For example, there are three more glass-enclosed doors in different directions other than the entrance door in the hall Z04 of the house in Buca, which did not calculate as the window to wall ratio. But it will be effective when all the rooms window shutters opened. All the rooms' stone interior walls are painted with white color which has the highest reflectance ratio. Besides, one of the interior walls which separate the kitchen from room Z03 is made of glass that affects the reflectance of the light from the surfaces. The colors of the rooms of the house in Basmane is darker than the house in Buca.

5.2. Thermal Performance of the Base Case Buildings

There are higher outdoor diurnal temperature and relative humidity differences than inside of the houses. Generally, the thermal mass of the massive stone exterior walls and the half infill stone interior walls lead to time lag that the temperature inside the house remained lower during the day and higher at night than the outside temperature in both base case houses. Consequently, the internal relative humidity becomes higher during the day lower during the night. The intervals of the heat transfer change in each interior space according to their location and spatial properties. However, the thermal mass is a very effective factor in the thermal behavior of the houses; it is not the only factor. The microclimatic conditions, the building envelope properties, building height, the plan layout of the building, settlement pattern are the other important factors that affect the thermal performance of the buildings. So, the thermal behaviors of each interior zones show minor differences due to the combination and strength of these factors in some periods. To understand the general thermal behaviors of these base case buildings, the most common features of these interior zones are examined and explained below.

When the analysis of the two-story house in Basmane was evaluated according to each interior space, the basement floor was found as the most different and characteristic spaces of this type of 19th Century İzmir Houses in terms of thermal properties. The basement was the only space that had been ventilated during the measurements because there were openings on both north and south facades of the basements. Because of the cross-ventilation, the compacted soil ground thermal properties, the adjacency of massive stone walls to the soil, and the low wall surface area exposed to external climatic conditions, the thermal behavior of this space is obviously differentiating. The indoor relative humidity remained higher and the dry-bulb air temperature remained lower and stable than the outdoor air temperature during the day in the basement, unlike the other zones of the house. When the fluctuating hot air coming from outside meets stable indoor air at low temperature, the moisture carrying capacity of the air formed inside increases, and the cooling rate of the incoming air increases. So, the monthly daily average relative humidity the graphics show fluctuating diagrams in the basement. Also, the basement stabilizes the temperature and relative humidity fluctuations of the rooms on the ground floor above.

The rooms on the ground floor were showing similar thermal characteristics with minor differences. The outdoor air temperature was higher than the internal air temperature from approximately from morning till the night and then lower till the morning at the ground floor with different intervals. The rooms Z02, Z04, Z06, and the entrance hall Z01 have a more stable diurnal indoor temperature difference than the stair hall Z03. The airflow through the upstairs at the hall Z03 is thought to be the reason for this difference. Among these zones, room Z02 which locates at the northeast corner of the building above the basement has the most stable monthly daily average graphics in terms of both relative humidity and dry bulb air temperature. Also, the indoor relative humidity was higher than the outdoor relative humidity from morning till the night and then lower till the morning with a shorter interval than the temperature changes. The halls Z01, Z03 have higher diurnal indoor relative humidity differences than the rooms on the ground floor because of the high air infiltration rate of these spaces. There is no basement under the room Z04. Furthermore, due to the ivy overlay on the street on the first floor level and the mosque behind it, the southern facade of the building cannot receive direct sunlight on the ground floor level. Therefore, room Z04 has a higher standard deviation in terms of relative humidity.

As on the ground floor, the rooms on the first floor were showing similar thermal characteristics with minor differences. The diurnal temperature differences of the zones on the first floor were showing a more fluctuating graphic, which means higher differences and standard deviations than the ground floor. The roof's thermal mass, cross ventilation, and the higher ratio of the walls exposed directly to the microclimatic conditions than the walls on the other floors cause these fluctuations. Among all the zones on the first floor, hall 101 has the highest diurnal temperature differences. It is thought to be the facts of the air infiltration from the staircase, cross ventilation between the oriel on the north facade and the south facade windows, the narrow and long rectangular form of the zone. The indoor air temperature of the interior zones on the first floor was lower than the outdoor air temperature from morning till the night then higher till the morning in all the measurement periods. As in the dry-bulb air temperature graphs, the relative humidity graphs of the zones on the upper floor are more fluctuating than the graphs on the ground floor. The indoor relative humidity of the interior zones on the first floor was higher than the outdoor relative humidity from morning till the night then lower till the morning in all the measurement periods except in June and July. In these periods, the relative humidity of the first floor remained lower most of the day. Besides, the highest relative humidity differences were seen in hall 101 during the measurement periods except for January and February.

The single-story house in Buca has both similar and different thermal characteristics with the house in Basmane. For instance, the dry bulb temperature and the relative humidity in the basement zone are much more stable in the house in Basmane. And as mentioned above in the basement of the house in Basmane, the indoor relative humidity remained higher, and the dry-bulb air temperature remained lower than the outdoor during the day. The basement zone in the Buca has the highest standard deviation ratios for both the indoor dry-bulb air temperature and the relative humidity. In addition, the indoor relative humidity remained higher from morning till night then remained lower at the rest while the dry-bulb air temperature remained lower from morning till night then remained higher at the rest of the day than the outdoor. The house in Basmane is semidetached to the annex building while the house in the Buca is detached. So, the exterior walls of the basement of the house in Buca exposed to the outdoor climatic conditions more than the house in Basmane. Also, the exterior wall opening ratio of the house in Buca is bigger than the house Basmane. These can be the reasons for the thermal behavior difference between the basement zones of the houses in Buca and Basmane.

The rooms on the ground floor were showing similar thermal characteristics with minor differences. The outdoor air temperature was higher than the internal air temperature from approximately from morning till the night and then was lower at the rest of the day at the ground floor with different intervals. The rooms Z01, Z02, and Z03 have a more stable diurnal indoor temperature than the entrance hall Z04. There is no basement under the entrance hall Z04. This hall is surrounded by 4 door openings, one of which is the entrance door. Among the rooms, room Z02 which locates at the northwest and southwest corner of the building above the basement has the most stable monthly daily average graphics in terms of both relative humidity and dry bulb air temperature in most of the measurement periods. This room has the lowest wall to window ratio and square shape. Besides, room Z03 has the most fluctuating daily average graphics in terms of both relative humidity and dry bulb air temperature in most of the measurement periods. This room has the highest window to wall ratio looking at the south facade and rectangular shape. As shown in the daylight distribution different than the room Z02, the direct sunlight comes to the room Z03. These spatial characteristics differences lead to thermal behavior differences. When the average standard deviation rates of the zones on the ground floor of the houses in Basmane and Buca it was seen that the house in Basmane is more stable in terms of thermal performance. It is mostly because of the differentiating factors such as microclimatic conditions, the settlement pattern the building envelope property, the building height, the plan layout of the building and the settlement pattern.

5.3. The Architectural Design Parameters Effect on Energy Consumption

In the earlier studies about the typology of the traditional houses, exemplary structures are modeled according to their different locations and structural features. In this study, the variations of the typology, which was mostly seen in the literature, were modeled and analyzed in the regions where they are mostly located. Two sample buildings were selected from the literature, one of which was a single-story and the other was two-story. As mentioned, they were modeled where they mostly located. The material properties, the construction systems and the zone heights of the building variations based on the selected samples and the surrounding environment kept constant while the other parameters intrinsic to the typology varied to clarify the results.

Building energy simulations for two- and single-story houses were carried out at two different locations, namely Alsancak and Buca, respectively. These places were chosen to contain the most common examples of such houses. The statistical analyses of two and single-story houses’ simulation results were separately performed. These statistical analyses were performed in two ways. At first, all the buildings' BES model simulations were included in the analyses. Secondly, only the buildings with basements BES model simulations were included in the analyses. Because, the statistical analysis performed with all the BES model simulations were revealed that the existence of basement space has a large impact on energy consumption, thus suppressing the impact of other architectural parameters. So, to understand the real impacts of the other architectural parameters, the statistical analyses were repeated for only the buildings with basements. The table prepared to compare the impact values of the design parameters as a whole is presented in the Appendix-H. The discussion about these analyses for each parameter was made separately and respectively in the following paragraphs.

In this context, it is determined that the interior space organization, the basement, window to wall ratio, wall to floor ratio, window to the floor, total building area, wall to volume ratio have different levels of impacts on total energy consumption per square meter for both two and single-story houses. Apart from these, the settlement pattern is determined as an effective parameter on the total energy consumption of single-story houses.

The interior space organization was evaluated with two parameters. The first parameter is solely the hall position of the houses, which is one of the most descriptive properties of İzmir Houses. The statistical analyses of the two-story İzmir houses results described a significant relationship between the hall location and energy consumption. The detached two-story houses with side halls consume less energy than the house with a central hall. The heat loss from the cross ventilation and the staircase of the house with a central hall can cause this situation. Also, the plan type parameter that is formed by the combination of the location of the hall and the staircase was figured out as an effective parameter on energy consumption due to the analysis. When the staircase is located at the corner of the main building and perpendicular to the L shaped hall which leads the hall form to become zig-zag between the rooms (heated zones), the energy consumption per square meter decreases the energy consumption per conditioned area increases. It can be said that the zigzag form of the hall contributes to the homogeneous distribution of the heated air inside the house. However, according to the correlation factors of each parameter, it is understood that the location of the hall is much effective than the staircase location. The results of the repeated analysis within the two-story buildings with basements have also verified the impacts of the interior space organization parameters.

However, the statistical analyses of the single-story İzmir houses included all the buildings were resulted differently than the statistical analyses of the single-story within the buildings that have basements. According to the analyses included in all the buildings, the interior space organization does not have a significant effect on energy consumption, whereas the analyses performed with the single-story houses with basements were revealed the significance of the interior space organization on energy consumption with the strength of moderate degree. The single-story İzmir houses in Buca with the central hall consumes less energy according to the mean values of these analyses. In these types of buildings, the wall areas exposed to the outdoor are lower than the buildings with side hall. Thus, the unconditioned hall zone is protected from the outdoor climatic conditions. Therefore, the energy consumption of buildings with side halls is lower than the energy consumption of middle halls. In addition, it can be summarized that in terms of energy consumption, the effect of the basement was very strong, which statistically suppressed the influence of the interior space organization within the single-story İzmir houses in Buca.

The İzmir Houses' relation between the utilization of the basement as a room or a ventilation space and the absence of basement space with the total energy consumption per total square meter were analyzed. The existence of the basement was found out another important parameter effective on total source energy consumption per square meter. Both İzmir houses types with two and single-story those have basements consume less energy than the houses that don't have basements. On the other hand, the utilization of the basement as a room or as a ventilation space does not have an important effect on energy consumption, especially for the two-story houses due to the analyses. The repeated correlation analyses were revealed a low degree relationship between the utilization of the basement and the total source energy consumption per square meter for the single-story houses. When the numerical values were considered, it was seen that the basement utilized as a room consumes slightly less energy than the building with a basement utilized as ventilation space especially in single-story İzmir houses. This can be explained with the positive relationship of the wall to volume ratio which will be explained in the following and the energy consumption.

The orientation has not a significant relationship with the total source energy consumption per square meter in both the two and single-story houses due to the statistical analyses of both kinds. The two-story houses modeled in Alsancak were a kind of row houses settled in a dense urban area. The ratio of the walls exposed to the microclimatic conditions was low. Thus, it was thought that the orientation differences did not affect the energy consumption significantly these buildings. On the other hand, the single-story houses modeled in Buca were in detached and semidetached order. These buildings have compacted form, and the ratio of the opening on their envelope was low. These should be the reason that the orientation was not a significant parameter in terms of energy consumption for the single-story İzmir houses in Buca.

The roof occupancy parameter of the two-story houses determines the zone type, whether heated or unheated. According to the statistical analysis of both kinds, there is a low degree of relationship between the occupancy of the roof and the total energy consumption per square meter that means it has a minor effect on total energy consumption. As found out in the study of Ulu (2018), the ratio of wall area to conditioned volume has a negative relationship with energy consumption while the ratio of wall to the conditioned area decreases the energy consumption increases.

The existence of the oriel has not much effect on the total energy consumption among the other parameters according to the analyses of both kinds. Nevertheless, the two-story houses with oriel consume slightly more energy than the houses without oriel due to the mean values. The lightweight construction materials of the oriel's thermal properties and high window to wall ratio can increase the heat loss from the main facade.

The window to wall ratio was revealed as a significant parameter for both the two and single-story İzmir houses due to the analyses of both kinds. The window to wall ratio of the two-story İzmir houses has a moderate degree positive effect on total source energy consumption per square meter due to the analyses included all the models. But according to the analyses performed with only the two story-buildings that have basements the window to wall ratio has a low degree positive effect on the energy consumption. The heating load is considerably higher than the cooling load of the İzmir houses, according to the analyses included all the two-story types. Most of the window openings were located on the facades of the conditioned zones of these buildings. And these buildings were in such a dense settlement pattern that the direct sunlight could not reach the depth of the narrow and long rectangular shape houses. Thus the heat loss of these houses windows was higher than the gain.

Besides the window to wall ratio's effect on all the single-story İzmir houses in Buca is nearly zero while the window to wall ratio's effect on the single-story İzmir houses that have basements is moderate degree negative. Also, according to the analyses, when the window to wall ratio increases the energy consumption decreases as seen in the previous studies Ulu (2018) The heating load is considerably higher than the cooling load of the İzmir houses according to the analyses included all the single-story type as in two-story type. The ratio of the window openings on the facades of the unconditioned zones of the single-story İzmir houses in Buca is higher than the İzmir houses in Alsancak. And these more compacted formed buildings were in a scattered settlement pattern that the direct sunlight could reach the depth of the houses. Thus the heat gain of these houses windows was higher than the loss. In addition, it can be concluded that in terms of energy consumption, the effect of the basement was very strong, which statistically suppressed the influence of the window to wall ratio.

The wall to floor ratio of both two and single-story houses was figured out as one of the most effective parameters on total source energy consumption per square meter regarding the comparison of the correlation factors of the each of the architectural design parameter. According to the statistical analyses of both two and single-story İzmir houses of both kinds, the wall to floor ratio is significant, and it has a high degree of a positive relationship with energy consumption. The energy consumption increases when the wall to floor ratio increases. It is understood that the heat losses from the external surface areas and the floor surface areas cause this relation.

The window to floor ratio is another significant parameter effective on total source energy consumption for both two and single-story İzmir houses regarding the statistical analyses of both kinds. According to the analyses, the wall to floor ratio is significant, and it has a high degree of a positive relationship with the energy consumption of the İzmir houses. The energy consumption increases when the window to floor ratio increases. The windows have a relation with solar gain and heat loss, which means it is the “determinant of the solid-void to balance heat load”(Kazanasmaz et al. 2014).

The total building area of both two and single-story İzmir houses was found out significant regarding the total source energy consumption per square meter due to the statistical analyses of both kinds. It is understood from the correlation factor results the total building has a high and negative effect on energy consumption. When the building area increases, the total energy consumption per square meter decreases. Because the heat transfer by the floor surfaces strongly affects energy consumption.

The wall to volume ratio of both two and single-story İzmir houses was revealed significant regarding the total source energy consumption per square meter due to the statistical analyses of both kinds. It is understood from the correlation factor results the total building has a high and positive effect on the energy consumption on the two-story houses in Alsancak. The wall to volume ratio has a low degree positive effect on the energy consumption of the single-story houses with and without a basement, whereas it has a high degree positive effect on energy consumption f the single-story houses only with basements. When the wall to volume ratio increases the total source energy consumption per square meter increases, it is consistent with previous studies that determined the area to volume ratio relationship between the energy consumption results that show the higher volume rate leads to the lower energy consumption because of the heat losses from the envelope (Kazanasmaz et al. 2014) .

Due to both kinds of statistical analyses, the settlement pattern of the single-story İzmir houses, which describes the attached or detached buildings, was found as an effective parameter in total source energy consumption per square meter as supposed from previous researches (Kazanasmaz et al. 2014). There is a moderate degree relationship between energy consumption and the settlement pattern. The İzmir houses in Buca that are semidetached to another building consumes less energy than the houses settled in a detached order. The heat loss from the exterior walls can be evaluated as the reason for this relation.

5.4. Conclusion

The architectural design parameters of 19th Century İzmir Houses were analyzed in this study to figure the optimum design parameter due to the total source energy consumption per square meter for future housing design. According to the BES results, the heating load is dominant over the cooling load in İzmir Houses. The wall to floor ratio, window to floor ratio, total building area the existence of the basement was found the most effective parameters regarding correlation and variance analyses among the other parameters. The parameters of the wall to floor ratio, window to floor ratio, total building area were mostly used parameters in previous studies in terms of building energy performance. These results were expected. The parameters such as the location of the hall, plan type, utilization, and the existence of the basement, the occupancy of the roof and the existence of the oriel were determined according to the basic characteristics of İzmir houses. These parameters and their relations with the building energy performance were the distinguishing features of this study from other studies in the literature. Because they are the intrinsic values of these types of houses which were determined as a result of an in-depth analysis of the architectural features of the buildings. Besides the location of the hall, plan type, the existence of the basement is effective on the building energy performance.

The least energy consuming building among the two-story İzmir houses type in Alsancak has a basement and side hall plan; the staircase is located at the corner of the main building and perpendicular to the hall, which leads the hall form became zig-zag between the rooms. The entrance facade of the house directs to the northeast. It has an unoccupied thus unheated roof. It has an oriel. The house has a window to wall ratio of 0.13, the wall to floor ratio of 0.66, window to floor ratio 0.08, total building area of 331-meter square and wall to volume ratio of 0.22. The total source energy consumption per total square meter is 186.78 kWh/m2. The least energy consuming building among the single-story İzmir houses type in Buca has a basement and central hall plan. It was semidetached to another building. The entrance facade of the house directs to the southwest. The house has a window to wall ratio of 0.13, the wall to floor ratio of 0.98, window to floor ratio 0.13, total building area of 197-meter square and wall to volume ratio of 0.34. The total source energy consumption per total square meter is 211.03 kWh/m2. The tables about the significant architectural design parameter best and the worst values and the general evaluation on their impact values can be seen in Appendix-H. When the analysis was evaluated overall, it can be revealed that the least energy consuming building types of İzmir houses generally have the most advantages design parameters regarding the energy efficiency analyzed in this study. So, these are evaluated as the optimum values of the architectural design parameters of İzmir houses in terms of energy efficiency. Investigation and comparison of the architectural design parameters of traditional buildings produced during the ages by trial and error method regarding energy performance are beneficial in terms of giving clues to the architects who will work in the same context. For instance, the results of this study explained above will be a hint for the two or single-story future houses designs in İzmir to reduce their construction and management costs and to reduce their dependency on the insulation and similar technological material.

As mentioned in the problem statement In Turkey, sometimes, restoration projects are built on the protection of the facade by ignoring the interior design parameters such as interior space organization. This approach causes to damage the architectural integrity and authenticity of these buildings. Unfortunately, one of the most seen kinds of these buildings is the examples of registered/listed civil architecture, which encapsulates traditional and vernacular houses. In this study, it was revealed that the interior space organization is not just an issue of integrity and authenticity; it is an issue of energy efficiency also that must be evaluated and protected. The representatives who specialize in engineering discipline should be included in the conservation councils of the Ministry of Culture. Therefore, the council can evaluate the restoration projects of these registered buildings as recommended in the Directive of Energy Performance.

In future studies, new housing design alternatives can be proposed by using the optimum design parameters in terms of energy efficiency evaluated in this study to examine how much these parameters limit the architect. Also, the occupancy factor can be added to the BES model simulations to understand their effects on energy consumption. Besides, another traditional or vernacular building typology can be evaluated by the method used in this study.

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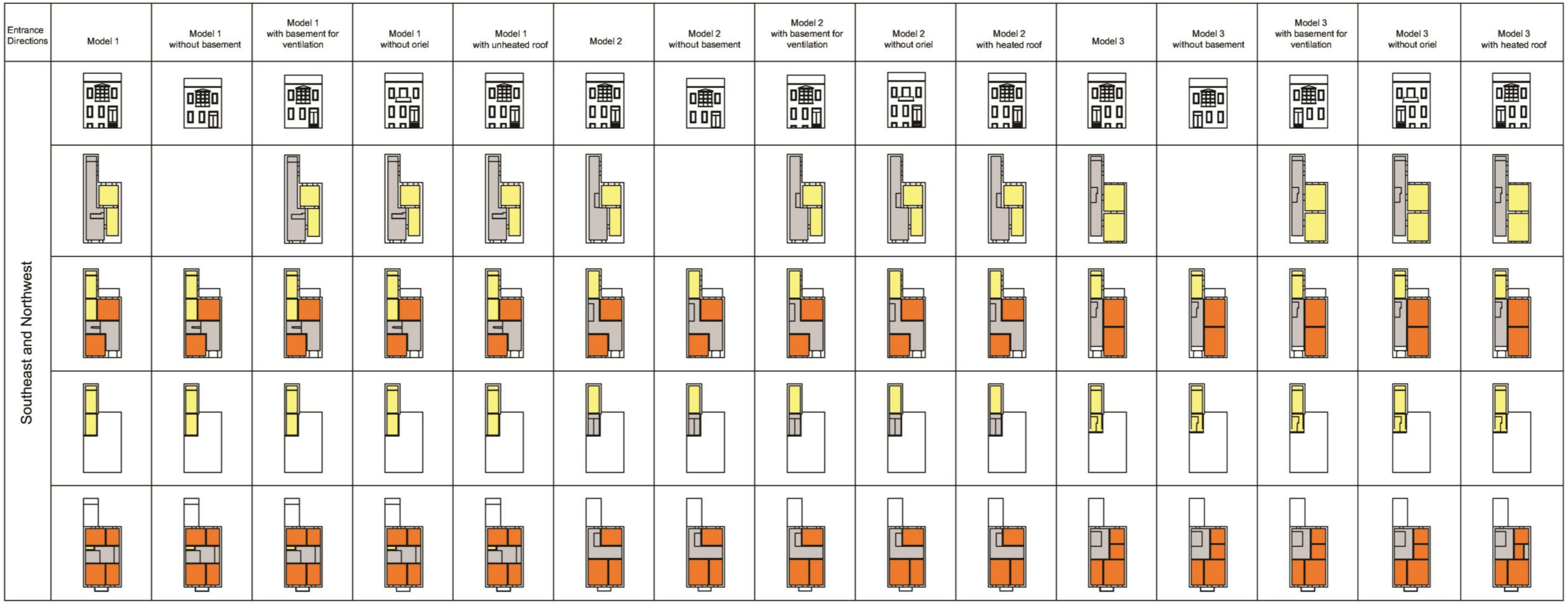
APPENDICES

APPENDIX A

VARIATIONS OF İZMİR HOUSES TYPES



(cont. on next page)

Figure A. 1. The two-story İzmir Houses types modelled and simulated

Figure A. 1. (cont.)

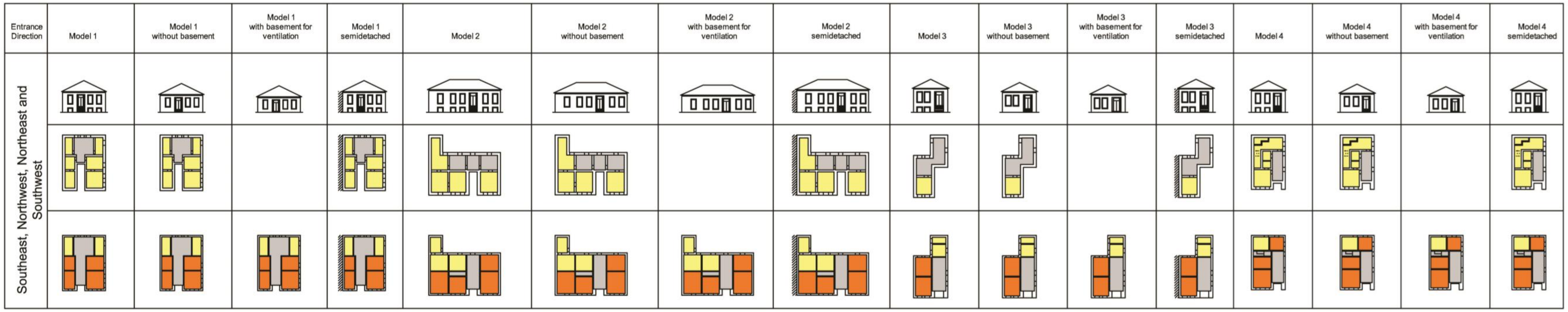


Figure A. 2. The single-story İzmir Houses types modelled and simulated

APPENDIX B

WEATHER DATA CALIBRATION AND ANALYSES

tmmob makina mühendisleri odası

MMO KALMEM

Kalibrasyon Laboratuvarı ve Metroloji Eğitim Merkezi

Kalibrasyon Sertifikası

Calibration Certificate

TÜRKAK Kalibrasyon TS EN ISO/IEC 17025 AB-0070-K

AB-0070-K
17.SCK.2872
12.2017

Cihaz / Ekipman *Device / Equipment*	:	DİJİTAL NEM VE SICAKLIK ÖLÇER *Digital Humidity and Temparature Meter*
Üretici Firma *Manufacturer*	:	HOBO
Seri No *Serial No*	:	2289962(15)
Tip / Model *Tip / Model*	:	onset U12-012
Talep Eden / Adresi *Issued For /Address*	:	**ÖZDEN COŞKUN ÖNER** İYTE KARABURUN İZMİR
Talep Numarası *Order no*	:	EK17001401/1
Kalibrasyon Tarihi *Date of Calibration*	:	06.12.2017
Sertifika Sayfa Sayısı *Page Number*	:	2

Bu kalibrasyon sertifikası, Uluslararası Birimler Sisteminde (SI) tanımlanmış birimleri realize eden ulusal ölçüm standartlarına izlenebilirliği belgeler. Kalibrasyon laboratuvarı olarak faaliyet gösteren MMO KALMEM, TÜRKAK'tan AB-0070-K ile TS EN ISO/IEC 17025:2012 standardına göre akredite edilmiştir. Türk Akreditasyon Kurumu(TÜRKAK) kalibrasyon sertifikalarının tanınırlığı konusunda Avrupa Akreditasyon Birliği(EA) ile Çok Taraflı Anlaşma ve Uluslararası Laboratuvar Akreditasyon Birliği(ILAC) ile karşılıklı tanıma anlaşması imzalamıştır. Ölçüm sonuçları, genişletilmiş ölçüm belirsizlikleri ve kalibrasyon metotları bu sertifikanın tamamlayıcı kısmı olan takip eden sayfalarda verilmiştir.

This calibration certificate documents the traceability to national standards, which realize the unit of measurement according to the International System of Units (SI). MMO KALMEM accredited by TÜRKAK under registration number AB-0070-K for TS EN ISO/IEC 17025:2012 as Calibration Laboratory. Turkish Accreditation Agency (TURKAK) is a signatory to the European co-operation for Accreditation (EA) Multilateral Agreement (MLA) and to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA) for the recognition of calibration certificates. The measurements, the uncertainties with confidence probability and calibration methods are given on the following pages which are partof this certificate.

Mühür *Seal*	**Tarih** *Date of Issue*	**Kalibrasyonu Yapan** *Calibrated by*	**Laboratuvar Müdürü** *Head of the Calibration Laboratory*
Makina Mühendisleri Odası · MMO KALMEM · Kalibrasyon Merkezi	08.12.2017	ERDAL KAÇAR	ALPER TORTOÇ
		Dijital olarak imzalayan: ERDAL KAÇAR	Dijital olarak imzalayan: ALPER TORTOÇ

EKC.05.09 30.12.2013 Rev.02

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A_ 251 sok. no: 33 d: 1-2 Manavkuyu Bayraklı İZMİR T_ (0232) 348 40 50 F_ (0232) 348 63 98 W_ www.kalmem.org | kalmem@mmo.org.tr

Figure B. 1. Calibration Certificate

tmmob makina mühendisleri odası

MMO KALMEM
Sanayinin Hizmetinde

AB-0070-K
17.SCK.2872
12.2017

1. Kalibrasyonda Kullanılan Referans:

Cihaz / Ekipman	Üretici	Seri No	İzlenebilirlik
Nem Ölçer	UME	EK 05.34	AB-0028-K
Sıcaklık Kalibratörü	EMS	EK 05.15	MMO KALMEM
Sıcaklık Sensörü	-	EK 05.35	MMO KALMEM

2. Kalibre Edilen Cihazın Özellikleri:

Cihaz	Ölçüm Aralığı	Çözünürlük	Çözünürlük
İJİTAL NEM VE SICAKLIK ÖLÇE	0 - 100 %RH	0,1 %RH	0,1 %RH

3. Ortam Şartları :

Laboratuvar Ortam Şartları:
Sıcaklık: (23 ± 3) °C **Bağıl Nem** : % (45 ± 15)

4. Kalibrasyon Yöntemi ve Prosedür

Cihazın kalibrasyonu EKT 05.10 No'lu talimata göre gerçekleştirilmiştir. Kalibrasyon nem kabininde kararlı nem ve sıcaklık ortamında, referans cihazdan ölçülen sıcaklık değerleri ile cihazın gösterge değerlerinin karşılaştırılması yöntemi ile gerçekleştirilmiştir.

5. Kalibrasyon Belirsizliği

Ölçüm belirsizlikleri sonuç tablosunda verilmiştir. Beyan edilen genişletilmiş belirsizlik değeri, standart belirsizliğin normal dağılım için yaklaşık %95 güvenilirlik seviyesini sağlayan k=2 kapsam faktörü ile çarpımının sonucudur. Standart ölçüm belirsizliği GUM ve EA-4/02 dokümanlarına uygun olarak hesaplanmıştır. Ölçüm belirsizliği uzun zaman kararlılığını kapsamamaktadır.

6. Fonksiyon ve Göz Kontrolü

Fonksiyon ve göz kontrolünde hasar veya eksiklik görülmemiştir.

7. Kalibrasyon Sonuçları

Yapılan ölçümlerin sonucunda aşağıdaki değerler elde edilmiştir:

Referans Değer %RH	Ölçülen Değer %RH	Sapma %RH	Belirsizlik %RH	Okunan Sıcaklık °C
		in		
31,7	35,6	3,9	3,00	23,2
58,6	60,2	1,6	3,00	25,1
79,2	79,1	-0,1	3,00	25,2

Referans Değer °C	Ölçülen Değer °C	Sapma °C	Belirsizlik °C
	in		
20,0	19,9	-0,1	0,5
25,0	24,9	-0,1	0,5
30,0	30,1	0,1	0,5

EKC 05.09 30.12.2013 Rev.02

8. Açıklamalar

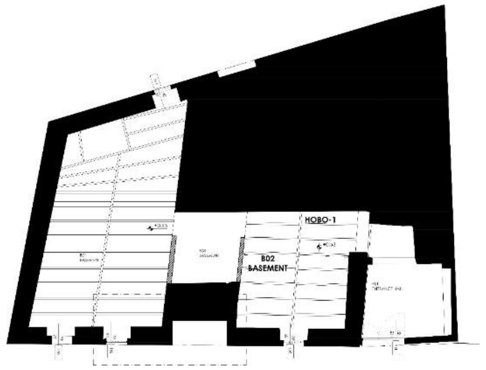
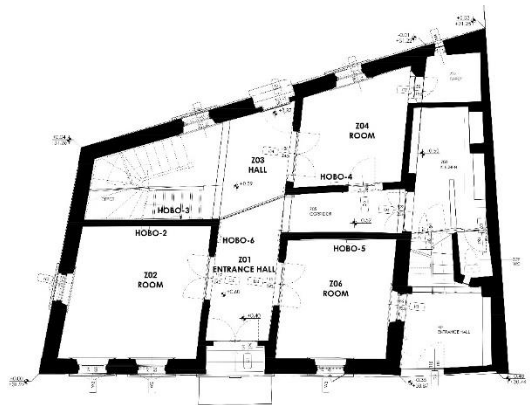
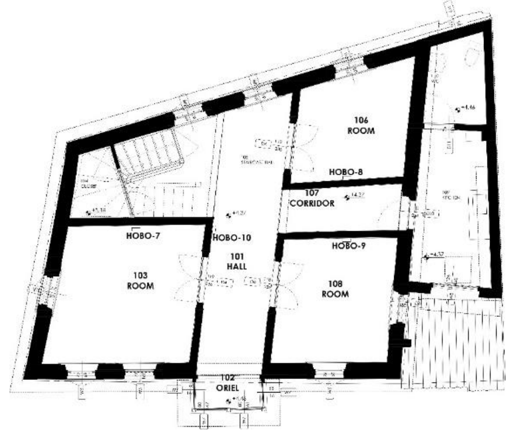
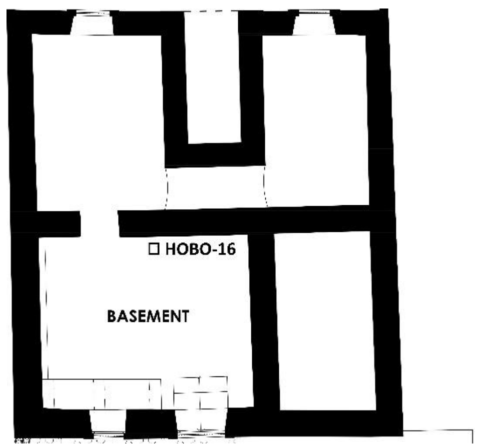
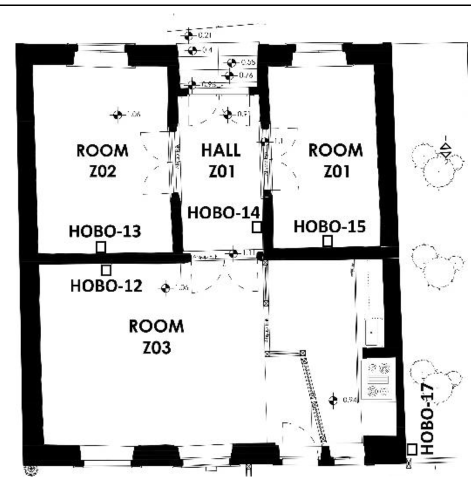
Kalibrasyon başında ve sonunda alınan 35,6 %rh
değerleri arasındaki fark histeresiz hatası olarak belirsizliğe eklenmiştir.
Kalibrasyon sonuçları sadece yukarıda belirtilen cihaza ait olup, kalibrasyon tarihinden itibaren ve sertifikada verilmiş olan şartlarda geçerlidir. Cihazın uygun aralıklarla kalibrasyonunun gerçekleşmesinden kullanıcı sorumludur.

9. Kalibrasyon Etiketinin Yeri Kalibrasyon etiketi cihazın ön tarafına yapıştırılmıştır.

A. 251 sok. no: 33 d: 1-2 Manavkuyu Bayraklı İZMİR T. (0232) 348 40 50 F. (0232) 348 63 98 W. www.kalmem.org | kalmem@mmo.org.tr

Figure B. 2. Calibration Certificate 2

Table B. 1. Calibration Equations of HOBO Data Loggers U12 012 Used at the İzmir Houses in Basmane and Buca

İZMİR HOUSE IN BASMANE					
NO	**TEMPERATURE DATA**	**RELATIVE HUMIDITY DATA**	**BASEMENT FLOOR PLAN**	**GROUND FLOOR PLAN**	**FIRST FLOOR PLAN**
1	$Y = 1.0204X - 0.7143$ $R^2 = 1$	$Y = 1.1025X - 6.1234$ $R^2 = 0.9996$			
2	$Y = 0.9901X + 0.3803$ $R^2 = 1$	$Y = 1.2637X - 17.343$ $R^2 = 0.9995$			
3	$Y = 0.9804X + 0.5882$ $R^2 = 1$	$Y = 1.1113X - 7.8822$ $R^2 = 0.9999$			
4	$Y = 0.9804X + 0.4902$ $R^2 = 1$	$Y = 1.1776X - 10.11$ $R^2 = 0.9999$			
6	$Y = 0.9901X + 0.4133$ $R^2 = 1$	$Y = 1.125X - 8.4856$ $R^2 = 0.9981$			
7	$Y = 0.9804X + 0.3922$ $R^2 = 1$	$Y = 1.1164X - 9.0687$ $R^2 = 0.999$			
8	$Y = 0.9803X + 0.526$ $R^2 = 0.9999$	$Y = 1.3961X - 25.776$ $R^2 = 0.9999$			
9	$Y = 1.1159X - 7.4067$ $R^2 = 0.9988$	$Y = 0.9804X + 0.6863$ $R^2 = 1$			
10	$Y = 0.9708X + 0.7936$ $R^2 = 1$	$Y = 1.3565X - 21.814$ $R^2 = 1$			
İZMİR HOUSE IN BUCA					
NO	**TEMPERATURE DATA**	**RELATIVE HUMIDITY DATA**	**BASEMENT FLOOR PLAN**	**GROUND FLOOR PLAN**	
12	$Y = 0.9999X + 0.17$ $R^2 = 0.9999$	$Y = 1.2935X - 20.121$ $R^2 = 1$			
13	$Y = 0.9901X + 0.3803$ $R^2 = 1$	$Y = 1.1217X - 7.5882$ $R^2 = 0.9999$			
14	$Y = 1.0198X - 0.4621$ $R^2 = 0.9994$	$Y = 1.2136X - 12.147$ $R^2 = 0.9976$			
15	$Y = 0.9803X + 0.526$ $R^2 = 0.9999$	$Y = 1.092X - 7.1653$ $R^2 = 1$			
16	$Y = 0.9999X + 0.1366$ $R^2 = 0.9999$	$Y = 1.1529X - 11.521$ $R^2 = 0.9983$			
17	$Y = 0.9901X + 0.1823$ $R^2 = 1$	$Y = 1.2636X - 18.935$ $R^2 = 1$			

APPENDIX C

CALIBRATION of BES MODELS

Table C. 1. Calibration of the BES model simulations of the İzmir houses in Basmane and Buca

İzmir house in Basmane									
location of the hobo	type of the data	24.06.2016-19.07.2016		01.10.2016-22.10.2016		08.01.2017-08.02.2017		02.04.2017-23.04.2017	
		CV(RMSE)	**MBE %**	**CV(RMSE)**	**MBE %**	**CV(RMSE)**	**MBE %**	**CV(RMSE)**	**MBE %**
Outdoor	temp °C	1.01	-0.04	1.37	-0.03	3.21	-0.08	1.79	-0.05
Basement	temp °C	8.58	-8.42	3.99	1.30	19.61	-13.07		
Z01 Hall	temp °C	4.13	2.87	4.16	0.09	19.81	-6.75	4.79	-2.47
Z02 Room	temp °C	3.51	-0.66	4.50	-1.87	19.72	-8.71	4.68	-1.60
Z03 Hall	temp °C	2.88	1.15	4.39	-1.74	16.72	-5.72	5.05	-2.61
Z04 Room	temp °C	6.82	6.22	5.35	2.66	21.38	-5.73	5.93	-4.13
Z06 Room	temp °C	3.31	-1.37	5.05	-3.46	21.68	-11.95	6.12	-4.73
101 Hall	temp °C	5.05	-3.80	8.97	-8.23	22.99	-10.98	5.46	-0.79
103 Room	temp °C	3.69	-2.03	6.92	5.77	25.03	-13.23	5.62	1.53
106 Room	temp °C	5.18	-3.71	10.99	-10.28	27.95	-17.40	6.51	-2.88
108 Room	temp °C	3.80	-2.04	6.44	-5.38	23.52	-10.48	5.27	0.95
İzmir house in Buca									
location of the hobo	type of the data	26.06.2016-19.07.2016		28.09.2016-26.10.2016		16.01.2017-15.02.2017		24.03.2017-22.04.2017	
		CV(RMSE)	**MBE %**	**CV(RMSE)**	**MBE %**	**CV(RMSE)**	**MBE %**	**CV(RMSE)**	**MBE %**
Outdoor	temp °C	2.59	-0.01	1.40	-0.01	3.60	0.05	2.20	0.01
Basement	temp °C	3.35	-2.01	5.21	-4.18	11.72	4.83	10.33	2.77
Z01 Room	temp °C	5.80	4.68	4.28	2.91	12.78	9.14	9.71	4.66
Z02 Room	temp °C	4.54	3.02	8.88	8.43	11.31	6.84	9.18	2.01
Z03 Room	temp °C	5.27	3.52	3.30	1.32	13.91	11.51	9.17	3.72
Z04 Hall	temp °C	4.36	3.01	3.59	2.44	18.42	16.86	8.81	3.98

APPENDIX D

GENERATION OF İZMİR HOUSES VARIATIONS' MODELS

Table D. 1. Material Properties of the BES Models of the Base Case İzmir Houses in Basmane

Base Case Building in Basmane								
Wall type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Wall/Oriel		Wood	0.02	0.1206	2217	650	2.978
External Wall/Main Building	Outermost	Lime plaster	0.025	1000	840	1800	1.688
		Stones with solid brick	0.35	0.94	1365	2316	
	Innermost	Lime Plaster	0.025	1000	1437	1800	
Partition Wall/Main Building Ground Floor	Outermost	Lime Plaster	0.025	1000	1437	1800	2.179
		Stones with solid brick	0.14	0.94	1365	2316	
	Innermost	Lime Plaster	0.025	1000	1437	1800	
Partition Wall/Main Building First Floor	Outermost	Lime Plaster	0.025	1000	1507	1800	2.231
		Stones with solid brick	0.13	0.94	1365	2316	
	Innermost	Lime Plaster	0.025	1000	1507	1800	
External Wall/Main Building Basement	Outermost	Face stone	0.05	0.94	1365	2316	1.429
		Lime mortar	0.03	1000	840	1800	
	Innermost	Stones with solid brick	0.42	0.94	1365	2316	
Below Grade Wall/Main Building Basement		Stones with solid brick	0.5	0.94	1365	2316	1.425
Partition Wall/Main Building Basement		Brick	0.1	0.72	840	1920	2.507
External Wall/Annex	Outermost	Cement Plaster	0.03	0.72	840	1760	2.064
		Brick Burned	0.12	0.85	840	1500	
	Innermost	Cement Plaster	0.03	0.72	840	1760	

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Table D. 1. (cont.)

Floor Type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Timber Floor/Oriel		Wood	0.6	0.1206	2217	650	0.193
Internal Floor /Annex	Outermost	Cast concrete	0.22	1.13	1000	2000	1.904
		Cement mortar	0.02	0.72	840	1760	
	Innermost	Ceramic tile	0.04	1.22	850	1996	
Compacted Soil Floor/Basement Main Building		Soil-earth. gravel-based	0.2	0.52	180	2050	1.682
Ceramic tile (karosiman) Ground Floor/Main Building	Outermost	Cement mortar	0.02	0.72	840	1760	3.731
	İnnermost	Ceramic tile (karosiman)	0.03	1.22	850	1996	
Timber Ground Floor/Main Building (Room)		Wood	0.03	0.1206	2217	650	1.928
Timber First Floor/Main Building	Outermost	Gypsium plastering	0.25	0.4	1000	1000	0.685
		Wood	0.01	0.1206	2217	650	
		Air gap 100mm (downwards)	0.1	0.014	820	1.95	
		Wood	0.03	0.1206	2217	650	
	Innermost	PVC/Rubber floor covering	0.005	0.4	1000	1380	
Roof type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Metal Cladding Roof/Oriel	Outermost	Metal surface	0.01	45.28	500	7824	1.511
		Wood	0.03	0.1206	2217	650	
		Air gap 25mm (downwards)	0.25	0.014	820	1.95	
	Innermost	Wood	0.01	0.1206	2217	650	
Flat Roof/Annex	Outermost	Asphalt	0.019	0.7	1000	2100	1.099
		Fibreboard	0.013	0.06	1000	300	
	Innermost	Cast concrete (lightweight)	0.2	0.38	1000	1200	
Pitched Roof/Main Building	Outermost	Clay tile (roofing)	0.3	0.84	800	1900	1.295
		Timber flooring	0.3	0.1206	2217	650	
	Innermost	Roofing felt	0.005	0.19	837	960	

Table D. 2. Material Properties of the BES Models of the Base Case İzmir Houses in Buca

Base Case Building in Buca							
Wall type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
External Wall/Main Building Basement	Outermost	Plaster	0.03	0.18	1000	600	1.195
	Innermost	Stones with brick	0.47	0.94	1365	2316	
Below Grade Wall/Main Building Basement		Stones with brick	0.5	0.94	1365	2316	1.425
External Wall/Main Building	Outermost	Lime plaster	0.025	1	840	1800	1.688
		Stones with brick	0.35	0.94	1365	2316	
	Innermost	Lime plaster	0.025	1	1437	1800	
Partition Wall/Main Building	Outermost	Plaster	0.025	0.5	1437	1300	1.965
		Stones with brick	0.14	0.94	1365	2316	
	Innermost	Plaster	0.025	0.5	1437	1300	
External Wall/Annex	Outermost	Plaster	0.03	0.4	1000	1000	2.311
		Brick burned	0.14	0.84	840	1500	
	Innermost	Ceramic/porcelain	0.03	1.3	840	2300	
Floor Type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Floor/Basement Main Building	Outermost	Soil-earth. gravel based	0.15	0.52	180	2050	1.843
	Innermost	Cast concrete	0.05	1.13	1000	2000	
Timber Ground Floor/Main Building (Room)		Wood	0.02	0.1206	2217	650	2.294
Brick Arch Ceramic Ground Floor/Main Building	Outermost	Gypsium plaster	0.02	0.4	1000	1000	1.621
		Brick -burned	0.05	0.4969	1377	2211	
		Lime mortar	0.09	0.5	1437	1300	
	Innermost	Ceramic tile (karosiman)	0.02	1.22	850	1996	
Roof type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Pitched Roof/Main Building	Outermost	Clay tile (roofing)	0.3	0.84	800	1900	1.295
		Timber flooring	0.3	0.1206	2217	650	
	Innermost	Roofing felt	0.005	0.19	837	960	
Flat Roof/Annex	Outermost	Floor/Roof Screed	0.05	0.41	840	1200	2.081
	Innermost	Cast Concrete	0.1	1.13	1000	2000	

Table D. 3. Material Properties of the BES models of the Two-Story İzmir Houses in Alsancak

Two-Story İzmir House Sample							
Wall type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Wall/Oriel		Wood	0.02	0.1206	2217	650	2.978
External Wall/Main Building	Outermost	Lime plaster	0.025	1000	840	1800	1.688
		Stones with solid brick	0.35	0.94	1365	2316	
	Innermost	Lime Plaster	0.025	1000	1437	1800	
Partition Wall/Main Building	Outermost	Lime Plaster	0.025	1000	1437	1800	2.179
		Stones with solid brick	0.14	0.94	1365	2316	
	Innermost	Lime Plaster	0.025	1000	1437	1800	
External Wall/Main Building Basement	Outermost	Face stone	0.04	2.9	900	2650	1.286
		Lime mortar	0.03	1000	840	1800	
	Innermost	Stones with solid brick	0.53	0.94	1365	2316	
External Wall/Main Building Basement	Outermost	Lime Plaster	0.03	1000	840	1800	1.24
	Innermost	Stones with solid brick	0.57	0.94	1365	2316	
Below Grade Wall/Main Building Basement		Stones with solid brick	0.6	0.94	1365	2316	1.237
Partition Wall/Main Building Basement		Stones with solid brick	0.4	0.94	1365	2316	1.679
External Adjacent Wall/Main Building	Outermost	Cement Plaster	0.375	0.72	840	1760	1.684
	Innermost	Cement Plaster	0.025	1000	1437	1800	
Floor Type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Timber Floor/Oriel		Wood	0.3	0.1206	2217	650	2.978
Floor/Basement Main Building	Outermost	Sand and gravel	0.05	2	1045	1950	2.883
		Lean Concrete	0.1	1.35	1000	1800	
		Cement Mortar	0.03	1.4	840	2000	
	Innermost	Ceramic tile (karosiman)	0.02	1.22	850	1996	
Brick Arch Marble Ground Floor/Main Building	Outermost	Lime plaster	0.02	1	840	1800	1.866
		Brick-burned	0.11	0.4979	1377	2211	
		Cement Mortar	0.02	1.4	840	2000	
	Innermost	Marble white	0.03	2.77	802	2600	
Brick Arch Ceramic Tile Ground Floor/Main Building	Outermost	Lime plaster	0.02	1	840	1800	1.822
		Brick-burned	0.11	0.4979	1377	2211	
		Cement Mortar	0.02	1.4	840	2000	
	Innermost	Ceramic tile (karosiman)	0.03	1.22	850	1996	

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Table D. 3. (cont.)

Brick Arch Timber Ground Floor/Main Building (Room)	Outermost	Lime plaster	0.02	1	840	1800	1.002
		Brick-burned	0.11	0.4979	1377	2211	
		Cement mortar	0.04	1.4	840	2000	
		Air gap 50mm (downwards)	0.04	0.3	1000	1000	
	Innermost	Wood	0.03	0.1206	2217	650	
Timber Floor/Main Building	Outermost	Lime Plaster	0.2	1	840	1800	0.993
		Wood	0.03	0.1206	2217	650	
		Air gap 100mm (downwards)	0.17	0.3	1000	1000	
	Innermost	Wood	0.03	0.1206	2217	650	
Timber Floor/Main Building Without Basement	Outermost	Lean Concrete	0.1	1.35	1000	1800	1.23
		Air gap 100mm (downwards)	0.12	0.3	1000	1000	
	Innermost	Wood	0.03	0.1206	2217	650	
Marble Ground Floor/Main Building Without Basement	Outermost	Lean Concrete	0.13	1.35	1000	1800	2.47
		Cement mortar	0.02	0.72	840	1860	
	Innermost	Marble white	0.03	2.77	802	2600	
Roof type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Metal Cladding Roof/Oriel	Outermost	Metal surface	0.01	45.28	500	7824	1.511
		Wood	0.03	0.1206	2217	650	
		Air gap 25mm (downwards)	0.25	0.014	820	1.95	
	Innermost	Wood	0.01	0.1206	2217	650	
Brick Arch Ceramic Roof/Annex	Outermost	Ceramic tile (karosiman)	0.02	1.22	850	1996	2.046
		Cement Mortar	0.03	1.4	840	2000	
		Brick-burned	0.11	0.4979	1377	2211	
	Innermost	Lime Plaster	0.2	1	840	1800	
Pitched Roof/Main Building	Outermost	Clay tile (roofing)	0.3	0.84	800	1900	0.823
		Timber flooring	0.3	0.1206	2217	650	
		Air gap 100mm (downwards)	0.17	0.3	1000	1000	
	Innermost	Timber flooring	0.3	0.1206	2217	650	

Figure D. 1. Layout Plan of İzmir Houses Sample with Two Story and Side Hall Plan Type
(Source: Boygar.Ö., Restoration Project)

Figure D. 2. Floor Plans and Facades of İzmir Houses Sample with Two Story and Side Hall Plan Type
(Source: Boygar,Ö., Restoration Project; İzmir Metropolitan Municipality Archive)

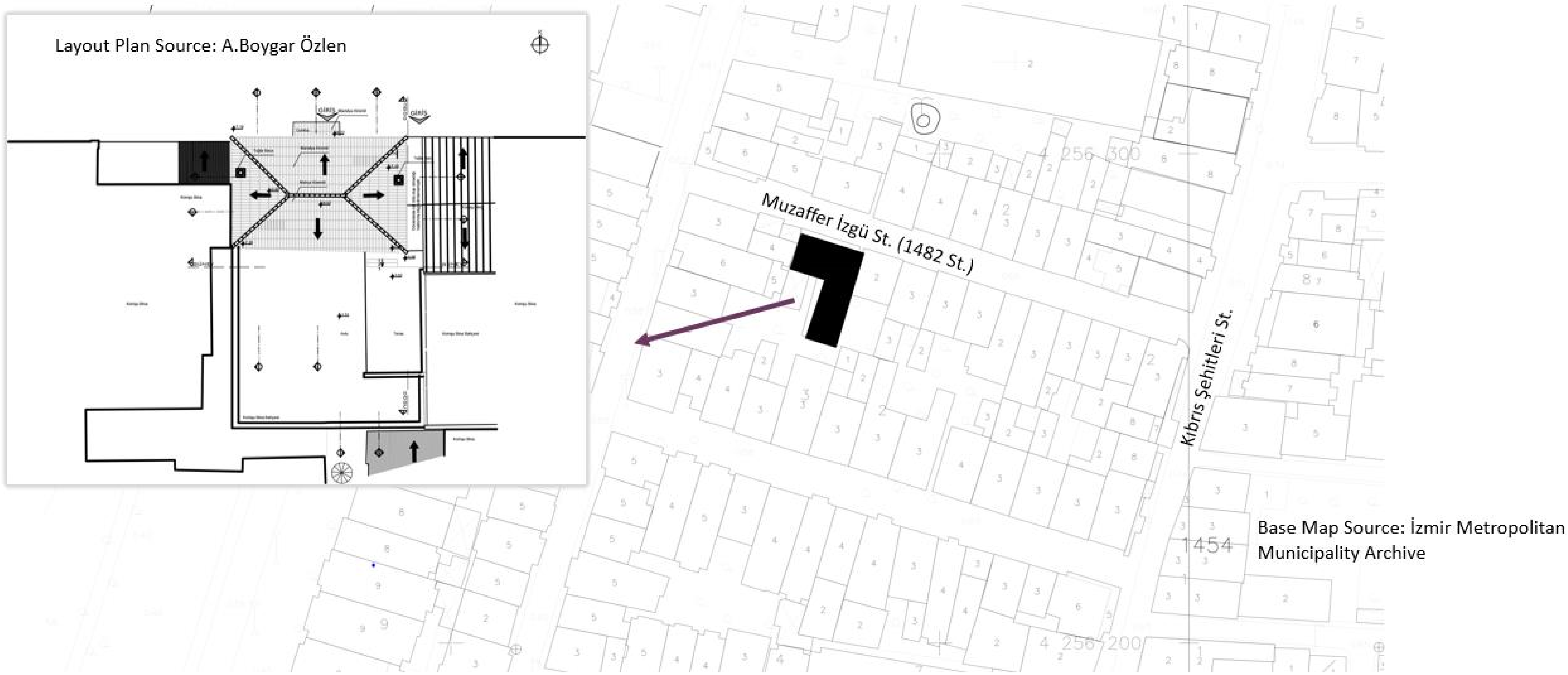

Figure D. 3. İzmir House sample with two story and central hall plan type
(Source: Boygar,Ö., Restoration Project; İzmir Metropolitan Municipality Archive)

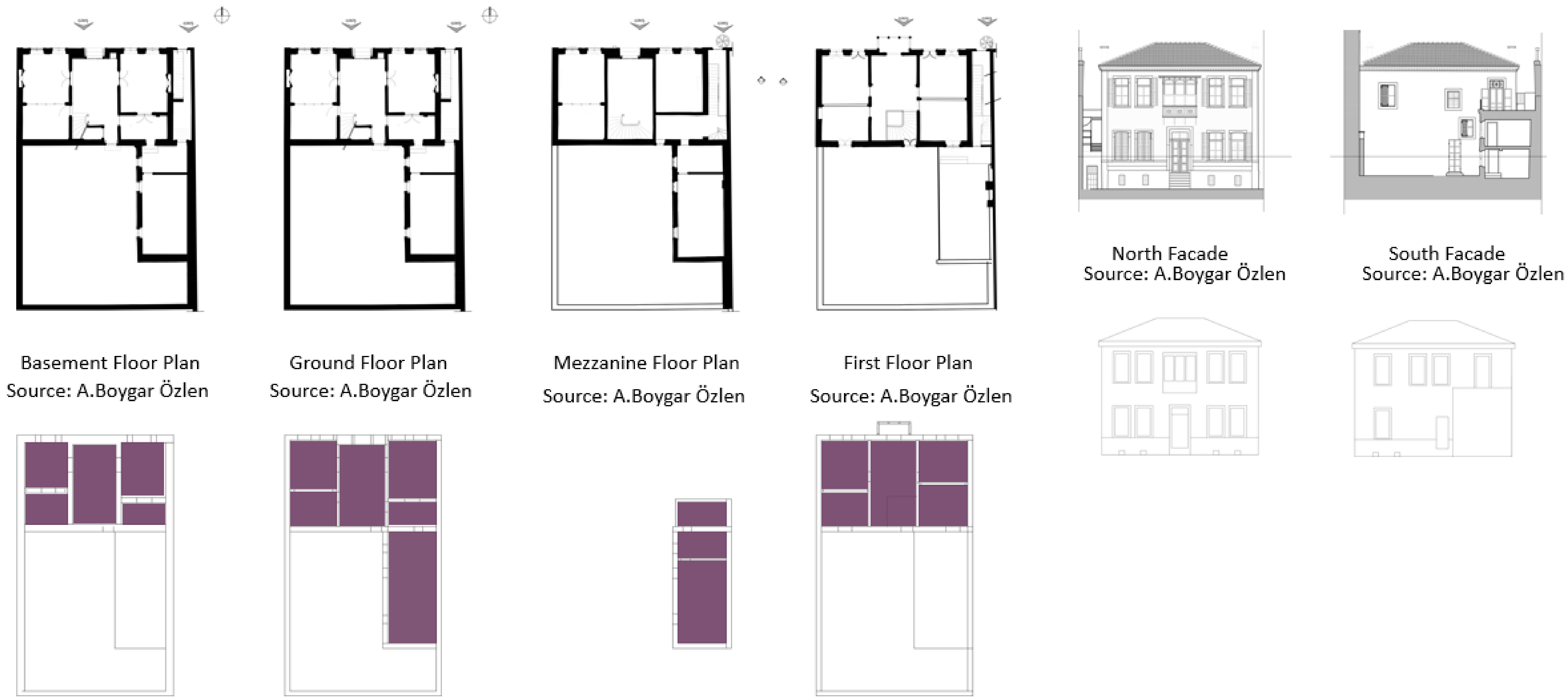

Figure D. 4. Floor Plans and Facades of İzmir Houses Sample with Two Story and Central Hall Plan Type
(Source: Boygar,Ö., Restoration Project; İzmir Metropolitan Municipality Archive)

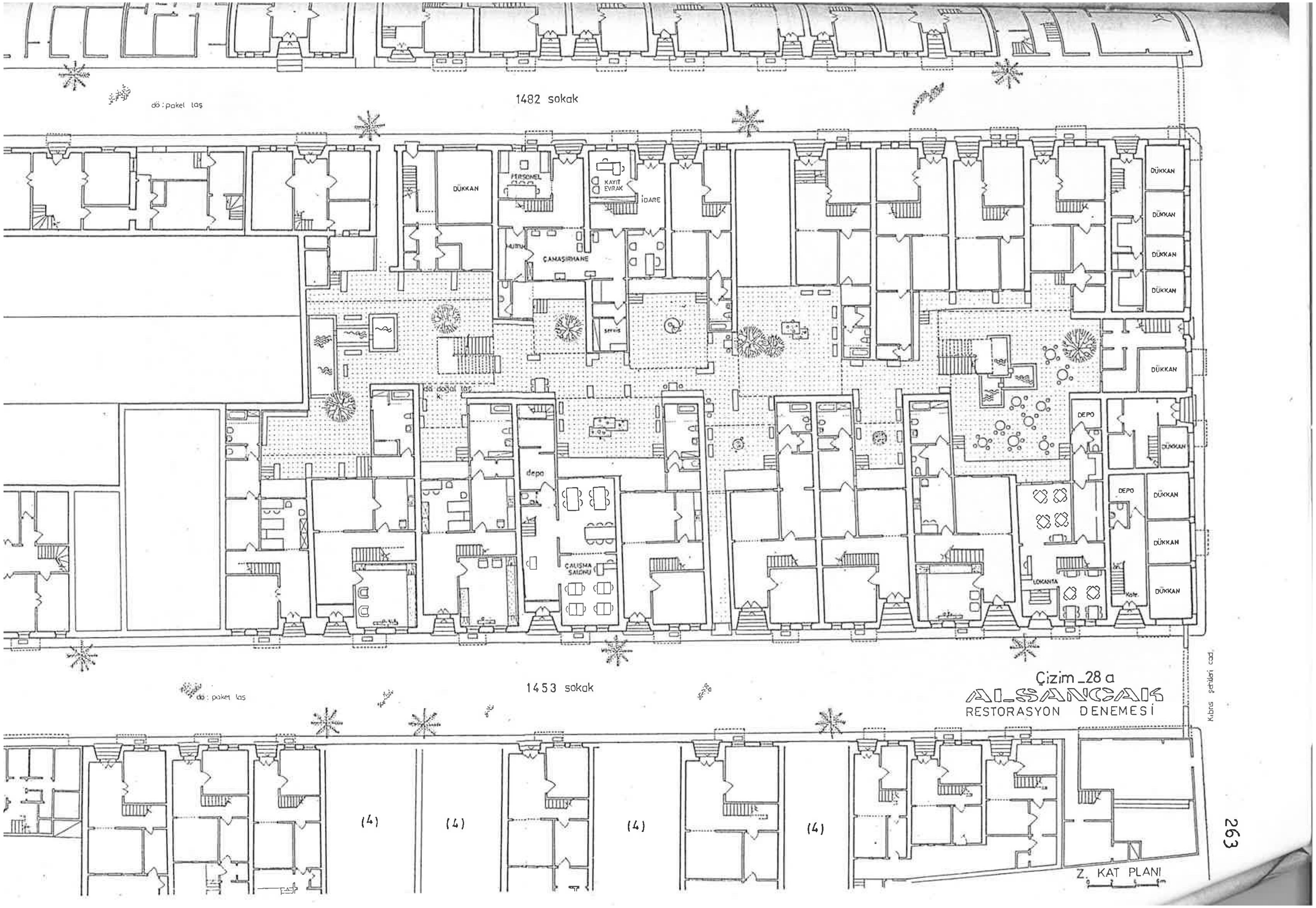

Figure D. 5. Ground Floor Plans of İzmir Houses on 1453 streets
(Source:Akyüz 1985)

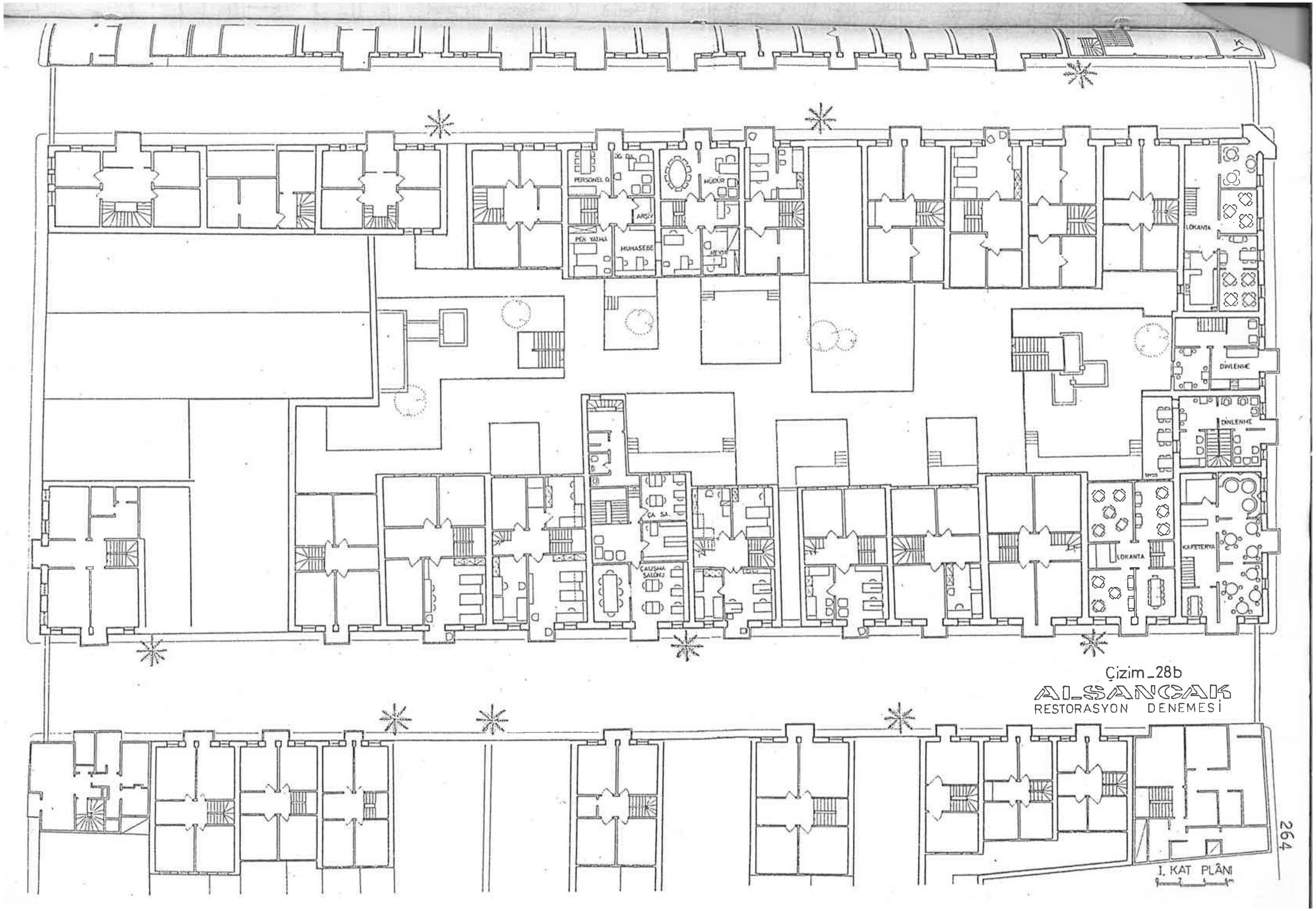

Figure D. 6. First Floor Plans of İzmir Houses on 1453 streets
(Source:Akyüz 1985)

Figure D. 7. Plans and Facades of İzmir Houses on 1482 and 1453 streets
(Source:Tosun 1983)

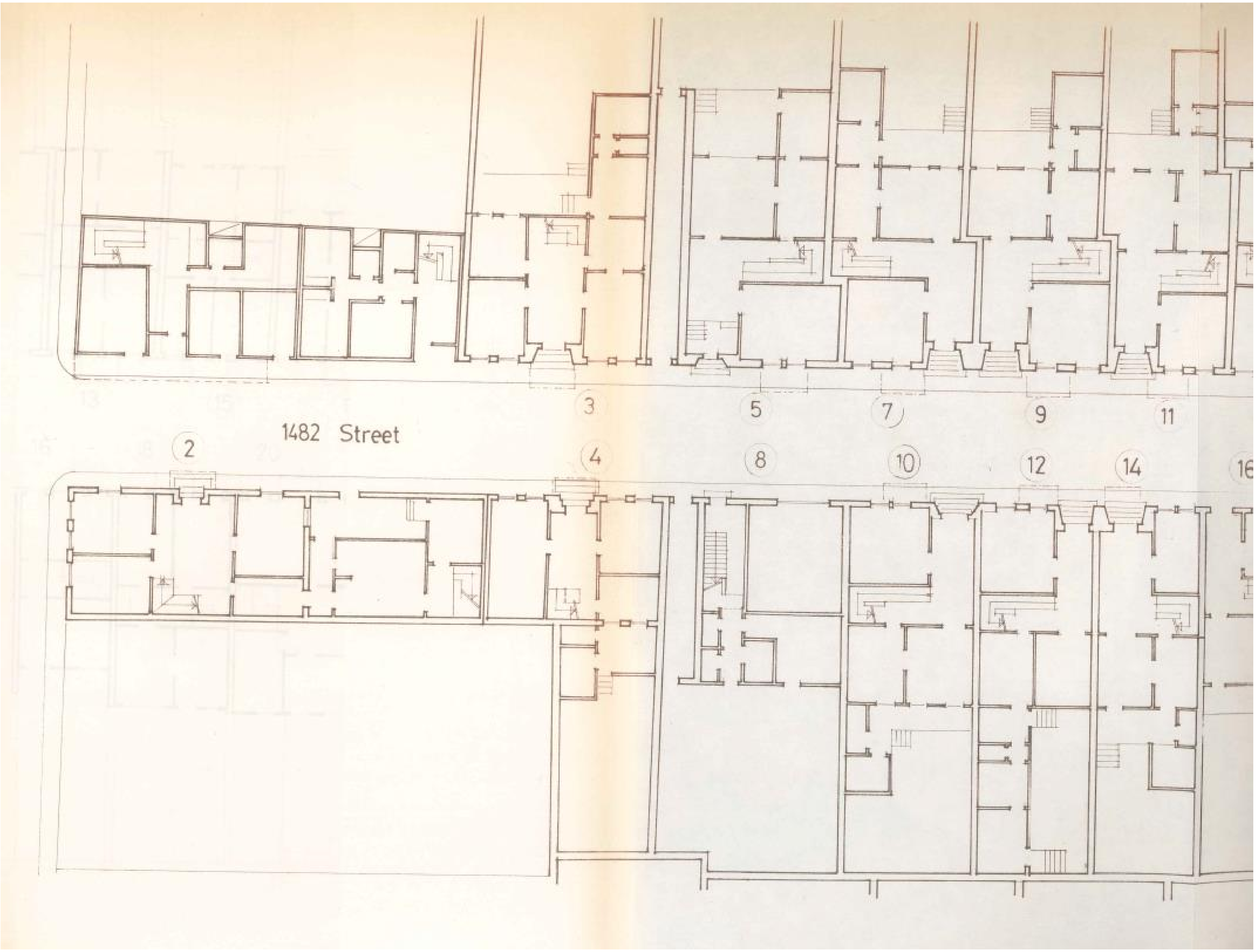

Figure D. 8. Ground Floor Plans of İzmir Houses on 1482 street
(Source:Moral 1990)

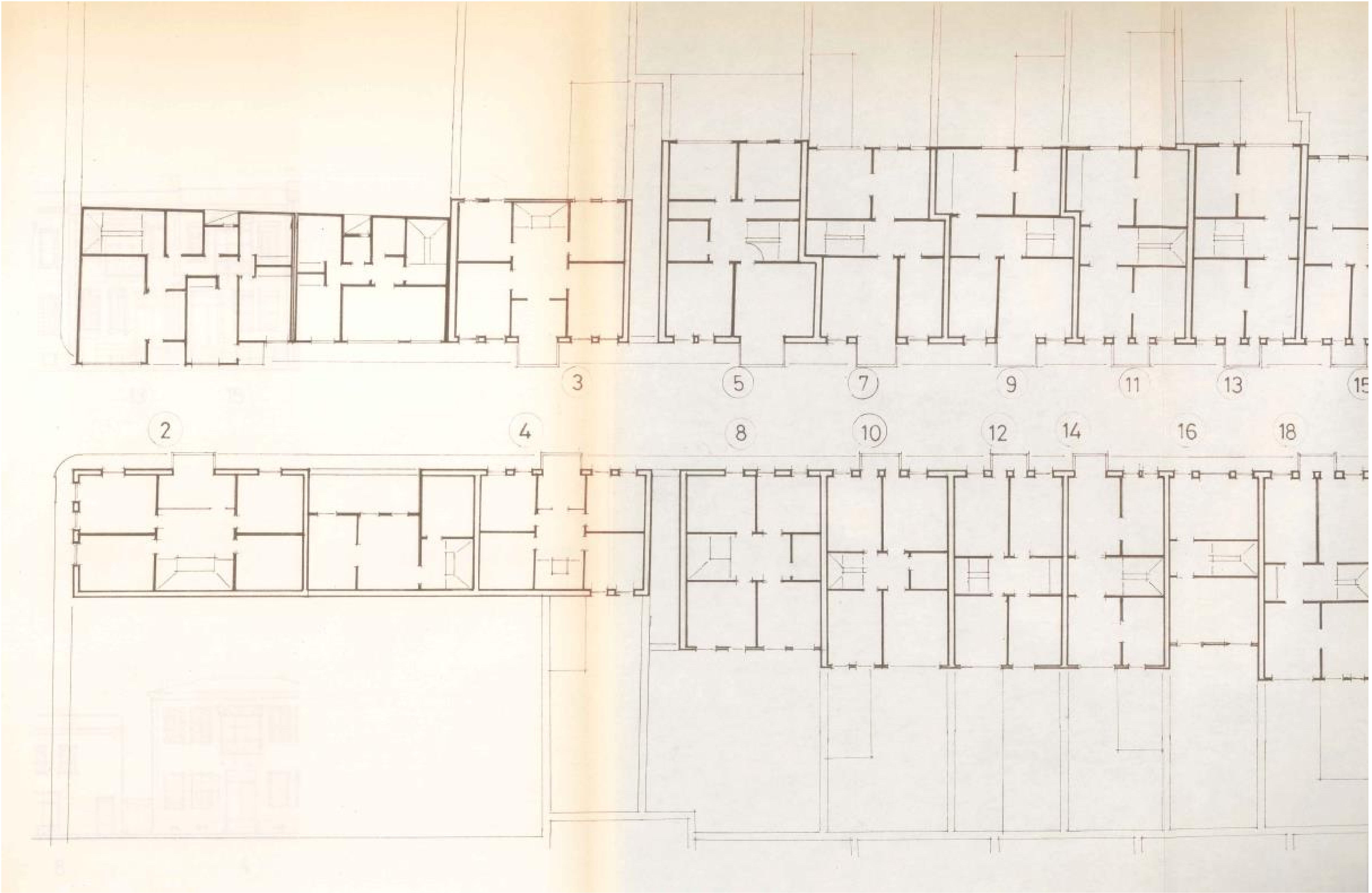

Figure D. 9. First Floor Plans of İzmir Houses on 1482 street
(Source:Moral 1990)

Table D. 4 Material Properties of the Single-Story İzmir Houses in Buca

Single-Story İzmir House Sample							
Wall type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
External Wall/Main Building	Outermost	Lime plaster	0.025	1000	840	1800	1.688
		Stones with solid brick	0.35	0.94	1365	2316	
	Innermost	Lime Plaster	0.025	1000	1437	1800	
Partition Wall/Main Building	Outermost	Lime Plaster	0.025	1000	1437	1800	2.179
		Stones with solid brick	0.14	0.94	1365	2316	
	Innermost	Lime Plaster	0.025	1000	1437	1800	
External Wall/Main Building Basement	Outermost	Face stone	0.04	2.9	900	2650	1.286
		Lime mortar	0.03	1000	840	1800	
	Innermost	Stones with solid brick	0.53	0.94	1365	2316	
External Wall/Main Building Basement	Outermost	Lime Plaster	0.03	1000	840	1800	1.24
	Innermost	Stones with solid brick	0.57	0.94	1365	2316	
Below Grade Wall/Main Building Basement		Stones with solid brick	0.6	0.94	1365	2316	1.237
Partition Wall/Main Building Basement		Stones with solid brick	0.4	0.94	1365	2316	1.679
External Adjacent Wall/Main Building	Outermost	Cement Plaster	0.375	0.72	840	1760	1.684
	Innermost	Cement Plaster	0.025	1000	1437	1800	
Floor Type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Floor/Basement Main Building	Outermost	Sand and gravel	0.05	2	1045	1950	2.883
		Lean Concrete	0.1	1.35	1000	1800	
		Cement Mortar	0.03	1.4	840	2000	
	Innermost	Ceramic tile (karosiman)	0.02	1.22	850	1996	
Brick Arch Marble Ground Floor/Main Building	Outermost	Lime plaster	0.02	1	840	1800	1.866
		Brick-burned	0.11	0.4979	1377	2211	
		Cement Mortar	0.02	1.4	840	2000	
	Innermost	Marble white	0.03	2.77	802	2600	
Brick Arch Ceramic Tile Ground Floor/Main Building	Outermost	Lime plaster	0.02	1	840	1800	1.822
		Brick-burned	0.11	0.4979	1377	2211	
		Cement Mortar	0.02	1.4	840	2000	
	Innermost	Ceramic tile (karosiman)	0.03	1.22	850	1996	

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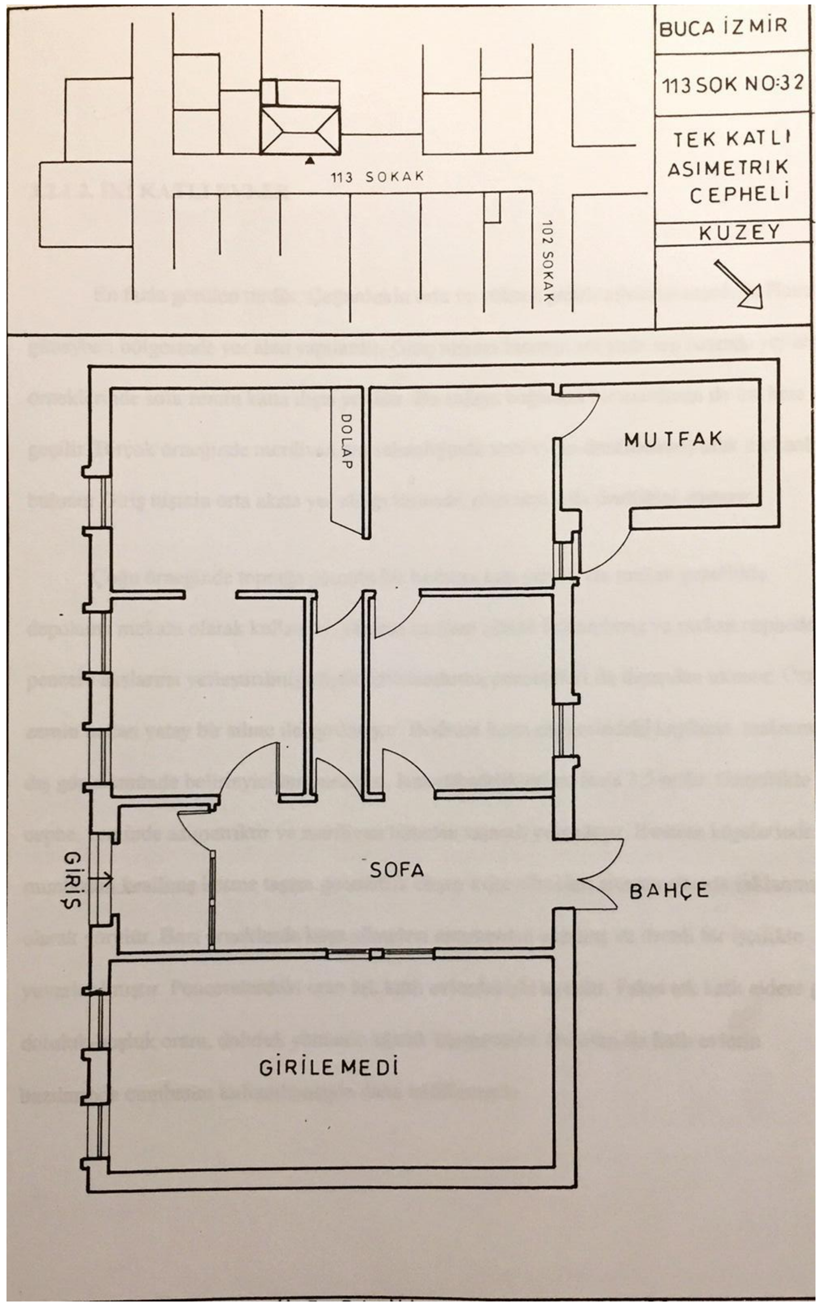
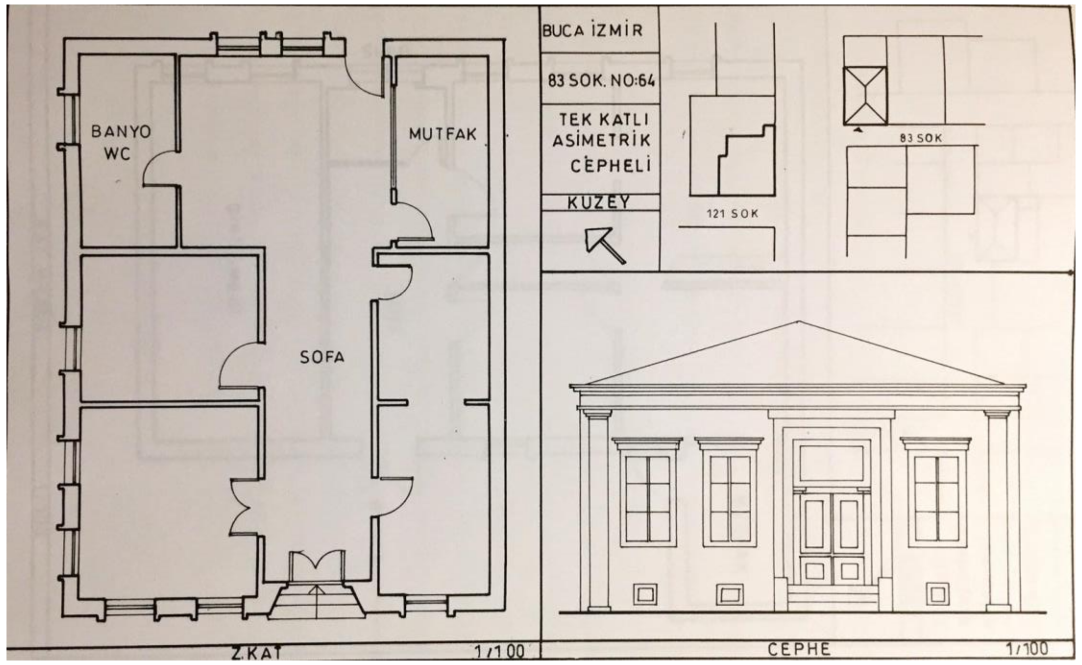
Table D. 4. (cont.)

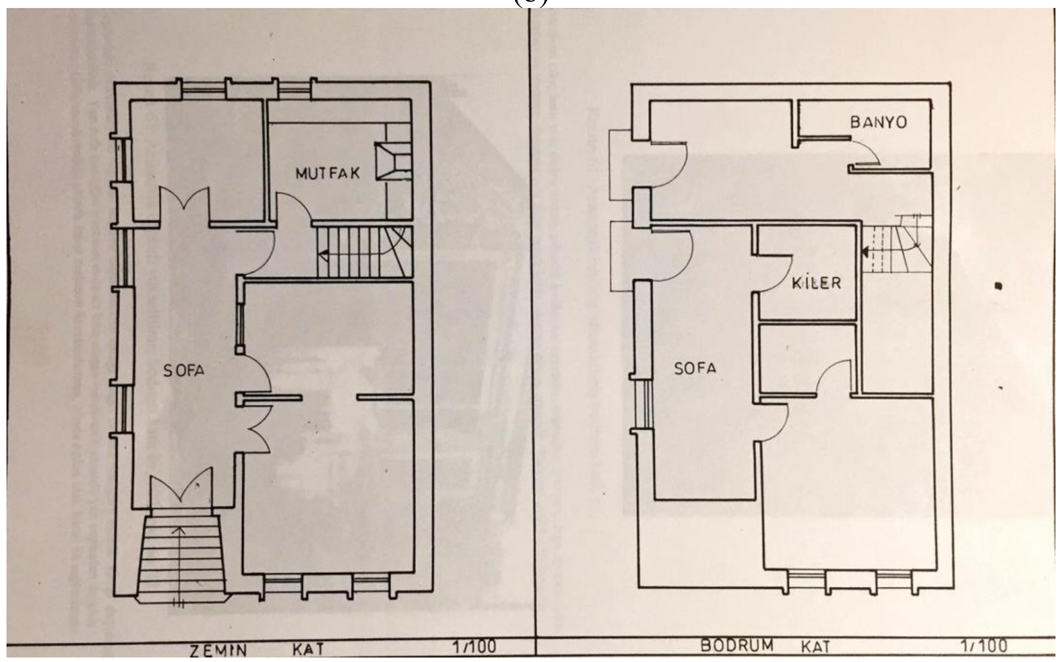
Brick Arch Timber Ground Floor/Main Building (Room)	Outermost	Lime plaster	0.02	1	840	1800	1.002
		Brick-burned	0.11	0.4979	1377	2211	
		Cement mortar	0.04	1.4	840	2000	
		Air gap 50mm (downwards)	0.04	0.3	1000	1000	
	Innermost	Wood	0.03	0.1206	2217	650	
Timber Floor/Main Building	Outermost	Lime Plaster	0.2	1	840	1800	0.993
		Wood	0.03	0.1206	2217	650	
		Air gap 100mm (downwards)	0.17	0.3	1000	1000	
	Innermost	Wood	0.03	0.1206	2217	650	
Ceramic Tile Ground Floor/Main Building Without Basement	Outermost	Lean Concrete	0.13	1.35	1000	1800	2.475
		Cement mortar	0.03	1.4	840	2000	
	Innermost	Ceramic tile (karosiman)	0.02	1.22	850	1996	
Timber Floor/Main Building Without Basement	Outermost	Lean Concrete	0.13	1.35	1000	1800	1.385
		Air gap 25mm (downwards)	0.03	0.3	1000	1000	
	Innermost	Wood	0.02	0.1206	2217	650	
Roof type and Location	**Position**	**Layer name**	**Thickness m**	**Conductivity W/m K**	**Spesific Heat J/kg K**	**Density Kg/m3**	**U value W/m2 K**
Pitched Roof/Main Building	Outermost	Clay tile (roofing)	0.3	0.84	800	1900	1.508
		Timber flooring	0.3	0.1206	2217	650	



(a)



(b)



(c)

Figure D. 10. (a) Plan of İzmir House on 113 street in Buca, (b) Plan of İzmir House on 83 street in Buca, (c) Plan of İzmir House on Atadan avenue in Buca (Source:Bilginperk 1999)

APPENDIX E

RESULTS OF DAYLIGHT ANALYSES

Table E. 1. Daylight Analysis Through Spatial Properties of the İzmir Houses in Basmane and Buca

İzmir House in Basmane										
spatial properties	**Type of the data**	**Z01 Entrance Hall**			**Z02 Room**			**Z06 Room**		
	WWR %	27			13,3			10,2		
	WFR %	21			32,2			29		
	depth (m)	3,61			3,65			3,27		
	width (m)	1,66			3,69			2,98		
	height (m)	3,58			3,5			3,5		
	facade direction	north			north and east			north and west		
Date	**Illuminance / Uniformity**	Morning	Noon	Evening	Morning	Noon	Evening	Morning	Noon	Evening
23.06.2016	**max (lux)**	559	819	934	445,6	89,9	280	560	575	579
	min (lux)	120	145,5	179,8	12,72	11,1	17,62	72,2	152	114,9
	average (lux)	225,4	354,7	377,5	74	28,8	66	191,4	251,9	231,1
	U_1 (E_{min}/E_{avg})	0,53	0,41	0,48	0,17	0,38	0,27	0,38	0,6	0,5
	U_2 (E_{min}/E_{max})	0,21	0,18	0,19	0,03	0,12	0,06	0,13	0,26	0,2
22.09.2016	**max (lux)**	773	1034	266	348,20	484,00	117,50	730	654	207,2
	min (lux)	155,3	90	46,4	24,23	18,67	12,46	115	75,3	31,18
	average (lux)	345,29	339,9	134,61	93,14	83,49	39,49	263,76	187,55	85,82
	U_1 (E_{min}/E_{avg})	0,45	0,26	0,34	0,26	0,22	0,32	0,44	0,40	0,36
	U_2 (E_{min}/E_{max})	0,20	0,09	0,17	0,07	0,04	0,11	0,16	0,12	0,15
21.12.2016	**max (lux)**	155,00	378,50	249,70	75,00	315,30	67,20	209,3	261	169,4
	min (lux)	19,21	56,10	23,33	3,84	11,48	2,58	27,06	60,80	14,51
	average (lux)	62,78	188,53	87,95	16,10	42,87	9,95	64,16	126,17	50,09
	U_1 (E_{min}/E_{avg})	0,31	0,30	0,27	0,24	0,27	0,26	0,42	0,48	0,29
	U_2 (E_{min}/E_{max})	0,12	0,15	0,09	0,05	0,04	0,04	0,13	0,23	0,09
23.03.2017	**max (lux)**	623	747	492	379	259,1	691	705	734	550
	min (lux)	157,30	169	158,6	13,73	15,34	30,43	134,3	140,2	124,4
	average (lux)	362,61	403,61	286,91	55,51	48,49	132,23	247,21	277,08	211,84
	U_1 (E_{min}/E_{avg})	0,43	0,42	0,55	0,25	0,32	0,23	0,54	0,51	0,59
	U_2 (E_{min}/E_{max})	0,25	0,23	0,32	0,04	0,06	0,04	0,19	0,19	0,23

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Table E. 1. (cont.)

İzmir House in Basmane																			
spatial properties	**Type of the data**	**101 Hall**			**102 Oriel**			**103 Room**			**106 Room**			**107 Corridor**			**108 Room**		
	WWR %	28,6			46			13,8			11,4			18,5			10,6		
	WFR %	36,3			33,1			29,6			16,8			24,8			26,7		
	depth (m)	7,11-2,75			0,78			3,63			2,79			1,16			3,24		
	width (m)	1,70-3,96			1,69			3,68			3			3,08			2,96		
	height (m)	3,17			2,55			3,17			3,17			3,15			3,16		
	facade direction	north and south			north, esast and west			north and east			south			west			north and west		
Date	**Illuminance / Uniformity**	Morning	Noon	Evening	Morning	Noon	Evening	Morning	Noon	Evening	Morning	Noon	Evening	Morning	Noon	Evening	Morning	Noon	Evening
23.06.2016	**max (lux)**	2336	1412	2083	3400	3620	-	978	884	877	1215	391,5	394,2	130,2	98	262,9	730	1143	3412
	min (lux)	107,7	125,6	136,3	1653	2449	-	129	193	226,8	47	60,3	84,4	25,45	37,8	63,7	90	265,6	397
	average (lux)	503,1	468,9	501,3	2499,8	3034,5	-	393,4	447,6	461,3	264,9	137,8	167,6	57,5	61,1	134	301,8	564,2	1277,7
	U_1 (E_{min}/E_{avg})	0,21	0,27	0,27	0,66	0,81	-	0,33	0,43	0,49	0,18	0,44	0,5	0,44	0,62	0,48	0,3	0,47	0,31
	U_2 (E_{min}/E_{max})	0,05	0,09	0,07	0,49	0,68	-	0,13	0,22	0,26	0,04	0,15	0,21	0,2	0,39	0,24	0,12	0,23	0,12
22.09.2016	**max (lux)**	2949	1049	749	4690	3644	2427	1888	1547	547	5960	952	413	110	54	136	1666	2332	1647
	min (lux)	387	63	84	3015	2326	1347	275	166	125	191,3	57,9	104,4	75	32,69	87,50	344	313,7	157,9
	average (lux)	1141,59	273,84	252,26	3799,25	2932,75	1906,50	662,91	602,71	266,08	1393,05	268,83	178,74	87,30	38,82	115,54	697,00	874,55	502,68
	U_1 (E_{min}/E_{avg})	0,34	0,23	0,33	0,79	0,79	0,71	0,41	0,28	0,47	0,14	0,22	0,58	0,86	0,84	0,76	0,49	0,36	0,31
	U_2 (E_{min}/E_{max})	0,13	0,06	0,11	0,64	0,64	0,56	0,15	0,11	0,23	0,03	0,06	0,25	0,68	0,61	0,64	0,21	0,13	0,10
21.12.2016	**max (lux)**	300,10	753	559	897	1614	1398	330,80	362,00	280,60	158,8	451	136,6	9,22	20,46	9,11	242,7	333,6	253,1
	min (lux)	17,63	44,10	23,50	575,00	1143	872	35,98	77,80	23,40	15,01	30,79	17,38	6,43	15,99	7,35	49,8	62,7	35,73
	average (lux)	77,77	227,38	97,47	721,50	1385,25	1107	120,36	161,95	103,63	44,49	134,66	48,51	7,228	17,682	7,906	104,845	176,83	96,6715
	U_1 (E_{min}/E_{avg})	0,23	0,19	0,24	0,80	0,83	0,79	0,30	0,48	0,23	0,34	0,23	0,36	0,89	0,90	0,93	0,47	0,35	0,37
	U_2 (E_{min}/E_{max})	0,06	0,06	0,04	0,64	0,71	0,62	0,11	0,21	0,08	0,09	0,07	0,13	0,70	0,78	0,81	0,21	0,19	0,14
23.03.2017	**max (lux)**	3583	2851	1202	2841	2420	2899	2361	824	949	2628	4510	429	204,5	141,2	86,4	784	768	1111
	min (lux)	301,20	329,5	104,0	1877	1730	1792	319,7	305	224,5	163,5	253,4	93	73,3	61	69,2	220,4	226,3	208,3
	average (lux)	916,05	827,90	351,65	2321,5	2077,3	2444	666,49	470,01	443,79	539,63	820,74	167,23	110,24	84,56	76,04	443,02	422,01	437,36
	U_1 (E_{min}/E_{avg})	0,33	0,40	0,30	0,81	0,83	0,73	0,48	0,65	0,51	0,3	0,31	0,56	0,66	0,72	0,91	0,50	0,54	0,48
	U_2 (E_{min}/E_{max})	0,08	0,12	0,09	0,66	0,71	0,62	0,14	0,37	0,24	0,06	0,06	0,22	0,36	0,43	0,8	0,28	0,29	0,19

Table E. 2. Daylight Analysis Through Spatial Properties of the İzmir houses in Buca

İzmir house in Buca													
spatial properties	**Type of the data**	**Z01 Room**			**Z02 Room**			**Z03 Room**			**Z04 Hall**		
	WWR %	7.6			6.9			11.5			34.5		
	WFR %	24.9			18.9			21.2			31.2		
	depth (m)	3.6			3.72			3.6			3.11		
	width (m)	2.12			2.7			4.42			1.61		
	height (m)	3.52			3.52			3.54			3.67		
	facade direction	north-west and north-east			north-west and south-west			south-east and south-west			north-west		
Date	**Illuminance / Uniformity**	Morning	Noon	Evening	Morning	Noon	Evening	Morning	Noon	Evening	Morning	Noon	Evening
24.06.2016	**max (lux)**	1260	1290	3022	827	1212	2230	2974	2196	1670	1507	1989	3990
	min (lux)	402	429	587	250.7	375	335.3	670	735	578	673	833	967
	average (lux)	677.92	665.58	1200.92	395.89	551.47	775.52	1284.96	1167.79	982.00	937.38	1198.50	2055.88
	U_1 (E_{min}/E_{avg})	0.59	0.64	0.49	0.63	0.68	0.43	0.52	0.63	0.59	0.72	0.7	0.47
	U_2 (E_{min}/E_{max})	0.32	0.33	0.19	0.3	0.31	0.15	0.23	0.33	0.35	0.45	0.42	0.24
26.09.2016	**max (lux)**	1077	947	623	651	705	663	8230	5430	1072	950	755	563
	min (lux)	300.6	301.8	160.2	246.4	178.4	152.5	889	615	379	540	281.1	256.8
	average (lux)	492.21	507.25	294.15	355.28	318.99	272.75	2499.13	1651.77	595.33	678.8	461.01	371.59
	U_1 (E_{min}/E_{avg})	0.61	0.59	0.54	0.69	0.56	0.56	0.36	0.37	0.64	0.8	0.61	0.69
	U_2 (E_{min}/E_{max})	0.28	0.32	0.26	0.38	0.25	0.23	0.11	0.11	0.35	0.57	0.37	0.46
22.12.2016	**max (lux)**	396	398	180.6	520	685	158.2	1801	593	502	265.9	384.5	82.4
	min (lux)	150.1	57.6	24.2	100.7	78.1	32.98	298.8	107.2	55.8	81.3	90.03	24.67
	average (lux)	212.55	165.07	62.67	201.05	221.06	65.47	691.96	218.86	148.85	153.3	179.35	43.43
	U_1 (E_{min}/E_{avg})	0.71	0.35	0.39	0.5	0.35	0.5	0.43	0.49	0.37	0.53	0.5	0.57
	U_2 (E_{min}/E_{max})	0.38	0.14	0.13	0.19	0.11	0.21	0.17	0.18	0.11	0.31	0.23	0.3
22.03.2017	**max (lux)**	757	1063	1351	586	953	1778	5220	4700	2432	352	602	916
	min (lux)	184.6	382	383	150.6	286.7	315.7	772	807	374	129.6	242.6	282.8
	average (lux)	330.17	588.56	674.11	257.35	465.29	658.91	1821	1944.6	999.6	209.13	382.66	488.38
	U_1 (E_{min}/E_{avg})	0.56	0.65	0.57	0.59	0.62	0.48	0.42	0.41	0.37	0.62	0.63	0.58
	U_2 (E_{min}/E_{max})	0.24	0.36	0.28	0.26	0.3	0.18	0.15	0.17	0.15	0.37	0.4	0.31

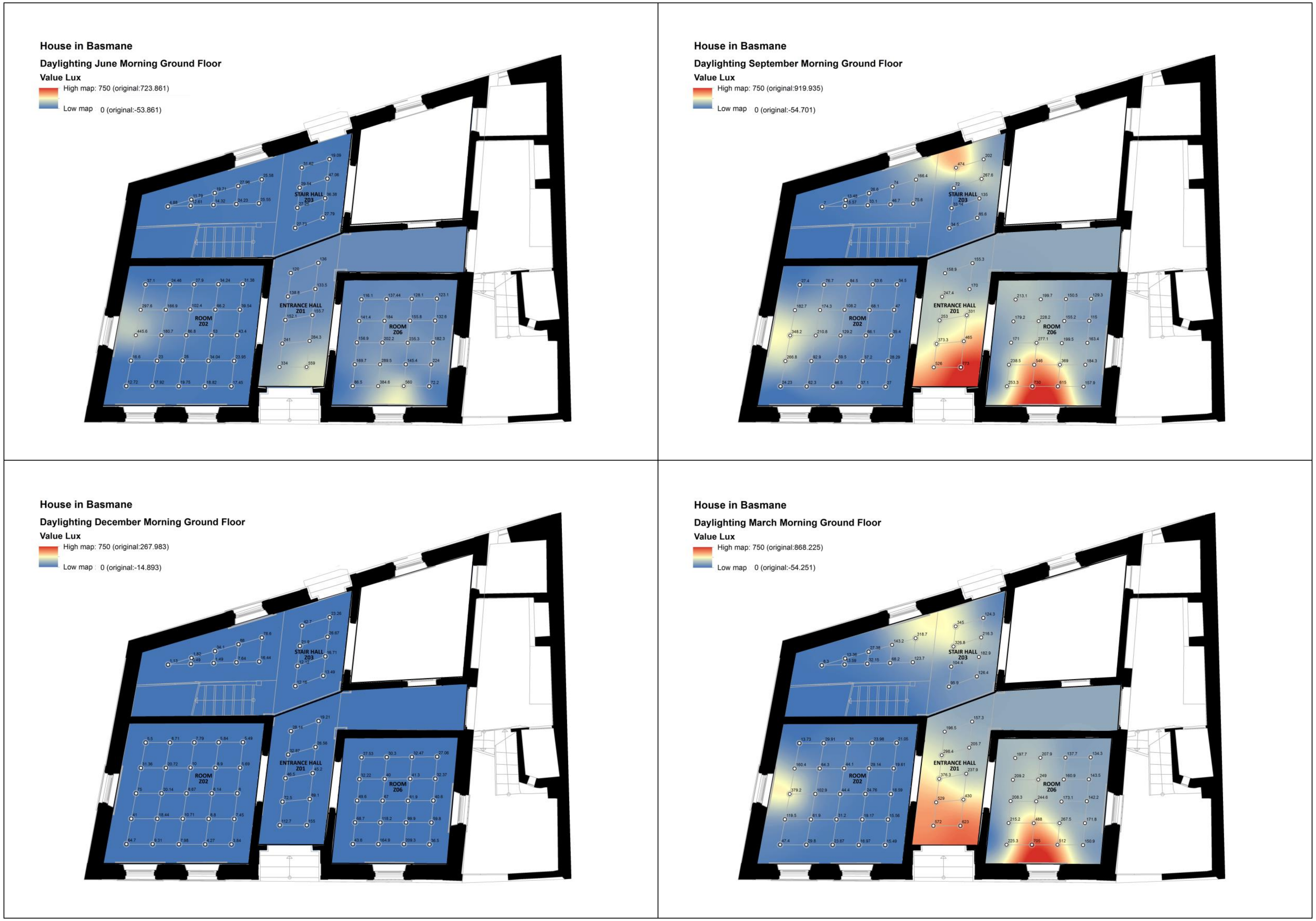


Figure E. 1. Seasonal Daylighting of the Ground Floor of the House in Basmane

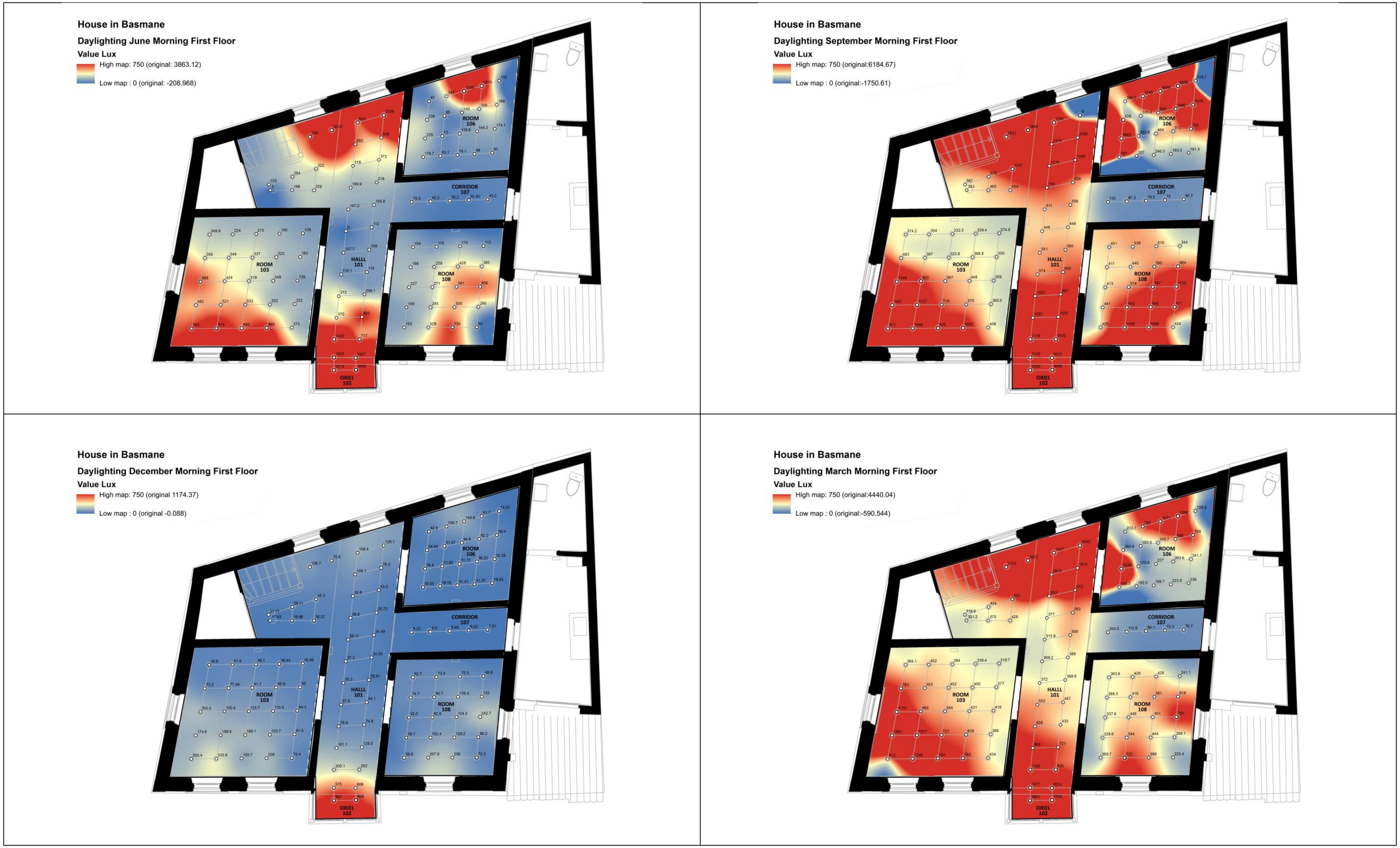


Figure E. 2. Seasonal Daylighting of the First Floor of the House in Basmane

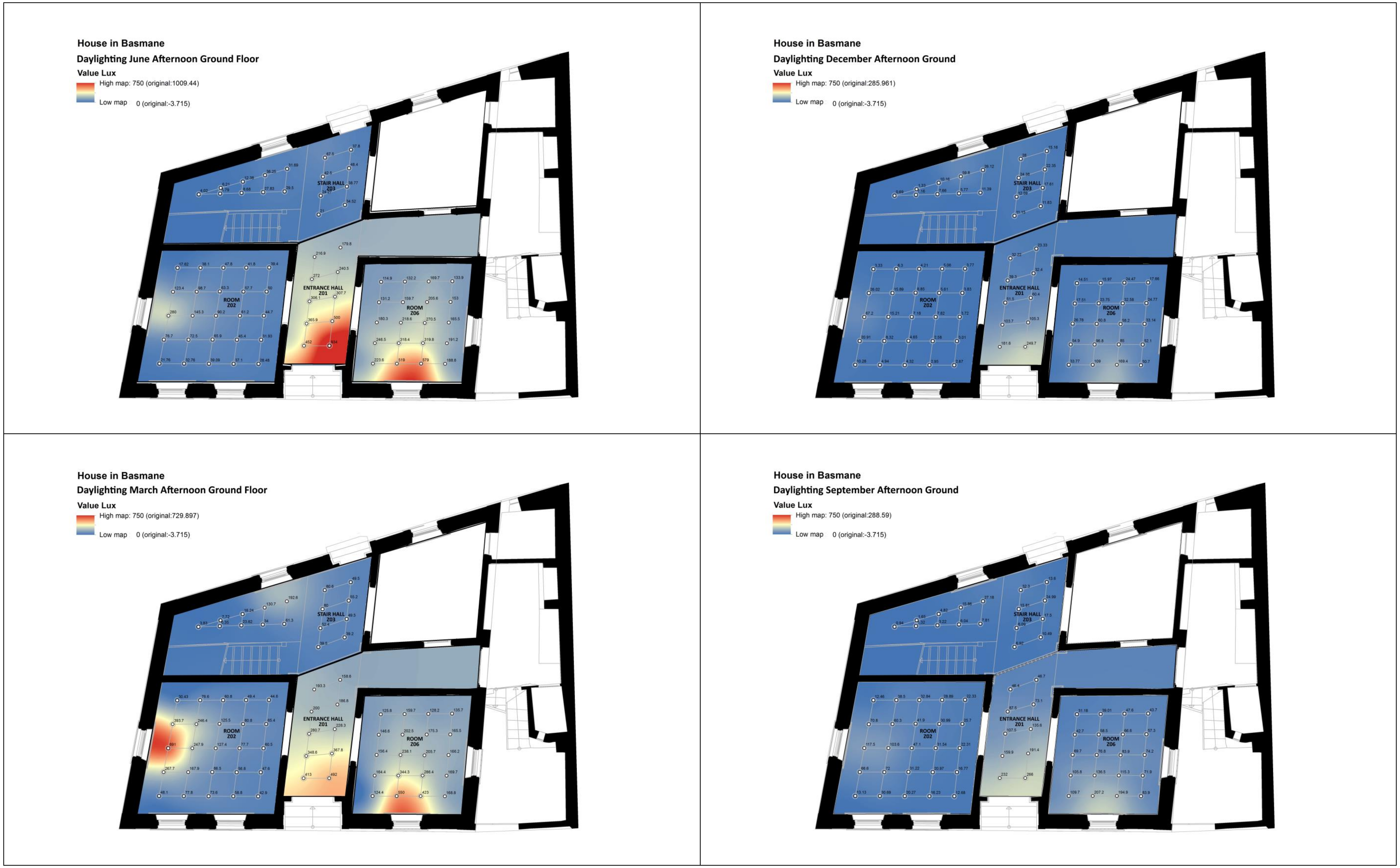


Figure E. 3. Seasonal Daylighting of the Ground Floor of the House in Basmane

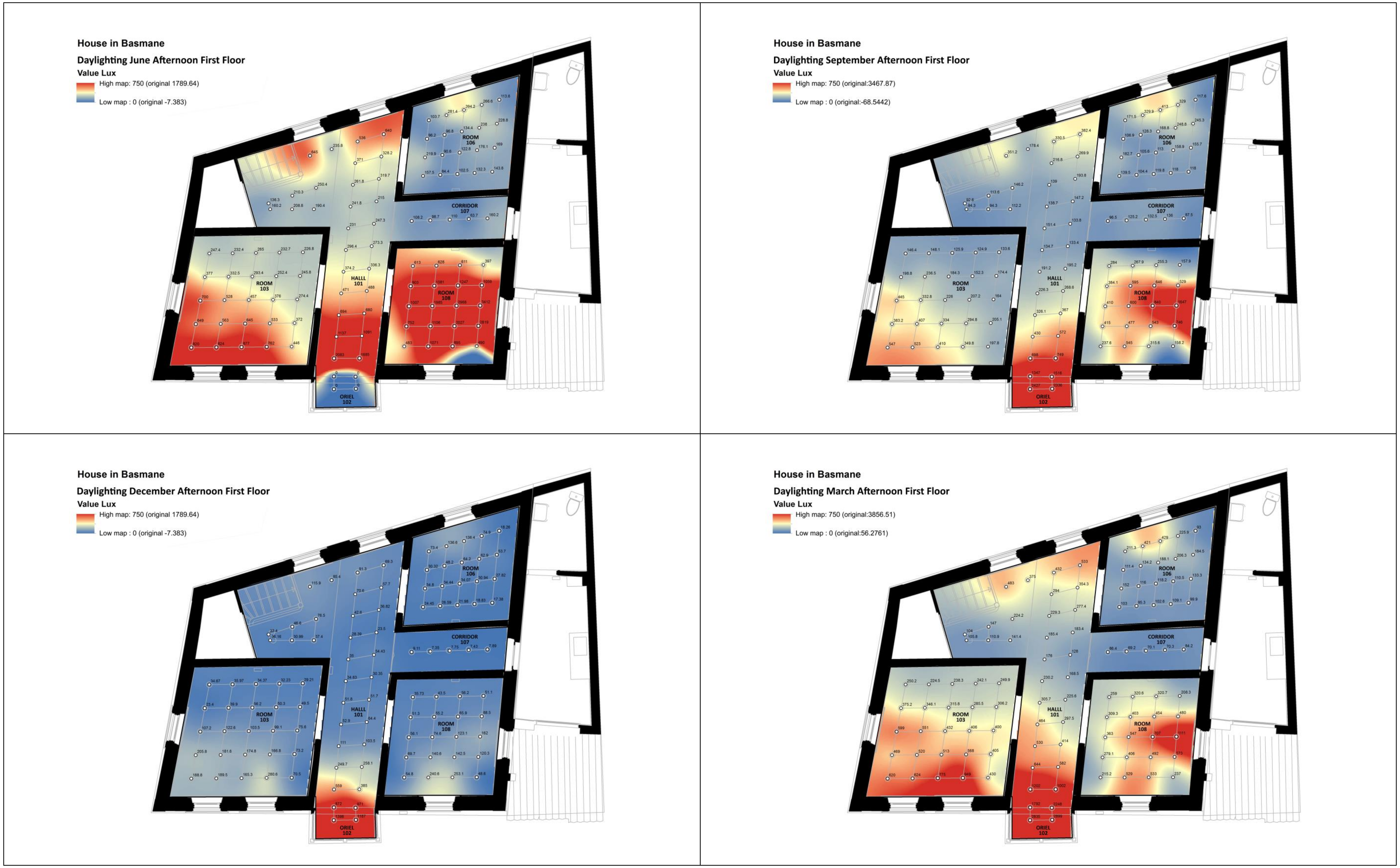


Figure E. 4. Seasonal Daylighting of the First Floor of the House in Basmane

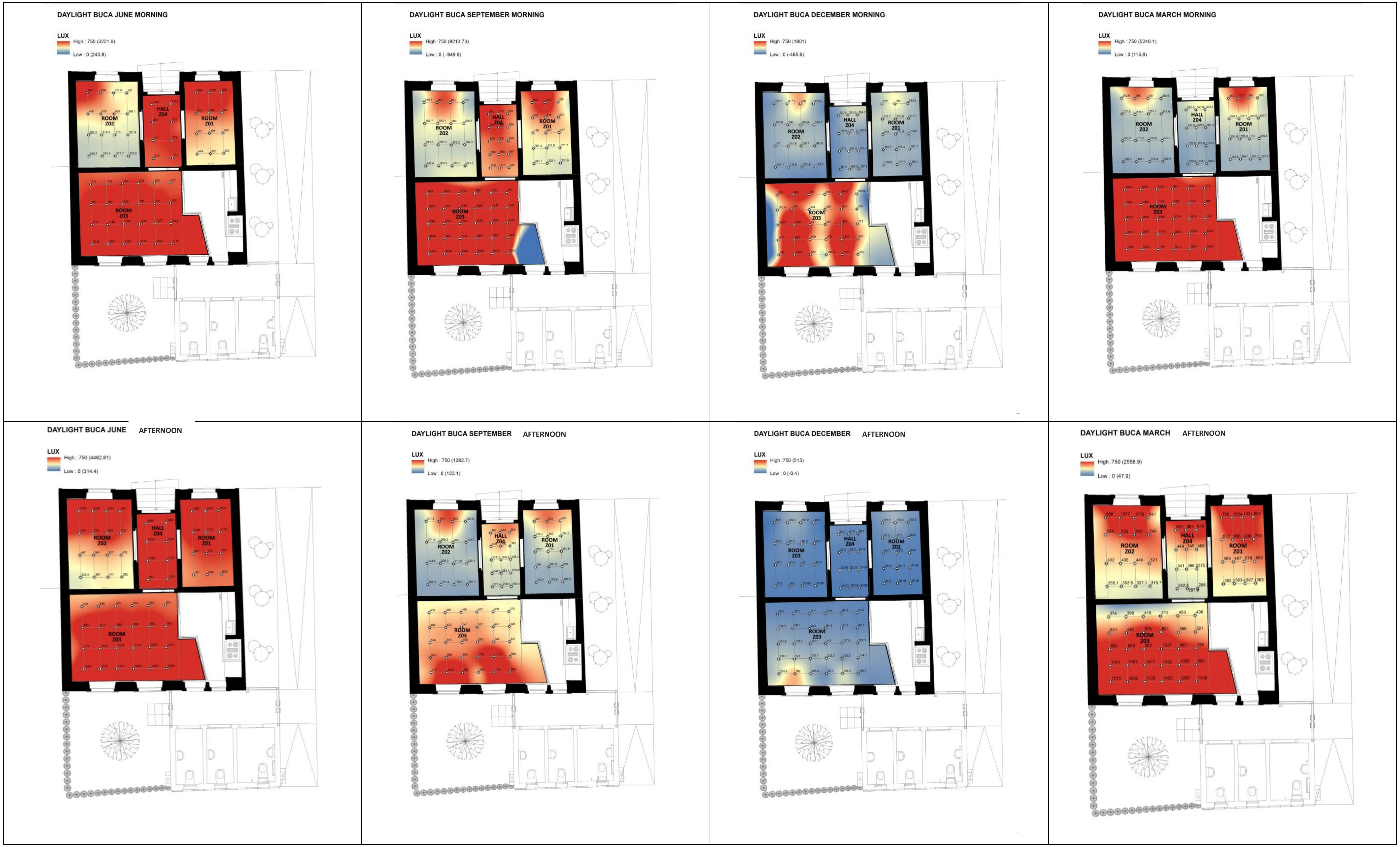


Figure E. 5. Seasonal Daylighting of the of the House in Buca

APPENDIX F

THERMAL BEHAVIOUR OF BASE CASE IZMIR HOUSES

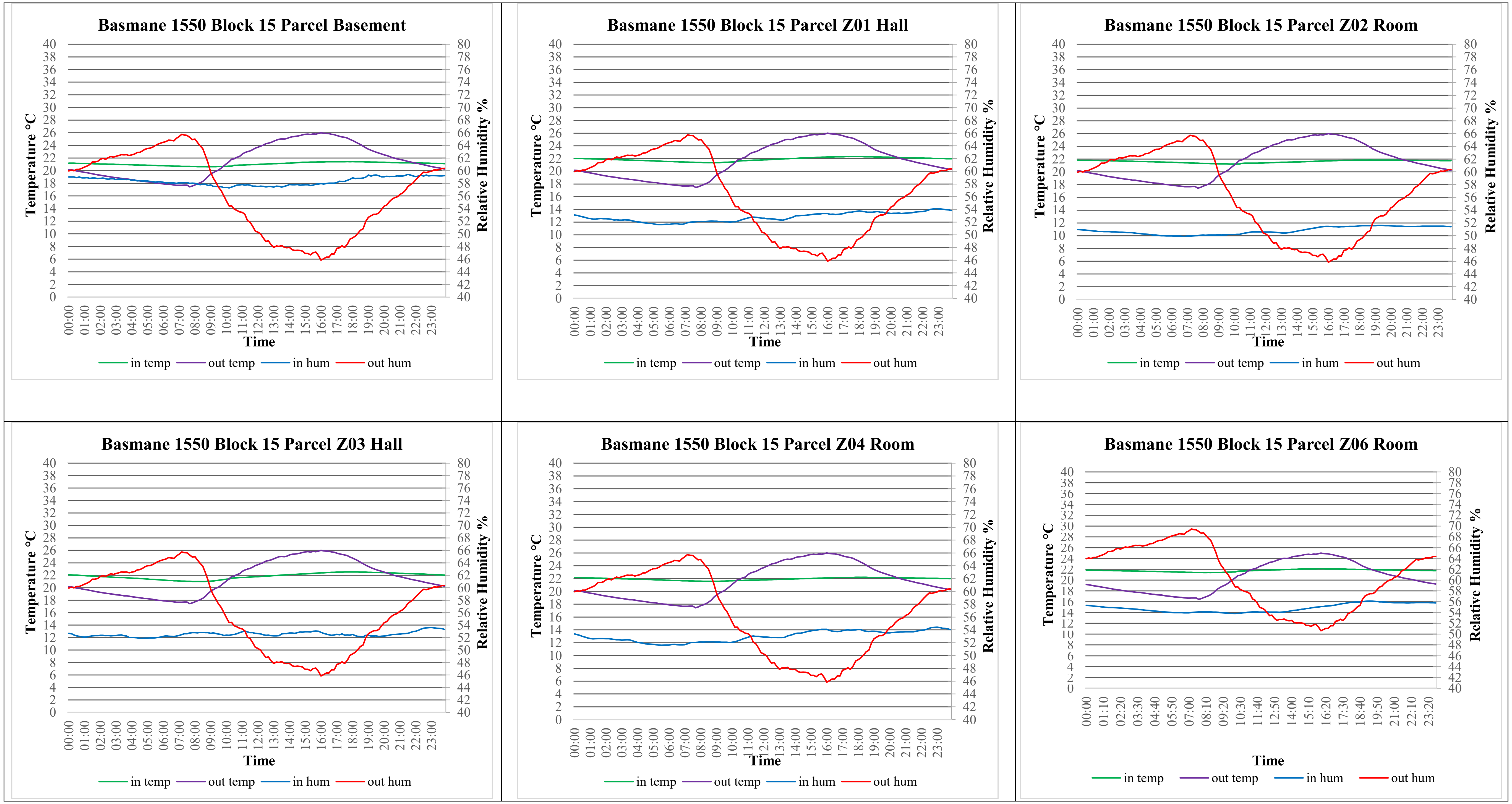


Figure F. 1 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Basmane 22.09.2016-22.10.2016

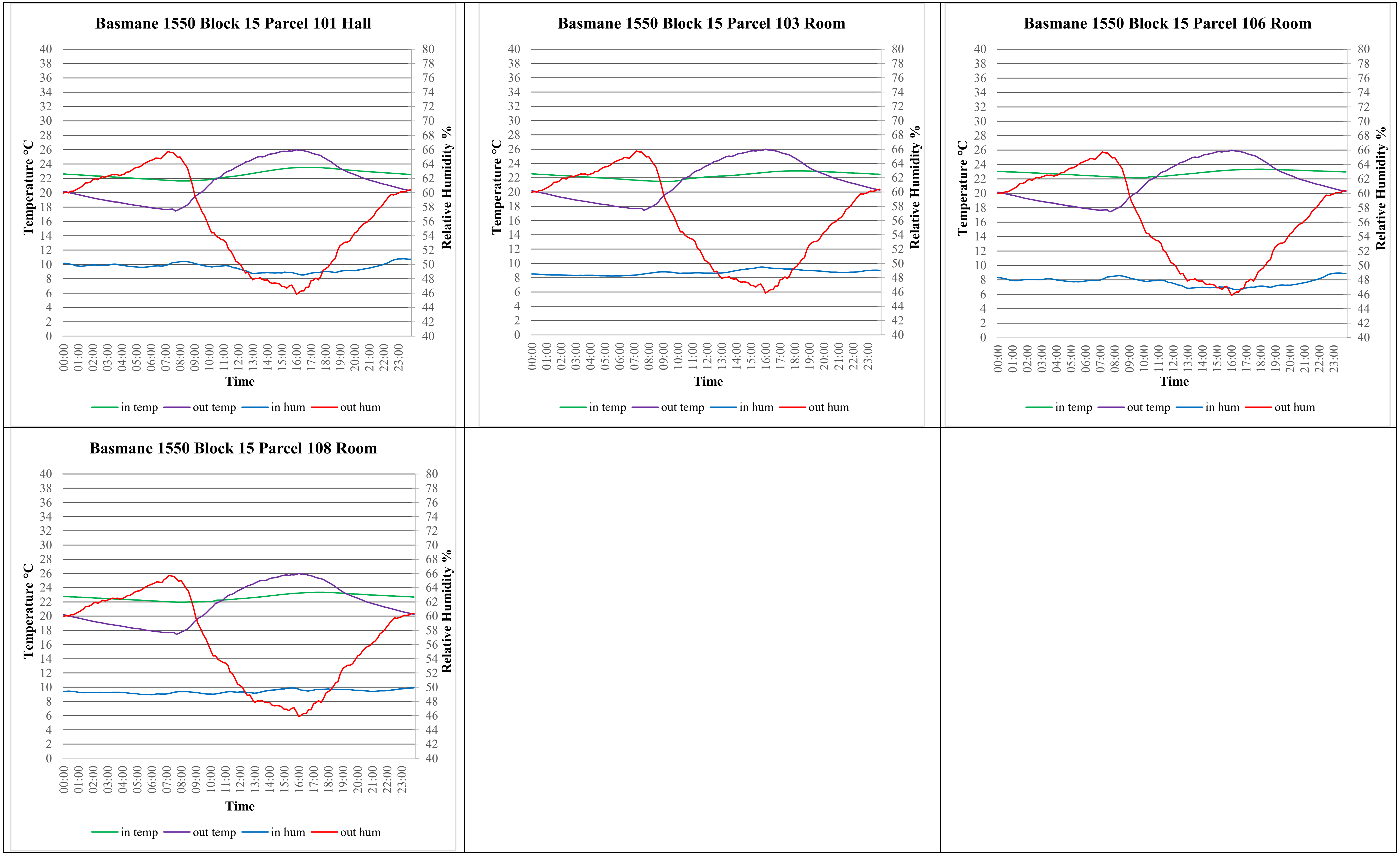


Figure F. 2 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Basmane 22.09.2016-22.10.2016

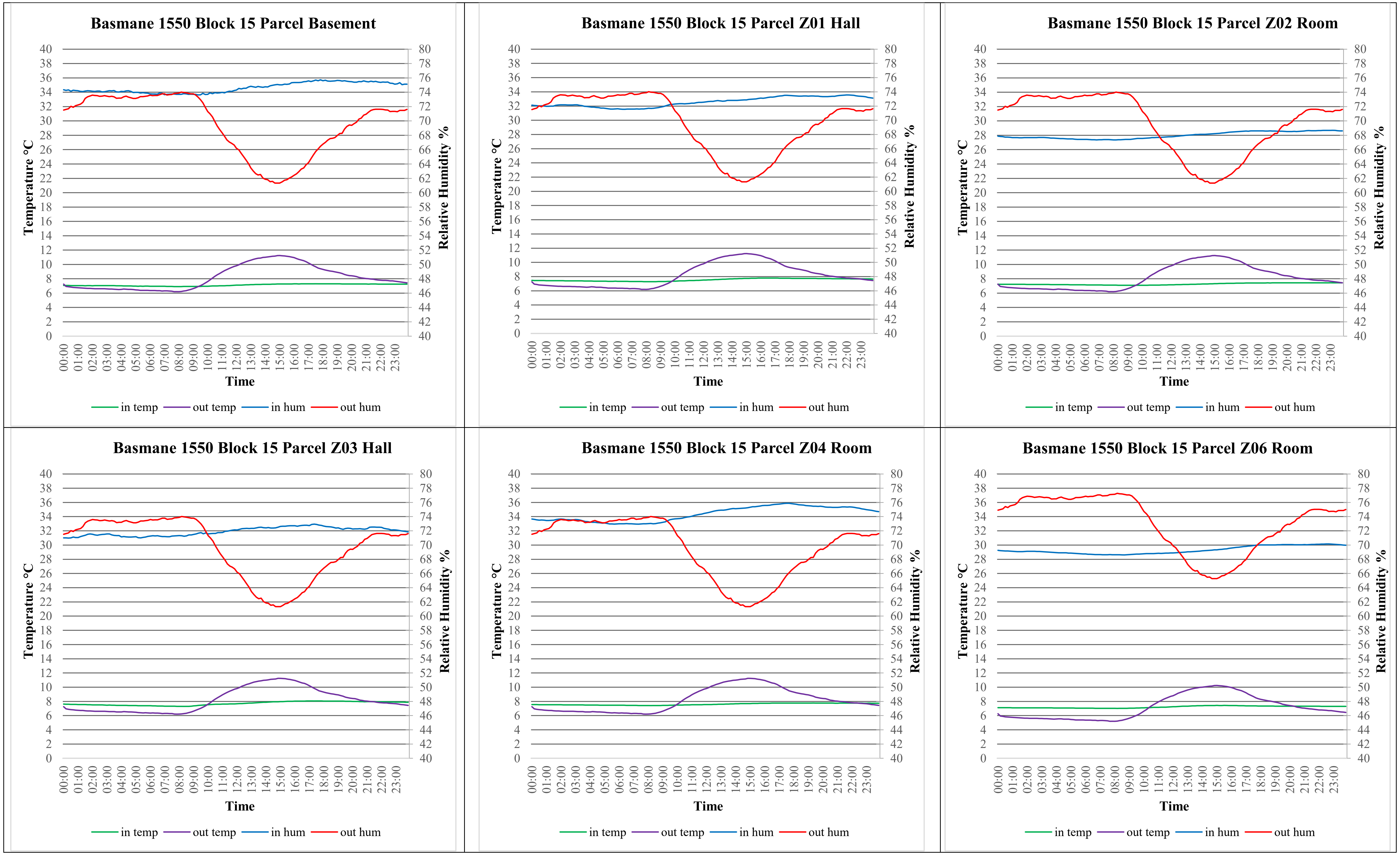


Figure F.3 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Basmane 08.01.2017-08.02.2017

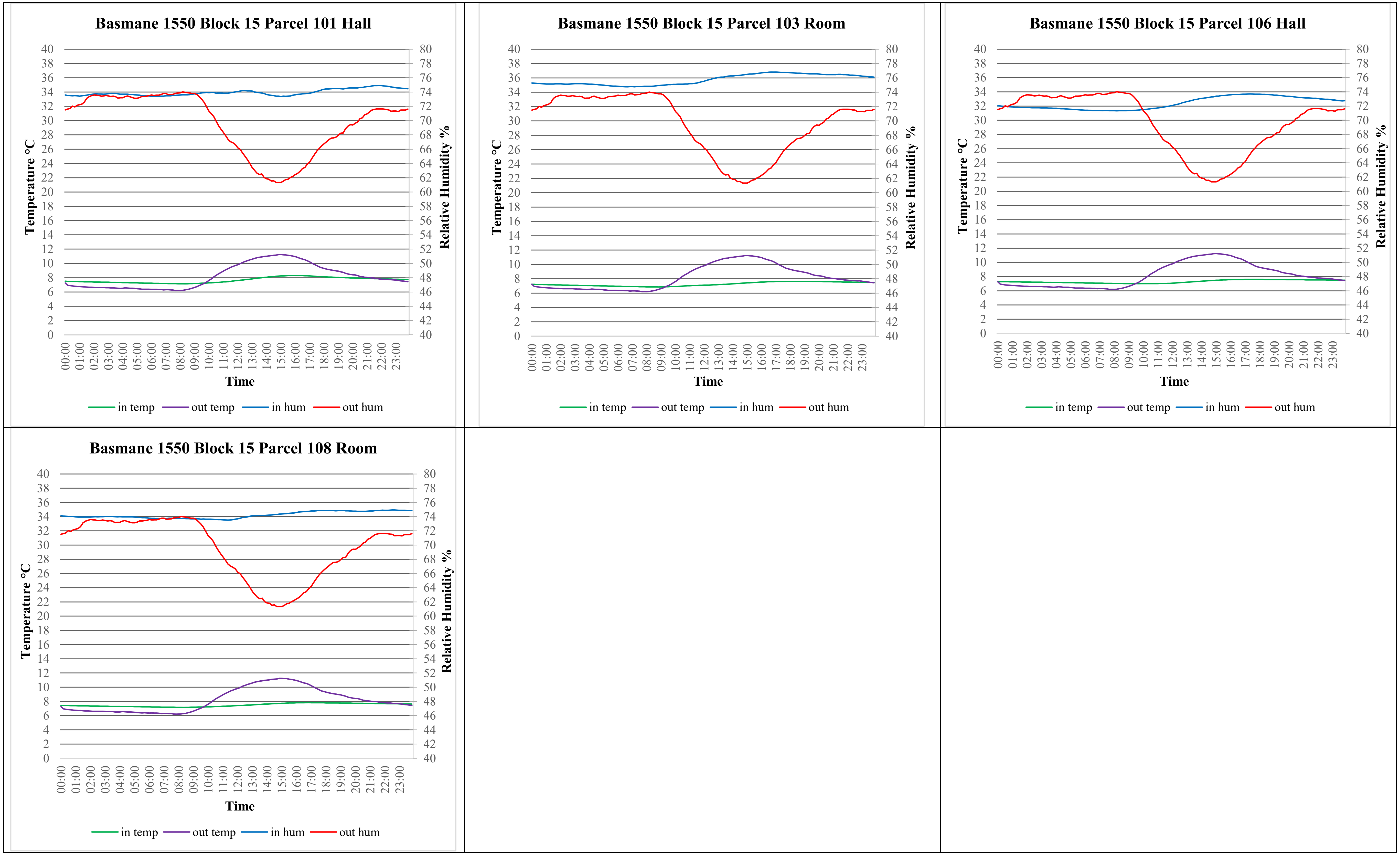


Figure F.4 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Basmane 08.01.2017-08.02.2017

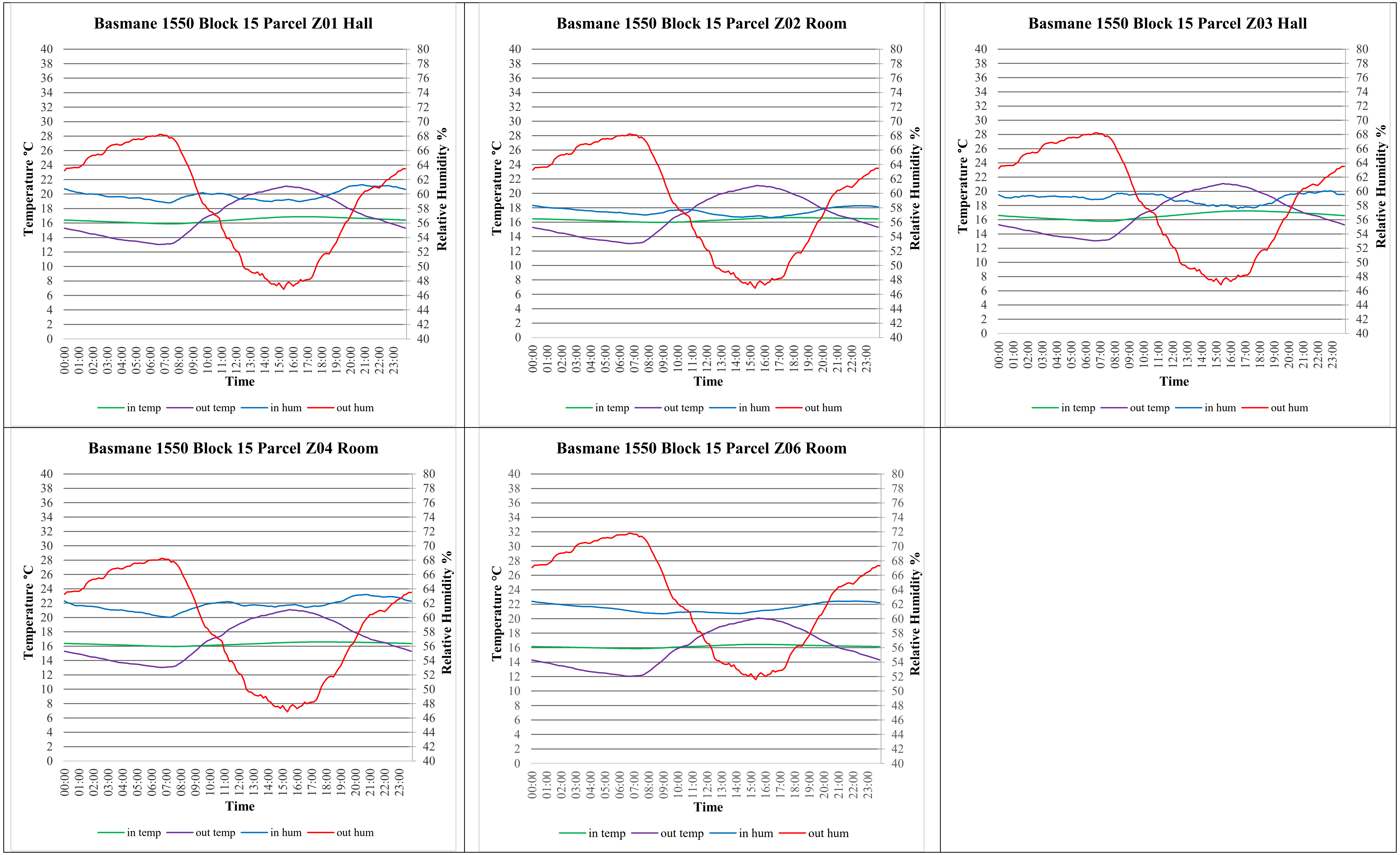
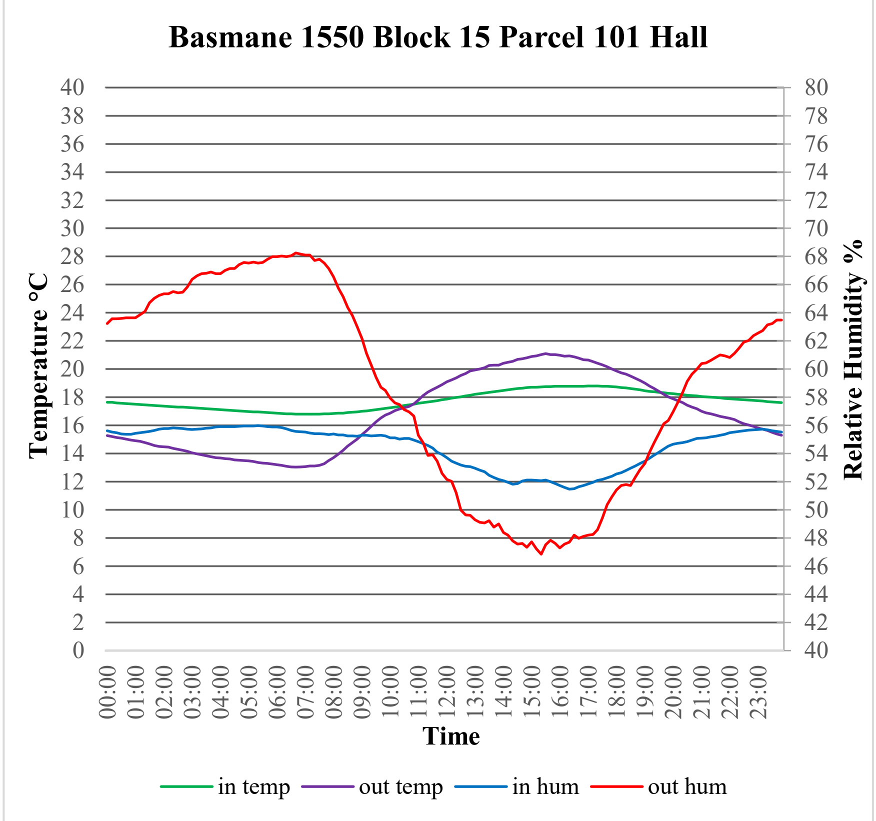
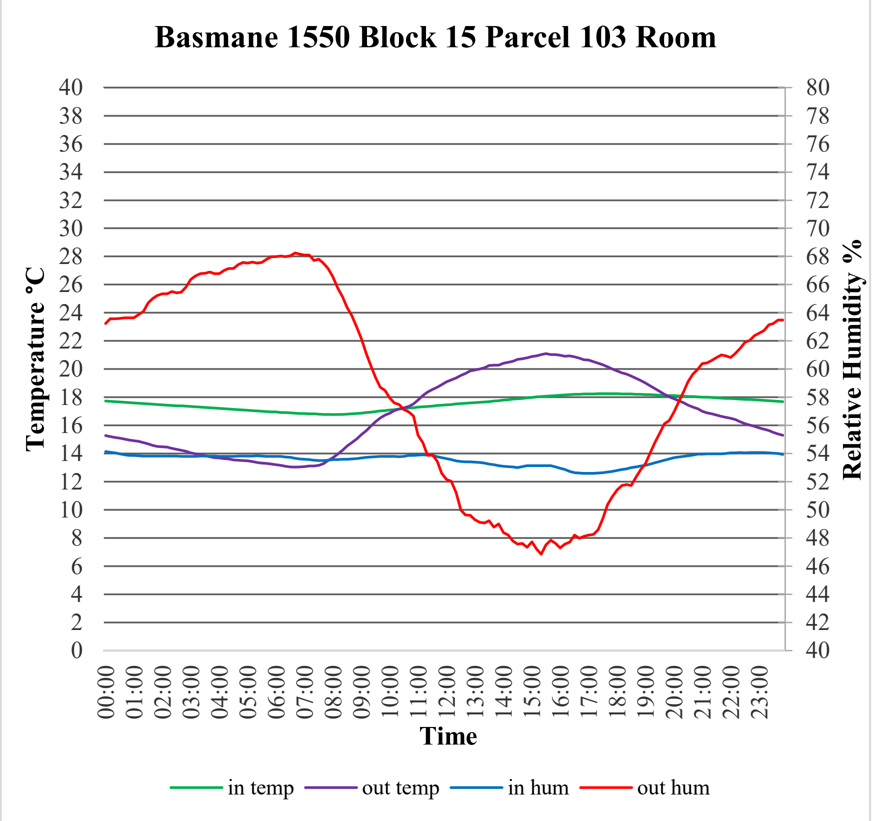
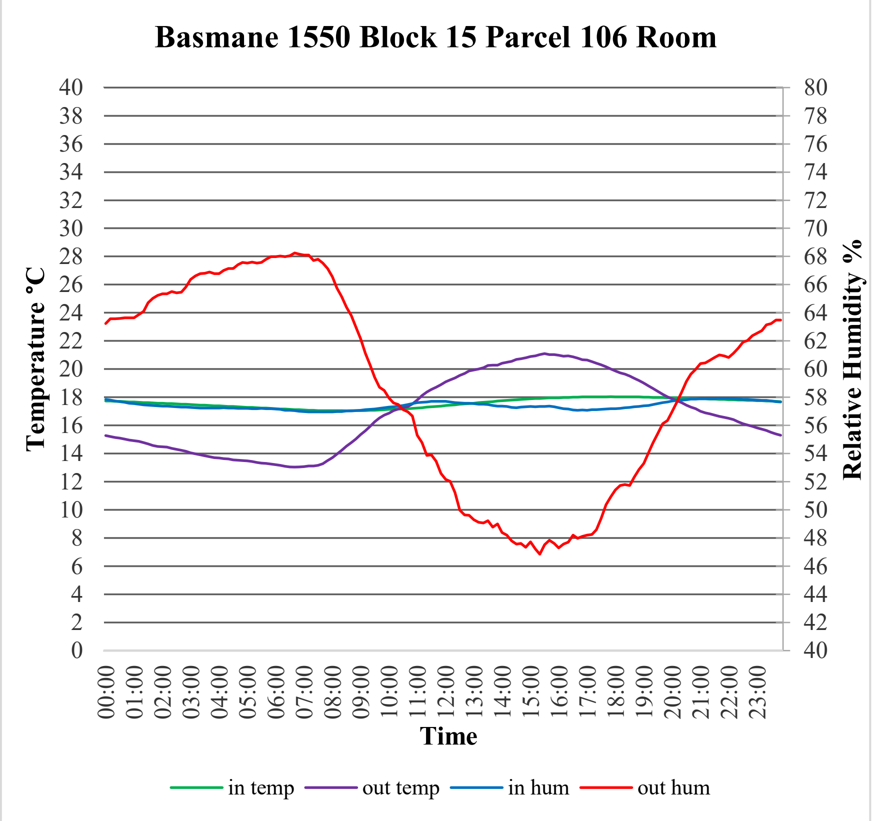


Figure F.5 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Basmane 24.03.2017-23.04.2017







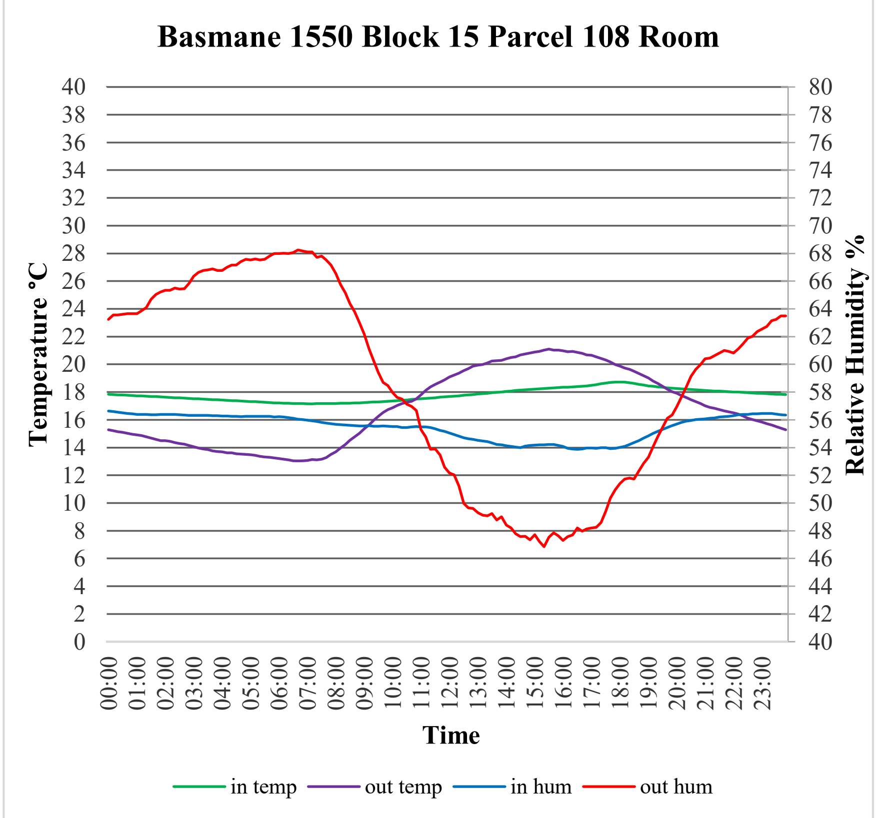


Figure F.6 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Basmane 24.03.2017-23.04.2017

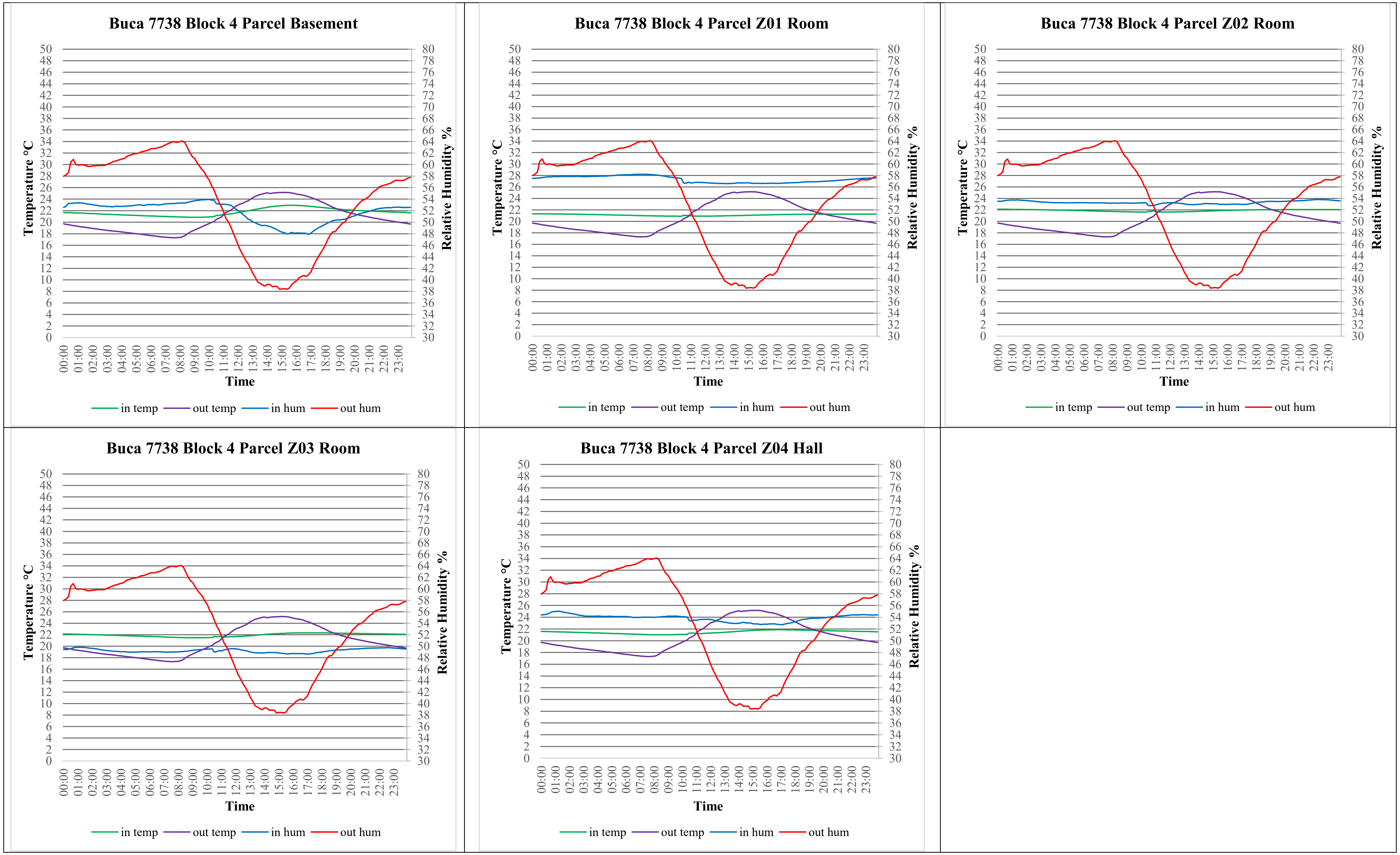


Figure F.7 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Buca 27.09.2016-26.10.2016

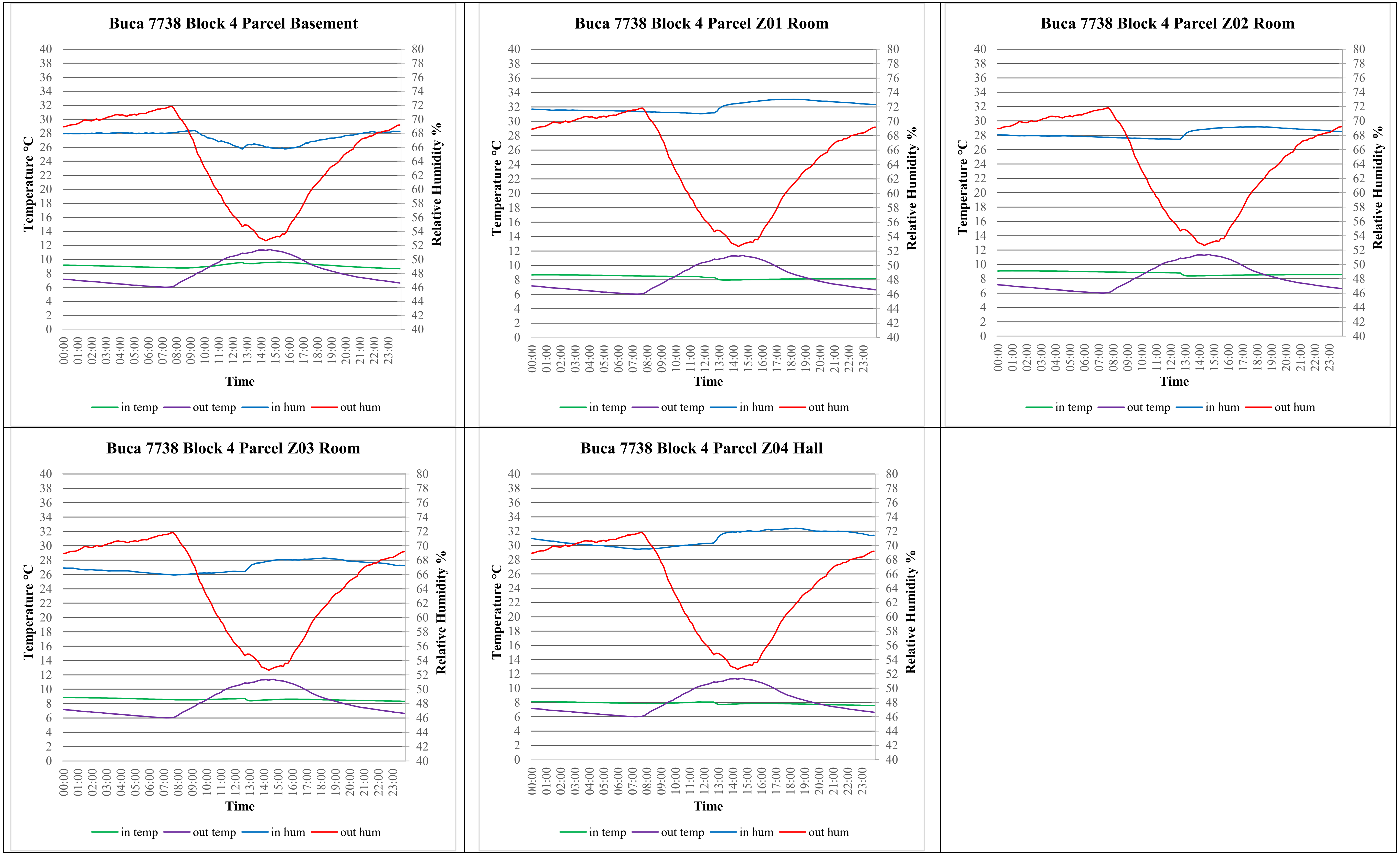


Figure F.8 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Buca 15.01.2016-15.02.2016

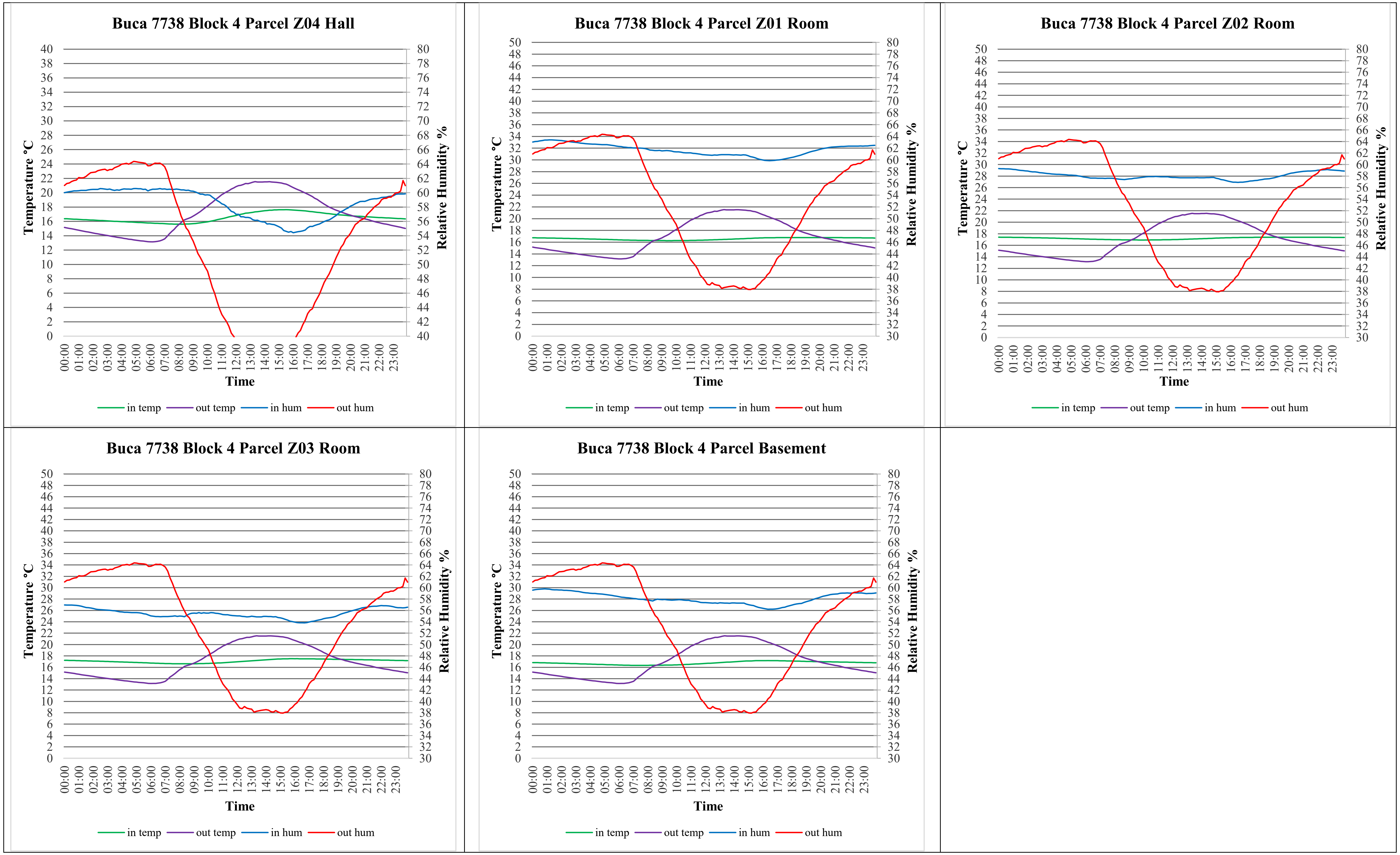


Figure F.9 Dry bulb temperature and relative humidity monthly daily average graphics of the ground floor of the house in Buca 23.03.2016-22.04.2016

APPENDIX G

BES MODELS SIMULATION ANALYSES RESULTS OF IZMIR HOUSES

Table G. 1. Properties and simulation results of BES models of two-story İzmir Houses variations with plan type 1

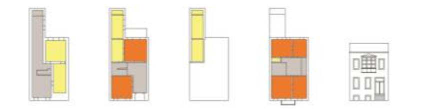
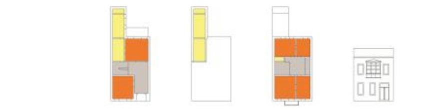
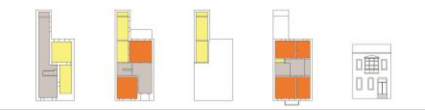
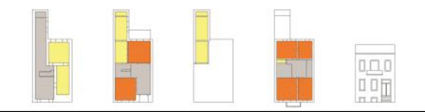
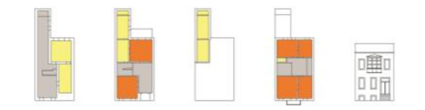
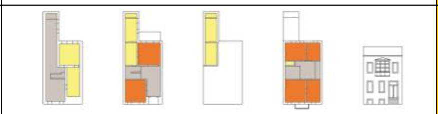
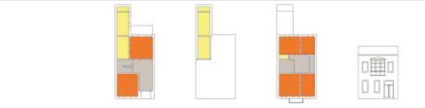
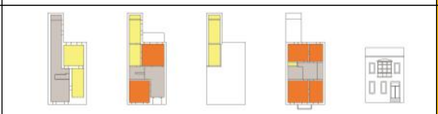
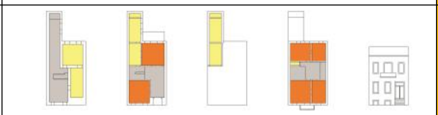
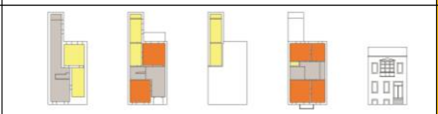
No	Plan and Facade	Model Name	Hall Position	Basement	Entrance Direction	Roof	Oriel	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total Building Area m2	Volume m3	Gross Wall to Volume Ratio	Source Energy Consumption per Total Building Area kWh/m2
1		Model 1	Side	Exist	Southwest	Heated	Exist	0.12	0.65	0.08	335.56	973.85	0.22	236.1
2		Model 1 without basement	Side	Not exist	Southwest	Heated	Exist	0.14	0.63	0.09	260.66	804.44	0.20	299.41
3		Model 1 with basement for ventilation	Side	Exist with half height	Southwest	Heated	Exist	0.11	0.64	0.07	347.35	912.29	0.24	277
4		Model 1 without oriel	Side	Exist	Southwest	Heated	Not exist	0.10	0.65	0.06	333.46	967.98	0.22	239.81
5		Model 1 with unheated roof	Side	Exist	Southwest	UnHeated	Exist	0.12	0.64	0.08	339.15	973.85	0.22	204.09
6		Model 1_north	Side	Exist	Northeast	Heated	Exist	0.12	0.65	0.08	335.56	973.85	0.22	228.25
7		Model 1_north without basement	Side	Not Exist	Northeast	Heated	Exist	0.14	0.63	0.09	260.66	804.44	0.20	286.77
8		Model 1 _north with basement for ventilation	Side	Exist with half height	Northeast	Heated	Exist	0.11	0.64	0.07	347.35	912.29	0.24	261.86
9		Model 1 _north without oriel	Side	Exist	Northeast	Heated	Not exist	0.10	0.65	0.06	333.46	967.98	0.22	232.13
10		Model 1_north with unheated roof	Side	Exist	Northeast	UnHeated	Exist	0.12	0.64	0.08	339.15	973.85	0.22	196.23

Table G. 2. Properties and simulation results of BES models of two-story İzmir Houses variations with plan type 2

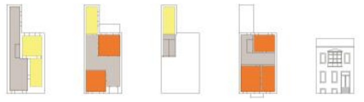
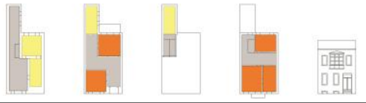
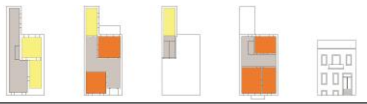
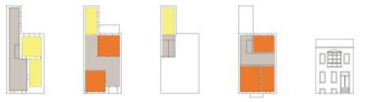
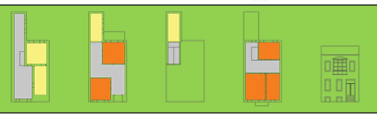
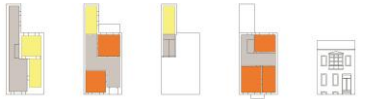
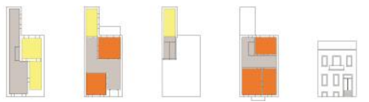
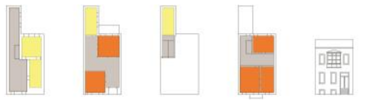
No	Plan and Facade	Model Name	Hall Position	Basement	Entrance Direction	Roof	Oriel	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total Building Area m2	Volume m3	Gross Wall to Volume Ratio	Source Energy Consumption per Total Building Area kWh/m2
11		Model 2	Side	Exist	Southwest	Unheated	Exist	0.13	0.66	0.09	331.02	982.18	0.22	196.42
12		Model 2 without basement	Side	Not exist	Southwest	Unheated	Exist	0.15	0.64	0.09	259.87	816.80	0.20	247.29
13		Model 2 with basement for ventilation	Side	Exist with half height	Southwest	Unheated	Exist	0.11	0.68	0.08	330.33	891.95	0.25	203.08
14		Model 2 without oriel	Side	Exist	Southwest	Unheated	Not exist	0.11	0.65	0.07	328.03	972.88	0.22	202.33
15		Model 2 with heated roof	Side	Exist	Southwest	Heated	Exist	0.13	0.66	0.09	331.02	982.18	0.22	227.72
16		Model 2_north	Side	Exist	Northeast	Unheated	Exist	0.13	0.66	0.09	331.02	982.18	0.22	186.78
17		Model 2_north without basement	Side	Not exist	Northeast	Unheated	Exist	0.15	0.64	0.09	259.87	816.80	0.20	233.43
18		Model 2_north with basement for ventilation	Side	Exist with half height	Northeast	Unheated	Exist	0.11	0.68	0.08	330.33	891.95	0.25	192.85
19		Model 2_north without oriel	Side	Exist	Northeast	Unheated	Not exist	0.11	0.65	0.07	328.03	972.88	0.22	193.19
20		Model 2_north with heated roof	Side	Exist	Northeast	Heated	Exist	0.13	0.66	0.09	331.02	982.18	0.22	217.69

Table G. 3. Properties and simulation results of BES models of two-story İzmir Houses variations with plan type 3

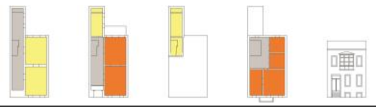
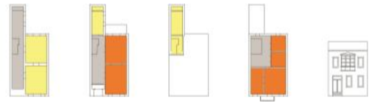
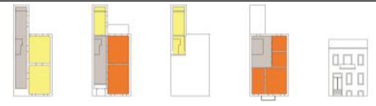
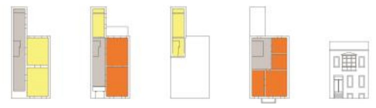
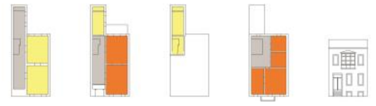
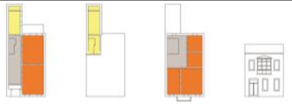
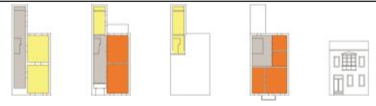
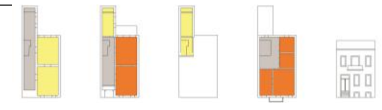
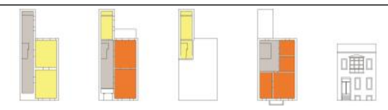
No	Plan and Facade	Model Name	Hall Position	Basement	Entrance Direction	Roof	Oriel	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total Building Area m2	Volume m3	Gross Wall to Volume Ratio	Source Energy Consumption per Total Building Area kWh/m2
21		Model 3	Side	Exist	Southwest	Unheated	Exist	0.12	0.66	0.08	332.05	980.71	0.22	203.2
22		Model 3 without basement	Side	Not Exist	Southwest	Unheated	Exist	0.14	0.64	0.09	256.8	810.61	0.20	261.39
23		Model 3 with basement for ventilation	Side	Exist with half height	Southwest	Unheated	Exist	0.12	0.61	0.07	331.97	889.90	0.23	202.86
24		Model 3 without oriel	Side	Exist	Southwest	Unheated	Not exist	0.10	0.65	0.06	329.95	974.84	0.22	206.48
25		Model 3 with heated roof	Side	Exist	Southwest	Heated	Exist	0.12	0.67	0.08	328.88	978.81	0.22	234.55
26		Model 3_north	Side	Exist	Northeast	Unheated	Exist	0.12	0.66	0.08	332.05	980.71	0.22	196.77
27		Model 3_north without basement	Side	Not exist	Northeast	Unheated	Exist	0.14	0.64	0.09	256.8	810.61	0.20	251.08
28		Model 3_north with basement for ventilation	Side	Exist with half height	Northeast	Unheated	Exist	0.12	0.61	0.07	331.97	889.90	0.23	194.98
29		Model 3_north without oriel	Side	Exist	Northeast	Unheated	Not exist	0.10	0.65	0.06	329.95	974.84	0.22	200.55
30		Model 3_north with heated roof	Side	Exist	Northeast	Heated	Exist	0.12	0.67	0.08	328.88	978.81	0.22	228.44

Table G. 4. Properties and simulation results of BES models of two-story İzmir Houses variations with plan type 4

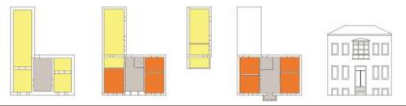
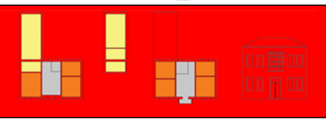
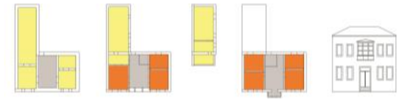
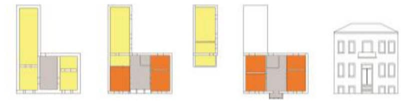
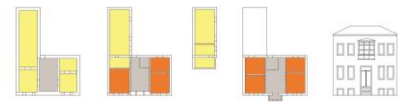
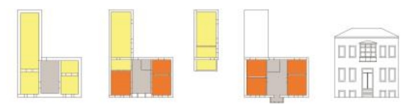
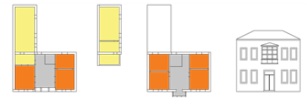
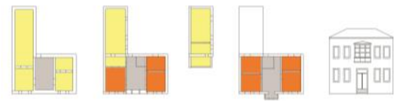
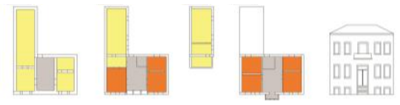
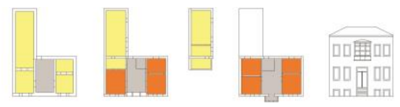
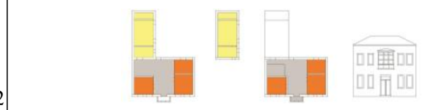
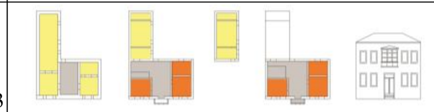
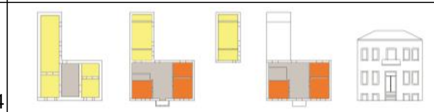
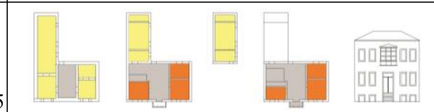
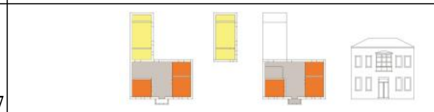
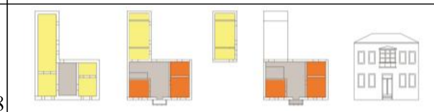
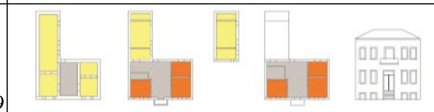
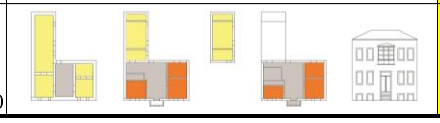
No	Plan and Facade	Model Name	Hall Position	Basement	Entrance Direction	Roof	Oriel	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total Building Area m2	Volume m3	Gross Wall to Volume Ratio	Source Energy Consumption per Total Building Area kWh/m2
31		Model 4	Central	Exist	Southwest	Unheated	Exist	0.13	1.07	0.13	294.92	928.74	0.34	279.88
32		Model 4 without basement	Central	Not exist	Southwest	Unheated	Exist	0.14	1.19	0.16	208.25	737.74	0.33	398.68
33		Model 4 with basement for ventilation	Central	Exist with half height	Southwest	Unheated	Exist	0.13	0.95	0.12	294.71	829.80	0.34	281.08
34		Model 4 without oriel	Central	Exist	Southwest	Unheated	Not exist	0.11	1.07	0.12	292.8	922.78	0.34	283.13
35		Model 4 with heated roof	Central	Exist	Northeast	Heated	Exist	0.13	1.07	0.13	294.27	926.30	0.34	280.77
36		Model 4_north	Central	Exist	Northeast	Unheated	Exist	0.13	1.07	0.13	294.92	928.74	0.34	276.66
37		Model 4_north without basement	Central	Not exist	Northeast	Unheated	Exist	0.14	1.19	0.16	208.25	737.74	0.33	390.64
38		Model 4_north with basement for ventilation	Central	Exist with half height	Northeast	Unheated	Not exist	0.13	0.95	0.12	294.71	829.80	0.34	275.07
39		Model 4_north without oriel	Central	Exist	Northeast	Unheated	Not exist	0.11	1.07	0.12	292.8	922.78	0.34	279.29
40		Model 4_north with heated roof	Central	Exist	Northeast	Heated	Not exist	0.13	1.07	0.13	294.27	926.30	0.34	277.84

Table G. 5. Properties and simulation results of BES models of two-story İzmir Houses variations with plan type 5

No	Plan and Facade	Model Name	Hall Position	Basement	Entrance Direction	Roof	Oriel	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total Building Area m2	Volume m3	Gross Wall to Volume Ratio	Source Energy Consumption per Total Building Area kWh/m2
41		Model 5	Central	Exist	Southwest	Unheated	Exist	0.13	1.08	0.14	293.36	929.94	0.34	255.15
42		Model 5 without basement	Central	Not exist	Southwest	Unheated	Exist	0.14	1.20	0.16	207.06	739.50	0.33	359.2
43		Model 5 with basement for ventilation	Central	Exist with half height	Southwest	Unheated	Exist	0.13	0.95	0.12	293.03	831.45	0.34	254.88
44		Model 5 without oriel	Central	Exist	Southwest	Unheated	Not exist	0.11	1.08	0.12	291.24	923.98	0.34	257.99
45		Model 5 with heated roof	Central	Exist	Southwest	Heated	Exist	0.13	1.08	0.14	292.64	927.22	0.34	276.8
46		Model 5_north	Central	Exist	Northeast	Unheated	Exist	0.13	1.08	0.14	293.36	929.94	0.34	253.35
47		Model 5_north without basement	Central	Not exist	Northeast	Unheated	Exist	0.14	1.20	0.16	207.06	739.50	0.33	353.25
48		Model 5_north with basement for ventilation	Central	Exist with half height	Northeast	Unheated	Exist	0.13	0.95	0.12	293.03	831.45	0.34	250.44
49		Model 5_north without oriel	Central	Exist	Northeast	Unheated	Not exist	0.11	1.08	0.12	291.24	923.98	0.34	255.71
50		Model 5_north with heated roof	Central	Exist	Northeast	Heated	Exist	0.13	1.08	0.14	292.64	927.22	0.34	274.73

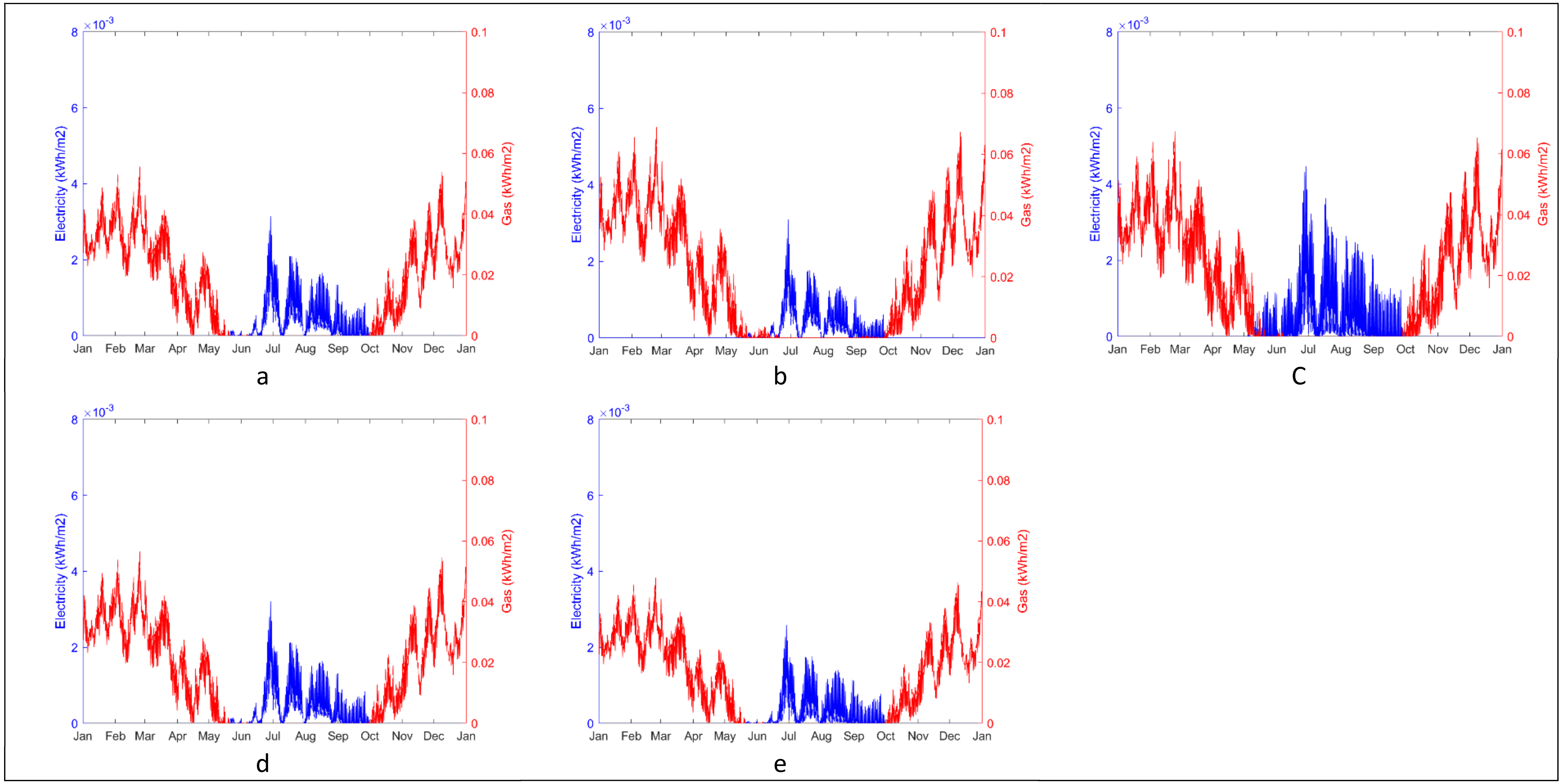


Figure G. 1. Annual energy consumption per square meter graphics of two-story İzmir houses types in Alsancak (a) Model 1 (b) Model 1 without basement (c) Model 1 with basement for ventilation (d) Model without oriel (e) Model 1 with unheated roof

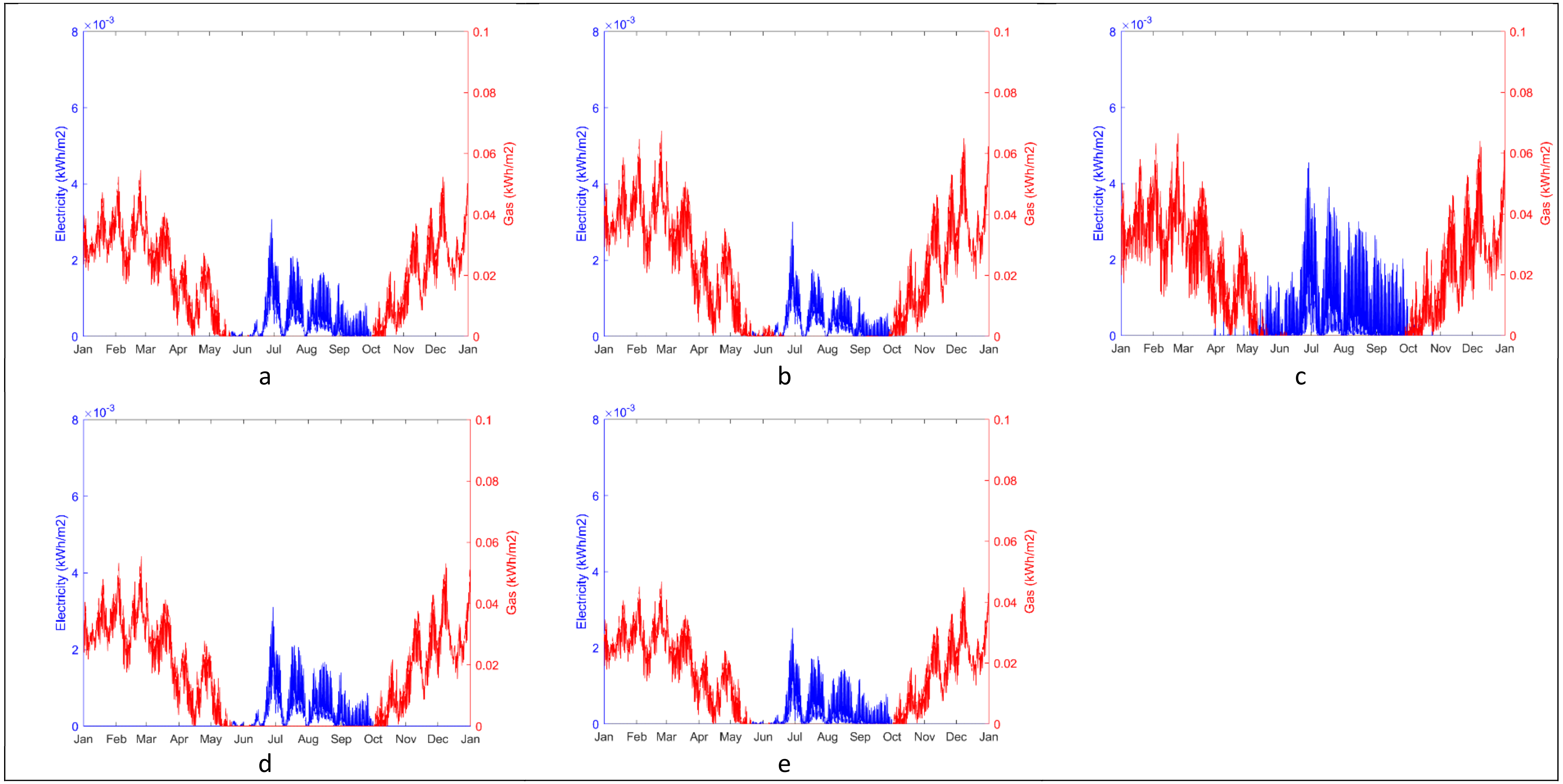


Figure G. 2. Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 1 north (b) Model 1 north without basement (c) Model 1 north with basement for ventilation (d) Model 1 north without oriel (e) Model 1 north with unheated roof

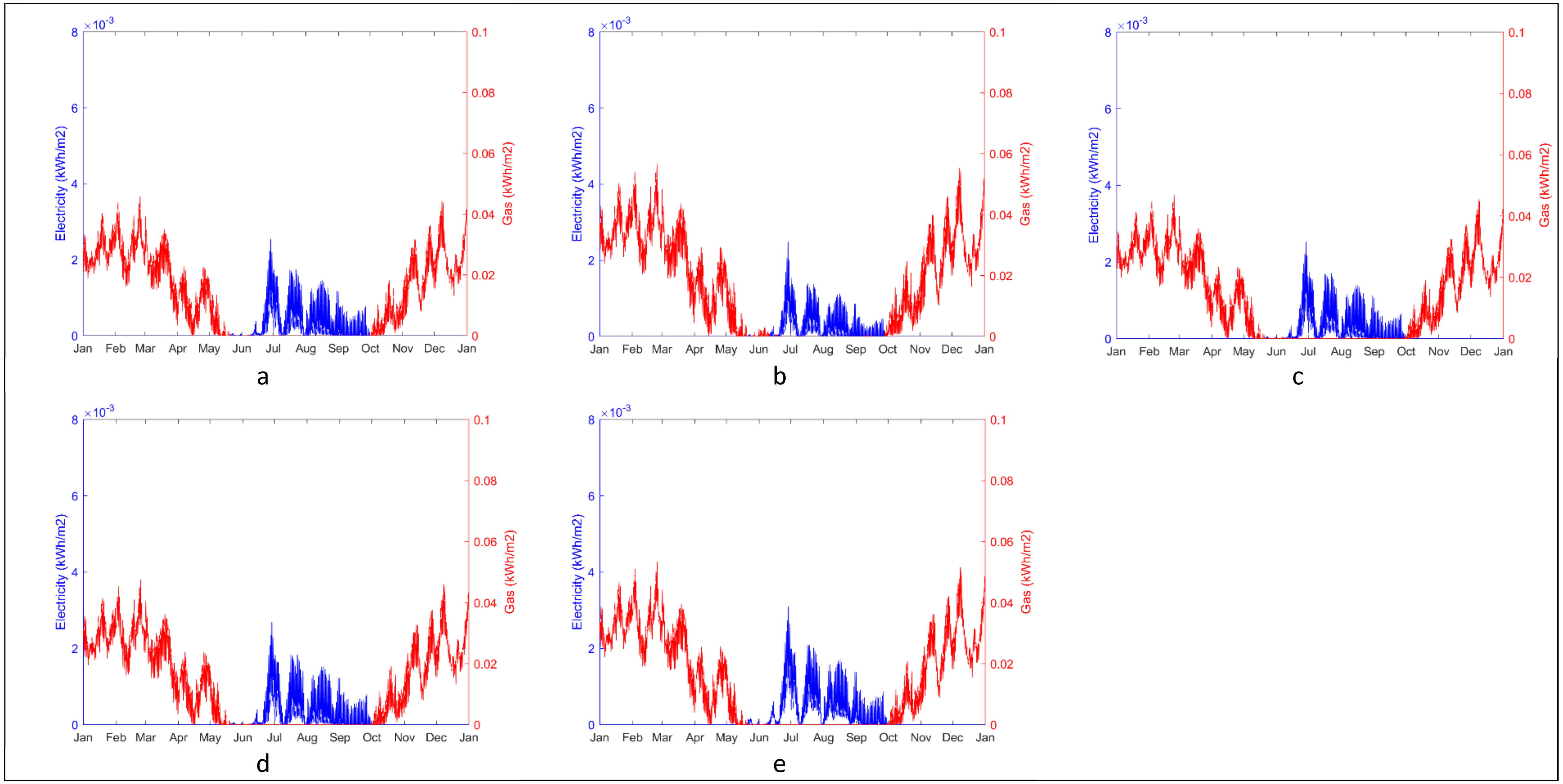


Figure G. 3. Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 2 (b) Model 2 without basement (c) Model 2 with basement for ventilation (d) Model 2 without oriel (e) Model 2 with heated roof

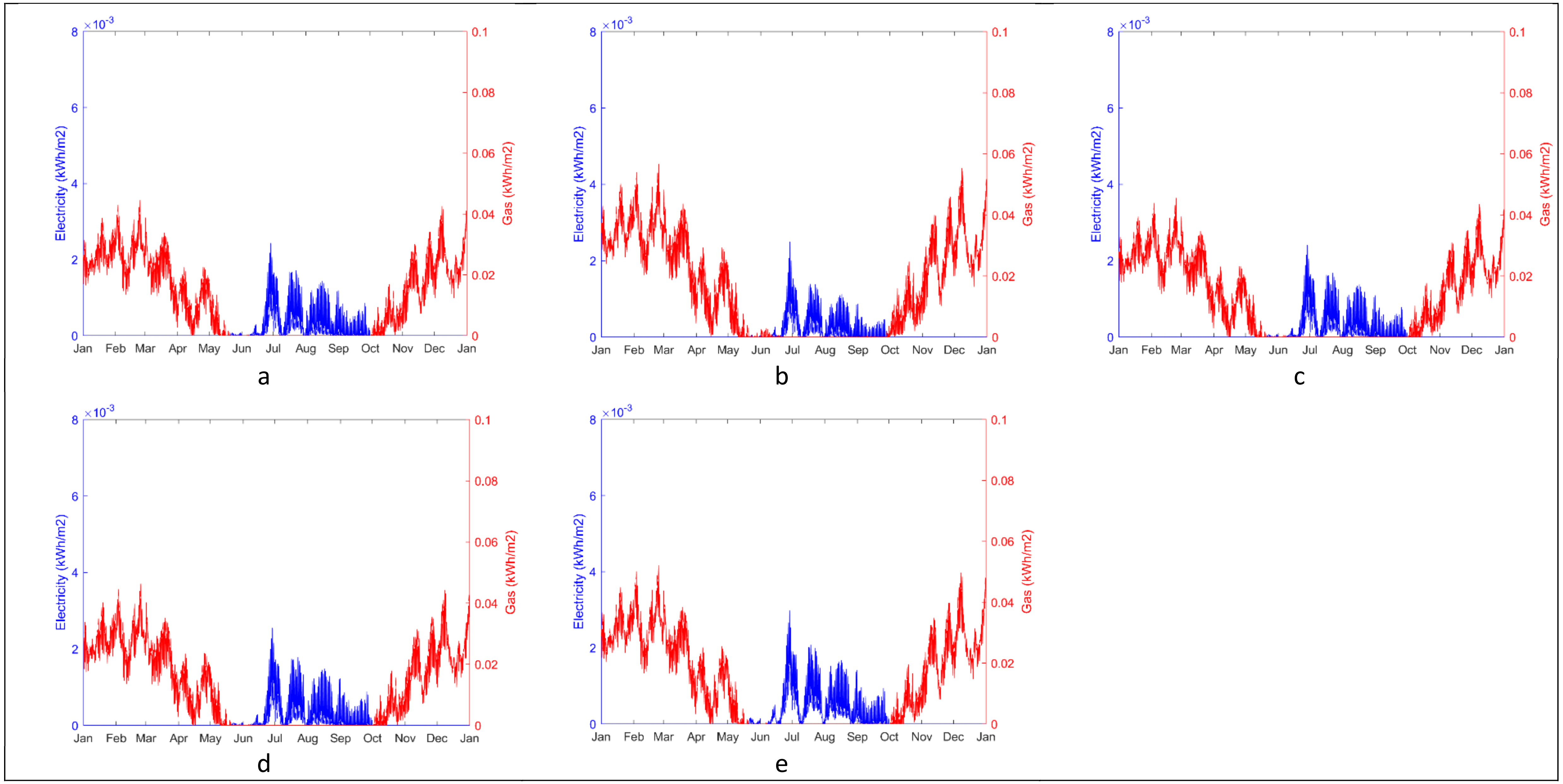


Figure G. 4. Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 2 north (b) Model 2 north without basement (c) Model 2 north with basement for ventilation (d) Model 2 north without oriel (e) Model 2 north with heated roof

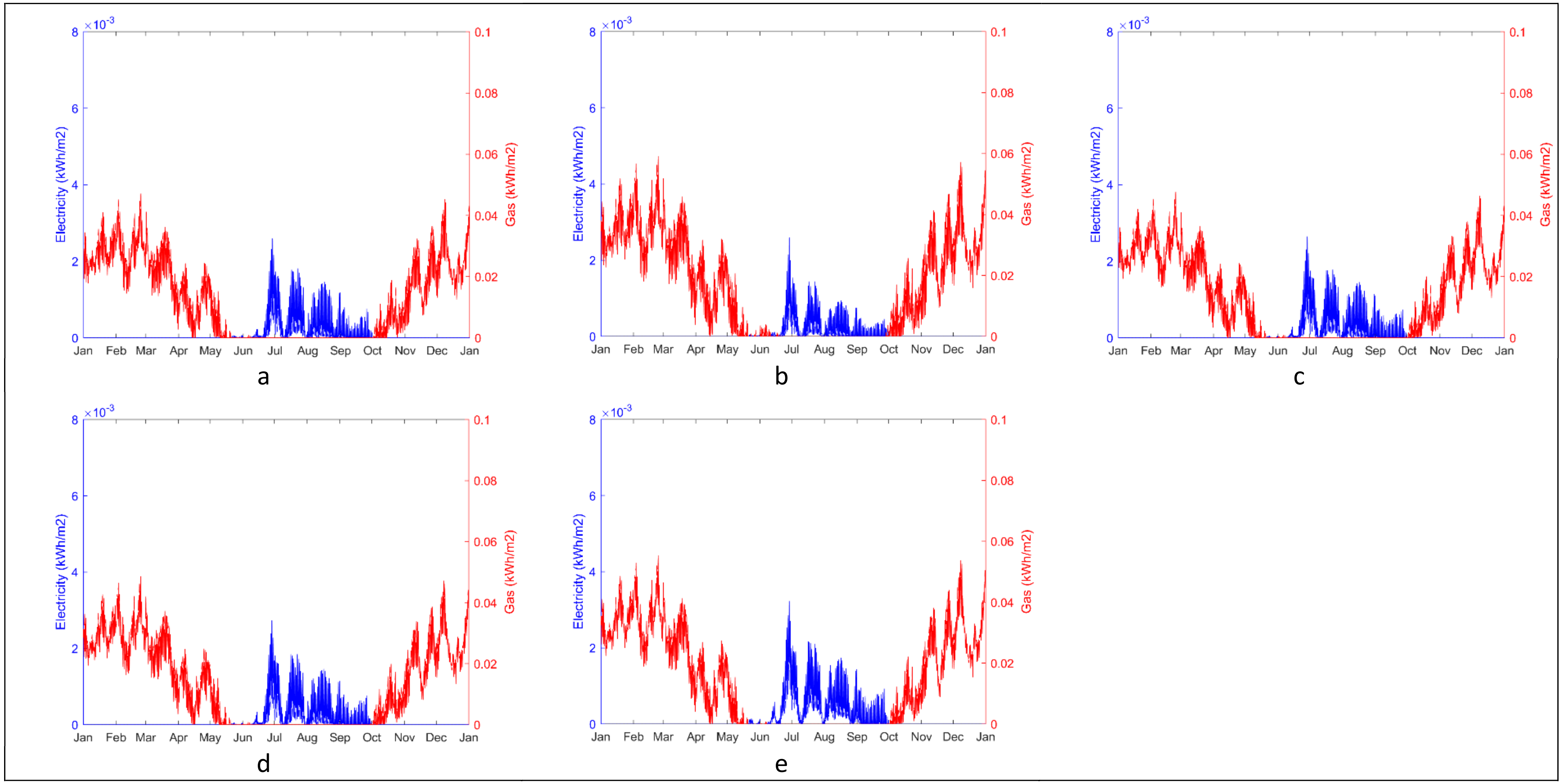


Figure G. 5. Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 3 (b) Model 3 without basement (c) Model 3 with basement for ventilation (d) Model 3 without oriel (e) Model 3 with heated roof

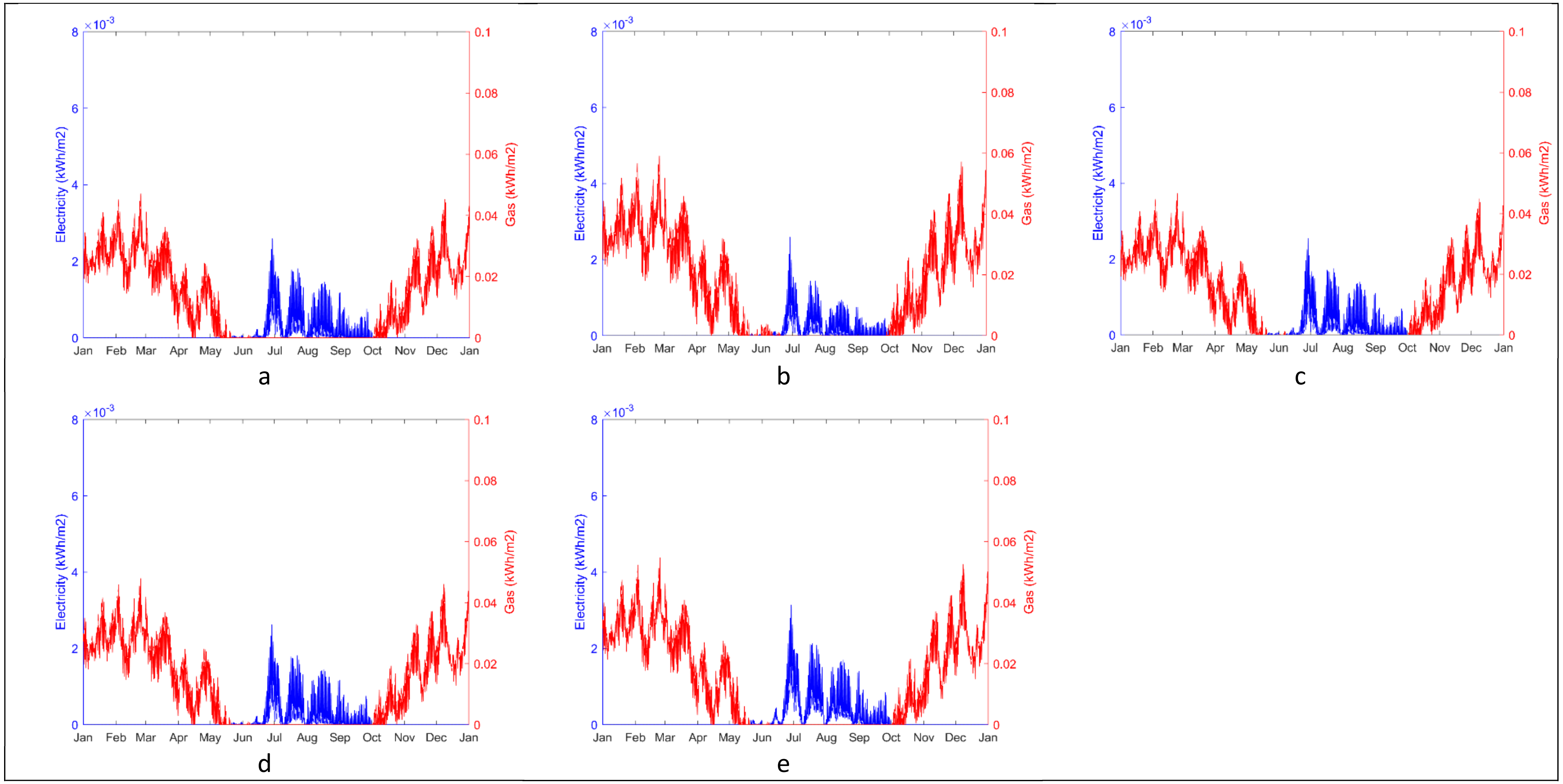


Figure G. 6 Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 3 north (b) Model 3 north without basement (c) Model 3 north with basement for ventilation (d) Model 3 north without oriel (e) Model 3 north with heated roof

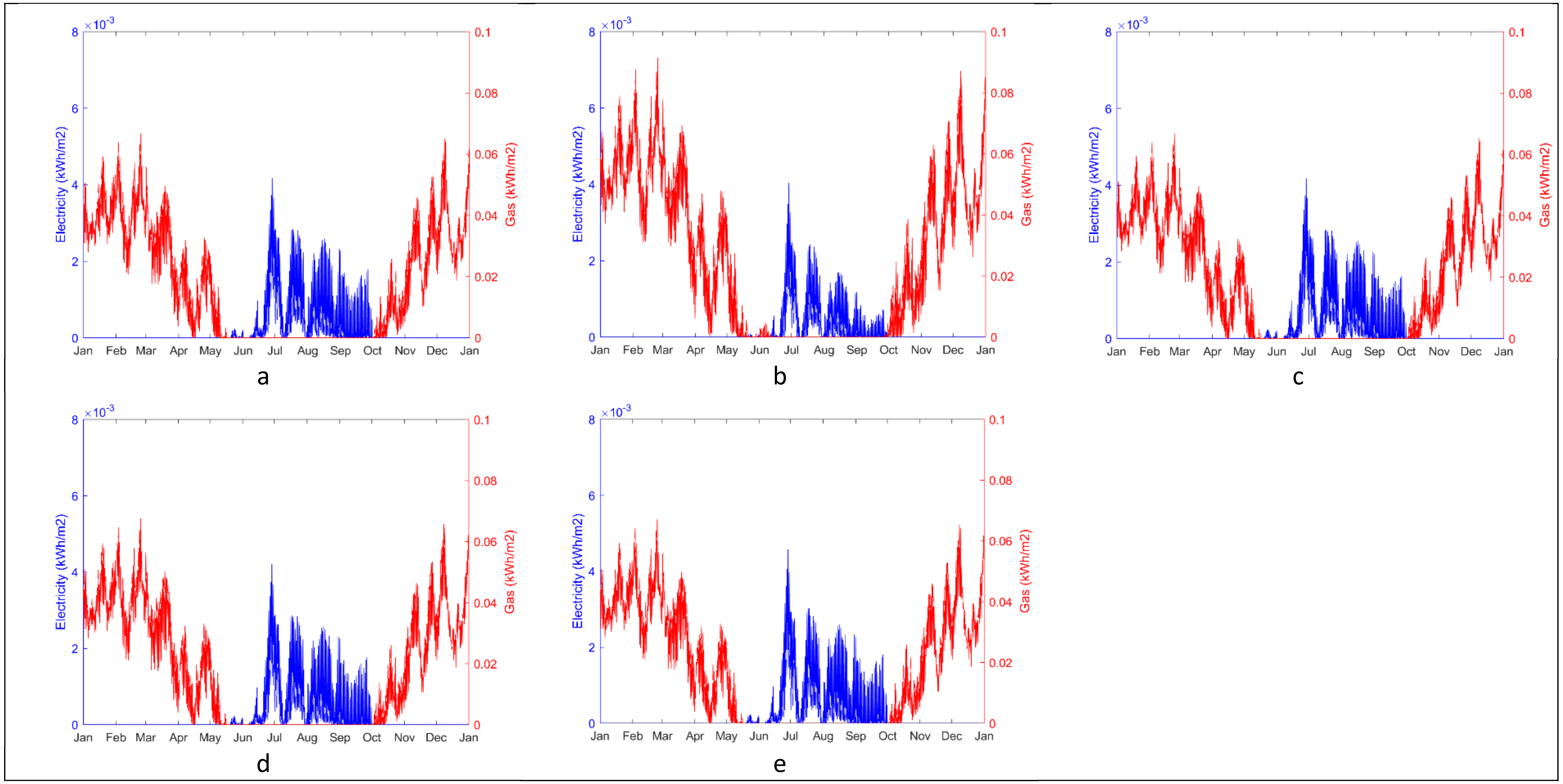


Figure G. 7 Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 4 (b) Model 4 without basement (c) Model 4 with basement for ventilation (d) Model 4 without oriel (e) Model 4 with heated roof

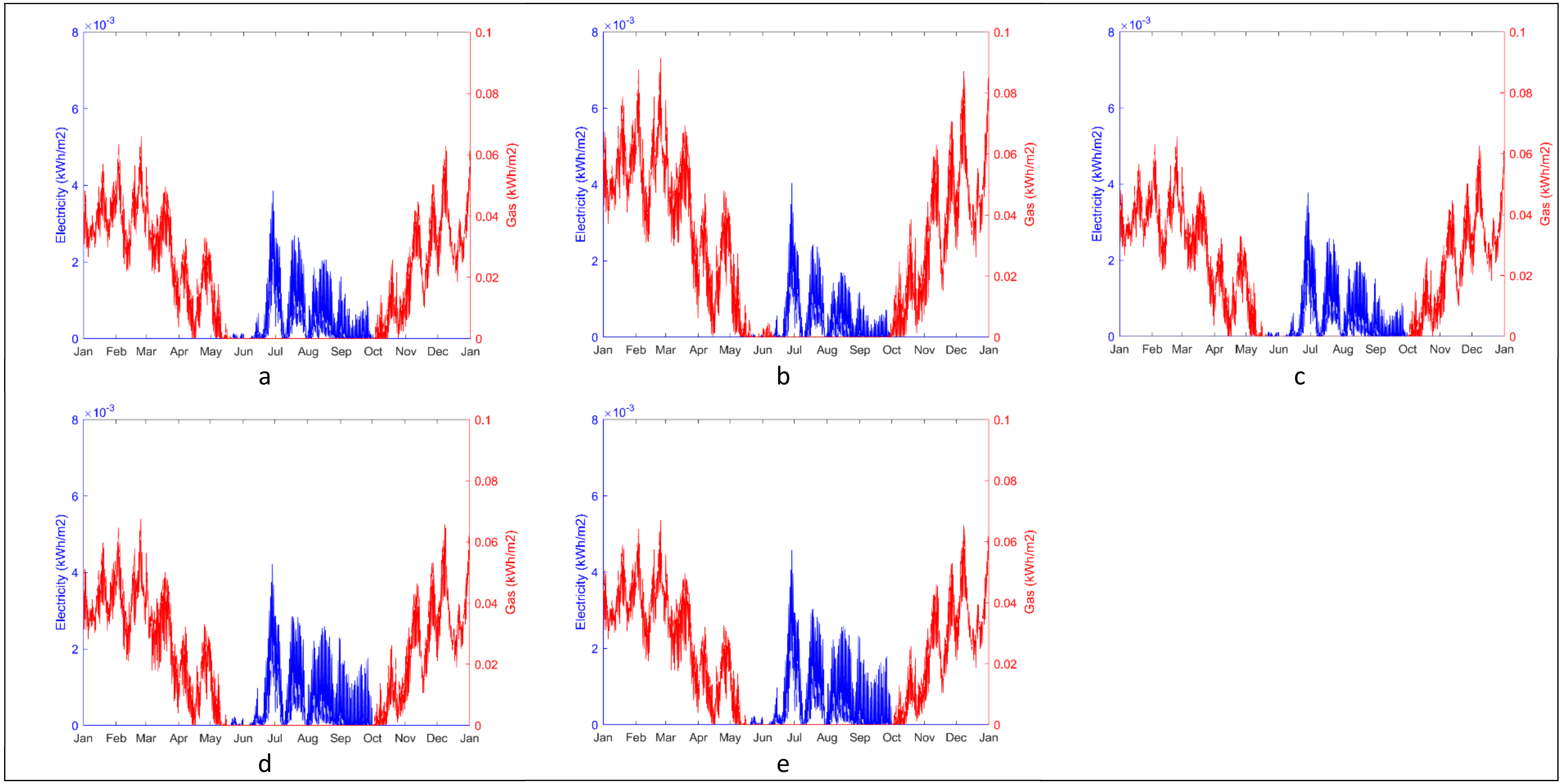


Figure G. 8 Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 4 north (b) Model 4 north without basement (c) Model 4 north with basement for ventilation (d) Model 4 north without oriel (e) Model 4 north with heated roof

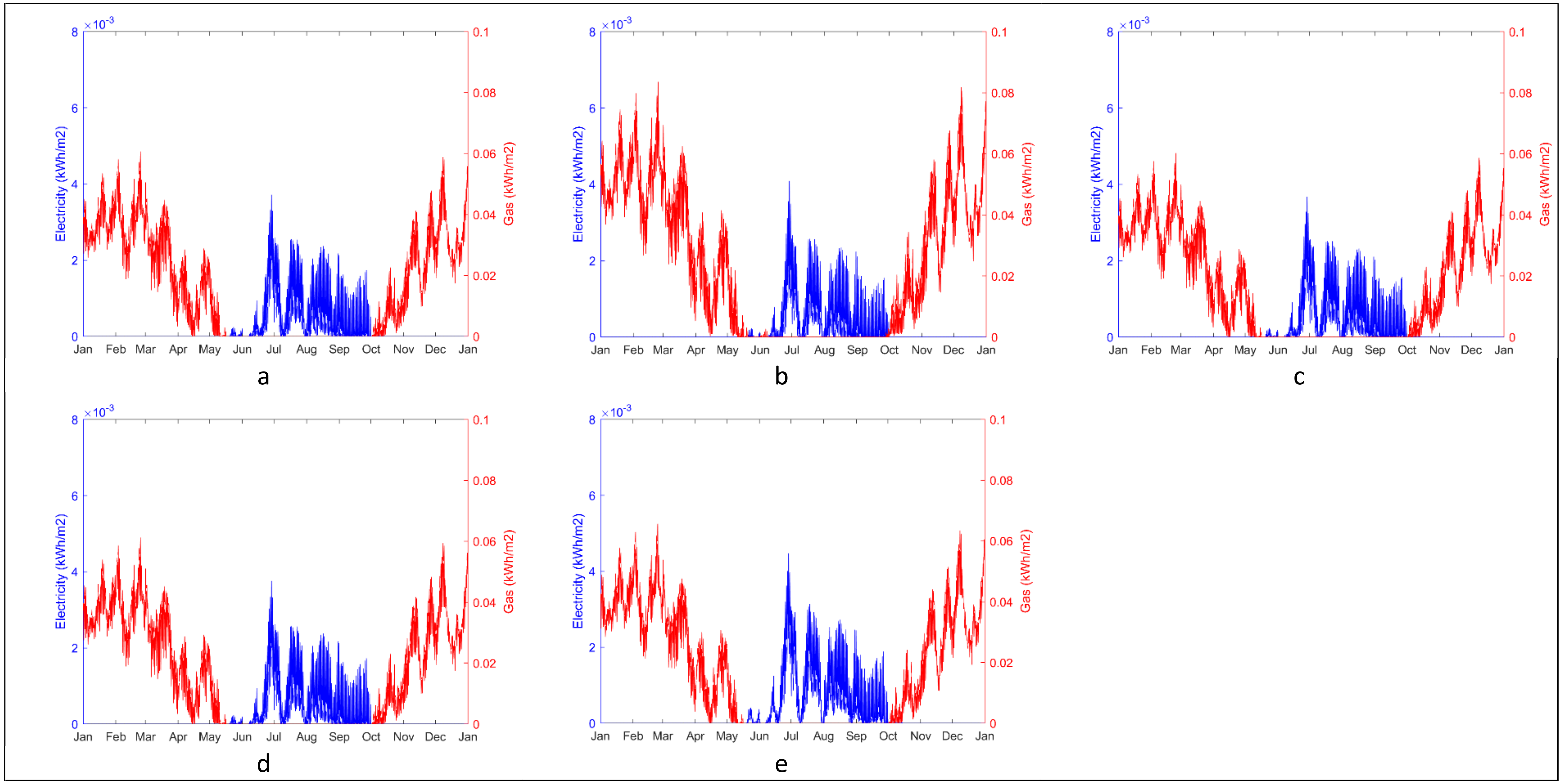


Figure G. 9. Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 5 (b) Model 5 without basement (c) Model 5 with basement for ventilation (d) Model 5 without oriel (e) Model 5 with heated roof

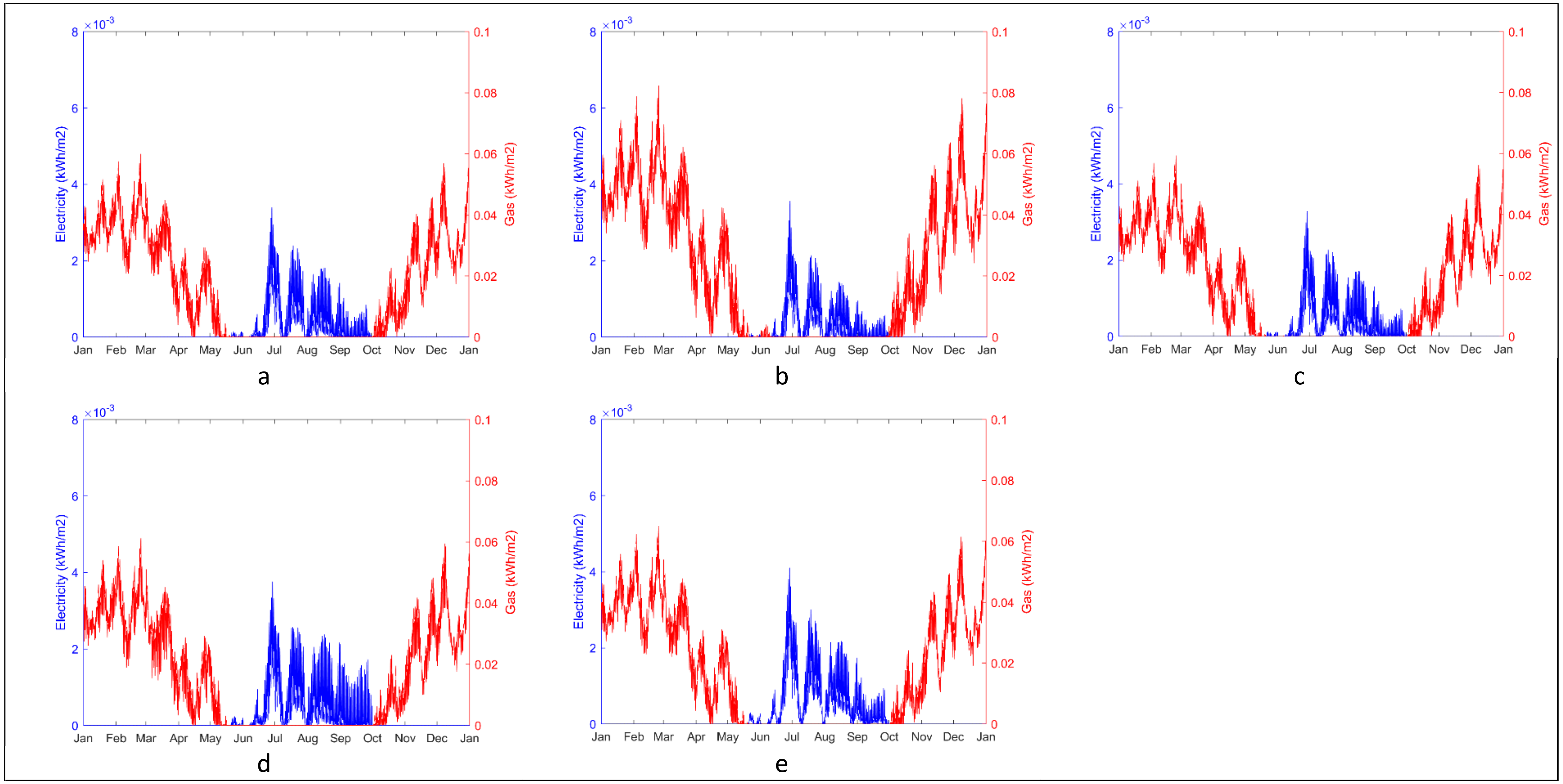


Figure G. 10. Annual energy consumption per total square meter graphics of two-story İzmir houses types in Alsancak (a) Model 5 north (b) Model 5 north without basement (c) Model 5 north with basement for ventilation (d) Model 5 north without oriel (e) Model 5 north with heated roof

Table G. 6. Properties and simulation results of BES models of single-story İzmir Houses variations with plan type 1

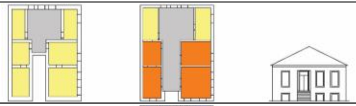
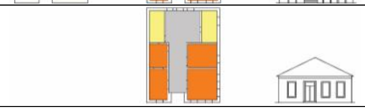
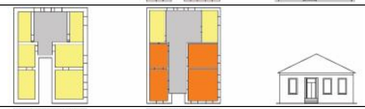
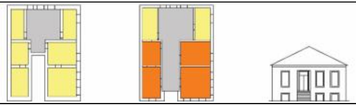
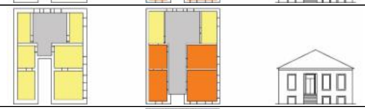
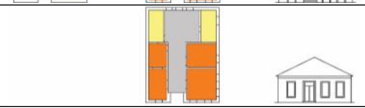
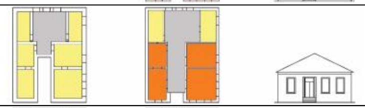
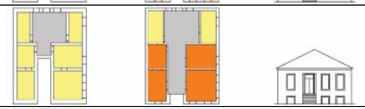
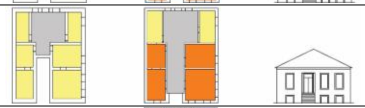
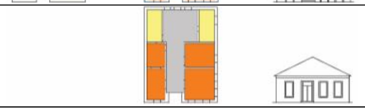
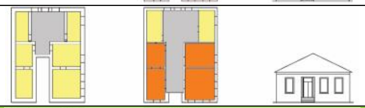
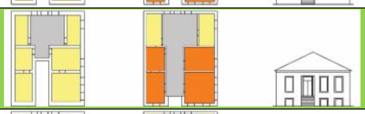
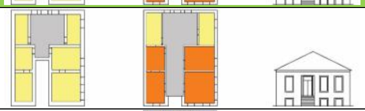
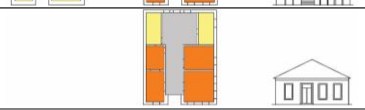
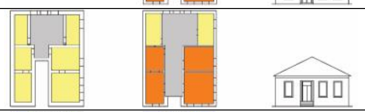
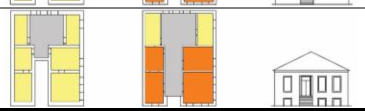
No	Plan and Facade	Model name	Hall Position	Basement as a room	Entrance direction	Setllement Pattern	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total building area m2	Volume m3	Wall to Volume ratio	Source Energy Consumption per Total Building Area kWh/m2
1		Model 1	Central	Exist	Northeast	Detached	0.10	1.32	0.13	197.19	562.34	0.46	275.82
2		Model 1 without basement	Central	Not exist	Northeast	Detached	0.11	1.42	0.15	112.94	389.50	0.41	471.15
3		Model 1 with basement for ventilation	Central	Exist with half height	Northeast	Detached	0.09	1.05	0.10	197.19	472.19	0.44	284.55
4		Model 1 semidetached	Central	Exist	Northeast	Semi-detached	0.13	0.98	0.13	197.19	558.67	0.34	243.17
5		Model 1_90d	Central	Exist	Southeast	Detached	0.10	1.32	0.13	197.19	562.34	0.46	264.71
6		Model 1_90d without basement	Central	Not exist	Southeast	Detached	0.11	1.42	0.15	112.94	389.50	0.41	452.73
7		Model 1_90d with basement for ventilation	Central	Exist with half height	Southeast	Detached	0.09	1.05	0.10	197.19	472.19	0.44	274.14
8		Model 1_90d semidetached	Central	Exist	Southeast	Semi-detached	0.13	0.98	0.13	197.19	558.67	0.34	232.73
9		Model 1_180d	Central	Exist	Southwest	Detached	0.10	1.32	0.13	197.19	562.34	0.46	253.11
10		Model 1_180d without basement	Central	Not exist	Southwest	Detached	0.11	1.42	0.15	112.94	389.50	0.41	436.12
11		Model 1_180d with basement for ventilation	Central	Exist with half height	Southwest	Detached	0.09	1.05	0.10	197.19	472.19	0.44	263.51
12		Model 1_180d semidetached	Central	Exist	Southwest	Semi-detached	0.13	0.98	0.13	197.19	558.67	0.34	211.03
13		Model 1_270d	Central	Exist	Northwest	Detached	0.10	1.32	0.13	197.19	562.34	0.46	264.11
14		Model 1_270d without basement	Central	Not exist	Northwest	Detached	0.11	1.42	0.15	112.94	389.50	0.41	453.30
15		Model 1_270d with basement for ventilation	Central	Exist with half height	Northwest	Detached	0.09	1.05	0.10	197.19	472.19	0.44	274.30
16		Model 1_270d semidetached	Central	Exist	Northwest	Semi-detached	0.13	0.98	0.13	197.19	558.67	0.34	222.83

Table G. 7. Properties and simulation results of BES models of single-story İzmir Houses variations with plan type 2

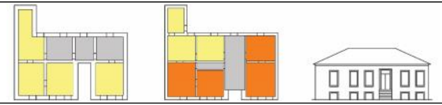
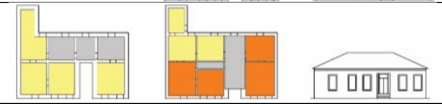
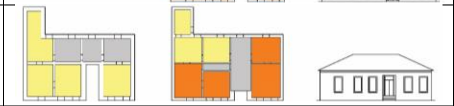
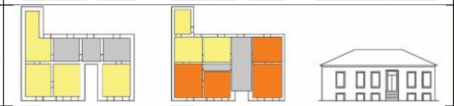
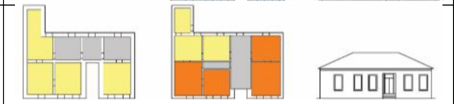
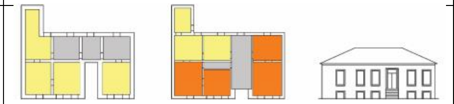
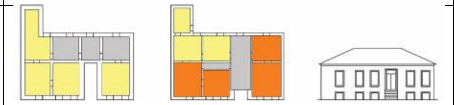
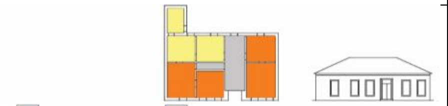
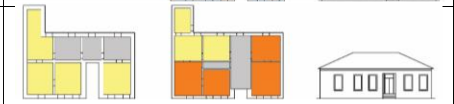
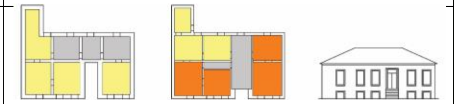
No	Plan and Facade	Model name	Hall Position	Basement as a room	Entrance direction	Setllement Pattern	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total building a	Volume m3	Wall to Volume ratio	Source Energy Consumption per Total Building Area kWh/m2
17		Model 2	Central	Exist	Northeast	Detached	0.07	1.37	0.10	227.98	647.82	0.48	311.92
18		Model 2 without basement	Central	Not exist	Northeast	Detached	0.08	1.51	0.12	127.62	440.07	0.44	539.25
19		Model 2 with basement for ventilation	Central	Exist with half height	Northeast	Detached	0.07	1.07	0.07	229.99	534.52	0.46	300.00
20		Model 2 semidetached	Central	Exist	Northeast	Semi-detached	0.09	1.08	0.10	227.98	647.82	0.38	286.01
21		Model 2_90d	Central	Exist	Southeast	Detached	0.07	1.37	0.10	227.98	647.82	0.48	298.66
22		Model 2_90d without basement	Central	Not exist	Southeast	Detached	0.08	1.51	0.12	127.62	440.07	0.44	519.21
23		Model 2_90d with basement for ventilation	Central	Exist with half height	Southeast	Detached	0.07	1.07	0.07	229.99	534.52	0.46	288.78
24		Model 2_90d semidetached	Central	Exist	Southeast	Semi-detached	0.09	1.08	0.10	227.98	647.82	0.38	273.36
25		Model 2_180d	Central	Exist	Southwest	Detached	0.07	1.37	0.10	227.98	647.82	0.48	297.14
26		Model 2_180d without basement	Central	Not exist	Southwest	Detached	0.08	1.51	0.12	127.62	440.07	0.44	517.40
27		Model 2_180d with basement for ventilation	Central	Exist with half height	Southwest	Detached	0.07	1.07	0.07	229.99	534.52	0.46	287.61
28		Model 2_180d semidetached	Central	Exist	Southwest	Semi-detached	0.09	1.08	0.10	227.98	647.82	0.38	263.42
29		Model 2_270d	Central	Exist	Northwest	Detached	0.07	1.37	0.10	227.98	647.82	0.48	309.45
30		Model 2_270d without basement	Central	Not exist	Northwest	Detached	0.08	1.51	0.12	127.62	440.07	0.44	538.49
31		Model 2_270d with basement for ventilation	Central	Exist with half height	Northwest	Detached	0.07	1.07	0.07	229.99	534.52	0.46	298.83
32		Model 2_270d semidetached	Central	Exist	Northwest	Semi-detached	0.09	1.08	0.10	227.98	647.82	0.38	276.10

Table G. 8. Properties and simulation results of BES models of single-story İzmir Houses variations with plan type 3

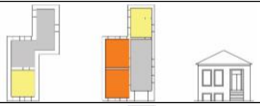
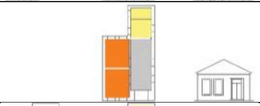
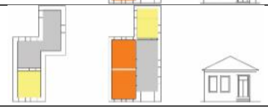
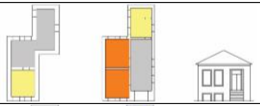
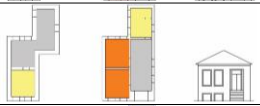
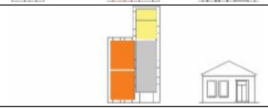
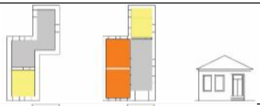
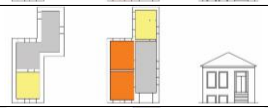
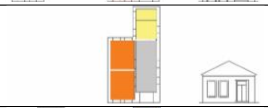
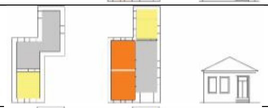
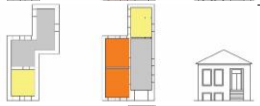
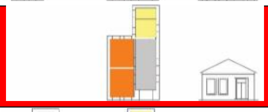
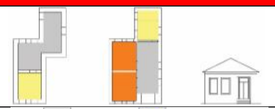
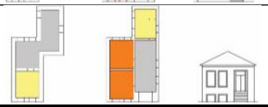
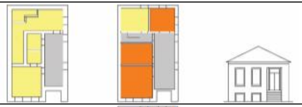
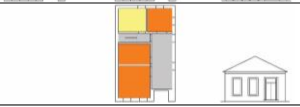
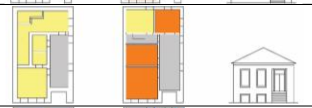
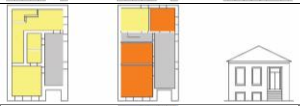
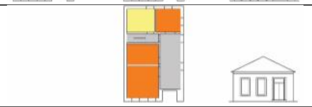
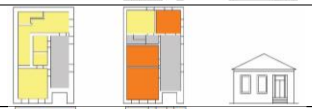
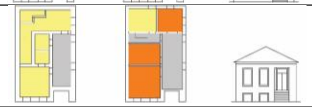
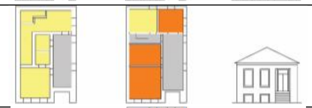
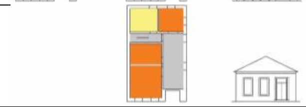
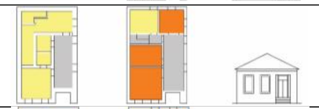
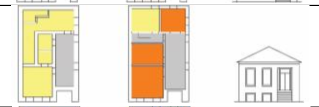
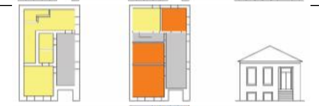
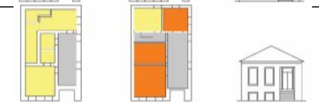
No	Plan and Facade	Model name	Hall Position	Basement as a room	Entrance direction	Setllement Pattern	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total building a	Volume m3	Wall to Volume ratio	Source Energy Consumption per Total Building Area kWh/m2
33		Model 3	Side	Exist	Northeast	Detached	0.09	2.51	0.23	91.57	265.12	0.87	342.47
34		Model 3 without basement	Side	Not exist	Northeast	Detached	0.12	2.30	0.27	55.44	190.34	0.67	544.72
35		Model 3 with basement for ventilation	Side	Exist with half height	Northeast	Detached	0.09	1.93	0.18	91.57	226.46	0.78	343.08
36		Model 3 semidetached	Side	Exist	Northeast	Semi-detached	0.11	2.05	0.23	91.57	265.12	0.71	308.13
37		Model 3_90d	Side	Exist	Southeast	Detached	0.09	2.51	0.23	91.57	265.12	0.87	346.08
38		Model 3_90d without basement	Side	Not exist	Southeast	Detached	0.12	2.30	0.27	55.44	190.34	0.67	550.76
39		Model 3_90d with basement for ventilation	Side	Exist with half height	Southeast	Detached	0.09	1.93	0.18	91.57	226.46	0.78	346.47
40		Model 3_90d semidetached	Side	Exist	Southeast	Semi-detached	0.11	2.05	0.23	91.57	265.12	0.71	312.10
41		Model 3_180d	Side	Exist	Southwest	Detached	0.09	2.51	0.23	91.57	265.12	0.87	342.45
42		Model 3_180d without basement	Side	Not exist	Southwest	Detached	0.12	2.30	0.27	55.44	190.34	0.67	550.14
43		Model 3_180d with basement for ventilation	Side	Exist with half height	Southwest	Detached	0.09	1.93	0.18	91.57	226.46	0.78	342.37
44		Model 3_180d semidetached	Side	Exist	Southwest	Semi-detached	0.11	2.05	0.23	91.57	265.12	0.71	292.49
45		Model 3_270d	Side	Exist	Northwest	Detached	0.09	2.51	0.23	91.57	265.12	0.87	345.72
46		Model 3_270d without basement	Side	Not exist	Northwest	Detached	0.12	2.30	0.27	55.44	190.34	0.67	551.04
47		Model 3_270d with basement for ventilation	Side	Exist with half height	Northwest	Detached	0.09	1.93	0.18	91.57	226.46	0.78	344.80
48		Model 3_270d semidetached	Side	Exist	Northwest	Semi-detached	0.11	2.05	0.23	91.57	265.12	0.71	297.31

Table G. 9. Properties and simulation results of BES models of single-story İzmir Houses variations with plan type 4

No	Plan and Facade	Model name	Hall Position	Basement as a room	Entrance direction	Setllement Pattern	Gross Window to Wal Ratio	Gross Wall to Floor Ratio	Gross Window to Floor Ratio	Total building a	Volume m3	Wall to Volume ratio	Source Energy Consumption per Total Building Area kWh/m2
49		Model 4	Side	Exist	Northeast	Detached	0.08	1.58	0.13	127.78	363.28	0.56	289.62
50		Model 4 without basement	Side	Not exist	Northeast	Detached	0.11	1.84	0.20	70.57	243.03	0.53	499.27
51		Model 4 with basement for ventilation	Side	Exist with half height	Northeast	Detached	0.09	1.28	0.12	127.78	301.12	0.54	287.36
52		Model 4 semidetached	Side	Exist	Northeast	Semi-detached	0.12	1.12	0.13	127.78	363.28	0.39	251.15
53		Model 4_90d	Side	Exist	Southeast	Detached	0.08	1.58	0.13	127.78	363.28	0.56	287.16
54		Model 4_90d without basement	Side	Not exist	Southeast	Detached	0.11	1.84	0.20	70.57	243.03	0.53	495.57
55		Model 4_90d with basement for ventilation	Side	Exist with half height	Southeast	Detached	0.09	1.28	0.12	127.78	301.12	0.54	285.19
56		Model 4_90d semidetached	Side	Exist	Southeast	Semi-detached	0.12	1.12	0.13	127.78	363.28	0.39	249.15
57		Model 4_180d	Side	Exist	Southwest	Detached	0.08	1.58	0.13	127.78	363.28	0.56	279.98
58		Model 4_180d without basement	Side	Not exist	Southwest	Detached	0.11	1.84	0.20	70.57	243.03	0.53	485.22
59		Model 4_180d with basement for ventilation	Side	Exist with half height	Southwest	Detached	0.09	1.28	0.12	127.78	301.12	0.54	277.99
60		Model 4_180d semidetached	Side	Exist	Southwest	Semi-detached	0.12	1.12	0.13	127.78	363.28	0.39	229.08
61		Model 4_270d	Side	Exist	Northwest	Detached	0.08	1.58	0.13	127.78	363.28	0.56	282.75
62		Model 4_270d without basement	Side	Not exist	Northwest	Detached	0.11	1.84	0.20	70.57	243.03	0.53	490.54
63		Model 4_270d with basement for ventilation	Side	Exist with half height	Northwest	Detached	0.09	1.28	0.12	127.78	301.12	0.54	281.12
64		Model 4_270d semidetached	Side	Exist	Northwest	Semi-detached	0.12	1.12	0.13	127.78	363.28	0.39	232.95

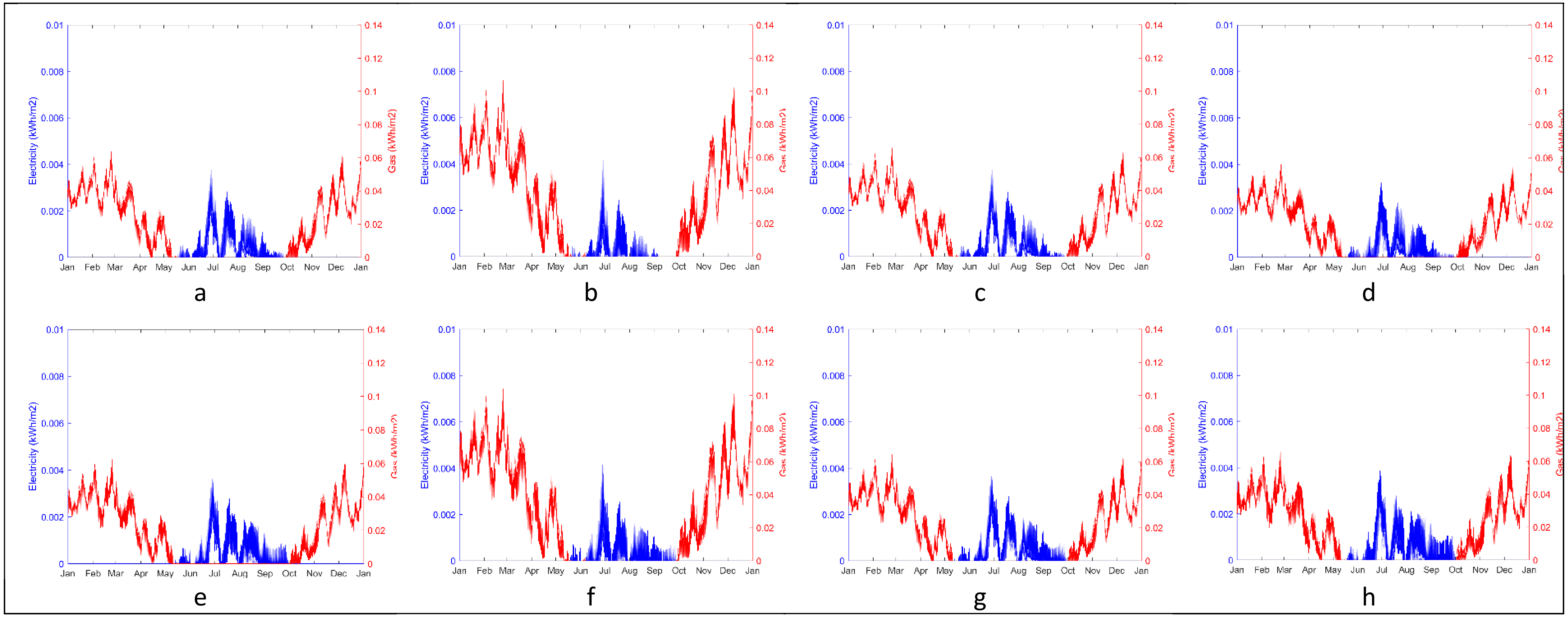


Figure G. 11. Annual energy consumption per total square meter graphics of single-story İzmir houses types in Buca (a) Model 1 (b) Model 1 without basement (c) Model 1 with basement for ventilation (d) Model 1 semidetached (e) Model 1 90d (f) Model 1 without basement 90d (g) Model 1 with basement for ventilation 90d (h) Model 1 semidetached 90d

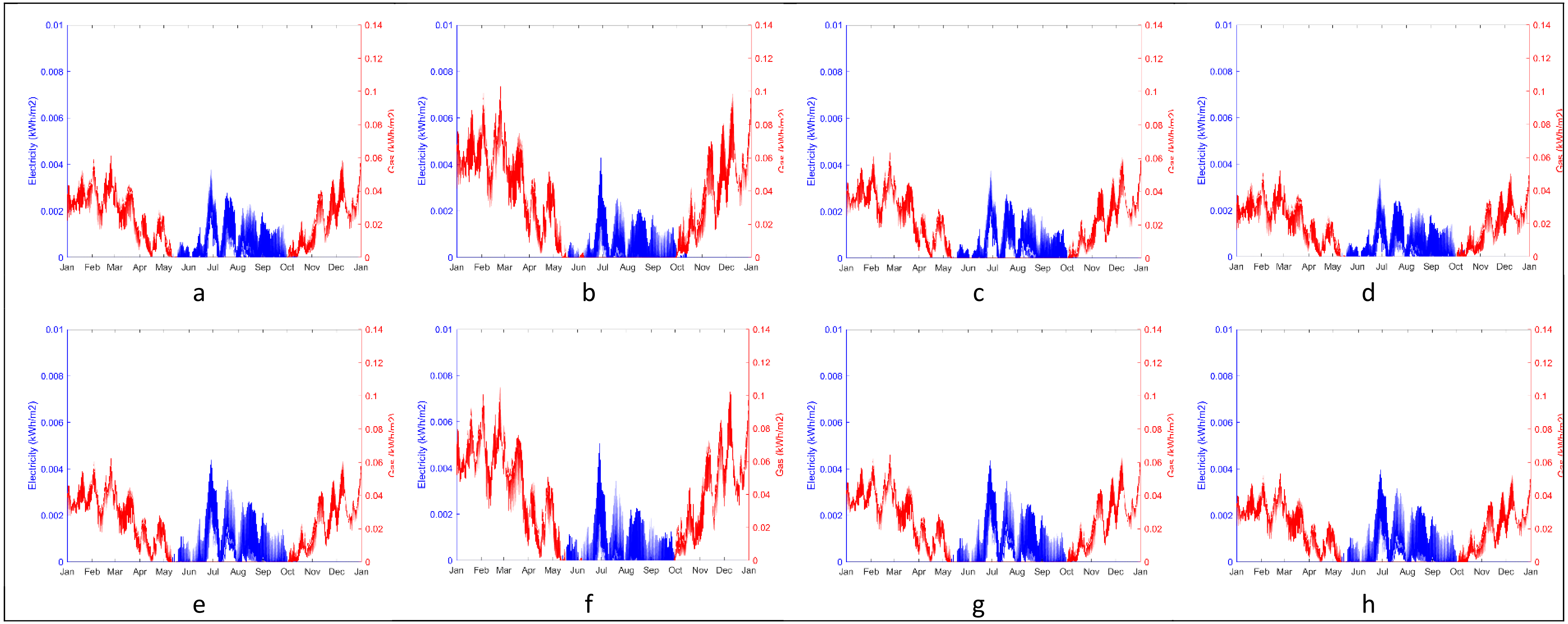


Figure F. 12. Annual energy consumption per total square meter graphics of single-story İzmir houses types in Buca (a) Model 1 180d (b) Model 1 without basement 180d (c) Model 1 with basement for ventilation 180d (d) Model 1 semidetached 180d (e) Model 1 270d (f) Model 1 without basement 270d (g) Model 1 with basement for ventilation 270d (h) Model 1 semidetached 270d

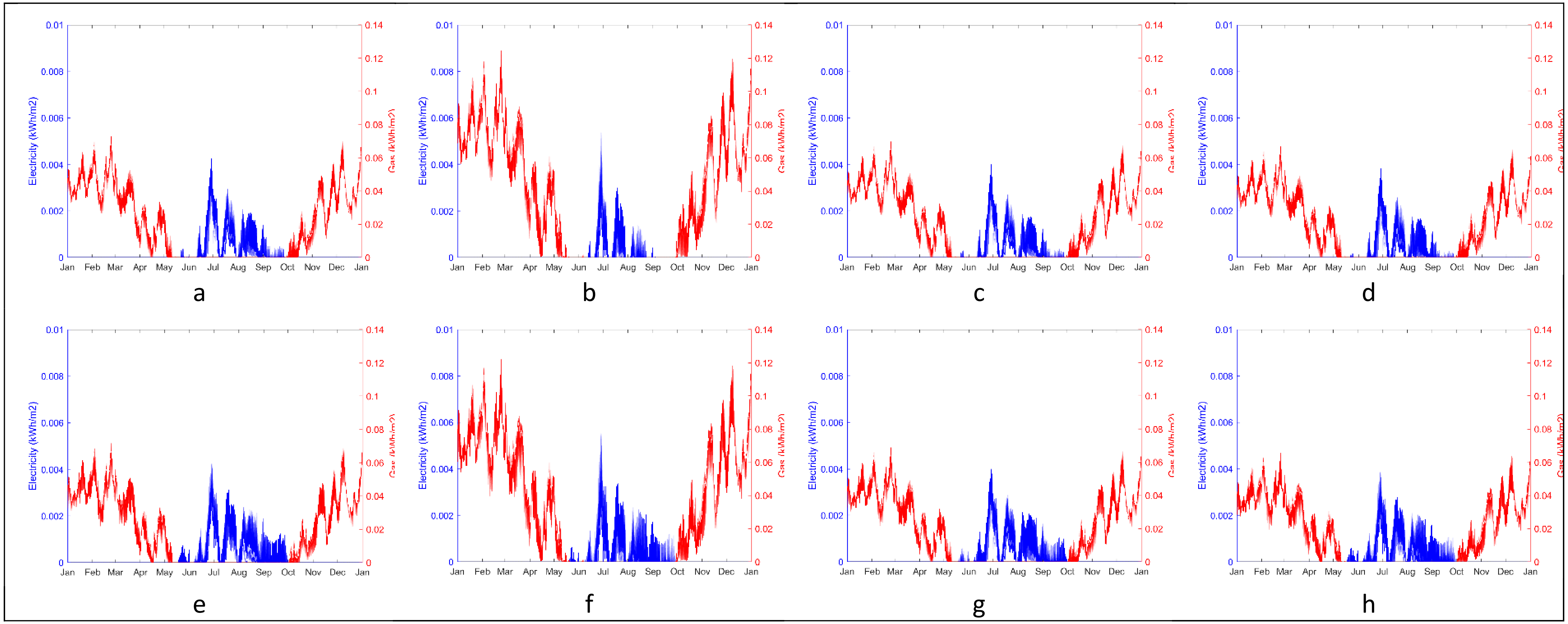


Figure G. 13. Annual energy consumption per total square meter graphics of single-story İzmir houses types in Buca (a) Model 2 (b) Model 2 without basement (c) Model 2 with basement for ventilation (d) Model 2 semidetached (e) Model 2 90d (f) Model 2 without basement 90d (g) Model 2 with basement for ventilation 90d (h) Model 2 semidetached 90d

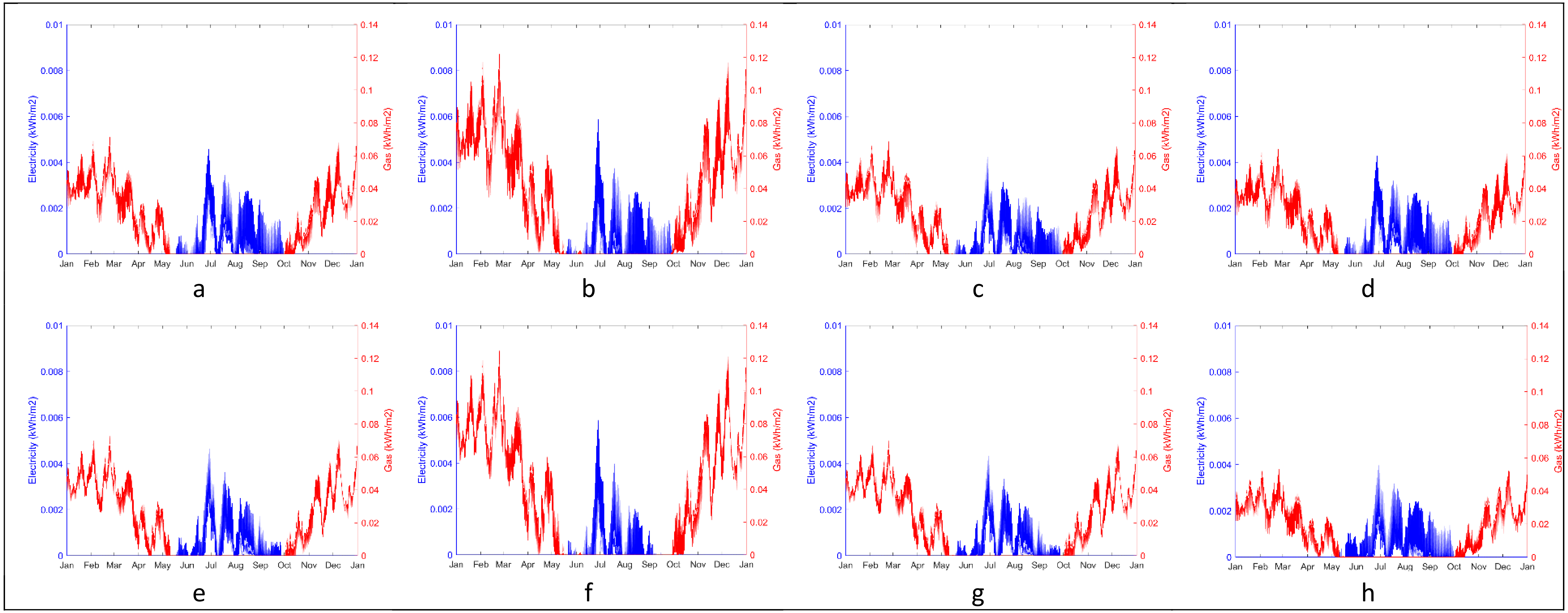


Figure G. 14 Annual energy consumption graphics per total square meter of single-story İzmir houses types in Buca (a) Model 2 180d (b) Model 2 without basement 180d (c) Model 2 with basement for ventilation 180d (d) Model 2 semidetached 180d (e) Model 2 270d (f) Model 2 without basement 270d (g) Model 2 with basement for ventilation 270d (h) Model 2 semidetached 270d

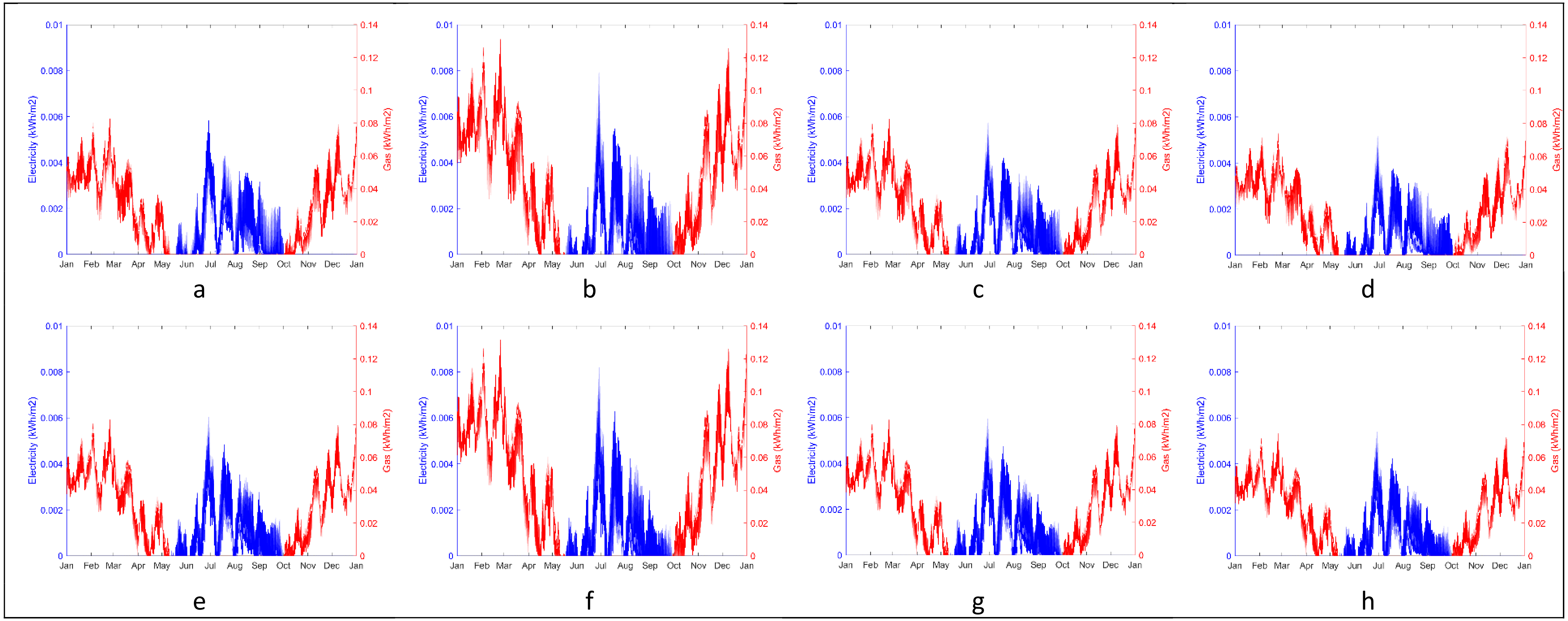


Figure G. 15 Annual energy consumption per total square meter graphics of single-story İzmir houses types in Buca (a) Model 3 (b) Model 3 without basement (c) Model 3 with basement for ventilation (d) Model 3 semidetached (e) Model 3 90d (f) Model 3 without basement 90d (g) Model 3 with basement for ventilation 90d (h) Model 3 semidetached 90d

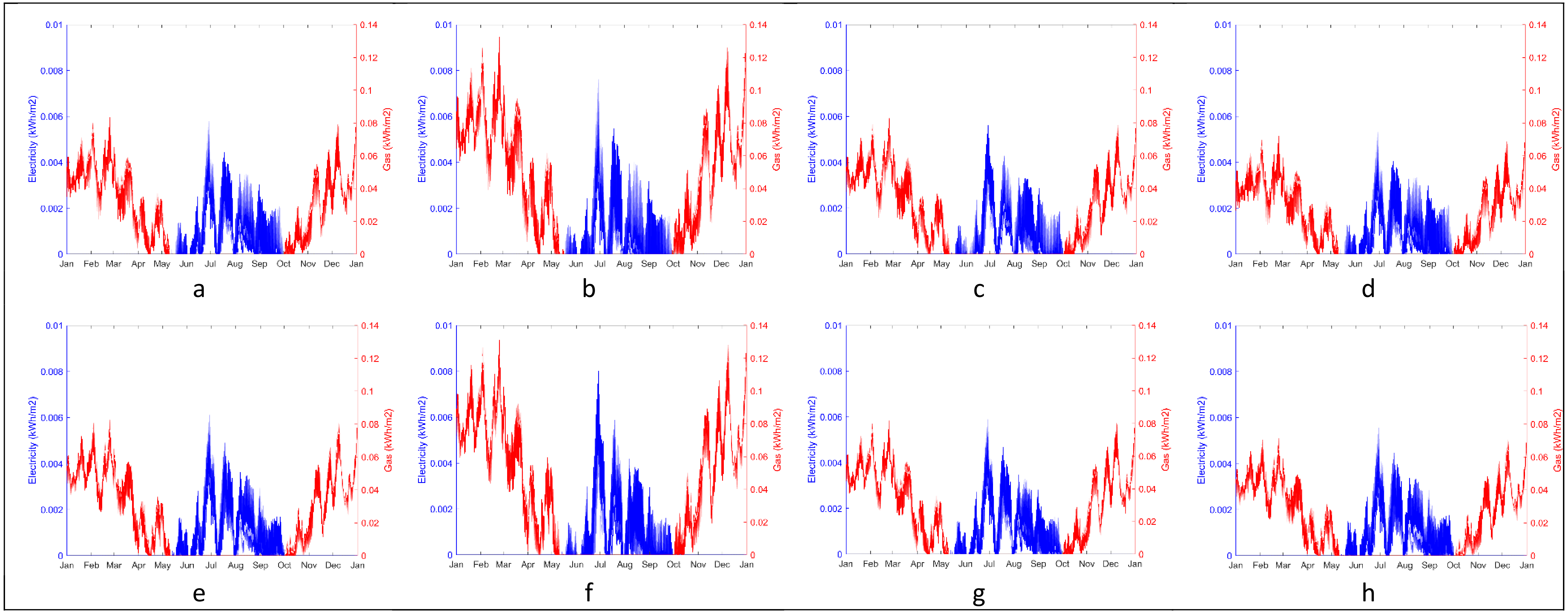


Figure G. 16 Annual energy consumption graphics per total square meter of single-story İzmir houses types in Buca (a) Model 3 180d (b) Model 3 without basement 180d (c) Model 3 with basement for ventilation 180d (d) Model 3 semidetached 180d (e) Model 3 270d (f) Model 3 without basement 270d (g) Model 3 with basement for ventilation 270d (h) Model 3 semidetached 270d

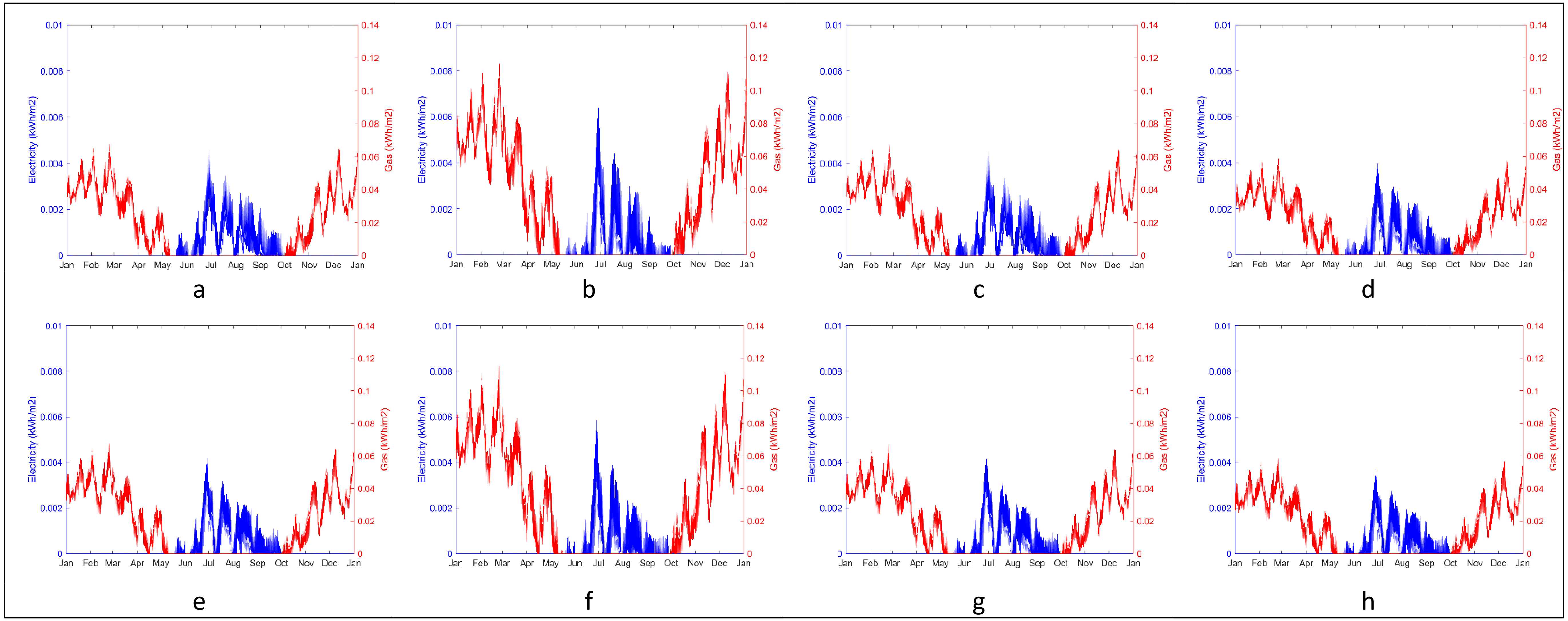


Figure G. 17 Annual energy consumption per total square meter graphics of single-story İzmir houses types in Buca (a) Model 4 (b) Model 4 without basement (c) Model 4 with basement for ventilation (d) Model 4 semidetached (e) Model 4 90d (f) Model 4 without basement 90d (g) Model 4 with basement for ventilation 90d (h) Model 4 semidetached 90d

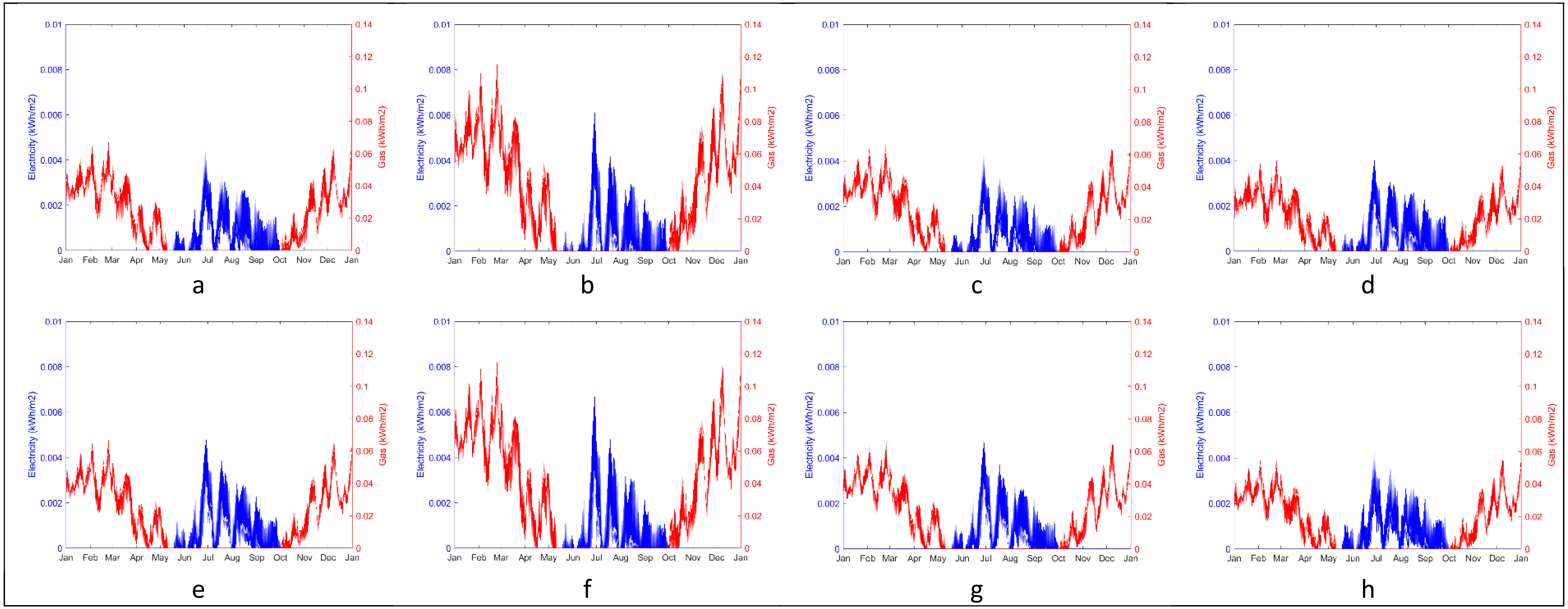


Figure G. 18 Annual energy consumption graphics per total square meter of single-story İzmir houses types in Buca (a) Model 4 180d (b) Model 4 without basement 180d (c) Model 4 with basement for ventilation 180d (d) Model 4 semidetached 180d (e) Model 4 270d (f) Model 4 without basement 270d (g) Model 4 with basement for ventilation 270d (h) Model 4 semidetached 270d

APPENDIX H

STATISTICAL ANALYSES RESULTS OF IZMIR HOUSES

Table H. 1. T-test analysis (equal variances) of energy consumption per square meter based on location of the hall space of the two-story houses

	Side Hall	*Central Hall*
Mean	224.7576667	290.727
Variance	922.0754461	2087.378675
Observations	30	20
Pooled Variance	1383.341307	
Hypothesized Mean Difference	0	
df	48	
t Stat	-6.144238221	
P(T<=t) one-tail	7.54585E-08	
t Critical one-tail	1.677224196	
P(T<=t) two-tail	1.50917E-07	
t Critical two-tail	2.010634758	

Table H. 2. T-test analysis (unequal variances) of energy consumption per square meter based on location of the hall space of the two-story houses with basements

	Side Hall	*Central Hall*
Mean	215.14	269.548125
Variance	542.7822087	149.9562563
Observations	24	16
Hypothesized Mean Difference	0	
df	36	
t Stat	-9.619863657	
P(T<=t) one-tail	8.65766E-12	
t Critical one-tail	1.688297714	
P(T<=t) two-tail	1.73153E-11	
t Critical two-tail	2.028094001	

Table H. 3. T-test analysis (equal variances) of energy consumption per square meter based on location of the hall space of the two-story houses with basements

	Side Hall	*Central Hall*
Mean	215.14	269.548125
Variance	542.7822087	149.9562563
Observations	24	16
Pooled Variance	387.7193327	
Hypothesized Mean Difference	0	
df	38	
t Stat	-8.561318377	
P(T<=t) one-tail	1.06208E-10	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	2.12417E-10	
t Critical two-tail	2.024394164	

Table H. 4. Variance analysis of energy consumption per square meter based on location of the hall space of the two-story houses with basement

Groups	*Count*	*Sum*	*Average*	*Variance*
Side Hall	24	5163.36	215.14	542.78
Central Hall	16	4312.77	269.55	149.96

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28418.34303	1	28418.34	73.2962	2,12417E-10	4.0982
Within Groups	14733.33464	38	387.72			
Total	43151.67768	39				

Table H. 5. T-test analysis (unequal variances) of energy consumption per square meter based on location of the hall space of the single-story houses

	Side Hall	*Central Hall*
Mean	355.1321875	327.591875
Variance	10718.17091	10093.5184
Observations	32	32
Hypothesized Mean Difference	0	
df	62	
t Stat	1.079916523	
P(T<=t) one-tail	0.14218124	
t Critical one-tail	1.669804163	
P(T<=t) two-tail	0.28436248	
t Critical two-tail	1.998971517	

Table H. 6. T-test analysis (unequal variances) of energy consumption per square meter based on location of the hall space of the single-story houses

	Side Hall	*Central Hall*
Mean	299.87375	273.1370833
Variance	1417.439998	689.5696998
Observations	24	24
Hypothesized Mean Difference	0	
df	41	
t Stat	2.853511421	
P(T<=t) one-tail	0.003374449	
t Critical one-tail	1.682878002	
P(T<=t) two-tail	0.006748897	
t Critical two-tail	2.01954097	

Table H. 7. T-test analysis (equal variances) of energy consumption per square meter based on utilization of the basement of the two-story houses with basement

	Basement as a room	*Basement as a ventilation space*
Mean	236.0676667	239.41
Variance	1068.422308	1342.627422
Observations	30	10
Pooled Variance	1133.365625	
Hypothesized Mean Difference	0	
df	38	
t Stat	-0.271891339	
P(T<=t) one-tail	0.393588697	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	0.787177395	
t Critical two-tail	2.024394164	

Table H. 8. T-test analysis (unequal variances) of energy consumption per square meter based on utilization of the basement of the two-story houses with basement

	Basement as a room	*Basement as a ventilation space*
Mean	236.0676667	239.41
Variance	1068.422308	1342.627422
Observations	30	10
Hypothesized Mean Difference	0	
df	14	
t Stat	-0.256438188	
P(T<=t) one-tail	0.400671212	
t Critical one-tail	1.761310136	
P(T<=t) two-tail	0.801342423	
t Critical two-tail	2.144786688	

Table H. 9. T-test analysis (equal variances) of energy consumption per square meter based on utilization of the basement of the single-story houses with basement

	Basement as a room	*Basement as a ventilation space*
Mean	280.38	298.75625
Variance	1330.462897	812.8716917
Observations	32	16
Pooled Variance	1161.683156	
Hypothesized Mean Difference	0	
df	46	
t Stat	-1.760870453	
P(T<=t) one-tail	0.042453553	
t Critical one-tail	1.678660414	
P(T<=t) two-tail	0.084907107	
t Critical two-tail	2.012895599	

Table H. 10. T-test analysis (unequal variances) of energy consumption per square meter based on orientation of the two-story houses

	Entrance Faces Southwest	*Entrance Faces Northeast*
Mean	254.7716	247.5192
Variance	2428.966956	2486.297699
Observations	25	25
Hypothesized Mean Difference	0	
df	48	
t Stat	0.517223561	
P(T<=t) one-tail	0.303687743	
t Critical one-tail	1.677224196	
P(T<=t) two-tail	0.607375486	
t Critical two-tail	2.010634758	

Table H. 11. T-test analysis (equal variances) of energy consumption per square meter based on orientation of the two-story houses with basement

	Entrance Faces Southwest	*Entrance Faces Northeast*
Mean	240.166	233.6405
Variance	1069.550173	1179.1791
Observations	20	20
Pooled Variance	1124.364636	
Hypothesized Mean Difference	0	
df	38	
t Stat	0.615403845	
P(T<=t) one-tail	0.270978225	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	0.54195645	
t Critical two-tail	2.024394164	

Table H. 12. T-test analysis (unequal variances) of energy consumption per square meter based on orientation of the two-story houses with basement

	Entrance Faces Southwest	*Entrance Faces Northeast*
Mean	240.166	233.6405
Variance	1069.550173	1179.1791
Observations	20	20
Hypothesized Mean Difference	0	
df	38	
t Stat	0.615403845	
P(T<=t) one-tail	0.270978225	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	0.54195645	
t Critical two-tail	2.024394164	

Table H. 13. Variance analysis of energy consumption per square meter based on orientation of the single-story houses with basement

Groups	*Count*	*Sum*	*Average*	*Variance*		
Entrance Faces Southwest	12	3340.18	278.34833 33	1535.3283 24		
Entrance Faces Northeast	12	3523.28	293.60666 67	934.53222 42		
Entrance Faces Northwest	12	3430.27	285.85583 33	1401.7542 63		
Entrance Faces Southeast	12	3458.53	288.21083 33	1182.5543 9		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1443.55 3975	3	481.18465 83	0.3808219 62	0.7672940 25	2.8164658 17
Within Groups	55595.8 6122	44	1263.5423			
Total	57039.4 1519	47				

Table H. 14. T-test analysis (equal variances) of energy consumption per square meter based on occupancy (heating) of the roof of the two-story houses

	Roof Heated	*Roof Unheated*
Mean	254.991875	249.3352941
Variance	709.9551362	3261.404989
Observations	16	34
Pooled Variance	2464.07691	
Hypothesized Mean Difference	0	
df	48	
t Stat	0.375873164	
P(T<=t) one-tail	0.354333668	
t Critical one-tail	1.677224196	
P(T<=t) two-tail	0.708667337	
t Critical two-tail	2.010634758	

Table H. 15. T-test analysis (unequal variances) of energy consumption per square meter based on occupancy (heating) of the roof of the two-story houses with basements

	Roof Heated	*Roof Unheated*
Mean	249.5492857	230.0938462
Variance	557.8310071	1298.215841
Observations	14	26
Hypothesized Mean Difference	0	
df	36	
t Stat	2.053335105	
P(T<=t) one-tail	0.023680089	
t Critical one-tail	1.688297714	
P(T<=t) two-tail	0.047360179	
t Critical two-tail	2.028094001	

Table H. 16. T-test analysis (equal variances) of energy consumption per square meter based on occupancy (heating) of the roof of the two-story houses with basements

	Roof Heated	*Roof Unheated*
Mean	254.991875	249.3352941
Variance	709.9551362	3261.404989
Observations	16	34
Hypothesized Mean Difference	0	
df	48	
t Stat	0.477563971	
P(T<=t) one-tail	0.317564067	
t Critical one-tail	1.677224196	
P(T<=t) two-tail	0.635128134	
t Critical two-tail	2.010634758	

Table H. 17. T-test analysis (equal variances) of energy consumption per square meter based on the existence of the oriel of the two-story houses

	Oriel Exist	*Oriel Not Exist*
Mean	255.1665	235.061
Variance	2700.192054	1120.275432
Observations	40	10
Pooled Variance	2403.957688	
Hypothesized Mean Difference	0	
df	48	
t Stat	1.159835672	
P(T<=t) one-tail	0.125926266	
t Critical one-tail	1.677224196	
P(T<=t) two-tail	0.251852531	
t Critical two-tail	2.010634758	

Table H. 18. T-test analysis (unequal variances) of energy consumption per square meter based on the existence of the oriel of the two-story houses with basements

	Oriel Exist	*Oriel Not Exist*
Mean	237.5173333	235.061
Variance	1138.756793	1120.275432
Observations	30	10
Hypothesized Mean Difference	0	
df	16	
t Stat	0.200568068	
P(T<=t) one-tail	0.421781809	
t Critical one-tail	1.745883676	
P(T<=t) two-tail	0.843563619	
t Critical two-tail	2.119905299	

Table H. 19. T-test analysis (equal variances) of energy consumption per square meter based on the existence of the oriel of the two-story houses with basements

	Oriel Exist	*Oriel Not Exist*
Mean	237.5173333	235.061
Variance	1138.756793	1120.275432
Observations	30	10
Pooled Variance	1134.379628	
Hypothesized Mean Difference	0	
df	38	
t Stat	0.199727895	
P(T<=t) one-tail	0.42137919	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	0.84275838	
t Critical two-tail	2.024394164	

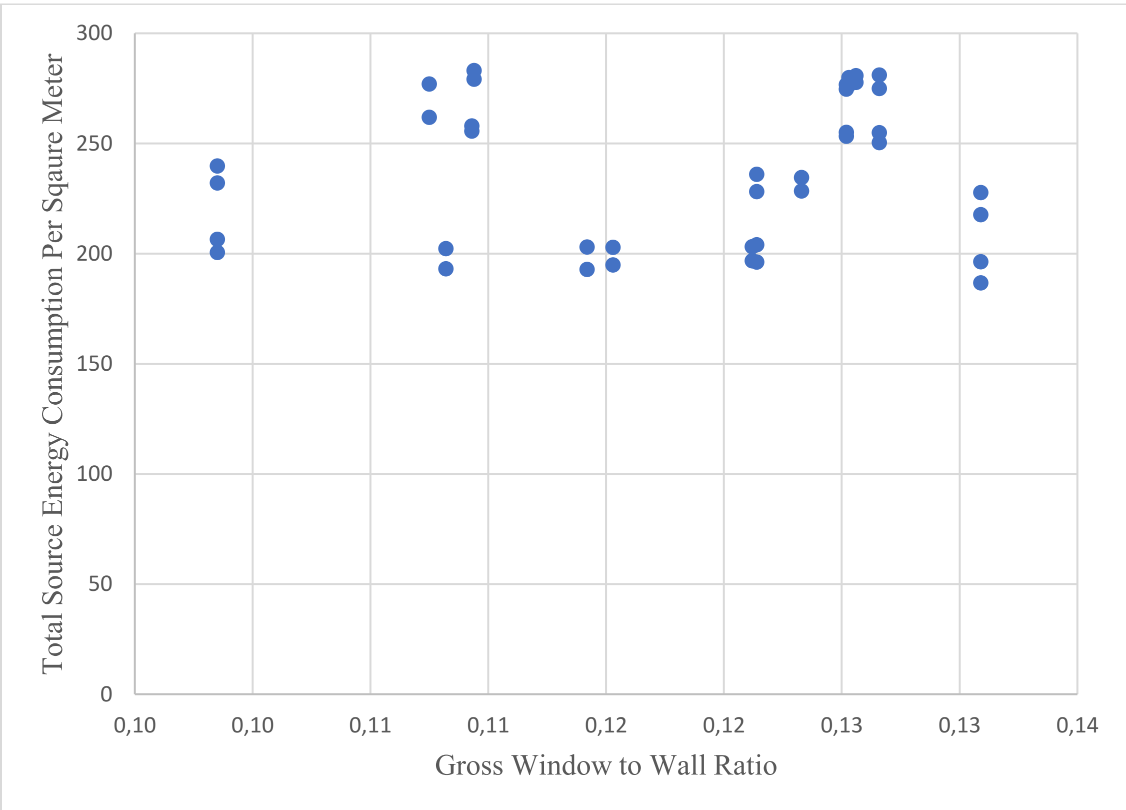


Figure H. 1. The distribution of the total energy consumption per square meter based on window to wall ratio of the two-story houses with basements

Table H. 20. Variance analysis of energy consumption per square meter based on gross window to wall ratio of the two-story houses with basements

Groups	*Count*	*Sum*	*Average*	*Variance*		
wwr 0.10	4	878.97	219.7425	366.8002		
wwr 0.11	10	2406.43	240.643	1445.943		
wwr 0.12	10	2125.47	212.547	290.5034		
wwr 0.13	16	4065.26	254.0788	963.5471		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11970.06	3	3990.019	4.606582	0.007907	2.866266
Within Groups	31181.62	36	866.1561			
Total	43151.68	39				

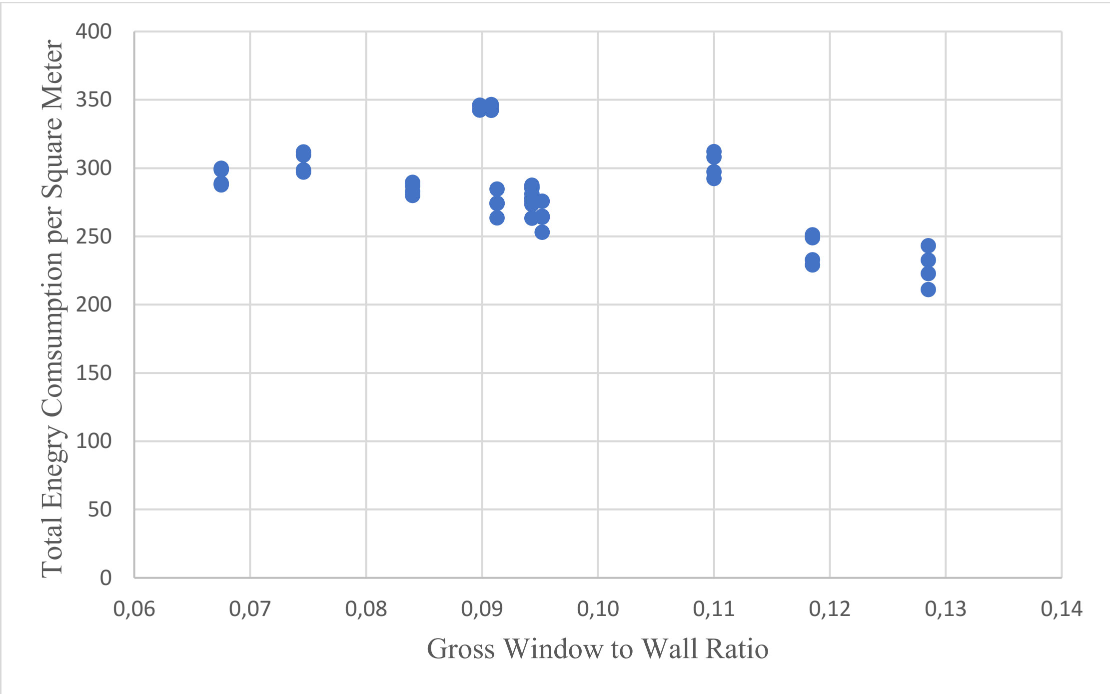


Figure H. 2. The distribution of the total energy consumption per square meter based on window to wall ratio of the single-story houses with basements

Table H. 21. Variance analysis of energy consumption per square meter based on gross window to wall ratio of the single-story houses with basements

Groups	*Count*	*Sum*	*Average*	*Variance*		
wwr 0.07	8	2392.39	299.0488	73.55636		
wwr 0.08	4	1139.51	284.8775	18.73763		
wwr 0.09-0.10	24	7138.24	297.4267	1205.611		
wwr 0.11-0.12	8	2172.36	271.545	1185.149		
wwr 0.13	4	909.76	227.44	188.6524		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	19877.26	4	4969.314	5.749949	0.000848	2.588836
Within Groups	37162.16	43	864.2362			
Total	57039.42	47				

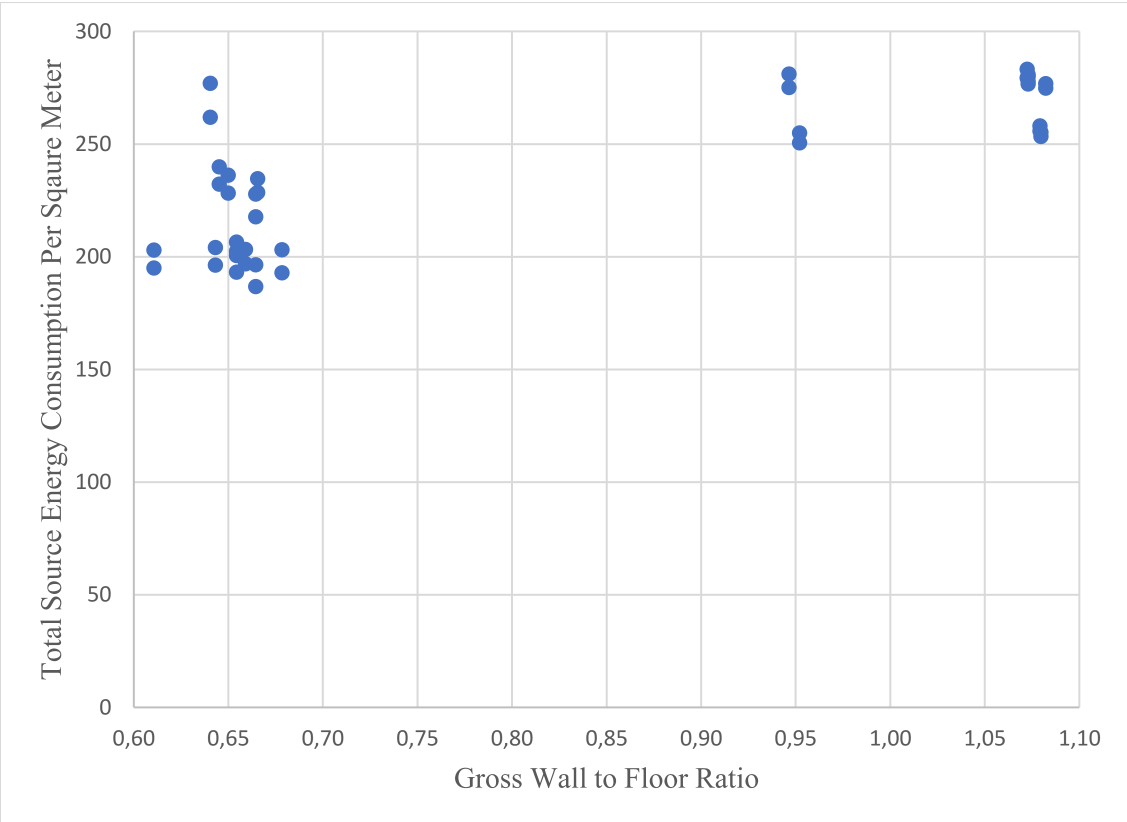


Figure H. 3. The distribution of the total energy consumption per square meter based on wall to floor ratio of the two-story houses with basements

Table H. 22. Variance analysis of energy consumption per square meter based on gross wall to floor ratio of the two-story houses with basements

Groups	*Count*	*Sum*	*Average*	*Variance*		
wafr 0.61-0.68	24	5163.36	215.14	542.7822		
wafr 0.95	4	1061.47	265.3675	224.613		
wafr 1.07-1.08	12	3251.3	270.9417	134.7537		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	28511.56	2	14255.78	36.02865	2.07E-09	3.251924
Within Groups	14640.12	37	395.6789			
Total	43151.68	39				

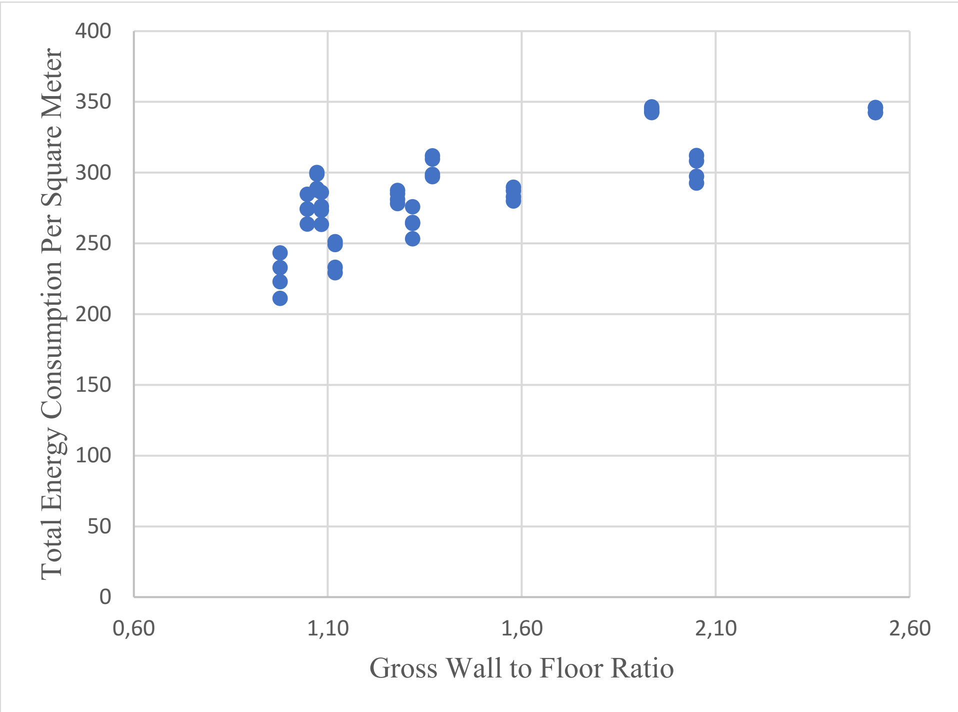


Figure H. 4. The distribution of the total energy consumption per square meter based on wall to floor ratio of the single-story houses with basements

Table H. 23. Variance analysis of energy consumption per square meter based on gross wall to floor ratio of the single-story houses with basements

Groups	*Count*	*Sum*	*Average*	*Variance*		
wafr 0.98-1.32	28	7432.11	265.4325	562.8662		
wafr 1.37-1.58	8	2356.68	294.585	139.6799		
wafr 1.93-2.05	8	2586.75	323.3438	533.4717		
wafr 2.51	4	1376.72	344.18	3.9662		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37118.07	3	12372.69	27.32739	3.91E-10	2.816466
Within Groups	19921.35	44	452.7579			
Total	57039.42	47				

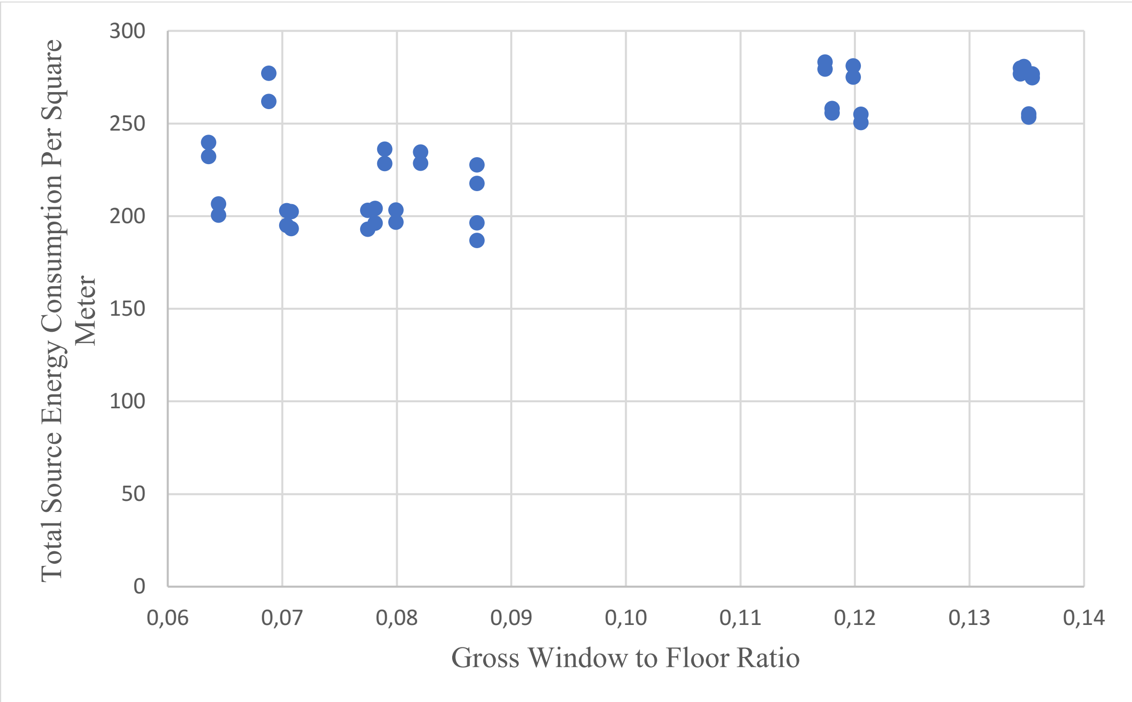


Figure H. 5. The distribution of the total energy consumption per square meter based on window to floor ratio of the two-story houses with basements

Table H. 24. T-test analysis (equal variances) of energy consumption per square meter based on gross window to floor ratio of the two-story houses with basements

	wfr 0.06-0.09	*wfr 0.12-0.14*
Mean	215.14	269.548125
Variance	542.7822087	149.9562563
Observations	24	16
Pooled Variance	387.7193327	
Hypothesized Mean Difference	0	
df	38	
t Stat	-8.561318377	
P(T<=t) one-tail	1.06208E-10	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	2.12417E-10	
t Critical two-tail	2.024394164	

Table H. 25. T-test analysis (unequal variances) of energy consumption per square meter based on gross window to floor ratio of the two-story houses with basements

	wfr 0.06-0.09	*wfr 0.12-0.14*
Mean	215.14	269.548125
Variance	542.7822087	149.9562563
Observations	24	16
Hypothesized Mean Difference	0	
df	36	
t Stat	-9.619863657	
P(T<=t) one-tail	8.65766E-12	
t Critical one-tail	1.688297714	
P(T<=t) two-tail	1.73153E-11	
t Critical two-tail	2.028094001	

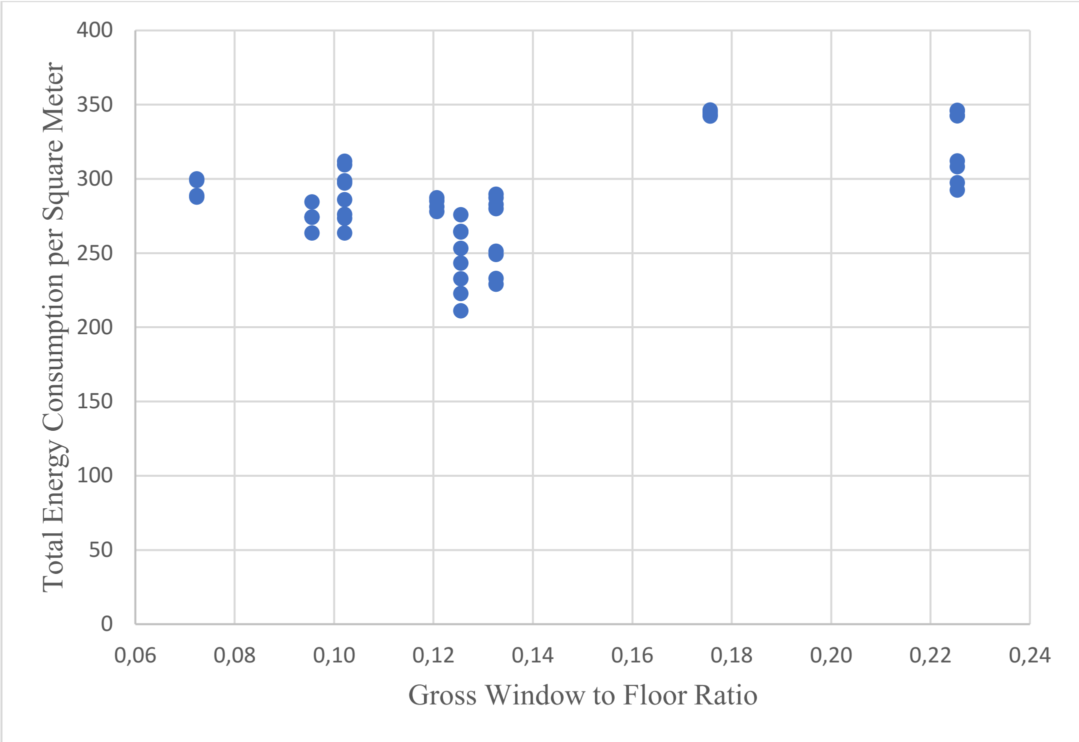


Figure H. 6. The distribution of the total energy consumption per square meter based on window to floor ratio of the single-story houses with basements

Table H. 26. Variance analysis of energy consumption per square meter based on gross window to floor ratio of the single-story houses with basements

Groups	*Count*	*Sum*	*Average*	*Variance*		
wfr 0.07-0.1	16	4587.78	286.7363	228.0979		
wfr 0.12-0.13	20	5201.01	260.0505	616.4057		
wfr 0.18-0.23	12	3963.47	330.2892	445.812		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37002.31	2	18501.15	41.5505	5.99E-11	3.204317
Within Groups	20037.11	45	445.2691			
Total	57039.42	47				

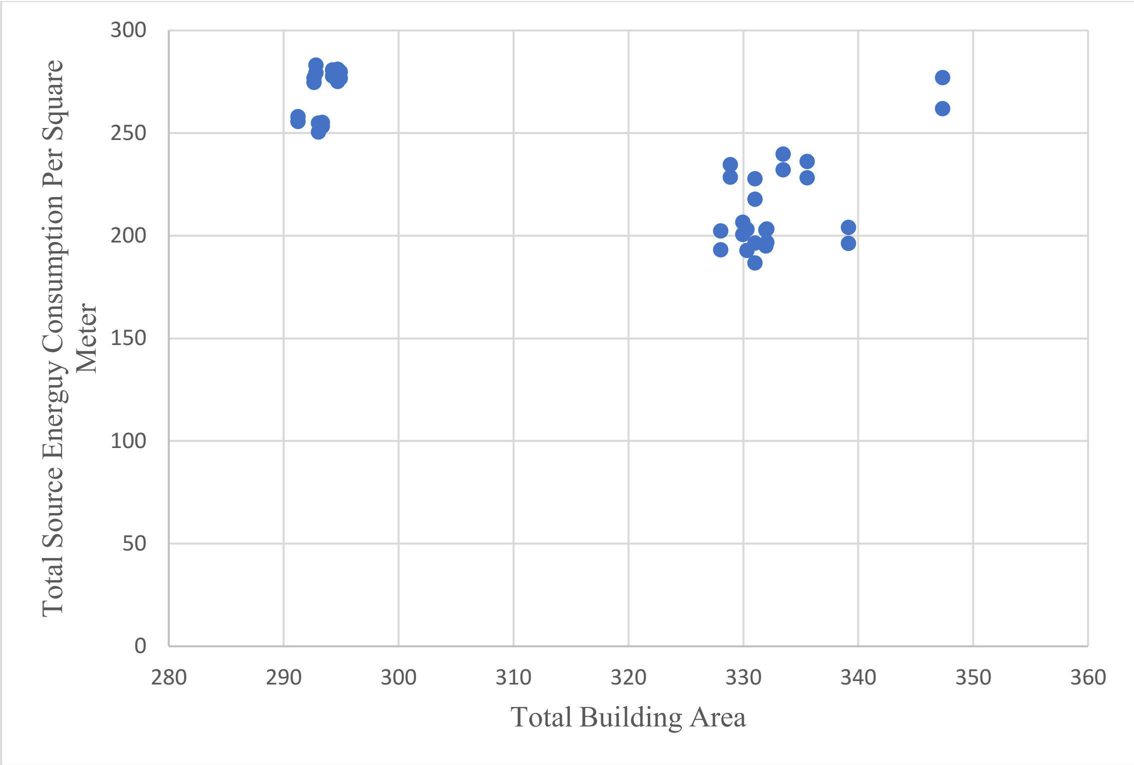


Figure H. 7. The distribution of the total energy consumption per square meter based on total building area of the two-story houses with basements

Table H. 27. Variance analysis of energy consumption per square meter based on total building area of the two-story houses with basements

Groups	*Count*	*Sum*	*Average*	*Variance*
total building area 291-295	16	4312.77	269.5481	149.9563
total building area 328-339	22	4624.5	210.2045	282.7943
total building area 348	2	538.86	269.43	114.6098

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34849.04	2	17424.52	77.65093	5.73E-14	3.251924
Within Groups	8302.635	37	224.3955			
Total	43151.68	39				

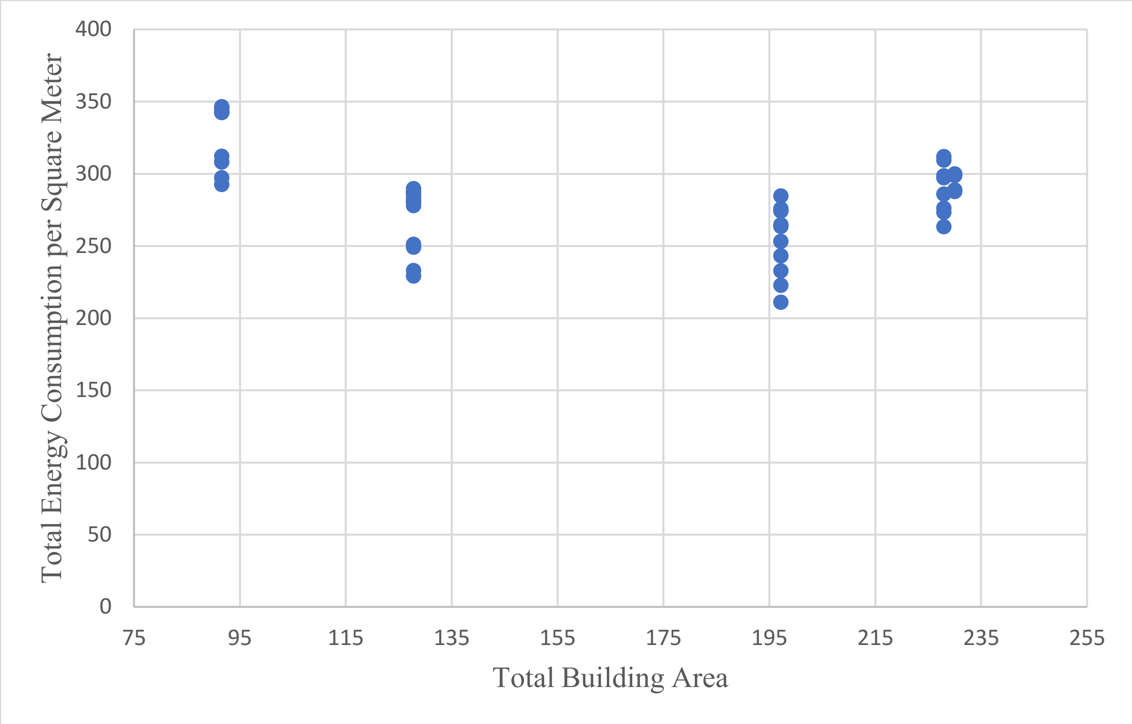


Figure H. 8. The distribution of the total energy consumption per square meter based on total building area of the single-story houses with basements

Table H. 28. Variance analysis of energy consumption per square meter based on total building area of the single-story houses with basements

Groups	*Count*	*Sum*	*Average*	*Variance*		
92 m2	12	3963.47	330.2892	445.812		
128 m2	12	3233.5	269.4583	499.5315		
197 m2	12	3064.01	255.3342	536.5095		
228m2	12	3491.28	290.94	213.8042		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	38387.19	3	12795.73	30.18471	9.33E-11	2.816466
Within Groups	18652.23	44	423.9143			
Total	57039.42	47				

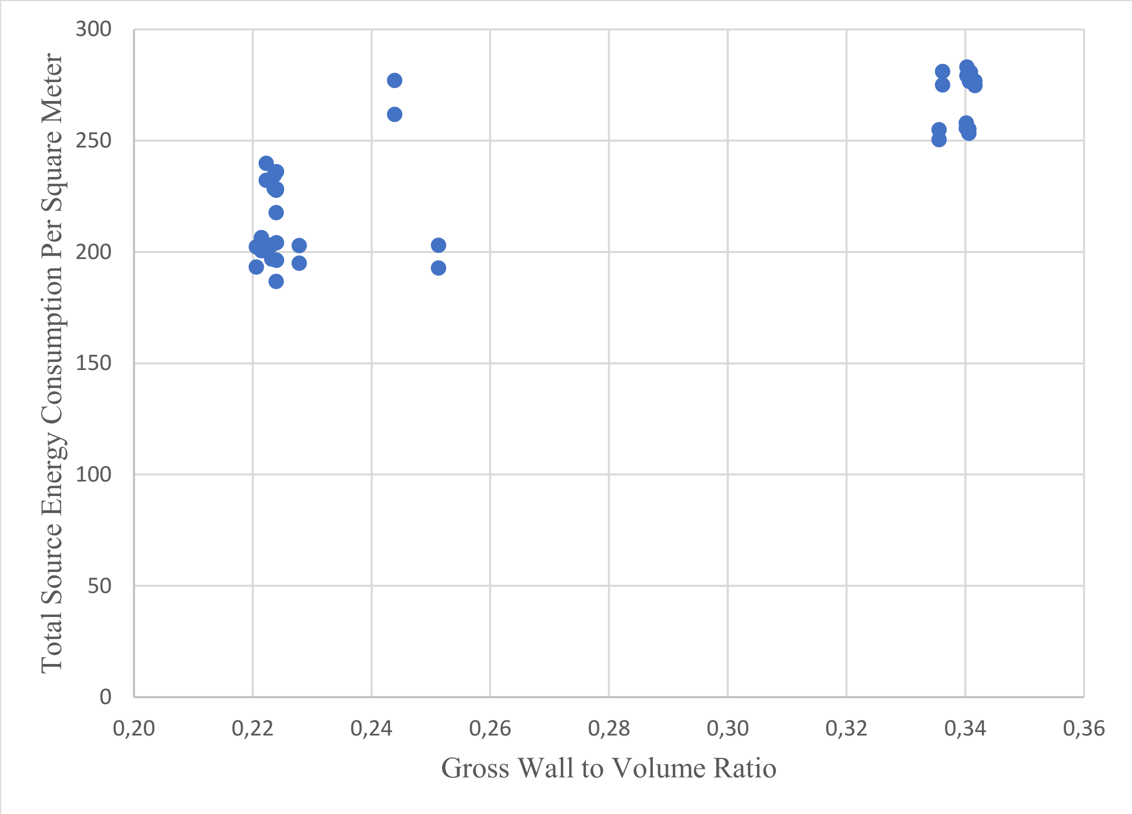


Figure H. 9. The distribution of the total energy consumption per square meter based on wall to volume ratio of the two-story houses with basements

Table H. 29. T-test analysis (equal variances) of energy consumption per square meter based on gross wall to volume ratio of the two-story houses with basements

	wavr 0.22-0.25	*wavr 0.34*
Mean	215.14	269.5481
Variance	542.7822	149.9563
Observations	24	16
Pooled Variance	387.7193	
Hypothesized Mean Difference	0	
df	38	
t Stat	-8.56132	
P(T<=t) one-tail	1.06E-10	
t Critical one-tail	1.685954	
P(T<=t) two-tail	2.12E-10	
t Critical two-tail	2.024394	

Table H. 30. T-test analysis (unequal variances) of energy consumption per square meter based on gross wall to volume ratio of the two-story houses with basements

	wavr 0.22-0.25	*wavr 0.34*
Mean	215.14	269.5481
Variance	542.7822087	149.9563
Observations	24	16
Hypothesized Mean Difference	0	
df	36	
t Stat	-9.619863657	
P(T<=t) one-tail	8.65766E-12	
t Critical one-tail	1.688297714	
P(T<=t) two-tail	1.73153E-11	
t Critical two-tail	2.028094001	

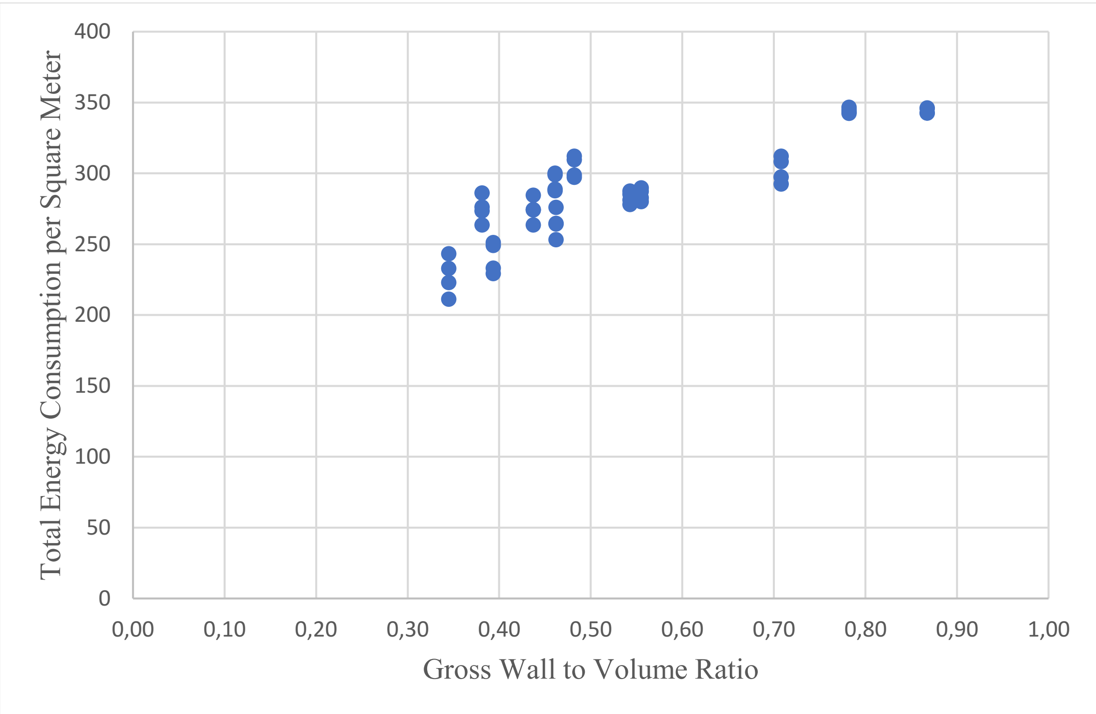


Figure H. 10. The distribution of the total energy consumption per square meter based on wall to volume ratio of the single-story houses with basements

Table H. 31. Variance analysis of energy consumption per square meter based on total wall to volume of the single-story houses with basements

Groups	*Count*	*Sum*	*Average*	*Variance*		
wavr 0.34-0.39	12	2970.98	247.5817	542.3365		
wavr 0.44-0.46	12	3329.47	277.4558	218.0154		
wavr 0.48-0.56	12	3488.34	290.695	126.6674		
wavr 0.71-0.87	12	3963.47	330.2892	445.812		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	42378.27	3	14126.09	42.39424	4.89E-13	2.816466
Within Groups	14661.14	44	333.2078			
Total	57039.42	47				

Table G. 8. T-test analysis (unequal variances) of energy consumption per square meter based on settlement pattern of the single-story houses with basements

	Detached	Semidetached
Mean	299.1015625	261.313125
Variance	856.1465104	1017.81573
Observations	32	16
Hypothesized Mean Difference	0	
df	28	
t Stat	3.975131057	
P(T<=t) one-tail	0.000224582	
t Critical one-tail	1.701130934	
P(T<=t) two-tail	0.000449164	
t Critical two-tail	2.048407142	

Table H. 32. T-test analysis (equal variances) of energy consumption per square meter based on settlement pattern of the single-story houses with basements

	Detached	Semidetached
Mean	299.1015625	261.313125
Variance	856.1465104	1017.81573
Observations	32	16
Pooled Variance	908.864734	
Hypothesized Mean Difference	0	
df	46	
t Stat	4.093772182	
P(T<=t) one-tail	8.48527E-05	
t Critical one-tail	1.678660414	
P(T<=t) two-tail	0.000169705	
t Critical two-tail	2.012895599	

Table H. 33. The general evaluation of the significance and the impact values of the design parameters on source energy consumption per total square meter

Building Type	Analyses Type	Architectural Design Parameters											
		Plan type	Hall Location	**Basement**	Orientation	The Roof Occupancy	The Oriel	Window to Wall Ratio	**Wall to Floor Ratio**	**Window to Floor Ratio**	**Total Building Area**	**Wall to Volume Ratio**	Settlement Pattern
Two-story İzmir Houses with and without basement	T-test, ANOVA	Significant	Significant	Significant	Insignificant	Insignificant	Insignificant	Significant	Significant	Significant	Significant	Significant	Not analysed
	Correlation factor	0.46	0.66	0.52	-0.07	-0.05	-0.17	0.42	0.73	0.80	-0.84	0.61	
Two-story İzmir Houses with basement	T-test, ANOVA	Significant	Significant	Insignificant	Insignificant	Insignificant	Insignificant	Significant	Significant	Significant	Significant	Significant	Not analysed
	Correlation factor	0.55	0.81	0.04	-0.10	-0.28	-0.03	0.14	0.80	0.75	-0.72	0.82	
Single-story İzmir Houses with and without basement	T-test, ANOVA	Insignificant	Insignificant	Significant	Insignificant	Not analysed	Not analysed	Significant	Significant	Significant	Significant	Significant	Significant
	Correlation factor	0.11	0.14	0.85	-0.03			0.09	0.54	0.54	-0.61	0.22	-0.46
Single-story İzmir Houses with basement	T-test, ANOVA	Significant	Significant	Insignificant	Insignificant	Not analysed	Not analysed	Significant	Significant	Significant	Significant	Significant	Significant
	Correlation factor	0.27	0.39	0.25	-0.11			-0.57	0.79	0.51	-0.44	0.86	-0.52

Table H. 34. The general evaluation of the values of the design parameters on energy performance of the 19th Century İzmir Houses

Analyses Samples	The energy performance	The Significant Architectural Design Parameters on Energy Performance								
		Building plan type	Hall Location	Basement	Window to Wall Ratio	Wall to Floor Ratio	Window to Floor Ratio	Total Building Area m2	Wall to Volume Ratio	Settlement Pattern
Two-story İzmir Houses with and without basement	The best	Model 2	Side	Exist	0.12	0.61-0.68	0.06-0.09	328-339	0.22-0.25	Not analysed
	The worst	Model 4	Central	Not exist	0.14	1.19-1.20	0.16	207-208	0.33-0.34	Not analysed
Two-story İzmir Houses with basement	The best	Model 2	Side	Exist	0.12	0.61-0.68	0.06-0.09	328-339	0.22-0.25	Not analysed
	The worst	Model 4	Central	Exist	0.13	1.07-1.08	0.12-0.14	291-295	0.34	Not analysed
Single-story İzmir Houses with and without basement	The best	Model 1	Central	Exist	0.13	0.98-1.32	0.07-0.1	197	0.34-0.39	Semi-detached
	The worst	Model 3	Side	Not exist	0.11-0.12	2.3	0.27	55	0.67	Detached
Single-story İzmir Houses with basement	The best	Model 1	Central	Exist	0.13	0.98-1.32	0.12-0.13	197	0.34-0.39	Semi-detached
	The worst	Model 3	Side	Exist	0.07	2.51	0.18-0.23	92	0.71-0.87	Detached

VITA

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Language – Turkish (Native), English (Full professional proficiency)

PUBLICATIONS

Paper

Coşkun Öner, Özden, "İzmir Tarih Projesi Bağlamında Namazgah Hamamı Restorasyonu", Meltem:İzmir Akdeniz Akademisi Dergisi, 5 (2019): 80-85.

Selected Conference Proceedings

Ö. Coşkun Öner, Ç.D. Kaplan, H.G. Kutlu, İzmir Tarih Project, 19th ICOMOS General Assembly and Scientific Symposium (ICOMOS 2017), December 2017, New Delhi, India

Ö. Coşkun Öner, H.G. Kutlu, C. Bilginperk Mimari Restorasyon Projelerinin Uygulama Sürecindeki Zorlukları: Konak Kemeraltı'nda Tarihi Bir Yapı Örneği, 5th Symposium on Consolidation and Transfer of Historical Monuments to the Future (TMMOB 2015), October 2015, Erzurum, Turkey

H.G. Kutlu, **Ö. Coşkun Öner**, K. Öztürk, D. Dayangaç, Project of Protection, Development and Sustenance Of Agora And Its Surroundings, (WHO, 2013) WHO European Healthy Cities Networks Annual Business and Technical Conference, June 2013, İzmir, Turkey

H.G. Kutlu, **Ö. Coşkun Öner**, Ö. Başağaç Reuse and Restoration of a House in Buca Kasaplar Square, İzmir,Turkey, International Conference on Structural Analysis of Historical Constructions, SAHC 2012, October 2012 Wroclaw, Poland (ISSN 0860-2395H ISBN 978-83-7125-216-7)