THE IMPACT OF ARCHITECTURAL DESIGN CRITERIA ON ENERGY PERFORMANCE OF RESIDENTIAL BUILDINGS: A CASE STUDY IN İZMİR

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ABSTRACT

THE IMPACT OF ARCHITECTURAL DESIGN CRITERIA ON ENERGY PERFORMANCE OF RESIDENTIAL BUILDINGS: A CASE STUDY IN İZMİR

The impact of architectural configuration and design norms on energy performance of buildings has been a critical issue. Even, it becomes noteworthy for residential buildings of good quality. New legislation in Turkey which was prepared to comply for the latest European Energy Performance of Buildings Directive 2010/31/EC requires information about the evaluation of energy performance of existing buildings. So, this study aimed to determine energy performance of residential buildings in Izmir, to analyze significant relationships between their performance and architectural configuration through statistical analyses (analysis of variance (ANOVA), regression, t-Test, scatter charts). Utilizing production drawings, certain area-based ratios and building dimensions were determined as architectural configuration indicators. Most prevailing architectural variables, such as, zoning status, external surface area and A/V ratios, and others, namely, orientation, floor counts in a building, aspect ratio, heating system were analyzed. Energy performance of case buildings were determined by using The Standard Assessment Method for Energy Performance of Dwellings (KEP-SDM) which referred to Turkish standard TS 825, and European standard EB ISO 13790. Majority of the investigated buildings were in Energy Class B and C, in CO_2 Class G; however, their energy consumption values were two times higher than the ones in European countries. Findings present such a clue that interactions between variables and their total effect on the energy performance and CO_2 emissions should be taken into consideration. They would also provide feedback information on the residential building stock in İzmir, selected as a representative city in Turkey.

ÖZET

MİMARİ TASARIM KRİTERLERİNİN KONUTLARIN ENERJİ PERFORMANSINA ETKİSİ: İZMİR'DE BİR ALAN ÇALIŞMASI

Mimari konfigürasyon ve tasarım normlarının binaların enerji performansına etkisi ciddi bir konu olarak önem taşımaktadır. Kaliteli konut tasarımında da dikkat edilmesi gerekir. Avrupa Birliği'nin en son çıkan Binalarda Enerji Performansı Yönergesi 2010/31/EC'e uymak için hazırlanan Türkiye'nin en yeni yönetmeliği, mevcut binaların enerji performansının değerlendirilmesi hakkında bilgi gerektirmektedir. Böylece, bu çalışma İzmir' deki konut binalarının enerji performanslarını belirlemeyi, istatistiksel analizlerle (tek yönlü varyans analizi (ANOVA), regresyon, t-Test ve dağılım grafikleri) enerji performansları ile tasarım verimlilik göstergeleri arasındaki ilişkiyi incelemeyi amaçlamıştır. Uygulama projeleri elde edilerek belirli alan bazlı oranlar ve bina ölçüleri mimari tasarım göstergeleri olarak belirlenmiştir. İmar durumu, dış yüzey alanı, alan/hacim oranı gibi en önemli mimari değişkenler ile yönlendirme, bir binadaki kat sayısı, en/boy oranı, ısıtma sistemi incelenmiştir. Örnek binaların enerji performansları, Türk standardı olan TS825 ile Avrupa standardı olan EB ISO 13790'ı temel alarak hazırlanan Konutlarda Enerji Performansı Standart Değerlendirme Metodu (KEP-SDM) kullanılarak belirlenmiştir. İncelenen binaların büyük çoğunluğu B ve C Enerji sınıfında ve G CO_2 sınıfında yer almaktadır. Buna rağmen ortalama enerji tüketimi değerleri Avrupa ülkelerinde olanlara göre iki kat daha fazladır. Sonuçlar bize öylesine bir ipucu sunmaktadır ki değişkenler arasındaki etkileşim ile bunların binaların enerji performansı ve CO_2 salımlarına olan etkilerinin düşünülmesi gereklidir. Ayrıca, elde edilen bulgular, ülkemizde örnek seçilen bir şehir olan İzmir'deki konut bina stoğu hakkında da geribildirim sağlamaktadır.

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CHAPTER 1

INTRODUCTION

In this chapter are presented first, the initial idea and framework of the study. Second, arguments are explained in relation to previous studies who worked on similar subjects. Then, objectives are mentioned as primary and secondary objectives. The procedure of the study is explained in the next part, and finally the contents of the study were briefly explained under disposition.

1.1. Argument

The construction of residential building in Turkey is rife with proposals that lay claim in improving efficiency due to sheltering needs of increasing population and providing a qualified habitat (Santamouris, 2005; Smeds and Wall, 2007; Borden et al., 1991). In addition, construction has become an expensive sector relatively among others. Due to the fuel crisis in 1970s, energy efficiency has been a critical issue to reduce energy cost and to ensure sustainability of energy throughout the world, and in Turkey as well. As the residential heating is the main source for energy and resource consumption in Turkey, residential buildings have gained utmost concern nowadays to reduce energy and resource consumption. Utilizing dwellings offering comfortable interior spaces, it would also be possible to reduce harmful gases released into the environment (Keskin and Ünlü, 2010; Miguez et al., 2006). According to construction permits given in 2000-2008, almost 80% of buildings are residential, and 80% of the total energy consumption of buildings are for the heating purpose. That's why the energy efficiency of the construction sector is based on insulation applications to avoid heat loss (EPBD, 2010). According to the breakdown of energy use in buildings in Turkey, almost 80% of energy consumption derived from conventional fuel use, as seen in Figure 1.1; thus 75% of energy is used for heating, cooling and hot water heating purposes (Yakar, 2010; PSDD, 2011).

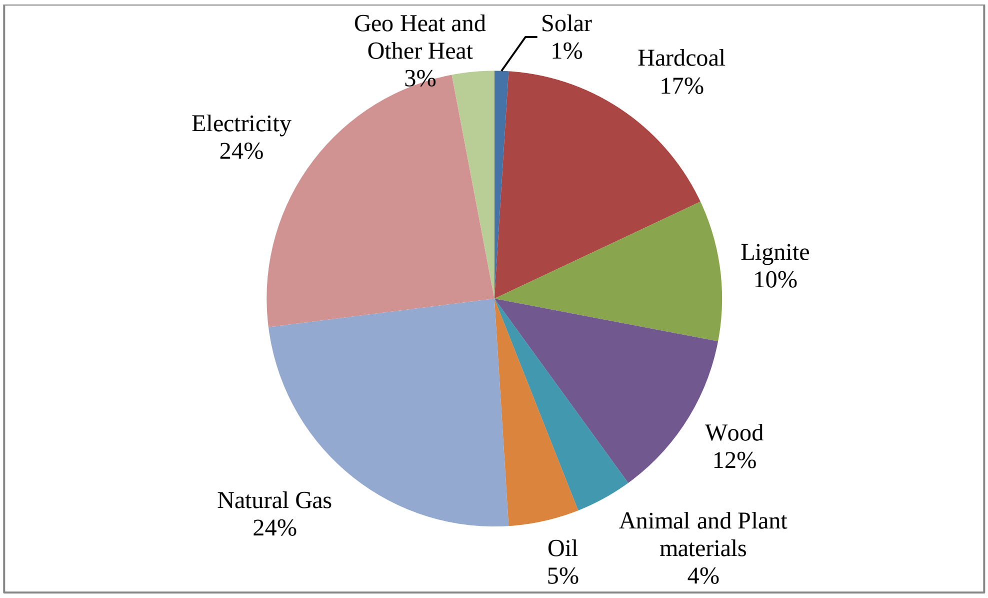


Figure 1.1. The breakdown of energy use in buildings in Turkey
(Source: PSDD,2011)

Regarding energy statistics, the rate of heating energy consumption caused by residential buildings is almost 30% of the total energy consumption in Turkey. Considering the heating energy consumption of other functional types of buildings, and the insufficient fuels used in heating systems, the contribution of this sector to the whole air pollution becomes enormous. According to those statistics, the real heating energy consumption in residential buildings ranges between 100-200 kWh/m^2 (the average is obtained as 175kWh/m^2) in Turkey. However, in European countries, this value is 100 kWh/m^2, including energy use of heating, cooling and ventilation. Recently, the existing studies in those countries are based on the reducing the real energy consumption of residential buildings below 50 kWh/m^2 (Dilmaç and Tırıs, 1995; Altas and Celebi, 1994). New buildings constructed according to the recent regulations in Turkey consume energy two times higher than the ones built in EU countries. When the energy consumption of a model building was compared according to insulation regulations in different countries, the results were 23 kWh/m^2 in Denmark, 34 kWh/m^2 in Netherlands, 35 kWh/m^2 in United Kingdom (Dilmaç and Tırıs, 1995). These values were extensively lower than the proposed values of Turkish standards. Considering these above issues, it has been worth to study energy consumption of residential buildings in Turkey.

From the beginning of the 1990s, the Member States in Europe dealt with the legal regulations about energy consumption in order to reduce carbon dioxide emissions, according to Kyoto Protocol. Turkey is now responsible to provide regulations to comply for the latest European Energy Performance of Buildings Directive 2010/31/EC (EPBD, 2010). In particular, the Thermal insulation requirements for buildings-TS825 (TS 825 “Binalarda Isı Yalıtımı Kuralları” Standardı) and Heat Insulation Regulation (Isı Yalıtım Yönetmeliği) (2000) were legally adopted in 2000: the latter is the complementary regulation of the former which offers the calculation method for the energy demand for heating in buildings (Turkish Standard Institution (Türk Standartları Enstitüsü), 1999; Ministry of Public Works (Bayındırlık Bakanlığı), 2008). The main purpose of TS 825 is to limit building’s energy demand according to exposed area to volume (A/V) ratio. TS 825 uses solar radiation and outdoor air temperature values which are tabulated according to climatic regions specifically determined for Turkey using degree-day method (Turkish Standard Institution (Türk Standartları Enstitüsü), 1999). Heat Insulation Regulation sets rules for all buildings to reduce heat loss, to provide energy saving and to determine application guideline (Ministry of Public Works (Bayındırlık Bakanlığı), 2008). Turkey complied with the rules by Directive 2010/31/EC, through Energy Efficiency Law-Enerji Verimliliği Yasası (2007) and Building Energy Performance Regulation-Binalarda Enerji Performansı Yönetmeliği (2008). As regards these regulations, following actions were proposed: the evaluation for the energy consumption of buildings, the classification of buildings and determination of minimum energy performance requirements of existing buildings for their renovation (Ministry of Public Works (Bayındırlık Bakanlığı), 2007; Ministry of Public Works (Bayındırlık Bakanlığı), 2008). “Standard Assessment Method for Energy Performance of Buildings” (Binalarda Enerji Performansı Hesaplama Yöntemi) has been developed by The Ministry of Public Works (Bayındırlık Bakanlığı) and was introduced in January 2011. It was legally adopted and implemented in practice. It drafted energy certificate and compared the energy performance of a building with ascertained energy limits. It included specific limitations and minimum requirements of energy efficiency dealing with the design and construction of various building types and according to varying floor areas (industrial, residential etc.). In addition, this method included climatic information, geographical location, building geometry, building envelope, heating, cooling, domestic hot water production, lighting energy consumptions and CO_2 emissions. Legislation also requires information about the evaluation of energy performance of existing buildings which will be renovated, not only new buildings. Thus, this study has become a preparation for this issue.

It is known that architectural configuration of buildings and design norms have direct impact on energy performance of buildings. Energy performance is an indicator for the energy cost of the building and for the visual and thermal comfort conditions of users, as well. On the other hand, to design architectural considerations properly lead to efficiently-constructed buildings and efficiently-designed interior spaces. By this way, it provides construction and maintenance costs at an optimum level. In view of this ongoing knowledge, this study aims to determine the significant relation between architectural configuration and energy performance of residential buildings in İzmir, by utilizing architectural drawings. It is considered that this would provide architects and engineers opportunity to encounter such problems in the design stage and give chance to propose precautions before the construction process and before the buildings are in use.

Utilizing various methodologies, related studies were conducted to determine energy rating of existing buildings. Theodoridou et al. (2011), studied energy consumption of residential building stock of two Greek cities. Utilizing door-to-door interviews, they obtained detailed information about these buildings to improve their energy performance and to emphasize problems related to the legal issues. They classified existing dwellings and applied statistical analysis between the heating energy consumption and the variables such as the construction year, the buildings' typology, the glazing type and the income. In another study, the classification of educational buildings was presented according to their energy performance and energy rating scheme based on fuzzy clustering techniques (Santamouris, 2007). EPIQR (Energy Performance and Indoor Environmental Quality Retrofit) is another methodology and software which was announced in the framework of a European project to assess buildings’ energy efficiency (Flourentzou et al., 2004; Balaras, 2000). In another study, the energy performance assessment for existing dwellings (EPA-ED) was introduced in line with the European Directive on the energy performance of buildings (Poel et al., 2007). A kind of energy classification was proposed by utilizing the standard measurements about the structure of the building shell (insulation values, window efficiency), lighting, ventilation, and heating-cooling systems (Santamouris, 2005; Alvarez, 2005). In addition, another study analyzed various rating systems in EU countries, by proposals for the improvement of the scores obtained (Miguez, 2006) and governments' standard assessment procedures for energy rating of dwellings were published such as SAP2005 in UK (BRE of UK, 2008). Other studies offered methods including meteorological and sociological influences on thermal load and energy estimations (Pedersen 2007); or impact of occupant behavior on energy consumption in dwellings (Santin et al., 2009).

In addition, several methods have been proposed and used to estimate effects of architectural design factors on energy demand. They involved such variables as thermo-physical characteristics of the exterior walls, building orientation and geometry, building location. Simulation programs have been commonly used as in the research of Floridesa et al.(2002). This study showed significant impact of building form (square versus elongated shape), south orientation, wall and roof material properties and window types on heating energy consumption. Similar approach by Dili et al.(2010) showed that building form and plan schemes influence the energy performance and users' comfort. A study, in the field of architecture, dealt with building form, window area on south façade and their impact on energy performance of residential buildings to obtain optimum values for each factor by using simulation program. The results showed that the case which involves the increase in the insulation thickness and south window area together improves the energy performance of the building better than the case which involves the increase in the insulation thickness only (İnanıcı and Demirbilek, 2010). On the other hand, another study focused on reducing south window areas while increasing north window dimensions. Results pointed out the very slight effect of window dimension on heating energy demand but showed the distinct impact on cooling energy demand. Moreover, different window types and orientations were sampled (Perssons et al., 2006; Wall, 2006). A similar research depicted that heating energy demand could be an estimated value by knowing the right orientation, mass design and insulation (Al-Sallal, 1998). To attain optimum energy performance of residential buildings in Gulf region, building shell, plan schemes, orientation, window area and building groups were analyzed by using simulation program, and significant values were obtained (Numan, 1999). Yılmaz (2007) observed that the heating capacity of the building shell performs better than insulation materials in hot regions. Several studies also analyzed building shell and other building materials' direct impact on energy performance and energy efficiency (Yılmaz, 2007; Oral et al., 2004; Ünver et al., 2004; Oral and Yılmaz, 2002).

Again, Turkey, preparing legislations for energy performance, is responsible to ensure compliance of 2010/31/EC and these legislations offer to conduct several studies for new and existing buildings in a 10-year-period. In view of these resent research and ongoing knowledge, this study was constructed for residential buildings in İzmir, which is the third most populated city of Turkey to analyze their energy performance and architectural configuration. The aim of this study is to determine the energy performance of residential buildings in İzmir; and to define relations between their energy performance and their architectural configuration by statistical analyses. Utilizing these analyses, it would be possible to propose certain boundary values for architectural indicators and this would guide architects to use such values in the design process of dwellings. Energy performance of case buildings were determined by using a calculation method named as The Standard Assessment Method for Energy Performance of Dwellings (KEP-SDM). It is thought that this study conducted for İzmir, would be a representative one which might be adapted for other cities.

This thesis has been prepared within the TÜBİTAK project titled "Determination of significant relations between energy performance of multi-floor residential buildings and their design efficiency indicators"-"Çok katlı konut yapılarının enerji performansları ile tasarım verimlilik göstergeleri arasındaki ilişkinin belirlenmesi" between April 2010 and April 2012. (Project No: 109M450). This Project was the first one including both the evaluation of energy performance of residential buildings and the impact of design efficiency indicators of these buildings on their energy performance. Another peculiar issue of this study is that the method has covered the subject in a wide context and will help to adapt the findings to the design and construction of buildings. On the other hand, it aims to be one of the special studies conducted to execute the European Union Requirement for conformity and Kyoto Protocol in the process of decreasing energy consumption and gases emissions. It also aims to be premise for similar studies. Legislation requires information about the evaluation of energy performance of existing buildings which will be renovated and new buildings. This project is a preparation for this issue. This study conducted for İzmir, will be a representative one which may be adapted for other cities and will be resulted with parametric rating of buildings by statistical methods.

1.2. Objectives

Objectives of this study were formulated under the purpose of establishing the relationships between energy performance of residential buildings and architectural configuration indicators. Furthermore, another aim of the study is to grade residential buildings according to design and energy efficiencies. There were two main objectives defined; one being the primary and the other being the secondary.

The primary objectives of the study were:

a. to obtain area-based data by investigating multi-story residential building projects(architectural and mechanical drawings);
b. to determine architectural configuration indicators by using these data;
c. to calculate energy and CO_2 performances of investigated buildings;
d. to investigate the relation between architectural configuration indicators of and energy performance;
e. to investigate the impact of architectural design criteria on energy performance; and
f. to indicate effects of design efficiency classes (by defining levels of indicators) on energy performance classes.

The secondary objectives of the study were:

a. to reduce energy consumption and green gas emissions in order to comply with Kyoto protocol and EU;
b. to be a pioneer to similar studies;
c. to make some recommendations about energy efficient design and construction and to guide new buildings which will be constructed; and
d. to propose certain boundary values for architectural indicators and this would guide architects to use such values in the design process of dwellings and give them chance to propose precautions before the construction process and before the buildings are in use.

1.3. Procedure

The aim of this study is to determine the energy performance of residential buildings in İzmir; and to define relations between their energy performance and their architectural configuration by statistical analyses (Figure 1.2). Prior to doing so the study was carried out seven phases:

In the first, a general survey about energy performance of residential buildings was conducted. Architectural parameters' impact on energy performance certificate systems and legislation in Turkey were investigated and presented.

In the second, a study about energy and CO_2 performances of residential buildings in İzmir was planned to define relations between their energy performance and their architectural configuration by statistical analyses.

In the third, data provided by Turkish Statistical Institute were analyzed. Data included the number of residential buildings which are constructed between 2000-2008 in municipalities of İzmir in addition to their heating systems, fuel type, construction material and technique, number of dwelling units, floor counts and floor area.

In the fourth, considering properties and sufficient numbers of buildings for statistical studies, total of 148 buildings in Konak, Karabağlar and Balçova were selected for the study according to several selection criteria determined. Their construction permits, architectural, mechanical and electrical drawings were obtained and investigated to determine their architectural characteristics.

In the fifth, architectural configuration indicators were, then, offered to conduct the assessment for the occurrence of significant relations between energy performances and architectural configuration of buildings.

In the sixth, energy performance of case buildings were determined by using a calculation method named as The Standard Assessment Method for Energy Performance of Dwellings (KEP-SDM).

In the seventh, the relations between energy performance of existing residential buildings in Izmir and their architectural configuration indicators were analyzed by ANOVA, t-Test and regression.

In the eight, levels of architectural configuration indicators were defined, and their association between the energy consumption and CO_2 emissions were stated by the help of defining boundary values.

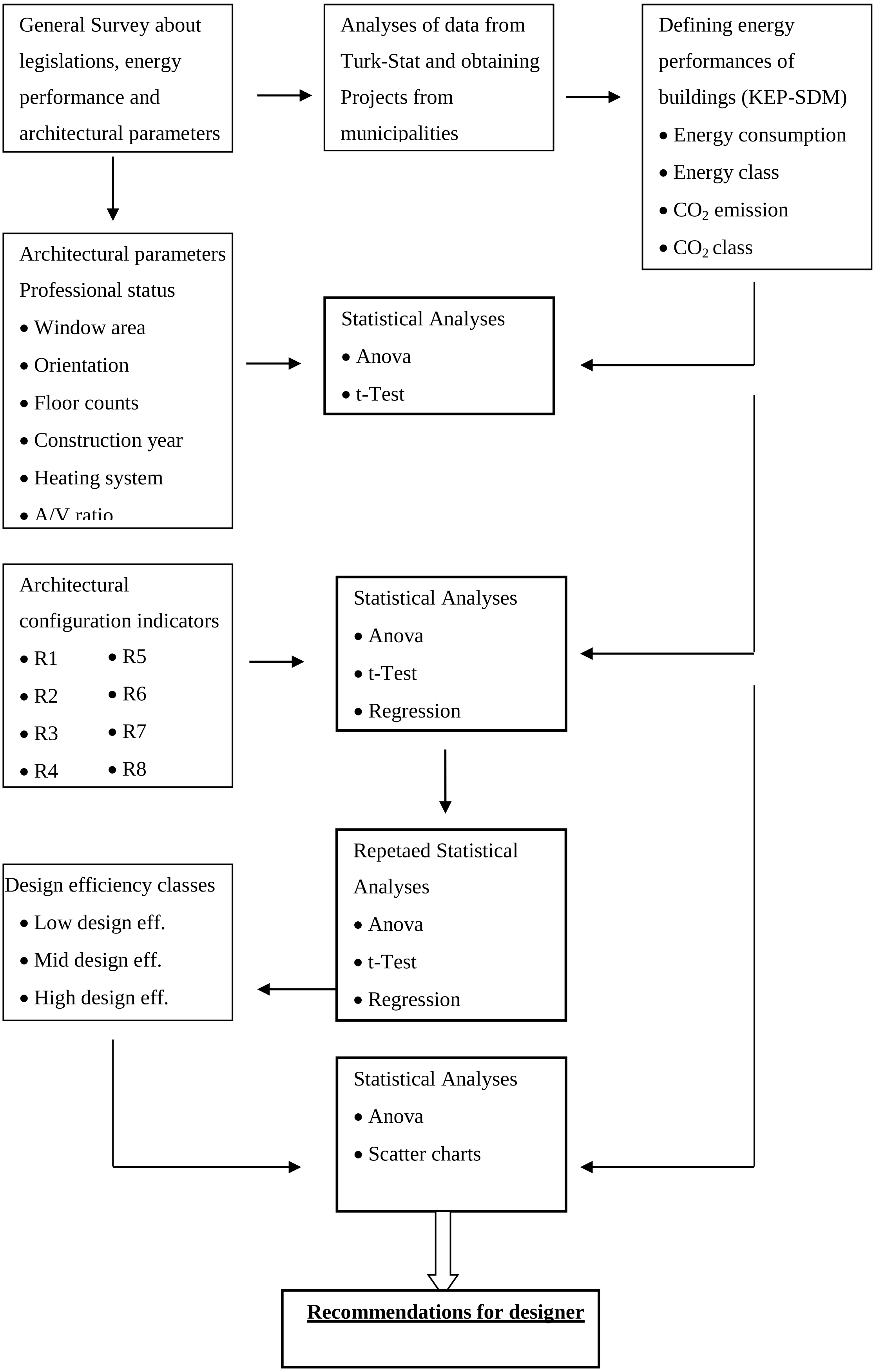


Figure 1.2. Structure of the thesis

1.4. Disposition

This report is composed of six chapters, of which the first one is the 'Introduction'. In this chapter importance of energy performance of residential buildings is covered first and then legislation about energy performance in Turkey is explained briefly. Studies about energy rating of existing buildings, and impact of architectural configurations and design norms on energy performance of buildings were presented.

Finally the aim of this study which is to determine the energy performance of residential buildings in İzmir; and to define relations between their energy performance and their architectural configuration by statistical analyses was explained.

In the second chapter, which is the 'Literature Survey', general aspects of energy efficiency are identified at first hand. Then, design criteria for energy efficient residential buildings are clarified. According to their usage of energy efficient design criteria some selected residential buildings are presented at the following of this part. Following these are given different certificate systems and their evaluation methods. In the context of energy efficiency, applicability of LEED and BREEAM in Turkey is discussed considering their criteria and evaluation methods. Finally there is an argument about regulations and laws in Turkey and their effects on residential building considering design criteria of energy efficiency.

In the third chapter which is named 'Material and Method', data compilation and analyses are explained. Firstly, determination and properties of case buildings, architectural configuration indicators, and data compilation obtained are clarified. Then the methodology of the data compilation and field study are defined. At the end of this chapter, the descriptions of KEP-SDM (KEP-IYTE-ESS software) and statistical analyses are presented.

In the fourth chapter, the results of the study are displayed. The results of analyzes of the energy consumption, CO_2 emissions, energy and CO_2 classes of the buildings by KEP-IYTE-ESS, according to the calculation method, KEP-SDM are given. Then, results of statistical analyses determined significant relationships between energy performance of the buildings and architectural configuration variables are mentioned.

The fifth chapter, namely the ‘Discussion’, includes the concluding remarks of results of analyses and threshold values of architectural configuration indicators which may indicate levels of energy performance are proposed.

The sixth chapter, namely the ‘Conclusion’, presents the concluding remarks of survey and recommendations about residential buildings in İzmir.

CHAPTER 2

LITERATURE SURVEY

In this chapter, energy efficiency is mentioned briefly and design criteria of energy efficiency are explained generally. Selected examples express design criteria for energy efficient residential buildings. Following sections include different certificate systems and their evaluation methods. In the context of energy efficiency, applicability of LEED and BREEAM in Turkey is discussed considering their criteria and evaluation methods. This chapter also includes an argument about regulations and laws in Turkey and their effects on residential building considering design criteria of energy efficiency.

2.1. Design Criteria of Energy Efficient Residential Buildings

Design criteria of energy efficient residential buildings intend to effect nature, human and economy usefully. These criteria include designing healthy places by providing comfort conditions and reducing harmful effect of greenhouse gas emissions (Esin and Yüksek, 2009).

This section involves these criteria mentioned above; these are location, form, size, type and function, orientation, distances and heights, positioning of building, properties of building envelope and materials, windows and shades plan scheme.

2.1.1. Building Location

The location of a building affects its energy performance in several ways. For a example, climatic data of the site such as solar radiation, air flow, temperature and humidity determine the indoor environmental quality (Yılmaz, 2005). Solar radiation is the main parameter in the heating and daylighting of the building. In hot regions, providing sun control could decrease cooling loads. Although wind increases heat loss in cold climatic region, in hot areas it has cooling effect by evaporation. Relative humidity is another significant parameter in consequence of its impact on temperature substantially. Intended relative humidity is between 40-60% despite it changes according to temperature (Soysal, 2008). Besides these, natural vegetation is necessary for the control of climate, environmental and noise pollution, and for users who needs to rest psychologically, as well. Addition to knowledge of climatic and natural vegetation data and designing according to these information, natural construction materials located in the region and labors ‘skill in accordance with the materials are essential factors to reduce energy consumption (Soysal, 2008; Esin and Yüksek, 2009; Borden et al., 1991). Even the type of soil has impact on the thermal performance of the building. For example, dry sandy soil can be used for ventilation as pre-heating or cooling because it quickly warms and then quickly cools. However, wet compacted soil which heats up slowly has heat loses due to evaporation. Therefore, ground floor on this type of soil requires insulation. Soil may be used not only as an insulation material but also as a source of heat pump (Borden et al., 1991).

2.1.2. Building Form

Form of the building is another variable which affects heat loss and gain in a building. Form is a geometrical shape that comprises the building’s horizontal area, length, volume, slope of roof, façade and openings. Building surface area to building volume ratio (A/V) must be considered in order to minimize heat loss in terms of energy efficiency. Sphere is the form that has least heat losses. Then the cylinder, cube and rectangular prism come after respectively (Soysal, 2008). Florides at al. (2002) examine the relation between building form and thermal loads. In this study, a square-formed residential building is compared with a rectangular residential building. It is observed that the annual heating load increases about 8.2% - 26.7% in the rectangular residential building. Complex forms of façades cause unnecessary heat losses; for that reason, compact form is preferred for cold climates. North façade of the building placed along the east-west direction displays the minimum heat loss but the south façade benefit from high amounts of heat gains from solar radiation (Borden et al., 1991). Concerning heat loss, the length of the building is a considerable parameter, as the plan scheme and façade are. Soysal (2008) states that ideal ratio of length to depth is ¼.

2.1.3. The Size, Type and Function of a Building

The size, type and function of a building are the key factors which represent the relation between human requirements, buildings, and their energy consumptions. Size and typology of the building must be determined according to several human needs. Accordingly lighting, heating system and construction cost of building must be taken into account. The construction process of small buildings requires less energy and cost. However, if inappropriate materials and inaccurate ratio of surface area/volume are used in such buildings, they consume high amount of energy as large buildings do (Smeds and Wall, 2007). On the other hand, close grouping buildings minimize heat losses. However, this type may prevent solar radiations for visual comfort and natural ventilation for passive air-conditioning. For this reason, such issues including the comfort, systems and amount of energy must be taken into consideration together when designing various types and sizes of buildings (Borden et al., 1991).

2.1.4. Building Orientation

The orientation of a building is important not only to satisfy such requirements as the adaptation of local topographical conditions, privacy, noise control and vista but also solar gain, natural light and natural ventilation. In this way, by utilizing advantages of natural conditions, energy consumption may be reduced and interior comfort conditions may be improved. Main façade of the building should face south, and large windows should be located on this façade to benefit from solar light and heat extensively (Smeds and Wall, 2007). Sunlight may be controlled with shading devices. Especially in cold climatic regions, insulated wall and small, multilayered windows are crucial to avoid heat losses from the northern façade of the building. Main façade should not face west or east due to the difficulty of sun control. Sun shading devices are necessary for the openings located in these directions. Wind increases the heat loss from the building surfaces so the prevailing wind direction should be considered in the design process. In summer, as the wind provides natural ventilation and cooling; so energy consumption caused by the cooling system decreases (Soysal, 2008; Esin and Yüksek, 2009; Borden et al., 1991).

2.1.5. Building Heights and Distances between Buildings

Solar radiation and wind should be considered to decide on the building height and distances between buildings for both development plan and construction of closed grouping buildings. Distances between buildings are related to the prevailing wind and its cooling effect which are specific to that region. The distance must be equal or longer than adjacent building's height in cold climate regions (Soysal, 2008). Numan et al. (1999) state that energy consumption in accordance with the cooling load may be decreased by reducing the amount of solar radiation which is dependent on the adjacent buildings' height. Land slope, orientation and density of the settlement are also significant parameters.

2.1.6. Buildings' Position

While preparing the development plan, it should be considered that taller buildings do not block small buildings' solar radiation to get maximum benefit from the sun. For regions exposed to the wind, attached/intermediate zoning status is desirable to minimize heat losses. In hot regions, buildings may settle in such a staggered position that ventilation effect of wind and protection from strong wind would be satisfied successfully. The amount of heat loss varies according to the different zoning status of housing (Soysal, 2008).

2.1.7. Properties of Building Envelope and Materials

Raw material which is defined as energy efficient and durable is provided from the nature. In addition, an energy efficient material helps professionals and building users to use energy more effectively. Raw material should be provided locally to save energy. Furthermore energy efficient materials do not cause environmental problems, as they produce less amount of waste. They should also be rapidly renewable. Labor and technology of the material should be appropriate for the construction process (Borden et al., 1991). Renewable materials like wood, bamboo, sunflower stalk may be supplied locally and processed with less energy and workmanship. Durable, removable and reuse materials require less maintenance. Besides labor and energy saving, these materials help to conserve natural resources. Esin and Yüksek (2009) express that building envelope separates the interior and the exterior environment. It includes horizontal, vertical and sloped components such as walls, windows, doors, and floors etc. The purpose of selecting energy efficient materials which are mentioned above is to improve the quality of indoor environment and minimize energy consumed by the cooling, heating and lighting systems. Most desirable visual and thermal comfort conditions could be obtained by considering the heat transfer characteristics of the construction material, the level of air tightness and transparency, preservation of building, location of windows, finishing materials, colors of glasses and parameters of reflection coefficients (Smeds and Wall, 2007; Soysal, 2008; Borden et al., 1991).

2.1.8. Windows and Shades

Size, orientation, transparency and frame transparency of glazed surfaces may improve the energy efficiency of buildings in terms of light and heat or vice versa. While sizing windows in hot regions, principles of the passive heating and cooling systems should be taken into consideration. Regarding thermal mass and insulation thickness together, orientation may also solve the heating problem (Al-Sallal, 1998). Persson et al.(2006) points out that the size of windows is not very effective for the heating purpose for winter conditions but it is more related to the cooling demand in summer. The size of windows facing to south should be determined according to the optimum sizes to prevent overheating and to minimize cooling loads. Glass type is as important as the area of the glass surface and its orientation. Glasses which are used to control light and heat may be heat absorbing-tinted glass, reflective glass, low-e glass, spectrally selective glass, polyester film coating, heat mirror glass, smart-switchable glass and inert gas inter gap of glasses (Smeds and Wall, 2007; Soysal, 2008).

The level of light and temperature which is required for the interior space may be provided by using solar shades with glass. Seasonal and orbital sun angles are determinants for the reflection of direct light coming from the sun. Flexible and movable sun shading devices display a high- sun-control performance. “Different solar shades, shutters, blinds, insulated shutters, awnings, jalousie and curtains as well as deep balconies, horizontal canopies, vertical sun breakers- wing walls, composite elements which are the combination of vertical and horizontal components are used for the solar control" (Soysal, 2008).

2.1.9. Plan Scheme of the Building

Distances between rooms, organization of heated and unheated volumes, (Borden et al., 1991) gathering similar volumes according to comfort conditions are essential issues for a plan scheme that is designed in consideration of energy efficiency (Esin and Yüksek, 2009). Also, Wan and Yik (2003) proposed that the sizes of spaces should be designed properly according to their usage type. For example, unheated volumes, services and circulation areas may be placed close to the north side; so, this scheme creates a buffer zone for heated spaces located in the south. Places facing to south may be protected by minimizing heat losses from north. To control heat loss from stairs and corridors, doors should be closed. In hot regions, the energy consumption of cooling loads may be reduced by gaining advantage from cross ventilation. If wind blows lower than 90 degrees to the windows facing to each other, it provides better ventilation. On the other hand, wind that blows 90 degrees to the openings in the adjacent walls provides required ventilation. In the plan scheme, considering orientation heated volumes may be located to the south. If the rooms used during the morning period are located to the east, this scheme benefits from the advantages of extensive energy from the sun (Borden et al., 1991)

2.2. Selected Studies about Design Criteria and Energy Efficient Design

In the literature, there are many studies about the effect of design criteria based on different variables. For example, the effect of architectural configuration parameters earthquake on the damage level of residential buildings is examined. By developing a similar method, some indicators are investigated, such as; placement of vertical structure element and building geometry, ratio of net usable building area to floor area, ratio of external surface area to total floor area, ratio of structural system's horizontal section area to total building area, ratio of the external borders, and ratio of height to depth (Kazanasmaz, 2009).

Similarly, it is known that architectural factors affect on heating and air conditioning loads. It is clear in literature that architectural configuration of buildings and design norms have direct impact on energy performance of buildings. Several studies have been conducted about thermo physical properties of building envelope (heat transfer coefficient of external wall, transparency ratio), orientation of volumes and buildings, building form, ratio of area to volume, distances between buildings, orientation and slope of site etc. İnanıcı and Demirbilek (2000) investigate the optimum values of south window size and building shape factor(ratio of width to length in plan area) according to thermal performance of residential building. It is obtained some results for different five cities by simulating. In a case analyzed in Ankara, increasing insulation thickness and south window size give out better results than only increasing 50% of insulation thickness. On the other hand, instead of increasing 60% of window size facing to South, insulation thickness may increase from 1.5 cm to 2.1 to get good thermal performance (İnanıcı and Demirbilek, 2000).

Floridesa et al. (2002) acknowledge that building form affects heating loads. If square residential building compares with a rectangular residential building, it is observed that the rise of annual heating load varies between 8.2 % and 26.7%. The most advantageous orientation is the longest façade facing to the South. Furthermore, roof and wall are examined for thermal mass performance. Eaves and different glass types are studied as shading devices by using simulation program (Floridesa et al., 2002). The basic design criteria for residential building with high energy performance are area-volume ratio which expresses the building geometry, window areas, and heating insulation that determine building envelope (Smeds and Wall, 2007). Manioğlu and Yılmaz (2008) compare contemporary residential building with modern residential building which has a rectangular plan. Moreover, properties of building envelope are investigated.

“Active heating of residential buildings consume the major portion of energy and source” (Berköz and Kocaaslan, 1994). Due to the fact that, residential building design which reduces energy and source consumption is getting importance. Especially, architectural factors must be considered to design passive heating and air conditioning systems for buildings. Structural elements and volumes should be examined with an integrated approach. Berköz and Kocaaslan(1994) inspected some design factors for Istanbul, such as; form factor, roof type and slope, orientation of walls, thermo physical and optical properties of external wall. The amount of heat loss from the buildig envelope is compared by testing different conditions for each factor. İmamoğlu (1994) states that thermal comfort is the most essential issue for good quality house. Interior conditions of house should be balanced with external climatic conditions. For instance, comfort conditions may be provided by less energy consumption in winter, and overheating must be prevented in summer (İmamoğlu, 2003). In another study, volumes with different form factors are compared. Heat transfer coefficient is 1.39 kcal/m^2h^0C, and transparency ratio is 0.18 for form factor 2/1, and heat transfer coefficient is 0.75 kcal/m^2h^0C and transparency ratio is 0.44 for form factor 1/1. Heating periods of these volumes differentiate from each other. Volume which has form factor 1/1 is preferable with short heating period (Berköz and Kocaaslan, 1994).

Different researches emphasize the impact of building envelope and structural elements to comfort and energy performance of buildings (Oral et al., 2004; Ünver et al., 2004; Yılmaz, 2007; Smeds and Wall, 2007; Oral and Yılmaz, 2002). TS 825 is released in order to reduce heating loss, energy saving and determine implementation principles (Bayındırlık ve İskan Bakanlığı, 2000). However, TS 825 is a regulation based on only heating energy saving and temperature-day relation. For example, in hot-dry climatic regions, building envelope may use heat storage instead of wall insulation (Yılmaz, 2007).

Al-Sallal (1998) mentions that the optimum window size should be considered to achieve the properly-designed passive cooling, heating and lighting systems. Although south-facing windows may provide energy saving, in heating systems, they have negative impact on cooling load in summer. However, the effectiveness of passive cooling systems may be reduced when the SSF (solar saving fraction) drops out from 65% to 60%. In hot climate regions, when designers resize windows, they should first consider the passive cooling principles before regarding the passive heating. Well-designed thermal mass, insulation with the appropriate orientation can solve the heating problem (Al-Sallal, 1998). There is another study about resizing north and south facing windows. They design south windows smaller than the others while enlarging the ones facing north. In low energy houses, the impact of window sizes on the energy consumption and the minimum heating load for 23-26 ^0C are investigated. Different orientation and windows types are tested by a dynamic building simulation tool, DEROB-LTH. (Persson et al., 2006). The authors mention that a window size does not have any obvious and significant effects on the heating load but they have strong relation with the passive cooling load. South facing window sizes should be optimum to prevent overheating in summer and reduce cooling loads (Persson, et. al., 2006; Smeds and Wall, 2007).

In Numan et al. (1999) study's, they present the simulation of a residential building located in Gulf region and observe its energy performance. Gulf region is a hot and dry region. It is essential to ventilate and cool the building. Electrical energy consumption increases constantly because of that climate is not taken into consideration in this new and modern building. The evaluation of the energy performance of this building is based on geometrical parameters such as; building envelope, plan ratios, orientation, glass ratio, and grouping building blocks etc. This building is an ordinary detached house for a medium-income-family. They examine different plan sizes oriented different directions and different glass ratio. Most appropriate orientation for Gulf region is ±15° to the north or south direction. This orientation can help the city planning and housing design. The study supplies knowledge about the ratio of width-to-length which should be less than 2:1. It is recommended that openings on the two façades are more useful than covering all façades with glasses. These two façades should orientate to southeast and northwest. According to results of the study, protection from the sun light by surrounding buildings is necessary to reduce cooling loads (Numan et al., 1999).

It is clear in the literature that design parameters have direct impact on residential building energy performance. Wan and Yik (2004) evaluate the effect of design parameters (areas of flats, ratio of spaces, wall-window ratio, window types and sunshades) to high-rise residential buildings. Energy data includes electrical, heating – cooling, ventilation, hot water energy consumption, and also type and number of tools. This study is continuation of a research about high-rise residential building in Hong-Kong. In the previous project, glass ratio, exterior wall colors, and thickness of walls and glass are determined by photos. In this study, two research methods are applied. First section is composed of bills and survey of building characteristics. Second section consists of architectural drawings of 15 residential building blocks which are constructed between 1970 and 2000. The results of evaluation show that 90% of the buildings are between A-C classes according to Hong-Kong Property and their floor areas vary from 40 m^2 to 69,9 m^2. The ratio of the living area to the dining area is 0.44

and the ratio of bedroom to total floor area is 0.15 on average. The number of floors of the 36% of these buildings are higher than 32 and the average of floor count is 25. A total of 86 % of the buildings have single-glazed glasses with 6 mm thickness. According to statistical analysis, electricity used in public and private residential buildings is dominant in the total energy consumption. Usage of the air conditioning system or electrical water heating system affects this amount of consumption. While average of annual energy consumption is 30000 MJ, average of gas emission is 15800 MJ. The amount of annual electricity consumption is 110 kWh/m^2. Annual energy consumption of air conditioning systems is 40-45 kWh/m^2 (Wan and Yik, 2004).

Niu(2004) states that the number of multi-storey residential buildings is increasing in Asian countries. Nowadays, green building concept and ecological architecture become important subjects. They offer some principles for high-rise residential buildings to efficient use of energy and provide healthy spaces for users. Although impact of orientation on facade design is clear in the literature, today's high-rise residences face one direction and curved-shaped glass surfaces become relatively accepted. Therefore, cooling loads increase due to the solar radiation. Solar shades may be used to prevent from sun light. However, they have some disadvantages such as; breaking sun lights more than requested, blocking the vista. Different type of glass and intelligent motorized façade design may be more appropriate techniques. Ventilation is another parameter for the indoor air quality. Users can not open the windows due to the air pollution. This problem brings innovative window designs based on air evacuation. These windows that move according to air pressure and provide ventilation are suitable for the solution of this problem. Another method for reducing cooling loads of hot Asian countries is to apply convenient color to façade. Sometimes, the façade color is more effective than the insulation. Balcony is an important element in architectural design to construct visual connection between building users and the environment. But society that lives in the high rise building characterizes the hanging out the laundry as solecism and they lead to dry their laundry inside. This implementation increases the moisture of internal environment and cause unnecessary energy consumption. Air conditioning system is most widely used tool for the heating and cooling purpose, despite its low efficiency than the central system. Some of the reasons may be cheap repairs and personal controllability. Building envelope materials can be dangerous for human health. According to researches about building materials, concrete and granite release radon gas, but wood usage on the floor inhibits this emission. Emission amounts of materials can be measured by national and international tests. Positions and distances of buildings cause some problems, such as; insufficient sun light and air quality. In high-rise buildings, it is expected that green roof and intermediate gardens can solve these problems by providing ventilation, wind and shading (Niu, 2004).

Wall (2006) made some measurements and simulation of 20 passive terrace houses in Gothenburg, Sweden. Predicted and observed energy performances are compared. According to passive house standards, the heating energy consumption must not exceed 10 W/m^2. For this reason, the range of well insulated wall thickness of the houses is between 40cm and 50 cm, glass used in window fenestration system is low-e and also, each house has 80% of the recycled mechanical ventilation system with a heating system. Solar collectors which are 5 m^2 provide 40% of hot water demand of each house. During design phase DEROB-LTH is used as simulation tool. According to simulation results, if interior temperature is assumed to vary from 20 to 26°C, heating demand will be 7.5 kWh/m^2. If interior temperature is constant at 20°C, heating demand will be 12.9 kWh/m^2. The reason of this is that thermal mass cannot store the heat during the day and night. If solar gain does not exist, space that requires 7.5 kWh/m^2 for heating will require 14.1 kWh/m^2. Energy consumption increases from opaque glazed windows, low-e glasses, and triple glazed to double glazed windows respectively. User number is as important as building characteristics. Internal gains from users should be calculated. According to simulation, internal gain from a family of 4 people is 4.3 W/m^2, and internal gain from a family of 2 people is 3.4 W/m^2 (Wall, 2006).

Nowadays, the indoor quality of residential buildings is insufficient for human health and this causes high amount of energy loss. In India, Kerala is a state that has humid and warm climate. Traditional residential buildings of Kerala which are 500 years old are reviewed in terms of ecology and some measurement are made and evaluated. Summers are very hot and rainy during the day and night. In winter, days are warm, and nights are cold with no rain. Residential buildings located in this area are constructed by a system named Vaastushastra and it varies from region to region. Generally, form of the building is square or rectangular, and it has courtyard with four blocks around it. Spaces have pitched roof with open courtyard. By this way, light from courtyard reaches to indoor spaces. Clean and cool air can ventilate through the spaces and dirty air leaks out from yard. Blocks of laterite, plastered with lime mortar, is used as a material. Wood is used as a construction material in column, roof when granite is used in foundation. Flexibility of plan scheme and building form enables to change activity areas by different periods of the year. Usage of courtyard varies according to wet and dry days. Orientation of the house is designed based on sun direction and shadow rate. While entrance of the building faces to south or east, rooms used in daytime is located in north and south, and spaces used at night look to the west. Living area with opening for ventilation faces to the south. Kitchen is placed in the north east because wind blows from south west. This organization prevents the dispersion of the kitchen to other rooms. Many windows with openings in roof and walls provide ventilation. External walls consist of two layers of laterite blocks and sand between these layers. 300 years old residential building is selected for measurements. This building has 3 courtyards and 2 of them are surrounded with single storey, one of them is surrounded double storey structure. Outdoor and indoor temperatures, relative humidity of interior spaces and courtyard, and air movement are measured. While outdoor temperature varies between 22 and 34°C, interior temperature varies between 26 and 30°C. The temperature measured in the courtyard is 5°C cooler than the outdoor temperature. Indoor temperature is 26°C, while outdoor temperature is lower than 22°C during night. It is observed that indoor relative humidity is 77% when outdoor temperature reaches 30°C. While outdoor humidity is 100%, indoor relative humidity varies between 84 and 88%. The measurement of air movement shows that a continuous air flows in the interior. While wind blows with a speed of 3.5 m/sec, air movement of interior spaces is 0.5m/sec. This study provides evidence about the indoor quality of traditional Kerala housing construction (Dili et al., 2010).

2.3. Certificate Systems and Evaluation

Ecological architecture is a concept which is occurred by noticing the negative impact of industrialization, technology and reviewing construction process in the twentieth century. Its philosophy includes less and efficient use of energy, respectful approach to people and nature, creating healthy spaces, durable and environmental-friendly material. Nowadays, this philosophy is known as the green building evaluated by the certificate systems. These buildings emphasize topics such as environment, health, production and economy mostly. Design process of green buildings contains a comprehensive design approach that provides buildings to be more environmentally efficient. Green buildings have less negative impact on environment and users than the traditional ones have. The amount of greenhouse gas emissions from production and operating buildings may decrease. Green buildings obtain healthy interior comfort conditions by consuming energy efficiently. Green buildings are energy efficient; they achieve water saving; they use durable, non toxic, renewable materials and they are combined with healthy spaces (Ali and Alnsairat, 2009; Esin and Yüksek, 2009; Soysal, 2008).

Certificate systems offer a scope to evaluate environmental performance of buildings and to integrate sustainable development with design and construction process. These systems may be used as design tools when determining performance criteria of sustainable design. In addition to this, they may be used as a management tool because they can configure and organize design, construction and operational phases of environmental considerations. Nowadays, certificate systems commence to use commonly to show environmental effects of green buildings perceptibly and to promote green building awareness. First of all, BREEAM (Building Research Establishment Environmental Assessment Method) (BREEAM, 2011) was established in UK in 90's. After, this process has continued with variety of certificate systems in consideration of different country's climate and sources. Certificate systems become evidences of comfort conditions and energy saving with their applicability and clarity. Furthermore, investors use certificate systems as economy guide to make building more valuable. Certificate systems are also used commonly for residential buildings. Residential buildings differ from the other types of buildings in terms of their importance of shelter, protection, resting properties and social status indicator. Assessment criteria are based on the life cycle of the building. In this way, building users and owners may obtain a long term benefit from this process (Ali and Alnsairat, 2009; Sev and Canbay, 2009).

The most commonly used certificate systems which were produced in three different continental and accepted by World Green Building Council are BREEAM (UK), LEED (USA) and CASBEE (Japan) (Sev and Canbay, 2009). Additionally, there are many green building assessment methods, such as SBTool (International), EcoProfile (Norway), PromisE (Finland), Green Mark for Buildings (Singapore), HK-BEAM and CEPAS (Hong Kong), GreenStar (Australia), SBAT (South Africa) and

Environmental Status (Sweeden). The aim here is to measure environmental sensitivity level of buildings depending on standards (Arısoy, 2009).

In our country, the number of residential buildings is 60% of the total number of buildings (Kılıç, 2009). Production of housing is an utmost concern due to increasing population and designing a qualified habitat and also becoming more expensive with respect to other sectors. Furthermore, as residential buildings are economically important in human life, dwellings should have sufficient technical equipment in terms of functionality safety and efficiency. To design residential buildings according to the green building criteria is significant for the detection of human life and sustainable environment. This section includes criteria of BREEAM, LEED, and CASBEE certificate systems, evaluation of LEED and BREEAM on the basis of housing and discussion of the applicability of residences in Turkey.

2.3.1. LEED and LEED-H

LEED (Leadership in Energy and Environmental Design) certificate system is a program that American Green Building Council published in 2000. The aim of this system has been to define sustainable, environmental- friendly standards for design, construction and operational phases of buildings, check and evaluate the appropriateness of the standards. This certificate system was introduced in US then it becomes widespread in Europe and China. LEED is based on ASHRAE 90.1 standard which published by American Society of Heating Refrigeration Air Conditioning Engineers. It becomes also popular in Turkey (Kalataş, 2009). LEED has five assessment categories which are sustainable sites, water efficiency, energy and atmosphere, materials and sources, indoor environmental quality. It also categorizes buildings according their usage type. For residential buildings, LEED has eight criteria which are innovation and design process, location and linkages, sustainable sites, water efficiency, energy and atmospheres, materials and sources, indoor environmental quality and awareness and education (USGBC, 2011).

LEED has advantages for human health, security and comfort. Moreover it provides economical benefits; it has sewage, traffic and infrastructure advantages for society. Users prefer buildings that have LEED certificate because of their advantages mentioned above and their lower insurance value (Kalataş 2009). Implementation of

LEED is obligatory in several states of USA. However, there are tax cuts and incentives in other states that LEED implementation is not obligatory. LEED assessments are varied according to usage and project type. LEED evaluate residential buildings over 130 points with respect to eight categories. Residential buildings which have 45-59 points are named as certified, 60-74 points are named as silver, 75-89 points are named as gold, and 90-128 points are named as platen. In LEED-H system innovation and design process category is 9 point, location and linkages category is 10 points, sustainable sites category is 21, water efficiency category is 15, energy and atmosphere category is 38, materials and sources category is 14, indoor environmental quality category is 20 and awareness and education category is 3 points. Furthermore, these categories have sub-criteria (Department for Communities and Local Government, 2006). When LEED-H (LEED for Homes) and LEED-NC (LEED for New Construction) (USGBC, 2008) are compared, it is noticed that they differ from each other and other certificate types in terms of their percentage of criteria. As it is displayed in the Table 2.1, water efficiency and energy-atmosphere categories are more important than others and several categories come out for residential buildings like location, awareness and education.

Table 2.1. Comparison of LEED -H and LEED-NC criteria.
(Source: Issa et.al. 2010; USGBC, 2007)

LEED CRITERIA	*LEED-H POINTS*	*WEIGHTS IN LEED-H (%)*	*WEIGHTS IN LEED-NC (%)*
Innovation and Design process	9	7	7
Location	10	8	-
Sustainable sites	21	16	20
Water efficiency	15	12	7
Energy and Atmosphere	38	29	25
Materials and Sources	14	11	19
Indoor Air Quality	20	15	22
Awareness and Education	3	2	-

2.3.2. BREEAM and BREEAM-Eco Home

In 1990, BREEAM (Building Research Establishment Environmental Assessment Method) was established by Building Research Establishment in the UK to determine criteria for evaluation of buildings' environmental and energy performances. At first, method was created according to conditions in UK. It was recognized across the world by different versions such as; BREEAM International, BREEAM Europe, BREEAM Gulf. This assessment method uses a grading system which categorizes buildings with respect to their types. In 2006, "BREEAM-EcoHomes" (Department for Communities and Local Government, 2006) was generated for residential buildings and in 2007; this method is enacted by getting the name of Code for Sustainable Homes. The evaluation of this code includes nine categories which are energy/CO_2, water, materials, surface water run-off, waste, pollution, health and well-being, management, ecology. Nine categories mentioned in the code are evaluated by rating from 1 to 6 stars. Categories and minimum standards are presented in the Table 2.2. According to this, one star (★) is the entry level and six stars (★★★★★★) is the highest level. Certificate that is obtained by getting these stars is entitled as good, very good, excellent and outstanding respectively. For every level of water and energy categories minimum standard should be provided and the residential building should integrate minimum requirements of material, surface water run-off, and waste categories at Code entry level. There are not any minimum standard for other four categories. As a result, system involves minimum standards and some criteria that include extra points. Although this certificate system introduces some rules according to different country, region, and project, these rules are determined with the help of the designer and adaptation of the rules to the project may be getting difficult (Department for Communities and Local Government, 2006; Somalı and Ilıcalı, 2009).

Table 2.2. Minimum standards in Code for Sustainable Homes.
(Sources: Department for Communities and Local Government, 2006)

Code Level	*Category*	*Minimum standard*
	Energy/CO_2	
1(★)	Percentage improvement over	%10
2(★★)	Target Emission Rate (TER)	%18
3(★★★)	(Building Regulation Standards 2006)	%25
4(★★★★)		%44
5(★★★★★)		%100
6(★★★★★★)		A zero carbon home (heating, lighting, hot water and all other energy uses in the home)
	Water	
1(★)	Internal potable water consumption	120 (l/p/d)
2(★★)	Measured in liters per person per day	105 (l/p/d)
3(★★★)	(l/p/d)	105 (l/p/d)
4(★★★★)		105 (l/p/d)
5(★★★★★)		80 (l/p/d)
6(★★★★★★)		80 (l/p/d)
1(★)	**Materials** Environmental impact of materials	At least three of the following 5 key element of construction are specified to achieve a BRE Green Guide 2006 rating of at least – Roof structure and finishes – External walls – Upper floor – Internal walls – Windows and doors
1(★)	**Surface water Run-off** Surface water management	Ensure that peak run-off rates and annual volumes of run-off will be no greater than the previous conditions for the development site.
1(★)	**Waste** Site waste Household waste	Site waste management Household waste storage

2.3.3. CASBEE

CASBEE (Comprehensive Assessment System for Built Environment Efficiency) is a system for Japan and other Asian countries. It has been released in 2001 by Japan Sustainable Building Consortium (JSBC) and Green Building Council (JaGBC). It categorizes buildings according to their construction phases which are buildings in design stage, new buildings, existing buildings and renovations. It is related with architectural design phases as before design, design and after design. This method includes some criteria such as; interior and quality of its environment, quality of outdoors, and quality of site, energy, source and materials to evaluate buildings (Tönük and Köksal, 2010).

2.3.4. Examples

Idea House is an LEED-GOLD certificated green building located in Carolina. Southern Living, a journal in USA, constructed this building as a guide model for families. Readers can obtain detailed information about LEED certificate and see the advantages of healthy, comfort green farmhouse. To prevent erosion, straw bales are used in addition to rain drains. Plants, growing in the region, that require 80% less irrigation are planted to the site. System that cuts and collects of the rain flow provides insulation and grey water for toilets. Applications which are conducted for water efficiency lead to 10 points over 15. Heating and hot water demand is provided from the solar collector. Furthermore, excess electricity from solar cells is sold to local electric company. This building consumes less energy by zoning heating-cooling system. By this way, Idea House gets 21 points over 38 in the energy and atmosphere criteria. Selections of materials and heating-air conditioning system are resulted with 16 points over 21 points. Panel walls are used to release small quantities of waste. Walls are painted with less volatile organic paint. Mechanical air conditioning system is used to filter fresh air. As a result, this house uses energy 43% more efficient than traditional house. It uses 80% less water for irrigation and 50% of the construction waste is used in the landfill (USGBC, 2009) (Figure 2.1).

(a)

(b)

Figure 2.1. Images from Idea House Project.

Another LEED certificated residential building project is Vista Dunes located in California, USA. This project consists of 80 houses. The aim here is to provide users' demand and become an example based on water and energy efficiency. Different types of houses, types with 1-3 rooms, enable for middle income families. Social and sporting activity areas are designed. In addition to a bus stop near the site, bicycle paths and park are designed. Vista dunes get 9 points from location criteria and 17 points from sustainable sites by this implementation. For landscaping design, drought-resistant plants are used. Collection of surface rain water in ponds leads to water saving. Special devices in the houses provide water saving that varies between 25 and 30%. So this project gets 9 points from water saving criteria. Location of the blocks reduce cooling energy load by shading each other. Colors of the materials avoid effects of desert climate. At the same time, recyclable materials are selected and these materials are pre-prepared before bringing to construction site. Moreover, meshes and plants are placed on the building façades and heat reflective materials are used on the roof to reduce cooling energy consumption. Wind chimney is designed as a supporter for sun light and ventilation. Every house has 16 photovoltaic panels that produce 70% of electricity demand of each unit. This applications based on energy saving provide 18 points. Material selection supports these by 10 points (USGBC, 2009) (Figure 2.2).

(a)

(b)

Figure 2.2. Images from Vista Dunes Project.

2.3.5. Applicability of Certification Systems in Turkey

Although LEED and BREEAM certificate systems inherit similar purposes, they have different criteria since they have been developed in different countries. As an example, green areas and water saving are not as important as other criteria wherefore it is established by UK which takes a lot of precipitation and has more green space than other countries. It is observed that LEED certificate system does not pay attention to reduce NO_x and CO_2 emissions (Somalı and Ilıcalı, 2009). When assessment criteria of two systems are compared, different approaches can be observed. LEED takes care of users comfort and health by evaluate the criteria of sustainable sites (21 points), energy and atmosphere (38 points), and indoor environment quality (20 points). BREEAM notice reducing the effect of building on the environment by evaluating criteria of energy and atmosphere, ecology, waste, pollution, surface water run-off.

The weights of assessment criteria which are prepared in developed countries should differ for developing countries. While comparing these assessment criteria with standards of country, if standards are more appropriate than minimum values of certificate criteria, the standard is applied. Every country has different standards based on its conditions. In this respect, implementation of the certificate system is flexible according to different regions and countries. There is not yet any comparison for standards of Turkey about certificate systems currently applied in our country. ASHRAE 90.1 (ASHRAE, 2007) should be known and has widespread usage in Turkey because LEED and BREEAM criteria refer to this international standard. There may be some difficulties for the applications in Turkey due to the less number of people who has information about this topic (Somalı and Ilıcalı, 2009).

From analyzing versions of certificate systems for residential buildings, it is observed that building location, local material and its quality, water and energy efficiency, indoor environment quality are more important than the other criteria. In our country, as the number of residential buildings is 60% of the total number of buildings, they are the most important building type in construction sector (Kılıç, 2009). Certificate systems such as LEED and BREEAM should be examined and adapted according to conditions of Turkey. Thus, more responsive solutions about environment and human, and some precautions about energy saving may be developed. There are some criteria that should be noticed for the application to residential buildings. Grading system of certificates should differ according to residential buildings in Turkey. Unawareness and ignorance about green buildings become a problem in our country as well as in other developing countries. The weight of education criterion in investigated certificate system is less than other criteria because of awareness and education in their countries. Therefore, it is recommended that weight of this criterion should be more than other countries. BREEAM takes into consideration of environmental impact of material and offers some requirements at least three building elements such as, roof, external walls, intermediate floors, interior walls, windows, and doors etc. (Department for Communities and Local Government, 2006). Weight of material and source criterion is 11% of all criteria. In our country, local material should be used instead of material which is harmful to the environment. Thus, material criterion should be more important for the assessment in Turkey. Significance of indoor environment quality is 15% in LEED-H (USGBC, 2007). Structural biology which includes the topics of human health and building health, and interaction of building elements, should be considered. Building materials may cause indoor air pollution. Harmful gases caused by materials which may spread them to the interior environment and affect human health negatively. Emission of these gases, such as, carbon monoxide, nitrogen oxides, sulfur, volatile organic compounds-formaldehyde, radon, ozone, can be prevented (Vural and Balanlı, 2005). Instead of using the hazardous material an ecological material should be considered in the construction of an interior space to improve its environmental quality and make occupants be encouraged to use such materials. The criterion about sustainable sites mentioned in the LEED should be applied in Turkey as well. In this way, by emphasizing the importance of sustainable building design and landscaping (play areas, green areas, cycle paths and parking spaces etc.), outdoor environment can be more healthy and livable.

2.4. Regulations in Turkey

There are many researches, studies and regulations about energy efficiency and use of renewable energy source in buildings (Aykal, 2009; Çalıkoğlu, 2004; Kavak, 2005; Moltay, 2010; Turan, 2004; Yaman, 2009).

2.4.1. Thermal Insulation Requirements for Buildings-TS825

TS825 "Thermal Insulation Requirements for Buildings" (TS 825 "Binalarda Isı Yalıtımı Kuralları" Standardı) is an official obligatory standard of Turkey derived from DIN V 18599. Main purpose of TS825 which has been in use since 2000 is to improve energy saving by limiting building's heating energy demand. TS825 includes a calculation method for the heating energy demand of buildings and the minimum criteria which are tabulated according to climatic regions specifically determined for Turkey using degree-day method. Material and construction system of new buildings should comply with this standard to make energy consumption values remain within the ranges mentioned in TS 825. Before renovation of the building, the amount of energy saving can be determined by energy saving precautions. TS825 standard sets rules for all buildings. The aim is to reduce the annual heat losses from the new constructed building envelope. Statistical method, simple method, accepts building as a single zone and calculates the zone degree as 19°C. This standard does not consider thermal storage feature of building envelope and heating system. It uses meteorological data of regions. (TS 825, 1999) TS 825 which is revised in 2008 to reduce building energy consumption by lowering maximum allowable total heat transfer coefficient.

2.4.2. Heat Insulation Regulation

The main purpose of Heat Insulation Regulation (Isı Yalıtım Yönetmeliği) (2008) is to reduce thermal losses, provide energy saving, and define application principles. It is used for all buildings of all regions including municipalities. This regulation is not applied for buildings which do not need to heat, such as; warehouse, armory, warehouse, barn, stables etc. By the application of Heat Insulation Regulation, buildings are insulated in accordance with environmental conditions and requirements. The monthly average outdoor temperatures have been renewed according to meteorological data. By this way, thicknesses of insulation materials have been increased, especially in cold regions. The calculated annual heating demand cannot exceed maximum value of annual heating demand by regions (Binalarda Isı Yalıtım Yönetmeliği, 2008). By accordance with the provisions of this regulation, thermal insulation project should be adequate with calculation method which is specified in

TS825. Thermal insulation project which is prepared by mechanical engineer is asked by relevant authorities during the construction permits (Eriş, 2009).

According to regulation, 4 climatic regions and values of maximum energy consumption in these regions are introduced. Heating energy consumption of existing buildings or buildings which will be constructed must be lower than these values. Besides, the regulation includes limitations about total heat transfer coefficient of building envelope and requires designing building elements without creating thermal bridge. Detail drawings of thermal insulation of building elements are presented as a section detail in architectural project. Wall-window ratio according to orientation is a significant parameter for both heating and daylighting. Insulation between soil and slab is important. Ratio of surface area to volume is another architectural parameter noticed in the regulation. According to heat insulation regulation, architecture decides the usage of renewable energy sources, solution of the problems in addition to design parameters.

2.4.3. Energy Efficiency Law and Building Energy Performance Regulation

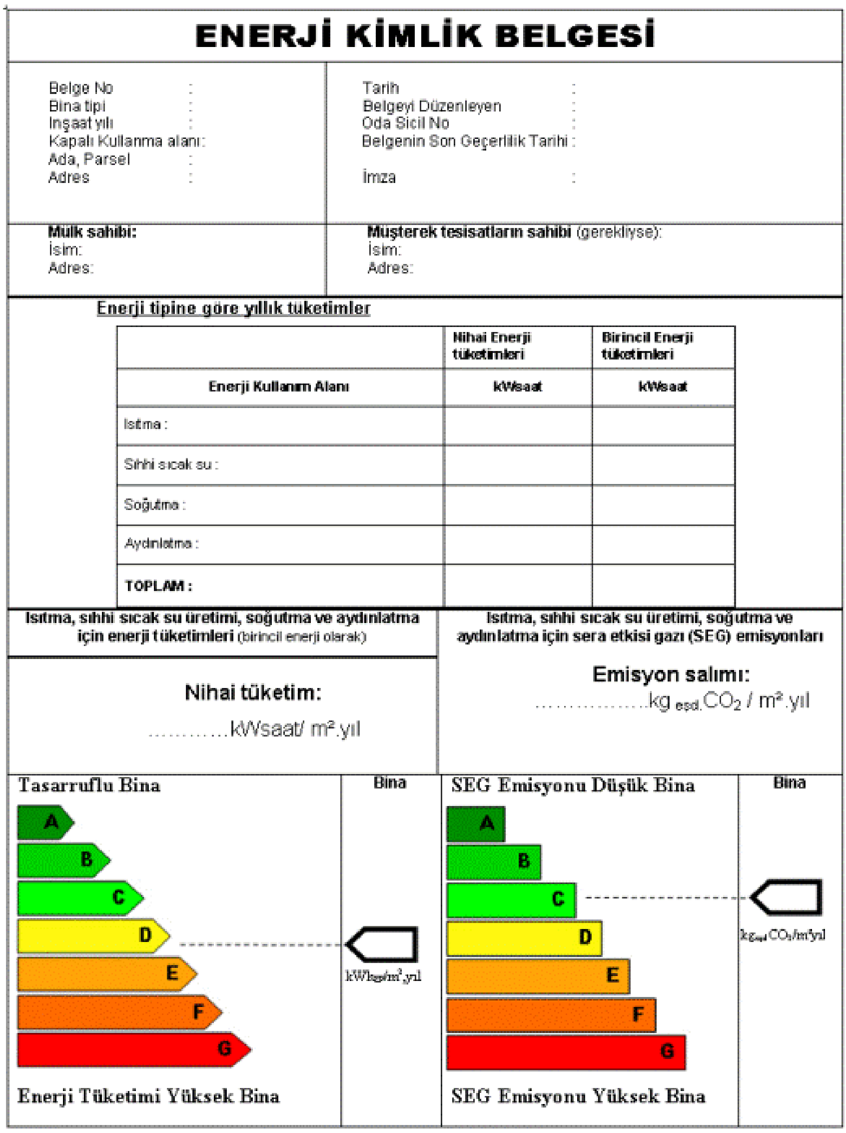
The aim of the Energy Efficiency Law (Enerji Verimliliği Yasası) is to increase energy efficiency in production, transmission, distribution and consumption phases, in buildings, electrical energy generation plants, industrial enterprises, transmission and distribution networks, and in the transportation. Furthermore, it supports the development of energy awareness and renewable energy in the society. In December 5, 2008 Building Energy Performance Regulation (Binalarda Enerji Performansı Yönetmeliği) is published by Ministry of Public Works (Bayındırlık Bakanlığı) (Ministry of Environment and Urban Planning-Çevre ve Şehircilik Bakanlığı) to determine calculation rules of building energy assessment, classification of energy and CO_2 emission, and minimum energy performance requirements of existing and renovated buildings. The regulation also includes the assessment of renewable energy implementations, control of heating and cooling systems, limitations of greenhouse gas emissions and regulations about protection of the environment (Energy Efficiency Law-Enerji Verimliliği Yasası, 2007; Ministry of Public Works-Bayındırlık Bakanlığı(Ministry of Environment and Urban Planning-Çevre ve Şehircilik Bakanlığı), 2008). Building Energy Performance Certificate, offered by law, consists of standards about architectural design, heating, cooling, thermal insulation, hot- water, electrical installations and lighting to improve energy performance of buildings and to develop a calculation method for energy performance (Keskin, 2007). Regulation involves existing and new buildings typologies, such as; residences, offices, training facilities, medical buildings, hotels, shopping and commercial centers.

In the Buildings Energy Performance Regulation (Binalarda Enerji Performansı Yönetmeliği), points to be considered in terms of architectural design phase are described briefly. Firstly, considering zoning status, heating, cooling, ventilation and lighting loads should minimize. It is required the benefits from natural heating, cooling, ventilation and lighting facilities should be maximum. However, it does not consist of any physical or numerical advices. Meteorological data, such as; sun, wind and humidity should be taken into consideration while architects orient buildings and interior spaces. In the regulation, it is mentioned that living spaces should benefit from natural light, heat and ventilation. There are some recommendations about these benefits but detailed information is needed.

2.4.4. Building Energy Performance Calculation Method (BEP HY)

Under the Building Energy Performance Regulation (Binalarda Enerji Performansı Yönetmeliği), a method (BEP-HY) and computer program (BEP-TR) for existing and new buildings (residences, offices, educational buildings, medical buildings, hotels, shopping and commercial centers) have been developed. This calculation method supports the energy performance comparison of design alternatives for design phase of the building. Furthermore, it shows the energy performance level of existing buildings and buildings which will be constructed. This method is also very helpful about the evaluation of energy efficiency implementation for existing buildings. Besides, this method consists of the calculation of heating and cooling energy amount, losses from energy systems, the determination of total energy consumption of heating, cooling and ventilation, benefits from solar radiation and energy consumption of hot-water.

This calculation method is formed by EU and Turkish standards, and ASHRAE standards are used in the case of necessary situations. BEP-TR is a simple hourly dynamic method. Simple hourly dynamic method calculates hourly net heating and cooling energy demand and consumption the systems. As a result of the calculation, annual heating, cooling, hot water, lighting and ventilation energy demands are determined as primary energy consumption. Renewable energy usage and CO_2 emissions are taken into account. Building energy consumption and CO_2 emission values are compared with values of the reference building. While determining the properties of reference building, site location, climate data, building geometry, building envelope, mechanical systems, lighting systems, hot-water systems, renewable energy and cogeneration systems are considered. Energy class is defined according to comparison of existing and reference building. By this way, energy performance certificate (Enerji Kimlik Belgesi) is created (Hastekin et al., 2010) (Figure 2.3).


ENERJİ KİMLİK BELGESİ

Belge No :
Bina tipi :
İnşaat yılı :
Kapalı Kullanma alanı :
Ada, Parsel :
Adres :

Tarih :
Belgeyi Düzenleyen :
Oda Sicil No :
Belgenin Son Geçerlilik Tarihi :
İmza :

Mülk sahibi:
İsim:
Adres:

Müşterek tesisatların sahibi (gerekliyse):
İsim:
Adres:

Enerji tipine göre yıllık tüketimler

	Nihai Enerji tüketimleri	Birincil Enerji tüketimleri
Enerji Kullanım Alanı	kWsaat	kWsaat
Isıtma :		
Sıhhi sıcak su :		
Soğutma :		
Aydınlatma :		
TOPLAM :		

Isıtma, sıhhi sıcak su üretimi, soğutma ve aydınlatma için enerji tüketimleri (birincil enerji olarak)

Nihai tüketim:
...........kWsaat/ m².yıl

Isıtma, sıhhi sıcak su üretimi, soğutma ve aydınlatma için sera etkisi gazı (SEG) emisyonları

Emisyon salımı:
.................kg eşd.CO₂ / m².yıl

Figure 2.3. Energy performance certificate according to BEP-HY.

CHAPTER 3

MATERIAL AND METHOD

This chapter involves two subsections, namely, residential buildings in İzmir and the analysis of data which are associated with the description of the study and statistical analysis. Determination and properties of case buildings, architectural configuration indicators, and data compilation obtained are presented in first subsection. Analysis of data includes a brief description of KEP-SDM (KEP-IYTE-ESS software) and statistical analyses.

3.1. Residential Buildings in Izmir

İzmir which is situated in the western part of Turkey (latitude 38°25'N, longitude 27°08'E), along the Gulf of İzmir, by the Aegean Sea, has a typical Mediterranean climate which is characterized by long, hot and dry summers; and mild to cool, rainy winters. The average temperatures of İzmir vary between 8.9-28.1 ^{0}C. Between 1975 and 2000, maximum daytime temperature was 43.0^{0}C, minimum temperature was 22.4 ^{0}C. The averages of temperature, maximum temperature, minimum temperature, amount of daylight, number of rainy days and precipitation are presented in the Table 3.1.

Table 3.1. Meteorological data of İzmir.
(Source: Turkish State Meteorological Service)

İZMİR	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Now	Dec
	1975-2010											
Average Temperature (°C)	8.9	9.4	11.8	16.0	20.9	25.7	28.1	27.6	23.6	18.9	13.8	10.3
Average of Maximum Temperature (°C)	12.6	13.4	16.5	21.0	26.1	31.0	33.3	32.8	29.1	24.0	18.3	13.9
Average of Minimum Temperature (°C)	6.0	6.2	8.0	11.6	15.7	20.2	22.8	22.7	18.8	14.8	10.5	7.5
Average of Sunshine Duration (hour)	4.4	5.0	6.5	7.5	9.9	11.7	12.2	11.7	10.0	7.4	5.4	4.1
Average Number of Rainy Days	10.8	10.5	8.8	8.1	5.0	2.3	1.8	1.4	3.4	5.9	8.7	12.0
Average Rainfall (kg/m²)	114.8	104.7	79.3	46.3	25.7	9.8	6.0	3.9	22.1	52.5	105.8	130.8
The Highest Temperature (°C)	22.4	23.8	30.5	32.2	37.5	41.3	42.6	43.0	40.1	36.0	29.0	25.2
The Lowest Temperature (°C)	-4.0	-5.0	-3.1	0.6	7.0	10.0	16.1	15.6	10.0	5.3	0.0	-2.7

Information based on housing typologies in İzmir can be achieved from the researches about building stock which have been constructed since 1960. For example, it is observed that advanced building materials, such as; cement and rebar, can be found easily at the end of the 1960s. However, after these dates, the opportunities offered by the construction industry have increased. The Condominium Law affected the construction of buildings. As a manufacturer of construction, there are architects, craftsmen, journeymen, and after that the contractors. Despite of this, economical problems affected the construction sector occasionally (Güner, 2006). Izmir has grown rapidly since 1960 and has become a metropolitan. In the 1970's, master plan of İzmir was prepared while southern region of the city has grown in the axis of Karabağlar-Cumaovası (Menderes). In the 1980's the city has been growing in every direction.

In these years, regular housing areas have been intended to build. In 1980's, there were several factors that affected construction sector. These were the emergence of the building control, active role of government in the process of building production, diversity of building materials by importing them from abroad.

3.1.1. Determination and Properties of Case Buildings

To determine location and number of case buildings, Building Construction Statistics by Turkish Statistical Institute (2000) were analyzed. Data included the number of residential buildings which are constructed and approved by municipalities of İzmir, in addition to their heating systems, fuel type, structural systems, building material and floor area. There are not any data based on municipalities.

Turkish Statistical Institute has provided data about residential buildings (cooperatives, home and apartment) constructed between 2000-2008 in Konak, Karabağlar, Bornova, Buca, Karşıyaka, Çiğli, Balçova, Gaziemir, Narlıdere, Güzelbahçe, Bayraklı. These data based on years are mentioned below;

- Number of residential buildings
- Floor area of residential buildings
- Number of residential buildings based on floor counts
- Number of residential buildings based on number of dwelling units
- Number of residential buildings based on heating system and fuel
- Number of residential buildings based on construction material and technique

Figure 3.1 shows the total number of residential buildings constructed in municipalities of İzmir between 2000 and 2008. Accordingly, a total of 14248 residential buildings' construction was completed in the central municipalities. Most of these (3137) were constructed in Buca. In Bornova, 2661 of them and in Karşıyaka 2159 of them were built. The rapid increase in the number of residential construction in Buca can be related to the public housing areas in the development plan, university campus and increasing population. Bornova has similar situation. According to data obtained from interviews with municipalities and 3D City Guide of Izmir; in Konak, the number of residential buildings constructed in recent years, are less than the ones in other three municipalities because Konak is an old settlement. There are multi-story residential buildings and detached dwellings together. Furthermore its development plan includes environmental design. Instead of adjacent building scheme, gardens for each building were designed. Due to its specifications mentioned, Balçova differs from the other four municipalities (Buca, Bornova, Karşıyaka, Konak). Karabağlar and Bayraklı Municipalities are commenced to work since 2008. A part of Konak municipality was taken into Karabağlar municipality. Therefore, comparing to others, the number of constructed residential buildings in Konak has been very low.

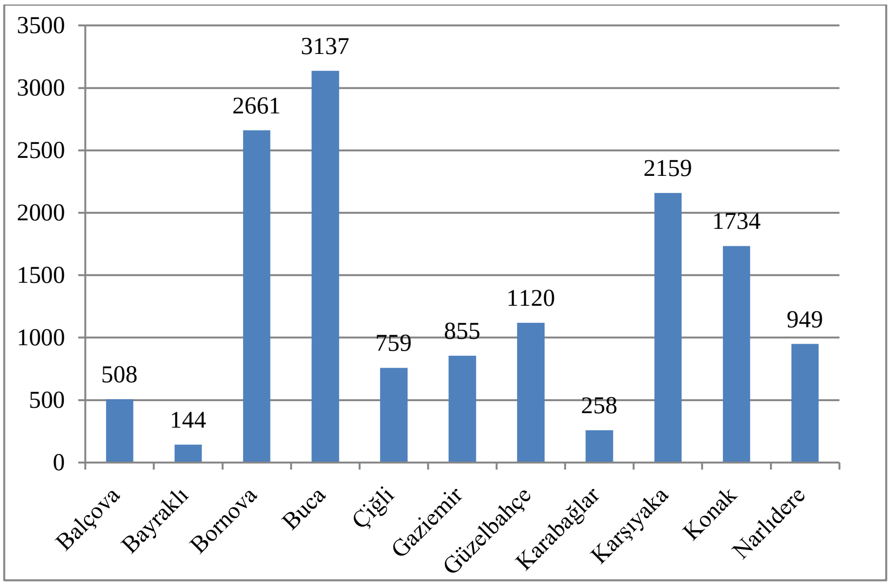


Figure 3.1. The number of residential buildings constructed in municipalities of İzmir between 2000 and 2008.

The annual distributions of residential buildings that are built in central municipalities of İzmir, between 2000 and 2008, are presented in the Figure 3.2. As it can be observed from Figure 3.2, residential construction has increased since 2002, and reached the highest number in 2006. It decreased only in 2007, after that time, it has continued to increase. As the increase in residential construction cost was 28% in 2002, the number of residential construction declined to its lowest level. However, the rate of increase in residential construction cost in 2004 was 14%, and in 2005, this cost reduced to 12.5%. Therefore, construction rate was increased (TOKİ, 2006). Reduction in the number of residential construction in 2007, on the other hand, can be explained by the increasing construction costs of square meters in the same year. According to Turkish Statistical Institute, in the first 9 months of 2006, the number of residential buildings with construction permits was 73596; this number was 64661 in 2007 by the reduction of 12.1% in all over Turkey (Dünya Gazetesi, 2007). Besides, decrease in the number of apartments was 4.3%. The year 2007 has been a period of reduced growth of the construction sector. "Sub-prime mortgage" crisis in the real estate market of North America and consequently, the global economic crisis began (Sektörel Dernekler

Federasyonu, 2009). In 2007, the number of residential construction in İzmir was affected by the mentioned crisis.

In the context of the legal developments related to the construction of the buildings, in 2000 Heat Insulation Regulation, in 2001 Regulation of Application Procedures and Principles in Building Control and in 2008 Building Energy Performance Regulation were published in Turkey.

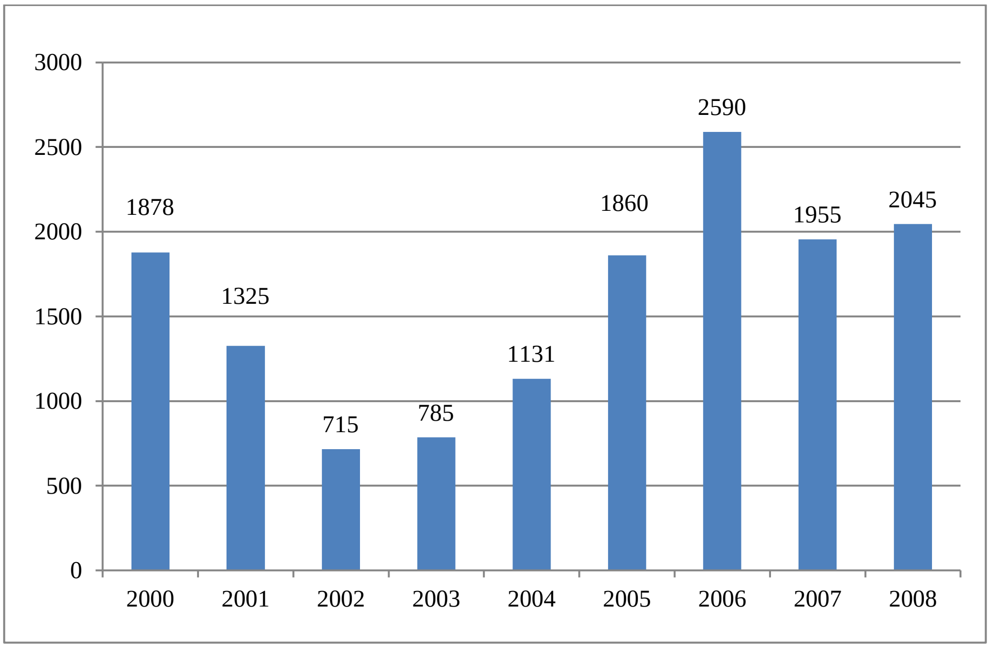


Figure 3.2. The annual distribution of residential buildings in İzmir.

The number of residential buildings based on floor counts is presented in Figure 3.3. Figure 3.3 indicates that 5-story-residential buildings and higher ones are 40% of total residential buildings. According to data of Turkish Statistical Institute, multi-story residential buildings were 32% of all buildings in 1999, this percentage increased 40% in 2003 (TUIK, 2003). Similar situation occurred in Izmir. It is considered that increasing population, lack of construction area and mass housing demand caused to this inclination in the construction of multi-story residential buildings.

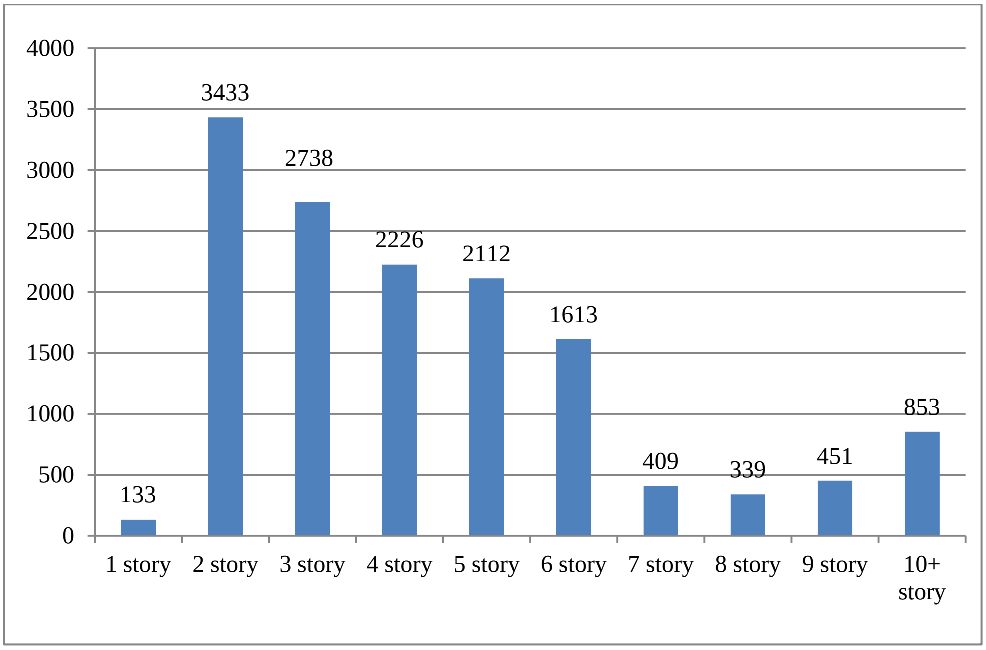


Figure 3.3. The number of residential buildings based on floor counts.

Figure 3.4 presents the number of residential buildings based on structural system. 60 % of total residential buildings have concrete structural system. Figure 10 indicates the number of residential buildings based on structural systems. Autonomous heating systems (stoves, boilers, air-conditioning) are widely used in our country. 77% of total residential buildings in İzmir have autonomous heating systems and 23 % of them have central heating system. By the Mediterranean climate, winters are not long; heating demand is lower than cooling demand. Therefore, central heating system seems to be an unpreferable system for İzmir. Central heating system usage may increase by the use of natural gas since 2005. However, according to data obtained from TSI, central heating system usage was 53% between 2000 and 2004; between 2005 and 2008, this rate was decreased to 1%. The reason of this situation may be the production and usage of autonomous gas boiler.

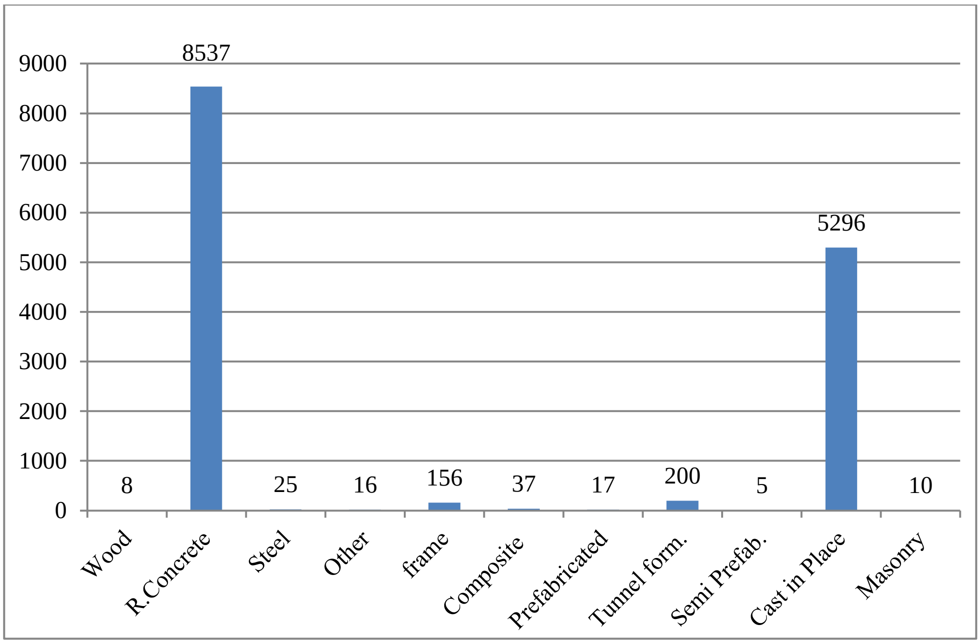


Figure 3.4. The number of residential buildings based on structural system.

Figure 3.5 presents the number of residential buildings based on floor counts annually. Figure 3.5 indicates that more than 40% of total residential buildings have 5 or more than 5 stories. This rate was 52% in 2000, 55% in 2001, 63% in 2002 and 2003, 66% in 2004, 75% in 2005, 76% in 2006, 70% in 2007, and 60% in 2008. So, construction of multi-story residential buildings increased between 2000 and 2006, this increasing rate commenced to decrease after 2006. Reasons of the increase in housing construction may be increasing population, regulations in zoning plans, lands allocated for construction, mass housing demand. The number of residential construction was decreased after 2006 according to the fact that construction costs of square meters were increased in 2007.

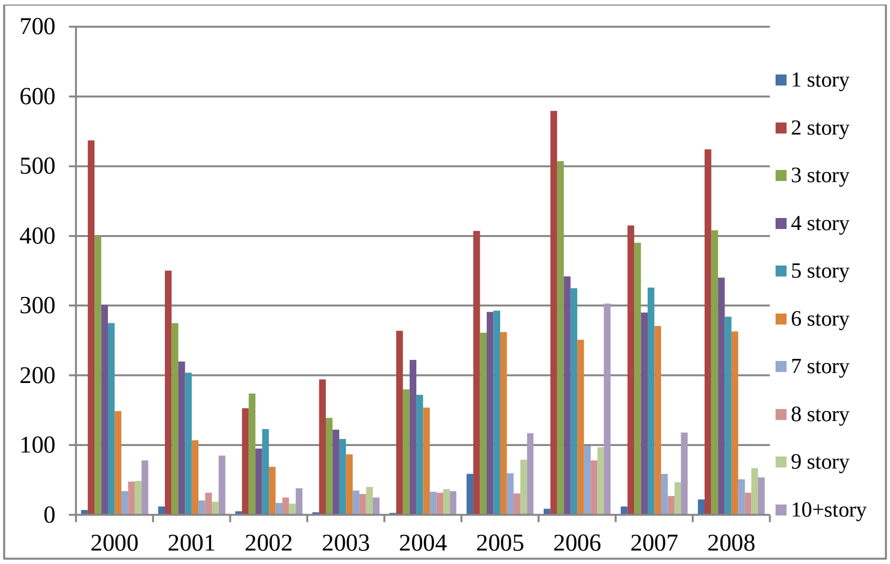


Figure 3.5. The number of residential buildings based on floor counts annually.

The numbers of residential buildings in municipalities based on floor counts are presented in Figure 3.6. 78% of total residential buildings have 5 or more than 5 stories in Karşıyaka, %53 in Gaziemir, 52% of them in Konak, 48% of them in Karabağlar, 47% of them in Bayraklı, and 45% in Balçova. The reasons of multi-story residential building construction in Karşıyaka and Gaziemir were the lands which were recently allowed to make buildings and increasing mass housing. Municipality of Konak is situated at the city centre, a representative area of high population, which is defined as a dense urban region with high residential construction

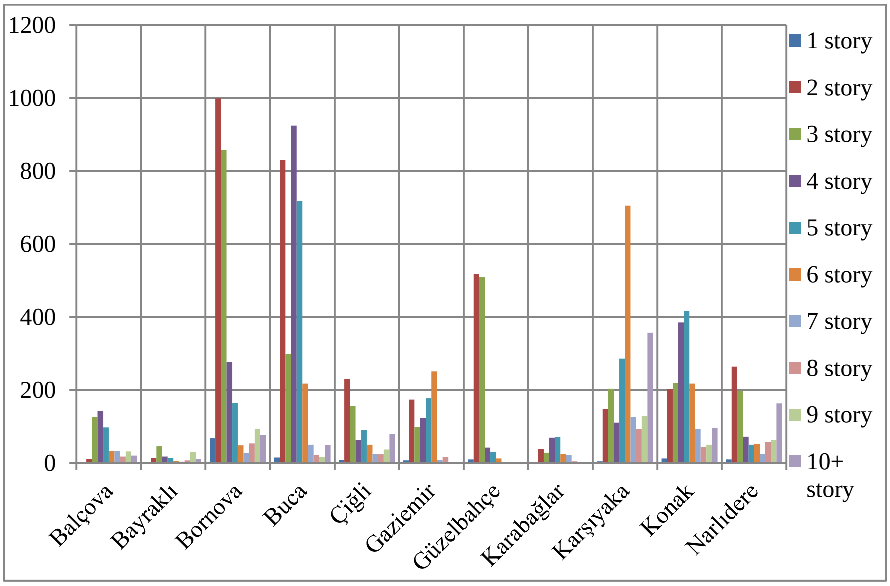


Figure 3.6. The numbers of residential buildings in municipalities based on floor counts.

Figure 3.7 presents numbers of residential buildings based on municipalities annually. According to that; most of the residential buildings constructed between the years of 2000-2003 were in Buca. However between the years of 2004-2008, residential buildings were built mostly in Karşıyaka. In terms of residential buildings, Konak municipality has the high level of construction rate after Buca and Karşıyaka municipalities have. Rates of residential construction in the municipalities were changed due to increase in the number of the central district municipalities (Bayraklı and Karabağlar Municipalities). In 2008, most of the completed residential buildings were constructed in Buca. It was followed by Çiğli, Bornova and Karabağlar.

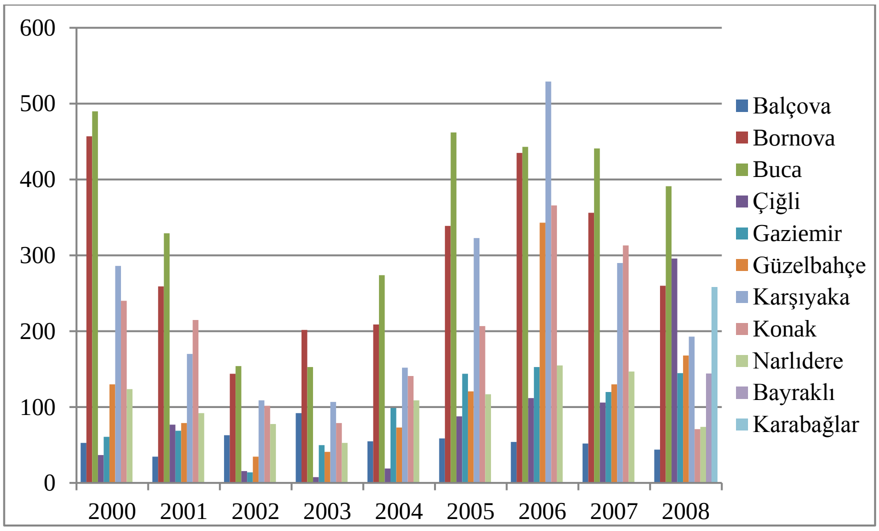


Figure 3.7. The numbers of residential buildings based on municipalities annually.

As a result of the investigation about the number of residential buildings and their floor counts, Konak and Karabağlar have been selected for high construction rates of multi-story residential buildings. Additionally, Balçova municipality has been selected for its different zoning plan and new buildable residential areas. Considering properties and sufficient numbers of buildings for statistical studies, total of 148 buildings were determined for the study. Selection criteria for residential buildings to be examined are listed below;

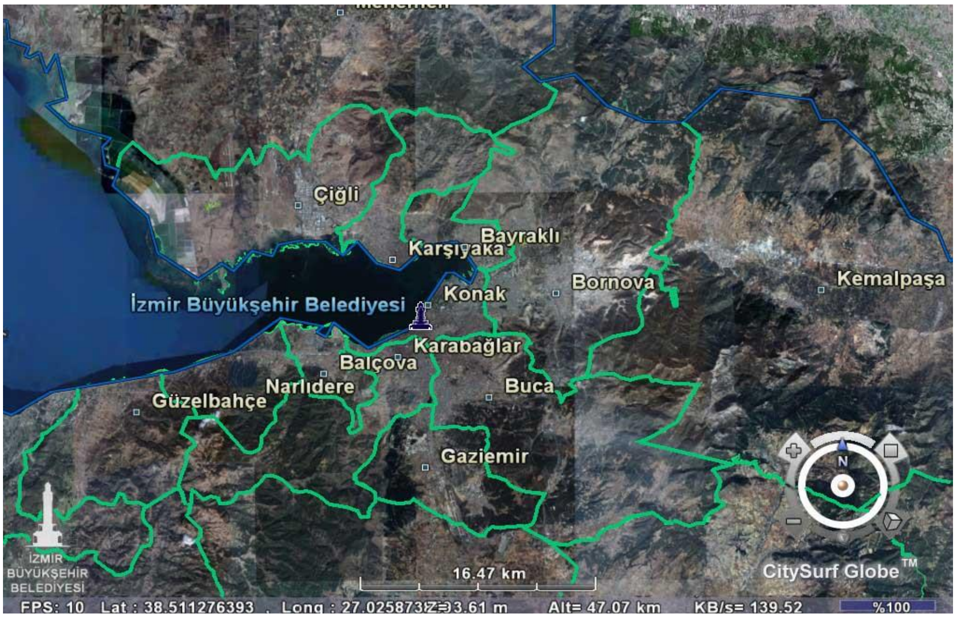
- Zoning status (attached, detached)
- Orientation (north, south, east, west)
- Floor counts (5-13)
- Designer professional status (B. Arch, MSc. Arch, MSc. Eng-Arch.)

- Heating system (autonomous, central)
- Construction year (TS 825 (2000) before and after).

3.1.2. Data Compilation

Construction permits, architectural and mechanical drawings were obtained from archives of Konak, Karabağlar and Balçova Municipalities by permits from the departments of Zoning and Urban Development. The data were determined by utilizing of architectural and mechanical projects obtained from related municipalities.

Island, plot and address information has been required to access projects in the archives. Thus, addresses (avenue, street and apartment number) and 3D models of majority of buildings in İzmir were accessed by using "3D City Guide of İzmir" which was prepared by department of Geographical Information Systems. Figure 3.8 indicates locations of Konak, Karabağlar and Balçova Municipalities (Figure 3.8(a)) and example image that includes 3d model and the address information of an apartment building (Figure 3.8(b)).



(a)

Figure 3.8. Example images from 3D City Guide of İzmir.

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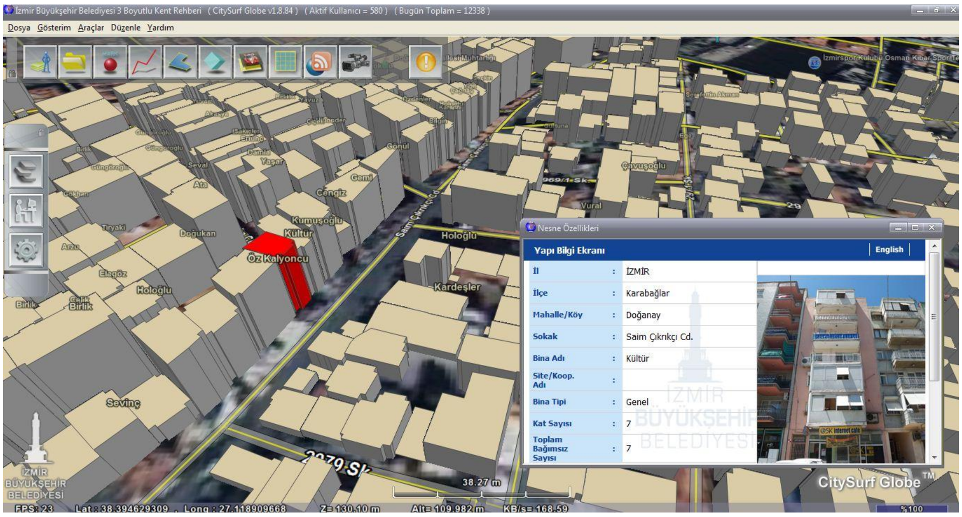


(b)

Figure 3.8. (cont.)

Projects obtained from municipalities by address, island and plot numbers, were investigated. A total of selected 148 multi story residential buildings had construction permits, architectural, mechanical and electrical drawings. Among these, 50 out of 148 were in Konak, the other 50 were in Balçova and the rest in Karabağlar. Investigated buildings had a total of 2136 apartments. 674 out of 2136 were in Konak, 790 in Karabağlar and the rest of 672 were in Balçova.

The data of architectural characteristics which were compiled from projects of residential buildings are listed below;

- Address (city, municipality, district, island, and plot): Address determines the location and zoning status of the building within the boundaries of municipality.
- Construction year: It is effective in determining the appropriateness of the buildings to the regulations of construction year. For example, it determines the differences between buildings constructed before and after the regulation
- Number of residential units (apartments) in the building: Apartment is a unit in the building site and suitable for use as an independent dwelling.
- Number of office units in the building: Office is a unit in the building site and suitable for use as an independent workplace.
- Floor counts: It is the number of floors in the building.
- Zoning status of building: It determines the relationship of the selected building with buildings in neighboring parcels

- Building orientation: Direction of the residential unit is important to benefit from natural climate conditions.
- Designer's professional status: It is the title of the person who has authority to sign the application project.
- Width, height and floor area of Building: Width, height and floor area are the parts composing the horizontal projection area of the building.
- Total net usable floor area of residential units: This is the sum of the closed floor area of residential units. Internal dimensions from the exterior walls are calculated.
- Total net-usable common floor area: It is commonly used and useful functional area except the residential and office units (entrance hall, shelter, stairs, etc.)
- Total net usable area of the building: It is the sum of useful areas of common places and the independent units.
- Total net usable floor volume of residential units: This is total closed floor volumes of residential units. Internal height dimension from floor to ceiling is calculated.
- Average of net usable area per residential unit: It is the ratio of net usable floor area to the number of residential units.
- Total window area of building: total area of the openings which are necessary to benefit from sunlight.
- Transmittance coefficient of external surface: It is the heat transfer coefficient of external surfaces which is calculated in accordance with rules and standards of engineering.
- Total heating load of building: total heating load of the building is calculated according to rules and standards of engineering.
- Total electrical lighting load of building: To illuminate interior volumes, total lighting load of building is calculated according to rules and standards of engineering.

Data about Architectural characteristics of residential units are listed below;

- Story height
- Internal useful volume
- Total wall and window area
- Total useful areas (living space, circulation area, bedrooms, wet spaces, kitchen, bin).

Table 3.2. The number of residential buildings based on architectural factors.

Municip.	Zoning Status			Floor Counts						Professional Status			Years					Heating Systems	
	Attach/ corner	Attach/ Inter.	Detach	5	6	7	8	9	10+	BSc. Arch.	MSc. Arch.	MSc. Eng	60-69	70-79	80-89	90-99	00-..	Central H.	Other
Konak	24	22	4	7	13	6	8	3	13	35	9	6	7	25	7	11	0	18	32
Karabağlar	29	19	0	4	2	1	2	21	18	35	2	11	3	10	19	11	5	23	25
Balçova	29	4	17	10	11	11	8	4	6	50	0	0	0	1	16	12	21	16	34

Projects obtained from municipalities were investigated in three groups based on zoning status. So, the zoning status of the case buildings were defined as attached/corner (attached to a building on one side and situated at the corner), attached/intermediate (attached to a building on two opposite sides) and detached (not attached to a building). Zoning status of the building was considered with the orientation (Figure 3.10). Figure 3.9 illustrates this case by an example of a sketch. As the figure shows, Building A is attached and located in the corner. Three façades of the building are open to the outdoor. Accordingly, zoning status of building A is attached/corner and its orientation is North/South/West. Zoning status of building B is attached/intermediate and its orientation is North/South because of that it has two façades facing to North and South. Building C has four façades facing outside. None of the buildings is adjacent to Building C. So, zoning status of building C is detached and its orientation is North/ South/ West/East.

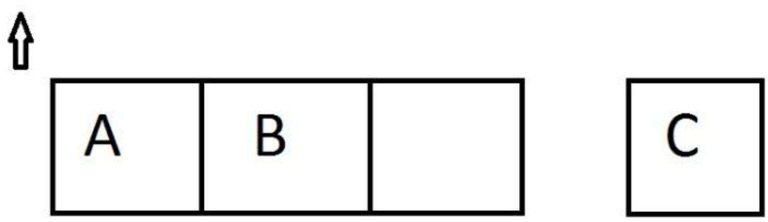


Figure 3.9. Sketch showing zoning status and orientation of buildings.

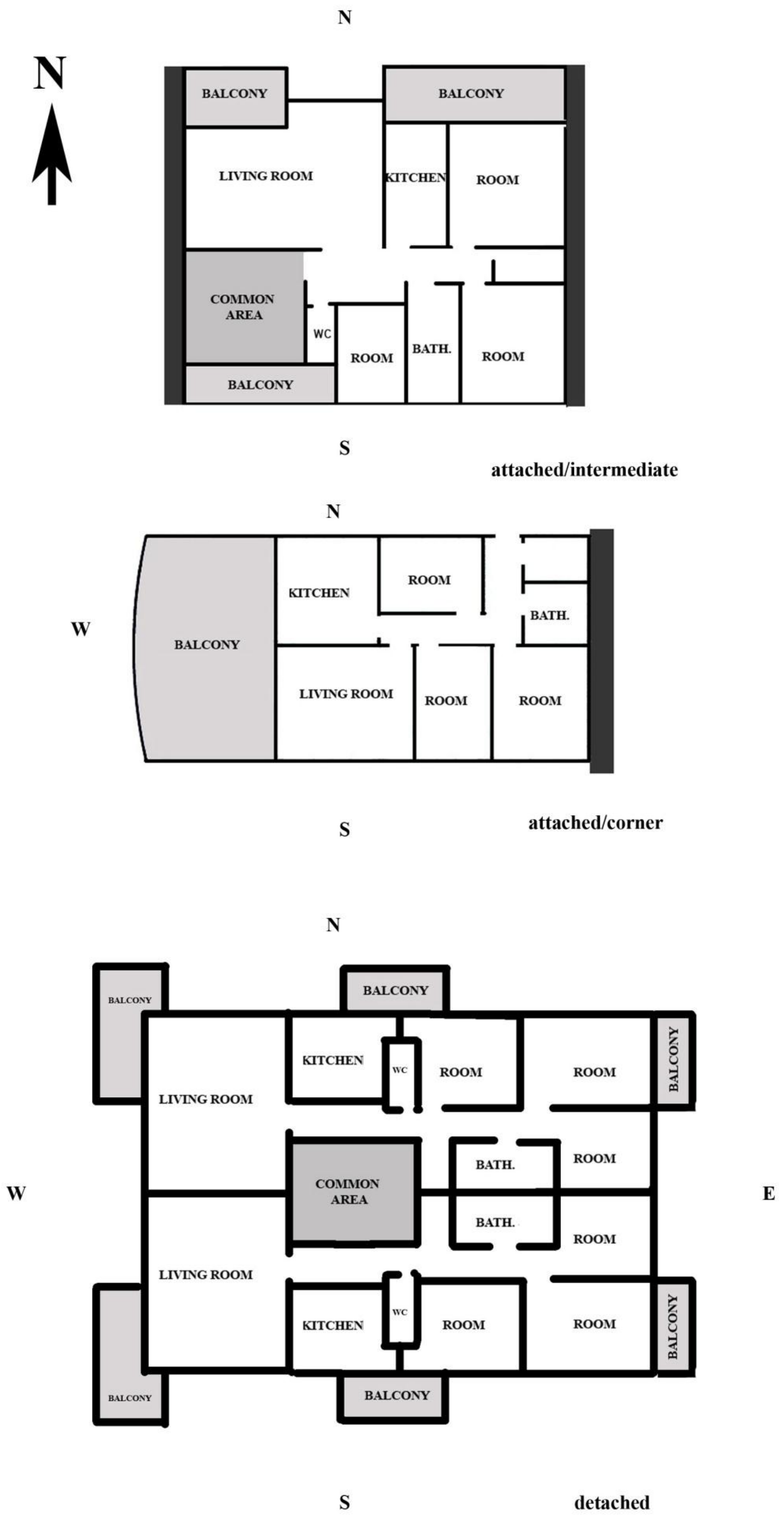


Figure 3.10. Plan scheme examples according to zoning status and orientation.

Figure 3.11 shows the distribution based on floor counts of all the investigated projects. 21 of 148 residential buildings are 5 storey, 26 of them are 6 storey, 18 of them are 7 storey, 18 of them are 8 storey, 28 of them are 9 storey and 37 of them are10 and 11 storey. Most of the investigated residential projects have more than 10 stories.

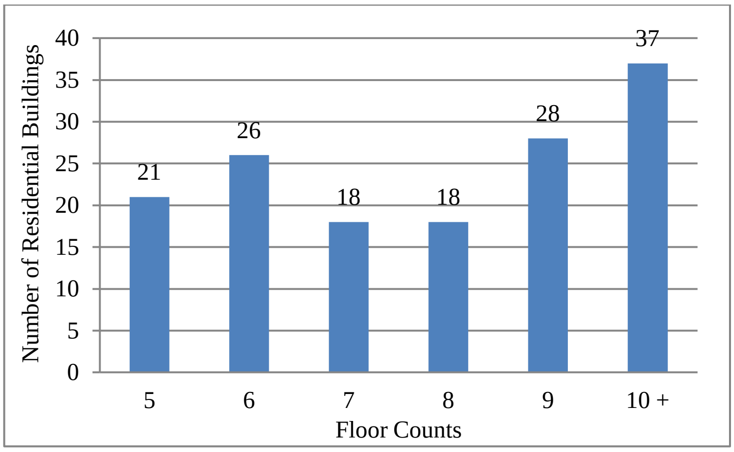


Figure 3.11. The distribution based on floor counts.

Figure 3.12 shows the distribution based on zoning status. According to

Figure 3.12 the number of attached/intermediate buildings is 45, the number of attached/corner buildings is 82, and the number of detached buildings is 21.

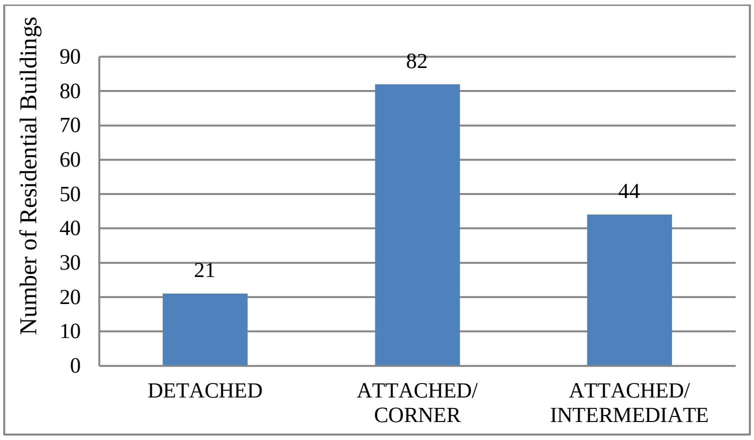


Figure 3.12. The distribution based on zoning status.

Figure 3.13 indicates the distribution based on designer professional status of architectural projects. 120 of designers are architect (34 in Konak, 30 in Karabağlar, 46 in Balçova), 11 of them are MSc. Architect and 17 of them are engineer.

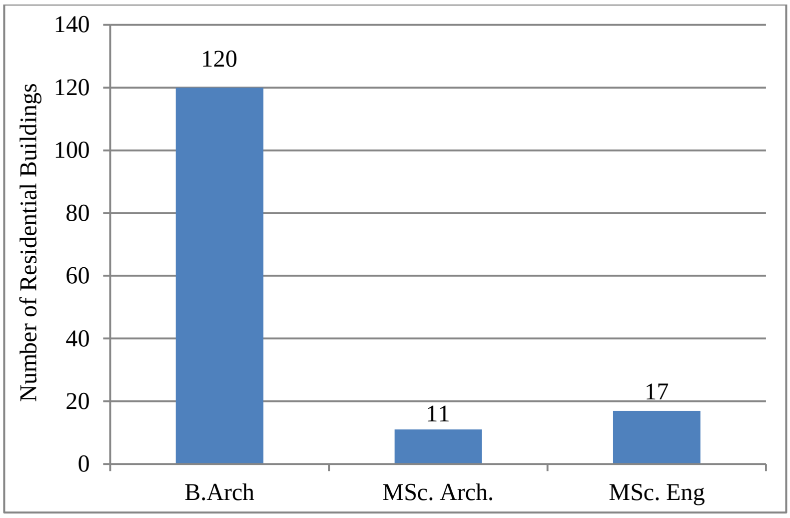


Figure 3.13. The distribution based on designer professional status.

Figure 3.14 indicates the distribution based on construction year. 10 of the investigated projects were constructed between 1960 and 1969, 36 of them between 1970 and 1979, 42 of them between 1980 and 1989, 34 of them between 1990 and 1999, and 26 of them between 2000 and 2010.

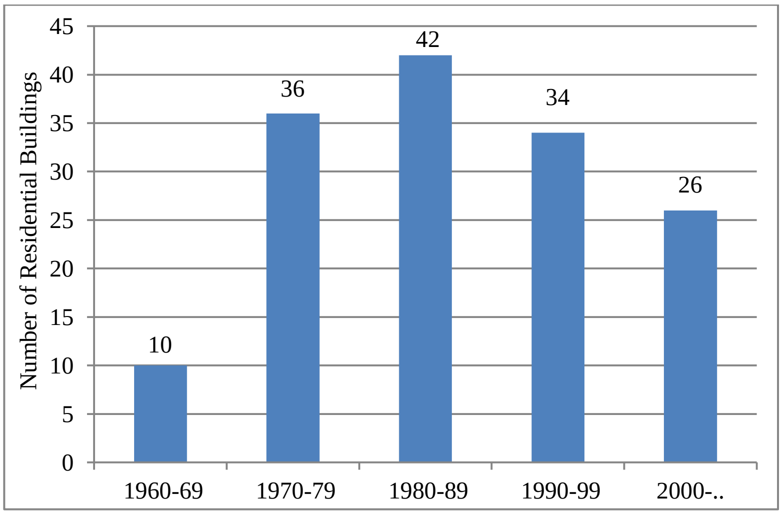


Figure 3.14. The distribution based on construction year.

As seen in the Figure 3.15, 30 of the projects had central heating systems and 65 of them had autonomous and 53 of them had air-conditioning system.

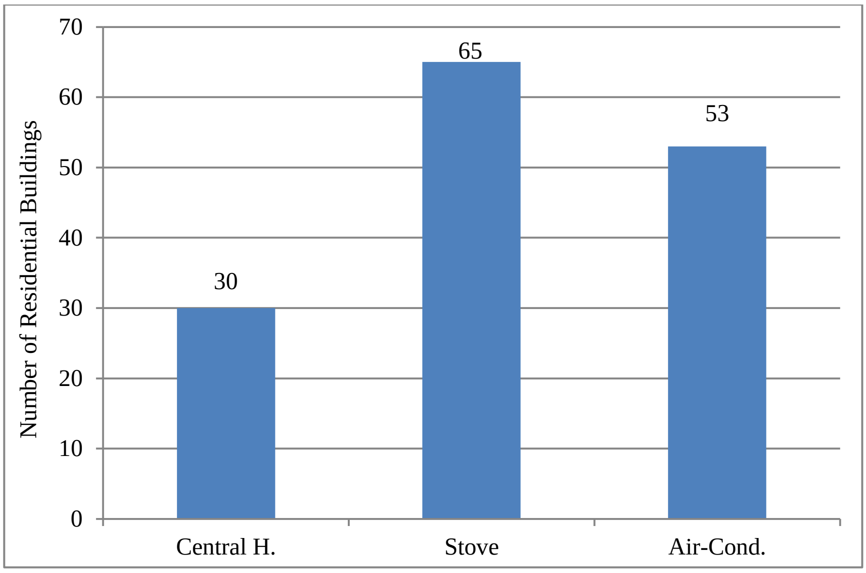


Figure 3.15. The distribution based on heating systems.

3.1.3. Architectural Configuration Indicators

Relevant attributes of the architectural configuration for these buildings are basically zoning status, orientation, floor counts, area/volume ratio, construction year together with other related factors such as designer's professional status and the heating system. In addition to data cited in previous section, relevant areas of architectural configuration calculated from drawings in this study were the following: net-usable floor area inclusive of all internal areas left out from footprint area of all structural elements); external surface area (calculated from external perimeter and the floor to ceiling height of residential building); net-usable common floor area (the exclusive of all residential flats from net-usable floor area); window area (area where high amount of heat would be gained/lost); external wall area and external dimension (width and length).

Architectural configuration indicators were, then, offered to conduct the assessment for the occurrence of significant relations between energy performances and architectural configuration of buildings. These ratios derived from above areas are described below;

Ratio of external surface area to net usable floor area (R1): This is an indicator that reflects form of building by its volume in zoning status. So it is highly related in exterior surface design and in cost efficiency of energy consumption by concerning surfaces.

Ratio of window area to external surface area (R2): This was viewed as the indicator for the equilibrium of solid-void, describing effects of void surfaces to hold minimum heat load.

Ratio of width to length (R3): This is an indicator of plan configuration. The objective here was to determine maximum utility spaces and building surfaces in suggested zoning plan

Ratio of external wall area to net-usable area (R4): This ratio was used to define design efficiency indicator related flexibility, utility and cost efficiency of designed spaces. It is the one of the general design principle, creating minimum wall area and minimum fragment plan scheme.

Ratio of net-usable common floor area to net-usable floor area (R5): Minimum common spaces have great potential on useful spaces to make them usable and generative. It is related in management cost of first and after construction.

Ratio of heating load to external surface area (R6): This ratio is an indicator of the efficiency power of the external surface area in controlling the heating load of the building. It is assumed that higher value for this ratio results in design deficiency, since high amount of energy will be consumed.

Ratio of heating load to net-usable floor area (R7): This ratio shows how sensitive a designer is in order to balance all effective factors in determining the heating load of the building. It determines to what extent this heating load is reflected to the building users.

Ratio of lighting load to net-usable floor area (R8): This ratio is an indicator of the efficiency power of the net-usable floor area in determining the lighting load of the building.

3.2. Analysis of Data

The aim of this study is to determine the energy performance of existing residential buildings in Izmir; and to define relations between their energy performance and their architectural configuration by statistical analyses. Energy performance of case buildings were determined by using a calculation method named as The Standard Assessment Method for Energy Performance of Dwellings (KEP-SDM).

3.2.1. KEP-SDM (KEP-İYTE-ESS Software)

In order to attribute a comprehensive energy efficiency strategy, Turkey has revised its legislations on building energy performance as foreseen in 2002/92/EC, as mentioned in introduction in detail. According to the latest regulation, new buildings and the ones under major renovation are urged to obtain an "Energy Certificate" by utilizing a calculation procedure. The Standard Assessment Method for Energy Performance of Dwellings (KEP-SDM) was developed as a part of this requirement including heating, domestic hot water production and lighting energy consumptions and CO_2 emissions of dwellings only by the Chamber of Mechanical Engineers, Izmir Institute of Technology and Istanbul Technical University in 2008. The method is referred to TS 825 (TS 825, 1999; Ministry of Public Works (Ministry of Environment and Urban Planning), 2008) which provides a framework for the calculation of heating energy demand in buildings and European standard EB ISO 13790 (2008) (Manioğlu, 2008).

According to EN ISO 13790 (2008), there are three classifications of energy performance evaluation methods: seasonal or monthly static method, simple hourly dynamic method (simple dynamic) and detailed hourly dynamic method (full dynamic). KEP-SDM is a monthly method including degree-day correction. The calculation is based on the energy balance considering a range of factors which contribute to energy efficiency, as mentioned below;

- Materials used for construction of the dwelling
- Thermal insulation of the building fabric
- Ventilation characteristics of the dwelling and ventilation equipment
- Efficiency and control of the heating system(s)
- Solar gains through openings of the dwelling
- The fuel used to provide space and water heating, ventilation and lighting
- Renewable energy technologies

The calculation is independent of factors related to the individual characteristics of the household occupying the dwelling, as mentioned below;

- Household size and composition
- Ownership and efficiency of particular domestic electrical appliances
- Individual heating patterns and temperatures.

KEP-SDM defines the dwelling as a single-zone but internal temperature is differentiated according to the living area and the rest. The calculation takes into account thermal bridges in the building unlike thermal mass of the building. Weather data is available in weather database obtained from National Meteorological Institution for each city. The outputs of the method are annual energy consumption per unit floor area (kWh/m^2year) and annual CO_2 emissions per unit floor area (kgCO_2/m^2year). The software adopted in this application was “KEP-IYTE-ESS”. The software determines the energy performance of buildings by using an algorithm including 17 calculation modules, as listed below;

- Dwelling dimensions and internal parameters
- Ventilation rate
- Heat losses
- Specific heat loss and heat loss parameter
- Domestic hot water
- Internal gains
- Solar gains and gain utilization factors
- Mean internal temperature
- Degree-days
- Space heating requirements
- Lighting energy requirements
- Total and primary energy consumption
- CO_2 emissions
- Energy and CO_2 certificates

3.2.2. Statistical Analysis

The data elaboration included ANOVA, t-Test and regression analysis. Factors/ parameters were examined by one-way analysis of variance, as listed below;

i. The phases to define relationship between designer professional status and energy classes are listed below;
   a. Firstly, there were three groups according to designer professional status. These were B. Architect, MSc. Architect and Engineer.
   b. In the second phase, the percentage distribution of energy classes based on designer professional status was set.
   c. In the third phase, the percentage distribution of designer professional status based on energy classes was set graphically.
   d. In the fourth phase, the three groups were tested by single factor ANOVA at a 5% level of significance. (α=0.05)

ii. To define relationship between zoning status and energy classes, similar phases were applied.
   a. Firstly, there were three groups according to zoning status. These were attached/corner attached/intermediate and detached.
   b. In the second phase, the percentage distribution of energy classes based zoning status was set.
   c. In the third phase, the percentage distribution of zoning status based energy classes was set graphically.
   d. In the fourth phase, the three groups were tested by single factor ANOVA at a 5% level of significance. (α=0.05)

iii. Analysis had two phases for significant differences between energy consumption of residential buildings and insulation.
   a. Firstly, there were two groups. These were insulated and uninsulated buildings.
   b. In the second phase, the two groups were tested by single factor ANOVA at a 5% level of significance. (α=0.05)

iv. The phases to define relationship between architectural configuration indicators and energy classes (energy consumption), are listed below;

a. Firstly, there were five groups according to energy classes of the buildings.
b. In the second phase, the distributions of energy classes for each indicator were established. The relations between these five groups were tested by single factor ANOVA at a 5% level of significance. (α=0.05)

- Ratio of external surface area to net usable floor area (R1) and building energy classes
- Ratio of window area to external surface area (R2) and building energy classes
- Ratio of width to length (R3) and building energy classes
- Ratio of external wall area to net-usable area (R4) and building energy classes
- Ratio of net-usable common floor area to net-usable floor area (R5) and building energy classes
- Ratio of heating load to external surface area (R6) and building energy classes
- Ratio of heating load to net-usable floor area (R7) and building energy classes
- Ratio of lighting load to net-usable floor area (R8) and building energy classes

c. In the third phase, efficiency classes were set according to architectural configuration indicators.

v. The relation between architectural configuration indicators to energy consumptions was tested by multiple linear regression analysis.

vi. The percentage distributions of each architectural configuration indicator based on energy consumption were investigated graphically.

vii. Variance analyses of energy consumption distributions based on architectural factors have three phases.

a. In the first phase, window area, ratio of A/V, orientations and floor counts were determined as architectural factors.
b. In the second phase, there were three groups according to window area, three groups according to ratio of A/V, four groups according to orientations and five groups according to floor counts.
c. In the third phase, these groups were tested by single factor ANOVA at a 5% level of significance. (α=0.05)

viii. The relation between recommended design efficiency groups and energy consumption tested by single factor ANOVA and t-test at a 5% level of significance. (α=0.05)

ix. The relation between architectural configuration indicators and architectural factors was tested by single factor ANOVA and t-test at a 5% level of significance. ($\alpha=0.05$) Analyses were repeated for zoning status and designer professional status.

x. Finally, distributions of related indicators based on simplified energy performance groups were set graphically. According to the findings, the effects of design efficiency groups on energy and CO_2 performance were presented in the tables. Design efficiency classes based on indicators and energy performance was compared by chart.

CHAPTER 4

RESULTS

This chapter involves two subsections, namely, general results obtained from analyzes of the energy consumption, CO_2 emissions, energy and CO_2 classes of the buildings by KEP-IYTE-ESS, according to the calculation method, KEP-SDM. Then, statistical analyses determined significant relationships between energy performance of the buildings and architectural configuration variables.

4.1. General Results

4.1.1. Energy Consumption and Energy Classes of Residential Buildings (Based on Years, Municipalities and Heating Systems)

Figure 4.1 indicates the percentage distribution of residential buildings' energy classes based on municipalities. The finding, which showed the 24% of the buildings being in Energy Class B and C were constructed in Balçova, was in accordance with the Building Energy Performance Regulation (2008). The number of residential buildings in Karabağlar and Konak follows respectively. The reason might be most of the buildings in Balçova which were constructed after 2000. Similarly, it is observed that the number of residential buildings constructed in recent years in Karabağlar has increased. The 15% of buildings being in Energy Classes D and E were in Konak. This rate was approximately 10% in other municipalities. The reason might be that construction years of buildings in Konak were between 1960 and 1999. That period was typical, since it was before the implementation of the TS825 and Heat Insulation Regulation (in 2000), and the constructions included old building materials applied with old construction techniques. However, most of the buildings constructed after 2000, in Karabağlar and Balçova, were in Energy Class B, since this period was to be the characteristic for the growth in construction sector due to technological improvements and contemporary building materials (such as well insulated buildings with less air infiltration).

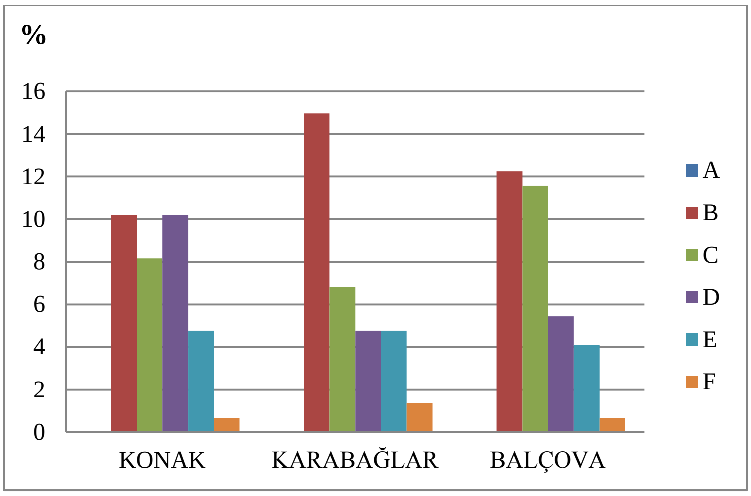
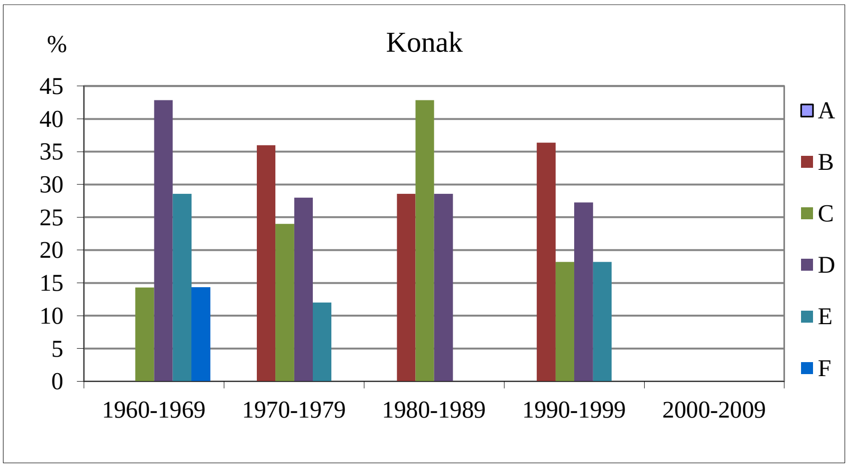


Figure 4.1. The distribution of energy classes of residential buildings according to municipalities.

According to yearly distribution of energy classes based on municipalities, the majority residential buildings constructed in 70's in Konak was in Energy Classes B and C (Figure 4.2). A reasonable cause may be based on the form of the Municipality of Konak with the attached/intermediate buildings in such a densely populated region and consequently, less heat losses from surface areas. Karabağlar and Balçova might have similar situation. However, residential buildings constructed after 2000 in these municipalities were in Energy Classes B and C.



(a)

Figure 4.2. Yearly distribution of energy classes based on municipalities.

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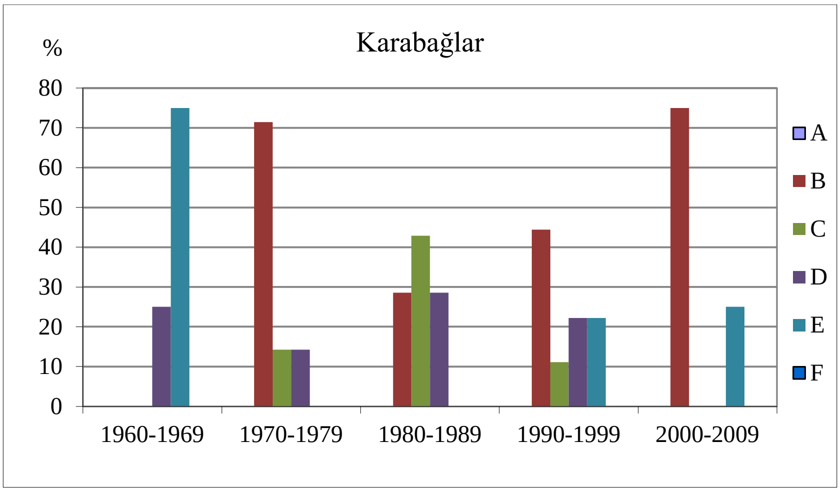
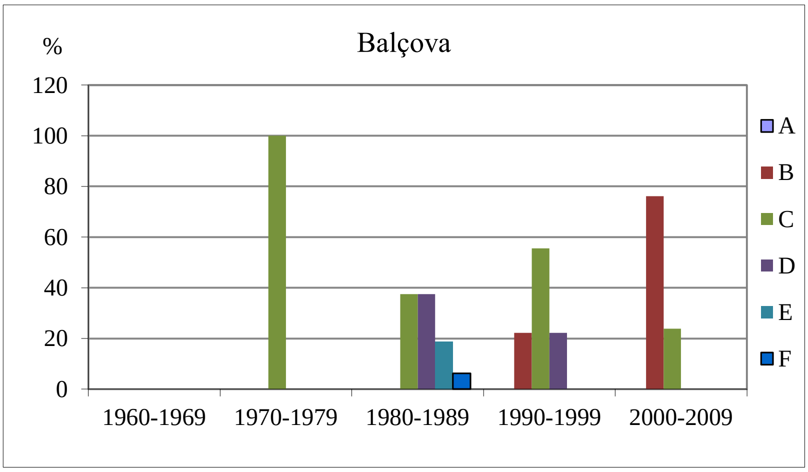


(b)



(c)

Figure 4.2. (cont.)

When heating system are taken into consideration as three different heating systems, it is observed that central heating system was used in 32 % of all investigated buildings which were in Energy Classes B and C (Figure 4.3). Air-conditioning system was used in 9 % of all investigated buildings were in Energy Classes D. Central heating system might be more efficient than other systems and contribute to energy performance. While stove and air conditioning system were accepted as autonomous heating system and heating systems were investigated as two groups, similar results were obtained from repeated analyses (Appendix-I).

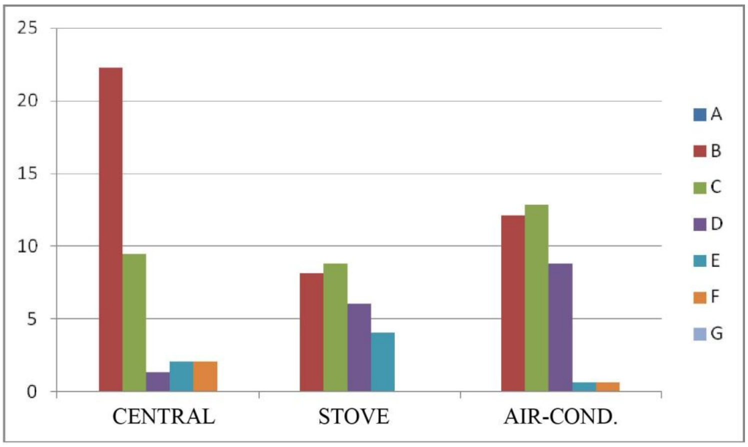


Figure 4.3. The distribution of energy classes of residential buildings according to heating systems.

4.1.2. CO_2 Emissions and CO_2 Classes of Residential Buildings (Based on Years, Municipalities and Heating Systems)

Figure 4.4 presents the percentage distribution of CO_2 classes of residential buildings based on municipalities. The majority of the investigated buildings were in CO_2 Classes G. 28% of residential buildings in Classes G were in Balçova, 25% of them in Konak, and 14% of them in Karabağlar.

The finding confirms that most of the buildings of this study were in CO_2 Classes G and cause environmental pollution enormously. The reason may be using lignite coal in central heating system of old residential buildings, coal in autonomous heating systems and fuel-oil in central heating system of new residential buildings. Also it is known that electrical energy (air conditioning system) is widely used in İzmir. All three types of fuel mentioned above damage the environment. It can be proposed the reduction these fuels and encourage the usage of natural gas.

According to distribution of CO_2 emissions based on municipalities, 28% of all investigated residential buildings were in Balçova and had higher CO_2 emissions. As residential buildings in Balçova are heated by autonomous heating systems (stove), such a result is unavoidable. The rate of residential buildings in Konak was similar as 25% of all of them. 14% of them are located in Balçova with CO_2 class G by widely use of central heating system with fuel-oil (Figure 4.4).

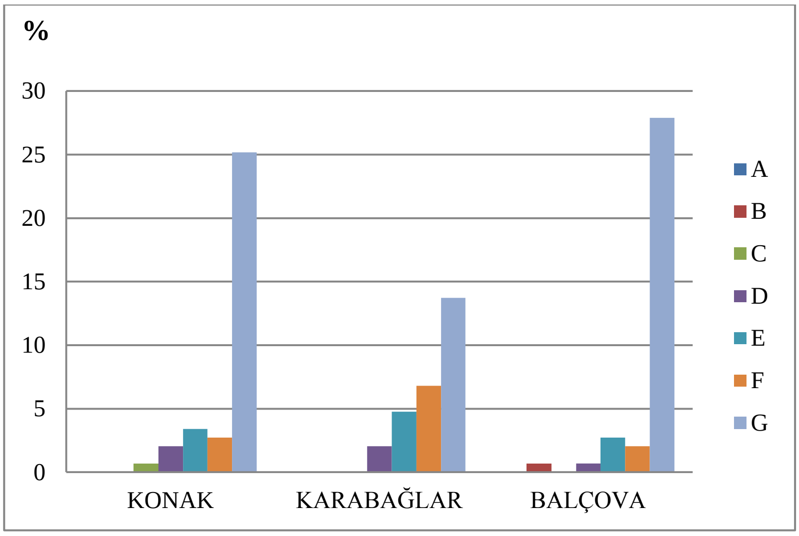


Figure 4.4. The distribution of CO_2 classes of residential buildings according to municipalities.

22% of all investigated buildings which were constructed betwwen 1980 and 1989 were in CO_2 class G. It is considered that fuel type and heating system of this period does not differentiate from other periods (Figure 4.5).

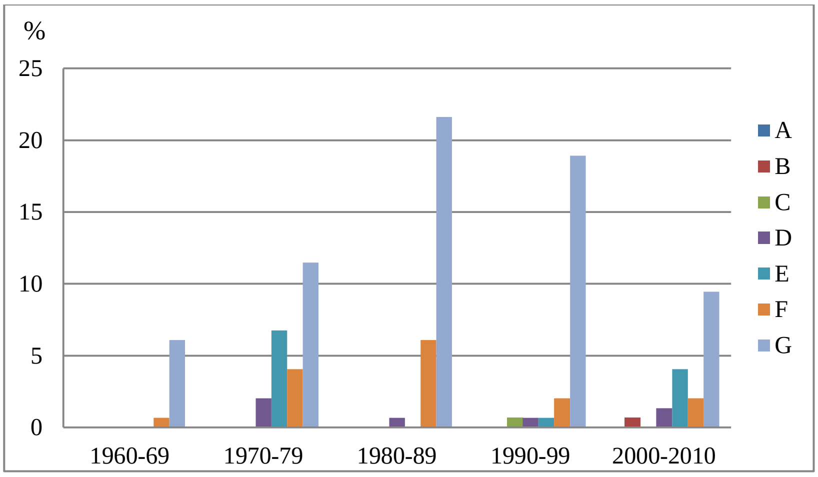


Figure 4.5. Yearly distribution of CO_2 classes.

Analyzing heating systems based on CO_2 classes, it is observed that 31% of all residential buildings have air-conditioning systems and are in CO_2 class G. 29% of them are in the same CO_2 class and are heated by stove. According to this fact that central heating system cause less environmental pollution. 7% of them are in Class G (Figure 4.6).

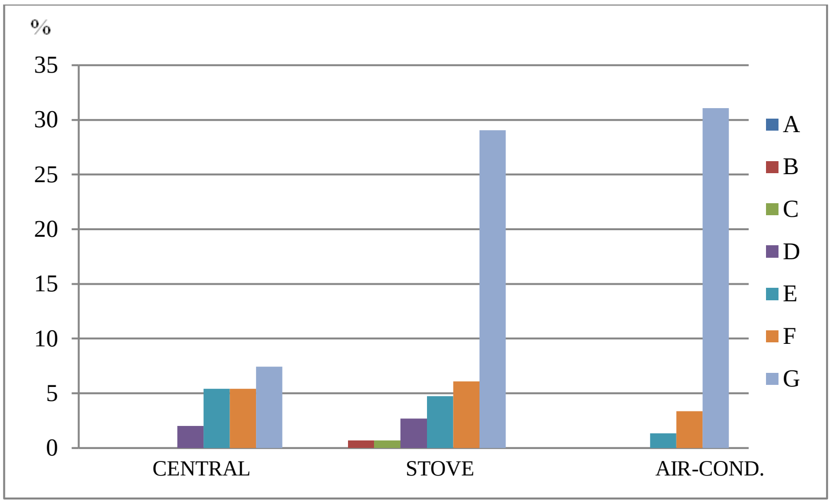


Figure 4.6. The distribution of CO_2 classes of residential buildings according to heating systems.

4.2. Statistical Results

Statistical analysis was performed to compare significant relationships between designers' professional status, plot status, architectural configuration indicators, architectural factors (window area, A / V ratio, orientation, and the number of floors) to energy consumption and energy classes of buildings. Similar analyses were repeated for CO_2 emissions and CO_2 classes. Heating sysems of investigated buildings were defined as central heating system, stove and air-conditioning. Analyses were repeated by using data of calculated energy performance of the buildings. The obtained results were explained below by tables and graphs.

By considering the impact of heating system on energy performance, air-conditioning usage was changed as stove to reduce this effect. All analyses were repeated. The obtained results were explained in the appendix by tables and graphs.

4.2.1. Relationship between Energy Consumption and CO_2 Emissions to Designers' Professional Status

Designers' professional status is the title of the person who has authority to sign the application project. In Turkey, a long-term analysis, different professional title have had building design authority (B. Architect, MSc. Architect, Engineer). According to the fact that designers with different personal status have different solutions, the relationship between energy consumption of buildings and designers' professional status was tested.

To define relationship between energy consumption of buildings and designers' professional status, the percentage distribution of energy classes based on designers' professional status was set (Figure 4.7). 37.4% of all investigated buildings are in Energy Class B. 30% of these projects were designed by architects. Buildings in Energy Class C are 25.8% of the residential buildings. 23% of the projects in Energy Class C were designed by architects, 2% of them by engineers. 22% of the residential buildings are in Energy Class D. Rate of architects as the professional status of buildings in Energy Class D is 22%, rate of MSc. Architects is 2% and rate of engineers is 0.6%. 11.5% of the projects in Energy Class E were designed by architects, 1.3% of them by MSc. Architects. 2.7% of all investigated buildings in Energy class F designed by MSc.architects.

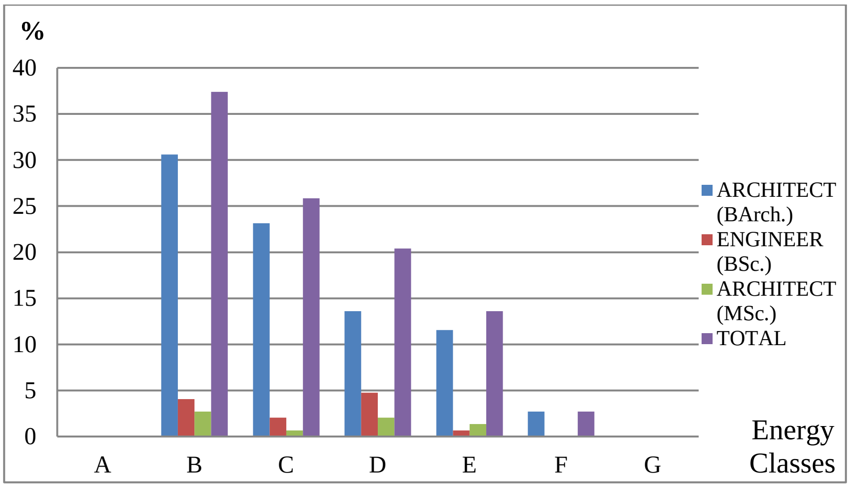


Figure 4.7. The distribution of designers' professional status of residential buildings according to energy classes.

According to the regulation, energy class of newly constructed buildings is required to be C or higher. In this regard, as more than half of the residential buildings analyzed in this study are in Energy Classes C and B, the results are encouraging. However, none of the case buildings were in Energy Class A and none of them benefited from renewable energy resources. This reminds us a question whether the use of such energy sources might upgrade these buildings' energy class from Class B to Class A or not. It is recomended to renovate the buildings in Energy Classes D and E.

Very few buildings in Energy Classes F and none of them in Energy Classes G give similar positive results.

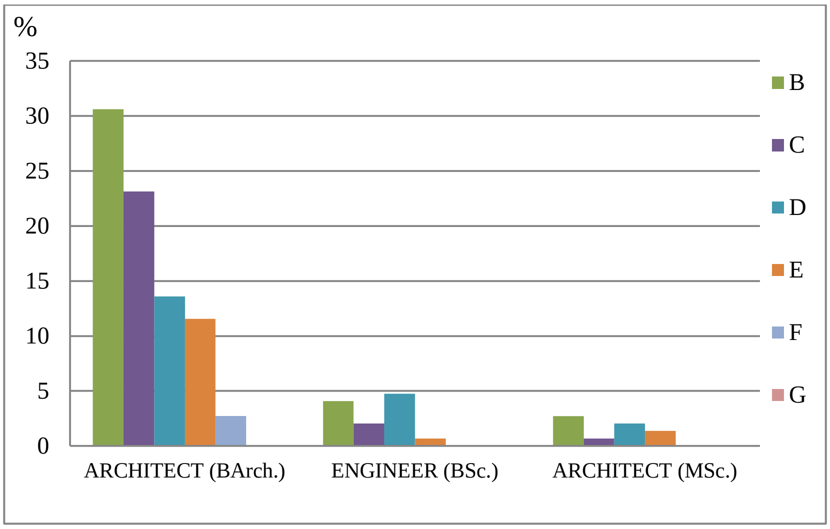


Figure 4.8. The distribution of energy classes of residential buildings according to designers' professional status.

According to findings, most of the residential buildings in İzmir were designed by architects (Figure 4.8). Older buildings were designed by engineers. Figure 4.9 and Figure 4.10 indicate the percentage distribution of CO_2 classes based on designers' professional status.

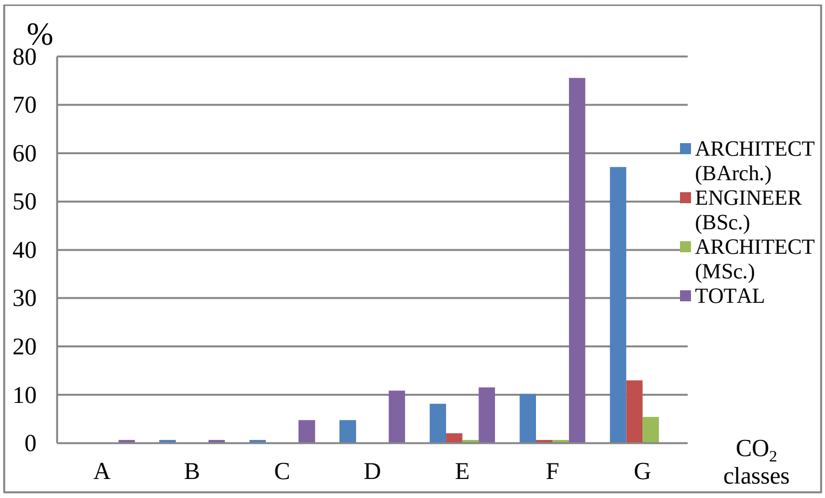


Figure 4.9. The distribution of designers' professional status of residential buildings according to CO2 classes.

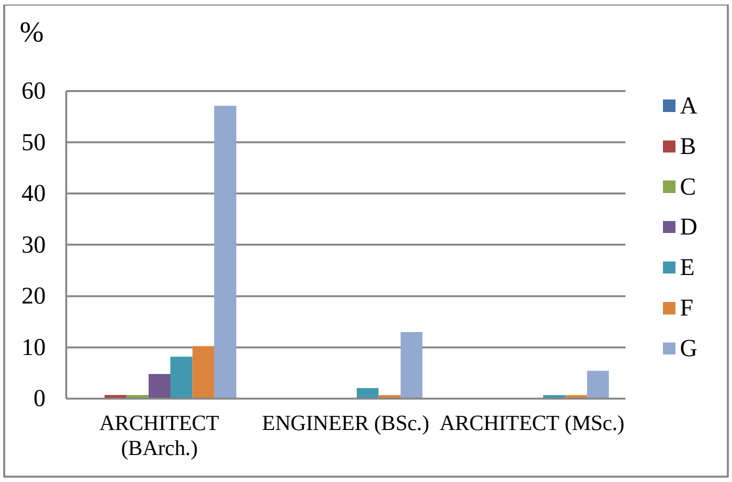


Figure 4.10. The distribution of CO_2 classes of residential buildings according to designers' professional status.

There was no relation between energy consumption of buildings and the professional status i.e. the energy consumption was independent of professional status. The null hypothesis was H_0:τ_i=0; there is no relation among energy consumption according to professional status. Accordingly, H_0 was accepted at 5% level of significance, it was concluded that professional status did not vary significantly according to energy consumption (Table 4.1)

Table 4.1. The distribution of energy consumption regarding designer professional status and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
Architect	120	19585.52	163.21	2099.05		
Engineer	1	2920.56	171.80	1221.10		
Msc. Architect	11	1850.44	168.22	1807.11		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1255.80	2	627.90	0.32	0.72882	3.06
Within Groups	7395.80	145	1982.04			
Total	288651.60	147				

Mean square between groups is 627.90 and mean square within groups is 1982.04. Means of groups are respectively 163.21, 171.80 ve 168.22. F value, 0.32, is less than F critic (α=0.05, 2, 3.056 for 145). Accordingly, H_0 was accepted at 5% level of significance, meaning that professional status did not vary significantly according to energy consumption. It can not be decided that calculated energy consumption of any building in the building groups based on professional status is higher or less than another. Briefly, personal status is not effective on energy comsumption. It is observed that designers who have different personal status do not give different solutions.

4.2.2. Relationship between Energy Consumption and Zoning Status

Zoning status of building determines the relationship of the selected building with buildings in neighboring parcels. Legal regulations were published for design and construction phase of multi-story residential buildings by considering public welfare. Zoning status (attached, detached etc.) which determines the relationship of the selected building with buildings in neighboring parcels affect design phase. In order to understand that energy consumption vary according to zoning status, this factor was selected.In the first phase of the determination of relationship between energy classes and zoning status, the percentage distribution of energy classes based on zoning status (

Figure 4.11, Figure 4.12). 82% of investigated buildings are attached/corner, 44% of them are attached/intermediate and 21% of them are detached. 37% of them are in Energy Class B. 4.7% of these are detached, 19.04% are attached/corner and 13.6% are attached/intermediate. The rate of buildings in Energy Class C is 25.8%. attached/intermediate buildings in class C are 9.5% of them, attached/corner buildings are 13.6% and detached ones are 2.7%. All of the buildings in energy class F are 2.7% of all analyzed buildings. Figure 4.13 and Figure 4.14 present the percentage distribution of CO_2 classes based on zoning status.

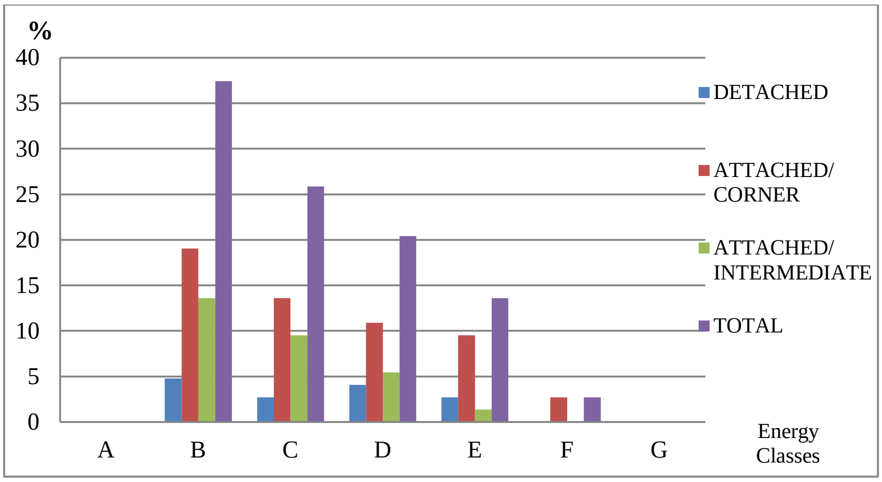
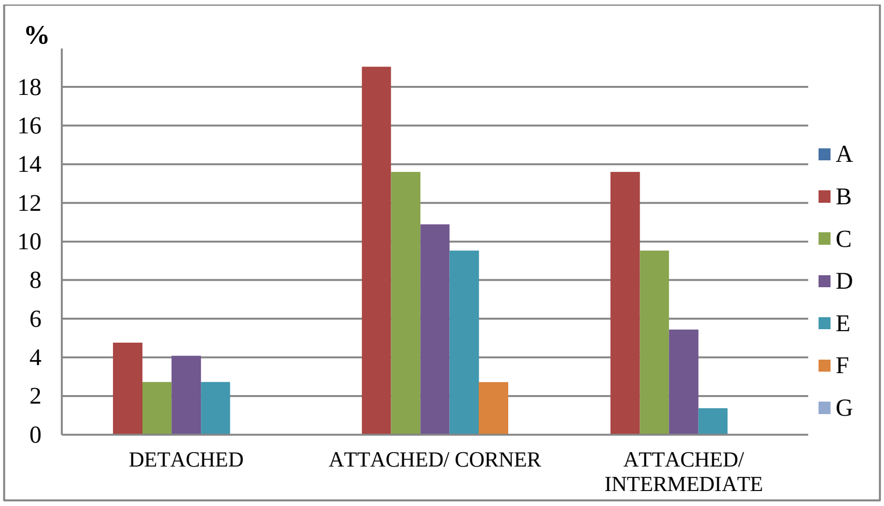
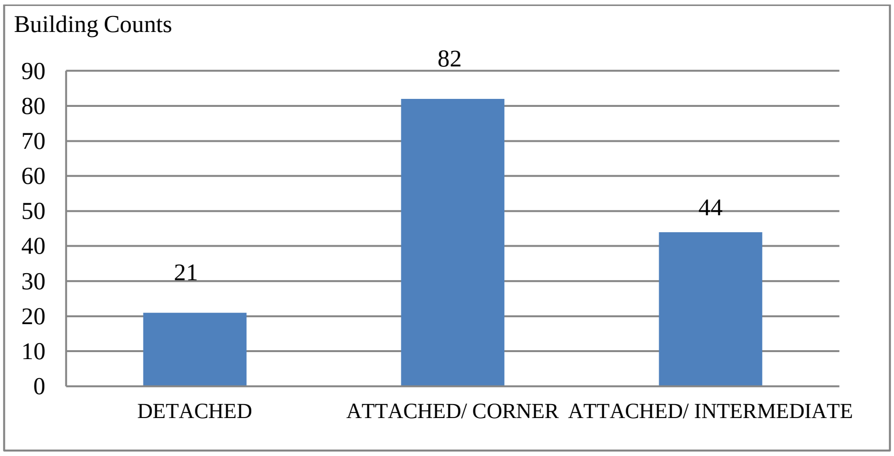


Figure 4.11. The distribution of zoning status of residential buildings according to energy classes.



(a)



(b)

Figure 4.12. The distribution of energy classes of residential buildings according to zoning status (a) and the number of rediential buildings based on zoning status(b).

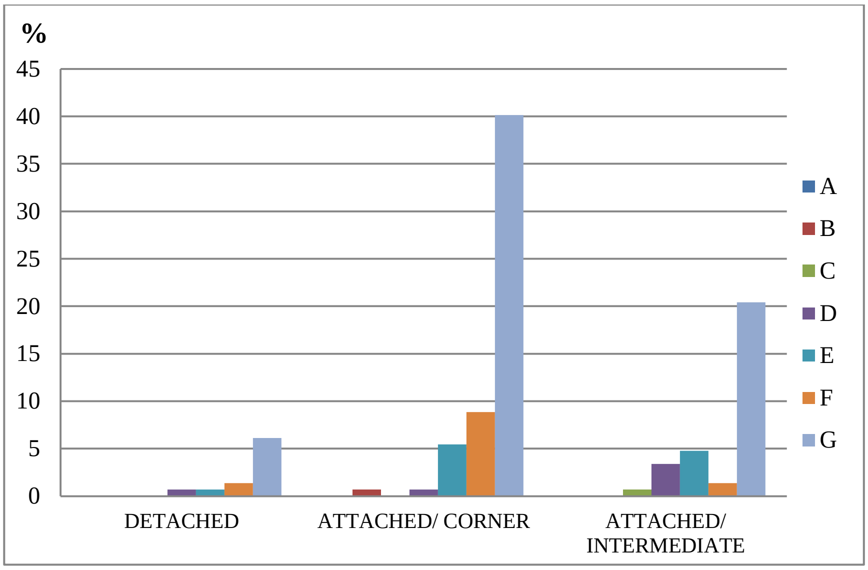


Figure 4.13. The distribution of CO_2 classes of residential buildings according to zoning status.

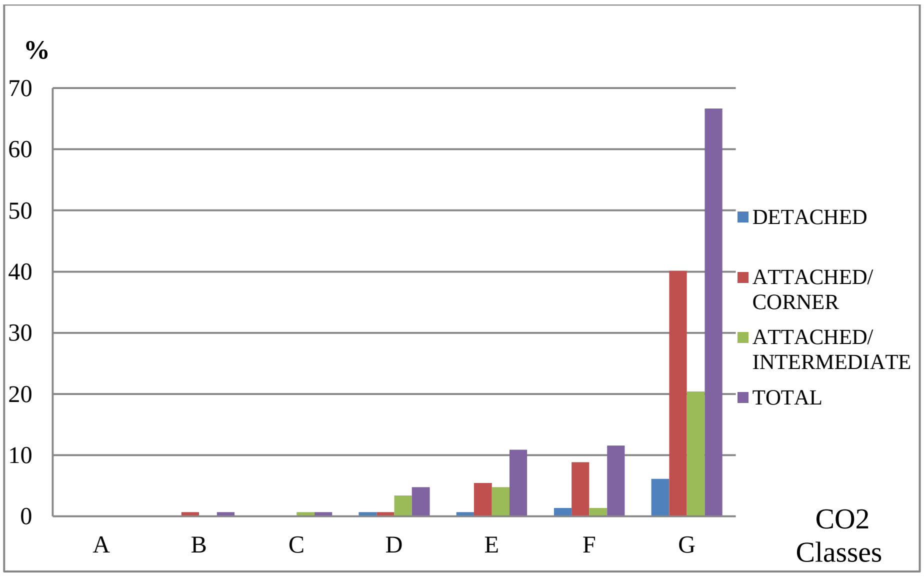


Figure 4.14. The distribution of zoning status of residential buildings according to CO_2 classes.

The null hypothesis constructed for the zoning status (H_0:τi=0; there is no relation among energy consumption according to zoning status) was rejected at 5% level of significance, meaning that there is a relation between zoning status and energy consumption (Table 4.2).

Table 4.2. The distribution of energy consumption based on zoning status and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
Attached	21	3635.54	173.12	2100.54		
Detached/ inter.	45	6717.75	149.28	1350.01		
Detached/ corner	81	13867.57	171.20	2134.85		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	15610.99	2	7805.49	4.13	0.02	3.06
Within Groups	272199.40	144	1890.27			
Total	287810.40	146				

Mean square between groups is 7805.49 and mean square within groups is 1890.27. Means of groups are respectively 173.12, 149.28 and 171.20. According to by one-way analysis of variance, F value, 4.13, is higher than F critic (α=0.05, 2, 3.06 for 144). Accordingly, H_0 was rejected at 5% level of significance. It was concluded that professional status vary significantly according to energy consumption. It can be decided that calculated energy consumption of any building in the building groups based on zoning status is higher or less than another. Briefly, zoning status is effective on energy comsumption. So, it is observed that there is a relationship between two variables.

4.2.3. Relationship between Energy Consumption and Insulation

Many factors affect the building energy performance. Especially, it is considered that insulation which is implemented to building shell is a dominant and effective factor in energy consumption. As KEP-SDM calculates only heating demand of buildings, materials, paticularly insulation, which is implemented to building shell is appropriate for the calculation of energy consumption. Firstly, there were two groups. These were insulated and uninsulated buildings. The relation between energy consumption of residential buildings and insulation is analyzed to prove significant effect of insulation.

(H_0:τi=0; there is no relation among energy consumption according to insulation) According to analysis results, there is a relationship between insulation and energy consumption.

Table 4.3. The distribution of energy consumption based on insulation and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
Insulated	122	20974.55	171.92	1802.49		
Uninsulated	26	3381.96	130.07	1320.74		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	37531.61	1	37531.61	21.82	6.73E-06	3.90
Within Groups	251120.00	146	1720.00			
Total	288651.60	147				

Mean square between groups is 37531.61 and mean square within groups is 1720.00. Means of groups are respectively 171.92 and 130.07. According to by one-way analysis of variance, F value, 21.82, is higher than F critic (α=0.05, 2, 3.90 for 146). Accordingly, H_0 was rejected at 5% level of significance. It was concluded that insulation vary significantly according to energy consumption. It can be decided that calculated energy consumption of any building in the building groups based on insulation is higher or less than another. Briefly, insulation is effective on energy consumption. So, it is observed that there is a relationship between two variables.

4.2.4. Relationship between Energy Consumption and Architectural Configuration Indicators

The relations between architectural configuration indicators, listed below, and building energy classes (A, B, C, D, E, F and G) were comparatively analyzed.

- Ratio of external surface area to net usable floor area (R1)
- Ratio of window area to external surface area (R2)
- Ratio of width to length (R3)
- Ratio of external wall area to net-usable area (R4)
- Ratio of net-usable common floor area to net-usable floor area (R5)
- Ratio of heating load to external surface area (R6)
- Ratio of heating load to net-usable floor area (R7)
- Ratio of lighting load to net-usable floor area (R8)

The statistical analysis was carried out by using the SPSS Version 15 and MS Excel software program. The data elaboration included ANOVA, t-Test and regression analysis.

Firstly, linear regression analysis were conducted in order to understand dependence level of energy consumption ranges, to each architectural configuration indicator. Direction, strength and form of the significant relation between energy consumption ranges and architectural configuration indicators can be eavluate by scatter charts. For instance, dependence level of energy consumption values on ratio of external surface area to net usable floor area (R1) can be observed. Furthermore, significant relationship between two variables can be evaluated. If dependence level is higher and there is a stronger relationship, energy consumption will vary according to changes of indicator.

Regarding regression analysis;

To determine whether the estimated linear regression equation is in accordance with sampling in general , it is essential to specify coefficient of inferential statistical, R2, to applicate F-test to the regression equation. R^2, is a good criterion for the prediction of outputs in further studies of the model. If R^2 is close to zero, the model is not appropriate for collected data. For this reason, the model should change. If R^2 is close to one, most of the changes in the dependent variable (building energy consumption) can be explaned by independent variable (R1-R8) (İkiz et al. 2006; McCall, 1990; SPSS, 2005; Vikipedi, 2011).

R^2 value was calculated as 0.47. In this example, as R^2 value is intermediate value between zero and one, the aptness of the model is in moderate level. 47% of the change in the building energy consumption can be explained by indicators (Table 4.4).

Table 4.4. Summary table of regression model.

Model Summary

Model	*R*	*R Square*	*Adjusted R Square*	*Std. Error of the Estimate*
1	.685(a)	.469	.347	26.901096352121450

a Predictors: (Constant), ratio of lighting load to net-usable floor area, ratio of heating load to net-usable floor area (kcal/h), ratio of window area to external surface area, ratio of width to length, ratio of net-usable common floor area to net-usable floor area , ratio of external surface area to net usable floor area, ratio of heating load to net-usable floor area (kcal/h), ratio of external wall area to net-usable area

Table 4.5. Table of significance of ANOVA.

ANOVA(b)

Model		*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*
1	Regression	22344.778	8	2793.097	3.860	.002(a)
	Residual	25328.414	35	723.669		
	Total	47673.192	43			

a Predictors: (Constant), ratio of lighting load to net-usable floor area, ratio of heating load to net-usable floor area (kcal/h), ratio of window area to external surface area, ratio of width to length, ratio of net-usable common floor area to net-usable floor area , ratio of external surface area to net usable floor area, ratio of heating load to net-usable floor area (kcal/h), ratio of external wall area to net-usable area

b Dependent Variable: energy consumption of the entire building

Value in the significance coloumn of ANOVA table indicates that relation between mentioned variables is statistically significant at the level $p < 0.05$. The equation;

$$F(8,35) = 3,86;\ p < 0,05 \text{ (Table 4.5)} \tag{4.1}$$

Regression coefficients and their significant levels are presented in the table of coefficients. In this analysis, it is observed that relation between energy consumption, ratio of external surface area to net usable floor area (R1) and ratio of lighting load to net-usable floor area (R8) is not statistically significant at the level $p < 0.05$ (Table 4.6). From the data in the table, expected value of building energy consumption can be formulated, as below.

$$\text{Building Energy Consumption} = 93.762 + 97.996\,R1 + 26.454\,R2 - 31.142\,R3 - 0.005\,R6 - 0.078\,R7 + 29.183\,R4 + 33.103\,R5 - 0.22\,R8 \tag{4.2}$$

Table 4.6. Coefficients table of regression model.

Coefficients(a)

Model		*Unstandardized Coefficients*		*Standardized Coefficients*	*t*	*Sig.*
		B	*Std. Error*	*Beta*	*B*	*Std. Error*
1	*(Constant)*	93.762	42.115		2.226	.033
	Ratio of external surface area to net usable floor area (R1)	97.996	57.707	.650	1.698	.098
	Ratio of window area to external surface area (R2)	26.454	69.434	.092	.381	.706
	Ratio of width to length (R3)	- 31.142	29.435	-.162	-1.058	.297
	Ratio of heating load to external surface area (R6)	-.005	.067	-.021	-.077	.939
	Ratio of heating load to net-usable floor area (R7)	-.078	.112	-.191	-.696	.491
	Ratio of external wall area to net-usable area (R4)	29.183	63.721	.189	.458	.650
	Ratio of net-usable common floor area to net-usable floor area (R5)	33.103	143.366	.040	.231	.819
	Ratio of lighting load to net-usable floor area (R8)	-.220	.114	-.340	-1.927	.062

a Dependent Variable: energy consumption of the entire building

The relations between energy classes and architectural configuration indicators were tested by one-way analysis of variance (ANOVA). According to analysis results;

- There is a statistical significant difference between R1 and energy classes.
- There is not a statistical significant difference between R2 and energy classes.
- There is not a statistical significant difference between R3 and energy classes.
- There is a statistical significant differ"rence between R4 and energy classes.
- There is not a statistical significant difference between R5 and energy classes.
- There is not a statistical significant difference between R6 and energy classes.
- There is a statistical significant difference between R7 and energy classes.
- There is not a statistical significant difference between R8 and energy classes.

ANOVA tables for each indicator are presented in Appendix-F.

Furthermore, relation between each architectural configuration indicator and building energy classes was investigated by scatter charts (regression analysis). Scatter charts are presented in Appendix-G. From the multiple regression in the example above, although it was observed that effect of each idicator on energy consumption is low, effect of all indicators is statistically significant. This result shows that all indicators, lighting and heating loads determine building energy consumption by interacting with each other.

4.2.5. Distribution of Energy Consumptions and Analysis of Variance According to Relevant Attributes of the Architectural Configuration

4.2.5.1. Regarding Window area

According to the result which indicates the relation between insulation and energy consumption, the relation between building energy classes and window area was analyzed by selecting uninsulated residential buildings. Then, statistical analysis determined a significant relation between variables mentioned above.

H_0:τ_i=0; there is no relation among energy classes according to window area (Table 4.7).

Table 4.7. The distribution of window area based on building energy classes and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	36	11543.33	320.65	19602.49		
C	34	8023.15	235.97	19778.42		
D	30	7491.43	249.71	16174.91		
E	18	4636.43	257.58	17825.03		
F	4	1556.94	389.24	44737.51		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	202907.10	4	50726.77	2.64	0.037	2.44
Within Groups	2245086.00	117	19188.77			
Total	2447993.00	121				

Mean square between groups is 50726.77 and mean square within groups is 19188.77. Means of groups are respectively 320.65, 235.97, 249.71, 257.58and 389.24. According to by one-way analysis of variance, F value, 2.64, is higher than F critic

(α=0.05, 4, 2.44 for 117). Accordingly, H_0 was rejected at 5% level of significance, meaning that window area vary significantly according to energy classes. Briefly, it is observed that window area is effective on energy classes.

4.2.5.2. Regarding Ratio of A/V

Ratio of A/V is effective on heating energy consumption of buildings. The relation between Ratio of A/V and building energy classes was analyzed. There is not a significant relation between variables mentioned above.

H_0:τ_i=0; there is no relation among energy classes according to ratio of A/V (Table 4.8).

Table 4.8. The distribution of A/V ratio based on building energy classes and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	36	15.54	0.43	0.021006		
C	34	13.49	0.39	0.012512		
D	30	11.36	0.38	0.000554		
E	18	7.01	0.39	0.002290		
F	4	1.52	0.38	0.000665		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.05	4	0.01	1.29	0.27	2.44
Within Groups	1.21	117	0.01			
Total	1.26	121				

Mean square between groups is 0.01 and mean square within groups is 0.01. Means of groups are respectively 0.43, 0.39, 0.38, 0.39 and 0.38. According to by one-way analysis of variance, F value, 1.29, is less than Fcritic (α=0.05, 4, 2.44 for 117). Accordingly, H_0 was accepted at 5% level of significance. It was concluded that ratio of A/V did not vary significantly according to energy classes. Briefly, it is observed that ratio of A/V does not affect energy classes.

4.2.5.3. Regarding Orientations

Building orientation is important for façades to utilizing advantages of solar light and heat. So, energy consumption may be reduced and interior comfort conditions may be improved. The statistical analysis was carried out for significant differences between orientations and energy consumption of buildings. Since calculations for energy performance included the solar gain attained from window area and coefficients to calculate solar gain changes according to orientation. Based on analysis, there is a significant relation between variables mentioned above.

H_0:τ_i=0; there is no relation among energy consumption according to orientations (Table 4.9).

Table 4.9. The distribution of orientations based on building energy classes and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
N/E/W	7	1037.45	148.21	5786.48		
S/E/W	16	2813.83	175.86	3763.16		
S/N	45	7008.94	155.75	2268.77		
S/N/E, S/N/E, S/N/W/E	45	8268.23	183.74	1971.54		
W/E	13	1901.08	146.24	2975.59		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	27631.32	4	6907.83	2.66	0.03557!	2.44
Within Groups	313447.40	121	2590.47			
Total	341078.70	125				

Mean square between groups is 6907.83 and mean square within groups is 2590.47. Means of groups are respectively 148.21, 175.86, 155.75, 183.74 and 146.24. According to by one-way analysis of variance, F value, 2.66, is higher than F critic (α=0.05, 4, 2.44 for 117). Accordingly, H_0 was rejected at 5% level of significance. It was concluded that orientations vary significantly according to energy classes. The effect of orientations on energy classes was observed.

4.2.5.4. Regarding Floor Counts

Significant differences between floor counts and energy consumption of buildings were tested by the statistical analysis. Based on analysis, there is not a significant relation between variables mentioned above.

H_0:τ_i=0; there is no relation among energy consumption according to floor counts (Table 4.10).

Table 4.10. The distribution of energy consumptions based on floor counts and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
5-6	47	8319.18	177.00	1753.72		
7-8-9	64	10155.33	158.67	1827.43		
10-11	37	5882.01	158.97	2283.45		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10647.93	2	5323.96	2.77	0.065547	3.05
Within Groups	278003.70	145	1917.27			
Total	288651.63	147				

Mean square between groups is 5323.96 and mean square within groups is 1917.27. Means of groups are respectively 177.00, 158.67 and 158.97. According to by one-way analysis of variance, F value, 2.77, is less than Fcritic (α=0.05, 2, 3.05 for 145). Accordingly, H_0 was accepted at 5% level of significance, meaning that orientations do not vary significantly according to energy classes. Briefly, it is observed that orientations are not effective on energy classes.

4.2.6. Analysis of Energy Consumptions Based on Proposed Design Efficiency Classes

According to analysis results, there is a statistical significant relation between some indicators and energy classes. In the next stage of the study, design efficiency groups was established and the relation between these groups and energy consumption were tested by one-way analysis of variance (ANOVA). By this way, there were residential building groups based on their energy performance. These were high-performance, mid-performance and low performance residential buildings. According to analysis results;

- There is a statistical significant difference between groups of R1 and energy consumption.
- There is a statistical significant difference between groups of R2 and energy consumption.
- There is no statistical significant difference between groups of R3 and energy consumption.
- There is no statistical significant difference between groups of R4 and energy consumption.
- There is no statistical significant difference between groups of R5 and energy consumption.
- There is a statistical significant difference between groups of R6 and energy consumption
- There is no statistical significant difference between groups of R7 and energy consumption
- There is no statistical significant difference between groups of R8 and energy consumption.

Firstly, 4 groups were established according to ratio of external surface area to net usable floor area. As seen in the Figure 4.15, R1 value of lowest performance group (1) is between 0.022 and 0.288, value of low performance group (2) is between 0.289 and 0.554, value of mid performance group (3) is between 0.555 and 0.82, and value of high performance group (4) is over 0.83. These four groups were tested by single factor ANOVA at a 5% level of significance. (α=0.05)

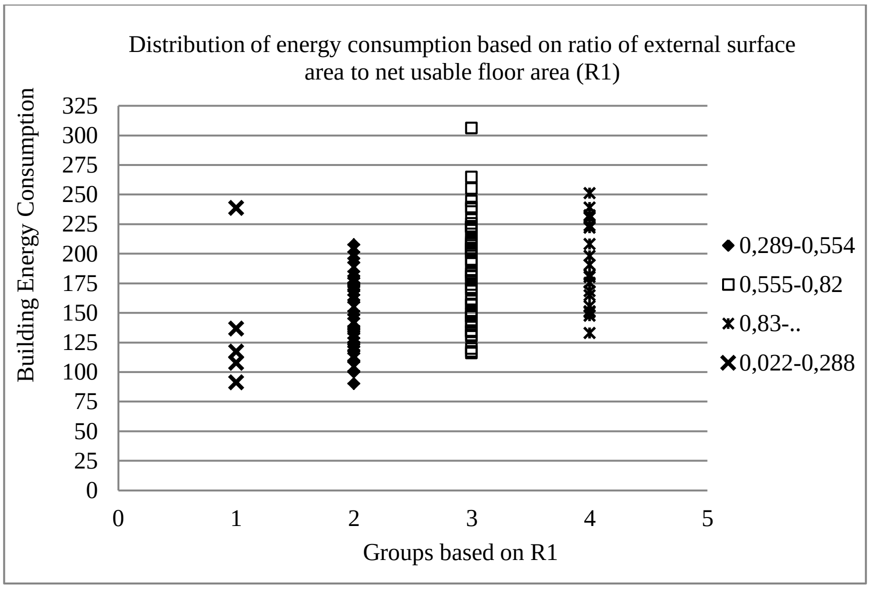


Figure 4.15. The distribution of energy consumption based on ratio of external surface area to net usable floor area (R1).

H_0:τ_i=0; there is no relation among ratio of external surface area to net usable floor area (R1) according to energy consumption (Table 4.11)

Table 4.11. The distribution of energy consumptions based on ratio of external surface area to net usable floor area (R1) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.022-0.288	5	691.65	138.33	3407.70		
0.289-0.554	39	5709.13	146.38	977.45		
0.555-0.82	59	10970.85	185.94	1652.060		
0.83-..	19	3602.91	189.62	1270.98		
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	48629.93	3	16209.98	11.28	1.45E-06	2.68
Within Groups	169471.60	118	1436.20			
Total	218101.50	121				

Regarding analysis result, mean square between groups is 16209.98 and mean square within groups is 1436.20. Means of groups are respectively 138.33, 146.38, 185.94 and 189.62. According to by one-way analysis of variance, F value, 11.28, is less than F critic (α=0.05, 3, 2.68 for 118). Accordingly, H_0 was rejected at 5% level of significance, meaning that ratios of external surface area to net usable floor area (R1) vary significantly according to energy consumption. Briefly, it is observed that while ratio of external surface area to net usable floor area increases, energy consumption increases. Energy consumption of low performance groups is lower than high performance groups.

Groups for other indicators and analysis results are presented in Appendix-H. Despite of previous analysis result, there is a statistical significant relation between ratio of window area to external surface area (R2) and energy classes. Three groups were established according to ratio of external surface area to net usable floor area and distribution of energy consumption for each groups were determined. R2 value of low performance group is between 0.104 and 0.237, value of mid performance group is between 0.238 and 0.36, and value of high performance groups is between 0.37 and 0.6. Analyzing energy consumption of each group, energy consumption increase when ratio of window area increase. According to analysis result, it is observed that there is a significant differences between energy consumptions and ratio of window area. Energy consumption of building (energy consumption for heating) with low ratio of window area is higher than building with high ratio of window area. This finding supports the idea in the first phase of the study, increase of solar gain and reduction of heating load by window area.

According to R3, four groups and distribution for each group were established. R3 value of low performance groups is between 0.213 and 0.408, value of mid performance groups is between 0.409 and 0.604, value of high performance groups is between 0.604 and 0.8, and value of highest performance groups is over 0.8. It is observed that while ratio of length to width increases, energy consumption increases. According to analysis result, there is not a significant relation between energy consumptions and ratio of length to width.

According to R4, four groups and distribution for each group were established. R4 value of low performance groups is between 0.013 and 0.32, value of mid performance groups is between 0.409 and 0.604, value of high performance groups is between 0.604 and 0.94, and value of highest performance groups is over 0.94. According to analysis result, there is not a significant relation between energy consumptions and ratio of external wall area to net-usable area.

According to R5, three groups and distribution for each group were established. R5 value of low performance groups is between 0.004 and 0.045, value of mid performance groups is between 0.046 and 0.086, and value of high performance groups is between 0.087 and 0.127. According to analysis result, there is not a significant relation between energy consumptions and ratio of net-usable common floor area to net-usable floor area.

According to R6, two groups and distribution for each group were established. R6 value of low performance groups is between 5.76 and 198.53, and value of mid performance groups is between 198.54 and 391.31. According to analysis result, there is a significant relation between energy consumptions and ratio of heating load to external surface area.

According to R7, two groups and distribution for each group were established. R7 value of low performance groups is between 5.04 and 69.5, value of mid performance groups is between 69.6 and 133.96. According to analysis result, there is not a significant relation between energy consumptions and ratio of heating load to net-usable floor area.

According to R8, three groups and distribution for each group were established. R8 value of low performance groups is between 0.14 and 47.15, value of mid performance groups is between 47.16 and 94.15, and value of high performance groups is between 94.16 and 141.15. According to analysis result, there is not a significant relation between energy consumptions and ratio of lighting load to net-usable floor area.

4.2.7. Repeated Analyses Based on Changes in Heating System

The results presented above, were obtained from the buildings with central heating system, stove and air-conditioning. Considering the impact of heating system on energy efficiency, heating systems of 53 buildings, which were air-conditioning, were changed to stove to reveal the impact of the other architectural parameters. Analyses were repeated. These results are presented Appendix I and J. Findings from two different conditions were summarized in Table 4.12. In general, although there was not a major change in the results, it was observed some significant differences. For example, changing air-conditioning to stove, energy consumption values decreased and energy classes increased. According to repeated analysis, there was a statistical relation between ratio of external wall area to net-usable area (R4) and ratio of lighting load to net-usable floor area (R8) to energy consumption. The significant effect ratio of A/V on energy consumption occured in the second condition. Other results were similar to the previous ones.

Table 4.12. Regarding heating system, relation between energy consumption and class and architectural indicators.

	central heating, stove, air-cond. (first condition)		*central heating, stove, (second condition)*	
	Energy class	*Energy consumption*	*Energy class*	*Energy consumption*
Designer personal status	×	o	×	o
Zoning status	√	o	√	o
Ratio of external surface area to net usable floor area (R1)	√	√	o	√
Ratio of window area to external surface area (R2)	×	√	o	√
Ratio of length to width (R3)	×	×	o	×
Ratio of external wall area to net-usable area (R4)	√	×	o	√
Ratio of net-usable common floor area to net-usable floor area (R5)	×	×	o	×
Ratio of heating load to external surface area (R6)	×	√	o	√
Ratio of heating load to net-usable floor area (R7)	√	×	o	×
Ratio of lighting load to net-usable floor area (R8)	×	×	o	√
Insulation	o	√	o	√
Window area	o	√	×	√
Ratio of A/V	o	×	×	√
Orientation	o	√	o	√
Floor counts	o	×	o	×

4.2.8. Effect of Proposed Design Efficiency Classes and Architectural Factors to Energy and CO_2 Performance

Figure 4.16 indicates the distribution of building energy performance based on R1 ad R2. Groups in the basis of energy performance were high-performance building which are in Energy Class A and B, mid-performance-building in C and D, and low performance-building in E, F, G. Most of the high-energy-performance buildings have R1 value, between 0.2 and 0.5, and R2 value, between 0.3 and 0.6. between these values, there are few low-energy performance buildings. Buildings with R1 value between 0.5 and 0.8 and R2 between 0.2 and 0.4 represent all performance groups. The majority of the buildings with R1 value over 0.8 and R2 between 0.1 and 0.3 are in the low-mid-performance groups.

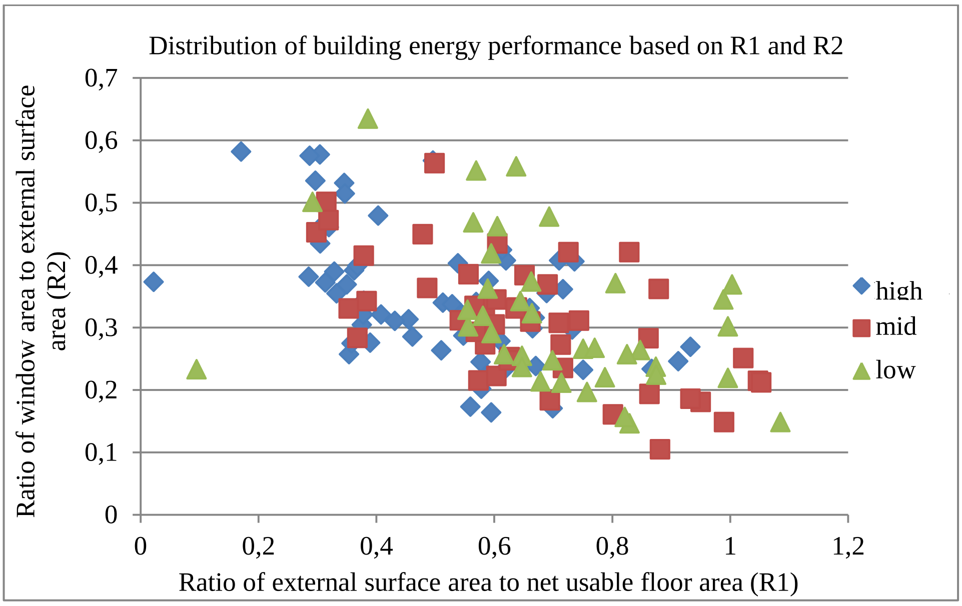


Figure 4.16. The distribution of building energy performance based on R1 and R2.

Figure 4.17 indicates the distribution of building energy performance based on R6 ad R8. Groups in the basis of energy performance were high performance building which are in Energy Class A and B, mid-performance-building in C and D, and low-performance-building in E,F,G. Most of the high energy performance buildings have R6 value, between 100 and 300, and R8 value, between 0 and 40. The majority of the buildings with R6 value less than 100 and R8 between 120 and 160 are in the high performance groups.

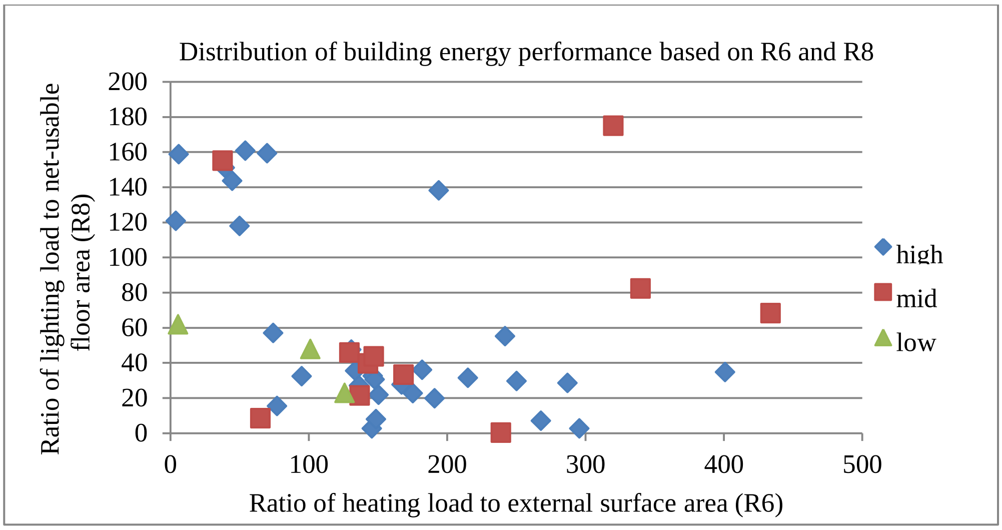


Figure 4.17. The distribution of building energy performance based on R6 and R8.

Figure 4.18 indicates the distribution of building energy performance based on A/V and R2. Groups in the basis of energy performace were high performance building which are in Energy Class A and B, mid performance building in C and D, and low performance building in E,F,G. Most of the low-energy performane buildings have R2 value, lower than 0.25, and A/V value, between 0.3 and 0.4. The majority of the buildings with R2 value between 0.25 and 0.4 are in the mid-low performance groups. It is observed that values of R2 and A/V increase energy performances of builings also increase.

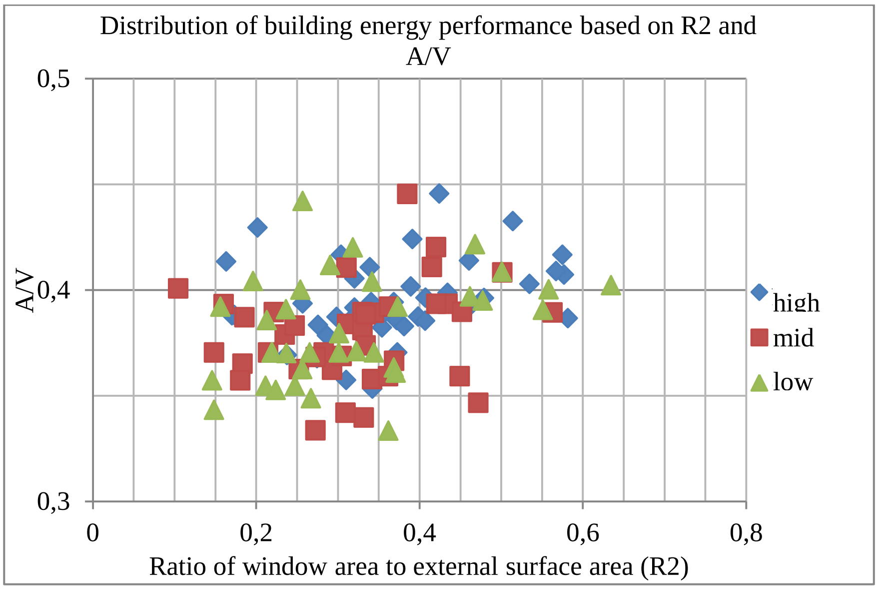


Figure 4.18. The distribution of building energy performance based on R2 and A/V.

There are three design efficiency groups based on architectural configuration indicators. Relations between these groups and energy consumption, and CO_2 emissions were analyzed (Table 4.13)

- Regarding R1, energy and CO_2 performances of buildings in low design efficiency groups (eg. R1<0,554) are high.
- Regarding R2, energy and CO_2 performances of buildings in high design efficiency groups (eg. R2>0.36) are high.
- Regarding R4, energy and CO_2 performances of buildings in low design efficiency groups (eg. R4<0.63) are high.
- Regarding R6, energy and CO_2 performances of buildings in high design efficiency groups (eg. R6>198) are high.
- Regarding R8, energy and CO_2 performances of buildings in high design efficiency groups (eg. R8>94) are high.

Table 4.13. Effects of architectural configuration indicators on energy consumption and CO_2 emissions (central heating and autonomous systems).

Architectural configuration indicators	*Design efficiency classes*		*Energy consumption*	*CO_2 emissions*
			active	*active*
Ratio of external surface area to net usable floor area (R1)	0.022-0.288	lowest	When R1 increases, energy and CO_2 performance decrease. High R1 efficiency class cause low energy performance.	
	0.289-0.554	low		
	0.555-0.82	mid		
	0.83-..	high		
			active	*active*
Ratio of window area to external surface area (R2)	0.104-0.237	low	When R2 increases, energy and CO_2 performance increase. High R2 efficiency class cause high energy performance.	
	0.238-0.36	mid		
	0.37-0.6	high		
			inactive	*inactive*
Ratio of length to width (R3)	0.2125-0.408	lowest	Higher/Lower levels of R3 may not result in lower/higher energy and CO_2 performance, relatively	
	0.409-0.604	low		
	0.605-0.8	mid		
	0.8-..	high		
			active	*active*
Ratio of external wall area to net-usable area (R4)	0,013815-0,32	lowest	When R4 increases, energy and CO_2 performance decrease. High R4 efficiency class cause low energy performance.	
	0,33-0,63	low		
	0,64-0,94	mid		
	0,95-…	high		
			inactive	*active*
Ratio of net-usable common floor area to net-usable floor area (R5)	0.00408-0.045	lowest	Higher/Lower levels of R5 may not result in lower/higher energy performance, relatively High R5 efficiency class cause low CO_2 performance.	
	0.046-0.086	low		
	0.087-0.127	mid		
	0.128-	high		
			active	*active*
Ratio of heating load to external surface area (R6)	5.76-198.53	low	When R6 increases, energy and CO_2 performance increase. High R6 efficiency class cause high energy performance.	
	198.54-391.31	mid		
			inactive	*inactive*
Ratio of heating load to net-usable floor area (R7)	5.04-69.50	low	Higher/Lower levels of R7 may not result in lower/higher energy and CO_2 performance, relatively.	
	69.6-133. 96	mid		
			active	*active*
Ratio of lighting load to net-usable floor area (R8)	0.14-47.159	low	When R4 increases, energy and CO_2 performance decrease. High R4 efficiency class cause low energy performance.	
	47.16-94.15	mid		
	94.15-141.15	high		

Considering architectural factors, when ratio of A/V increases CO_2 performance decrease. It is observed that increase in the orientation efficiency performance cause decline in energy and CO_2 performance. Energy performance of the building increase with the ratio of A/V lower than 0.4 and orientation of North/South or East/West.

Table 4.14. Effects of architectural factors on energy consumption ad CO_2 emissions (central heating and autonomous systems).

Architectural Factors	*Design efficiency classes*		*Energy consumption*	*CO_2 emissions*
			active	*active*
Ratio of A/V	0.33-0.373	low	When A/V increases, energy and CO_2 performance decrease. High A/V efficiency class cause low energy performance.	
	0.374-0.416	mid		
	0.417..	high		
			active	*active*
Orientations	N/S	lowest	When efficiency performance of orientation increases, energy and CO_2 performance decrease. High orientation efficiency class cause low energy performance.	
	E/W	low		
	N/E/W	mid		
	(N/S/W, N/S/E, N/S/W/E)	high		
	S/W/E	highest		
			inactive	*active*
Floor counts	5 and 6	lowest	Higher/Lower levels of floor counts may not result in lower/higher energy and CO_2 performance, relatively High efficiency class of floor counts cause high CO_2 performance.	
	7 and 8	low		
	9	mid		
	10 and 11	high		

CHAPTER 5

DISCUSSION

This chapter involves three subsections, namely, energy and CO_2 performance of investigated residential buildings, relation between architectural factors and architectural configuration indicators to energy consumption, and regarding method and energy performance estimation.

5.1. Energy and CO_2 Performance of Investigated Residential Buildings

Energy performance of case buildings were determined by using a calculation method named as The Standard Assessment Method for Energy Performance of Dwellings (KEP-SDM). Energy consumption of whole residential building and all residential units in the building can calculate by this assessment method.

It is clear in literature, also in the calculation phase of energy consumptions that there are many factors (architectural, mechanical, usage etc.) affecting building energy performance. Although impact of each single factor is little, impact of all factors together is high on the final performance. This situation should be considered before renovation.

According to findings of this study, the majority of the buildings were in energy Class B and C; and in CO_2 Class G. The former is considered to be favorable, since this situation is appropriate according to the circumstances that required by the Turkish energy performance legislation. However, the latter was a result which depicts that low performance due to the type of fuel used in these buildings caused environment pollution extensively. It is proposed that heating systems used in residential buildings should be modernized, central heating systems should become prevalent and type of fuels should be changed.

Findings depicted the energy consumption of residential buildings were dependent of their construction year. As regards construction years of the buildings, energy performances of constructed residential buildings in Balçova and Karabağlar (in

Energy Classes B and C) after 2000 are higher than other buildings. This period is after the implementation of the TS825 and Heat Insulation Regulation (in 2000). So, insulation impacts very strongly energy consumption. Energy consumptions of residential buildings in Konak are higher due to their construction years, between 1960 and 1999, and included old building materials applied with old construction techniques

Heating system with fuel type is a significant factor for energy and CO_2 performance. Heating systems of investigated buildings were defined as central heating system, stove and air-conditioning. Especially, energy performances of the buildings with central heating system are higher than buildings with other systems. CO_2 emissions of the buildings air-conditioning system differentiate clearly from others. By considering the impact of heating system on energy performance, air-conditioning usage was changed as stove to reduce this effect. Energy consumptions of the buildings were re-calculated. To improve energy performance of the buildings, it is proposed that central heating systems should become prevalent and air-conditioning usage should reduce.

Energy and CO_2 performance of the buildings were calculated by considering current used heating systems and fuel types. It is mentioned in the literature that passive methods and renewable energy sources (sun, wind etc.) reduce the active energy consumption of buildings. Developing calculation methods, passive heating systems and usage of renewable energy resources should be taken notice.

5.2. Relation between Architectural Factors and Architectural Configuration Indicators to Energy Consumption

This study aims to determine the significant relation between architectural configuration and energy performance of residential buildings in İzmir, by utilizing architectural drawings. It is considered that this would provide architects and engineers opportunity to encounter such problems in the design stage and give chance to propose precautions before the construction process and before the buildings are in use.

In this context, the impact of architectural factors, such as zoning status, orientation, A/V ratio, window ratio, floor counts to energy consumption have been determined. Zoning status is an effective factor in energy performance of the buildings. Exterior surface area which cause heat loses is related with zoning status, eg.

attached/corner, detached etc. The orientation has a relation with solar gain and the amount of exterior surfaces. As supposed from previous studies (Al-Sallal, 1998; İnanıcı and Demirbilek, 2000; Numan et al., 1999; Persson et al.,2006; Smeds and Wall, 2007; Wall, 2006), its meaningful and significant impact on energy consumption was observed. This can be explained in relation to the buildings' zoning status and the area of exterior surfaces. Since buildings which were attached/intermediate displayed the best energy performance are located in north/south and east/west direction. The fact that two mean values for two groups of orientation are very close to each other and their variances differ from each other can be explained by two factors. First, their zoning statuses are similar. Second, the orientation has not much influence on energy performance as the amount of exterior surfaces has. For example, three groups of corner buildings--north/south/west, north/south/east, and south/west/east--, showed similar variances and average values of energy consumption. North orientation seemed to have minor influence on energy performance, as all groups above involve the impact of south orientation.

Although the energy consumption was dependent of A/V ratio, the values of energy performance were not raising constantly as the external surface area per volume increase, despite our expectations. Two situations may point out such an anomaly. One is that the construction period of the former can include recent years, when buildings with high quality and energy efficient building materials of high u-values have been mostly built. The other one is that the impact of zoning status can eliminate the high amount of energy loss through the exterior surfaces, even though the building is taller or larger. This finding shows that insulation is applied to the buildings constructed after 2000 and it has statistical significant impact on energy performance. It is observed that insulation on the building envelope is important to reduce heat losses. It can be said that implemented regulations are necessary and beneficial.

Window indicator, here, is not only the source of solar gain but also the determinant of the solid-void to balance heat load. Studies (İnanıcı and Demirbilek, 2000; Persson et al., 2006) define the window area as an energy efficient design component. Window area influenced heating loads very slightly, but affected cooling loads dominantly in those. Increasing 50% of window size and insulation thickness give out better results than only increasing. Window area ratio of investigated buildings varies between 0.1 and 0.6. According to statistical analysis result, although there is not a significant difference between energy classes and ratio of window area, it is observed that ratio of window area has a significant relation with energy consumption.

As regards the floor counts in a building, there seemed to be no significant association with the energy consumption; however, the intermediate floors had better energy performance than the ground and the top floors. As the arithmetic mean of energy consumption values of all floors determine the building's total performance, it became clear that the higher the building, the lower the energy consumption.

Configuration indicators analyzed in this study may be used to obtain optimum design values regarding both the construction and the maintanence costs. Thus, buildings and spaces serving for various functions may be designed and constructed much more efficiently and much cheaply than they are now. For the active indicator it can be mentioned the energy performance groups of the buildings, such as; low, mid, and high efficiency groups. Such findings are valid for the residential buildings, in İzmir, that were the subject of this study. Further investigations including larger set of sample buildings may be carried out to be comprehensive and to make generalizations throughout the country.

This study analyzed most prevailing architectural factors and approximate relationships were defined between configuration indicators and energy performance. Increase of ratio of external surface area to net usable floor area (R1) cause inefficiency in terms of design and increase construction cost and operating cost. In addition, it increases A/V ratio and external surface area causing heat losses. So energy performance of building will reduce due to increase of heating energy load. Besides, increase of window area relatively external surface disturbs solid-void balance in terms of design and cause inefficiency by increasing construction cost and operating costs. Well designed façade with balance of solid-void display better energy performance.

Dealing with the indicators in this aspect is essential to realize problems before construction and operation and solve these. This study sought to classify such threshold values to indicate the relationship between the level of configuration indicators and the energy performance of residential buildings in the population of investigated ones.

5.3. Regarding Method and Energy Performance Estimation

Implementing energy legislations in regard to the European Directive may deserve a certain time, as it needs experience and constant standards. To determine the energy performance of residential buildings is a multi-variable and complex task, involving architectural, mechanical, constructional, economic and legal issues. In relation to above issues, legislation in Turkey requires information about the evaluation of energy performance of existing buildings which will be renovated, not only new buildings. This study was a preparation for this task and dealt with the architectural attributes and their relation with the energy performance. Further detailed investigations are prerequisites to obtain an extensive knowledge and prevailing technical and sociological information to finalize such energy policies.

This study analyzed the energy performance of buildings by KEP-IYTE-ESS, according to the calculation method, KEP-SDM. There are several suggestions for this method. The cooling load which was out of the method of this study should also be taken into the consideration in further studies. Considering energy performance, positive effects of renewable energy sources and passive system should be calculate by similar programs and make occupants be encouraged to use While proposing calculation methodologies to determine energy performance of dwellings, integrated simulation programs may be developed to visualize such architectural issues in the design stage. Energy behavior of the building would be analyzed by such supportive tools. It would be possible, then, to observe the impact of all variables together. This would guide professionals about several deficiencies of energy consumption caused by the interior spaces, building elements or design decisions. This would provide them opportunity to take measurements before the construction process. Better architectural solutions may be proposed to design buildings with better energy performance, and buildings whose construction and management facilities were comparatively less costly than previous solutions.

Data obtained from architectural drawings and method of KEP-SDM, were analyzed statistically in this study. According to result of these analyses, there are significant relationships between building energy classes and architectural configuration indicators. Design efficiency groups were set according to architectural configuration indicators. The relation between recommended design efficiency groups and energy consumption tested by single factor ANOVA and t-test at a 5% level of significance. (α=0.05) By this way, there were residential building groups based on their energy performance. These were high-performance, mid-performance and low performance residential buildings.

Firstly, four groups were established according to ratio of external surface area to net usable floor area. There is a statistical significant difference between groups of R1 and energy consumption. It is observed that while ratio of external surface area to net usable floor area increases, energy consumption increases. Energy consumption of low performance groups is lower than high performance groups. Three efficiency groups (low: 0.104- 0.237, mid: 0.238-0.36, high: 0.37-0.6) were established according to ratio of external surface area to net usable floor area (R2). As previous analysis result, there is a statistical significant relation between groups of R2 and energy consumption. Analyzing energy consumption of each group, energy consumption increases when ratio of window area increases. This finding supports the idea in the first phase of the study, increase of solar gain and reduction of heating load by window area. Similar result is observed from analysis of ratio of heating load to external surface area (R6). According to four groups established by ratio of width to length (R4), when R4 increases, energy consumption increase. According to analysis result, there is not a significant relation between energy consumptions and ratio of external wall area to net-usable area. There is not any significant relation for other indicators. However, as regards of repeated analyses based on heating systems, there are significant relations between ratio of external wall area to net-usable area (R4), ratio of lighting load to net-usable floor area (R8) and energy consumption.

Distribution of the residential buildings classified according to energy performances (high performance, A and B; mid performances, C and D; and low performance E, F, G classes) were investigated based on active indicators. Energy performances of the buildings in certain limit values can be evaluated. For instance, most of the high-energy-performance buildings have R1 value. The majority of the buildings with R1 value over 0.8 and R2 between 0.1 and 0.3 are in the low-mid-performance groups.

In the final stage, architectural configuration indicators were classified as low, mid and high design efficiency groups. Relations between these groups and energy consumption, and CO_2 emissions were analyzed. Regarding R1 an R4, energy and CO_2

performances of buildings in low design efficiency groups are high. Regarding R6 and R8, energy and CO_2 performances of buildings in high design efficiency groups are high. Proposed threshold values of indicators classes may indicate levels of energy performance. Regarding A/V ratio and orientation, energy and CO_2 performances of buildings in high design efficiency groups are low.

As a logical consequence, an existing residential building whose external surface area to net usable floor area is below 0.55, ratio of window area to external surface area is above 0.36 and ratio of external wall area to net-usable area is below 0.60, and which has an attached/intermediate zoning status, central heating system and insulation might resemble a high performance building as regard to energy efficiency.

CHAPTER 6

CONCLUSION

This study included analysis of architectural and mechanical drawings of residential buildings in İzmir to bring out their energy performance for all professionals in construction and energy sector as well as for researchers in relevant disciplines. By utilizing these drawings, it is aimed to offer certain significant values of architectural indicators be used in the architectural design process. By this, it is thought that high-performance-residential buildings would be attained and early-precautions against high energy consumptions would be taken in the design stage. In addition, the methodology aimed to determine the relation between architectural configuration attributes and the energy performance. According to findings of architectural issues analyzed in this study, energy conservation strategies should be enhanced in regarding indicators. In addition to the most prevailing variables, such as, zoning status, external surface area and A/V ratios, other variables, namely, orientation, floor counts in a building, aspect ratio, heating system and configuration indicators should be taken into consideration when constructing energy strategies for new buildings and renovating existing buildings.

As regards the impact of architectural considerations on energy performance, the best energy performed-buildings were attached/intermediate which are located in North/South and East/West. Both groups of buildings due to orientation had similar average energy consumption. Two outcomes may explain this situation. First, apart from obtaining solar gain, orientation is interconnected such design parameters as the zoning status and the area of wall surface. Second, however, its impact on energy performance is not as effective as the area of wall surface has. This study exhibited such a clue that interactions between variables and their total effect on the energy performance should be taken into consideration.

Regarding energy consumptions of investigated residential buildings of İzmir some recommendations might be developed. It was observed that existing residential buildings were in CO_2 class G and heating system with fuel type is a significant factor for energy and CO_2 performance. According to this, heating systems used in residential buildings should be modernized, central heating systems should become prevalent and type of fuels should be changed. Therefore, energy consumption values and CO_2 emissions of buildings might be reduced. Besides, insulation has significant impact on energy performance based on statistical analysis. By application of insulation, energy performance of existing buildings might be improved.

Regarding energy classes of the buildings analyzed in this study, it was observed that none of them used renewable energy resources and had maximum energy performance, i.e. in Energy Class A. Additionally architectural issues, renewable energy resources should be taken notice and make occupants be encouraged to use. Better architectural solutions may be proposed to design buildings with better energy performance, and buildings whose construction and management facilities were comparatively less costly than previous solutions.

To determine the energy performance of residential buildings is a multi-variable and complex task, involving architectural, mechanical, constructional, economic and legal issues. In relation to above issues, legislation in Turkey requires information about the evaluation of energy performance of existing buildings which will be renovated, not only new buildings. This study was a preparation for this task and dealt with the architectural attributes and their relation with the energy performance. As this study was specific to the sample buildings constructed in İzmir, it would be possible to apply this to the other cities of Turkey to generalize the findings throughout the country in future. Such further detailed investigations are prerequisites to obtain an extensive knowledge and prevailing technical and sociological information to finalize such energy policies.

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APPENDIX A

PERMISSION LETTER SEND TO MUNICIPALITIES

T.C. İZMİR YÜKSEK TEKNOLOJİ ENSTİTÜSÜ

Mimarlık Fakültesi

KONU: Bilgi ve belge temini

İZMİR …. Ocak 2010

İZMİR …………… BELEDİYE BAŞKANLIĞI,
(İMAR VE ŞEHİRCİLİK MÜDÜRLÜĞÜNE)

Fakültemiz Mimarlık Bölümü Öğretim Görevlisi Dr. Zehra Tuğçe KAZANASMAZ; **“Çok katlı konut yapılarının enerji performansları ile tasarım verimlilik göstergeleri arasındaki ilişkinin belirlenmesi”** konulu TÜBİTAK araştırma projesi kapsamında farklı semtlerden toplam yaklaşık 150-200 adet ve kat adedi 1-13 arasında değişen farklı mimari özellikteki konut yapıları seçileceğinden, söz konusu konutların;

Isı yalıtım değerlerinin ve ısıtma yüklerinin tespiti için tesisat projelerine ve ısı yalıtım bilgilerine,

Mimari özelliklerin (yön, pencere alanı, dış duvar alanı v.b.) tespiti için de mimari projeleri ile ilgili her türlü yazılı, görsel, ve dijital belgeyi inceleme çalışmalarına ihtiyaç duymaktadır.

Adı geçen öğretim görevlimize incelemeleri sırasında arşivinizden faydalanabilmesi için gerekli yardım ve kolaylığın gösterilmesi konusunda ilgilerinizi bekler, gereğini müsaadelerinize arz ederim.

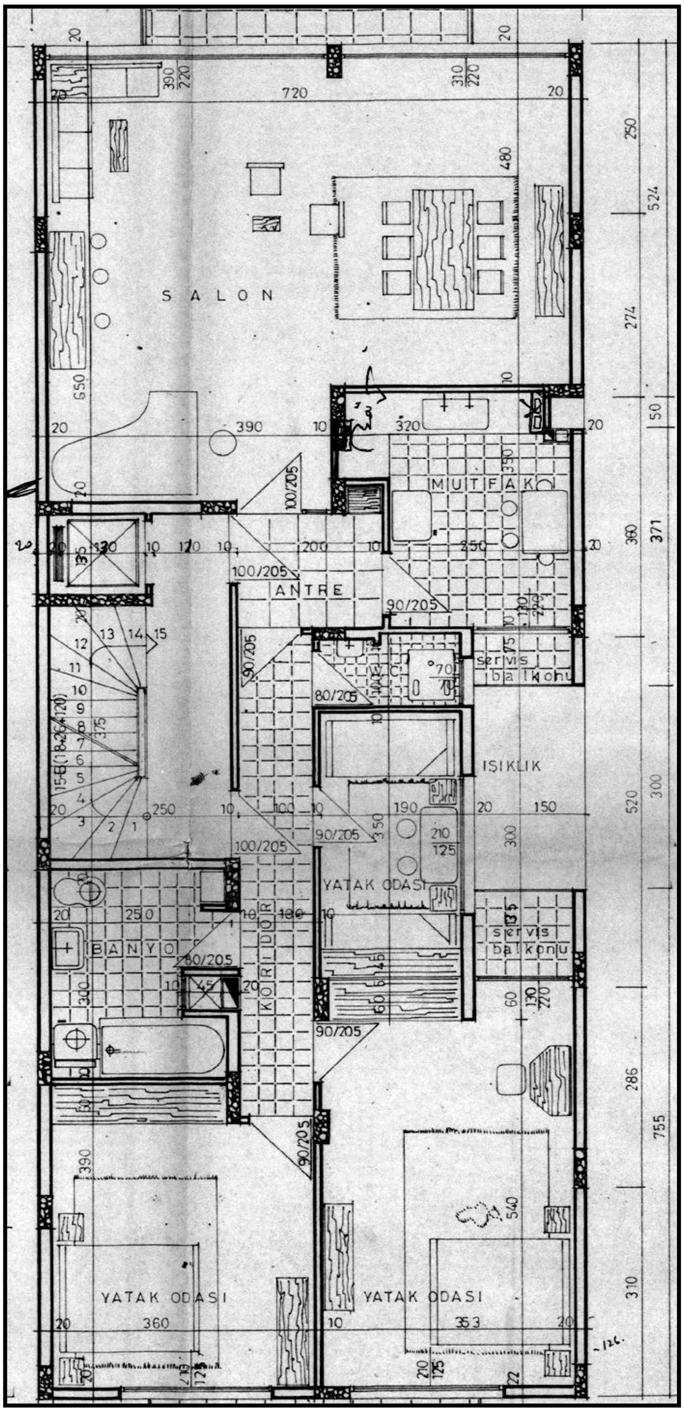
imza

DEKAN

Gülbahçe Köyü 35430 Urla/İzmir Tel: (232) 7507000 Faks: (232)7507012
E-posta: mimfak@iyte.edu.tr Elektronik Ağ:www.iyte.edu.tr

APPENDIX B

ARCHITECTURAL PROJECT EXAMPLE OF RESIDENTIAL BUILDING



APPENDIX C

DATA OF RESIDENTIAL UNITS FROM ARCHITECTURAL PROJECTS (KONAK)

	Total net usable floor volume of res. units	*Floor Height*	*wall area*									*window area*									*Total useful area of residentail units*
KONAK 01			N	S	E	W	NE	NW	SE	SW	Total	N	S	E	W	NE	NW	SE	SW	Total	
	868.617	2.7																			
Z01(D)	171.909	2.7	18.78	22.8	0	0	0	0	0	0	41.58	3	2.76	0	0	0	0	0	0	5.76	63.67
101	174.177	2.7	14.5	19.78	0	0	0	0	0	0	34.28	4.28	3.02	0	0	0	0	0	0	7.3	64.51
201	174.177	2.7	14.5	19.78	0	0	0	0	0	0	34.28	4.28	3.02	0	0	0	0	0	0	7.3	64.51
301	174.177	2.7	14.5	19.78	0	0	0	0	0	0	34.28	4.28	3.02	0	0	0	0	0	0	7.3	64.51
401	174.177	2.7	14.5	19.78	0	0	0	0	0	0	34.28	4.28	3.02	0	0	0	0	0	0	7.3	64.51
																					321.71
KONAK 02			N	S	E	W	NE	NW	SE	SW	Total	N	S	E	W	NE	NW	SE	SW	Total	
	3748.788	2.7																			
B02	319.41	2.7	0	26.46	0	3.5	40.64	15.1	0	26.65	112.35	0	0	0	1.92	0	2.44	0	4.8	9.16	118.3
B01	319.41	2.7	0	26.46	0	3.5	40.64	15.1	0	26.65	112.35	0	0	0	1.92	0	2.44	0	4.8	9.16	118.3
Z01	284.256	2.7	0	23.58	0	3.5	40.64	15.1	0	28.84	111.66	0	2.88	0	1.92	0	2.44	0	1.8	9.04	105.28
101	353.214	2.7	0	20.3	0	3	40.64	15.1	0	27.08	106.12	0	6.16	0	2.44	0	2.44	0	2.88	13.92	130.82
201	353.214	2.7	0	20.3	0	3	40.64	15.1	0	27.08	106.12	0	6.16	0	2.44	0	2.44	0	2.88	13.92	130.82
301	353.214	2.7	0	20.3	0	3	40.64	15.1	0	27.08	106.12	0	6.16	0	2.44	0	2.44	0	2.88	13.92	130.82
401	353.214	2.7	0	20.3	0	3	40.64	15.1	0	27.08	106.12	0	6.16	0	2.44	0	2.44	0	2.88	13.92	130.82
501	353.214	2.7	0	20.3	0	3	40.64	15.1	0	27.08	106.12	0	6.16	0	2.44	0	2.44	0	2.88	13.92	130.82
601	353.214	2.7	0	20.3	0	3	40.64	15.1	0	27.08	106.12	0	6.16	0	2.44	0	2.44	0	2.88	13.92	130.82
701	353.214	2.7	0	20.3	0	3	40.64	15.1	0	27.08	106.12	0	6.16	0	2.44	0	2.44	0	2.88	13.92	130.82
801	353.214	2.7	0	20.3	0	3	40.64	15.1	0	27.08	106.12	0	6.16	0	2.44	0	2.44	0	2.88	13.92	130.82
																					1388.44

	building width	*building height*	*floor area*	*net usable floor area*	*net-usable common*	*net usable area*	*external surface area*	*Transmittance coefficient of external surface*		*heating load of building*	*electrical lighting load (W)*	*Average of net usable area*
KONAK 01								**wall**	**window**			
	6.55	12.5	81.875	321.71	37.39	359.1	213.66	1.43	2.8		11750	80.4275
KONAK 02								**wall**	**window**			
	8.5	15.05	137	1388.4	113.5	1501.9	1324.04	1.37	2.8	86371	12780	126.1
KONAK 03								**wall**	**window**			
	14.22	20	675	1553.9	106.6	1704.3	544.78	1.43	2.8	42052	26050	106.512
KONAK 04								**wall**	**window**			
	14.1	20	284	1973.4	119.12	2092.5	732.91	1.43	2.8	128523	47420	140.957857
KONAK 05								**wall**	**window**			
	8.9	22	186	0	29.6	1256.4	1364	1.37	2.8	138125	59980	104.666667
KONAK 06								**wall**	**window**			
	9	22	198	2498.7	70.84	2569.5	438.88	1.43	2.8	335887	59205	146.98
KONAK 07								**wall**	**window**			
	11	18	198	1841.4	69.55	1910.9	1043.38	1.48	3	174464	52740	102.298333
KONAK 08								**wall**	**window**			
	7.6	20	152	1017	104.645	1121.6	389.07	1.43	6	70845	40270	112.999444
KONAK 09								**wall**	**window**			
	9	20.9	190	1260.5	78.73	1339.3	384.57	1.43	2.8		13715	90.0378571
KONAK 10								**wall**	**window**			
	15.02	23.55	233	1536.8	84.33	1621.2	489.91	1.37	2.8	118207		109.773

	City	Municipality	District	Island	Parcel	Cons. Year	residential unit	office	floor counts	Zoning status	orientation	prof. Status
KONAK 01	İZMİR	KONAK	M.ALİ AKMAN	6591	8	1983	5	0	5	Attached /Int.	N/S	B.Arch.
KONAK 02	İZMİR	KONAK	GÖZTEPE	6430	6	1986	11	0	2+9	Attached /corner	N/W/E	B.Arch.
KONAK 03	İZMİR	KONAK	GÖZTEPE	834	24	1990	15	3	8	Attached /Int.	NW/SE	B.Arch.
KONAK 04	İZMİR	KONAK	GÖZTEPE	834	23	1990	14	1	8	Attached /Int.	NW/SE	B.Arch.
KONAK 05	İZMİR	KONAK	ÜÇKUYULAR	6259	12	1977	18	0	9+1	Attached /Int.	S	B.Arch.
KONAK 06	İZMİR	KONAK	ÜÇKUYULAR	6259	13	1975	17	2	9+1	Attached /Int.	N/S	B.Arch.
KONAK 07	İZMİR	KONAK	ÜÇKUYULAR	6259	20	1976	18	3	9+1	Attached /corner	N/S/W	B.Arch.
KONAK 08	İZMİR	KONAK	1. KARANTİNA	635	11	1972	9	0	9	Attached /Int.	NW/SE	B.Arch.
KONAK 09	İZMİR	KONAK	ÜÇKUYULAR	6259	15	1984	14	4	9+1	Attached /Int.	N/S	B.Arch.
KONAK 10	İZMİR	KONAK	1. KARANTİNA	734	17	1976	14	3	8	Attached /Int.	NE/SW	B.Arch.

APPENDIX D

DATA FROM KEP-SDM (K:KONAK)

	internal gain W	Total solar gain W	Heating Demand of volume kWh	electrical lighting consumption kWh	total energy consumption of volume(main heating cons.) (kWh/year)	annual total primary energy consumption (kWh/yıl)	annual total primary energy consumption per m2 (kWh/m2 year)	Annual total CO2 emission (kgCO2/yıl)	annual total CO2 emission per m2 kgCO2/m2 yıl	energy class	CO2 emission class
K 01											
Z01(D)	318.35	424.29	2139.44	592.13	4578.41	9954.65	156.34	6142.01905	96.46	C	G
101	322.55	394.76	2596.63	599.94	5556.8	10979.4	170.19	6774.2898	105.01	C	G
201	322.55	391.66	2609.37	599.94	5584.06	11006.67	170.61	6791.11539	105.27	C	G
301	322.55	391.66	2609.37	599.94	5584.06	11006.67	170.61	6791.11539	105.27	C	G
401	322.55	443.24	4229.01	599.94	9050.77	14472.67	224.34	8929.63739	138.42	E	G
						57420.06		**35428.177**			
								building energy consumption	**Building CO_2 emission**	**building energy class**	**building CO_2 emission class**
								159.899916	**98.6582485**	**C**	**G**
K 02											
B02	591.5	775.3752	12087.59	1100.19	19898.04	27579.52	233.13	9101.2416	76.93	E	G
B01	591.5	746.61	9108.79	1100.19	14944.48	22675.96	191.68	7483.0668	63.25	D	G
Z01	526.4	681.03	4354.96	979.41	7168.93	14295.89	135.78	4717.6437	44.81	B	E
101	530.6	759.6	9177.96	986.51	15108.35	22271.86	209.87	7349.7138	69.26	D	G
201	654.1	916.11	8965.55	1216.62	14758.68	22952.08	175.44	7574.1864	57.90	C	G
301	654.1	916.11	8965.55	1216.62	14758.68	22952.08	175.44	7574.1864	57.90	C	G
401	654.1	916.11	8965.55	1216.62	14758.68	22952.08	175.44	7574.1864	57.90	C	G
501	654.1	916.11	8965.55	1216.62	14758.68	22952.08	175.44	7574.1864	57.90	C	G
601	654.1	916.11	8965.55	1216.62	14758.68	22952.08	175.44	7574.1864	57.90	C	G
701	654.1	916.11	8965.55	1216.62	14758.68	22952.08	175.44	7574.1864	57.90	C	G
801	654.1	918.41	9080.08	1216.62	14947.21	23140.62	176.88	7636.4046	58.37	C	G
						247676.33		**81733.1889**			
								building energy consumption	**building CO_2 emission**	**building energy class**	**building CO_2 emission class**
								164.904277	**54.4184115**	**C**	**G**

APPENDIX E

ARCHITECTURAL CONFIGURATION INDICATORS (BA: BALÇOVA, KA: KARABAĞLAR, K: KONAK)

	Ratio of external surface area to net usable floor area (R1)	*Ratio of window area to external surface area (R2)*	*Ratio of width to length (R3)*	*Ratio of external wall area to net-usable area (R4)*	*Ratio of net-usable common floor area to net-usable floor area (R5)*	*Ratio of heating load to external surface area (R6)*	*Ratio of heating load to net-usable floor area (R7)*	*Ratio of lighting load to net-usable floor area (R8)*
BA 01	0.875	0.224	0.548	0.679	0.064	5.762	5.040	61.916
BA 10	0.864	0.194	0.879	0.696	0.053	129.357	111.710	45.718
BA 12	0.639	0.249	0.705	0.480	0.100	44.765	28.582	143.629
BA 13	1.048	0.215	0.667	0.823	0.145	320.292	335.516	174.904
BA 22	0.736	0.406	0.659	0.438	0.120	3.954	2.912	120.744
BA 26	0.933	0.269	0.983	0.682	0.066	39.384	36.748	151.114
BA 28	0.538	0.403	0.651	0.321	0.130	6.159	3.317	158.603
BA 30	1.023	0.251	0.647	0.766	0.159	433.714	443.554	68.290
BA 45	0.710	0.308	0.819	0.491	0.063	37.932	26.923	155.010
KA 06	0.305	0.577	0.800	0.153	0.063	287.043	87.456	28.471
KA 07	0.314	0.372	0.386	0.197	0.045	241.948	75.887	55.190
KA 09	0.548	0.287	0.598	0.391	0.044	133.543	73.172	35.327
KA 17	0.671	0.238	0.600	0.511	0.052	95.033	63.745	32.364
KA 32	0.557	0.385	0.542	0.342	0.050	136.925	76.244	21.458
KA 37	0.879	0.362	0.812	0.326	0.071	143.009	125.749	39.587
KA 40	0.660	0.331	0.812	0.282	0.068	150.492	99.377	21.753
KA 46	0.404	0.479	0.517	0.224	0.052	250.192	100.980	29.547
K 02	0.882	0.105	0.565	0.789	0.076	65.233	57.506	8.509
K 03	0.320	0.461	0.711	0.172	0.063	77.191	24.674	15.285
K 04	0.350	0.369	0.705	0.221	0.057	175.360	61.420	22.662
K 20	0.513	0.340	0.793	0.339	0.026	148.579	76.237	7.870
K 22	0.569	0.341	0.560	0.375	0.056	215.084	122.482	31.486
K23	0.639	0.332	0.351	0.427	0.089	147.176	93.974	43.560
K 24	0.581	0.319	0.552	0.396	0.112	125.898	73.147	22.832
K30	0.496	0.568	0.593	0.215	0.059	191.143	94.834	19.663

APPENDIX F

ANOVA TABLES OF ARCHITECTURAL CONFIGURATION INDICATORS

Table F.1. Distribution of energy consumption based on ratio of external surface area to net usable floor area (R1) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	55	28.77291	0.523144	0.031332		
C	39	24.86962	0.637683	0.052057		
D	30	19.27736	0.642579	0.03285		
E	20	14.85147	0.742573	0.023558		
F	4	2.786726	0.696682	0.00603		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.857693	4	0.214423	6.025928	0.000165	2.434947
Within Groups	5.088433	143	0.035583			
Total	5.946127	147				

(cont. on next page)

Table F.1. (cont.)

Test of Homogeneity of Variances

DisAlan

Levene Statistic	df1	df2	Sig.
2.437	4	143	.050

Multiple Comparisons

Dependent Variable: DisAlan

	(I) Enerji	(J) Enerji	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Scheffe	1.00	2.00	-.11454	.03949	.083	-.2378	.0087
		3.00	-.11943	.04281	.106	-.2531	.0142
		4.00	-.21943*	.04926	.001	-.3732	-.0657
		5.00	-.17354	.09769	.534	-.4784	.1313
	2.00	1.00	.11454	.03949	.083	-.0087	.2378
		3.00	-.00490	.04581	1.000	-.1479	.1381
		4.00	-.10489	.05188	.398	-.2668	.0570
		5.00	-.05900	.09904	.986	-.3681	.2501
	3.00	1.00	.11943	.04281	.106	-.0142	.2531
		2.00	.00490	.04581	1.000	-.1381	.1479
		4.00	-.09999	.05445	.500	-.2699	.0700
		5.00	-.05410	.10041	.990	-.3675	.2593
	4.00	1.00	.21943*	.04926	.001	.0657	.3732
		2.00	.10489	.05188	.398	-.0570	.2668
		3.00	.09999	.05445	.500	-.0700	.2699
		5.00	.04589	.10332	.995	-.2766	.3683
	5.00	1.00	.17354	.09769	.534	-.1313	.4784
		2.00	.05900	.09904	.986	-.2501	.3681
		3.00	.05410	.10041	.990	-.2593	.3675
		4.00	-.04589	.10332	.995	-.3683	.2766
Tamhane	1.00	2.00	-.11454	.04364	.102	-.2408	.0117
		3.00	-.11943*	.04080	.048	-.2381	-.0007
		4.00	-.21943*	.04180	.000	-.3435	-.0953
		5.00	-.17354	.04557	.095	-.3754	.0283
	2.00	1.00	.11454	.04364	.102	-.0117	.2408
		3.00	-.00490	.04929	1.000	-.1476	.1378
		4.00	-.10489	.05013	.344	-.2514	.0416
		5.00	-.05900	.05331	.969	-.2490	.1310
	3.00	1.00	.11943*	.04080	.048	.0007	.2381
		2.00	.00490	.04929	1.000	-.1378	.1476
		4.00	-.09999	.04767	.346	-.2403	.0403
		5.00	-.05410	.05101	.978	-.2451	.1369
	4.00	1.00	.21943*	.04180	.000	.0953	.3435
		2.00	.10489	.05013	.344	-.0416	.2514
		3.00	.09999	.04767	.346	-.0403	.2403
		5.00	.04589	.05182	.994	-.1466	.2384
	5.00	1.00	.17354	.04557	.095	-.0283	.3754
		2.00	.05900	.05331	.969	-.1310	.2490
		3.00	.05410	.05101	.978	-.1369	.2451
		4.00	-.04589	.05182	.994	-.2384	.1466

*. The mean difference is significant at the .05 level.

Tablo F.2. Distribution of energy consumption based on ratio of window area to external surface area (R2) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	55	19.39462	0.352629	0.011217		
C	39	11.88143	0.304652	0.01176		
D	30	9.30398	0.310133	0.009711		
E	20	6.39318	0.319659	0.011749		
F	4	1.519454	0.379864	0.016938		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.076334	4	0.019083	1.696817	0.153965	2.434947
Within Groups	1.608268	143	0.011247			
Total	1.684602	147				

Table F.3. Distribution of energy consumption based on ratio of width to length (R3) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	55	34.63475	0.629723	0.039166		
C	39	23.42837	0.600727	0.030232		
D	30	20.32131	0.677377	0.036377		
E	20	13.37117	0.668559	0.049091		
F	4	2.083784	0.520946	0.014764		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.17564	4	0.04391	1.185692	0.319684	2.434947
Within Groups	5.295741	143	0.037033			
Total	5.471381	147				

Table F.4. Distribution of energy consumption based on ratio of external wall area to net-usable area (R4) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	55	18.93596	0.34429	0.024486		
C	39	17.88526	0.458597	0.046266		
D	30	13.81523	0.460508	0.040583		
E	20	11.37031	0.568516	0.060103		
F	4	1.849051	0.462263	0.019503		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.851434	4	0.212858	5.577188	0.000335	2.434947
Within Groups	5.457724	143	0.038166			
Total	6.309158	147				

(cont. on next page)

Table F.4. (cont.)

Test of Homogeneity of Variances

DuvarAlani

Levene Statistic	df1	df2	Sig.
2.649	4	143	.036

Multiple Comparisons

Dependent Variable: DuvarAlani

	(I) Enerji	(J) Enerji	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Scheffe	1.0000	2.0000	-.1143063	.0402567	.095	-.239942	.011329
		3.0000	-.0924748	.0441314	.360	-.230203	.045253
		4.0000	-.2518696*	.0493292	.000	-.405819	-.097920
		5.0000	-.1179726	.0995871	.843	-.428770	.192825
	2.0000	1.0000	.1143063	.0402567	.095	-.011329	.239942
		3.0000	.0218315	.0471532	.995	-.125327	.168990
		4.0000	-.1375633	.0520502	.143	-.300005	.024878
		5.0000	-.0036662	.1009625	1.000	-.318757	.311424
	3.0000	1.0000	.0924748	.0441314	.360	-.045253	.230203
		2.0000	-.0218315	.0471532	.995	-.168990	.125327
		4.0000	-.1593948	.0551017	.085	-.331360	.012570
		5.0000	-.0254978	.1025690	1.000	-.345602	.294606
	4.0000	1.0000	.2518696*	.0493292	.000	.097920	.405819
		2.0000	.1375633	.0520502	.143	-.024878	.300005
		3.0000	.1593948	.0551017	.085	-.012570	.331360
		5.0000	.1338970	.1049104	.803	-.193514	.461308
	5.0000	1.0000	.1179726	.0995871	.843	-.192825	.428770
		2.0000	.0036662	.1009625	1.000	-.311424	.318757
		3.0000	.0254978	.1025690	1.000	-.294606	.345602
		4.0000	-.1338970	.1049104	.803	-.461308	.193514
Tamhane	1.0000	2.0000	-.1143063	.0403920	.060	-.231332	.002720
		3.0000	-.0924748	.0359251	.120	-.197091	.012141
		4.0000	-.2518696*	.0626765	.005	-.443999	-.059741
		5.0000	-.1179726	.0729447	.878	-.566237	.330292
	2.0000	1.0000	.1143063	.0403920	.060	-.002720	.231332
		3.0000	.0218315	.0450748	1.000	-.108721	.152385
		4.0000	-.1375633	.0683335	.414	-.342142	.067015
		5.0000	-.0036662	.0778592	1.000	-.392877	.385545
	3.0000	1.0000	.0924748	.0359251	.120	-.012141	.197091
		2.0000	-.0218315	.0450748	1.000	-.152385	.108721
		4.0000	-.1593948	.0657919	.197	-.358322	.039532
		5.0000	-.0254978	.0756383	1.000	-.436578	.385582
	4.0000	1.0000	.2518696*	.0626765	.005	.059741	.443999
		2.0000	.1375633	.0683335	.414	-.067015	.342142
		3.0000	.1593948	.0657919	.197	-.039532	.358322
		5.0000	.1338970	.0914269	.863	-.212249	.480044
	5.0000	1.0000	.1179726	.0729447	.878	-.330292	.566237
		2.0000	.0036662	.0778592	1.000	-.385545	.392877
		3.0000	.0254978	.0756383	1.000	-.385582	.436578
		4.0000	-.1338970	.0914269	.863	-.480044	.212249

*. The mean difference is significant at the .05 level.

Table F.5. Distribution of energy consumption based on ratio of net-usable common floor area to net-usable floor area (R5) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	55	4.038032	0.073419	0.001637		
C	39	3.091692	0.079274	0.001056		
D	30	2.076163	0.069205	0.000757		
E	20	1.494533	0.074727	0.001039		
F	4	0.374508	0.093627	0.001284		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.003242	4	0.000811	0.6659	0.616679	2.434947
Within Groups	0.174074	143	0.001217			
Total	0.177316	147				

(cont. on next page)

Table F.5. (cont.)

Test of Homogeneity of Variances

VAR00006

Levene Statistic	df1	df2	Sig.
.272	4	143	.895

Multiple Comparisons

Dependent Variable: Ortakalan

	(I) EnerjiSýnýfý	(J) EnerjiSýnýfý	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Scheffe	1.00	2.00	-.00585539	.00730381	.958	-.0286496	.0169388
		3.00	.00421334	.00791893	.991	-.0205006	.0289272
		4.00	-.00130790	.00911031	1.000	-.0297399	.0271241
		5.00	-.02020823	.01806815	.869	-.0765965	.0361800
	2.00	1.00	.00585539	.00730381	.958	-.0169388	.0286496
		3.00	.01006874	.00847287	.842	-.0163739	.0365114
		4.00	.00454749	.00959572	.994	-.0253994	.0344944
		5.00	-.01435283	.01831770	.961	-.0715199	.0428142
	3.00	1.00	-.00421334	.00791893	.991	-.0289272	.0205006
		2.00	-.01006874	.00847287	.842	-.0365114	.0163739
		4.00	-.00552124	.01007183	.990	-.0369540	.0259116
		5.00	-.02442157	.01857154	.785	-.0823808	.0335377
	4.00	1.00	.00130790	.00911031	1.000	-.0271241	.0297399
		2.00	-.00454749	.00959572	.994	-.0344944	.0253994
		3.00	.00552124	.01007183	.990	-.0259116	.0369540
		5.00	-.01890033	.01910996	.913	-.0785399	.0407392
	5.00	1.00	.02020823	.01806815	.869	-.0361800	.0765965
		2.00	.01435283	.01831770	.961	-.0428142	.0715199
		3.00	.02442157	.01857154	.785	-.0335377	.0823808
		4.00	.01890033	.01910996	.913	-.0407392	.0785399
Tamhane	1.00	2.00	-.00585539	.00753920	.997	-.0274895	.0157787
		3.00	.00421334	.00741675	1.000	-.0171481	.0255748
		4.00	-.00130790	.00903858	1.000	-.0280059	.0253901
		5.00	-.02020823	.01872698	.986	-.1350032	.0945867
	2.00	1.00	.00585539	.00753920	.997	-.0157787	.0274895
		3.00	.01006874	.00723239	.842	-.0108751	.0310125
		4.00	.00454749	.00888793	1.000	-.0218340	.0309290
		5.00	-.01435283	.01865474	.999	-.1304094	.1017038
	3.00	1.00	-.00421334	.00741675	1.000	-.0255748	.0171481
		2.00	-.01006874	.00723239	.842	-.0310125	.0108751
		4.00	-.00552124	.00878430	1.000	-.0316978	.0206553
		5.00	-.02442157	.01860558	.956	-.1413699	.0925268
	4.00	1.00	.00130790	.00903858	1.000	-.0253901	.0280059
		2.00	-.00454749	.00888793	1.000	-.0309290	.0218340
		3.00	.00552124	.00878430	1.000	-.0206553	.0316978
		5.00	-.01890033	.01930947	.992	-.1255955	.0877949
	5.00	1.00	.02020823	.01872698	.986	-.0945867	.1350032
		2.00	.01435283	.01865474	.999	-.1017038	.1304094
		3.00	.02442157	.01860558	.956	-.0925268	.1413699
		4.00	.01890033	.01930947	.992	-.0877949	.1255955

Table F.6. Distribution of energy consumption based on ratio of heating load to external surface area (R6) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	32	5402.696	168.8342	20842.28		
C	13	2413.822	185.6786	13336.42		
D	2	238.1897	119.0948	635.83		
E	5	593.9984	118.7997	4781.661		
F	2	257.4017	128.7008	1047.659		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23551.19	4	5887.798	0.348872	0.843548	2.561124
Within Groups	826957.9	49	16876.69			
Total	850509.1	53				

Table F.7. Distribution of energy consumption based on ratio of heating load to net-usable floor area (R7) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	32	2261.905	70.68453	1414.45		
C	13	2045.972	157.3824	14339.12		
D	2	186.1801	93.09003	567.5898		
E	5	351.9207	70.38413	1668.564		
F	2	170.6107	85.30534	258.1071		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	72496.93	4	18124.23	3.975015	0.007162	2.561124
Within Groups	223417.4	49	4559.538			
Total	295914.3	53				

(cont. on next page)

Table F.7. (cont.)

Test of Homogeneity of Variances

ÝsistmaAlan

Levene Statistic	df1	df2	Sig.
6.471	4	49	.000

Multiple Comparisons

Dependent Variable: ÝsistmaAlan

	(I) Enerji	(J) Enerji	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Scheffe	1.0000	2.0000	-86.697911*	22.20854	.009	-157.780839	-15.614983
		3.0000	-22.405502	49.21641	.995	-179.932570	135.121567
		4.0000	.3003998	32.47142	1.000	-103.630955	104.231755
		5.0000	-14.620803	49.21641	.999	-172.147872	142.906265
	2.0000	1.0000	86.6979110*	22.20854	.009	15.614983	157.780839
		3.0000	64.2924091	51.28843	.813	-99.866582	228.451400
		4.0000	86.9983108	35.53366	.217	-26.734375	200.730996
		5.0000	72.0771076	51.28843	.740	-92.081884	236.236099
	3.0000	1.0000	22.4055019	49.21641	.995	-135.121567	179.932570
		2.0000	-64.292409	51.28843	.813	-228.451400	99.866582
		4.0000	22.7059017	56.49493	.997	-158.117544	203.529347
		5.0000	7.7846986	67.52435	1.000	-208.340656	223.910054
	4.0000	1.0000	-.3003998	32.47142	1.000	-104.231755	103.630955
		2.0000	-86.998311	35.53366	.217	-200.730996	26.734375
		3.0000	-22.705902	56.49493	.997	-203.529347	158.117544
		5.0000	-14.921203	56.49493	.999	-195.744648	165.902242
	5.0000	1.0000	14.6208033	49.21641	.999	-142.906265	172.147872
		2.0000	-72.077108	51.28843	.740	-236.236099	92.081884
		3.0000	-7.7846986	67.52435	1.000	-223.910054	208.340656
		4.0000	14.9212032	56.49493	.999	-165.902242	195.744648
Tamhane	1.0000	2.0000	-86.697911	33.87050	.214	-200.566677	27.170855
		3.0000	-22.405502	18.11067	.993	-746.066618	701.255615
		4.0000	.3003998	19.44002	1.000	-90.694944	91.295743
		5.0000	-14.620803	13.16264	.993	-245.705105	216.463498
	2.0000	1.0000	86.6979110	33.87050	.214	-27.170855	200.566677
		3.0000	64.2924091	37.23982	.700	-66.688607	195.273425
		4.0000	86.9983108	37.90412	.304	-35.883636	209.880258
		5.0000	72.0771076	35.10075	.467	-46.131356	190.285572
	3.0000	1.0000	22.4055019	18.11067	.993	-701.255615	746.066618
		2.0000	-64.292409	37.23982	.700	-195.273425	66.688607
		4.0000	22.7059017	24.84970	.996	-132.193565	177.605368
		5.0000	7.7846986	20.31867	1.000	-369.106040	384.675437
	4.0000	1.0000	-.3003998	19.44002	1.000	-91.295743	90.694944
		2.0000	-86.998311	37.90412	.304	-209.880258	35.883636
		3.0000	-22.705902	24.84970	.996	-177.605368	132.193565
		5.0000	-14.921203	21.51200	.999	-119.526377	89.683971
	5.0000	1.0000	14.6208033	13.16264	.993	-216.463498	245.705105
		2.0000	-72.077108	35.10075	.467	-190.285572	46.131356
		3.0000	-7.7846986	20.31867	1.000	-384.675437	369.106040
		4.0000	14.9212032	21.51200	.999	-89.683971	119.526377

*. The mean difference is significant at the .05 level.

Table F.8. Distribution of energy consumption based on ratio of lighting load to net-usable floor area (R8) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
B	49	3136.501	64.01022	2874.267		
C	34	1864.545	54.83956	1772.049		
D	21	974.7919	46.41866	1026.247		
E	16	997.0477	62.31548	1627.88		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5222.883	3	1740.961	0.836634	0.476416	2.682809
Within Groups	241385.6	116	2080.91			
Total	246608.5	119				

APPENDIX G

DISTRIBUTION CHARTS OF ARCHITECTURAL CONFIGURATION INDICATORS

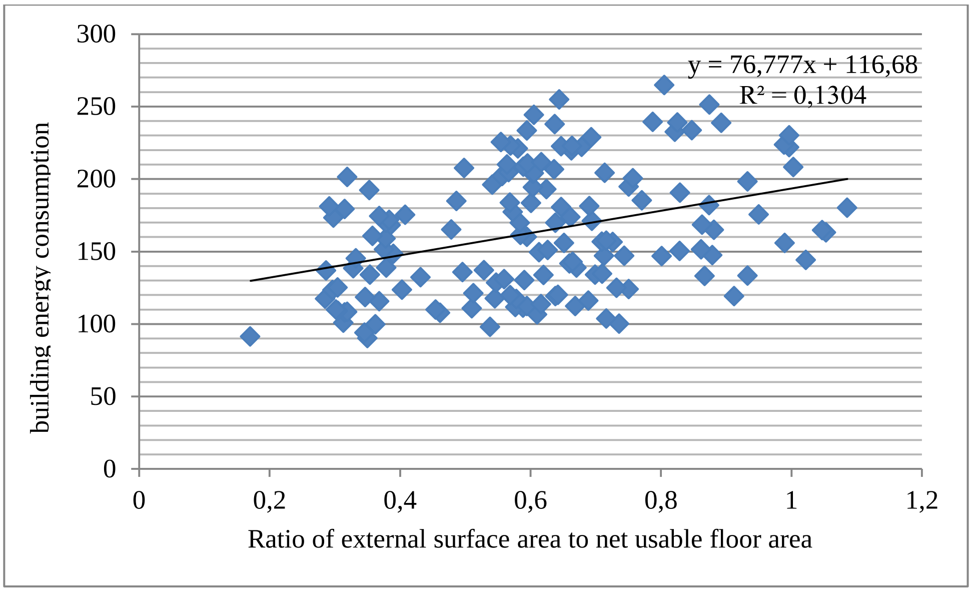


Figure G.1. Distribution of energy consumption based on ratio of external surface area to net usable floor area (R1).

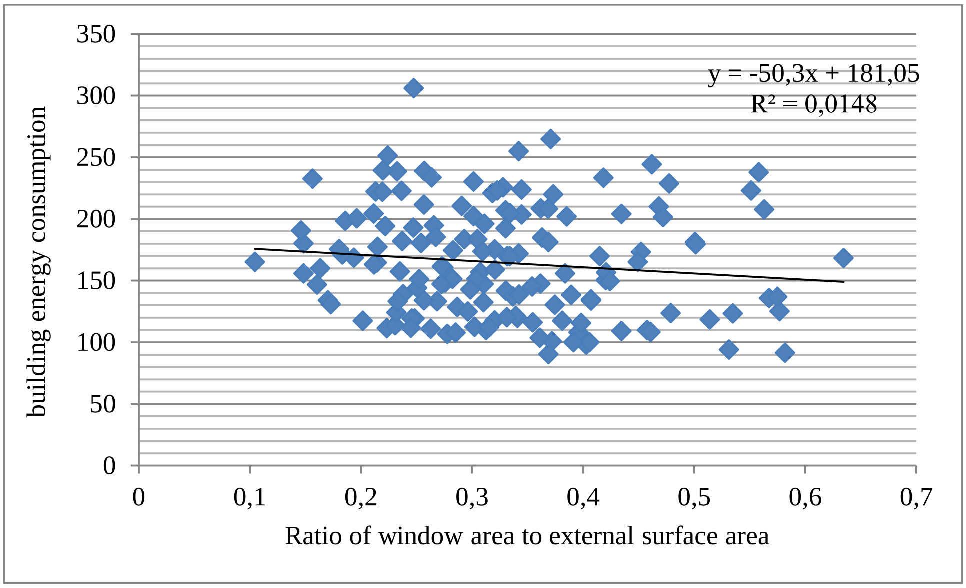


Figure G.2. Distribution of energy consumption based on ratio of window area to external surface area (R2).

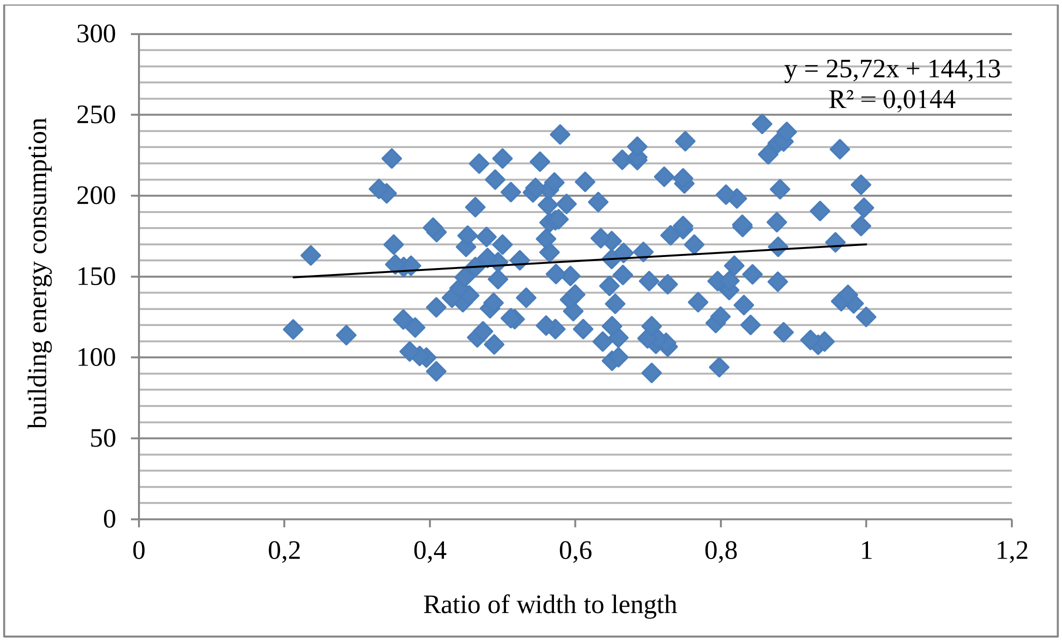


Figure G.3. Distribution of energy consumption based on ratio of width to length (R3).

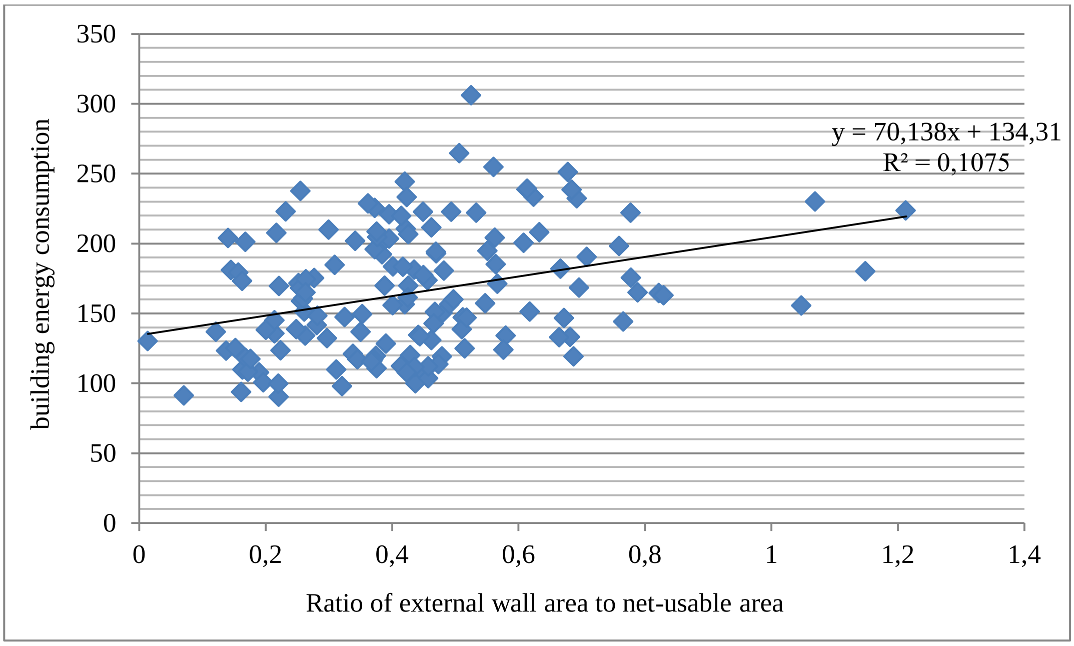


Figure G.4. Distribution of energy consumption based on ratio of external wall area to net-usable area (R4).

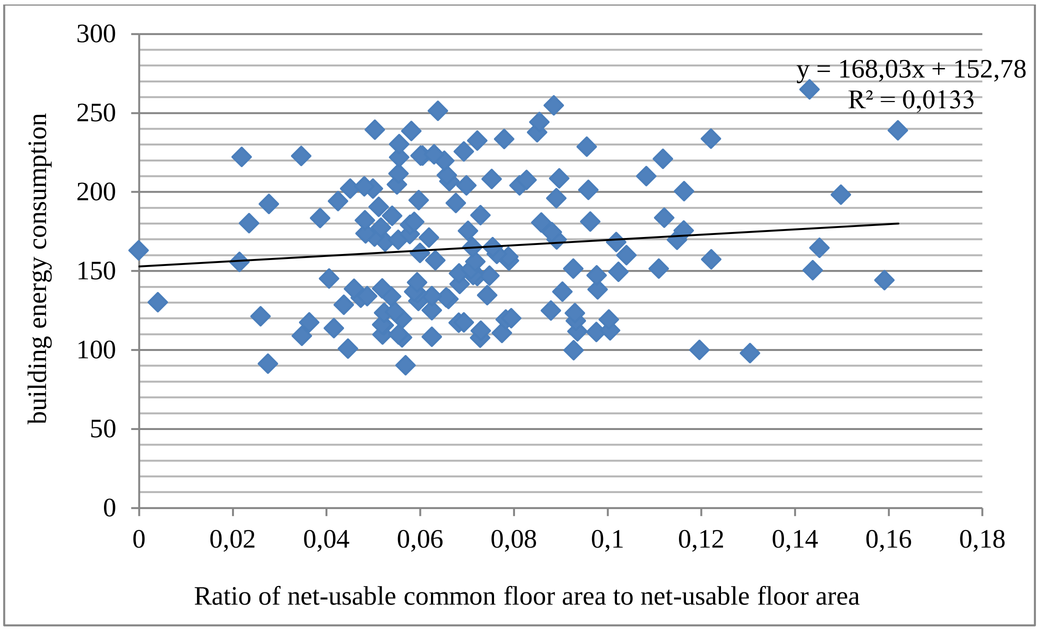


Figure G.5. Distribution of energy consumption based on ratio of net-usable common floor area to net-usable floor area (R5).

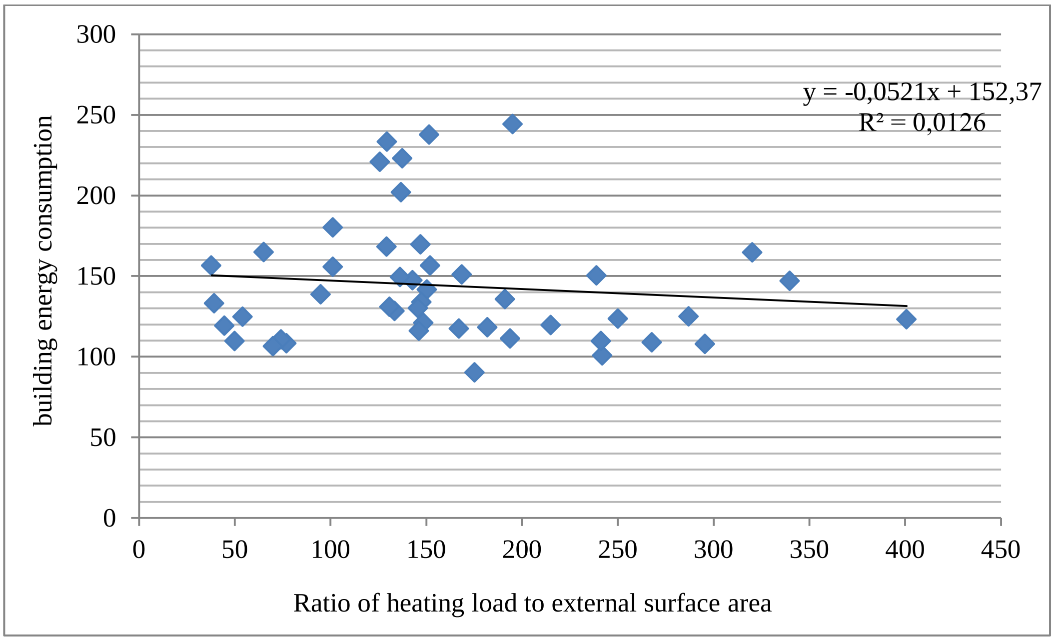


Figure G.6. Distribution of energy consumption based on ratio of heating load to external surface area (R6).

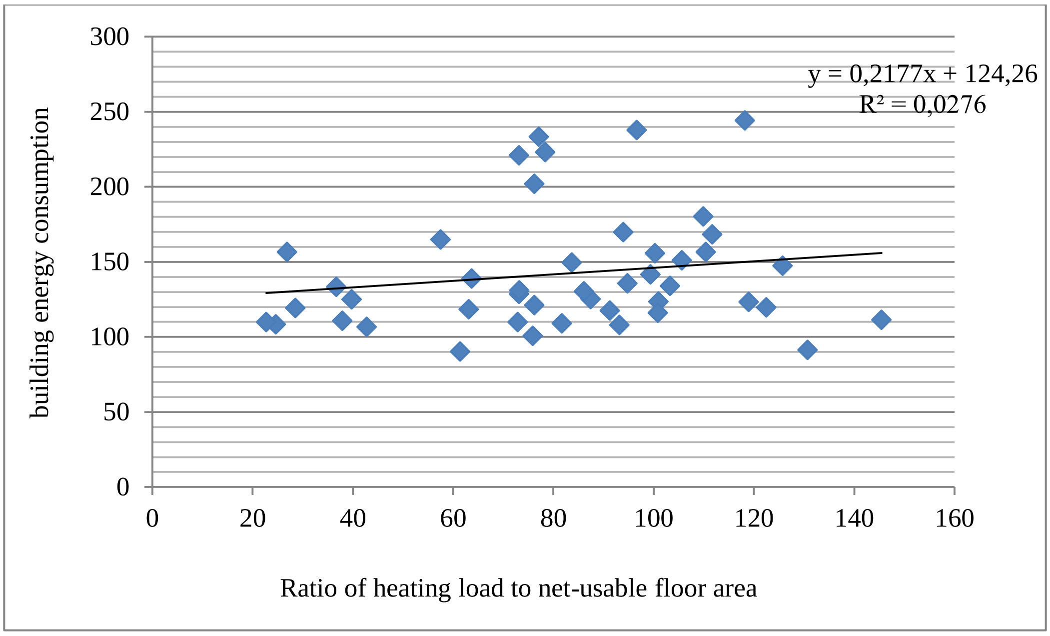


Figure G.7. Distribution of energy consumption based on ratio of heating load to net-usable floor area (R7).

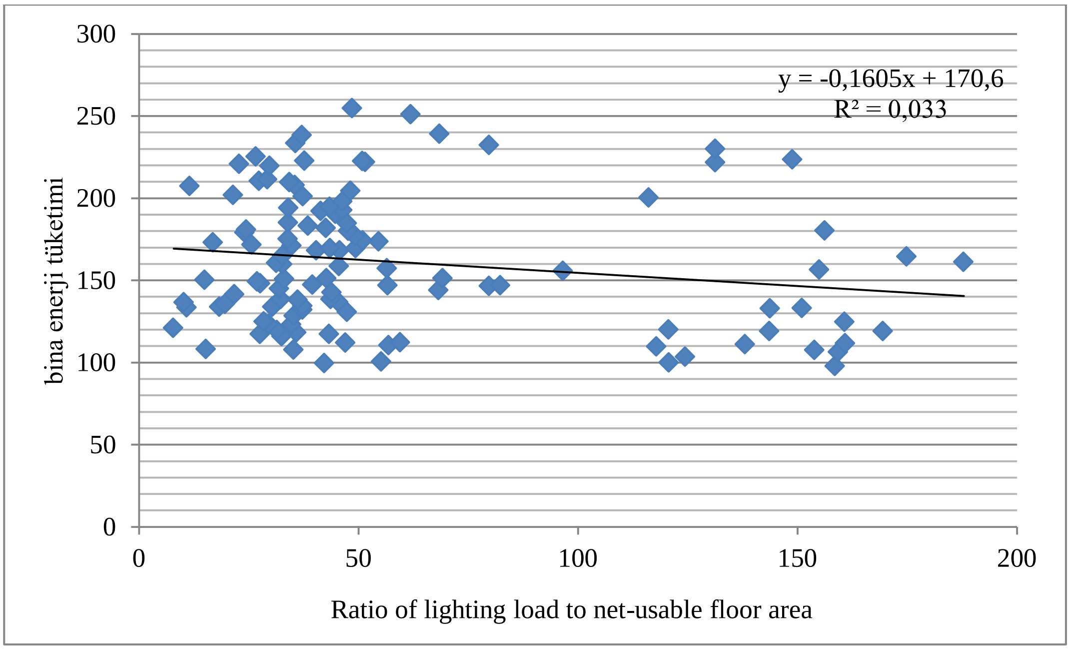


Figure G.8. Distribution of energy consumption based on ratio of lighting load to net-usable floor area (R8).

APPENDIX H

DISTRIBUTIONS OF ENERGY CONSUMPTIONS BASED ON RECOMMENDED DESIGN EFFICIENCY GROUPS AND VARIANCE ANALYSES

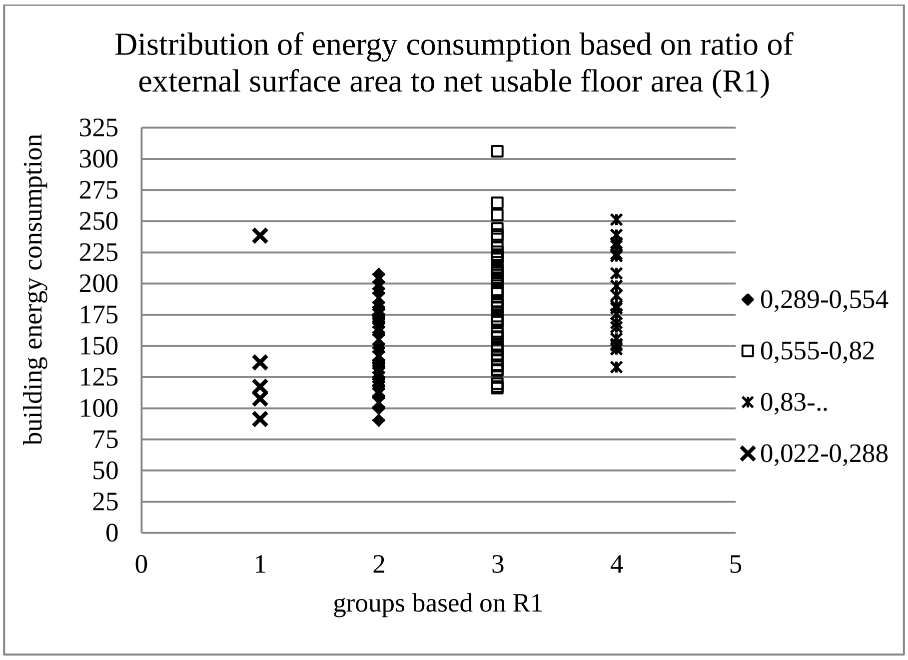


Figure H.1. Distribution of energy consumption based on ratio of external surface area to net usable floor area (R1).

Table H.1. Distribution of energy consumption based on ratio of external surface area to net usable floor area (R1) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.022-0.288	5	691.6528	138.33	3407.70		
0.289-0.554	39	5709.133	146.38	977.45		
0.555-0.82	59	10970.85	185.94	1652.06		
0.83-..	19	3602.912	189.62	1270.98		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	48629.9	3	16209.98	11.28	1.45E-06	2.681466
Within Groups	169471.6	118	1436.2			
Total	218101.5	121				

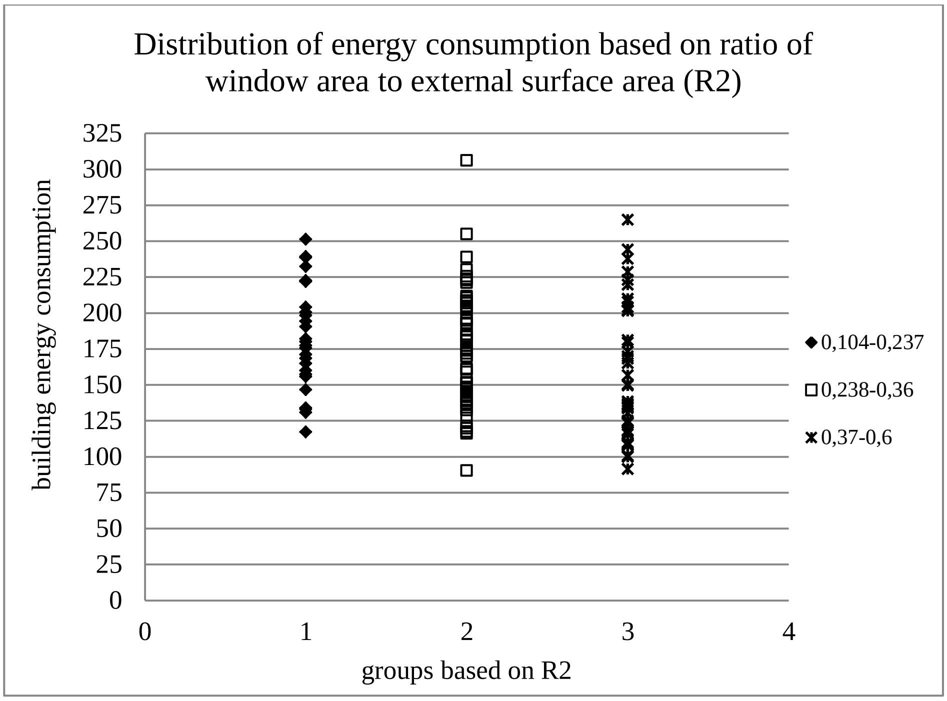


Figure H.2. Distribution of energy consumption based on ratio of window area to external surface area (R2).

Table H.2. Distribution of energy consumption based on ratio of external surface area to net usable floor area (R1) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.104-0.237	27	4968.693	184.0257	1349.576		
0.238-0.36	56	9812.777	175.2282	1604.812		
0.37-0.6	39	6193.081	158.7969	2196.365		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11286.02	2	5643.008	3.246942	0.042364	3.072429
Within Groups	206815.5	119	1737.945			
Total	218101.5	121				

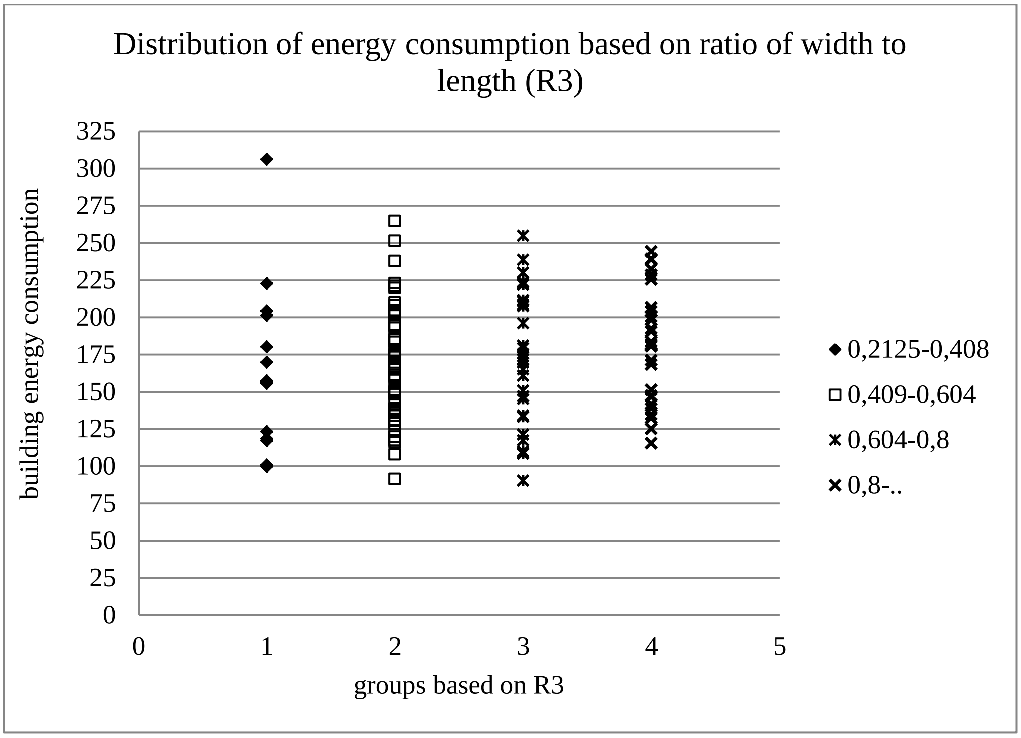


Figure H.3. Distribution of energy consumption based on ratio of width to length (R3)

Table H.3. Distribution of energy consumption based on ratio of width to length (R3) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.2125-0.408	14	2312.568	165.1834	3164.062		
0.409-0.604	49	8225.519	167.8677	1533.85		
0.605-0.8	32	5536.551	173.0172	1966.304		
0.8-..	27	4899.913	181.4783	1478.587		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3945.222	3	1315.074	0.724605	0.53925	2.681466
Within Groups	214156.3	118	1814.884			
Total	218101.5	121				

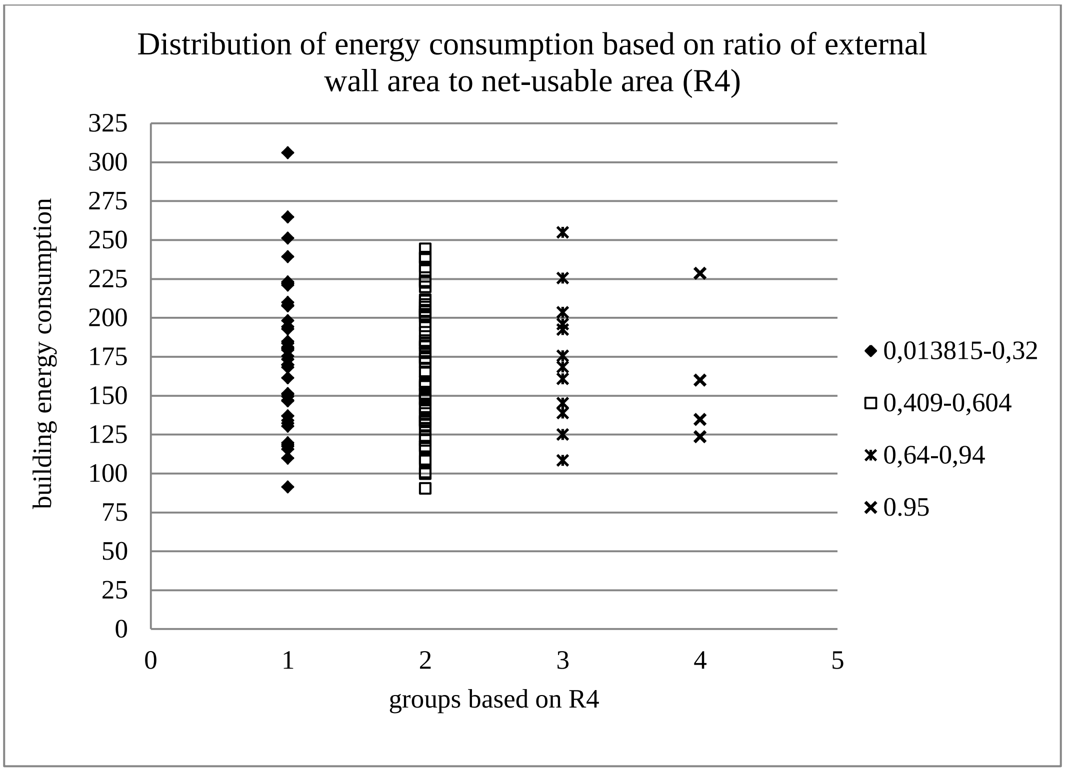


Figure H.4. Distribution of energy consumption based on ratio of external wall area to net-usable area (R4).

Table H.4. Distribution of energy consumption based on ratio of external wall area to net-usable area (R4) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.013815-0.32	43	7522.508	174.9421	2033.07		
0.33-0.63	62	10573.38	170.5383	1705.929		
0.64-0.94	12	2093.329	174.4441	1806.365		
0.95-…	4	646.6154	161.6538	2223.222		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	999.8173	3	333.2724	0.180531	0.909428	2.682132
Within Groups	215990.3	117	1846.071			
Total	216990.1	120				

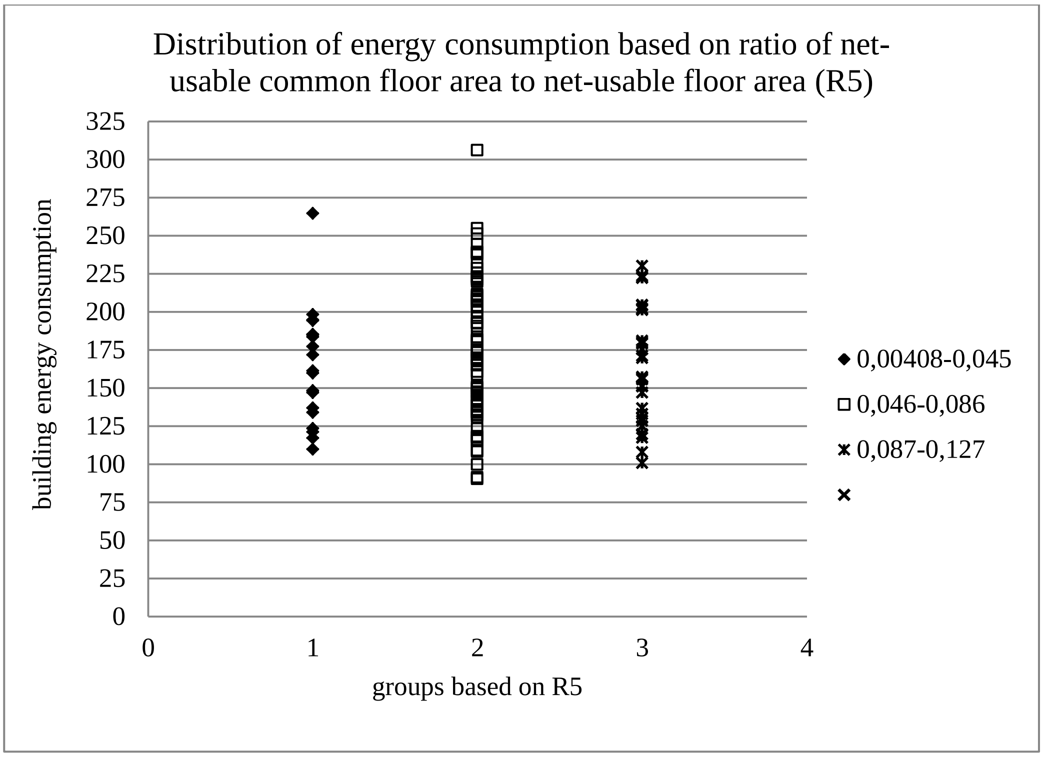


Figure H.5. Distribution of energy consumption based on ratio of net-usable common floor area to net-usable floor area (R5).

Table H.5. Distribution of energy consumption based on ratio of net-usable common floor area to net-usable floor area (R5) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.00408-0.045	19	3112.99	163.8416	1415.319		
0.046-0.086	73	12875.12	176.3715	2057.273		
0.087-	30	4986.442	166.2147	1408.244		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3663.003	2	1831.502	1.016369	0.365026	3.072429
Within Groups	214438.5	119	1802.004			
Total	218101.5	121				

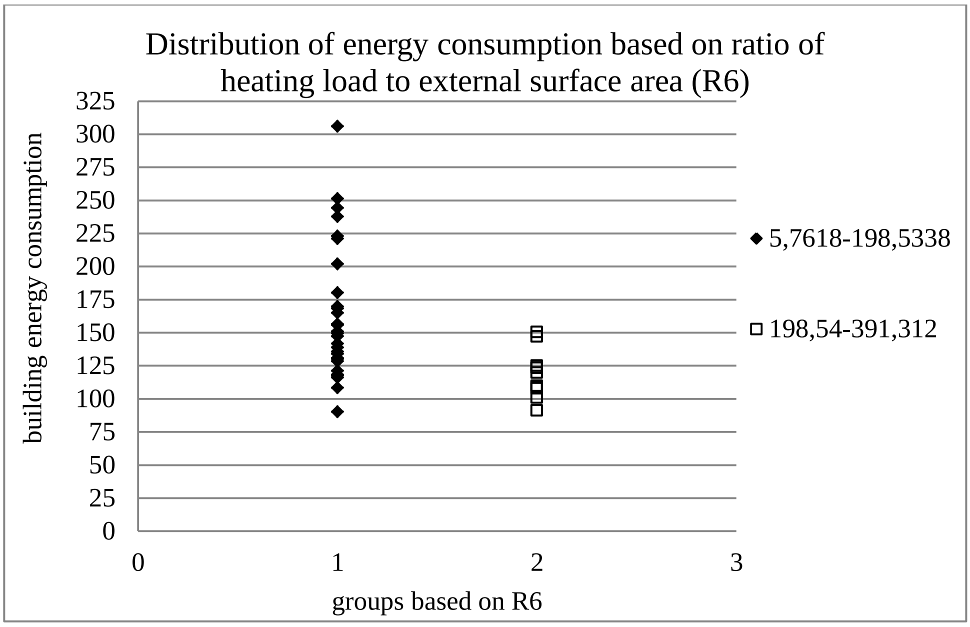


Figure H.6. Distribution of energy consumption based on ratio of heating load to external surface area (R6).

Table H.6. T-test analysis of energy consumption based on ratio of heating load to external surface area (R6).

	5.76-198.53	198.54-391.31
Mean	163.3940012	118.8351697
Variance	2577.654179	326.0268738
Observations	29	11
Hypothesized Mean Difference	0	
df	38	
t Stat	4.092905165	
P(T<=t) one-tail	0.000107072	
t Critical one-tail	1.685954461	
P(T<=t) two-tail	0.000214144	
t Critical two-tail	2.024394147	

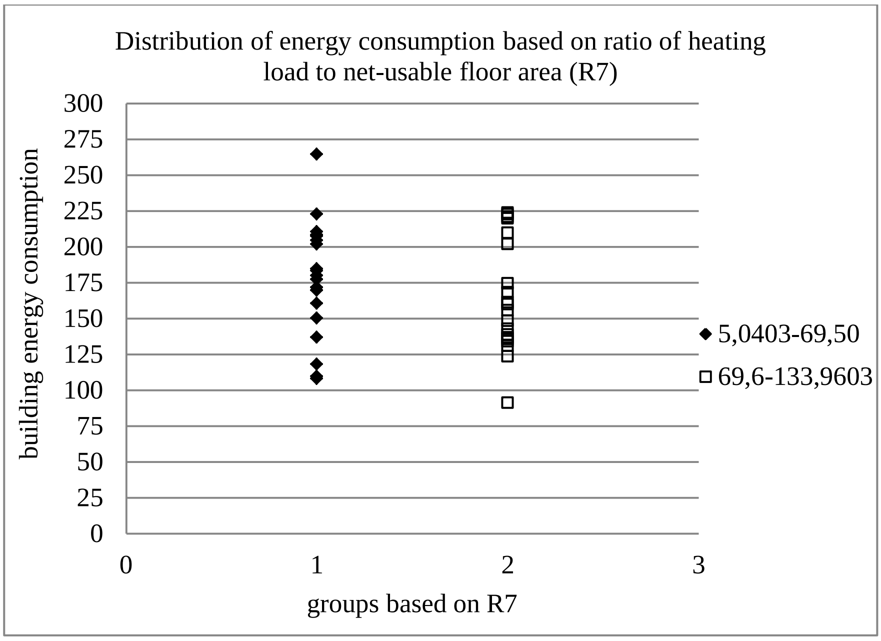


Figure H. 7 Distribution of energy consumption based on ratio of heating load to net-usable floor area (R7).

Table H.6.7. T-test analysis of energy consumption based on ratio of heating load to net-usable floor area (R7).

	5.04-69.50	69.6-133.96
Mean	177.0668138	164.9978009
Variance	1566.618284	1521.544193
Observations	20	20
Hypothesized Mean		
Difference	0	
df	38	
t Stat	0.971262629	
P(T<=t) one-tail	0.168779794	
t Critical one-tail	1.685954461	
P(T<=t) two-tail	0.337559587	
t Critical two-tail	2.024394147	

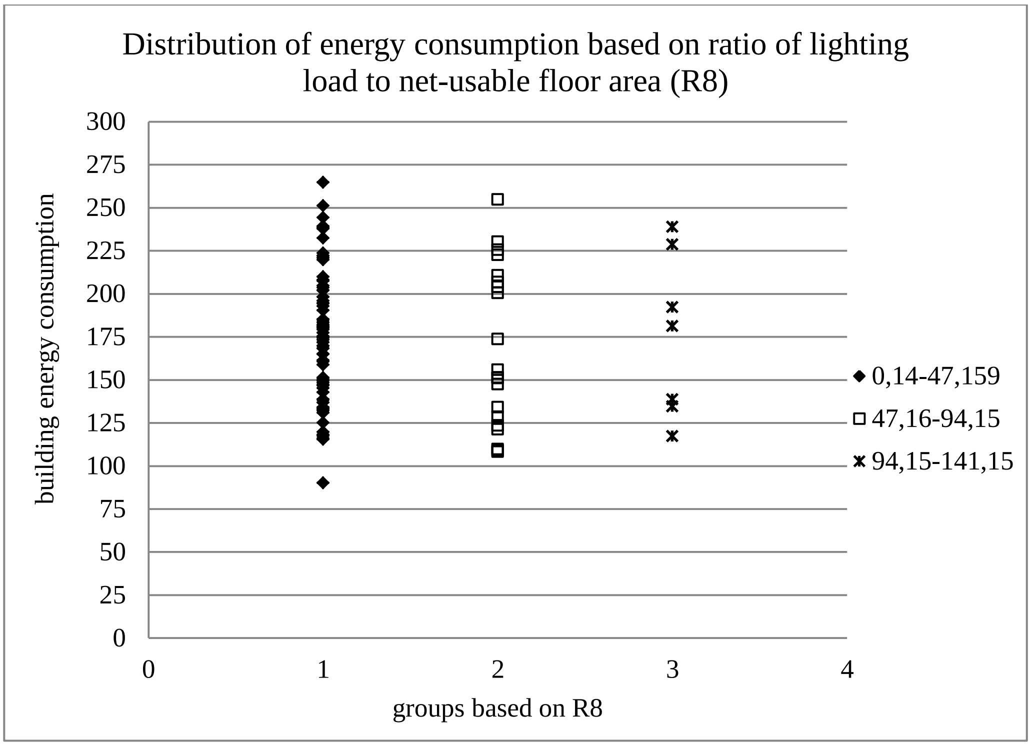


Figure H.8. Distribution of energy consumption based on ratio of lighting load to net-usable floor area (R8).

Table H.8. Distribution of energy consumption based on ratio of lighting load to net-usable floor area (R8) and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.14-47.159	73	12761.52	174.8154	1429.081		
47.16-94.15	20	3367.219	168.3609	2202.858		
94.15-141.15	7	1231.455	175.9221	2259.758		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	694.532	2	347.266	0.212782	0.808709	3.090187
Within Groups	158306.7	97	1632.028			
Total	159001.2	99				

APPENDIX I

REPEATED ANALYSES ACCORDING TO CENTRAL AND AUTONOMOUS HEATING SYSTEMS

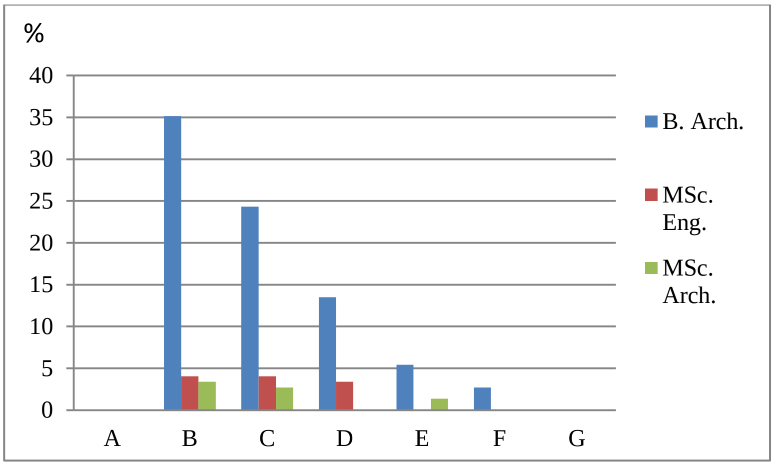


Figure I.1. The distribution of designers' professional status of residential buildings according to energy classes.

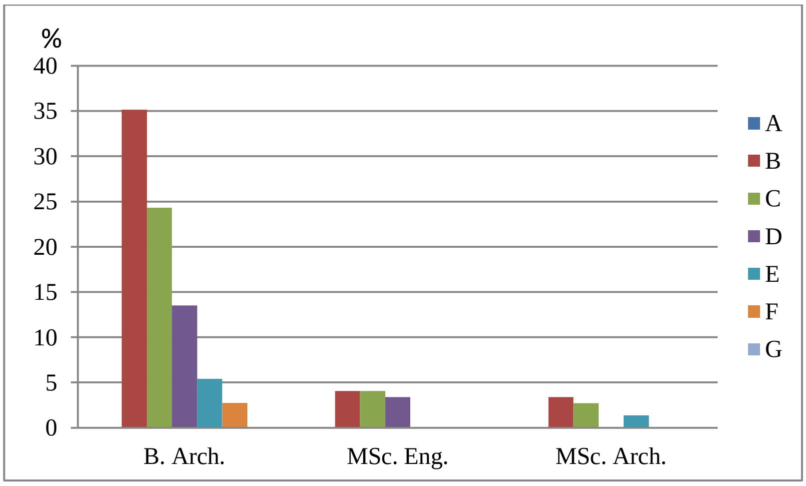


Figure I.2. The distribution of energy classes of residential buildings according to designers' professional status.

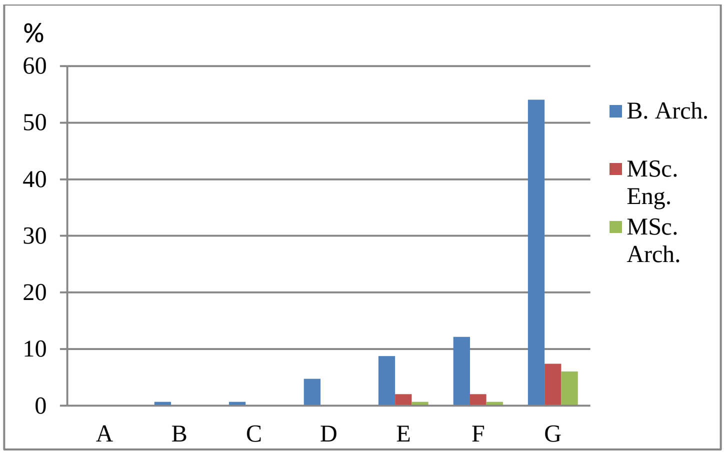


Figure I.3. The distribution of designers' professional status of residential buildings according to CO_2 classes.

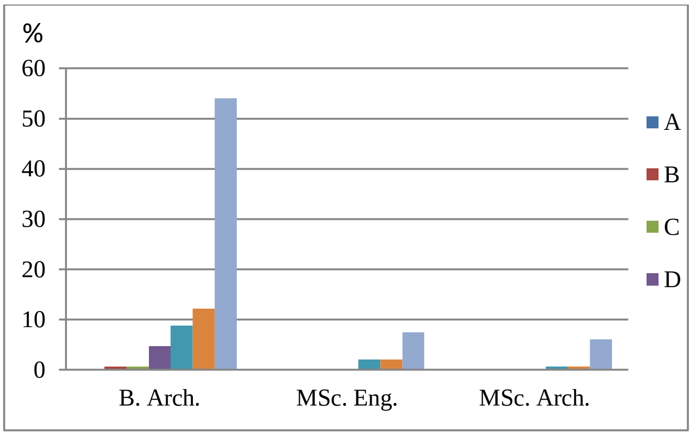


Figure I.4. The distribution of CO_2 classes of residential buildings according to designers' professional status.

Table H.1. The distribution of energy classes of residential buildings according to designers' professional status and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
Architect	120	18706.92	155.891	1823.763		
Engineer	17	2666.99	156.8818	952.3068		
Msc. Architect	11	1675.949	152.359	1608.756		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	150.6387	2	75.31933	0.043975	0.956991	3.058486
Within Groups	248352.3	145	1712.775			
Total	248503	147				

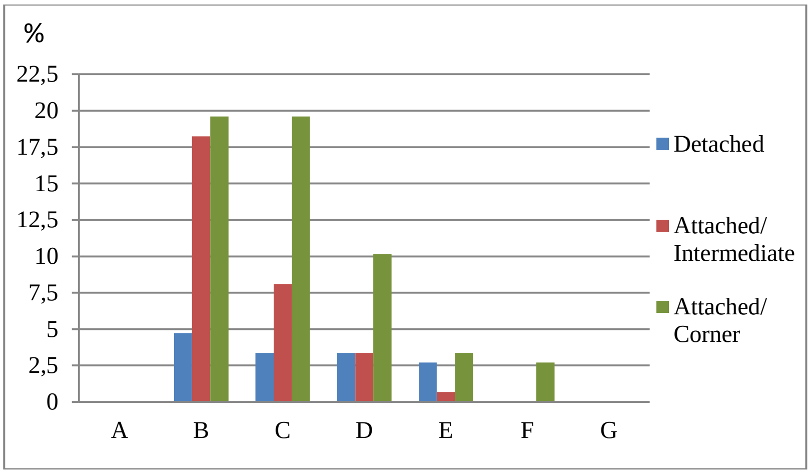


Figure I.5. The distribution of zoning status of residential buildings according to energy classes.

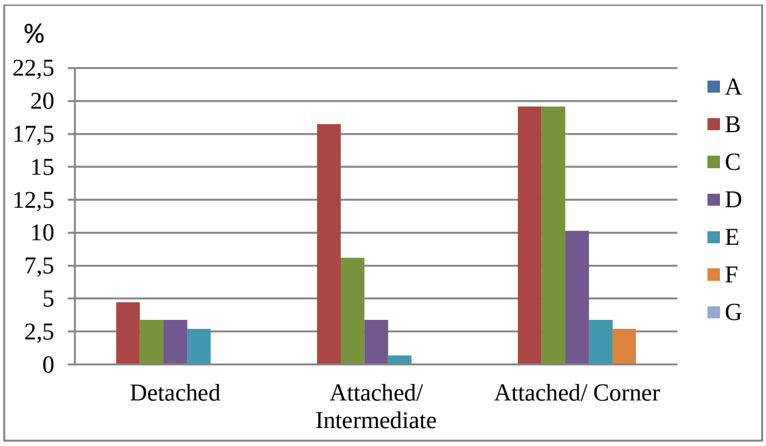


Figure I.6. The distribution of energy classes of residential buildings according to zoning status.

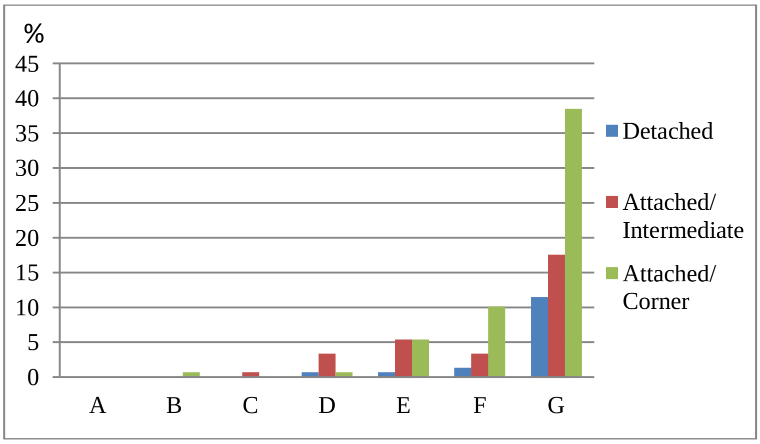


Figure I.7. The distribution of zoning status of residential buildings according to CO2 classes

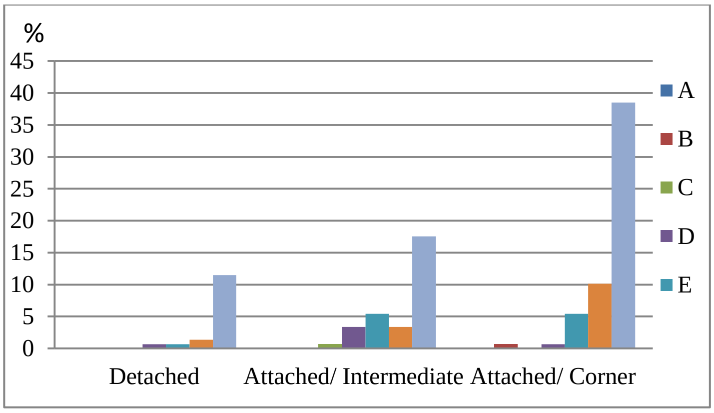


Figure I.8. The distribution of CO2 classes of residential buildings according to zoning status.

Table I.2. The distribution of energy consumption according to zoning status and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
Attached	21	3583.996	170.6665	1915.78		
Detached/ inter.	45	6242.018	138.7115	1051.562		
Detached/ corner	82	13223.84	161.2664	1773.911		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	20231.79	2	10115.9	6.425713	0.002119	3.058486
Within Groups	228271.2	145	1574.284			
Total	248503	147				

(cont. on next page)

Table I.2. (cont.)

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.451	2	145	.238

Multiple Comparisons

	(I) Zoning	(J) Zoning	Mean Diff. (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	31.95498(*)	10.48570	.011	6.0212	57.8888
		3.00	9.40010	9.70384	.626	-14.5999	33.4001
	2.00	1.00	-31.95498(*)	10.48570	.011	-57.8888	-6.0212
		3.00	-22.55488(*)	7.36089	.011	-40.7602	-4.3496
	3.00	1.00	-9.40010	9.70384	.626	-33.4001	14.5999
		2.00	22.55488(*)	7.36089	.011	4.3496	40.7602
Tamhane	1.00	2.00	31.95498(*)	10.70494	.016	4.9212	58.9887
		3.00	9.40010	10.62359	.765	-17.4514	36.2516
	2.00	1.00	-31.95498(*)	10.70494	.016	-58.9887	-4.9212
		3.00	-22.55488(*)	6.70829	.003	-38.8170	-6.2927
	3.00	1.00	-9.40010	10.62359	.765	-36.2516	17.4514
		2.00	22.55488(*)	6.70829	.003	6.2927	38.8170

* The mean difference is significant at the .05 level.

		N	Subset for alpha = .05	
	Zoning	1	2	1
Scheffe (a.b)	2.00	45	138.7115	
	3.00	82	161.2664	161.2664
	1.00	21		170.6665
	Sig.		.055	.600

Table I.3. The distribution of energy consumption according to insulation and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
Uninsulated	122	19708.75	161.5471	1643.94		
Insulated	26	3341.114	128.5044	1047.433		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	23400.37	1	23400.37	15.17732	0.000149	3.905942
Within Groups	225102.6	146	1541.799			
Total	248503	147				

(cont. on next page)

Table I.3. (cont.)

t-Test: Two-Sample Assuming Different Variances

	Uninsulated	*Insulated*
Mean	161.5470918	128.5043866
Variance	1643.940228	1047.432708
Observations	122	26
Hypothesized Mean Difference	0	
df	44	
t Stat	4.506535135	
P(T<=t) one-tail	2.41249E-05	
t Critical one-tail	1.680229977	
P(T<=t) two-tail	4.82497E-05	
t Critical two-tail	2.015367547	

Table I.4. The distribution of energy consumption according to window area and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*
B	44	12887.11	292.8889	21788.68
C	41	10750.64	262.2107	17781.81
D	24	5997.976	249.9157	20110.43
E	9	2058.612	228.7347	12054.27
F	4	1556.944	389.236	44737.51

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	106620.5	4	26655.13	1.331975	0.262183	2.449202
Within Groups	2341372	117	20011.73			
Total	2447993	121				

Table I.5. The distribution of A/V ratio based on building energy classes and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*
B	63	25.72754	0.408374	0.013019
C	46	17.61985	0.38304	0.010855
DEF	39	14.66466	0.376017	0.002346

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.030546	2	0.015273	1.599199	0.205601	3.058486
Within Groups	1.384804	145	0.00955			
Total	1.41535	147				

Table I.6. The distribution building energy consumption of based on A/V ratio and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.33-0.373	42	7645.9	182.0452	1663.401		
0.374-0.416	66	9886.9	149.8015	1275.334		
0.417..	14	2175.944	155.4246	1580.251		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	27277.37	2	13638.69	9.455892	0.000154	3.072429
Within Groups	171639.4	119	1442.348			
Total	198916.8	121				

Table I.7. The distribution of orientations based on building energy classes and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
N/E/W	5	812.4351	162.487	2014.94		
S/E/W	15	2631.317	175.4211	1427.475		
S/N	44	6446.249	146.5056	1528.614		
S/N/E, S/N/E, S/N/W/E	45	7871.408	174.9202	1596.917		
W/E	12	1786.404	148.867	1095.77		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	22823.74	4	5705.934	3.758751	0.006517	2.44988
Within Groups	176092.6	116	1518.04			
Total	198916.4	120				

Table I.8. The distribution of energy consumptions based on floor counts and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
5-6	47	7835.742	166.7179	1663.146		
7-8	36	5490.398	152.511	1668.843		
9	28	4223.217	150.8292	1353.077		
10-11	37	5500.503	148.6622	1902.427		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8568.302	3	2856.101	1.714127	0.166733	2.667443
Within Groups	239934.6	144	1666.213			
Total	248503	147				

Analysis of Energy Consumptions Based On Proposed Design Efficiency Classes

According to analysis results;

- There is a statistical significant difference between groups of R1 and energy consumption.
- There is a statistical significant difference between groups of R2 and energy consumption.
- There is not a statistical significant difference between groups of R3 and energy consumption.
- There is a statistical significant difference between groups of R4 and energy consumption.
- There is not a statistical significant difference between groups of R5 and energy consumption.
- There is a statistical significant difference between groups of R6 and energy consumption.
- There is not a statistical significant difference between groups of R7 and energy consumption.
- There is a statistical significant difference between groups of R8 energy consumption.

Table I.9. Variance analysis of energy consumption based on ratio of external surface area to net usable floor area (R1).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.022-0.288	5	657.6042	131.5208	3683.609		
0.289-0.554	39	5275.872	135.2788	715.1593		
0.555-0.82	63	11007.21	174.7176	1450.077		
0.83-..	15	2768.059	184.5373	1201.877		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	50275.21	3	16758.4	13.30376	1.54E-07	2.681466
Within Groups	148641.6	118	1259.674			
Total	198916.8	121				

(cont. on next page)

Table I.9. (cont.)

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.348	3	118	.262

Multiple Comparisons

	(I) R1	(J) R1	Mean Differences. (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	-7.16385	17.04015	.981	-55.4942	41.1665
		3.00	-43.38831	16.79775	.089	-91.0312	4.2545
		4.00	-53.01641(*)	18.62329	.049	-105.8370	-.1958
	2.00	1.00	7.16385	17.04015	.981	-41.1665	55.4942
		3.00	-36.22446(*)	7.23122	.000	-56.7341	-15.7148
		4.00	-45.85255(*)	10.81449	.001	-76.5253	-15.1798
	3.00	1.00	43.38831	16.79775	.089	-4.2545	91.0312
		2.00	36.22446(*)	7.23122	.000	15.7148	56.7341
		4.00	-9.62809	10.42837	.837	-39.2057	19.9495
	4.00	1.00	53.01641(*)	18.62329	.049	.1958	105.8370
		2.00	45.85255(*)	10.81449	.001	15.1798	76.5253
		3.00	9.62809	10.42837	.837	-19.9495	39.2057
Tamhane	1.00	2.00	-7.16385	27.49392	1.000	-135.1062	120.7785
		3.00	-43.38831	27.60829	.710	-170.4605	83.6838
		4.00	-53.01641	28.58053	.548	-174.2912	68.2584
	2.00	1.00	7.16385	27.49392	1.000	-120.7785	135.1062
		3.00	-36.22446(*)	6.68502	.000	-54.1681	-18.2809
		4.00	-45.85255(*)	9.96589	.001	-74.7656	-16.9395
	3.00	1.00	43.38831	27.60829	.710	-83.6838	170.4605
		2.00	36.22446(*)	6.68502	.000	18.2809	54.1681
		4.00	-9.62809	10.27720	.930	-39.1106	19.8544
	4.00	1.00	53.01641	28.58053	.548	-68.2584	174.2912
		2.00	45.85255(*)	9.96589	.001	16.9395	74.7656
		3.00	9.62809	10.27720	.930	-19.8544	39.1106

* The mean difference is significant at the .05 level.

	R1	N	Subset for alpha = .05		
		1	2	3	1
Scheffe (a.b)	1.00	5	131.5208		
	2.00	43	138.6847	138.6847	
	3.00	59		174.9092	174.9092
	4.00	15			184.5373
	Sig.		.968	.093	.926

Table I.10. Variance analysis of energy consumption based on ratio of window area to external surface area (R2).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.14-0.237	27	4775.885	176.8846	1173.3		
0.238-0.36	56	9169.362	163.7386	1583.475		
0.37-0.68	39	5763.498	147.782	1771.31		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14010.08	2	7005.039	4.508218	0.012964	3.072429
Within Groups	184906.7	119	1553.838			
Total	198916.8	121				

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.111	2	119	.333

Multiple Comparisons

	(I) R2	(J) R2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	13.14605	9.23562	.366	-9.7480	36.0401
		3.00	29.10265(*)	9.86872	.015	4.6393	53.5660
	2.00	1.00	-13.14605	9.23562	.366	-36.0401	9.7480
		3.00	15.95660	8.22126	.157	-4.4229	36.3361
	3.00	1.00	-29.10265(*)	9.86872	.015	-53.5660	-4.6393
		2.00	-15.95660	8.22126	.157	-36.3361	4.4229
Tamhane	1.00	2.00	13.14605	8.46947	.332	-7.6666	33.9587
		3.00	29.10265(*)	9.42729	.009	5.9709	52.2343
	2.00	1.00	-13.14605	8.46947	.332	-33.9587	7.6666
		3.00	15.95660	8.58455	.187	-4.9852	36.8984
	3.00	1.00	-29.10265(*)	9.42729	.009	-52.2343	-5.9709
		2.00	-15.95660	8.58455	.187	-36.8984	4.9852

* The mean difference is significant at the .05 level.

	R2	N	Subset for alpha = .05	
		1	2	1
Scheffe (a.b)	3.00	39	147.7820	
	2.00	56	163.7386	163.7386
	1.00	27		176.8846
	Sig.		.222	.358

Table I.11. Variance analysis of energy consumption based on ratio of length to width (R3).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.21-0.408	14	2250.66	160.7614	2833.193		
0.409-0.604	49	7660.486	156.3364	1596.036		
0.605-0.8	32	5292.38	165.3869	1778.372		
0.8-…	27	4505.219	166.86	1068.194		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2572.965	3	857.6549	0.515439	0.672439	2.681466
Within Groups	196343.8	118	1663.931			
Total	198916.8	121				

Table I.12. Variance analysis of energy consumption based on ratio of external wall area to net-usable area (R4).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.138-0.32	44	6251.277	142.0745	1300.395		
0.33-0.63	63	10664.91	169.2842	1582.929		
0.64-0.94	11	2003.027	182.0934	1082.148		
0.95…	4	789.5355	197.3839	1266.84		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	30236.17	3	10078.72	7.05054	0.000212	2.681466
Within Groups	168680.6	118	1429.497			
Total	198916.8	121				

(cont. on next page)

Table I.12. (cont.)

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.220	3	118	.882

Multiple Comparisons

	(I) VAR00011	(J) VAR00011	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	-27.20974(*)	7.42826	.005	-48.2782	-6.1412
		3.00	-40.01892(*)	12.74530	.023	-76.1680	-3.8699
		4.00	-55.30939	19.74494	.054	-111.3113	.6925
	2.00	1.00	27.20974(*)	7.42826	.005	6.1412	48.2782
		3.00	-12.80919	12.35494	.783	-47.8511	22.2327
		4.00	-28.09965	19.49524	.558	-83.3933	27.1940
	3.00	1.00	40.01892(*)	12.74530	.023	3.8699	76.1680
		2.00	12.80919	12.35494	.783	-22.2327	47.8511
		4.00	-15.29046	22.07552	.923	-77.9025	47.3215
	4.00	1.00	55.30939	19.74494	.054	-.6925	111.3113
		2.00	28.09965	19.49524	.558	-27.1940	83.3933
		3.00	15.29046	22.07552	.923	-47.3215	77.9025
Tamhane	1.00	2.00	-27.20974(*)	7.39461	.002	-47.0658	-7.3537
		3.00	-40.01892(*)	11.31068	.016	-73.7720	-6.2659
		4.00	-55.30939	18.60818	.252	-152.9239	42.3051
	2.00	1.00	27.20974(*)	7.39461	.002	7.3537	47.0658
		3.00	-12.80919	11.11319	.844	-46.2471	20.6287
		4.00	-28.09965	18.48880	.763	-127.1749	70.9756
	3.00	1.00	40.01892(*)	11.31068	.016	6.2659	73.7720
		2.00	12.80919	11.11319	.844	-20.6287	46.2471
		4.00	-15.29046	20.37369	.982	-100.7275	70.1466
	4.00	1.00	55.30939	18.60818	.252	-42.3051	152.9239
		2.00	28.09965	18.48880	.763	-70.9756	127.1749
		3.00	15.29046	20.37369	.982	-70.1466	100.7275

* The mean difference is significant at the .05 level.

		N	Subset for alpha = .05	
	VAR00011	1	2	1
Scheffe (a.b)	1.00	44	142.0745	
	2.00	63	169.2842	169.2842
	3.00	11	182.0934	182.0934
	4.00	4		197.3839
	Sig.		.123	.409

Table I.13. Variance analysis of energy consumption based on ratio of net-usable common floor area to net-usable floor area (R5).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.00408-0.045	19	2796.547	147.1867	1465.826		
0.046-0.086	73	11859.11	162.4536	1676.614		
0.087-0.127	26	4252.592	163.5612	1376.507		
0.128-	4	800.4967	200.1242	2455.527		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10036.44	3	3345.481	2.090036	0.105229	2.681466
Within Groups	188880.3	118	1600.681			
Total	198916.8	121				

Table I.14. T-test analysis of energy consumption based on ratio of heating load to external surface area (R6).

	5.76-198.53	*198.54-391.31*
Mean	159.1091	118.8351697
Variance	2258.483677	326.0268738
Observations	29	11
Hypothesized Mean Difference	0	
df	38	
t Stat	3.88404566	
P(T<=t) one-tail	0.000198858	
t Critical one-tail	1.685954461	
P(T<=t) two-tail	0.000397716	
t Critical two-tail	2.024394147	

Table I.15. T-test analysis of energy consumption based on ratio of heating load to net-usable floor area (R7).

	5.04-69.50	*69.6-133.96*
Mean	147.5952413	148.4722971
Variance	3086.610741	1093.677966
Observations	20	20
Hypothesized Mean Difference	0	
df	31	
t Stat	-0.06066512	
P(T<=t) one-tail	0.476007668	
t Critical one-tail	1.695518742	
P(T<=t) two-tail	0.952015336	
t Critical two-tail	2.039513438	

Table I.16. Variance analysis of energy consumption based on Ratio of lighting load to net-usable floor area (R8).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.14-47.159	73	10796.66	147.8995	1185.044		
47.16-94.15	20	3489.995	174.4998	1473.652		
94.15-141.15	7	1350.802	192.9717	1329.44		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	21189.3	2	10594.65	8.472285	0.000406	3.090187
Within Groups	121299.2	97	1250.507			
Total	142488.5	99				

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Table I.16. (cont.)

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.087	2	97	.916

Multiple Comparisons

	(I) VAR00015	(J) VAR00015	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	-26.60031(*)	8.92500	.014	-48.7882	-4.4125
		3.00	-45.07222(*)	13.99193	.007	-79.8567	-10.2878
	2.00	1.00	26.60031(*)	8.92500	.014	4.4125	48.7882
		3.00	-18.47190	15.52962	.495	-57.0791	20.1353
	3.00	1.00	45.07222(*)	13.99193	.007	10.2878	79.8567
		2.00	18.47190	15.52962	.495	-20.1353	57.0791
Tamhane	1.00	2.00	-26.60031(*)	9.48241	.027	-50.6807	-2.5199
		3.00	-45.07222(*)	14.35804	.048	-89.6825	-.4619
	2.00	1.00	26.60031(*)	9.48241	.027	2.5199	50.6807
		3.00	-18.47190	16.23584	.626	-64.0786	27.1348
	3.00	1.00	45.07222(*)	14.35804	.048	.4619	89.6825
		2.00	18.47190	16.23584	.626	-27.1348	64.0786

* The mean difference is significant at the .05 level.

		N	Subset for alpha = .05	
	VAR00015	1	2	1
Scheffe (a.b)	1.00	73	147.8995	
	2.00	20	174.4998	174.4998
	3.00	7		192.9717
	Sig.		.134	.375

APPENDIX J

REPEATED ANALYSES FOR CO_2 EMISSIONS AND CLASSES ACCORDING TO CENTRAL AND AUTONOMOUS HEATING SYSTEMS

Table J.1. The distribution of CO2 emissions according to designers' professional status and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
Architect	120	8160.932	68.00777	693.8536		
Engineer	18	1207.196	67.06647	393.4339		
Msc. Architect	10	615.0438	61.50438	243.7769		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	393.4826	2	196.7413	0.311943	0.732513	3.058486
Within Groups	91450.95	145	630.6962			
Total	91844.43	147				

Table J.2. The distribution of CO_2 emissions according to zoning status and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
Attached	21	1753.45	83.49763	932.0069		
Detached/ inter.	45	2617.982	58.17738	432.8784		
Detached/ corner	82	5611.74	68.43585	553.0954		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9356.91	2	4678.455	8.223983	0.000414	3.058486
Within Groups	82487.52	145	568.8794			
Total	91844.43	147				

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Table J.2. (cont.)

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
2.307	2	145	.103

Post Hoc Tests
Multiple Comparisons

	(I) VAR00002	(J) VAR0000	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	25.32024(*)	6.30327	.000	9.7307	40.9098
		3.00	15.06177(*)	5.83327	.038	.6346	29.4889
	2.00	1.00	-25.32024(*)	6.30327	.000	-40.9098	-9.7307
		3.00	-10.25847	4.42485	.071	-21.2022	.6853
	3.00	1.00	-15.06177(*)	5.83327	.038	-29.4889	-.6346
		2.00	10.25847	4.42485	.071	-.6853	21.2022
Tamhane	1.00	2.00	25.32024(*)	7.34852	.005	6.7016	43.9388
		3.00	15.06177	7.15027	.129	-3.1637	33.2873
	2.00	1.00	-25.32024(*)	7.34852	.005	-43.9388	-6.7016
		3.00	-10.25847(*)	4.04532	.038	-20.0812	-.4357
	3.00	1.00	-15.06177	7.15027	.129	-33.2873	3.1637
		2.00	10.25847(*)	4.04532	.038	.4357	20.0812

* The mean difference is significant at the .05 level.

Homogeneous Subsets
VAR00001

	VAR00002	N	Subset for alpha = .05	
		1	2	1
Scheffe (a.b)	2.00	45	58.1774	
	3.00	82	68.4359	
	1.00	21		83.4976
	Sig.		.188	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 36.569.
b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Table J.3. The distribution of CO_2 classes according to window area and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
D	6	1489.709	248.2848	4627.508		
E	11	3879.512	352.6829	21891.63		
F	19	6538.601	344.1369	27806.17		
G	86	21343.46	248.1798	17444.89		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	222611.9	3	74203.98	3.934639	0.010222	2.681466
Within Groups	2225381	118	18859.16			
Total	2447993	121				

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.720	3	118	.167

Multiple Comparisons
Dependent Variable: window

	(I) CO_2 class	(J) CO_2 class	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	-104.39808	69.69693	.526	-302.0770	93.2809
		3.00	-95.85206	64.31003	.530	-278.2523	86.5482
		4.00	.10505	57.98694	1.000	-164.3613	164.5714
	2.00	1.00	104.39808	69.69693	.526	-93.2809	302.0770
		3.00	8.54601	52.02938	.999	-139.0231	156.1151
		4.00	104.50312	43.97456	.136	-20.2204	229.2266
	3.00	1.00	95.85206	64.31003	.530	-86.5482	278.2523
		2.00	-8.54601	52.02938	.999	-156.1151	139.0231
		4.00	95.95711	34.81206	.060	-2.7791	194.6933
	4.00	1.00	-.10505	57.98694	1.000	-164.5714	164.3613
		2.00	-104.50312	43.97456	.136	-229.2266	20.2204
		3.00	-95.95711	34.81206	.060	-194.6933	2.7791
Tamhane	1.00	2.00	-104.39808	52.54902	.335	-263.7126	54.9165
		3.00	-95.85206	47.27297	.290	-233.0798	41.3757
		4.00	.10505	31.21056	1.000	-108.2539	108.4640
	2.00	1.00	104.39808	52.54902	.335	-54.9165	263.7126
		3.00	8.54601	58.76760	1.000	-160.4271	177.5191
		4.00	104.50312	46.82943	.243	-42.3060	251.3122
	3.00	1.00	95.85206	47.27297	.290	-41.3757	233.0798
		2.00	-8.54601	58.76760	1.000	-177.5191	160.4271
		4.00	95.95711	40.82071	.155	-21.3750	213.2892
	4.00	1.00	-.10505	31.21056	1.000	-108.4640	108.2539
		2.00	-104.50312	46.82943	.243	-251.3122	42.3060
		3.00	-95.95711	40.82071	.155	-213.2892	21.3750

Table J.4. The distribution of CO_2 emissions according to A/V ratio and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.33-0.373	63	4868.374	77.27577	724.5632		
0.374-0.416	69	4112.752	59.6051	391.9732		
0.417..	16	1002.047	62.62791	637.7653		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10700.85	2	5350.426	9.560975	0.000126	3.058486
Within Groups	81143.58	145	559.6109			
Total	91844.43	147				

Table J.5. The distribution of CO2 emissions according to orientation and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
N/E/W	5	286.5826	57.31653	351.5098		
S/E/W	15	1103.785	73.5857	608.5302		
S/N	44	2647.931	60.18025	373.3944		
S/N/E, S/N/E, S/N/W/E	45	3528.943	78.42095	771.058		
W/E	12	869.6602	72.47169	763.6		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8495.34	4	2123.835	3.606699	0.008269	2.44988
Within Groups	68307.57	116	588.8584			
Total	76802.91	120				

Table J.6. The distribution of CO_2 emissions according to floor counts and variance analysis.

Groups	*Count*	*Sum*	*Average*	*Variance*		
5-6	47	3557.013	75.68112	506.3204		
7-8	36	2625.395	72.92765	1002.975		
9	28	1604.214	57.29336	367.0373		
10-11	37	2196.55	59.36623	388.0225		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9570.742	3	3190.247	5.583749	0.001188	2.667443
Within Groups	82273.69	144	571.345			
Total	91844.43	147				

Analysis of CO_2 Emission Based On Proposed Design Efficiency Classes

According to analysis results;

- There is a statistical significant difference between groups of R1 and CO_2 emission.
- There is a statistical significant difference between groups of R2 and CO_2 emission.
- There is no statistical significant difference between groups of R3 and CO_2 emission.
- There is a statistical significant difference between groups of R4 and CO_2 emission.
- There is a statistical significant difference between groups of R5 and CO_2 emission.
- There is a statistical significant difference between groups of R6 and CO_2 emission.
- There is no statistical significant difference between groups of R7 and CO_2 emission.
- There is a statistical significant difference between groups of R8 and CO_2 emission.

Table J.7. Variance analysis of CO2 emission based on ratio of external surface area to net usable floor area (R1).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.022-0.288	5	253.0514	50.61028	369.3033		
0.289-0.554	39	2287.179	58.64562	417.2993		
0.555-0.82	63	4792.881	76.07748	665.9384		
0.83-..	15	1173.474	78.23163	567.0139		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10241.96	3	3413.986	6.052353	0.000721	2.681466
Within Groups	66560.96	118	564.0759			
Total	76802.92	121				

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Table J.7. (cont.)

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.980	3	118	.405

Multiple Comparisons

	(I) R1	(J) R1	Mean Diff. (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	-8.03533	11.28178	.917	-40.0335	23.9628
		3.00	-25.46719	11.03489	.156	-56.7651	5.8307
		4.00	-27.62135	12.26459	.173	-62.4070	7.1643
	2.00	1.00	8.03533	11.28178	.917	-23.9628	40.0335
		3.00	-17.43186(*)	4.83912	.006	-31.1569	-3.7068
		4.00	-19.58601	7.21585	.066	-40.0521	.8801
	3.00	1.00	25.46719	11.03489	.156	-5.8307	56.7651
		2.00	17.43186(*)	4.83912	.006	3.7068	31.1569
		4.00	-2.15415	6.82339	.992	-21.5071	17.1988
	4.00	1.00	27.62135	12.26459	.173	-7.1643	62.4070
		2.00	19.58601	7.21585	.066	-.8801	40.0521
		3.00	2.15415	6.82339	.992	-17.1988	21.5071
Tamhane	1.00	2.00	-8.03533	9.19569	.962	-45.7293	29.6587
		3.00	-25.46719	9.18864	.205	-63.1741	12.2397
		4.00	-27.62135	10.56700	.164	-63.5797	8.3370
	2.00	1.00	8.03533	9.19569	.962	-29.6587	45.7293
		3.00	-17.43186(*)	4.61199	.002	-29.8271	-5.0366
		4.00	-19.58601	6.96426	.059	-39.6739	.5018
	3.00	1.00	25.46719	9.18864	.205	-12.2397	63.1741
		2.00	17.43186(*)	4.61199	.002	5.0366	29.8271
		4.00	-2.15415	6.95495	1.000	-22.2033	17.8949
	4.00	1.00	27.62135	10.56700	.164	-8.3370	63.5797
		2.00	19.58601	6.96426	.059	-.5018	39.6739
		3.00	2.15415	6.95495	1.000	-17.8949	22.2033

* The mean difference is significant at the .05 level.

	R1	N	Subset for alpha = .05	
		1	2	1
Scheffe(a.b)	1.00	5	50.6103	
	2.00	39	58.6456	58.6456
	3.00	63	76.0775	76.0775
	4.00	15		78.2316
	Sig.		.064	.226

Table J.8. Variance analysis of CO_2 emission based on ratio of window area to external surface area (R2).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.14-0.237	27	2088.197	77.34062	706.1405		
0.238-0.36	56	3995.309	71.34481	564.1019		
0.37-0.68	39	2423.08	62.13025	617.2436		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3962.401	2	1981.2	3.236699	0.042778	3.072429
Within Groups	72840.52	119	612.1052			
Total	76802.92	121				

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.227	2	119	.797

Multiple Comparisons

	(I) R2	(J) R2	Mean Diff.(I-J)	Std. Error	Sig.	95%Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	5.99581	5.79664	.587	-8.3734	20.3650
		3.00	15.21038	6.19399	.053	-.1438	30.5646
	2.00	1.00	-5.99581	5.79664	.587	-20.3650	8.3734
		3.00	9.21456	5.15999	.207	-3.5764	22.0056
	3.00	1.00	-15.21038	6.19399	.053	-30.5646	.1438
		2.00	-9.21456	5.15999	.207	-22.0056	3.5764
Tamhane	1.00	2.00	5.99581	6.01885	.692	-8.9103	20.9019
		3.00	15.21038	6.47921	.066	-.7589	31.1796
	2.00	1.00	-5.99581	6.01885	.692	-20.9019	8.9103
		3.00	9.21456	5.08920	.206	-3.1984	21.6275
	3.00	1.00	-15.21038	6.47921	.066	-31.1796	.7589
		2.00	-9.21456	5.08920	.206	-21.6275	3.1984

	R2	N	Subset for alpha = .05	
		1	2	1
Scheffe(a.b)	3.00	39	62.1302	
	2.00	56	71.3448	71.3448
	1.00	27		77.3406
	Sig.		.279	.580

Table J.9. Variance analysis of CO_2 emission based on ratio of length to width (R3).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.21-0.408	14	853.7804	60.98432	456.317		
0.409-0.604	49	3345.919	68.28407	647.6747		
0.605-0.8	32	2282.892	71.34039	656.9672		
0.8-…	27	2023.994	74.96273	670.0338		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1995.548	3	665.1825	1.049249	0.373553	2.681466
Within Groups	74807.37	118	633.9608			
Total	76802.92	121				

Table J.10. Variance analysis of CO_2 emission based on ratio of external wall area to net-usable area (R4).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.138-0.32	44	2686.586	61.05877	519.3553		
0.33-0.63	63	4666.919	74.07808	684.6392		
0.64-0.94	11	893.6969	81.24517	557.7119		
0.95…	4	259.3838	64.84596	130.8186		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	6053.436	3	2017.812	3.365422	0.021024	2.681466
Within Groups	70749.48	118	599.5719			
Total	76802.92	121				

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.045	3	118	.375

Multiple Comparisons

	(I) R4	(J) R4	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	-13.01930	4.81078	.068	-26.6640	.6254
		3.00	-20.18640	8.25428	.119	-43.5977	3.2249
		4.00	-3.78718	12.78748	.993	-40.0559	32.4815
	2.00	1.00	13.01930	4.81078	.068	-.6254	26.6640
		3.00	-7.16710	8.00147	.849	-29.8614	15.5272
		4.00	9.23212	12.62577	.911	-26.5779	45.0421
	3.00	1.00	20.18640	8.25428	.119	-3.2249	43.5977
		2.00	7.16710	8.00147	.849	-15.5272	29.8614
		4.00	16.39922	14.29684	.726	-24.1504	56.9488
	4.00	1.00	3.78718	12.78748	.993	-32.4815	40.0559
		2.00	-9.23212	12.62577	.911	-45.0421	26.5779
		3.00	-16.39922	14.29684	.726	-56.9488	24.1504
Tamhane	1.00	2.00	-13.01930(*)	4.76139	.044	-25.7998	-.2389
		3.00	-20.18640	7.90599	.125	-44.1066	3.7338
		4.00	-3.78718	6.67145	.995	-30.4531	22.8787
	2.00	1.00	13.01930(*)	4.76139	.044	.2389	25.7998
		3.00	-7.16710	7.84655	.941	-30.9966	16.6625
		4.00	9.23212	6.60090	.771	-17.6568	36.1210
	3.00	1.00	20.18640	7.90599	.125	-3.7338	44.1066
		2.00	7.16710	7.84655	.941	-16.6625	30.9966
		4.00	16.39922	9.13267	.466	-12.6095	45.4080
	4.00	1.00	3.78718	6.67145	.995	-22.8787	30.4531
		2.00	-9.23212	6.60090	.771	-36.1210	17.6568
		3.00	-16.39922	9.13267	.466	-45.4080	12.6095

* The mean difference is significant at the .05 level.

	R4	N	Subset for alpha = .05
		1	1
Scheffe(a. b)	1.00	44	61.0588
	4.00	4	64.8460
	2.00	63	74.0781
	3.00	11	81.2452
	Sig.		.315

Table J.11. Variance analysis of CO_2 emission based on ratio of net-usable common floor area to net-usable floor area (R5).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.00408-0.045	19	1083.96	57.05055	383.7065		
0.046-0.086	73	5163.871	70.73796	670.9197		
0.087-0.127	30	2258.754	75.2918	604.5935		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4056.772	2	2028.386	3.318086	0.039602	3.072429
Within Groups	72746.14	119	611.3121			
Total	76802.92	121				

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.465	2	119	.629

Multiple Comparisons

	(I) R5	(J) R5	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	-13.68741	6.36777	.104	-29.4724	2.0975
		3.00	-18.24124(*)	7.24923	.046	-36.2112	-.2712
	2.00	1.00	13.68741	6.36777	.104	-2.0975	29.4724
		3.00	-4.55383	5.36202	.698	-17.8456	8.7380
	3.00	1.00	18.24124(*)	7.24923	.046	.2712	36.2112
		2.00	4.55383	5.36202	.698	-8.7380	17.8456
Tamhane	1.00	2.00	-13.68741(*)	5.42086	.047	-27.2567	-.1181
		3.00	-18.24124(*)	6.35202	.019	-34.0016	-2.4809
	2.00	1.00	13.68741(*)	5.42086	.047	.1181	27.2567
		3.00	-4.55383	5.41699	.788	-17.8811	8.7735
	3.00	1.00	18.24124(*)	6.35202	.019	2.4809	34.0016
		2.00	4.55383	5.41699	.788	-8.7735	17.8811

* The mean difference is significant at the .05 level.

	R5	N	Subset for alpha = .05	
		1	2	1
Scheffe(a. b)	1.00	19	57.0506	
	2.00	73	70.7380	70.7380
	3.00	30		75.2918
	Sig.		.104	.775

Table J.12. T-test analysis of CO_2 emission based on ratio of heating load to external surface area (R6).

	5.76-198.53	198.54-391.31
Mean	55.17303437	39.21560599
Variance	314.8072802	35.50432655
Observations	29	11
Hypothesized Mean Difference	0	
df	38	
t Stat	4.252202459	
P(T<=t) one-tail	6.63461E-05	
t Critical one-tail	1.685954461	
P(T<=t) two-tail	0.000132692	
t Critical two-tail	2.024394147	

Table J.13. T-test analysis of CO2 emission based on ratio of heating load to net-usable floor area (R7).

	5.04-69.50	69.6-133.9
Mean	46.1718735	51.76323
Variance	326.291105	283.1908
Observations	7	33
Hypothesized Mean Difference	0	
df	8	
t Stat	-0.7526082	
P(T<=t) one-tail	0.23662347	
t Critical one-tail	1.85954803	
P(T<=t) two-tail	0.47324694	
t Critical two-tail	2.30600413	

Table J.14. Variance analysis of CO_2 emission based on ratio of lighting load to net-usable floor area (R8).

Groups	*Count*	*Sum*	*Average*	*Variance*		
0.14-47.159	73	4643.958	63.61586	599.5142		
47.16-94.15	20	1642.14	82.10702	749.1183		
94.15-141.15	7	519.544	74.22058	207.9873		
Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5653.821	2	2826.91	4.675671	0.011518	3.090187
Within Groups	58646.2	97	604.6			
Total	64300.02	99				

Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.363	2	97	.261

Multiple Comparisons

	(I) VAR00031	(J) VAR00031	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
			Lower Bound	Upper Bound	Lower Bound	Upper Bound	Lower Bound
Scheffe	1.00	2.00	-18.49116(*)	6.20582	.014	-33.9190	-3.0633
		3.00	-10.60472	9.72901	.554	-34.7914	13.5819
	2.00	1.00	18.49116(*)	6.20582	.014	3.0633	33.9190
		3.00	7.88644	10.79821	.766	-18.9583	34.7312
	3.00	1.00	10.60472	9.72901	.554	-13.5819	34.7914
		2.00	-7.88644	10.79821	.766	-34.7312	18.9583
Tamhane	1.00	2.00	-18.49116(*)	6.75784	.032	-35.6543	-1.3280
		3.00	-10.60472	6.15833	.311	-28.3197	7.1102
	2.00	1.00	18.49116(*)	6.75784	.032	1.3280	35.6543
		3.00	7.88644	8.19563	.722	-13.4218	29.1946
	3.00	1.00	10.60472	6.15833	.311	-7.1102	28.3197
		2.00	-7.88644	8.19563	.722	-29.1946	13.4218

* The mean difference is significant at the .05 level

		N	Subset for alpha = .05
	VAR00031	1	1
Scheffe (a.b)	1.00	73	63.6159
	3.00	7	74.2206
	2.00	20	82.1070
	Sig.		.134