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ENERGY PERFORMANCE OF GLASS BUILDING MATERIALS

Assoc. Prof. Dr. Arzuhan Burcu GÜLTEKİN [1], Elnaz BAGHERI FARAHBAKHSH [2]

abgultekin@ankara.edu.tr, farahbakhsh.e@gmail.com

[1, 2] Ankara University, Faculty of Applied Sciences, Department of Real Estate Development and Management, Ankara, Turkey

Abstract

The type of glass has become one of the parameters affecting the amount of energy gains and losses caused by transparent surfaces and it can affect energy consumption used for heating buildings. The analysis of glasses according to climatic conditions and development of solutions for the amount of energy consumption caused by glasses is very important from an energy-efficient design perspective. In this regard, this paper aims to raise awareness about the increasing number of residential buildings in Turkey on the selection of energy-efficient glass types and to provide guidelines for the actors involved in the construction sector. In this study, a typical type residential building project of the Housing Development Administration of Turkey (TOKİ) located in three degree day regions of Turkey with different degrees of sunlight was evaluated according to the Thermal Insulation Standard for Buildings (TS 825). Twelve scenarios were created from single thermopane, double thermopane, single low-e glass, and double low-e glass options. These scenarios were analysed by eQuest energy analysis program in terms of energy consumption resulting from natural gas use for house heating. According to the analysis, use of single thermopane in III. degree-day region gives the highest energy consumption rate while use of single low-e glass in I. degree-day region gives the lowest rate. The obtained results have indicated that the type of glass affects energy consumption.

Key Words: Energy Performance, Glass Building Material, Low-e Glass, eQUEST

1. INTRODUCTION

Environmental pollution occurred as a consequence of industrial development, population growth and urbanization is one of the most important problems of our day. The construction sector consumes 17% of fresh water supplies, 25% of forestry products and 40% of energy resources [1-3]. 28% of the consumed resources in Turkey are domestic and 72% of them are imported, but this import rate increases day by day [4, 5]. In parallel with these rates, the concept of energy has gain importance in the Turkish construction sector [6]. The energy amount consumed for heating a unit volume in Turkey is 50% bigger than Germany, 60% than the USA and 73% than Sweden [7]. Therefore, it is highly essential to promote the construction of new buildings in Turkey in an energy-efficient way and to increase the energy efficiency of the existing building stock. Solar energy is one of the most important factors affecting energy consumption in buildings. Solar energy is gained in buildings by means of transportation, transmission and radiation. Thus, transparent and opaque surfaces forming the building envelope have a critical role in energy requirement. Such design parameters as window/wall space ratio, frame type and glass type should be taken into account while planning to decrease energy consumption. It is possible to obtain the intended values of energy efficiency by carrying out climate-based energy analyses and using simulation programs in the preliminary design phase of the architectural design process. One of the most influential parameters in terms of heat losses and gains is the thermal transmittance coefficient of the elements constituting the building envelope. As windows show far less resistance than such construction elements as wall, roof and floor, heat losses and gains are substantially occurred through windows [8]. Within this context, the energy performance of windows varies depending on the thermal features of frames, glass coating types, spaces between glasses and gas types used for these spaces. It can be possible to increase the energy performance of windows if these coefficients are determined having regard to the features of climatic zones [9].

The objective of this study is to provide a guideline for enabling relevant actors in the construction sector to understand, implement and generalize energy-efficient design parameters in the buildings. The study also aims to raise awareness about the energy-efficient design of new residential buildings, which are rapidly increasing in Turkey, and renewing the existing buildings in an energy-efficient way and to light the way for researchers and designers about selecting glass types with high energy performance.

2. ENERGY EFFICIENCY

Energy efficiency is generally defined as using energy resources at the highest possible efficiency in all phases from production to consumption [10]. International Energy Agency (IEA) describes energy efficiency as decreasing energy consumption without reducing production and hampering social welfare by using new technologies or utilizing and recycling all kinds of waste and energy losses which can be in various forms like heat, steam, compressed air and electricity [11].

The energy need of the world increases at the rate of 4-5 % every year due to several reasons like rapid population growth, industrialization and high standards of living. Among the most common fuel types around today's globe, the oil reserves are on the verge of running out within 15-45 years, coal within 150-200 years and natural gas within 40-50 years [12]. Within this context, it can be asserted that there are many studies conducted by International Organization for Standardization (ISO), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the European Union (EU) in order to maintain energy efficiency in the global construction sector. Turkey also has made progress in recent years with respect to organizing mass education activities, making legislative regulations and funding energy efficiency projects of the finance sector for the purpose of increasing energy efficiency. However, these policies could not be coordinated effectively and their results have not become sufficiently visible yet [13].

2.1 Turkish Legal Regulations on Energy Efficiency in the Construction Sector

Turkey is a strategic country due to its geopolitical situation at the crossroads of Asia and Europe and in the vicinity of 70% of world energy supplies. It is the world's 34th largest country with a total area of 783,562 km^2 and has a population of 77,7 million by the year of 2014 [14]. Between the years of 1970-2006, Turkey's population increased at the rate of 107 % and per capita consumption of energy at the rate of 148%. While energy consumption increases more rapidly than population in Turkey as in the world, per capita consumption of energy has increased more rapidly in Turkey than the world. Energy bears a strategic importance for Turkey during the EU harmonization process. Therefore, a number of legal regulations which would provide energy efficiency have been made especially in recent times. The most significant step taken within this framework is the *Energy Efficiency Law* [15] enacted in 2007. According to the law, energy efficiency is the reduction of energy consumed per unit of service or product without causing a reduction in living standards and service quality in buildings, and quality and amount of production in industrial plants [16]. This law has determined basic rules and policies for increasing energy efficiency during the production, transmission, distribution and consumption phases of energy, in the industry, buildings, transportation, and in the transmission and distribution networks [12].

The Regulation on Thermal Insulation in Buildings [17] entered into force in 2008 in order to reduce heat losses and enable energy conservation in buildings. The regulation encompasses reducing heat losses in buildings, enabling energy conservation and procedures & principles regarding the enforcement. Within the scope of the harmonization process with the EU legislation, *The Regulation on Energy Performance in Buildings* [18] was enacted in 2008 with the intention of arranging procedures and principles in regard to initiating minimum energy performance practices in the buildings in the EU countries, using energy and energy supplies in these buildings efficiently and preventing energy waste. The objective of the regulation is to determine calculation rules needed for evaluating all energy uses of a building taking into consideration outdoor climate conditions, indoor necessities, local conditions and cost effectiveness, to specify minimum energy performance needs for existing buildings to be renovated, to evaluate the applicability of renewable energy resources, to settle performance criteria and codes of practice for buildings and to maintain the protection of the environment [19]. According to the regulation, it is aimed that buildings are insulated in compliance with the minimum conditions of thermal insulation specified in the Thermal Insulation Standard for Buildings (TS 825) and in a way that there will arise no thermal bridge between the junctions of wall, floor, balcony, cantilever, base, ceiling, roof and window which constitute the building envelope. The buildings meeting the aforementioned conditions are granted an “Energy Performance Certificate” for a period of 10 years and this certificate is a prerequisite of occupancy permit for new buildings [20].

The Ministry of Energy and Natural Resources prepared *The Regulation on Increasing Efficiency in the Use of Energy Sources and Energy* [21] in 2011 with the aim of providing energy efficiency, preventing energy waste, easing the burden of energy costs on the economy and protecting the environment. Within the framework of “*The Energy Efficiency Strategy Paper 2012-2023* [22]” prepared with the participation of public sector, private sector and non-governmental organizations under the coordination of the Ministry, it is aimed to reduce Turkey’s energy amount per GDP (gross domestic product) by the year of 2023 to a rate at least 20% lesser than the values of 2011. The paper also targets to reduce the energy demands and carbon emission of buildings, to increase the number of energy-efficient and sustainable buildings using renewable energy resources, to mainstream the practice of onsite reproduction in buildings and to transform at least one fourth of the total buildings in 2010 into sustainable buildings until 2023.

2.2 Energy Consumption of the Buildings in Turkey

According to the “Building Census” report prepared by the Turkish Statistical Institute (TÜİK) in 2001, buildings used only as residence constitute 75 % of the total building number, namely the largest portion, in a distribution with respect to the intended purposes of buildings. Buildings used both as residence and for other purposes have a portion of 12%. Commercial buildings constitute 6 % and industrial buildings 2 % of the total building number [23]. Residential buildings, which form the majority of the existing building stock, are responsible for 35% of the ultimate energy consumption with reference to the 2010 data of the Ministry of Energy and Natural Resources.

According to the Ministry’s 2011 data, the residential sector has a share of 26 % in the natural gas consumption [24]. TÜİK’s findings indicate that the industry sector accounts for 47.28%, residential sector for 23.79% and business sector for 16.40% of the total energy consumption of sectors in 2011 [25]. According to TÜİK, there were detected 7.096.277 housing units within the municipal boundaries in the building census conducted in 1984 and this number climbed to 16.235.830 with an increase of 129% in the building census conducted in 2000. When the age distribution of buildings is analysed, it is seen that the fastest housing took place after 1970 with a rate of 77% and the average age of buildings is 21 years [23]. A study made by the Association of Real Estate and Real Estate Investment Companies (GYODER) reveals that the number of residences situated in urban areas is 18.063.800 in the year of 2011 [26].

In reference to the study on household energy consumption made by TÜİK in 1998, 84% of existing buildings are single glazed and only 16% of them have roof insulation. According to the perception research of the Association of Thermal Insulation, Waterproofing, Sound Insulation and Fireproofing Material Producers, Suppliers and Applicators (İZODER), only 9% of consumers makes the buildings in which they reside insulated [26]. Within the scope of the research on the energy efficiency awareness of Turkey carried out by GFK (Growth from Knowledge) Turkey in 2009, it is found that 82% of the energy consumed in buildings has been used for heating, only 20% of buildings have insulation and 58% of buildings have double glazing, 39% single glazing and 6% insulated glass [27].

According to the Research Report on Household Energy Efficiency prepared by the General Directorate of Renewable Energy, only 13.9% of residential buildings have thermal insulation on their walls and roofs. The same report asserts that 60% of windows are double glazed, 39.2% single glazed and 0,9% coated glass [28]. Therefore, it is believed that the findings acquired from this study can serve as a guideline in determining the options of glass building materials with high energy performance which could be preferred for residential buildings in different degree-day regions of Turkey as of the preliminary design phase.

3. GLASS BUILDING MATERIALS

Transparency has always been an important problem and an objective to be achieved in the construction sector. Technical restrictions of the past of the glass have given way to developed technical properties, aesthetical features, and design flexibility in our day [29]. Glass, discovered in eastern Mesopotamia 4000 years ago [30], has started to enable designers to create magnificent designs in terms of thermal, optical, resistance and surface coating features along with technological and aesthetical specifications. In order to overcome the negative effects of the transparency of windows, new technologies providing sun control and thermal insulation have been developed and the below described properties have been gained [31].

Thermal properties of glass: Thermal transmittance of glass is an important factor in terms of heat loss and negatively affects heating costs. Heat losses which occur through radiation can be reduced by applying some coatings on the glass. Convection can be controlled via some additives to the frit. The thermal expansion value of glass changes depending on its chemical structure.

Optical properties of glass: It is important that the glass construction material used in buildings has luminous transmittance. The non-crystalline structure of glass enables light rays to transmit it without refraction.

Resistance properties of glass: It is vital for glass to involve high quantities of silica in order to become tough and resistant. However, this increases the fragility of glass. The structure of glass cannot overcome plastic deformations. It may undergo elastic deformation up to the stress point which would lead an instantaneous rupture.

The architectural systems developed after the Industrial Revolution enabled that window bays are opened more freely in facades and glass material has started to be used on all facades. Subsequently, the expected performance level of windows has been towered up as they are expected to allow the control of many factors like brightness and radiation heat of the sun, general heat differentiation, outdoor noise and resistance [32]. Today, in the wake of developing natural lighting systems in parallel with the developing technology, modern systems are designed which saves energy by providing the efficient usage of sunlight and offers visual comfort conditions by preventing direct sunlight [33]. There are several types of glass used in buildings. Each of them has distinctive features. Glasses can be categorized as normal glass, coated glass, safety glass and laminated glass. This study has taken under review *low-e glass* among coated glass types and *thermopane* among laminated glass types.

Coated Glass: The features of glass related with sun control depend on radiation conductivity [34]. An effective sun control can be acquired by coating the glasses with a reflector. Coatings are used widely and effectively in order to reduce the heating costs in winter and cooling costs in summer and to improve the comfort conditions of living spaces and workspaces inside the building [35]. Coated glasses can be categorized as *low-emissivity (low-e) glass*, cold mirror glass and ceramic-enamel coated glass.

Laminated Glass: Laminated glasses can be categorized as laminated glass loaded by air, thermochromic and electrochromic laminated, and photovoltaic (PV) module laminated. Laminated glass loaded by air is called as climate control glass or *thermopane*. These glasses are formed by bonding the edges of two or three glass sheets with dry air between them and cutting off inside and outside air in order to prevent surface heat loss. They can be used as transparent or translucent depending on their intended use in buildings [36].

4. EVALUATION OF THE ENERGY PERFORMANCE OF GLASS BUILDING MATERIALS IN TURKEY

This study includes the evaluation of glass options, used in a residential building project in three different degree-day regions of Turkey hypothetically with the same topographical features, in terms of the climatic conditions of the aforementioned regions within the scope of the Thermal Insulation Standard for Buildings (TS 825). In line with the abovementioned assumption, *the energy consumption* of that kind of residential building in each degree-day region *resulting from natural gas usage for house heating* has been analysed with the eQUEST simulation program and the energy performance has been evaluated.

4.1 Climatic Features of Degree-Day Regions in Turkey as part of TS 825

Climatic regions are classified in different ways in different scientific studies. The most widely accepted classification of the world is the one belonging to Köppen who made it basing on the relation of precipitation and temperature with vegetation. This classification contains 5 main climate zones and 24 climatic types [37].

Several studies have been conducted in order to make a climate classification in Turkey. These studies have separated Turkey into 7 different climatic regions depending on the evaluation of the climatic data acquired from 35 different centres [37]. Recent researches have accepted that Turkey is consisted of 5 main climatic regions [38].

In this study, the classification grounding on the degree-day regions as part of TS 825 [39] has been used. According to TS 825, Turkey's provinces are categorized into four different climatic regions with regard to the number of their heating degree days (HDD). These regions called as I., II., III. and IV. degree-day regions are demonstrated in the Figure 1.

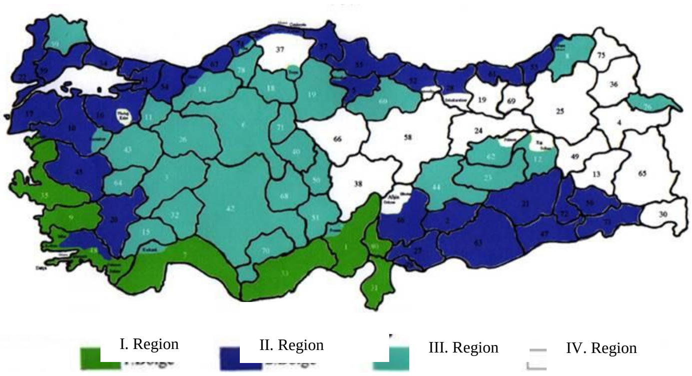

Figure 1. The Map of Degree-Day Regions in Turkey [40]

Only I., II. and III. degree-day regions have been evaluated in this study. I. degree-day region bears the features of a hot and humid climatic region. The weather is warm and rainy in winters, and hot and arid in summers. The annual heating period is shorter than the annual cooling period. The mean yearly temperature is 18,4˚C. II. degree-day region generally bears the features of hot and arid, and warm and humid climatic region. The mean yearly temperature is 15˚C. III. degree-day region bears the features of a warm and dry climatic region. The annual heating period is longer than the cooling period. While the weather is warm in winters, heat gains climb over the comfort conditions in summers [41]. The detailed information about the temperature and radiation values of these regions can be obtained from TS 825 [39].

4.2 Evaluation of the Energy Performances of Thermopane and Low-e Glasses Used in TOKİ Residential Building in Different Degree-Day Regions

This chapter includes the evaluation of *the energy performance and the analysis on the annual energy consumption resulting from natural gas usage for house heating* of different glass types used in a three-floored residential building accepted to exist in reality, according to the climatic features of I., II. and III. degree-day regions specified in TS 825.

The cities of Izmir situated in I. degree-day region; İstanbul in II. degree-day region and Ankara in III. degree-day region, have been chosen for evaluation. It has been assumed that the residential building has been positioned under the same topographic conditions northwestwardly in one year period for every three cities. The window/wall ratio has been regarded as the same in all facades as well as the frame types. However different window/wall ratios, directions and time intervals should also be evaluated in further studies.

The plan type in question is K-6, one of the typical projects of TOKİ built in every degree-day regions of Turkey. The reason of choosing the K-6 plan type is that it minimizes thermal changes due to orientation as it has a rectangular layout and that it is built in many settlements in Turkey.

As Table 1 shows, the sample residential apartment block consists of 3 floors (Basement Floor + Ground Floor + 3) and 16 apartments. Every apartment has 1 saloon, 3 rooms, 1 water-closet and 1 bathroom. The floor space of the building is 467 m^2 and total block & floor area including the basement is 2335 m^2.

Table 1

Space Distribution Table of The Evaluated Building [42]

Number of Floors	Number of Apartments in a Floor	Number of Apartments in the Block	Total Number of Blocks	Construction Area of the Block	Total Number of Apartments	Floor Area of the Block		Total Block & Floor Area (including Basement)
						Open to Inhabiting	Close to Inhabiting	
B+G+3	4	16	25	1962 m^2	400	94	373	2335

Figure 2 exhibits the layout plan, ground floor plan, profiles and images of the TOKİ K-6 type residential building project.

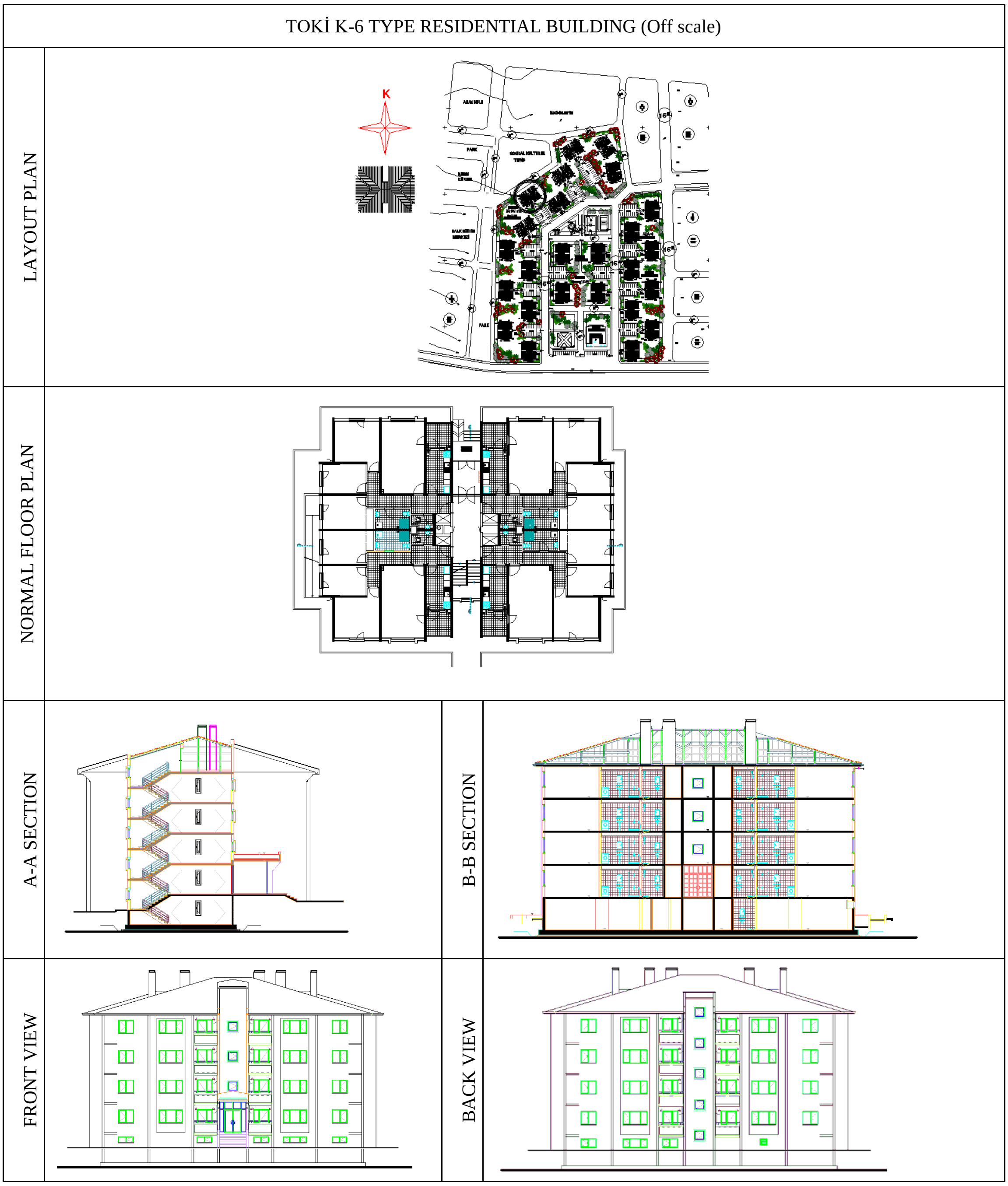

Figure 2. TOKİ K-6 Type Residential Building Project [42]

Table 2 presents the areas of the building envelope components which cause heat losses in the residential building accepted to locate in I., II. and III. degree-day regions.

Table 2

Areas of The Building Envelope Components Of The TOKİ K-6 Residential Building

Building Envelope Specifications of TOKİ K-6 Residential Building	
Floor Areas	A_{floor} = 533,84 m^2 (Soil based floor area)
Window Areas	$A_{window\ (north)}$ = 43,11 m^2
	$A_{window\ (south)}$ = 41,79 m^2
	$A_{window\ (east)}$ = 32,76 m^2
	$A_{window\ (west)}$ = 29,20 m^2
Roof Areas	A_{roof} = 564,28 m^2

The modelling and energy consumption analysis in this study have been prepared with the eQUEST 3.65 (the Quick Energy Simulation Tool 3.65) simulation program [43]. The eQUEST is a DOE-2 based simulation program developed by the Department of Energy (DOE) [44] and tested according to the ASHRAE 140 standard [45]. It is widely used for energy performance analysis, energy consumption analysis, conceptual design performance analysis, LEED evaluation, energy and atmosphere credit analysis, compatibility analysis and life cycle costing, and as a building design wizard in the fields of DOE-2 and PowerDOE and an energy efficiency measuring wizard. Therefore, eQUEST enables the modelling of the building features related with heating, cooling, lighting and air-conditioning and analysing the energy performances of buildings [44]. Accordingly, annual energy consumption of buildings can be calculated in terms of area lighting, task lighting, misc. equipment, exterior usage, pumps and aux, ventilation fans, water heating, ht pump supp, space heating, refrigeration, heat rejection and space cooling by eQUEST.

For the energy consumption analysis, firstly information about the location of the building, building footprint and external windows and then data about the shape, direction, dimensions, ceiling height, roof specification and zonings of the building have been installed into the program. The residential building in question has a northwestwardly rectangular layout. In order to define the window area, the method of “net wall area percentage from floor up to ceiling” has been chosen. The ratio of window/wall area is accepted to steadily be 40% in all facades. The information about the glass category, glass type and frame thickness is determined as shown in Table 3.

Table 3

Glass And Frame Options Preferred For The Energy Consumption Analysis of The TOKİ K-6 Residential Building

Glass and Frame Options Used within the eQUEST Program	
Glass Category	Single Thermopane
	Single Low-e Glass
	Double Thermopane
	Double Low-e Glass
Glass Type	Single Thermopane, 1.4in
	Single Low-e Glass [E2=.2], 1.4 in
	Double Thermopane, 1.4in,1.2, [Argon]
	Double Low-E Glass [E2=.1] ,1.4in,1.2in,[Argon]
Frame Type	Ins Fibergls/Vinyl Operable
	Ins Fibergls/Vinyl Operable
	Ins Fibergls/Vinyl Oper,Mtl Spacer
	Ins Fibergls/Vinyl Oper,Mtl Spacer

The climatic data of the cities of Izmir, İstanbul and Ankara have been uploaded into the eQUEST program and the existing database of the program has been utilized for other necessary data. Cooling has been ignored and only heating has been taken into account while making the evaluation. It has been assumed that natural gas is used for house and water heating. The study has accepted kWh as the natural gas consumption unit. The data related to electricity, lighting and air-conditioning in the program has been made fixed. By changing the climate data, some values of separate heating (house and water heating) load for each cities and total energy consumption have been acquired.

4.3 Comparison and Discussion of the Findings

12 different scenarios have been created according to the glass types in Table 3 and 3 different degree-day regions (I., II. and III.) which were taken into consideration during the evaluation have been carried out for this study. The results belonging to the scenarios are summarized in Table 4. The other annual energy consumption in the table consists of lighting, cooling and plug load. The over values in the total result from the losses from the glass surfaces.

Table 4

The Findings of The Scenarios Evaluated In The Simulation

Scenario	City	Glass Type	Annual Energy Consumption (kWh)		
			Heating (House Heating)	Other	Total
S1	Izmir	Single Thermopane, 1.4in	51.143839	176.563274	277.527113
S2	Izmir	Single Low-E Glass (e2=.2) 1.4 in	30.165809	176.520344	256,486153
S3	Izmir	Double Thermopane 1.4in,1.2-Argon	33.067213	176,529136	259,396349
S4	Izmir	Double Low-E Glass (e2=.1) 1.4 in,1.2 in, Argon	26.153666	176,537928	252,491594
S5	İstanbul	Single Thermopane, 1.4in	98.477753	182.034931	330.312684
S6	İstanbul	Single Low-E Glass (e2=.2) 1.4 in	62.740663	181.912	294.452663
S7	İstanbul	Double Thermopane 1.4in,1.2-Argon	66.782113	181.927862	298.509975
S8	İstanbul	Double Low-E Glass (e2=.1) 1.4 in,1.2 in, Argon	53.350664	103.150664	285,044387
S9	Ankara	Single Thermopane, 1.4in	178.969733	193.795041	422.564774
S10	Ankara	Single Low-E Glass (e2=.2) 1.4 in	129.742579	193.595041	373.13762
S11	Ankara	Double Thermopane 1.4in,1.2-Argon	134.601698	193.627972	378.02967
S12	Ankara	Double Low-E Glass (e2=.1) 1.4 in,1.2 in, Argon	113.998799	193.566764	312.365554

The percentage rates of energy consumption resulting from natural gas usage for house heating in the residential building situated in I., II. and III. degree-day regions and using different types of glass are presented in Table 5 as quantity and in Figure 3 as a graphic. These percentage rates are obtained from eQUEST energy analysis program and the obtained results are validated according to previous scientific studies [9, 18].

Table 5

Energy Consumption Rates Resulting From Natural Gas Usage For House Heating

Glass Type	I. Degree-Day Region (Izmir)	II. Degree-Day Region (Istanbul)	III. Degree-Day Region (Ankara)
Single Thermopane, 1.4in	% 44 (S1)	% 58 (S5)	% 68 (S9)
Single Low-E Glass (e2=.2) 1.4 in	% 31 (S2)	% 47 (S6)	% 61 (S10)
Double Thermopane 1.4in,1.2-Argon	% 34 (S3)	% 48 (S7)	% 62 (S11)
Double Low-E Glass (e2=.1) 1.4 in,1.2 in, Argon	% 28 (S4)	% 43 (S8)	% 58 (S12)

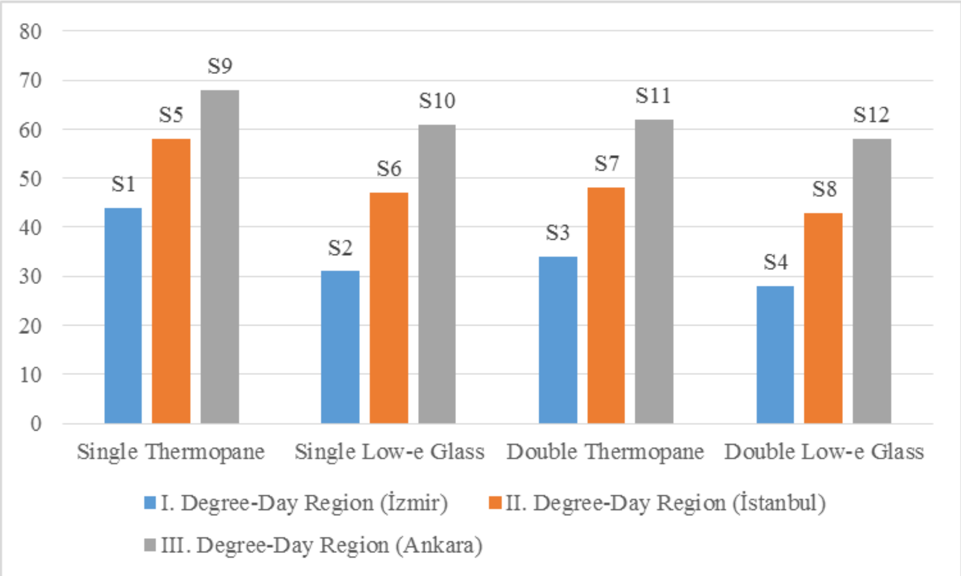

Figure 3. Comparison Of Energy Consumption Resulting From Natural Gas Usage For House Heating As Per I., II. And III. Degree-Day Regions

The reviews on I., II. and III. degree-day regions can be interpreted according to Table 5 and Figure 3 as follows:

- In Izmir, the energy consumption resulting from natural gas usage for house heating is 44% in a building using single thermopane (S1), 31% in a building using single low-e glass (S2), 34% in a building using double thermopane (S3) and 28% in a building using double low-e glass (S4). These rates indicate that the highest energy consumption takes place in the S1 scenario and the lowest energy consumption in the S4 scenario.

- In İstanbul, the energy consumption resulting from natural gas usage for house heating is 58% in a building using single thermopane (S5), 47% in a building using single low-e glass (S6), 48% in a building using double thermopane (S7) and 43% in a building using double low-e glass (S8). These rates indicate that the highest energy consumption takes place in the S5 scenario and the lowest energy consumption in the S8 scenario.

- In Ankara, the energy consumption resulting from natural gas usage for house heating is 68% in a building using single thermopane (S9), 61% in a building using single low-e glass (S10), 62% in a building using double thermopane (S11) and 58% in a building using double low-e glass (S12). These rates indicate that the highest energy consumption takes place in the S9 scenario and the lowest energy consumption in the S12 scenario.

- It is observed that in the analysed degree-day regions, the highest energy consumption takes place in the scenarios using single thermopane and the lowest energy consumption takes place in the scenarios using double low-e glass. Thus, it is concluded that single thermopane should not be used on any facades of buildings and in any degree-day regions.

- It is seen that in the analysed degree-day regions, there is a slight difference between the options of single low-e glass and double thermopane in terms of energy consumption, with a maximum rate of 3% and minimum rate of 1%. Nonetheless, single low-e glass is recommended instead of double thermopane due to such reasons that it provides protection against UV rays, protects the colors of indoor stuffs and does not transmit indoor heat out of the building.

The reviews on I., II. and III degree-day regions can be interpreted in terms of their energy consumptions for heating purposes as follows (See Table 5 and Figure 3):

- It is observed that there is a difference of 11% in Izmir, 10% in İstanbul and 6% in Ankara between single and double thermopane. Therefore, it will be more economical to use double thermopane rather than single thermopane.

- It is observed that there is a difference of 3% in Izmir, 4% in İstanbul and 3% in Ankara between single and double low-e glass. The reason why there is a very slight difference between single and double low-e glass is that double coating was applied on the single low-e glass (E2=.2) used in the evaluation, but single coating was applied on the double low-e glass (E2=.1)

- It is seen that there is a difference of 6% in Izmir, 5% in İstanbul and 4% in Ankara between double low-e glass and double thermopane. The substance of both glass types is 1,4 inches and the interstitial spaces are filled with argon gas in a distance of 1,2 inches. There is a single low-e coating on double low-e glass unlike double thermopane. The differences in their values result from this coating. Ultimately, double low-e glass type should be preferred.

- It is seen that there is a difference of 13% in Izmir, 11% in İstanbul and 7% in Ankara between single low-e glass and single thermopane. The substance of both glass types is the same and the e_2 value of low-e glass is 2. Thusly, it causes lesser energy consumption than single thermopane in all degree-day regions.

- It is noticed that there is a difference of 3% in Izmir, 1% İstanbul and 1% in Ankara between single low-e glass and double thermopane. The substance of both glass types is the same, however low-e glass has double coating and double thermopane has an interstitial space filled with argon gas. This is why there is not much difference between them.

- When the impact of glass type only on energy consumption for heating purpose is analysed, it is realized that there occurs not much difference due to the properties of low-e coated glass type.

5. CONCLUSION AND SUGGESTIONS

Reducing energy consumption in existing buildings and designing new buildings in an energy-efficient manner bear great importance in terms of contributing to energy efficiency in the construction sector. The non-transparent and transparent facades of buildings play a significant role in energy losses and gains. The glass type is one of the main parameters affecting the amounts of heat losses and solar energy gains through windows. It is required to analyse the amount of heat losses and solar energy gains through windows according to local climatic conditions in the preliminary design phase because of its impact on energy consumption for heating purpose within the scope of energy-efficient design. So, the parameters affecting the building energy performance should be evaluated via energy analysis programs in order to create energy-efficient solutions in renewing existing buildings in an energy-efficient way or in the early stages of architectural design process. At the end of a design process paying regard to design parameters, energy-efficient buildings causing minimum energy consumption can be produced. Energy-efficient buildings will make significant contribution to the reduction of energy costs in Turkey. The conclusions obtained from this study can be summarized as follows:

- It is observed from the research carried out within TS 825 in Izmir, İstanbul and Ankara, located in I., II. and III degree-day regions, that glass type has an impact on energy consumption.

- It is noticed that in the analysed degree-day regions, the highest energy consumption takes place in the scenarios using single thermopane and the lowest energy consumption takes place in the scenarios using double low-e glass. Thus, it is concluded that single thermopane should not be used on any facades of buildings and in any degree-day regions.

- It is seen that there is a difference of 11% in Izmir, 10% in İstanbul and 6% in Ankara between single and double thermopane in terms of their energy consumptions for heating purposes. Therefore, it will be more economical to use double thermopane rather than single thermopane.

- The energy-efficient restoration of buildings gains importance day by day especially considering the fact that the majority of existing buildings in Turkey have insufficient thermal performance. It will be highly useful for energy efficiency to increase the thermal performance of transparent components and to use a proper type of glass during the renovations of residential buildings in different degree-day regions of Turkey.

The building analysed in this study has a rectangular layout. Other buildings in different forms can generate different levels of energy consumption. Therefore, subsequent researches on energy-efficient design may assess buildings in different forms according to different degree-day regions. Moreover, the cost factor has not been taken into account in the evaluation of this paper. One may measure the economy of the suggestions hereby via making a life cycle cost calculation and a performance-cost review. There is no legal obligation regarding the energy-efficient building design in Turkey. For this reason, energy efficiency in buildings should be supported through scientific researches, training programs, laws and regulations. In conclusion, it can be alleged that designing new buildings and renewing the old ones in an energy-efficient way have an important role in terms of energy consumption and protection of the environment. Energy saving can substantially be maintained by using proper glass types for different degree-day regions.

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