Birlesik Dünya BD-CENTER Yenilik Araştırma ve Yayıncılık Merkezi

New Trends and Issues Proceedings on Advances in Pure and Applied Sciences

PROPAAS New Trends and Issues Proceedings on Advances in Pure and Applied Sciences

Issue 14, (2021) 71-88

www.propaas.eu

Selected paper of 9th Global Conference on Environmental Studies (CENVISU-2021) Antalya, Turkey
14 – 16 October 2021 (ONLINE CONFERENCE)

Relation between energy efficient glasses and energy expenditures in buildings

Aynur Kazaz [a 1], Akdeniz University, Civil Engineering Department, Antalya, Turkey

Ender Yetim [b], Akdeniz University, Civil Engineering Department, Antalya/Turkey

Suggested Citation:

Kazaz, A. & Yetim, E. (2021). Relation between energy efficient glasses and energy expenditures in buildings. *New Trends and Issues Proceedings on Advances in Pure and Applied Sciences*. (14), 71-88 Available at www.propaas.eu

Received from October 25, 2021; revised from November 13, 2021; accepted from November 25, 2021
Selection and peer review under responsibility of Assoc. Dr. Murat Sonmez, Middle East Technical University Northern Cyprus, North Cyprus

Abstract

This article aimed to examine the type and the effect of the energy performance of buildings, using the case of Antalya – based apartment complex, which is located in the Mediterranean Climate Region and classified in the 1st Degree Day Region according to TS 825 Standards. Energy efficiency on transparent surfaces in the base buildings made of 3 blocks selected was studied considering the location, orientation, facade lengths, window/wall area ratio of the buildings. As a result of the analysis made on the energy consumption values of the heating, cooling, and ventilation systems, it has been seen that the window glass-lined system (coated glass) with the combination of "4mm+16+4mm+16+4mm" and using argon gas as the filling material between window glasses is the optimal scenario for the Mediterranean Climate Region. By applying the best possible scenario to the base buildings, annual energy savings can reach change depending on the type of combustible used in the buildings.

Keywords: Building energy simulation; cost analysis; energy efficiency; energy-efficient design; window.

* ADDRESS FOR CORRESPONDENCE: Aynur Kazaz, Akdeniz University, Civil Engineering Department, 07058, Antalya/Turkey
E-mail address: akazaz@akdeniz.edu.tr

1. Introduction

Today, approximately 54.5% of the world's population live in cities. And currently, around 75 million people move from the village to the city every year, so the urban population is increasing day by day (TCMinistry of Development, 2018). To meet the people's needs for shelter because of this situation, new residential areas, buildings are opened and city infrastructure is growing. Constantly growing cities lead to an increase in energy demand. To meet this demand, scarce natural resources are being consumed quickly and unconsciously. This situation turns into a global environmental disaster causing climate change. The increase in energy costs along with the increase in the energy demand has turned out into a bad deal: energy now takes the top place in the list of the essential issues of the countries.

The research carried out by the United Nations (UN) predicts that the world's energy demands will increase between 40% and 50% until 2030(Pamir, 2017). EU(European Union) points out that the greenhouse gas emissions should be reduced up to 95% of the 1990 greenhouse gas level; It is aimed to support renewable energies and to make combustibles such as coal and natural gas cleaner based on high energy efficiency and smart energy technologies in construction and transportation. Starting from 2014, it is planned that the energy efficiency of the member countries of the Council of Europe would go up by 27% until 2030 (Güven, 2019).

About 71% of our country's energy demands get imported (Pamir, 2017). Moreover, this number increases by 4% every year(Kürekçi & Erdem, 2019). In line with the EU membership goal for Turkey, decisions must be taken at the local level such as reducing foreign dependency, ensuring maximum use of renewable resources, increasing energy efficiency, etc. This all is gaining importance for Turkey to achieve its energy goals (Kavas Bilgiç & Başoğlu Acet, 2019).

According to the Turkish Energy Efficiency Law, the policy has to be aimed to "increase the effectiveness in the use of energy resources to use energy effectively, prevent waste, alleviate the burden of energy costs on the economy and protect the environment" (TC Presidency Legislation Information System, 2007). In this context, it is stated in the Final Declaration on Combating Climate Change in 2021, that by expanding smart city applications energy usage, and implementing climate-sensitive new projects will be established in our country (TC Ministry of Environment and Urbanization, 2021).

Approximately 20% of the energy in Turkey and approximately 22% of the total electricity consumption is used in residences, as stated in the Turkey Energy Efficiency Development Report prepared by the Ministry of Energy and Natural Resources in 2018 (Aydın & Bıyıklıoğlu, 2020). While the energy consumed for heating the space in the European countries constitutes 57% of the energy consumed, in Turkey this rate rises to 81% (Turan, 2019). Low energy building can be described as a building that needs less energy with the measures to be taken into account at the design and construction stage and that provides the energy it needs from renewable sources and uses it efficiently (İslamoğlu, 2017). Energy-efficient building, on its behalf, integrates the use of renewable energy resources in addition to the combination created by the best use of parameters related to location, place, climate, materials, and building envelope, that create an energy-efficient building(Erol, 2017).

A large part of the energy consumed in buildings is used for heating, cooling, and ventilating the spaces to ensure the climatic comfort of the users(Mangan & Koçlar Oral, 2014). In multi-story buildings, 30% of the total heat losses occur through the windows (Yaman et al., 2015). Choosing the proper 'building's shell' in most cases is the ideal way according to the optical and thermophysical properties of the building to minimize the annual energy costs. Artificial air conditioning load varies depending on the total amount of heat gained and lost in the outer structure of the building. Exactly, for this reason, optical and thermophysical factors in the building's shell/ are one of the most important parameters in an energy-efficient design(Karagözlü, 2006). According to the "Population and Housing Research Study" conducted by the Turkish Statistical Institute (TUIK), it has been shown that 88% of the houses in Turkey have single window glass and 12% have double glass systems (Kobalas, 2015). The fact that 81% of the energy used in houses in Turkey is used for heating purposes and 88% of the houses have single glass windows without heat isolation shows, that the houses are insufficient in terms of energy efficiency.

When we talk about windows we should bear in mind that they are directly related to parameters such as natural light, ventilation, and passive solar light that determine energy demand in the building; also they are important components that determine the energy needs of buildings for heating, cooling, and lighting. That is why the glasses must have suitable optical and thermophysical properties, in terms of designing an energy-efficient building envelope. Window glasses differ in their ability to reflect, absorb and control heat and light energy from the sun (Şenyurt & Altın, 2020). The number of glass layers of the windows, their location, and the type of joinery should be selected following the climatic characteristics to benefit from or be protected from direct solar radiation gain. The total heat transfer coefficient should also be determined to provide the desired value of the building envelope (Özdemir, 2005).

The decisions to be taken at the design or construction stage in buildings determine the amount of energy that the building will consume during its utilization. Energy is assigned for heating, cooling, ventilation, and lighting of the building during its use. The required energy can be provided with the help of both active systems and passive systems. For a building to be energy efficient requires the application of energy-efficient criteria at the design stage. The energy-saving potential in buildings in Turkey is considered to be up to 50% (Pamir, 2017). Among the energy-efficient building criteria, zoning plans, land location, situations with neighboring parcels, withdrawal distance, user demand, etc., the most important aspect that the designer can be most involved in - is the design of the building envelope. There are many studies on energy-efficient envelope design in scientific publications, as well as about the optical and thermophysical properties of the transparent components in the building envelope.

1.1. Related research

Here we can mention the study of Göksal & Yıldız (2019) on the effect of the double envelope facade system applied in the office in a university building in Izmir in terms of the cooling load depending on the window glass type, which was investigated experimentally and with a simulation model. In this study 2 office spaces located on different floors on the south front elevation of the university building in the İzmir region with a hot-humid climate were determined as the experimental study area. The energy performance of the double-shell or double envelope facade was calculated by Design-Builder for 6 different glass options with different U-values and solar heat gain coefficient values. In the current situation, it has been observed that the cooling load in the office with a double skin facade is 20% higher than in the office with a single skin facade. In addition, the cooling load savings obtained in the case of the double-skin facade, when the outer glass type is changed with glasses with different properties, varies between 7.1% and 30.4%.

In the research made by Kon & Bulgurcu (2015) according to TS 825 (Thermal Insulation Requirements for Buildings standards), for a single-storey house with a roof in Balıkesir (located in the 2nd Region by standards) heating (natural gas) and cooling (electricity) energy requirements together with windows with different glass (single glass, coated glass, low coated, comfort glass), joinery (Aluminum, PVC) options were investigated by the 'degree-day' method. Except this, by using blinds, curtains, and blinds on the windows, the change in heating and cooling energy needs and fuel consumption were examined. After that, the annual energy and fuel savings were calculated for the window with the lowest heat transmission coefficient and the window with the highest heat transmission coefficient in the heating and cooling period.

In the study conducted by Mert (2019), the research subject was an education building located in the province of Izmir with hot-humid climatic conditions. The effect of window/wall area ratio change in different directions for different glass types on energy consumption was compared using the energy analysis program EnergyPlus. According to the simulation results, it has been observed that the ratio of window/wall area, direction, and glass type has a big effect on energy consumption in buildings. When the ratio of window/wall area in different directions is increased from 10% to 60%, the reduction in energy consumption for heating purposes goes to its maximum due to the change in the south front, and it is minimum in the east front. In terms of cooling, it was determined that the change in the south front caused the highest value, while the change in the north front caused the lowest value. In terms of total energy consumption (heating + cooling), it has been calculated that the east and west facades have the most impact, while the north facade has the least influence.

In cases when low coated window glass was used instead of double glass (existing), it was observed that the ranking according to the directions did not change. In short, it was concluded that the evaluation of the parameters that affect the energy performance of the building, in the early stages of the architectural design process or the energy-efficient improvement of existing buildings, through energy analysis programs will make significant contributions to the creation of energy-efficient solution offerings.

The same is shown in the Koyun & Koç (2017) study; the effect of the window/wall area ratio in different directions on the heat loss was calculated for different glass types in the split house in Antalya. According to the results obtained, it has been observed, that when the window/wall area ratio is between 30% and 40%, it affects energy consumption. In general, the total heat loss value of the whole building also increases when the window/wall area ratio in different directions is increased from 30% to 40%.

To minimize this increase, heat loss calculations were repeated by using double glazing and coated reflective glass instead of single glazing. As the result, we aim to find the optimum value in terms of applicability and economic situation. According to the calculations obtained, it was seen that the most appropriate value was achieved by the combination of 30% window/exterior wall ratio, aerated concrete brick wall, plastic frame, and coated 4-12-4 mm glass type. In Kon's (2016) study on fuel consumption in terms of CO_2 and SO_2 emission reduction, the author focused on double-glazed windows with optimum air layer thickness for different degrees/days and compared them to single-glazed windows. Coal, natural gas, and fuel oil were used as combustible materials. Calculations were made using duration of use/cost analysis and degree/day method. It has been stated, that the optimum air layer thickness for double-glazed windows varies between 14.1-17.8mm when coal is used, 13.9-17.8mm when natural gas is used and lies between 16.3-18.2mm when fuel-oil is used.

The reduction in fuel consumption due to calculated air layers varies between 16,634-102.065 kg/m² when speaking of coal as combuster, 9.841-60.296 m³/m² when natural gas is used, and 9.902-59.604 kg/m² when fuel-oil is used. Depending on the amount of fuel consumed, the reduction in CO_2 emissions varies between 51.865-318.238 kg/m² for coal, 19.797-121.298 kg/m² when natural for gas, and 31.895-191.985 kg/m² when fuel oil is used. The SO2 emission reduction was calculated between 0.107-0.653 kg/m² when coal is used and 0.166-0.995 kg/m² when fuel oil is used. In his study, Urbikain (2020) analyzed to reduce greenhouse gas emissions and use energy efficiently in such cities as Berlin and Bilbao, with different window systems, double and triple glazed low-emission window sets with frames, designed to be used with wall cladding for heating and cooling demands. To determine the best combination of insolation and window type, heat transfer simulations were performed using windows and optics in buildings located in the cool climate of Berlin and the hot climate of Bilbao.

With the help of the Design-Builder simulation program for moderately humid (Istanbul), hot humid (Antalya) and cold (Erzurum) climate regions of Turkey, energy simulations have been made and scenarios to reduce current energy consumption and CO2 emissions have been developed in the study of Mangan & Koçlar Oral (2014). By comparing the scenarios of improving opaque components, they calculated the annual heating (natural gas) and cooling (electricity) energy consumptions, improving transparent components, and integrating systems using renewable energy sources with the current situation.

With all the scenarios suggested for Antalya, we will reduce total (heating+cooling) energy consumption by 7.67% by improving opaque components, by 8.41%, by 11.86% by improving transparent components, and by reducing CO_2 emission values by 6.56% and 22.54% seen. As Gasparellavd points out in his research (2011), considering the climate data of four cities in Central and Southern Europe (Paris, Milan, Nice, and Rome), different types of glazing systems (two double and two triple glazings), window size (16% to 41% of the window to floor area ratio), the orientation of the front face with the main window and its effect on energy consumption must be evaluated by making statistical analyzes.

There are many studies on the determination of optimum energy-efficient transparent surfaces by using different glass types and glass combinations in buildings located in various climatic zones in the scientific literature and publications(Gazioğlu et al., 2013; Pul et al., 2016; Kumar et al., 2017; Yardimci & Guneli, 2019; Mousavi et al., 2021; Sayadi, Hayati & Salmanzadeh, 2021).

1.2. Purpose of study

Looking at existing research, it is seen that the transparent component design in the building envelope is generally analyzed by using natural gas and electricity as the fuel type for the heating and cooling energy requirements in the buildings, respectively. In this study for Antalya, which is located in the Mediterranean Climate Region and classified in the 1st Degree Day Region according to TS 825, natural gas as a fuel type is preferred as well as electrical energy in the heating energy requirement of buildings. In this context, the change in energy cost, emission and savings rate in the case of using electrical energy as heating energy has been examined. In addition, the most distinctive feature that distinguishes the study from other studies is that energy efficiency is not evaluated on a building, floor, or location, but on campus, where it is based on the location, orientation, and distance between buildings. This article aimed to examine the type and the effect of the energy performance of buildings, using the case of Antalya –based apartment complex

2. Materials and Methods

2.1. Data collection

This study collected data using a case study. Energy efficiency on transparent surfaces in the base buildings made of 3 blocks selected was studied considering the location, orientation, facade lengths, window/wall area ratio of the buildings. In summary, 8 scenarios were applied for each base building model, and design building models were created, for example, with different double window series (K, K3+), window combination (4mm+12+4mm, 4mm+16+4mm, 4mm+12+) instead of C series ordinary double window (4mm+12+4mm, 4mm+16+4mm) used in base buildings (4mm+12+4mm, 4mm+16+4mm+16+4mm) with different filling gases (air, argon) between the window glasses. Energy costs, emissions, and savings rates among existing building models and specially designed building models were obtained by performing hourly analyzes with the DesignBuilder simulation program using the EnergyPlus dynamic thermal simulation motor. Within the scope of the study, alongside the usage of natural gas as a fuel type in heating in designed buildings, the change in energy cost, emission, and savings rates according to the fuel type (including also electrical energy) has been examined.

2.2. Population

We selected a plot-based urban transformation project in Antalya for this study, which is located in the Mediterranean Climate Region and is classified in the 1st Degree Day Region according to TS 825, with a hot-humid climate. It was chosen to examine the energy-saving rate and cost increase that will occur as a result of replacing the window glasses in the building envelope with energy-efficient glasses to save energy. We examined the extent to which the energy needs of the users can be reduced as a result of the improvement of the glass in this residential settlement.

2.3. Procedure

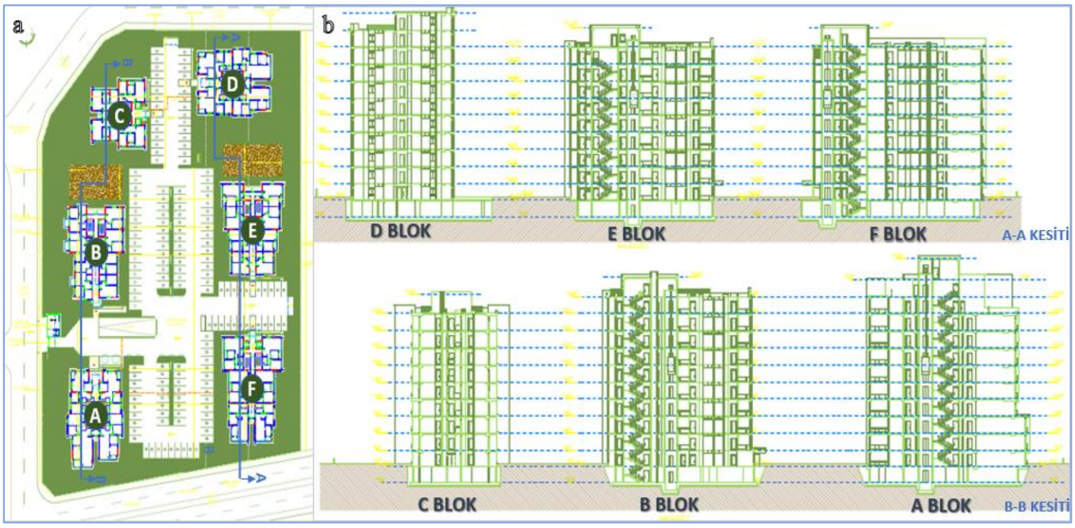
At first, we created Base Building Models according to energy consumption and cost data separately for Block B, Block D, and Block F. For each material used in the Base Building and Design Building models, cost calculations were made according to the market research. We calculated the analyzes using the meteorological database, which is a dynamic thermal simulation program, and the DesignBuilder and EnergyPlus dynamic simulation tools with 3D modeling software. For each glass combination, electrical energy was used as well as natural gas as heating energy.

In the scope of this study, we created 2 Base Building models for each reference block, according to the energy type used in heating. The "Design Building-1" model was obtained by applying window glass improvement scenarios to the "Base Building-1" (heating natural gas; cooling electricity) model, which was created when natural gas was used as heating energy. In the case where electrical energy was used as heating energy, the "Design Building-2" model was obtained by applying glass improvement scenarios to the "Base Building-2" (heating electricity; cooling electricity) model.

3. Results

The research area chosen by us is a plot-based urban transformation project that consists of 6 blocks, 317 residences, and a total construction area of 37,647 m^2 (Figure 1). Block A consists of 10 floors and 41 single spaces. Block B consists of 10 floors and has 76 single spaces and a total net usable area of 4743.7 m^2. C block has 8 floors and 36 single spaces. D block has 11 floors, 41 single spaces, and a total net usable area of 5102.4 m^2. Block E consists of 9 floors and has 72 single spaces. Block F has 9 floors, 51 single spaces, and a total net usable area of 5201.3 m^2.

Figure 1
Project for Urban Transformation



Note: a) situation plan, b) sections B Block, D Block, and F Block was chosen as the “Base Building” considering the factors such as orientation, positioning, facade area, the transparent surface ratio of the buildings in the settlement(Table 1.), (Figure 2., Figure 3., Figure 4.).

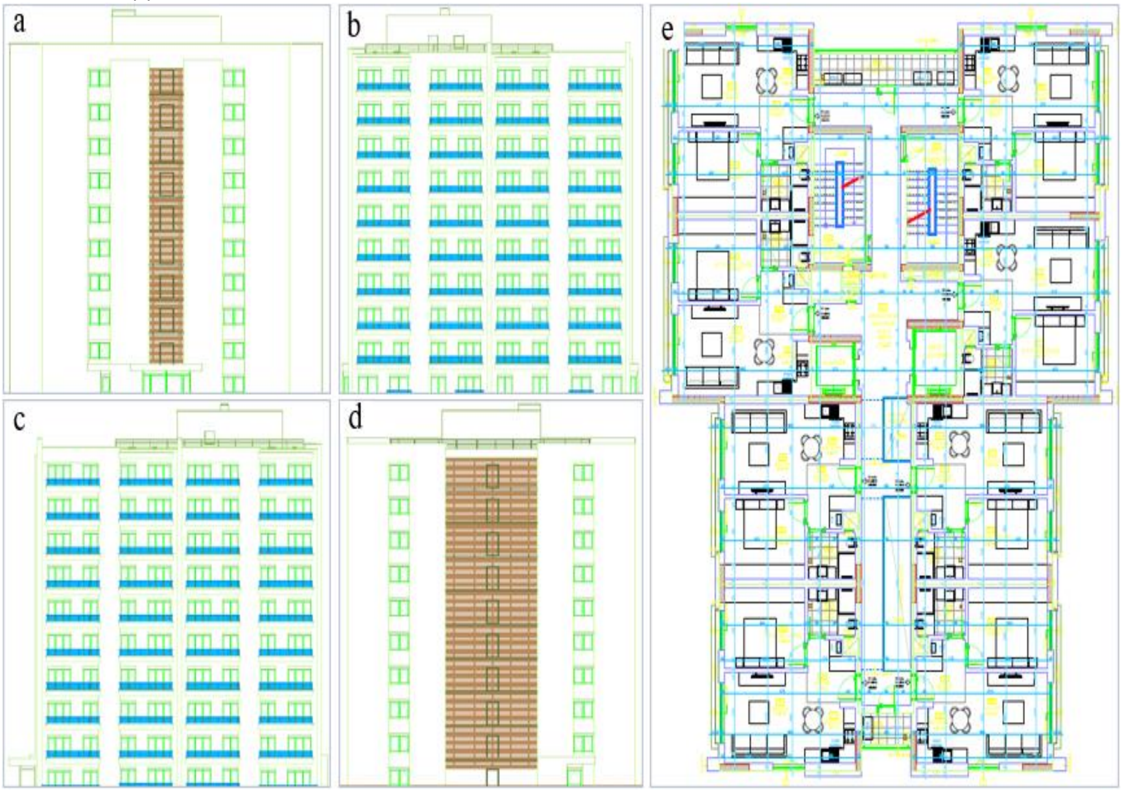
Table 1

Optical Design Parameter Properties of Base Buildings

Parameters		Base Buildings		
		B Block	D Block	F Block
Window area (m²)	Southern Front	60,60	278,70	193,80
	Northern Front	51,70	229,10	24,05
	Eastern Front	388,30	309,70	402,10
	Western Front	394,10	135,70	402,10
	Totally	894,70	953,20	1022,05
Transparency Ratio (Transparent/Opaque Surface Area)		0,30	0,32	0,39
A/V Ratio (Total External Surface Area/Building Volume)		0,22	0,20	0,16

Figure 2

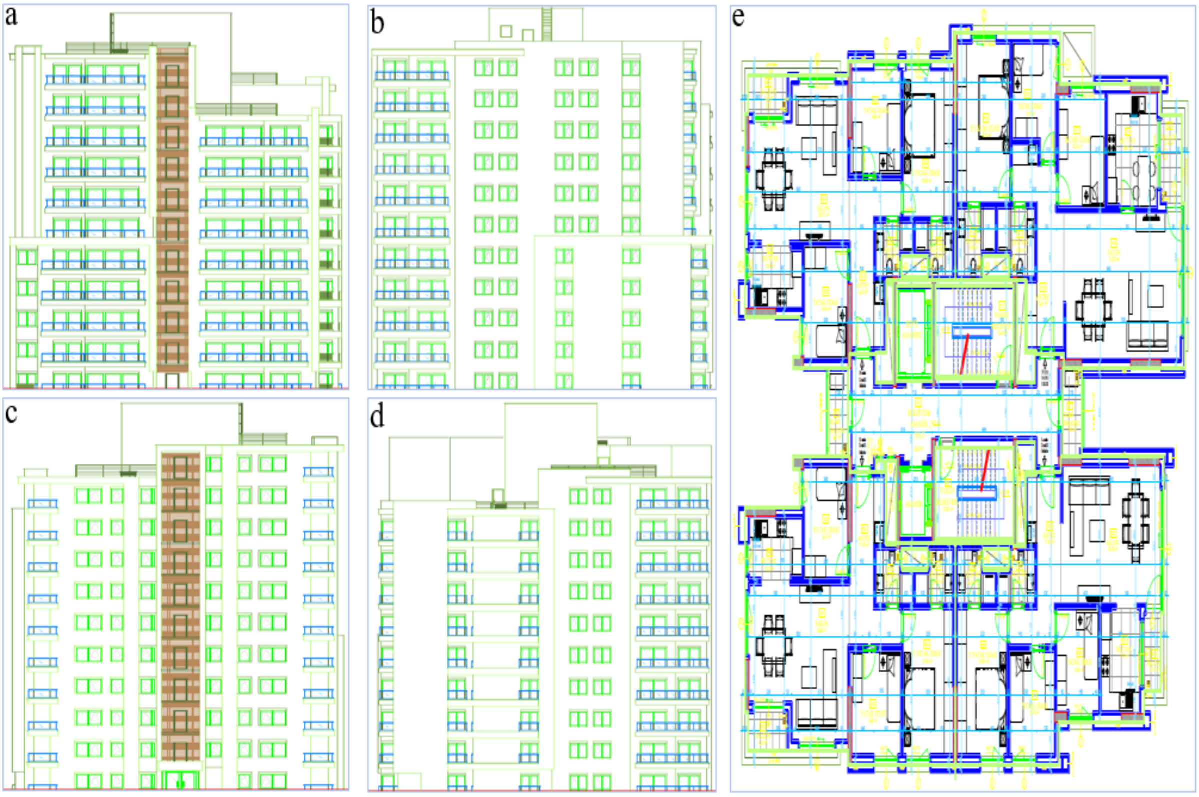
Block B and its appearance



Note: a) south front; b) western front; c) eastern front; d) north front; e) regular floor plan

Figure 3

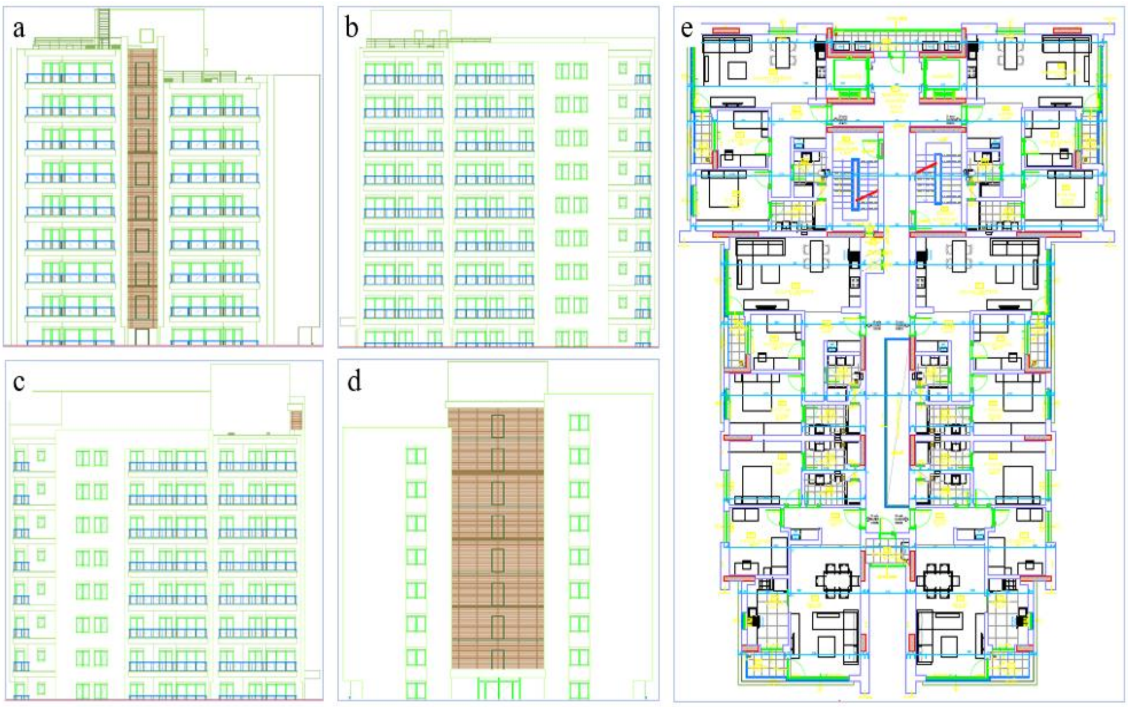
Block D and its appearance



Note: a) south front; b) western front; c) eastern front; d) north front; e) regular floor plan

Figure 4

Block F and its appearance



Note: a) south front; b) western front; c) eastern front; d) north front; e) regular floor plan

3.1. Analysis of base buildings models

In our study we took heating and cooling load calculations for the province of Antalya where the Base Buildings are located, according to the ASHRAE 90.1-2010 standards recommended by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), ASHRAE Climate Zone 3A Zone (1st Climate Zone of Turkey) climate data for the province of Antalya measured between 1984-2008 were used. Heating in the buildings was provided by a boiler and radiator and split air conditioner (7800W, COP:3.20), cooling was done by the split air conditioner(7100W, EER:3.00). In the calculations, the indoor temperature comfort value is taken as 22°C for the heating period and 25°C for the cooling period.

Natural ventilation has been designed in the buildings and the air exchange coefficient (ACH) has been taken as 0.5(1/h). Base Buildings and Design Buildings were modeled according to the ASHRAE Standard residential use profile. The number of residents of the buildings is taken as 20 m2/person and the operating hours/days are taken as continuous 24/7. The indoor comfort temperature value is taken as 22°C for the heating period and 25°C for the cooling period in our calculations. Natural ventilation has been designed in the buildings and the air exchange coefficient (ACH) was around 0.5(1/h). Base Buildings and Design Buildings are modeled according to the ASHRAE Standard residential use profile. In this context, according to the number of residents of the buildings we took as 20 m2/person and the using hours/days are foreseen as 24/7.

The energy efficiency index of the buildings within the scope of the study is in the category and building type - normal energy-efficient building. In the building envelope of the blocks, C class, PVC framed ordinary double-glazed windows with 4mm + 12 + 4mm combination and aluminum-framed, 4mm+14+4mm ordinary double-glazed doors are used. Considering the design criteria such as the location, orientation, and the number of floors of the buildings in the study area, the island-based campus representing the energy consumption behaviors of the existing buildings is modeled (Figure 5.). The energy modeling of the selected Base Buildings is made separately and shown in Figure 6., Figure 7. and Figure 8.

Figure 5

The model figure of a researched-based building plot

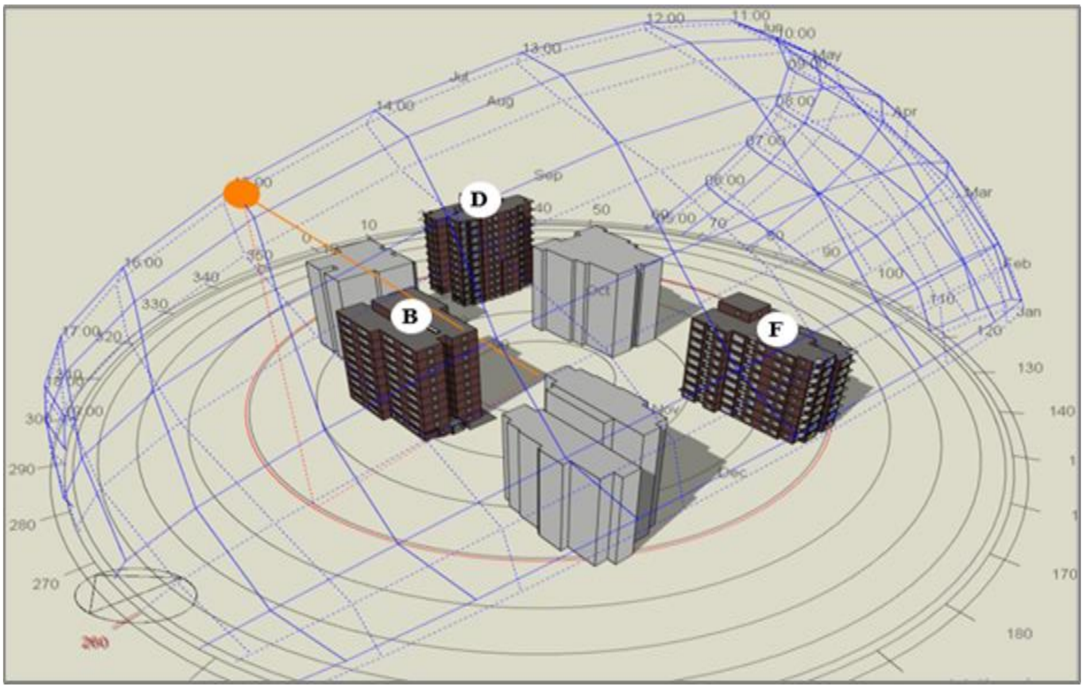
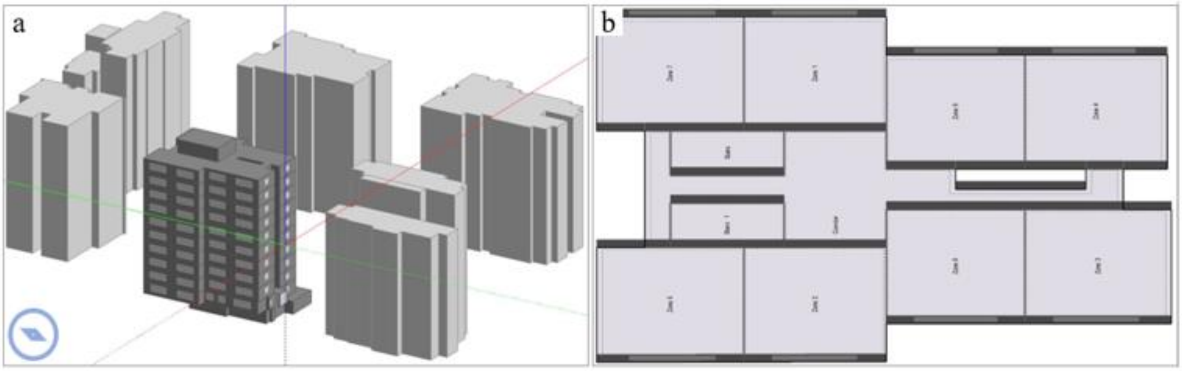


Figure 6

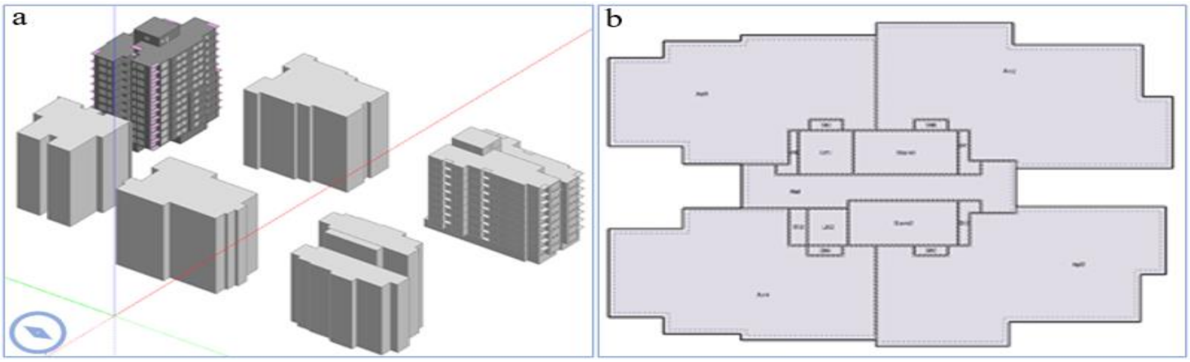
Block B model



Note: a) site plan, b) floor plan

Figure 7

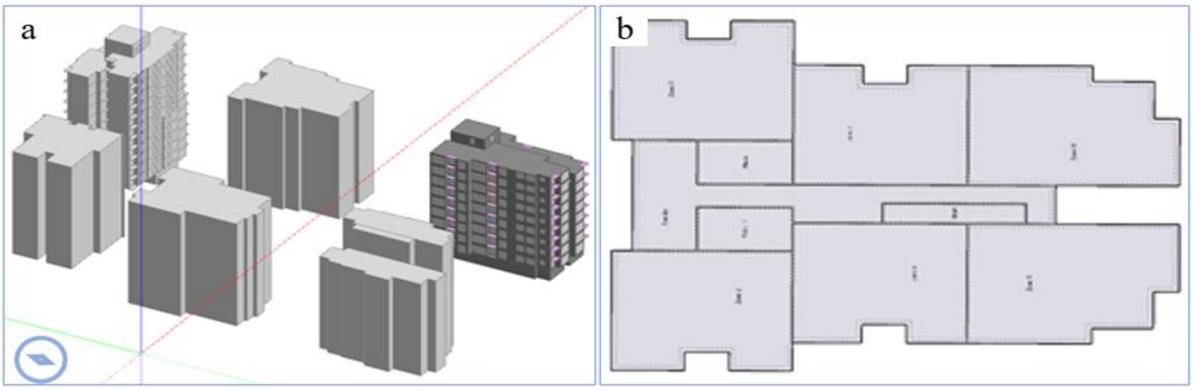
D block model



Note: a) site plan, b) floor plan

Figure 8

F block model

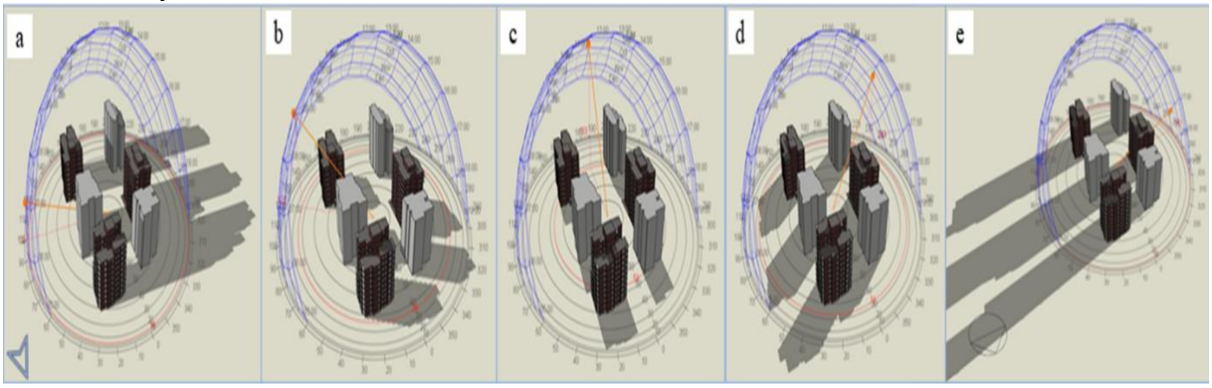


Note: a) site plan, b) floor plan

Buildings can play a role of solar radiation barriers for each other according to the distances between them, density, height, and positioning. The effect of these basic alternatives on energy efficiency has drawn our attention. Equinox data shows the shadow effect of buildings on each other at a different time(Figure 9., Figure 10., Figure 11., Figure 12.).

Figure 9

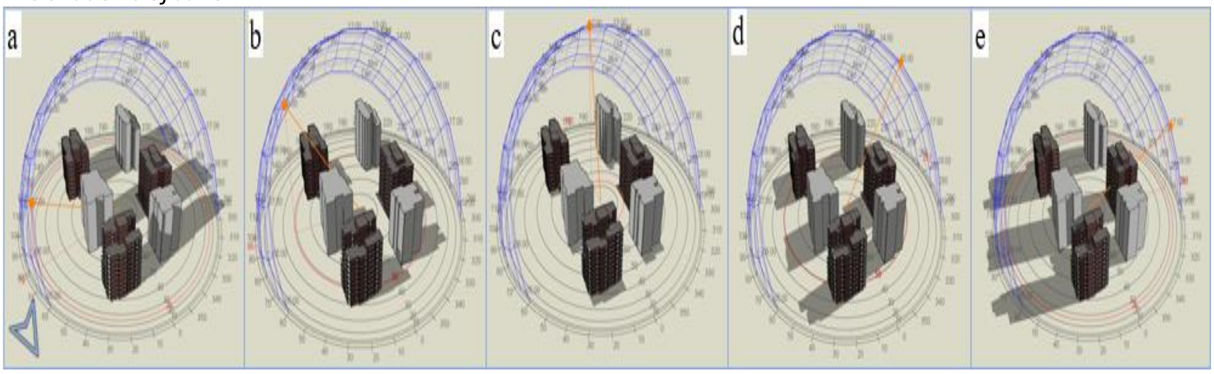
The shadows of March 21



Note: a) 7:00 a.m., b) 9:00 a.m., c) 12:00 a.m., d) 15:00 p.m., e) 17:00 p.m.

Figure 10

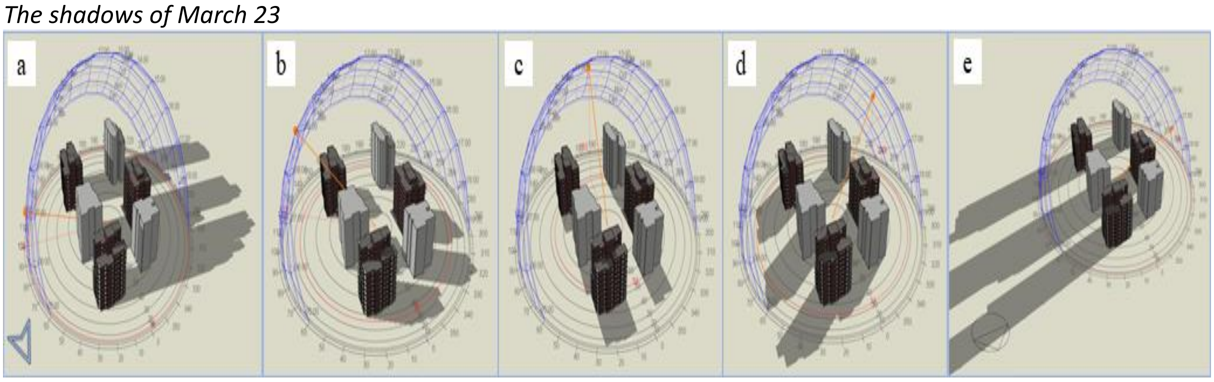
The shadows of June 21



Note: a) 7:00 a.m., b) 9:00 a.m., c) 12:00 a.m., d) 15:00 p.m., e) 17:00 p.m.

Figure 11

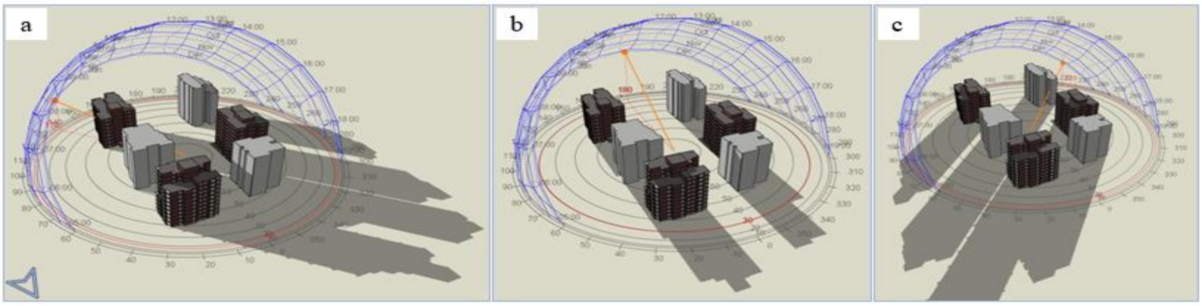
The shadows of March 23



Note: a) 7:00 a.m., b) 9:00 a.m., c) 12:00 a.m., d) 15:00 p.m., e) 17:00 p.m.

Figure 12

The shadows of December 21



Note: a) 7:00 a.m., b) 9:00 a.m., c) 12:00 a.m., d) 15:00 p.m.,

3.2. Improvement of window glass used in the building envelope.

In our research, we created 8 scenarios using different insulating glass series, different window glass combinations, and different filling gas between the glasses, instead of ordinary double glasses with C class, 4mm+12+4mm and 4mm+14+4mm combinations used in B Block, D Block, and F Block(Table 2.).

Table 2

Optical and Thermophysical Properties of Window Glass Used in Base Buildings and Design Buildings

Scenario	Insulating Glass Series	Window combinations	Daylight (EN 410)		Sun Power (EN 410)		Heat Permeability Coefficient (U Value) (EN 673)	
			permeability %	Projection %	Total Permeability %	Shading Coefficient	Air	Argon
Current state	C	4mmDC+12+4mmDC	80	14	75	0,86	2,9	X
	C	4mmDC+14+4mmDC	80	14	75	0,86	2,7	X
Scenario-1	K	4mm+12+4mm	71	10	44	0,51	1,6	X
Scenario-2	K	4mm+12+4mm	71	10	44	0,51	X	1,3
Scenario-3	K	4mm+16+4mm	71	10	44	0,51	1,3	X
Scenario-4	K	4mm+16+4mm	71	10	44	0,51	X	1,1
Scenario-5	K 3+	4mm+12+4mm+12+4 mm	63	12	39	0,44	0,9	X
Scenario-6	K 3+	4mm+12+4mm+12+4 mm	63	12	39	0,44	X	0,7
Scenario-7	K 3+	4mm+16+4mm+16+4 mm	63	12	39	0,44	0,7	X
Scenario-8	K 3+	4mm+16+4mm+16+4 mm	63	12	39	0,44	X	0,6

Design building energy models were created by applying glass improvement scenarios to each base building model separately. We used a DesignBuilder, a dynamic thermal simulation program to calculate the energy performance of the Base Buildings and the energy efficiency of the Design Buildings. EnergyPlus, an integrated simulation program, was used as the DesignBuilder simulation engine.

The annual total energy consumption was calculated according to thermal zone, Using DesignBuilder and EnergyPlus dynamic simulation programs, defining building envelope properties, and modeling mechanical equipment. When we compare the energy consumption, costs, and emission rates between the Base Buildings and the Design Buildings in the calculations made after the glass improvement, we see exactly the best solution: the energy-efficient optimal glass scenario is K3+ with the combination of ''4mm+16+4mm+16+4mm'' and argon gas as the filling material between the glasses which corresponds to the Scenario-8, which is in the insulating glass class.

The international standards TS 825 “Thermal Insulation Rules in Buildings” include the values for calculation of the heating energy needs of the buildings and the rules for determining the maximum allowable heating energy. Considering the thermal transmittance (UP) coefficients W/m²K prepared to be used in the selection of glass suitable for heat zones in Turkey (TS 825/1), it is recommended to have a maximum of 1.8 UP in our climate Zone. While the UP value was 2.9 in Base Buildings, this value became 0.6 in Design Buildings as a result of the application of Scenario-8 to base buildings.

3.3. Optimum Glass Combination and Cost Analysis

The material price of the optimum window glass combination was obtained by conducting market research. The properties and unit prices of glass used in Base Buildings and Optimum Design Buildings are presented in Table 3 and Table 4, respectively.

Table 3

Optical and Thermophysical Properties of Glass Used in Base Buildings and Optimum Design Buildings

Parameters	Insulating Glass Series	Window Combination	Daylight (EN 410)		Solar energy (EN 410)		Heat Permeability Coefficient (EN 673)	
			Permeability (%)	Projection (%)	Total Permeability (%)	Shading coefficient	Air	Argon
Current state	C	4mmDC+12+4mmDC	80	14	75	0,86	2,9	X
	C	4mmDC+14+4mmDC	80	14	75	0,86	2,7	X
Optimal Scenario	K 3+	4mm+16+4mm+16+4mm	63	12	39	0,44	X	0,6

Table 4

Unit Price for Glass Used in Base Buildings and Optimum Design Buildings

Position No.	Definition	Measurement unit	Unit price ($)[a]
Market research	Installing of a double-glazed window unit with a 12 mm gap of 4+4 mm thickness with a profile on PVC and aluminum joinery (4mmDC+12+4mm DC) Installing of a double-glazed window unit of 4+4 mm thickness with 14 mm gap between PVC and aluminum joinery profiles (4mmDC+14 +4mm DC) Installing a triple double-glazed window unit with 4+4+4 mm thickness, 16 mm gap, argon gas, inner glass with heat control coating, outer glass with sun control coating, with profile to PVC and aluminum joinery (4mm Solar Low-e+16AB+4mm DC+16AB+4mm Low-e)	m²	14,50
Market research	According to the Central Bank of Turkey on 01.04.2021	m²	15,28
		m²	33,03

Table 5

Glass Cost Analysis of Base Buildings and Optimum Design Buildings

Glass Areas Used on Exterior Surfaces	Area (m²)	Glass Cost ($)		Cost Increase ($)
		Current State	After Improvement	
B Block				
Glass Used in Windows	895	12979,87	29558,16	16578,29
Glass Used in Doors	42	641,80	1387,09	745,29
Total Cost		13621,67	30945,25	17323,58
Floor Cost		1362,17	3094,52	1732,36
Cost Per Flat		179,23	407,17	227,94
D Block				
Glass Used in Windows	953	13821,03	31473,66	17652,63
Glass Used in Doors	100	1528,09	3302,59	1774,50
Total Cost		15349,11	34776,25	19427,13
Floor Cost		1395,37	3161,48	1766,10
Cost Per Flat		374,37	848,20	473,83
F Block				
Glass Used in Windows	1023	14836,21	33785,47	18949,26
Glass Used in Doors	27	412,58	891,70	479,12
Total Cost		15248,80	34677,17	19428,37
Floor Cost		1694,31	3853,02	2158,71
Cost Per Flat		299,00	679,94	380,95

*Note:*The cost of glass used before and after the implementation of the optimum glass scenario in the Base Buildings.

Table 6

Comparison of Glass Costs for Base Buildings and Optimal Design Buildings

Account Items	Base Building-1	Design Building-1	Base Building -2	Design Building -2
Block B				
Consumption (kW)	351880,75	285872,57	311386,4248	260254,7711
Costs ($)	13621,67	30945,25	13621,67	30945,25
Energy-saving(kW)	18,76%		16,42%	
Cost increase ($)	17323,58		17323,58	
Block D				
Consumption (kW)	325667,92	265987,89	275640,13	234436,61
Costs ($)	15349,11	34776,25	15349,11	34776,25
Energy-saving (kW)	18,33%		14,95%	

Cost increase ($)	19427,13		19427,13	
Block F				
Consumption (kW)	343797,43	274662,49	301847,08	249310,66
Costs ($)	15248,80	34677,17	15248,80	34677,17
Energy-saving (kW)	20,11%		17,40%	
Cost increase ($)	19428,37		19428,37	

Table 6 shows the comparison of Base Buildings and Design Buildings in terms of annual energy consumption values, energy-saving rates, and cost increase.

4. Discussions

Among findings obtained in our research we can mention examination of Base Buildings and Design Buildings and the amount of energy consumed in them, the cost of the window glass, and the emission rates, which we compared before and after the energy-efficient glass improvement scenarios. It has been observed that the optimum energy-efficient glass design for Antalya, which is located in the Mediterranean Climate Region, is the design with the combination of "4mm+16+4mm+16+4mm" in the K3+ double glazing class, and with argon gas as the filling material between the glasses. So, for example, if optimal energy-efficient glasses are used instead of the existing glasses in Block B, Block D, and Block F when natural gas is preferred as the heating energy in the building, it reaches %34,72; %35,58; %38,22 in a row for heating, and in cooling respectively %38,10; %34,76; %38,96 of energy savings rate. When fuel type electricity is preferred as heating energy, the rates are %38,10; %34,76; %38,96 in a row of energy savings achieved respectively.

In terms of emissions, if optimal energy-efficient glasses are used instead of the existing glasses in Block B, Block D, and Block F, CO_2 emission rates are 24.19%; 25.08%; 26.38%, - when natural gas is preferred as the heating energy in the building, and 16.42% 14.95%; 17.40% - when fuel type electricity is preferred as heating energy, which shows a reduction of emissions. In the case of using energy-efficient glasses instead of the existing glasses in Block B, Block D, and Block F, the cost increases are \$3.65/m2, \$3.81/m2; and 3.74 $ / m2 respectively. It has been observed that the cost increase per flat is 361 $ / flat on average. With the implementation of the optimum glass scenario, the highest energy saving was achieved in F Block Design Building-1 with 20.11%. It can be said that the high energy saving rate in F Block compared to other blocks was possible due to the high transparency rate. This finding is similar to that of Zhang et al., (2020) who studied Transparent wood composites.

In this context, it can be said that as the glass surface area increases, the energy-efficient improvements to be made on the glasses will increase the energy savings (Lutzenhiser, 2014; Friess & Rakhshan, 2017). With the use of energy-efficient glass in F Block Base Buildings, the total cost rising was calculated up to $19,428.37. When we look at both the energy-saving and emission rates, it can be concluded that the cost rising is not an obstacle to the preference of energy-efficient window glasses in buildings. Since the heating needs in the buildings in the Mediterranean Climate Region are widely met with electrical energy, our scenarios included electrical energy in addition to natural gas for heating and as a result of the analyzes made, the use of electrical energy in heating in buildings was 11% less on average compared to the use of natural gas, with the preference of energy-efficient glasses, so less energy can be consumed. This can be explained by the fact that the efficiency of electrical energy (η=0.99) is greater than the efficiency of natural gas energy (η=0.93).

However, when the energy cost comparison is made, it has been seen that the electricity unit price (0.08$/kW) is higher than the natural gas unit price (0.02$/kW), which makes natural gas an ideal choice as heating energy in buildings in terms of energy cost savings. Considering the sunshine duration of the Mediterranean Climate Region, it can be said that the most ideal energy for heating in buildings can be electrical energy, by keeping the energy cost at a minimum level and due to producing electricity from solar energy with photovoltaic panel applications in buildings (Benli, 2016). As a result of the application of glass improvement scenarios in buildings, the savings rate obtained with the use of natural gas in heating and electrical energy in cooling (Design Building-1) is higher than the savings rate obtained in the use of electrical energy in heating and cooling (Design Building-2) It has been seen, that it is more effective in preventing losses (heating load) than gaining the heat (cooling load).

5. Conclusion

In summary, within the scope of the study, we wanted to show that energy costs can be reduced by using energy-efficient glasses in buildings located in the Mediterranean Climate Region. The research concludes that the use of a coated glass system with a combination of "4mm+16+4mm+16+4mm" in the buildings located in the Mediterranean Climate Region, using argon gas as the filling material between the glasses, would be more appropriate in terms of sustainability and cost.

In the study, it is thought that the results will contribute significantly to the municipalities, science sphere, and the construction sector, and the analysis of the cost relationship with the application of the energy-efficient glass combination and its focus on sustainable energy has a guiding role in improving city infrastructure.

References

Aydın, N., & Bıyıkoğlu, A. 2020. The effect of cooling load on optimum insulation thickness ın residential buildings. *Journal of Thermal Science and Technology, 40*(2), 281-291. https://dergipark.org.tr/en/pub/isibted/issue/57550/817036

Benli, H. (2016). Potential application of solar water heaters for hot water production in Turkey. *Renewable and Sustainable Energy Reviews*, *54*, 99-109. https://www.sciencedirect.com/science/article/pii/S136403211501031X

Erol, H. (2017). Energy-efficient architectural design approaches in high-rise structures and analysis of application examples. Istanbul: Fatih Sultan Mehmet Vakıf University Institute of Engineering and Physical Sciences. http://acikerisim.fsm.edu.tr/xmlui/handle/11352/2539

Friess, W. A., & Rakhshan, K. (2017). A review of passive envelope measures for improved building energy efficiency in the UAE. *Renewable and Sustainable Energy Reviews*, *72*, 485-496. https://www.sciencedirect.com/science/article/pii/S136403211730045X

Gasparella, A., Pernigotto, G., Cappelletti, F., Romagnoni, P., & Baggio, P. (2011). Analysis and modeling of window and glazing systems energy performance for a well-insulated residential building. *Energy and Buildings*(43), 1030-1037. https://www.sciencedirect.com/science/article/pii/S0378778811000053

Gazioglu, A. (2012). *An Improvement Study on Reducing Heating Energy Expenditures in Energy Efficient Building Design* (Doctoral dissertation, Institute of Science and Technology). https://polen.itu.edu.tr/handle/11527/8130

Göksal Ö., T., & Yıldız, Y. (2019). Sıcak-nemli iklimde çift kabuk cephe enerji performansının incelenmesi. *Orta Doğu Teknik Üniversitesi Mimarlık Fakültesi Dergisi, 36*(1), 137-156. https://open.metu.edu.tr/bitstream/handle/11511/50592/metujfa2019102.pdf

Güven, E. (2019). *Evaluation of energy efficiency before and after urban transformation in residential buildings.* Bursa: Bursa Uludağ University Institute of Science and Technology

İslamoğlu, A. K. (2017). *The design techniques which effect energy consumption in buildings and analysis of application examples with BEP-TR*. Istanbul: Fatih Sultan Mehmet Vakıf University Institute of Engineering and Physical Sciences. http://acikerisim.fsm.edu.tr:8080/xmlui/handle/11352/2537

Karagözlü, A. B. (2006). *The study regarding the reduction of energy cost ın residences.*Istanbul: Istanbul Technical University Institute of Science and Technology. https://polen.itu.edu.tr/xmlui/handle/11527/8198

Kavas Bilgiç A. & Başoğlu Acet, D. (2019). Renewable energy in local governments 'policies.*Journal of Urban Studies, 27*(10), 410-446.

Kobalas, G. D. (2015). *Energy-efficient retrofit study for an existing residential building: afyon toki agricultural village project*. Istanbul: Istanbul Technical University Institute of Science and Technology. https://polen.itu.edu.tr/handle/11527/14287

Kon, O. & Bulgurcu, H. (2015). With additional control and cooling energy in the different glass and joinery features of the houses. Energy performance in buildings symposium, (p. 1483-1495). Izmir. https://docplayer.biz.tr/2136698-Konutlarin-farkli-cam-ve-dograma-ozellgggndekg-pencerelere-bagli-isitma-ve-sogutma-enerjg-gereksgngmg.html

Kon, O. (2016). An evaluation of fuel consumption and emission for double glazed windows that have optimum air layer. *Uludağ University Journal Of The Faculty Of Engineering, 21*(2), 133-144. https://dergipark.org.tr/en/pub/uumfd/article/256433

Koyun, T., & Koç, E. (2017). Effect of window/wall area rates on building heat losses according to variable glass and outer wall types of a building. *Engineer and Machinery, 58*(688), 1-14. https://dergipark.org.tr/en/pub/muhendismakina/issue/48822/621726

Kumar, G. K., Saboor, S., & Babu, T. A. (2017). Study of various glass windows and building wall materials in different climatic zones of India for energy-efficient building construction. *Energy Procedia*(138), 580-585. https://www.sciencedirect.com/science/article/pii/S1876610217351068

Lutzenhiser, L. (2014). Through the energy efficiency looking glass. Energy Research & Social Science, 1, 141-151. https://www.sciencedirect.com/science/article/pii/S2214629614000255

Mangan, SD, & Oral, GK (2013). Energy-efficient improvement of a residential building in different climatic regions of Turkey. 11th *National Installation Engineering Congress*, 17-20. https://www.mmo.org.tr/sites/default/files/4b07956f719f5ec_ek.pdf

Mert C. A. P. , Güçlü, T. , Beşir, A. B. & Cuce, E. (2019). Sustainable and environmental friendly window and glass technologies for energy-efficient buildings: recent developments and applications.*Uludağ University Journal of The Faculty of Engineering*, *24* (3), 503-522. https://dergipark.org.tr/en/download/article-file/905510

Mousavi Motlagh, S. F., Sohani, A., Saghafi, M. D., Sayyaadi, H., & Nastasi, B. (2021). Acquiring the foremost window allocation strategy to achieve the best trade-off among energy, environmental and comfort criteria in a building. *Energies, 14*(13), 3962. https://www.mdpi.com/1996-1073/14/13/3962

Özdemir, B. B. (2005). *Energy Efficient Building Design as Passive Systems for a Sustainable Environment* (Doctoral dissertation, M. Sc. Thesis, Istanbul Technical University Institute of Science and Technology). https://www.ulusaltezmerkezi.net/surdurulebilir-cevre-icin-binalarin-enerji-etkin-pasif-sistemler-olarak-tasarlanmasi/

Pamir, N. (2017). *Power of Energy. Istanbul: Hayygrup Publishing*.

Sayadi, S., Hayati, A., & Salmanzadeh, M. (2021). Optimization of window-to-wall ratio for buildings located in different climates: An IDA-Indoor climate and energy simulation study.*Energies, 14*(7), 1974. https://www.mdpi.com/1058820

Stamp, H., Ertürk, M., Keçebaş, A., Uygunoğlu, T., & Daşdemir, A. (2016). Optimum air layer thickness analysis for double and triple glazed windows on a provincial basis. Journal of Plumbing Engineering(151), 5-13.

Şenyurt, S. U., & Altın, M. (2020). A Method to be Use for Defining Effect of Environmental Friendly Facade Design Parameters on Energy Consumption for Office Buildings//Ofis Yapıları İçin Çevreyle Uyumlu Yapı Dış Kabuğu Tasarım Parametrelerinin Enerji Tüketimine Etkisini Belirlemede Kullanılabilecek Bir Yaklaşım. *Megaron*, *15*(1), 55. https://search.proquest.com/openview/8dbecb4c058252b59281c7eed2587ffe/1?pq-origsite=gscholar&cbl=2049746

T.C. Ministry of Development. (2018). Energy supply security and efficiency special commission report. T.R. Presidency of Strategy and Budget: https://www.sbb.gov.tr/wpcontent/uploads/2020/04/EnerjiArzGuvenligi_ve_VerimliligiOzelIhtisasKomisyonuRaporu.pdf

TC Ministry of Environment and Urbanization. (2021, Şubat 17). *İklim Değişikliğiyle Mücadele Sonuç Bildirgesi.* 2021 tarihinde T.C. Çevre ve Şehircilik Bakanlığı: https://csb.gov.tr/bakan-kurum-iklim-degisikligiyle-mucadele-zirvesi-sonuc-bildirgesini-acikladi-bakanlik-faaliyetleri-30880

TC Presidency Legislation Information System. (2007, Mayıs 02). *Energy Efficiency Law. Regulatory Information System on October 10, 2021*: https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=5627&MevzuatTur=1&MevzuatTertip=5

Turan, B. (2019). *Analysis of the effects of green roofs on the heating and cooling load of buildings for different climate regions.* Elazığ: Fırat University Institute of Science and Technology

Urbikain, M. K. (2020). Energy-efficient solutions for retrofitting a residential multi-storey building with vacuum insulation panels and low-e windows in two European climates. *Journal of Cleaner Production*(269), 121459. https://www.sciencedirect.com/science/article/pii/S0959652620315067

Yaman, Ö., Şengül, Ö., Selçuk, H., Çalıkuş, O., Kara, İ., Erdem, Ş., & Özgür, D. (2015). Thermal Insulation and Thermal Insulation Materials in Buildings. *Turkey Engineering News (TMH)* , *487* (4), 62-75. https://dergipark.org.tr/tr/download/article-file/368194

Yardımcı, S.,& Güneli, Z. (2019). An approach to renewing an existing office structure in the context of energy-efficient design in Istanbul. *Urban Academy12*(3), 600-617. https://dergipark.org.tr/en/pub/kent/issue/49318/609392

Zhang, L., Wang, A., Zhu, T., Chen, Z., Wu, Y., & Gao, Y. (2020). Transparent wood composites fabricated by impregnation of epoxy resin and W-doped VO2 nanoparticles for application in energy-saving windows. *ACS Applied Materials & Interfaces*, *12*(31), 34777-34783. https://pubs.acs.org/doi/abs/10.1021/acsami.0c06494