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RESEARCH ARTICLE

Evaluation of energy-cost efficient design alternatives for residential buildings

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Abstract

A considerable amount of energy is consumed in buildings because of the economic developments and the increased population. By taking in consideration that 40% of total energy use is consumed in the building, the proper design of building's envelope is crucial for reducing the adverse effects of high energy consumption in the economy and environment of a country. This study aims to investigate the proper design alternatives on the reduction of energy consumption and life-cycle cost (LCC) of residential buildings for heating and cooling purposes. The study is carried out in two cities, Ankara and Antalya, which represents the cold and hot climate region. For this study, the same flat of 1+1 floor plan designed for a family of two in a reference residential building project is simulated with different location, in Ankara and Antalya. For these flats, the annual zone heating and total cooling energy consumptions and life cycle costs are calculated using DesignBuilder simulation program according to different window-wall ratios, glazing types and insulation thickness. Window assembly alternatives are composed of double glazing units with clear glass, low-e glass, blue tinted glass and reflective glass, and PVC frame and the investigated insulation thickness options are EPS 100 mm and EPS 50 mm. At the end of the study, energy, and cost-efficient design alternatives for cold and hot climate regions are proposed.

Keywords

DesignBuilder; Design alternatives; Energy efficiency; Life cycle cost; Residential buildings

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1. Introduction

Recently, the reduction of energy consumption in the building sector has become an important issue. Since the 1970s, with the beginning of the energy crises, obligatory and incentive policies have been undertaken by governmental and independent authorities. This movement aimed to reach zero energy consumption to hinder the depletion of natural resources, protect the environment and increase the wellbeing of the population. A significant effort is made to improve the energy efficiency in buildings because energy consumed in this sector consists of 40% of overall energy use. In buildings, the energy is used, especially, 42% for maintaining the thermal comfort of the occupants, 12% for working lighting devices, 13% for hot water supply and 33% for miscellaneous equipment [1]. A considerable amount of energy goes for compensating the heat loss/ gains occurring in the building's envelope. The building envelope is composed of walls, floors, roofs, fenestrations, and doors. For residential buildings in Turkey, heat-losses occurring through building envelope are respectively 25% in roofs, 25% in windows and

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doors, 20% in building structural system and 15% in walls [1]. Similarly, the heat gains are 25 - 35% in roofs, 25 - 35% in windows, 15 - 25% in walls, 10 - 20% ground floors, and 5 - 25% air infiltration [1]. More heat losses and gains are translated into more energy consumption to maintain the thermal comfort. In Turkey, 80% of total building stock is residential building [2]. Because of the increasing population and the economic development, in Turkey, the electric energy consumption is expected to increase up to 6.9% until 2020 [3]. While, in governmental level, it is evaluated as more energy supply-demand, depletion of natural resources and adverse effects on the environment [4].

An optimal building envelope design contributes to reducing the energy consumed for heating/cooling and lighting. The heat losses and gains in the building envelope occur because of three main thermodynamic phenomena: conduction, convection, and radiation. The heat transfer performance of a building envelope element is related to several parameters which are thermal resistance (R-value), thermal mass for opaque elements (wall, roof, etc.), heat transmittance coefficient (U-value), solar heat gain coefficient (SHGC), and visible light transmittance (VT) for transparent elements (windows, skylight etc.) [5, 6]. By taking into consideration the above mention thermal properties of the materials and the climate conditions of the building's site, it can be designed more energy and cost efficient buildings.

In the literature, it is given great importance to the investigation of the effect of the buildings envelope's elements on the total heating and cooling loads of a building [6–15]. The latest investigated the energy efficiency of different building envelopes alternatives, especially, for office and lodging buildings. For example, Raji et al. [9] analyzed the effect of envelope elements on building energy consumption by considering an existing high-rise office building in Neverland with a temperate climate. The examined elements were: roof and glazing type, window/wall ratio (WWR), and shading devices. Several papers have examined the performance of various aspects of a building envelope for residential buildings[16–18]. For instance, Taleb [18] researched the passive cooling strategies implemented in a residential villa located in a hot-dry climate region. The passive cooling strategy included double glazing, insulation, shading device, green roof, etc. Furthermore, Mirrahimi et al. [16] conducted a study where the impact of several elements like external walls, roofs, windows and shading devices by taking in consideration the building orientation and form, were investigated for a high-rise residential building in a hot-humid climate.

In Turkey, also, the performance of several energy efficient measures was examined based on different climate types [2, 19-26]. In these studies, various scenarios were taken into consideration. The investigated parameters were: climate condition, windows/wall ratio, insulation type and thickness, glazing properties, the number of glazing layers, buildings type, etc. These parameters affect the heating/cooling loads of a building considerably. Yaşar and Maçka [19] concluded that low-e#2+clear glass in cold climate is more appropriate regarding energy and cost efficiency. Also, in Ucar and Balo [21] was seen that energy cost savings, with a variation of 4,2 $\$/m^2$ to 9,5 $\$/m^2$, were in function of the city and insulation materials. When considering the energy efficiency of the building, it is crucial to investigate even the life cycle cost of the design alternatives. That's why, this study aims to examine the effect of design alternatives regarding energy and cost efficiency for two residential buildings, one located in Ankara with a cold climate and the other located in Antalya with a hot climate. Because heat losses and gains occur mostly in walls and windows, this study is focused on determining the energy performances and life cycle costs of glazing and insulation thickness alternatives according to different window/wall ratios. In the following sections, the methodology and the results of this study are discussed.

2. Methods

The current study utilizes a reference high-rise residential project with a 1+1 typical floor plan for a family of two located in cities with cold and hot climate in Turkey. For this purpose, these buildings are located in Ankara and Antalya, in Climate Region III and I, a cold and hot climate, respectively. It was desired to investigate the effects of the different glass types, insulation thickness and window/wall ratio (WWR) on the zone heating and total cooling loads of buildings. Therefore, all the parameters except glazing units of windows, WWR and insulation thickness of exterior walls were kept constant. The used glazing units are composed of double-glazing units with a low-e coating, tinted (blue) units, clear reflective units, and reflective+low-e coating units, instead of the widely available clear double-glazing units. Also, EPS insulation with 50 mm and 100 mm thicknesses were used. Zone heating and total cooling loads through these glasses and insulation thickness were calculated based on monthly and annual periods using the DesignBuilder energy simulation software. Next, for each combination composed of different WWR, glazing units, and insulation thickness, the life cycle costs were calculated by summing the initial capital investment and the annual energy operational cost. Finally, the energy and cost efficiency of the used glazing units and insulation thickness were investigated, and the most suitable alternative was determined.

2.1. Glass types in building

The heat conservation performance and solar control performance of any glass are respectively dependent on the heat transmittance coefficient (U-value, W/m^2K) and the solar heat gain coefficient (SHGC). A low U-value corresponds to high heat protection performance, and a low SHGC corresponds to high solar control performance. Instead of the available glass typically used in the flats, the research is conducted with investigated blue tinted glass, low-e coated glass, clear reflective glass, and reflective+low-e coated glass. In Table 1 are shown the thermophysical–optical and dimensional properties of the single glasses used in the double-glazed units. The thermal performance criteria of the double-glazed units composed of the single glasses were calculated using DesignBuilder software and are given in Table 2.

2.2. Wall types in building

The thermal performance of wall is related to the thermal resistance (R-value) of the insulation. A higher value of thermal resistance (R-value) of the insulation produced higher R-value of the wall assembly. The optimum insulation thickness changes about the climate condition of the building site. In this research 50 and 100 mm, EPS insulations are used, and other elements of the exterior wall are kept constant. The core layers of the exterior walls consist of a 20 mm thick plaster layer on each side, a 200 mm thick concrete layer. The heat transmittance coefficient (U-value) of the exterior wall is 0.599 W/m^2K and 0.343 W/m^2K for 50 and 100 mm EPS insulation, respectively. The properties of the Wall materials used in both flats are given in Table 3.

2.3. DesignBuilder energy simulation software

DesignBuilder v. 5.3.0.014 as a dynamic building energy simulation software is used for calculating the monthly and yearly zone heating and total

Table 1. The thermophysical–optical and dimensional properties of the single glasses

Glass Types	d (mm)	λ (W/mK)	T_{sol}	R_{sol1}	R_{sol2}	T_{vis}	R_{vis1}	R_{vis2}	e_1	e_2
Clear Glass	6	0.9	0.775	0.071	0.071	0.881	0.080	0.080	0.840	0.840
Low-e Glass 3	5.638	1	0.662	0.113	0.100	0.819	0.108	0.102	0.157	0.840
Reflective Glass	5.89	1	0.438	0.356	0.272	0.326	0.509	0.440	0.837	0.837
Blue Tinted Glass	5.95	1	0.345	0.050	0.050	0.540	0.057	0.057	0.840	0.840
Reflective/Low-e Glass	5.918	1	0.580	0.227	0.186	0.665	0.285	0.254	0.209	0.840

Table 2. The thermal performance criteria of double-glazed units in the building simulation model

Double glazed units (6-12-6 mm)	U (W/m^2K)	SHGC	T_{SOL}	T_{VIS}
CLR	2.685	0.703	0.604	0.781
LECLR3	1.877	0.669	0.527	0.727
RFLCLR	2.688	0.403	0.329	0.301
BLCLR	2.690	0.413	0.282	0.473
CLRRFLLE3	1.963	0.584	0.459	0.601

Table 3. Properties of wall materials used in flat

	Density (kg/m^3)	Specific heat capacity (J/kg K)	Thermal conductivity (W/mK)
Concrete	1800	1000	1.35
Gypsum plaster	1000	1000	0.40
Expanded Polystyrene-EPS	15	1400	0.04

cooling loads in the flats. This software uses the EnergyPlus dynamic thermal simulation engine for calculating thermal performance of a building with multiple zones located in different climates and occupancy schedules conditions. The user determines parameters like occupancy schedules, operation periods of heating and cooling, air conditioning systems, lighting, and home appliances. According to these parameters, the software calculates the heat gain losses through building elements, energy loads, solar gains through glazing, etc. [27].

2.4. *Meteorological data*

The building models were located in Ankara (40.12ºN, 33.00ºE, altitude 949 m) and Antalya (36.87ºN, 30.73ºE, altitude 54 m), in Climate Region III and I, representing the cold and hot climate of Turkey. Meteorological data for Turkey's Climate Region III and I are given in Table 4 [28].

During the period of 1926-2016, the lowest temperature was -24.9 ºC in January for Ankara and -4.6 ºC in February for Antalya while the highest temperature was 41 ºC for Ankara and 45 ºC for Antalya in July.

Table 4. Annual meteorological data for Ankara and Antalya

	Ankara	Antalya
Average Temperature (ºC)	12.1	18.4
Average Maximum Temperature (ºC)	17.9	24.4
Average Minimum Temperature (ºC)	6.7	13.3
Mean Solar Time (hour)	78.9	99.7

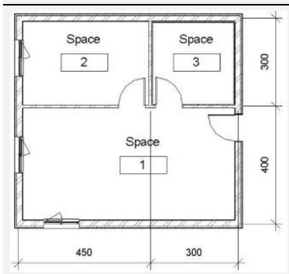
2.5. *Building model*

A typical flat with 1+1 floor plan designed for a family of two in a reference residential building project, with different window/wall ratios, was used for the energy and cost efficiency analysis. The simulation study is based on the layout of the flat on the 10th floor of a residential building. The flat's height is 3 m. Table 5 shows the typical flat layout of reference residential building in two mentioned cities and the zones of this plan. This flat with a total floor area of 43.09 m^2, has one bedroom, one living room+kitchen, and one bathroom. This flat, with three thermal zones, faces southwest. In Fig. 1, it is shown the modeled flats with different WWR: a) 50%, b) 75% and c) 100%, respectively.

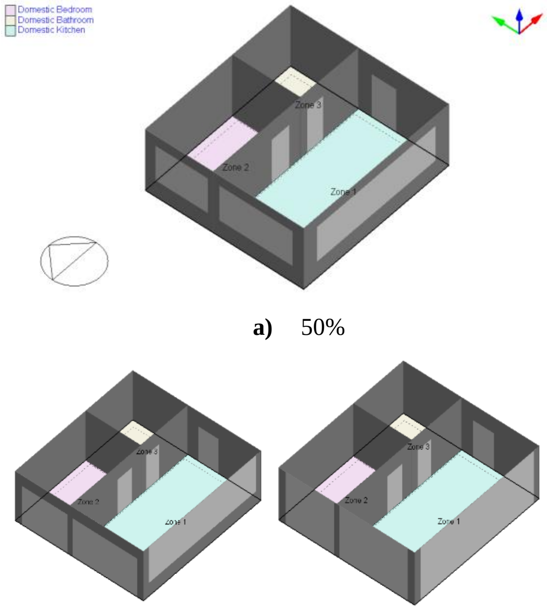
2.6. *Building model construction*

The investigated typical flat has both exterior and partition walls. The partition walls consist of three layers of material: a 20 mm thick plaster layer on each side and a 200 mm thick concrete layer. The plaster layers for all of the walls are gypsum. The heat transmittance coefficient (U-value) of the exterior wall is 2.304 W/m^2K.

Table 5. Flat layout and zones areas of the flat



	Area (m^2)
Living Room+Kitchen	25.19
Bedroom	10.92
Bathroom	6.98
Total	43.09



a) 50%

b) 75% **c)** 100%

Fig. 1. Flat model with WWR

The flat floors consist of three layers of material, listed from the outer to the interior surface: a 20 mm thick gypsum plaster layer on each side and a 100 mm thick concrete layer. The flat roof is not pitched roof because the investigated flat is on intermediate floors. This roof consists of four layers of material, listed from the outer to the interior surface: a 20 mm thick gypsum plaster layer, a 200 mm thick concrete layer, a 50 mm thick expanded polystyrene–EPS heat insulation (on the interior surface), a 20 mm thick gypsum plaster layer. The heat transmittance coefficient (U-value) of the floor and ceiling construction is 2.604 W/m^2K and 0.610 W/m^2K, respectively. The properties of the building materials used in the flat are given in Table 3. The existing windows in the flat are composed of polyvinyl chloride (PVC)-20 mm and a double-glazing unit with two 6 mm thick panes and a 12 mm thick air gap. The heat transmittance coefficient (U-value) of polyvinyl chloride is 3.476 W/m^2K.

2.7. Utilization of model flats

General functional information of flat is given in Table 6.

Table 6. General functional information for the flat

	General information
User type	Two adults
Occupancy schedule	Weekday - 18:00-08:00 Weekend - 00:00-24:00
Zone types	Zone 1. Living room+Kitchen Zone 2. Bedroom Zone 3. Bathroom
Equipment types	Miscellaneous (Television, refrigerator etc.) Computer
Heating system	Fan Coil (from October 1st to March 31st)
Heated zone	Zone 1 and Zone 2
Cooling system	Air conditioner running on electricity
Cooled zone	Zone 1 and Zone 2

2.8. Life cycle cost analysis

The life cycle cost is the total cost of a unit element of the building including the initial cost of maintenance/repair replacement, operation, and disposal. The following formula is used to calculate the life-cycle cost (LCC) [29]:

$$LCC = I + M - R - O + R - RV \tag{1}$$

Where: I-Initial cost; M-R-O-Maintenance-Repair-Operation cost; R-Replacement cost; RV-Residual value. In this study, it is considered only initial and operating costs because of no accurate data related to maintenance and repair costs. Parameters used in the LCC analysis are given Table 7. The discount rate of 15% and the inflation rate of 10.68% is used for Turkey [30]. The unit price of natural gas and electricity used in the calculation of energy expenditures were retrieved from the official website of distributor companies in Ankara and Antalya [31–33]. Respective unit prices of the glazing and EPS heat insulation are illustrated in Tables 8 and 9, respectively. Glazing and insulation prices were obtained from the manufacturers that are operating in Turkey.

According to LCC analysis, Table 10 shows the total initial capital investment for all the combinations of different glazing types, insulation thickness, and windows/wall ratios. Furthermore, annual operational costs for Ankara and Antalya are given in Table 11, respectively.

Table 7. Parameters used in the life cycle cost analysis

Analysis type	General LCC analysis-non-federal, no taxes
Beginning date for LCC	2018
Study period	30 years
Planning/Construction period	2 years
Discount rate	15%
Life of glazing	60 years
Fuel type	Natural gas, electricity
The unit cost of natural gas (for 2018)*	0.1112 TL/kWh (for Ankara) 0.1102 TL/kWh (for Antalya)
The unit cost of electricity (for 2018)*	0.4482 TL/kWh (for both cities)

Table 8. Cost of double glazed units

Double glazed units	Supply price/m2 (TL)**
CLR	70.8
LECLR3	159.3
RFLCLR	149.86
BLCLR	149.86
CLRRFLLE3	159.3

Table 9. Cost of EPS heat insulation units

Thickness of insulation	Supply price/m2 (TL)**
5 cm	9.2
10 cm	18.51

3. Results and discussion

After the simulation, the total cooling loads and zone heating loads for Antalya and Ankara cities were obtained. In the following sections, the effects of the different glass types, insulation thickness, and WWR on the total annual loads and the most energy and cost efficient combination will be discussed for the above cities.

3.1. The effects of different glass types, insulation thickness, and WWR

3.1.1. According to glass types

The total monthly load of the buildings with 50% WWR, 50 mm insulation thickness and using different glass types are shown in Figs. 2 and 3.

Using reflective, blue tinted and low-e/reflective glasses cause 73%, 61%, and 24% respectively, less total annual cooling loads compared to clear glass, while low-e glass produces 3% higher loads than clear glass. In contrast, reflective and blue tinted glass cause 15% and 12% respectively, higher total annual heating loads compared to clear, while low-e and low-e/reflective glasses produce 10% and 5% fewer loads than clear glass. However, as seen in Fig. 2, based on the total monthly loads, for the building located in Ankara the use of low-e glass produces fewer loads than the other glasses. In Ankara city with high heating energy demand, the use of low-e glass reduces the heat losses due to conduction during the heating period.

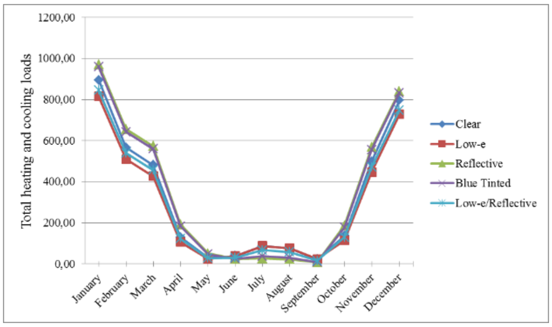


Fig. 2. Total monthly loads in Ankara

Table 10. Total initial capital investment of all combinations (TL)

	WWR (%)	50		75		100	
	Insulation thickness (mm)	50	100	50	100	50	100
Glazing type	Clear	1476.29	1485.60	2116.78	2126.09	2778.50	2787.81
	Low-e	3228.59	3237.90	4683.28	4692.59	6185.75	6195.06
	Reflective	3041.68	3050.99	4409.52	4418.83	5822.31	5831.62
	Blue tinted	3041.68	3050.99	4409.52	4418.83	5822.31	5831.62
	Low-e/ Reflective	3228.59	3237.90	4683.28	4692.59	6185.75	6195.06

Table 11. Annual energy expenditures of all combinations (TL)

Ankara							
	WWR (%)	50		75		100	
	Insulation thickness (mm)	50	100	50	100	50	100
Glazing type	Clear	489.45	428.29	610.98	556.42	756.05	707.82
	Low-e	451.43	391.56	568.69	516.05	721.95	676.04
	Reflective	476.67	415.60	538.35	482.50	613.67	563.49
	Blue tinted	479.07	417.89	550.44	494.57	637.23	587.11
	Low-e/ Reflective	444.60	384.26	537.81	484.25	662.04	612.86

Antalya							
	WWR (%)	50		75		100	
	Insulation thickness (mm)	50	100	50	100	50	100
Glazing type	Clear	597.43	530.59	891.76	833.61	1172.30	1121.99
	Low-e	578.29	510.30	888.86	829.75	1205.01	1153.63
	Reflective	381.09	318.11	528.41	470.66	670.36	619.28
	Blue tinted	430.68	365.85	608.94	550.22	781.82	729.12
	Low-e/ Reflective	510.76	444.30	770.60	708.67	1034.05	981.49

High cooling energy demand characterizes Antalya city. As seen from Fig. 3, reflective glass produces less total monthly loads than the other glasses. When total annual cooling loads are analyzed, low-e, reflective, blue tinted and low-e/reflective cause 2%, 44%, 34% and 15%, respectively, fewer loads compared to clear glass. On the other hand, when total annual heating loads are analyzed, low-e and low-e/reflective cause 16% and 4% fewer loads compared to clear and reflective and blue tinted produce 46% and 38% higher loads than clear glass.

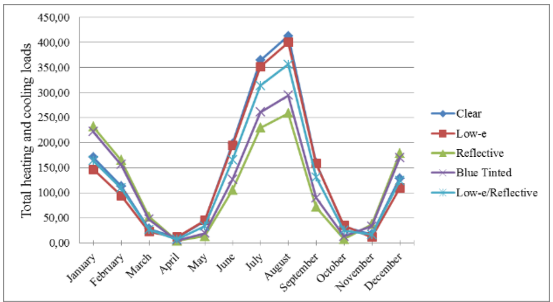


Fig. 3. Total monthly loads in Antalya

3.1.2. According to insulation thickness

In this section, the effect of different insulation thickness is examined. The total monthly loads of the buildings in Ankara and Antalya using different insulation thickness are shown in Fig. 4. Because low-e glass for Ankara and reflective glass for Antalya are the best glass options as concluded in the previous section, during the simulations, these types of glasses and WWR 50% for both cities are used.

From Fig. 4, it is implied that in both cities the use of 100 mm EPS insulation results in less total monthly loads. The use of 100 mm EPS causes 13.7% in Ankara and 13.1% in Antalya less total annual loads than 50 mm EPS insulation.

3.1.3. According to window/wall ratio

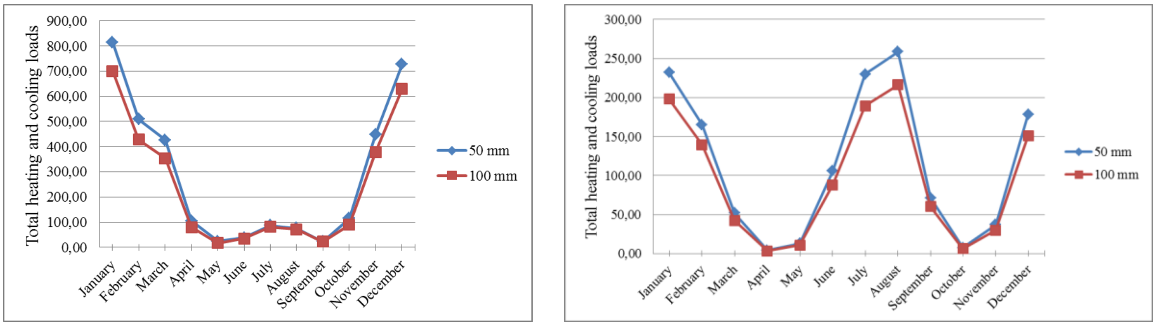
In this section, the effect of different WWR on the total annual loads are investigated. From the above sections, it is concluded as the best glass option low-e glass for Ankara and reflective glass for Antalya. Also, the use of 100 mm EPS insulation thickness is preferred because it produces lower total annual loads in both cities. In Fig. 5 are shown the total monthly loads with different WWR for Antalya and Ankara.

As implied from Fig. 5, for both cities, the use of WWR 50% leads to less total annual loads than the other WWR, respectively, 75% and 100%. In Ankara, the use of WWR 50% causes 8.5% and 21.6% less total annual loads than WWR 75% and WWR 100%, respectively. In Antalya, the use of WWR 50% causes 31% and 62.5% less total annual loads than WWR 75% and WWR 100%, respectively. From these results, it can be concluded that Antalya city is more affected by the change of WWR than Ankara city regarding total annual loads. As a conclusion, based on total annual loads, the best combination for Ankara is low-e glass + WWR 50% + 10 cm EPS and for Antalya reflective glass + WWR 50% + 10 cm EPS.

3.2. The most energy and cost efficient combinations

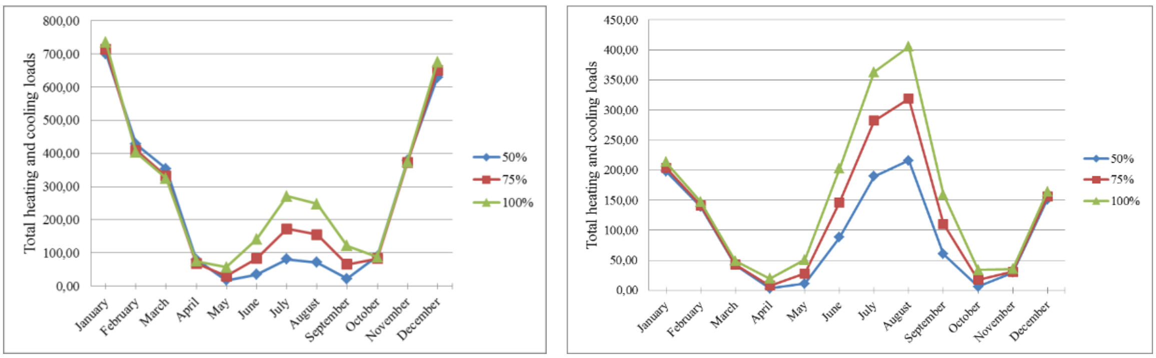
In order to find the most energy and cost efficient combinations, for both cities, the life cycle cost analysis was conducted. Figs. 6 and 7 show the total annual loads and the respective life cycle costs of the 30 combinations in Ankara and 30 combinations in Antalya.

Based on Fig. 6, for Ankara, it can be concluded that the best combination regarding total annual heating and cooling loads and life cycle cost are: low-e glass + 100 mm EPS + WWR 50% and clear glass + 100 mm EPS + WWR 50%. Compared to the reference case clear glass + 50mm EPS+WWR 50%, low-e glass + 100 mm EPS + WWR 50% causes 23% less total annual loads and 53% higher life cycle cost while clear glass + 100 mm EPS + WWR 50% produces 14% less total annual loads and 6% less life cycle cost.



a) Ankara **b**) Antalya

Fig. 4. The total monthly loads with different insulation thickness



a) Ankara **b**) Antalya

Fig. 5. The total monthly loads with different WWR

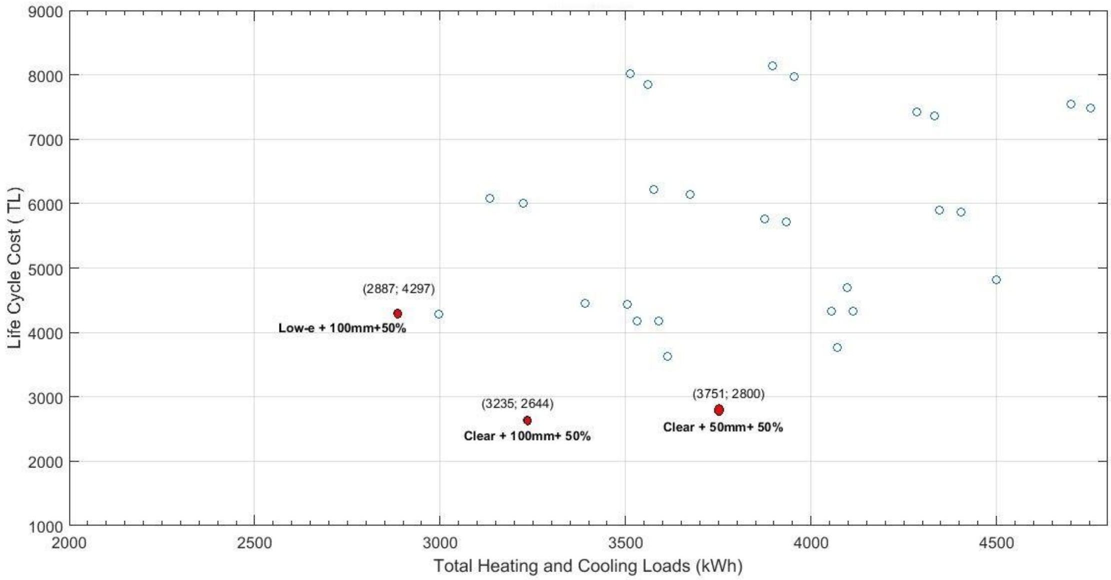


Fig. 6. The total annual heating and cooling loads and the respective life cycle costs of all combinations for Ankara

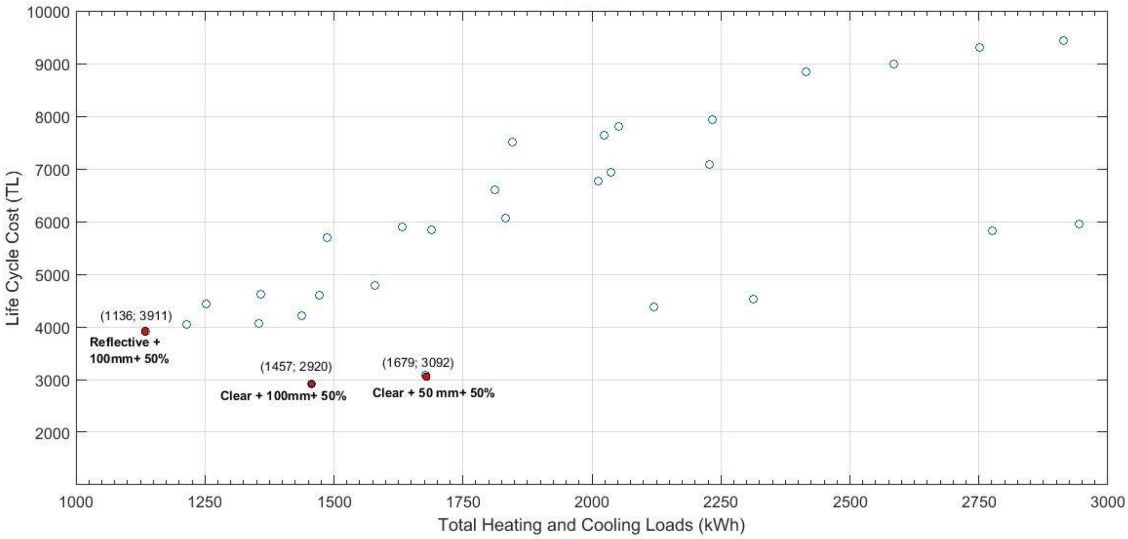


Fig. 7. The total annual heating and cooling loads and the respective life cycle costs of all combinations for Antalya

For Antalya, as seen from Fig. 7, the best combination regarding total annual heating/cooling loads and life-cycle cost are reflective glass + 100 mm EPS + WWR 50% and clear glass + 100 mm EPS + WWR 50%. Reflective glass + 100 mm EPS + WWR 50% causes 32% less total annual loads and 27% higher life cycle cost while clear glass + 100 mm EPS + WWR 50% produces 13% less total annual loads and 6% less life-cycle cost compared to the reference case clear glass + 50mm EPS+WWR 50%.

From the above results, it can be implied that the most energy efficient combination is low-e glass + 100 mm EPS + WWR 50% for Ankara and reflective glass + 100 mm EPS + WWR 50% for Antalya. Also, the most cost-efficient combination is clear glass + 100 mm EPS + WWR 50% for Ankara and Antalya.

As a result, 100mm EPS and WWR 50% should be used in Ankara and Antalya cities to reduce the heat losses and gains due to conduction and solar gains. Also, for Ankara, it is proposed to use low-e glass. Low-e glass is characterized by lower U-value than the other glass types, that's why the heat losses from conduction in the heating period are reduced. Furthermore, for Antalya, it is suggested to use reflective glass which reduces the solar heat gains due to lower SHGC value.

4. Conclusion

In this study, the effect of five glazing type, two insulation thickness, and three WWR on the total annual heating/cooling loads and the life-cycle cost were investigated. To this end, for the simulations, a flat of 1+1 floor plan designed for a family of two in a residential building located in cold and hot climate region was taken into consideration. Some of the key findings of this study are:

1. Regarding total annual heating and cooling loads, the most energy efficient glass is low-e for cold climate and reflective glass for a hot climate. For both climate regions, the best insulation thickness was 100 mm EPS, and WWR was 50%.
2. The most cost-efficient combination was clear glass with 100mm EPS and WWR 50% for both climate regions.
3. For Ankara, the most energy-efficient option provides 11% less total annual loads and 63% higher life cycle cost than the most cost-efficient option.
4. For Antalya, the most cost-efficient option causes 28% higher total annual loads and 25% less life cycle cost than the most energy-efficient option.

Consequently, it is concluded that the most energy efficient combination is low-e glass + 100 mm EPS + WWR 50% for cold climate regions and reflective glass + 100 mm EPS + WWR 50% for hot climate region. Also, the most cost-efficient combination is clear glass + 100 mm EPS + WWR 50% for both regions. In the current study, the lighting loads were not considered in the total annual loads. The lighting loads are related to parameters like WWR and the glazing type. As the future work, the effect of the above parameters in terms of the total energy use and cost efficiency including lighting energy can be investigated.

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Nomenclature

CLR	6 mm clear glass + 12 mm air space + 6 mm clear glass
LECLR3	6 mm clear glass + 12 mm air space + 6 mm Low-E glass #3
RFLCLR	6 mm reflective glass + 12 mm air space + 6 mm clear glass

BLCLR	6 mm blue tinted glass + 12 mm air space + 6 mm clear glass
CLRRFLLE3	6 mm reflective - Low-E glass #3 glass + 12 mm air space + 6 mm clear