The Effect of Shading Factor for Single and Double Glazing According to Solar Heat Gain / Window Heat Loss Ratio in Turkey for Residential Buildings

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The Effect of Shading Factor for Single and Double Glazing According to Solar Heat Gain / Window Heat Loss Ratio in Turkey for Residential Buildings

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Abstract: In this study, solar heat gains due to solar radiation and heat losses due to air temperature difference between outdoor and indoor from single and double glazed windows for the heating period in residential buildings were determined and their ratios were calculated. For five climate zones in Turkey determined by Turkish Building Insulation Standard (TS 825); the heating months were identified for the south, north, and east-west directions. The reference indoor temperature value for heating is 19^0C. It is accepted that heating will be performed in the months when the outdoor air temperatures are below this temperature. The warmest climate zone is the first zone and the coldest climate zone is the fifth zone. July has the highest air temperature month for all climate zones and January has the lowest. The highest value of solar radiation occurs in June and the lowest in December. The effects of the shading factor and the number of layers for the windows were found in the calculations. In order to find the effect of shading factor, the shading factor for discrete and adjacent buildings and heat transfer coefficients for single and double glazing were determined from TS 825. Then, the solar heat gains, window heat losses and their ratios were determined by using the shading factor for discrete and adjacent buildings and without shading factor for single and double glazing. It was calculated that the solar heat gain/window heat loss ratio was higher in double glazed windows. It means that benefit from solar energy for double layer glazing is much more than single layer glazing for heating period.

1. Introduction

Nowadays, where energy is very important, designing structures that use energy in the most efficient way is the best solution. Thus, energy-efficient building designs are highly important. At the energy-efficient structure; it is aimed to minimize heat losses in winter and gain maximum benefit from solar energy. Besides, to save heating energy; renewable energy sources such as solar, wind, and water are used instead of fossil energy sources such as oil, natural gas, and coal [1].

In energy-efficient building design, 25 % of the heat losses in the building are realized through windows. When this situation is examined, the measures to be taken in the windows will be able to provide a significant improvement in heating and cooling energy costs [1].

The aim of this study is to determine the heat losses due to air temperature difference between outdoor and indoor and the solar heat gain due to solar radiation from single and double glazed windows for the heating period in residential buildings and to calculate their ratios. In this case, it is assumed that heating is performed at temperatures where the outdoor air temperature is less than 19 °C. For these months, solar radiation values for different directions were taken from the TS 825. Solar heat gains with or without using shading factors for discrete and adjacent buildings was found. The solar heat gain was calculated by multiplying the shading factor, solar energy transmission factor, and solar radiation values. For single and double glazed windows, heat loss was calculated by multiplying the internal and external temperature difference and the heat transfer coefficients of the windows. Then, the ratio of these gains and losses were determined.

2. Method

2.1. Parameters Used in Calculations

In the study, the heat transfer coefficient is 5.62 W/m^2.K for single glazed windows with aluminium joinery. For double glazed windows with PVC joinery, Low-E, and the 16 mm air gap heat transfer coefficient is 1.50 W/m^2.K. These values were taken from TS 825. The shading coefficient was taken as 0.8 for discrete buildings and 0.5 for adjacent buildings. The solar transmittance factor for single glazing was 0.68 and for double glazing 0.40. Heat loss calculations were performed for the months with outdoor air temperature less than 19 ^{0}C for the heating period [2].

The outdoor air temperature in Turkey according to TS 825 changes between 8.4 to 28.7 ^{0}C for the first climate zone, between 2.9 to 24.9 ^{0}C for the second climate zone, between -0.3 to 21.7 ^{0}C for the third climate zone, between -5.4 to 21.4 ^{0}C for the fourth climate zone, and between -10.5 to 18.6 ^{0}C for the 5th climate zone. The coldest month is January and the hottest month is July. Depending on the different directions, the solar radiation values varies between 64 to 95 W/m^2 for south direction, between 22 to 83 W/m^2 for north direction, for west and east direction between 37 to 122 W/m^2. The highest solar radiation value for all directions is observed in June. Figure 1 shows the average monthly outdoor temperature values for the five climate zones in TS 825. Figure 2 shows the solar radiation values in different directions in TS 825.

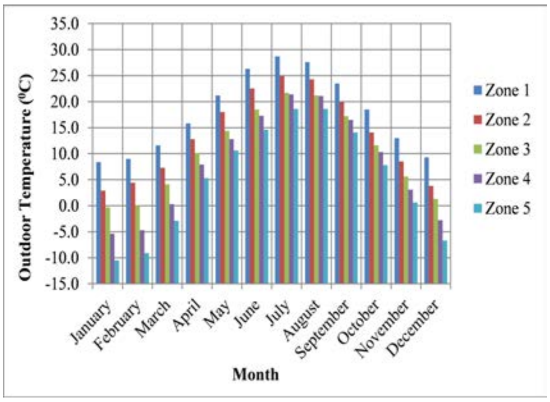


Figure 1. Monthly average outdoor temperature values for five climate zones [2].

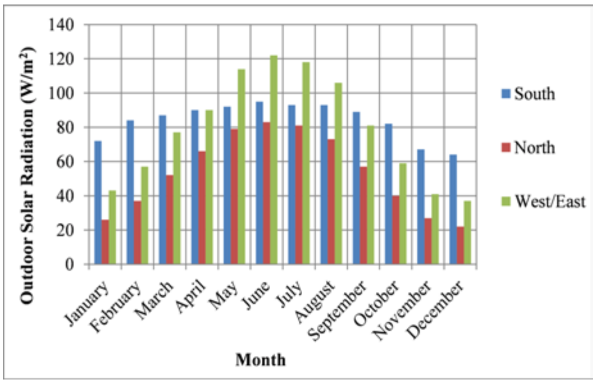


Figure 2. Solar radiation values in different directions [2].

2.2. Formulas Used in Calculations

Here, $r_i.g_g.\ I_m$ formula is solar heat gain formula from windows and $U.\Delta T$ is heat loss from windows [2,3,4,5].

If $r_i.g_g.\ I_m > U.\Delta T$ it means heating gain (1)

If $r_i.g_g.\ I_m = U.\Delta T$ it means heating gain=heating loss (2)

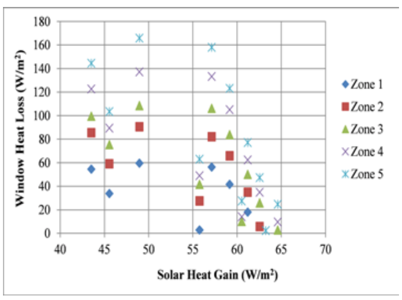
If $r_i.g_g.\ I_m < U.\Delta T$ it means heating loss (3)

$$k=\frac{r_i.g_g.I_m}{U.\Delta T} \quad \text{solar heat gain/window heat loss ratio} \tag{4}$$

Here, r_i indicates the shading factor due to the fact that the building is discrete or adjacent, g_g shows the solar energy transmission factor connected to the glazing type of the windows (single glazing, double glazing, coated double glazing, etc.), I_m is the solar radiation due to the different directions of the windows. U is the heat transfer coefficient for single and double glazed windows, and ΔT ($\Delta T=T_i-T_o$) indicates to the temperature difference between the indoor and outdoor environment.

3. Consult and Discussion

In Figure 3, solar heat gain and window heat loss graph of single glazing without shading factor was given. In Figure 4, solar heat gain/window heat loss ratio graph of single glazing without shading factor the heating months was given. In Figure 5, solar heat gain and window heat loss graph of single glazing with shading factor in discrete buildings was given. Figure 6 shows the solar heat gain/window heat loss ratio by using single glazing and shading factor in discrete buildings during the heating months was given. In Figure 7, solar heat gain and window heat loss graph of double glazing with shading factor in discrete buildings was given. In Figure 8, solar heat gain/window heat loss ratio graph was given using double glazing without shading factor the heating months was given. Figure 9 shows the solar heat gain and window heat loss graphs using double glazing with shading factor in adjacent buildings was given. Figure 10 shows the solar heat gain/window heat loss ratio by using double glazing with shading factor in adjacent buildings during the heating months was given. At these graphs, a) is south direction, b) is north direction, and c) is west/east direction for five different climate zones.



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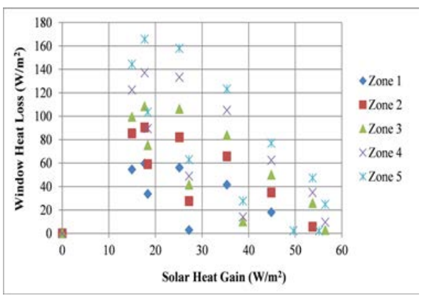

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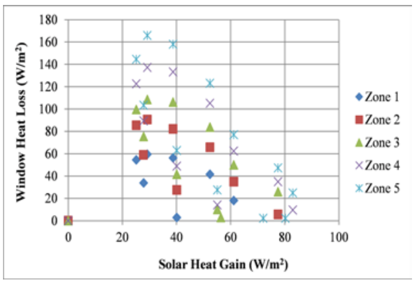
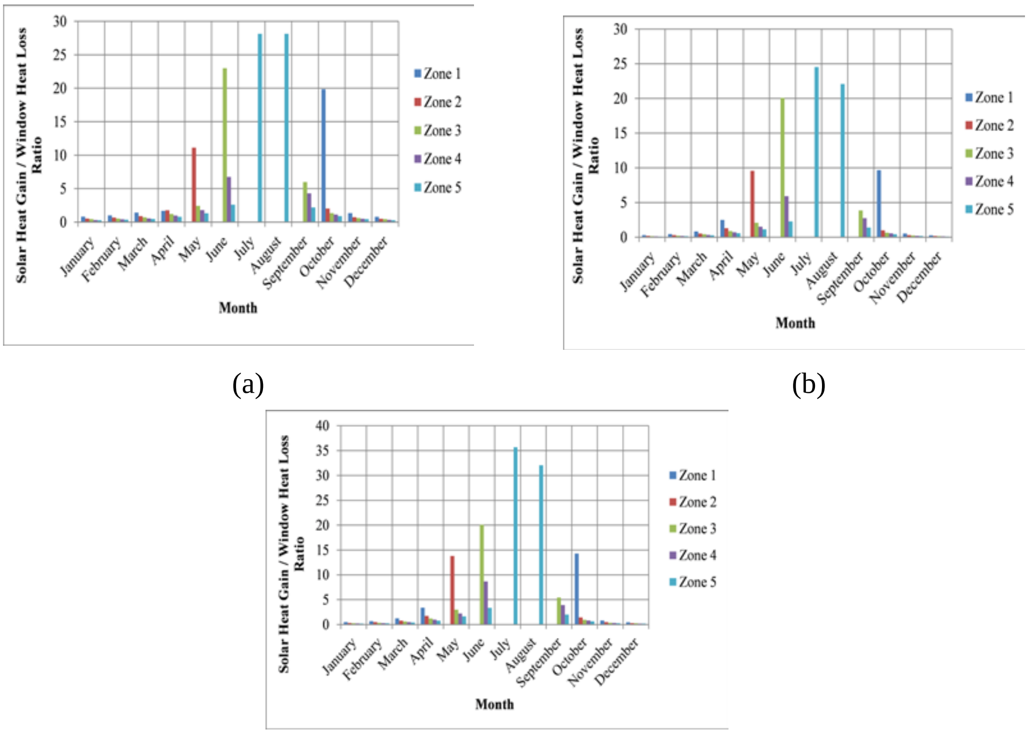


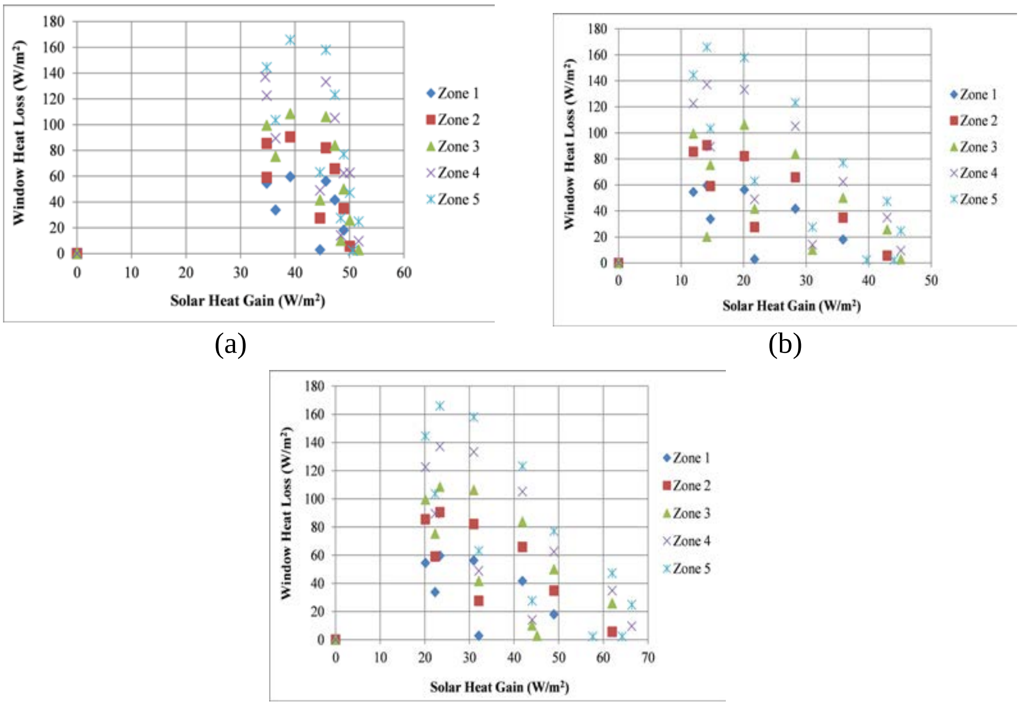
Figure 3. The solar heat gain and window heat loss graph of single glazing without shading factor a) south direction, b) north direction, and c) west/east direction.



(a) (b)

(c)

Figure 4. The solar heat gain/window heat loss ratio graph of single glazing without shading factor for different heating months a) south direction, b) north direction, and c) west/east direction.



(a) (b)

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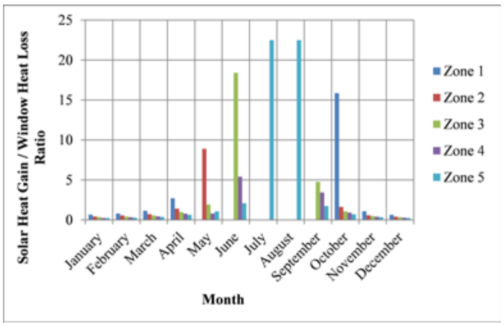
Figure 5. The solar heat gain and window heat loss graph of single glazing with shading factor in discrete buildings a) south direction, b) north direction, and c) west/east direction.



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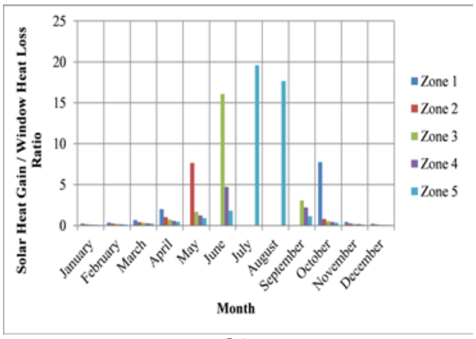

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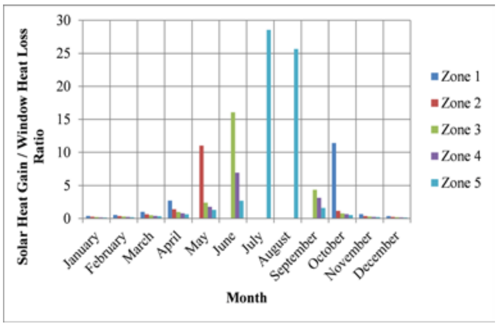

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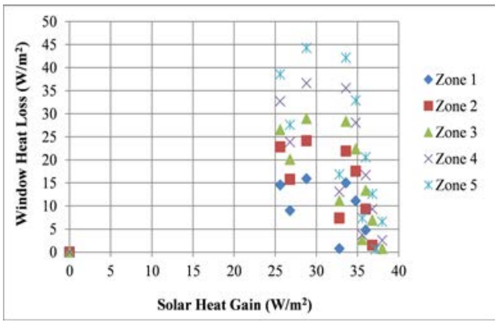
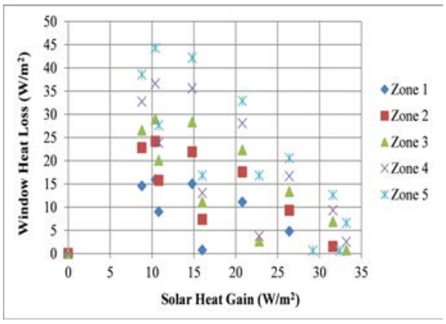
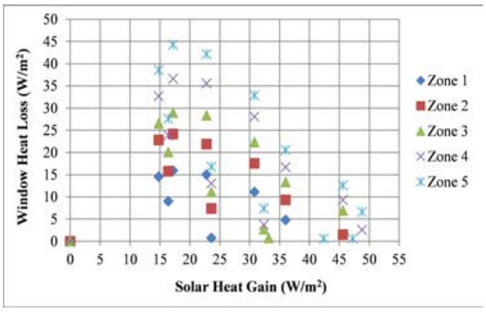
Figure 6. The solar heat gain/window heat loss ratio by using single glazing and shading factor in discrete buildings during the heating months a) south direction, b) north direction, and c) west/east direction.

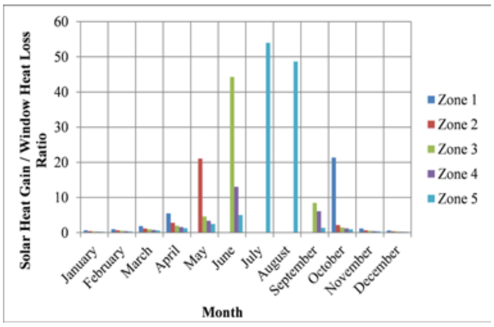






(c)

Figure 7. The solar heat gain and window heat loss graph of double glazing without shading factor in discrete buildings a) south direction, b) north direction, and c) west/east direction.



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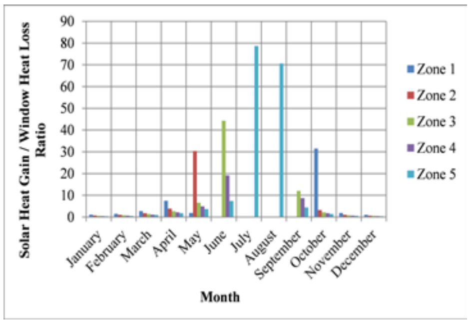

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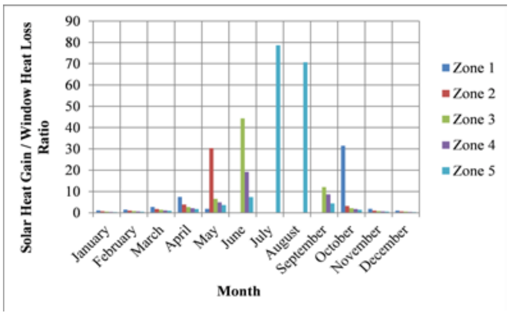
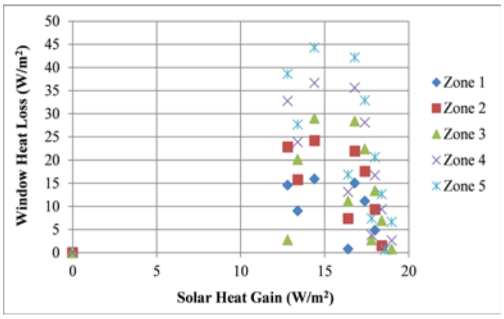


(c)

Figure 8. The solar heat gain/window heat loss ratio graph of double glazing without shading factor during different heating months a) south direction, b) north direction, and c) west/east direction.



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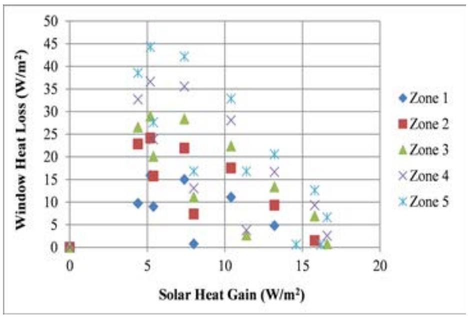

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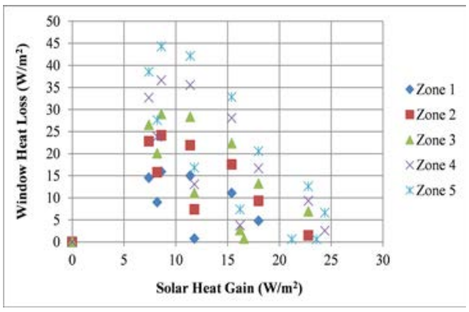
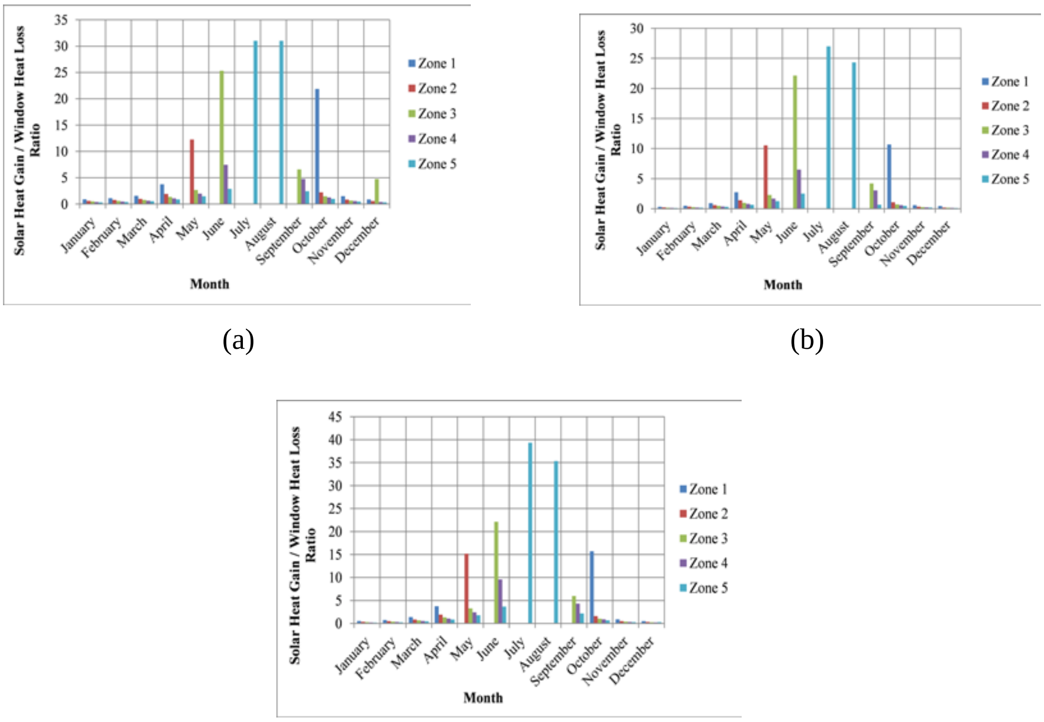


(c)

Figure 9. The solar heat gain and window heat loss graphs of double glazing with shading factor in adjacent buildings a) south direction, b) north direction, and c) west/east direction.



(a) (b)

(c)

Figure 10. The solar heat gain/window heat loss ratio of double glazing with shading factor in adjacent buildings during the different heating months a) south direction, b) north direction, and c) west/east direction.

The solar heat gain for single glazing without using shading factor in buildings for the heating period was calculated for June in the third, fourth and fifth climate zones with the highest value of 64.600 W/m^2 for the south direction and for all months. In the north direction, the highest value was calculated as 56.440 W/m^2 for June in the third, fourth and fifth climate zones. The highest value was calculated as 82.960 W/m^2 for the fourth and fifth climatic zones for June in the West / East direction. The highest window heat loss value was calculated as 165.790 W/m^2 for January in the fifth climate zone in the south direction. For the north direction, the highest window heat loss value was calculated as 165.790 W/m^2 for January in the fifth climate zone. Similarly, for the west/east direction, the highest window heat loss value was calculated as 165.790 W/m^2 for January in the fifth climate zone. The solar heat gain/window heat loss ratio was calculated for August and July in the fifth climate zone with the highest value of 28.132 for all climatic zones and all months for the south direction. It was calculated as 24.502 and 35.693 for July in the fifth climate zone in the north and east/west directions, respectively.

The highest solar heat gain for single glazing and discrete buildings (shading factor value 0.8) during the heating period was calculated as 51.680 W/m^2 for June in the third, fourth and fifth climatic zones at the south direction. In the north direction, the highest solar heat gain was calculated as 45.152 W/m^2 for June in the third, fourth and fifth climate zones. In the east/west direction, the highest solar heat gain was calculated as 66.368 W/m^2 for June in the fourth and fifth climate zones. The highest window heat loss from the south direction was calculated as 165.790 W/m^2 for January in the fifth climate zone. Similarly, for the north and east/west directions, the highest window heat losses were calculated as 165.790 W/m^2 for January in the fifth climate zone. The solar heat gain/window heat loss ratio was calculated for August and July in the fifth climate zone with the highest value of 22.505 for all climatic zones and all months for the south direction. It was calculated as 19.601 and 28.555 for July in the fifth climate zone in the north and east/west directions, respectively.

The highest solar heat gain for single glazing and adjacent buildings (shading factor value 0.5) during the heating period was calculated as 32.300 W/m^2 for June in the third, fourth and fifth climatic zones at the south direction. In the north direction, the highest solar heat gain was calculated as 28.220 W/m^2 for June in the third, fourth and fifth climate zones. In the east/west direction, the highest solar heat gain was calculated as 41.480 W/m^2 for June in the fourth and fifth climate zones. The highest window heat loss from the south direction was calculated as 165.790 W/m^2 for January in the fifth climate zone. Similarly, for the north and east/west directions, the highest window heat losses were calculated as 165.790 W/m^2 for January in the fifth climate zone. The solar heat gain/window heat loss ratio was calculated for August and July in the fifth climate zone with the highest value of 14.066 for all climatic zones and all months for the south direction. It was calculated as 12.251 and 17.847 for July in the fifth climate zone in the north and east/west directions, respectively.

The solar heat gain for double glazing without using shading factor in buildings for the heating period was calculated for June in the third, fourth and fifth climate zones with the highest value of 38.000 W/m^2 for the south direction and for all months. In the north direction, the highest value was calculated as 33.200 W/m^2 for June in the third, fourth and fifth climate zones. The highest value was calculated as 48.800 W/m^2 for the fourth and fifth climatic zones for June in the West/East direction. The highest window heat loss value was calculated as 44.250 W/m^2 for January in the fifth climate zone in the south direction. For the north direction, the highest window heat loss value was calculated as 44.250 W/m^2 for January in the fifth climate zone. Similarly, for the west/east direction, the highest window heat loss value was calculated as 44.250 W/m^2 for January in the fifth climate zone. The solar heat gain/window heat loss ratio was calculated for August and July in the fifth climate zone with the highest value of 62.000 for all climatic zones and all months for the south direction. It was calculated as 54.000 and 78.667 for July in the fifth climate zone in the north and east/west directions, respectively.

The highest solar heat gain for double glazing and discrete buildings (shading factor value 0.8) during the heating period was calculated as 30.400 W/m^2 for June in the third, fourth and fifth climatic zones at the south direction. In the north direction, the highest solar heat gain was calculated as 26.560 W/m^2 for June in the third, fourth and fifth climate zones. In the east/west direction, the highest solar heat gain was calculated as 39.040 W/m^2 for June in the fourth and fifth climate zones. The highest window heat loss from the south direction was calculated as 44.250 W/m^2 for January in the fifth climate zone. Similarly, for the north and east/west directions, the highest window heat losses were calculated as 44.250 W/m^2 for January in the fifth climate zone. The solar heat gain/window heat loss ratio was calculated for August and July in the fifth climate zone with the highest value of 49.600 for all climatic zones and all months for the south direction. It was calculated as 43.200 and 62.933 for July in the fifth climate zone in the north and east/west directions, respectively.

The highest solar heat gain for double glazing and adjacent buildings (shading factor value 0.5) during the heating period was calculated as 19.000 W/m^2 for June in the third, fourth and fifth climatic zones at the south direction. In the north direction, the highest solar heat gain was calculated as 16.600 W/m^2 for June in the third, fourth and fifth climate zones. In the east/west direction, the highest solar heat gain was calculated as 24.400 W/m^2 for June in the fourth and fifth climate zones. The highest window heat loss from the south direction was calculated as 44.250 W/m^2 for January in the fifth climate zone. Similarly, for the north and east/west directions, the highest window heat losses were calculated as 44.250 W/m^2 for January in the fifth climate zone. The solar heat gain/window heat loss ratio was calculated for August and July in the fifth climate zone with the highest value of 31.000 for all climatic zones and all months for the south direction. It was calculated as 27.000 and 39.333 for July in the fifth climate zone in the north and east/west directions, respectively.

For all directions, it is accepted that no heating is performed between May-September in the first climate zone, June-September in the second climate zone, July and August in the third and fourth climate zones, depending on the indoor temperature of 19 °C.

Since the outdoor air temperature values are the lowest in January, the highest heat loss from the windows occurs in January in all zones. The hottest month is July. Since no heating was made in all zones except the fifth zone in July, the heat loss from the windows was assumed as zero. In the fifth zone, it was assumed that the heating was performed since the outdoor temperature values were less than 19 ^{0}C (18.6 ^{0}C) in July. For the other four zones, July is considered as a cooling period and no heat loss in windows. On the contrary, there is a heat gain. The highest solar heat gain from windows from all directions during the heating period in the first zone occurs in April. It reaches the highest value in May for the second region and in June for the third, fourth and fifth zones. In these months, solar radiation has the highest value. The highest solar heat gain/window heat loss ratio was calculated for the south direction in the fifth zone for June. For the other directions, it was found in the fifth zone but in July. This is due to high solar heat gain due to solar radiation in all directions during these months. In addition, since the air temperature difference between the outdoor and indoor environment is the lowest, thus this ratio reaches the highest value.

4. Results

During the heating period, solar heat gain and solar heat gain/window heat loss ratio for all zones and directions in discrete buildings for single and double glazing reduce 20 %. Besides, in adjacent buildings, it decreases by 50 %. Since the temperature difference and heat transfer coefficients of the windows remain the same, the heat loss from the windows does not change.

Without using the shading factor, solar heat gain decreased by 41.176 %, window heat loss decreased by 73.310 % and solar heat gain/window heat loss ratio increased by 120.390 % for double glazed windows compared to the single glazed windows. It is seen that the heat loss from the window is much less in double glazed windows. Thus, it is seen that the gain and loss ratio is higher in double glazed windows. This means that the benefit of solar energy will be much more in the double-glazed window for the heating period.

5. References

[1] Maçka S 2008 Determination of Energy Efficient Window Types According to Turkish Climate Regions Karadeniz Technical University Department of Architecture Master's thesis Trabzon Turkey
[2] Turkish Standard, TS 825 Thermal insulation requirements for buildings, December 2013.
[3] M Heinrich and M Urs-Peter 2012 Energy performance of glazings in European climates *Renewable Energy* 37, 226-232.
[4] Jaber S and Ajib S 2011 Thermal and economic windows design for different climate zones *Energy and Buildings* 43, 3208–3215,
[5] Carlos J S and Corvacho H 2014 Evaluation of the thermal performance indices of a ventilated double window through experimental and analytical procedures: Uw-values *Renewable Energy* 63, 747-754.