

# The Effect of Solar Control Elements on Building Energy Consumption in Hot Dry Climate Regions the Case of Diyarbakir

Sevilay Akalp<sup>1</sup>, Havva Özyılmaz<sup>2\*</sup>

<sup>1</sup> Department of Architecture, Faculty of Fine Arts, Harran University, Şanlıurfa, Turkey

<sup>2</sup> Department of Architecture, Faculty of Architecture, Dicle University, Diyarbakir, Turkey

\* Corresponding author's e-mail: havvaozy@dicle.edu.tr

## ABSTRACT

Solar control devices have a significant effect on providing indoor thermal comfort by minimizing annual energy costs in hot-dry climates. Within the scope of the study, the settlement pattern Şilbe 1st Stage Mass Housing settlement located in the city of Diyarbakir, which is located in the hot dry climate zone, was discussed. Horizontal-vertical solar control devices were placed on the transparent surfaces in east-west and northeast-southwest directions, which give optimum results due to the shadow effect, by means of the DesignBuilder Simulation Programme, and the effect of annual heating and cooling energy load expenses was examined. This study aimed to examine the effect of solar control devices on energy saving in hot dry climate regions. As a result of the study, solar control devices placed in both east and west directions provided a significant decrease in annual energy costs. In addition, the types of solar control devices (horizontal or vertical) used had an impact on annual energy costs. As a result of the analysis, it was determined that horizontal solar control devices should be preferred in hot-dry climate regions. This study will be a guide for the studies carried out within the scope of energy efficient structure design of solar control devices.

**Keywords:** design builder energy simulation programme, solar control devices, mass housing, heatingload, cooling load.

## INTRODUCTION

The developments in the use of materials with industrialization have increased the window/wall areas in buildings [Kim, et al., 2005]. This increase in transparent surface ratios in building design has brought the window design to the agenda at the stage of questioning thermal comfort. For this reason, controlling the heat loss or gains caused by the window surfaces has been an important design input in providing thermal comfort [Jung et al., 2020; Jung et al. 2021]. In order to minimize the annual energy costs, it is possible to control the direct or indirect sunlight coming into the building from the window surfaces with suitable shading elements. The main purpose of the shading elements is to prevent the entry of solar radiation from the transparent facades of the building under summer conditions and to stop the

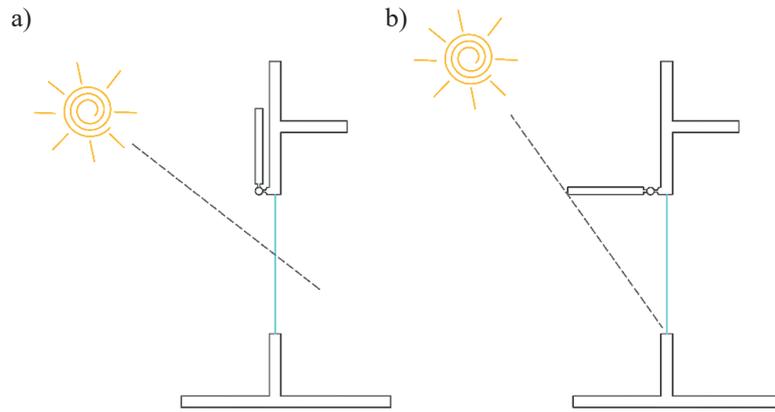
unwanted energy flow within the building [Koç et al., 2021]. In this way, overheating of the space is prevented by providing thermal comfort inside the building. Failure to use shading elements in the appropriate form and orientation according to the climatic regions causes an increase in heating and cooling loads by increasing or decreasing the solar radiation entering the inner surface of the building, indoor air temperatures [Grynning, 2013]. For this reason, the type, form and material properties of the solar control elements used differ according to the climatic regions. The size and location of the solar control elements have a significant effect on the heating-cooling loads [Valladares et al., 2017]. In addition, the orientation of the solar control elements causes variation in annual energy costs. It is stated that the south façade, which is exposed to direct sunlight for the longest time, provides energy savings of up to

33% if horizontal solar shading control devices are used [Yassine, 2013]. Diyarbakir is a city with a continental climate with a high annual average temperature. When the annual meteorological data are examined, the average temperature and sunshine duration in the summer season are longer than the whole of Turkey, and the hot period lasts longer than the cold period. In this context, cooling energy costs have a very important place for the city of Diyarbakir, which is located in a hot-dry climate zone, especially in summer, due to the use of artificial cooling elements. In this context, passive systems are used to control annual energy costs at the design scale. It is necessary to implement the design practices that will minimize the cooling load and energy costs in all processes from the building design stage to after use. Within this framework, in Diyarbakir where the annual sunshine duration is quite high, horizontal or vertical solar control elements are used on the facades in order to save cooling energy. Parameters such as orientation, positioning on the facade surfaces, types (horizontal or vertical) of these systems used differ according to the climatic regions. Within the scope of the study, the types of solar control elements and their positioning according to the facades were investigated for hot-dry climate regions. In this respect, analyses were made for the city of Diyarbakir, which is located in a hot dry climate zone, by placing different solar control elements on different transparent surface directions, using the Design Builder Energy Simulation program. As a result of the study, it has been proven that significant savings in energy losses can be achieved when the appropriate thermophysical and building envelope is selected, especially in hot-dry climate regions, while designing energy efficient buildings. Another unique value of the study is that even after the building design and construction process is completed, it is possible to prevent energy losses if climatic solutions suitable for facade and transparent surface designs are brought. This study shows that it is possible to design an energy efficient structure by interfering with the thermophysical properties of the building after the construction of the building, which is carried out without considering the building design criteria, especially in the hot dry climate region.

Solar control devices reduce heat gains caused by solar radiation and allow the use of daylight and natural ventilation [Priatman et al., 2015]. In order for solar control elements to give

an effective result in energy saving, they must have an orientation suitable for climatic conditions inside or outside the building. Solar control elements should be positioned appropriately in order to reduce the heat increase caused by solar radiation [Li, 2017]. Before deciding on the solar control element system to be applied to the building, design ideas such as climatic, topographic, building type and intended use of the place where the building design will take place should be carefully evaluated. Solar control devices are divided into two basic classes i.e. fixed and movable [Bellia et al., 2014]. Solar control elements, which differ on the energy performance of the building, are grouped into indoor and outdoor systems. External shading systems reduce annual energy costs by preventing the penetration of solar radiation into the building and provide more effective results than internal shading devices [Jung et al., 2021]. Solar control elements, which can be integrated into the exterior surfaces of the building either as movable or fixed, differ according to the sun direction, climate type, material used, and solar azimuth angle. Fixed solar control elements applied to the outer surface of the building provide energy savings by controlling the solar radiation [Kirimta et al., 2017]. Fixed solar control elements can be used horizontally, vertically or mixed, depending on the incidence angles of solar radiations. Movable solar control devices, which can be adjusted according to the sun's arrival angles, are effective in reducing annual indoor heat gains [Alhuwayil et al., 2019]. Movable shading devices have a significant effect on annual heating-cooling loads. It is an effective element that allows the building to use energy effectively by preventing sunlight in the summer season when the hot period lasts for a long time, while allowing solar radiation in the winter season [Kim et al., 2017].

The horizontal or vertical shape of the solar control elements differ according to the direction of the sun, the solar diagram, the climatic data and the hemisphere where it is located (Fig. 1). In addition, after analyzing the average temperature values correctly in line with the energy efficient design principles, it should be decided whether the solar control element is vertical or horizontal. In the northern hemisphere, horizontal solar control elements are used in order to break the continuous incoming solar radiation in the south direction, and vertical solar control devices are used in the east-west orientations. [Utpariya &



**Figure 1.** Horizontal shading devices (a) heating season, b) cooling season [Lechner, 2014]

Mishra, 2018]. Horizontal solar control elements are designed as horizontal protrusions on the surface of the windows. However, before deciding on this design, the window width, height, geometric form, Sun diagram and the rising of the Sun at noon should be considered and decided accordingly.

Due to the movement of the solar radiation's in the morning and afternoon, the height it has is lesser, the closer the Sun is to the east and west in terms of location. Therefore, the solar radiation comes at an angle in the east and west orientation. It is suitable for solar-controlled use, facing the sunlight horizontally in the east-west direction [Görgün, 2019].

## STUDY AREA

### Location and climatic features of the province of Diyarbakır

The city of Diyarbakır is located in the Southeastern Anatolia region of Turkey (Fig. 2). The city of Diyarbakır is a place with harsh summer conditions throughout Turkey in terms of climatic characteristics.

Turkey is located in the northern hemisphere mid-latitude. Since the Sun's rays vary greatly throughout the year, four different seasons are experienced together in this attitude. Especially the southern part of the mid-latitude, close to the



**Figure 2.** Location of Diyarbakır [Map Gallery, 2021]

**Table 1.** Regions of Turkey by sunshine hours [<http://gunesenerjisi.uzerine.com/index.jsp>]

Region	Sunshine duration (hour/year)
The Southeastern Anatolia Region	2.993
The Mediterranean Region	2.956
The Eastern Anatolia Region	2.644
The Central Anatolia Region	2.628
The Aegean Region	2.738
The Marmara Region	2.409
The Black Sea Region	1.917

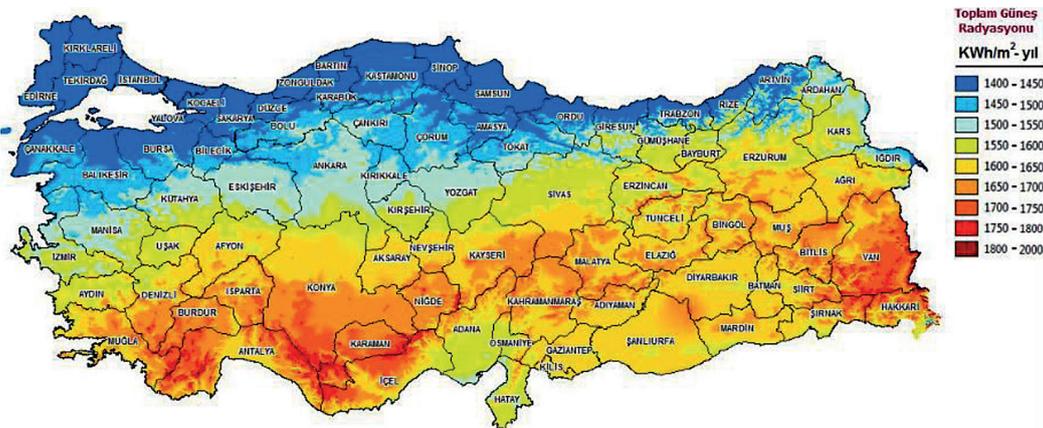
equator, is exposed to more solar radiation than the northern regions. Sunshine hours and solar energy potentials differ for Turkey, which has 7 different geographical regions. According to Turkey’s Solar Energy Potential Atlas (SEPA), it has been determined that the total annual sunshine duration is 2,737 hours (7.5 hours per day), and 1,527 kWh/m<sup>2</sup> from the annual total incoming solar energy that was shown in Figure 3.

Considering the sunshine duration on a regional scale, Southeastern Anatolia region is the region with the highest sunshine hours. In this

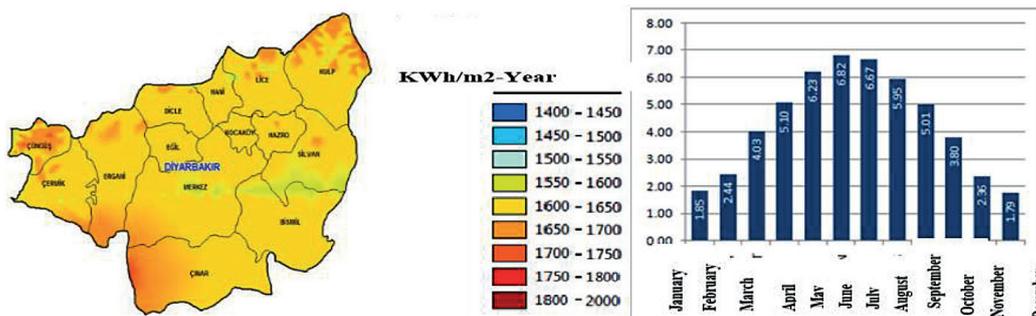
context, when all regions in Turkey are examined, the physical elements to be used to provide solar control have an important place, especially in energy efficient building design.

The Diyarbakir province, where the study area is located, is located in the Mediterranean climate region, which is considered as a dry-hot subtropical climate region according to the Köppen climate classification. Considering the annual average temperature, the summer seasons are quite harsh, and July is known as the month when the heat is felt most intensely. Total solar radiation for the city of Diyarbakir reaches up to 1550-1650 kWh/m<sup>2</sup> annually. If the global radiation values of Diyarbakir city are examined according to the months, the maximum level of global radiation was observed in June. From April to September, the global radiation level does not fall below 5 kWh/m<sup>2</sup>. In addition, the lowest global radiation value was reached in December (Figure 4).

In the province of Diyarbakir, located in the Southeastern Anatolia region, attacks against the storms coming from the south continue in the summer season. This situation has led to drought and causes an increase in air temperature in the



**Figure 3.** The map of Turkey solar energy potential [<http://www.yegm.gov.tr>, 2021]



**Figure 4.** The map of solar radiation according to the Diyarbakir province and global radiation value by month (kWh/m<sup>2</sup>) [The general minister of meteorology, 2021]

summer season. When the meteorological data are examined, the highest average temperature between 1929 and 2020 was reached in July. The lowest average temperature is in January. When the temperature averages are examined, the number of frost events and rainy days is quite low in this city, and the hot period lasts longer than the cold period shown in Figure 5. When all these meteorological data are evaluated, Diyarbakir is a city with a harsh dry climate and a long sunshine duration. In the building design process, it is necessary to transmit the unwanted solar radiation to the outside of the building in order to take the solar radiation into the building in a controlled manner and to provide indoor comfort when necessary.

### Settlement status of Şilbe mass housing buildings

The urbanization process of Diyarbakir province has occurred in the Suriçi region until 1940. The fact that the residence period did not expire in 1950 does not mean that urbanization disappears during the day. After 1990, the security problems experienced in this region led to an increase in migration from rural areas to the city center. The rate of increase in the urban population of Diyarbakir has reached 2-3 times due to the migration density [Özyılmaz et al., 2008]. In particular, migrations have increased urban infrastructure problems and led to the housing stock deficit [Güneli, 1998].

In order to increase the housing stock and prevent squatting, the Housing Development Administration started its housing production activities in 1993. The Mass Housing Administration (TOKİ) built the first mass housing settlement texture in the city of Diyarbakir in the 1st stage of Şilbe. Production and construction of 2050 houses was completed in 1997 shown in Figure 6. Şilbe mass housing units are the first mass housing settlement unit produced in Diyarbakir. In addition, it has the highest number and orientation alternatives among the mass housing settlement patterns produced in Diyarbakir from past to present. Especially for Turkey, TOKİ has an important place in the housing production sector. The energy losses and gains in the many residential complexes it produces have a significant volume in the design of energy efficient buildings in the Turkish housing sector. In this context, within the scope of the study, a 100 m<sup>2</sup> plan dwelling typology that was shown in Figure 7 was chosen in the first produced Şilbe 1st stage mass housing settlement unit, which offers different settlement alternatives in Diyarbakir. Since the 80 m<sup>2</sup> housing typologies do not offer different orientation options, they are excluded from the scope of the study.

### Software selection

Design Builder is an integrated GUI simulation software for dynamic applications [Zhang, 2014]. Compared to other software, it has a good user interface and no extra software is needed

Climate Period (1991-2020)													
Average Temperature (°C)	2.1	3.8	8.7	13.5	18.9	26.3	31	30.5	25.0	17.8	9.3	3.8	15.9
Average Highest temperature (°C)	7.3	9.6	15.0	20.5	26.8	34.4	38.9	38.7	33.4	25.7	16.3	9.2	23.0
Average Lowest Temperature (°C)	-2.0	-1.1	2.6	6.6	10.9	16.8	21.7	21.2	15.9	10.4	3.8	-0.5	8.9
Average Sunshine duration (Hours)	4.0	4.8	5.6	7.0	9.1	11.6	11.7	11.0	9.3	7.1	5.5	3.7	7.5
Average Rainy Days	11.77	11.10	10.80	12.43	11.40	3.80	0.83	0.60	2.13	7.00	8.2	11.3	9.39
Average Monthly Total Rainfall Amount (mm)	63.6	66.8	67.5	63.1	50.00	10.8	1	0.4	8.4	37.3	54.3	75.2	49.4
Measuring Period (1929-2020)													
The Highest Temperature (°C)	16.9	21.8	28.3	35.3	39.8	42.0	46.2	45.9	42.0	35.7	28.4	22.5	46.2
The Lowest Temperature (°C)	-24.2	-21.0	-14.0	-6.1	0.8	1.8	9.9	11.4	0.0	-1.8	-12.9	-23.4	-24.2

Figure 5. Diyarbakir province solar radiation map and global radiation value by month [The general minister of meteorology, 2021]

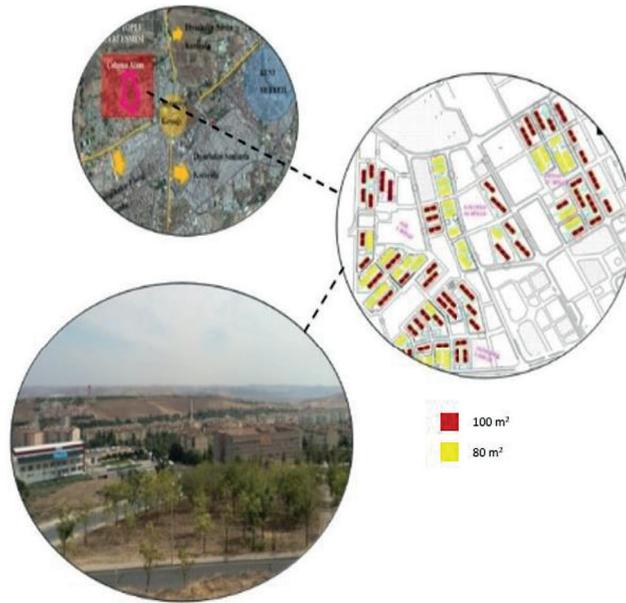


Figure 6. Location of the Şilbe mass housing settlement

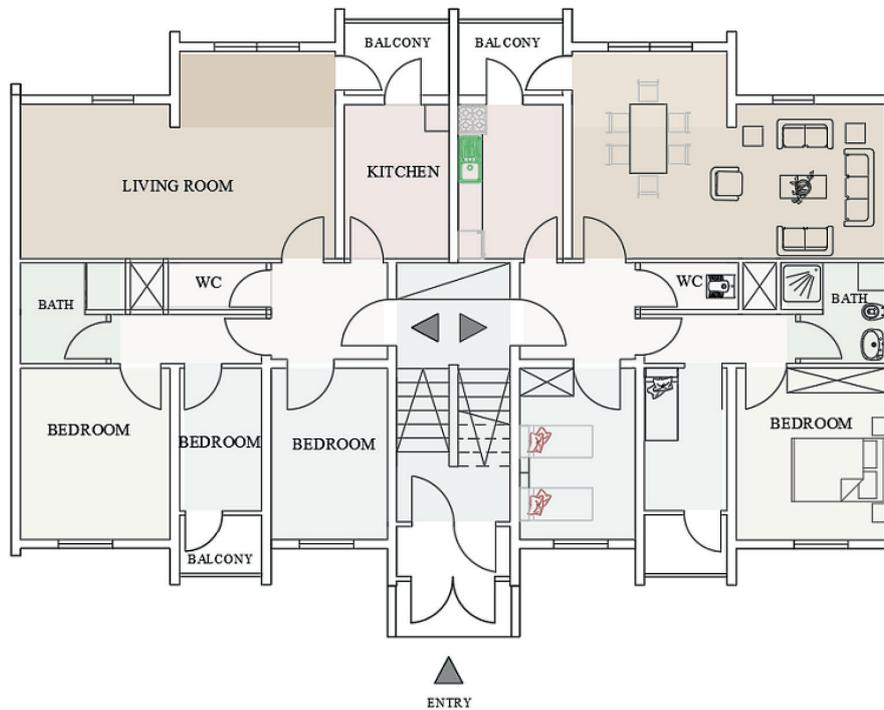


Figure 7. Plan of 100 m<sup>2</sup> houses

for modeling [Esabegloo, et al., 2016]. Design Builder has the most comprehensive user-friendly interface of the Energy Plus dynamic thermal simulation engine [Zhai, 2006; Pawar, et al., 2018]. The Design Builder simulation program allows both the creation of building geometry and the import of CAD-based DXF documents. In this way, it is possible to perform both building modeling and simulation together. The Design Builder program performs CFD, daylight, cost and carbon

simulations calculations. The DesignBuilder program used within the scope of the study was preferred because of its user-friendly interface and the fact that the data it obtained reflects the truth [Moussa, et al., 2020]. Designbuilder, which has a wide library with alternatives that offer different building envelopes and thermophysical properties, can perform simulations on transparent surfaces with solar control element alternatives and building skin changes in a short time.DesignBuilder

simulates realistically, taking into account the climatic data of each region. It references ASHRAE (American Society of Heating, Cooling and Air Conditioning Engineers) standards and Energy Plus' hourly meteorological file access to current climatic data is free of charge [Zhang, 2014]. Within the framework of all these positive features, the DesignBuilder simulation program was preferred within the scope of the study.

### The simulation process

In this part of the study, the effect of solar control elements applied on transparent surfaces on heating-cooling loads was examined through the DesignBuilder energy simulation program. Plans of 100 m<sup>2</sup> were previously prepared in Autocad and transferred to the Design Builder simulation program in DXF format. The 2D floor plan was modeled in 3D with the help of the Designbuilder simulation program. Energy losses and gains due to different orientation alternatives were calculated. As a result of the analyses, east-west and northeast-southwest directions, which had previously provided energy gain due to shadow effect in the literature, were taken as reference [Akalp, 2008]. With the help of the Design Builder program, horizontal and vertical solar control elements were placed in the selected east-west and northeast-southwest directions, and the effect on the annual heating-cooling load expenses was examined. As a result of the analyses carried out,

energy losses-gains were determined by comparing the heating-cooling load values of the block type with shadowless effect. The types of solar control elements included in the DesignBuilder program and used in shade analysis are shown in Figure 8.

The type (horizontal or vertical) of the solar control elements, the material, the angle values that can be made with the window can be changed optionally by the program user.

In the first stage, different horizontal-vertical elements and small shadows from the view were used on the east-west low façade. Then, cooling-heating energy loads were calculated by using shading elements of different lengths (0.5 meters and 1 meters) in both west and east directions. The same steps were performed for the northeast-southwest direction. In the first stage, horizontal-vertical shading elements of different lengths were placed in the northeast-southwest direction only in the northeast direction, and then in both directions, the annual total heating-cooling energy loads were compared. The study process are shown in Figure 9.

## RESULTS AND DISCUSSION

The above items on the heating loads of the horizontal and vertical transition elements. In the first stage, horizontal shading elements of 0.5 meters and 1 m widths of different sizes were used.

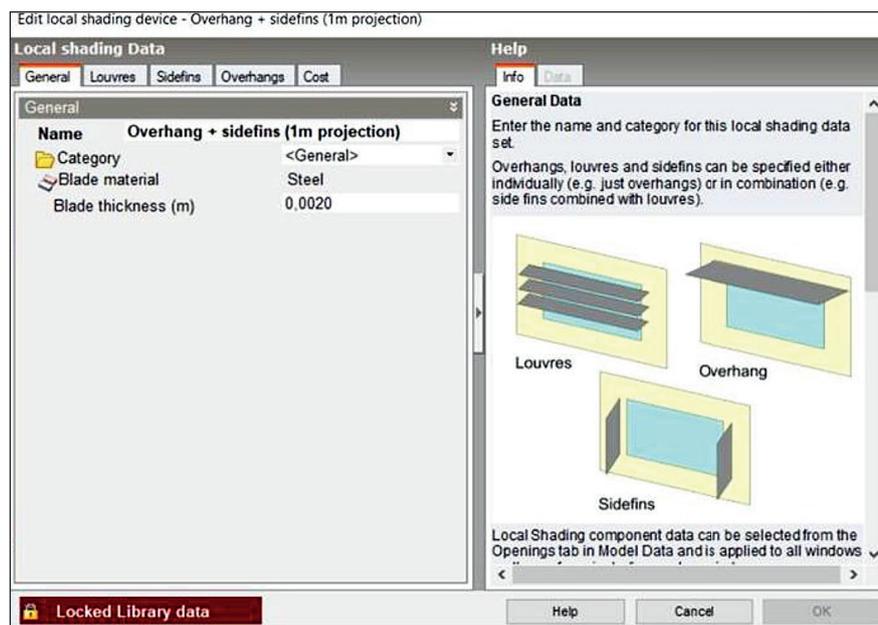


Figure 8. Shading elements in DesignBuilder program [Designbuilder V5, 2019]

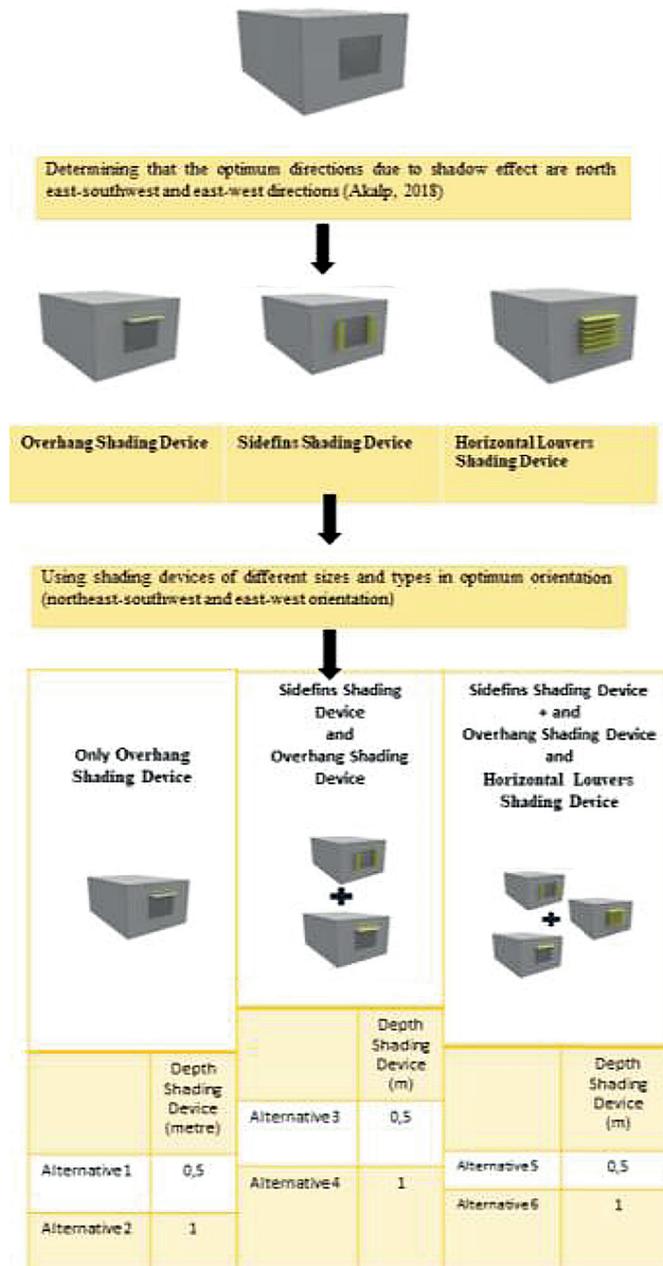


Figure 9. Study process

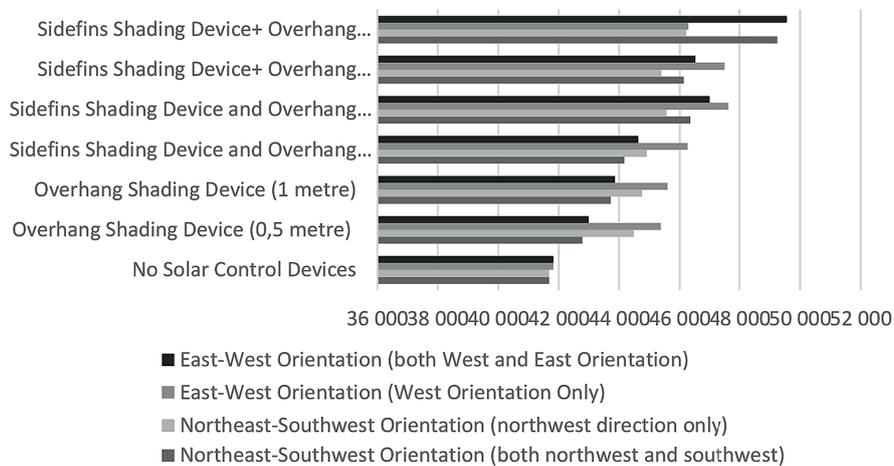


Figure 10. Variation of shading elements on heating load value

The horizontal overhang shading devices was placed on a single facade, only west and north-east, and then northeast-southwest; analyses were carried out by using them together in east-west orientations. In the next stage of the analysis, the overhang shade devices are supported by sidefins shade devices and horizontal louvres on the solar control element, and the effect of elements of different orientations and sizes on energy costs was examined.

As a result of the alternatives created by applying a shading element only to the west façade in the block type located in the east-west orientation, an increase of 8–13% in the annual total heating load values was determined. When shading elements were applied to both east and west directions of the blocks positioned in the east-west direction, the heating load of the shade element with a blinds depth of 0.5 meters decreased by about 3–11%. With the application of 1 m depth shading elements, an increase of approximately 19% was detected in the heating loads.

As a result of the application of 0.5 m and 1 m depth shading elements in the northeast-southwest direction only in the northeast orientations, it has been determined that the increase in heating loads is numerically close to each other. The use of overhang + sidefins + horizontal louvres shading devices together with the highest heating load value at 1 m depth has emerged as an

alternative. In the alternative where these 3 shading elements are used together, an increase of 10% was observed in the annual total heating load values. In the alternative where 0.5 m deep shading elements are used together in the northeast and southwest directions, an annual increase of 5–11% was achieved in heating loads. In addition, in the alternative with a depth of 1 meter, where 3 solar control elements in the same direction are used together, the heating loads increased by 18% annually. The effect of shading elements on cooling loads is shown in Figure 11.

Only on the western facade, a decrease of 5–11% was observed as a result of the application of overhang shading devices with a depth of 0.5 mt, and a decrease of approximately 10–14% in cooling loads as a result of the application of shading elements with a length of 1 mt.

As a result of the application of 0.5 mt depth overhang shading devices to both east and west directions, cooling loads decrease by 7.5–20%. The best combination to minimize the annual cooling load expenses was the alternative where 1 m depth overhang + sidefins + horizontal louvers shading devices were applied together, and as a result, a reduction of up to 30% in cooling loads was achieved.

As a result of using 0.5 mt depth overhang shading devices only in northeast direction in northeast-southwest orientation, cooling loads

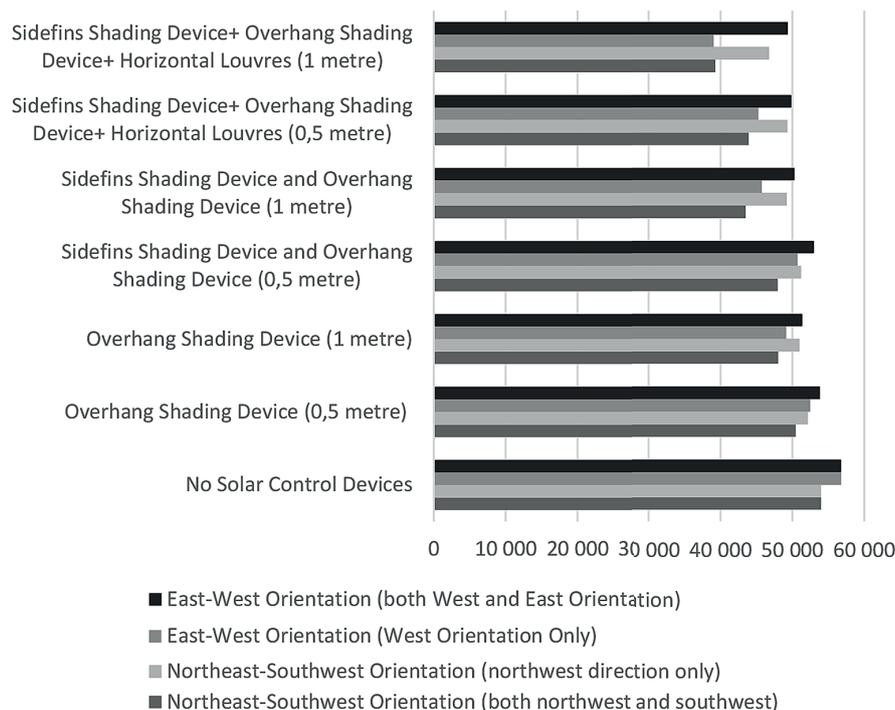


Figure 11. The variation of the shading elements on the cooling load value

decreased by 3.5–8.6%. As a result of using 0.5 m depth overhang shading element in both orientations in the northeast-southwest direction, the cooling loads were reduced by 6.5–19%. The lowest value on cooling loads was the alternative where overhang + sidefins + horizontal louvers shading devices were applied together at a depth of 1 m. This resulted in a 27% reduction in annual cooling loads. As a result of the application of solar control elements with different properties in different directions, the increase-decrease percentages in the total of the heating-cooling load values are given in Table 2.

The annual total heating-cooling load values of the shading elements at different depths applied to the transparent surfaces differed. In other words, it has been determined that the annual total heating-cooling load values of shading elements with a depth of 1 m are less than the load values of shading elements at a depth of 0.5 m. Among the applied shading elements, it has been determined as a result of the analysis that the alternative with the least heating-cooling load value is the combination of 1 m depth overhang + sidefins + horizontal louvers shading devices applied together in both east and west directions.

As a result of the using shading elements in both directions of the blocks located in the east-west direction, there was a decrease of 3.2–10.5% in the annual total heating-cooling load values. As a result of the applying shading elements in both directions of the blocks located in the

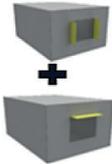
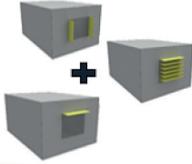
northeast-southwest direction, a decrease of 2.5–7.4% was detected in the annual total heating-cooling load values.

As a result of applying shading element only to the northwest orientation, a maximum decrease of 2.8% in annual total heating-cooling load values, and a maximum decrease of 3% in annual total heating-cooling energy load values as a result of applying a shading device only to the west direction.

### CONCLUSIONS

Within the scope of the study, the least preferred east-west and the optimal northeast-southwest directions in terms of climatic comfort for the hot-dry climatic regions determined previously were chosen to place solar control devices. Alternative solar control devices with different horizontal and vertical depths and properties were placed on the transparent surfaces in east-west and northeast-southwest directions using the DesignBuilder Energy Simulation programme, and analyses were carried out. As a result of all these analyses, it has been determined that the application of shading devices in one direction does not give an effective result on the annual-heating-cooling load values. It was understood as a result of the analysis that both directions should be applied together in order for the shading devices to give an effective result. It was determined that

**Table 2.** Annual total energy gain and loss percentage changes due to shadow effect of shading elements applied in different orientations

Energy loss and gains of shading elements on annual cooling loads, %						
Orientation	Solar control devices alternatives					
						
	Overhang shading device		Sidefins shading device + overhang shading device		Sidefins shading device + overhang shading device + horizontal louvers shading device	
Metre (m)	Depth shading device					
	0.5	1	0.5	1	0.5	1
Northeast-Southwest orientation (both northwest and southwest)	+2.5	+4.1	+3.7	+6	+5.86	+7.4
Northwest direction	-0.8	-0.09	-0.4	+0.9	1.0	+2.8
East-West orientation (both West and East orientation)	+3.2	+5.7	+3.3	+6.2	+6.9	+10.15
West orientation	-0.6	+0.8	-0.6	+0.7	+1.2	+3.0

the shading devices have a negative effect on the heating load values in all cases, and it was also obtained as a result of the analyses that they increase the annual heating costs, have a positive effect on the cooling loads and reduce the annual cooling energy costs.

The orientations in which the shading elements gave the most effective results were the alternatives in which both horizontal and vertical elements were applied together in the east-west direction. The direction that the shading elements give effective results on the heating-cooling load values was determined as the east-west direction and as an alternative where both overhang, sidefins and horizontal louvers shading devices are used together. No significant results were observed among the annual energy loads of solar control elements placed in optimal directions in hot-dry climate regions. In other words, it was obtained as a result of the analysis that the cost of sun shading can be avoided if the building is placed in the appropriate direction and direction, taking into account the energy efficient building design criteria in the building design.

When the types of shading elements (horizontal or vertical) are compared, it was determined that the 0.5 mt eave shading device does not give effective results on the annual heating-cooling load values. In the case the overhang depths are 1 mt, it was obtained as a result of the analyses that the annual heating and cooling load values decreased. As a result of the analyses, it has been understood that the shade elements designed on the facades, especially in hot dry climate regions, will give effective results when they are designed in appropriate size and in the range of 0.5-1 meters. In addition, it has been determined that the shutters, which are vertical shading elements, do not give effective results on the annual total heating-cooling load values. However, it has been determined that horizontal overhang with a depth of 0.5 and 1 mt between the shading elements cause a significant decrease in the annual total heating-cooling load values. It is the heights that are important on the load values of the transparent overloaded shading elements. As a result of all analyzes, it has been determined that the shading element used in 1 mt length has less heating-cooling load values compared to 0.5 mt.

For the province of Diyarbakir, which is located in a hot-dry climate zone, the hot period lasts longer than the cold period. Therefore, it is necessary to take the measures to minimize cooling

costs in building design. Within the scope of the study, solar control devices were placed on transparent surfaces by referring to the optimum and highest energy load orientations depending on the shadow effect previously determined in the literature. As a result of the study, it was concluded that shade devices are effective on annual energy costs, especially for hot dry climate regions. It has been reached that energy savings can be achieved if both horizontal and vertical solar control elements are used together in the east-west direction, especially in hot-dry climatic regions, where annual energy costs are high. It has been determined that solar control elements applied in optimal directions do not give an effective result in annual energy gains. It was concluded that if the building orientations are chosen in the optimal direction according to the climatic zones while performing the building design, the use of solar control elements will be less needed. Another important result that can be drawn from the study is the form of solar control elements used in the building design process in hot dry climate regions. Horizontal sunshade elements should be supported by vertical shade elements in order to provide an effective reduction in annual energy costs in hot dry climate regions. This study shows that it is possible to design an energy efficient structure by interfering with the thermophysical properties of the building after the construction of the building, which is carried out without considering the building design criteria, especially in the hot dry climate zone. Another important result of the study is that the solar control elements selected in the appropriate size and shape make a significant contribution to the energy efficient building design practice by leading to a significant reduction in annual energy costs.

## REFERENCES

1. Akalp, S. 2018. Toplu Konutlarda Farklı Yerleşim Düzenlerinin Enerji Etkinliğinin Karşılaştırılması: Diyarbakır Şilbe Örneği, Dicle Üniversitesi, FBE, Yüksek Lisans Tezi, Diyarbakır.
2. Alhuwayil, W.K., Mujeebu, M.A., Algarny, A.M.M. 2019. Impact of external shading strategy on energy performance of multi-story hotel building in hot-humid climate. *Energy*, 169, 1166–1174.
3. Bellia, L., Marino, C., Minichiello, F., Pedace, A. 2014. An overview on solar shading systems for buildings. *Energy Procedia*, 62(20140), 309–317.

4. Designbuilder V5
5. Esabegloo, A., Haghshenas, M., Borzoui, A. 2016. Comparing the results of thermal simulation of rasoulian house in Yazd by design builder software. with experimental data. *Iran University of Science & Technology*, 26(2), 121–130.
6. Görgün, A.Ö. 2019. Shading device design and optimization via genetic algorithm by using surface temperature metric and electricity load, Yaşar Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, İzmir.
7. Grynning, S., Gustavsen, A., Time, B., Jelle, B.P. 2013. Windows in the buildings of tomorrow: Energy losers or energy gainers? *Energy and buildings* 61, 185–192.
8. Güneli, Z. 1998. Bölge içi Zorunlu Göçten Kaynaklanan Toplumsal Sorunların Diyarbakır Kenti Ölçeğinde Araştırılması TMMOB yayını, Ankara.
9. Jung, D. E., Lee, C., Do, S. L. 2020. Analysis of the window glazing heat transfer of installation of an external shading device. *Korean Journal of Air Conditioning and Refrigeration Engineering*, 32, 278–287.
10. Jung, D.E., Lee, C., Lee, K.H., Shin, M., Do, S.L. 2021. Evaluation of Building Energy Performance with Optimal Control of Movable Shading Device Integrated with PV System. *Energies*, 14(7), 1799.
11. Kim, Y.S., Park, B.C., Jeong, K.Y., Choi, A.S.L.J. 2007. A comparison of daylight distribution from different height of roller shade and venetian blind. *ArchitInst Korea*, 24, 1001–1004.
12. Kim, S.H., Shin, K.J., Choi, B.E., Jo, J.H., Cho, S., Cho, Y.H. 2015. A study on the variation of heating and cooling load according to the use of horizontal shading and venetian blinds in office buildings in Korea. *Energies*, 8(2), 1487–1504.
13. Kiritat, A., Koyunbaba, B.K., Chatzikonstantinou, I., Sariyildiz, S. 2016. Review of simulation modeling for shading devices in buildings. *Renewable and Sustainable Energy Reviews*, 53, 23–49.
14. Koç, S.G., Kalfa, S.M. 2021. The effects of shading devices on office building energy performance in mediterranean climate regions. *Journal of Building Engineering*, 44, 102653.
15. Lechner, N. 2014. Heating, cooling, lighting: Sustainable design methods for architects. John Wiley & Sons, New York.
16. Li, L., Darkwa, J., ve Kokogiannakis, G. 2017. Heat transfer analysis of an integrated double skin façade and phase change material blind system. *Building and Environment*, 125, 111–121.
17. Map Gallery, 2021. <http://www.maphill.com/turkey/diyarbakir/location-maps/graymap/>
18. Moussa, R.R., Moawad, D.R.M. 2020. Investigating the efficiency of building energy simulation software on architectural design process. In: *Proceedings of the 9th International Conference on Software and Information Engineering, ICSIE*, 37–40.
19. Özyılmaz, H., Karakaş, S., Karaşin, A. 2008. Diyarbakır’da Yoğun Göçün Getirdiği Çarpık Kentleşme Sorunları. Afet Sempozyumu.
20. Pawar, B.S., Kanade, G.N. 2018. Energy optimization of building using design builder software. *International Journal of New Technology and Research (IJNTR)*, 4(1), 69.
21. Priatman, J., Soegihardjo, O., Loekita, S. 2015. Towards energy efficient facade through solar-powered shading device. *Procedia-Social And Behavioral Sciences*, 179, 266–275.
22. Turkish State Meteorological Service, accessed on 8 March 2021.
23. Utpariya, A., Mishra, S.A. 2018. Passive Cooling by Shading Devices in High Rise Buildings in Tropical Climate.
24. Valladares-Rendón, L.G., Schmid, G., Lo, S.L. 2017. Review on energy savings by solar control techniques and optimal building orientation for the strategic placement of façade shading systems. *Energy and Buildings*, 140, 458–479.
25. Yassine, F. 2013. The effect of shading devices on the energy consumption of buildings: A study on an office building in Dubai.
26. Zhai, Z. 2006. Application of computational fluid dynamics in building design: aspects and trends, *Indoor and Built Environment*, 4(15), 305–313.
27. Zhang, L. 2014. Simulation analysis of built environment based on design builder software. In *Applied Mechanics and Materials*. Trans Tech Publications Ltd, 580, 3134–3137.
28. <http://gunesenerjisi.uzerine.com/index.jsp?objid=705>, accessed on 10 January 2020)
29. <http://www.yegm.gov.tr/MyCalculator/>, accessed on 25 February 2020.