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Energy Saving Opportunities through Glazing and Shading Alternatives

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Abstract

Windows are the weakest elements due to their high heat transfer coefficient and are responsible for 60% energy heat/gain loss. Healthcare buildings are one of the biggest consumers of energy due to continuous occupation hours and medical requirements, providing comfortable conditions for people in need of care and staff; yet recently less attention was given to healthcare buildings due to their unique operational requirements and advanced medical equipment. Thus, the main purpose of this study was to evaluate energy saving potentials of windows through glazing and shading alternatives over a case study. Within this study, a single patient room in Izmir Turkey has been chosen as a case study, and the room was simulated for sixteen scenarios generated by using four different glazing and shading systems. Each design scenario was simulated using DALEC for their lighting, heating, cooling, and total energy consumption. Results showed that lighting energy consumption constitutes the highest energy demand (up to 52%) and high transmitting glazing usage can reduce lighting loads. Finally, up to 16.3%, energy saving is possible only by changing shading and glazing types. Though there is a great diversity of glazing and shading types, this study's outputs only reflect the selected four glazing and four shading system types that are offered by DALEC. Healthcare buildings spend a vast amount of energy to provide thermal and visual comfort for various user profiles. Considering the large number of patient rooms in healthcare facilities, only careful consideration of glazing or shadings can significantly contribute to energy savings. This study focuses on shading and glazing alternatives as an energy-saving strategy. For simulation, an underrecognized BES tool DALEC was hyped to show integrated thermal and visual energy consumption. The findings highlight that energy savings of up to 16.3% is possible.

Keywords: *Glazing, shading, healthcare buildings, energy consumption, DALEC*

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INTRODUCTION

In terms of energy consumption, it is predicted that buildings constitute the second largest sector and the current consumption will increase further in the future (Özbalta et al., 2012). The energy used in buildings accounts for more than one-third of the total energy consumed (Lei et al., 2021; Yu & Su, 2015). In the last decade, the environmental consequences of energy usage in buildings are recognized, and embracing a more sustainable design approach was agreed upon(Wu, 2011). Interestingly, for a long-time healthcare building were out of sight in terms of energy-saving concerns, and energy conservation practices were not widespread in these buildings. Due to that, comprehensive investigations to reduce the energy consumption of healthcare are limited in literature(Ji & Qu, 2019). Among various building types, healthcare buildings are responsible for a significant portion of energy consumption due to continuous occupation hours, medical requirements, and providing high standard requirements for indoor environmental comfort conditions. They consume approximately 10% of total energy consumption (Alshayeb et al., 2015; Englezou & Michael, 2020; Wang et al., 2016) and this is more than twice of other public buildings' energy consumption (Ji & Qu, 2019). Healthcare spaces spend a vast amount of energy to provide thermal comfort (50%), visual comfort (30%), equipment (12%), and hot water usage(8%) (Bawaneh et al., 2019; Fifield et al., 2018; García-Sanz-Calcedo, 2014).

Windows have a significant role in energy consumption in buildings since they work as a barrier between indoor and exterior environments. However, they are the weakest component of buildings due to their high heat transfer coefficient (Vanhoutteghem & Svendsen, 2014) and responsible for the majority of heat gain/loss(Dutta et al., 2017). When compared with other building components, windows have the highest heat gain/loss by 60% while flooring by 9%, walls by 8%, and roof by 8% (Dutta et al., 2017; Jelle et al., 2012).

Energy-efficient design for windows requires careful consideration of climate, orientation, window design, and its components (Eisazadeh et al., 2021). The influence of variations for window design is diverse in various climates. For instance in hot-arid climate dominated regions, such as Egypt, increasing window area may result in excessive heat gains and cooling loads (Sadek & Mahrous, 2018) while in cold climate dominated regions it may increase energy loss and heating loads (Altomonte, 2015). Modifying windows (such as ratios, glazing and, shading type) can make meaningful savings. For instance, changing the window-to-wall ratio (WWR) of an office building from 13,3% to 53,3% in India resulted in a 53,33% increase in total energy consumption (Ghosh & Neogi, 2018). While, in Hassouneh et al.'s study (2010) using solar-e glass instead of clear glass in an apartment block saved energy by up to 160% (Hassouneh et al., 2010). Similar effects can be observed also in patient rooms since they are one of the most significant spaces in healthcare facilities in terms of both energy consumption and users' well-being. For

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instance, according to Sherif & Sabry's study in a healthcare building, modification of glazing and shading elements can cause significant energy savings that can reach up to 30% (Sherif & Sabry, 2014). Thus when windows are carefully designed, energy savings can be achieved while preventing glare, excessive heat gains, and adaptation problems (Stevanovi & Stevanović, 2013; Zhang et al., 2017).

To adopt energy-efficient daylight strategies, all window components such as glazing, frame (panes, rails, sill, etc.), and shadings (interior or exterior) should be considered. Among the given window components, mainly shading and glazing materials determine thermal transmittance and solar radiation since they are the two most energy-effective components of windows (Mohammad Yusoff, 2021; Raji et al., 2015). Shading systems (either present outside or inside the building) directly affect the amount of daylight entering interiors as well as the heat gain and privacy (Gomes et al., 2014). Through various glazing and shading combinations, daylight illumination can be increased in non-light areas of the building, while total energy consumption can be reduced (Alhazzaa, 2020; Do & Chan, 2020; Huo et al., 2021; Raheem et al., 2015).

Building Energy Simulation (BES) tools are quite helpful for predicting and optimizing building energy performance during the design phase (Magni et al., 2021). However, they require both several detailed input data for building characteristics and advanced computer skills which can be very time-consuming. Although the number of BES tools is increasing, aspects such as simulation flexibility, user-friendly interface, efficient runtime while preserving detailed results and free access are still rare. For daylight simulation, several BES tools that are capable of supporting both thermal and visual performance evaluation of façade systems such as; EnergyPlus, TRNSYS, IES VE, IDA ICE v4.8, ESP-r and DALEC (Hauer M., De Michele G., Demanega I., Avesani S., 2019). Among the listed BES, DALEC is the only free online tool for the evaluation of building facades in terms of visual and thermal aspects within seconds. DALEC is provided by Zumtobel due to its rapid runtime, user-friendly interface, and free access; it can be quite helpful for people without deep expert knowledge(Ebert et al., 2018).

The number of studies that predict and evaluate the impacts of architectural design and material usage on the energy performance of buildings through BES has increased significantly over the last 20 years. Having diversity in conducted studies, in terms of climate, architectural properties, and parameters may be quite helpful for future designers. Within this study a case study building located in Izmir, Turkey was simulated using DALEC. Previous studies which were carried out in Izmir focused on natural illumination levels and total energy consumption concerning window dimensions (Gündoğdu & Cilasun Kunduraci, 2019; İnan, 2013; Yildiz et al., 2011)(Yildiz et al., 2011) in educational buildings. Also, some other studies focused on the window to wall ratio (WWR) and daylight's influence in offices(Baş & Kazanasmaz, 2020; Kazanasmaz, 2013), nevertheless, the impact of window components in healthcare buildings has not been focused on. Healthcare buildings are complex facilities that should provide a safe and healthy environment for all of their users who are vulnerable or have differing and sensitive needs. Achieving energy-efficient window design decisions made for patient rooms is not an easy task due to the high market diversity for glazing and shading options. The wide range of alternatives should be examined in terms of both thermal (transferring solar heat) and visual (providing natural light) aspects to reduce energy consumption (Eisazadeh et al., 2021; Shahbazi et al., 2019). Despite that, generally, window design is treated like a black box where their combined effects of energy efficiency are limited with assumptions, and decisions are left to building engineers and architects (Bülow-hübe, 2001).

Within this study, a sample patient room was simulated by using DALEC to evaluate energy saving potentials of various glazing and shading configurations. Results were compared in terms of lighting, heating, cooling, and total energy consumption. The main objectives of this study were to evaluate potential energy savings due to *(1) glazing alternatives, (2) various shading types, and (3) estimate the total energy (heating, lighting, and cooling) changes of each scenario.* The larger aim was to highlight how glazing and shading type decisions influence energy consumption aspects (lighting, heating, and cooling) and how the DALEC online tool can help researchers for future projects and research.

METHODOLOGY

The method describing the followed processed was explained step by step. First, DALEC software was acquainted with its significance and limitations. Later the alternative sets of glazing and shadings were introduced and finally, the patient room that was used as a baseline scenario was introduced with its characteristics.

Simulation Tool: DALEC

Architects and building engineers can use simulation tools for accurate and rapid evaluation of alternatives yet the number of software that allows simulating daylight both in terms of visual and thermal performance were limited. DALEC software, which was used in this study, can help architects through window design, with its thermal-visual integrated friendly interface and rapid simulations. The case study room was simulated using DALEC (Day and Artificial Light with Energy Calculation) which is a web-based free and user-friendly online tool that combines visual and thermal simulations at once(Miller et al., 2020). It has been developed by Bartenbach Zumtobel Lighting and the University of Innsbruck (Ebert et al., 2018). DALEC allows designers to achieve thermal and visual comfort goals together and helps to examine the impact of various factors on energy consumption.

For simulation, DALEC online tool uses already determined input factors that affect building energy consumption. The mentioned input values are; material properties, reflectivity values of surfaces, window

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wall ratio, shading systems, orientation, window type, window permeability rate, heating and cooling data, natural and artificial lighting amount, and heat permeability rate of interior and exterior walls. A screenshot of the DALEC interface can be seen in Figure 1 and detailed input values of general, visual and thermal can be summarized in Figure 2.

Figure 1. Opening interface of DALEC

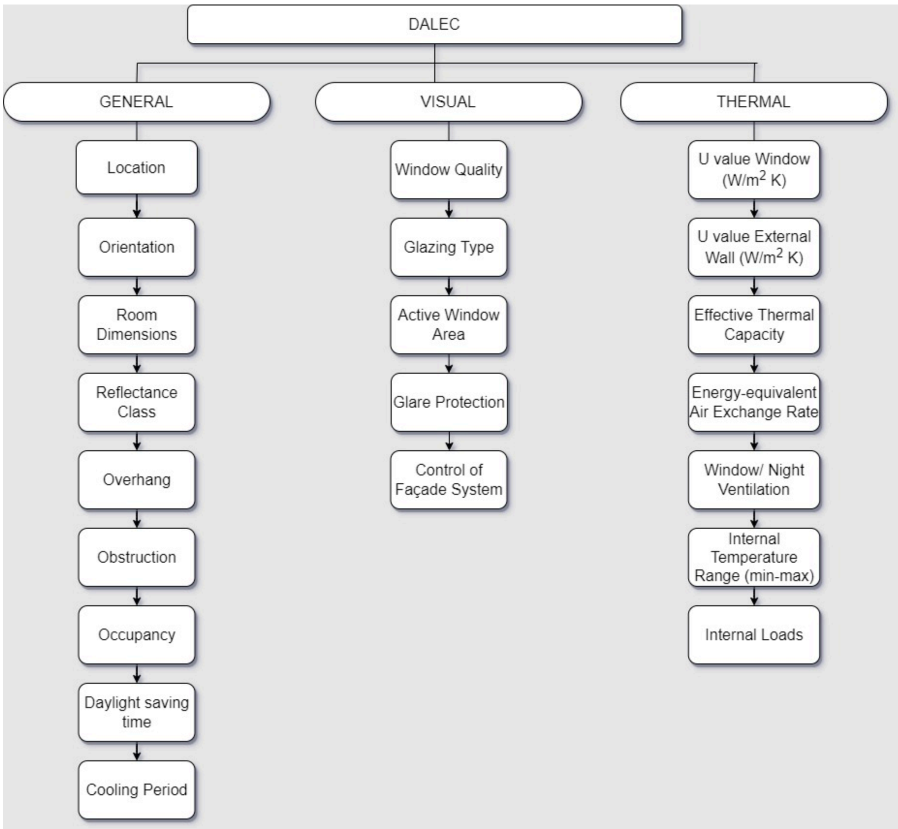

Figure 2. DALEC input parameters.

DALEC can simulate various façade systems in more than 2000 locations worldwide. Complex thermal and visual simulations of daylight

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can be simply evaluated for heating, cooling, and lighting loads either separately or combined. Besides artificial lighting loads, user behavior and various control strategies such as dimming or daylight-dependent controls are considered in simulations(Ebert et al., 2018; Hauer M., De Michele G., Demanega I., Avesani S., 2019). DALEC provides calculation of lighting metrics such as continuous daylight autonomy cDA (continuous daylight autonomy), luminance limit [cd/m²] as well as overheating frequency, and annual energy need kWh / (m^2 a).

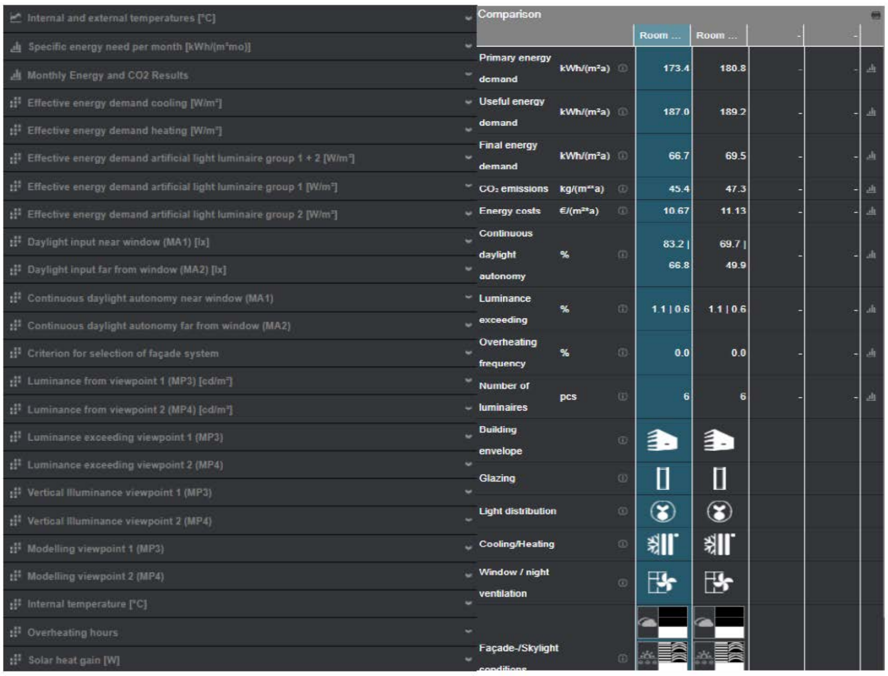

Figure 3. DALEC's results interface.

By selecting locational, constructional properties and occupation type from the given list of options, DALEC is capable of calculating artificial lighting, heating, and cooling consumptions for hourly-based scenarios in less than a second (Miller et al., 2020; Werner et al., 2017). DALEC provides comparison tables of various scenarios at the same interface (Figure 3) and also offers individual graphs of the below-listed aspects.

- Internal and external temperatures,
- specific energy need per month,
- the monthly energy and CO_2,
- effective energy demand for cooling, heating, and artificial lighting,
- daylight input near and far from the window,
- continuous daylight autonomy near and far from the window,
- the criterion for the selection of the façade system,
- luminance from the viewpoint,
- luminance exceeding viewpoint,
- vertical illuminance viewpoint,
- modeling viewpoint,

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- internal temperature,
- overheating hours and
- solar heat gain

Though the DALEC is available since 2017, it is not a commonly used or well-known software in literature. DALEC has some limitations as well; for instance, it does not give the opportunity to manually type in the building components or materials, instead, users have to choose among the given alternatives because different calculations and integration of each of these components require considerable computation and time (Werner et al., 2017). Non-linear room geometry, organic forms, and special architectural features can not be simulated in the DALEC web interface yet an integration into Building Integrated Modelling (BIM) environment such as a plug-in for Revit is also developed which could diminish these limitations (Hauer M., De Michele G., Demanega I., Avesani S., 2019).

Case Study Description

A private hospital located in İzmir, Turkey (38° 24′ 45″ N 27° 8′ 18″ E) was selected as a case study. Izmir experiences a warm Mediterranean climate which is hot-humid and categorized as Csa (Cs for dry summer and a for hot summer) in Köppen - Geiger climate categorization (Gercek & Arsan, 2015). A single patient room of dimension 3,66 m × 6,99 m × 3 m located on a ground floor level of a healthcare building (due to the preference of the authorities of the institution, the name of the hospital was not shared) had been chosen for the present study. The layout and dimensions are shown in Figure 4 while a detailed description of the building materials was provided in Table 1.

The case study patient room was selected as a south-facing room without any protrusion (canopy) or exterior shading devices to assess the most critical conditions in terms of solar control. The heat transmission coefficient (U-value) of the building's exterior walls was 1.44 [W / (m^2 K)]. Inner walls were considered adiabatic and have no external connection with the roof or floor. It is assumed that window/night ventilation is active and windows were opened by users when the outside temperature is lower than the indoor temperature. It has been considered that the windows and doors were closed most of the day and the air exchange rate is 0.3. The room interior temperature is set as 24 °C. When this value is exceeded, it is simulated that window/light ventilation is activated. The set points of the range (minimal and maximal) of inner room temperature were 20 – 26 °C. When the temperature is above or lower than the setpoints, the heating or conversely cooling is activated. It is thought that active cooling and heating systems were targeting the determined values. The reduction factor used to account for the reduction of the glass's permeability due to the dirt ratio was considered to be 0.9. The described case study was simulated for 16 scenarios consisting of 4 glazing types and 4 shading system alternatives that were given as options in DALEC (Table 4).

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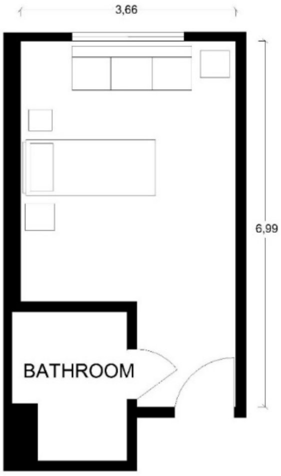

Figure 4. Plan layout of case study single patient room.

Table 1. The details of the case study

Location	38° 24′ 45″ N 27° 8′ 18″ E in İzmir, Turkey
Room Dimensions	3.66 m x 6.99 m x 3 m
Protrusion (canopy)	0 m
Horizontal obstruction	0 °
Orientation	270 ° (South)
Occupancy time	0 - 24h
Number of working days per week	7
Interior reflectance values (ceiling, wall, floor)	70 % - 50 % - 20 %
U-value outer wall	1.44 [W / (m^2 K)]
U-value inner wall	adiabatic
Effective thermal capacity	165000 J / (m^2*K).
Energy equivalent air exchange rate	0.62
Window / night ventilation	Active
Air exchange rate	0.3
Limit temperature window ventilation	24 °C
Internal temperature (min–max)	20 °C – 26 °C
Other internal loads	7 W / m^2
Cooling and Heating Systems	Active
Reduction factor	0.9
Artificial Lighting	Zumtobel 42932522 LF3 A 1600-940 MINI LDE BK
Maintenance factor	0.67
Mounting type	Surface Mounted
Flux per luminaire	1552 lm
Direct light ratio	0.95
Power per luminaire	17.5 W
Lamp dimming characteristic	LinearLed
Switching status	Dimmable

Description of Alternative Materials

To see the effect of various glazing types on energy consumption, four glazing types were selected among the given options of DALEC; heat control glass (HCG), solar control glass (SCG), heat and solar control glass (HSCG), and reflective solar glass (RSG). Double glazing has been applied

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for all glazing types. The space between the glasses was chosen as air because it affects the heat transmission values. Selected glazings' light transmittance for normal incidence (Tau-value), heat gain from sun (g-value), and heat transfer coefficient (U-value) values were given in Table 2.

Table 2. Glazing type alternatives and their properties

	Glazing Type	Tau-value	g-value	U-value
Heat Control Glass (HCG)	4 mm Low-E Glass	79 %	55 %	1.3
Heat Solar Control Glass (HSCG)	4 mm Solar Low-E Glass	72 %	44 %	1.3
Solar Control Glass (SCG)	6 mm Green Float Glass	66 %	45 %	2.7
Reflective Solar Glass (RSG)	6 mm Green Tentesol	29 %	27 %	2.7

Shading System Types

Four types of shading systems were selected from ten different shading systems offered by DALEC and those were; No shading (NS), film roller blind (FRB), external Venetian blinds 0° (EVB 0°) and external Venetian blinds 45° (EVB 45°) (*Table 3*). All 16 scenarios were simulated and results can be seen with a comparative interface in DALEC (Figure 3).

Table 3. Shading Systems and Features

Shading System	Shading feature
No shading (NS)	Glazing only
Film Roller blind (FRB)	Clear Screen
External Venetian blinds (EVB 0°)	0 °
External Venetian blinds (EVB 45°)	45 °

Table 4. Scenario and material lists

Scenario	Glazing	Shading
1	Heat Control Glass (HCG) (4 mm Low-E glass)	No Shading (NS)
2	Heat Control Glass (HCG) (4 mm Low-E glass)	Film Roller Blind (FRB)
3	Heat Control Glass (HCG) (4 mm Low-E glass)	External Venetian Blind 0° (EVB 0°)
4	Heat Control Glass (HCG) (4 mm Low-E glass)	External Venetian Blind 45° (EVB 45°)
5	Heat Solar Control Glass (HSCG) (4 mm Solar Low-E Glass)	No Shading (NS)
6	Heat Solar Control Glass (HSCG) (4 mm Solar Low-E Glass)	Film Roller Blind (FRB)
7	Heat Solar Control Glass (HSCG) (4 mm Solar Low-E Glass)	External Venetian Blind 0° (EVB 0°)

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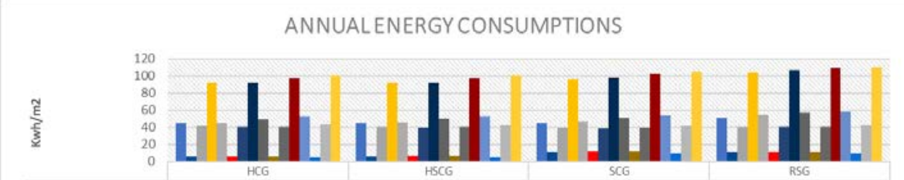
8	Heat Solar Control Glass (HSCG) (4 mm Solar Low-E Glass)	External Venetian Blind 45° (EVB 45°)
9	Solar Control Glass (SCG) (6 mm Green Float Glass)	No Shading (NS)
10	Solar Control Glass (SCG) (6 mm Green Float Glass)	Film Roller Blind (FRB)
11	Solar Control Glass (SCG) (6 mm Green Float Glass)	External Venetian Blind 0° (EVB 0°)
12	Solar Control Glass (SCG) (6 mm Green Float Glass)	External Venetian Blind 45° (EVB 45°)
13	Reflective Solar Glass (RSG) (6 mm Green Tentesol)	No Shading (NS)
14	Reflective Solar Glass (RSG) (6 mm Green Tentesol)	Film Roller Blind (FRB)
15	Reflective Solar Glass (RSG) (6 mm Green Tentesol)	External Venetian Blind 0° (EVB 0°)
16	Reflective Solar Glass (RSG) (6 mm Green Tentesol)	External Venetian Blind 45° (EVB 45°)

RESULTS

Considering the combinations between glazing and shading types, 16 scenarios were simulated for the single patient room by using DALEC software.

Table 5 illustrates a comparative graph of simulation results of a single patient room and each scenario was discussed individually in terms of lighting, heating, cooling, and total energy consumption in detail.

Table 5. Lighting, heating, cooling, and total energy consumption results of all glazing and shading types



	HCG	HSCG	SCG	RSG
NS LIGHTING	44.70	45.00	45.40	51.50
NS HEATING	5.90	6.20	11.40	11.50
NS COOLING	41.40	40.40	39.80	40.80
NS TOTAL ENERGY C.	92.00	91.60	96.60	103.80
EVB0 LIGHTING	45.00	45.70	46.60	54.20
EVB0 HEATING	6.30	6.60	11.90	11.40
EVB0 COOLING	40.90	39.90	39.20	41.00
EVB0 TOTAL ENERGY C.	92.20	92.20	97.70	106.60
EVB45 LIGHTING	49.80	50.60	51.40	57.00
EVB45 HEATING	6.30	6.40	11.70	11.40
EVB45 COOLING	40.90	40.30	39.50	41.00
EVB45 TOTAL ENERGY C.	97.00	97.30	102.60	109.40
FRB LIGHTING	52.60	53.20	53.80	58.20
FRB HEATING	5.10	5.00	9.70	9.30
FRB COOLING	43.10	42.70	41.50	42.60
FRB TOTAL ENERGY C.	100.80	100.90	105.00	110.10

Lighting Energy

In terms of lighting energy consumption, among the four glazing types, the highest energy is consumed by RSG, while HCG is the most energy-efficient glazing type. Using HCG saved up to 20.4% (with EVB 0°) energy compared to alternatives using RSG. This saving can be explained by the transmission coefficient (tau) difference. The Tau value of HCG is 79% while it is 29% for RSG (*Table 2*) therefore this difference reflects the

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amount of light transmitted to interiors. Lighting energy consumptions of HSCG and SCG were close to each other yet HSCG consumes 0.6 % to 1.6 % and SCG consumes 1.6 % to 3.6 % more energy compared to HCG.

The usage of all three shading types increased the energy consumption for lighting. This increase is most visible on FRB with 30.2 % compared to NS (with RSG), while the difference is less significant between EVB 45° and EVB 0° shadings. For instance, EVB 45° consumes only 5.2 % (with RSG) to 10.7 % (with HCG) more lighting energy compared to EVB 0°. Results show that using shading (all three types) has increased lighting energy consumption compared to the alternative without shading (NS). Though it seems like not using a shading device can be an energy-efficient solution, without shading discomfort problems might occur. Within this study daylight related comfort parameters (such as daylight glare probability and daylight glare index) were not taken into consideration.

Heating Energy

In terms of heating energy consumption, among the four glazing types, the highest energy was consumed by SCG and RSG. When RSG is used, the energy required for heating has increased by 94.9 % compared to HCG (with NS). Similarly, the heating demand of SCG is 85.7 % to 93.2 % more than HCG. The heating energy demands vary significantly among glazing types depending on their U and g values. To minimize the energy consumption for heating, both U and g values were quite important.

Using a shading system decreased heating energy demand in some cases. For all four glazing types when FRB shading is used the heating demand reduces up to 19.4 % (compared to HSCG with NS). However, using EVB 0° and EVB 45° as shading, increased heating energy consumption for each glazing type. The difference between EVB 0° and EVB 45° shading types is closer, however, EVB 0° consumes 3.1 % (with RSG) more energy compared to EVB 45°. As an alternative set, SCG with EVB 0° has the highest, while HSCG with FRB has the lowest heating energy demand.

Cooling Energy

Among each type of energy demand, the least difference was observed in cooling energy demand comparisons; both in terms of glazing and shading systems. The differences between the alternatives were significantly close to each other, yet SCG has the lowest cooling energy consumption despite its high heating demand of it. For shading devices, the usage of EVB 0° and EVB 45° shadings (with all four glazing types) have the least energy consumption compared to the others. For instance, when FRB is used as a shading system, the cooling energy demand increases up to 7 % (in HSCG). The lowest energy demand is observed when SCG is used with EVB 0° while the highest is observed with HCG is used with FRB and the possible cooling energy savings can be 9 % between these two alternatives.

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Total Energy Consumption

When results were compared, using different glazing types can save energy up to 15.6 %. Among the four glazing types, HCG and HSCG have the lowest energy consumptions and their consumption values were very similar to each other (for all four shading options). On the other hand, RSG and SCG have higher total energy consumption, particularly, RSG has the highest total energy consumption and it consumes 15.6 % more energy compared to HCG. This energy consumption increase is a total of lighting, heating, and cooling, therefore some of the glazings have better performance in terms of lighting (such as HCG), while another has a better performance for cooling (such as SCG) (Figure 5).

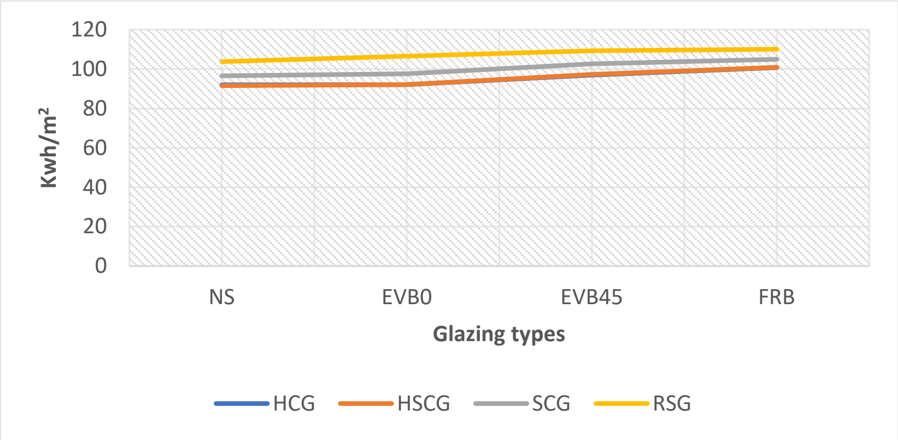

Figure 5. Annual total energy consumption according to glazing types

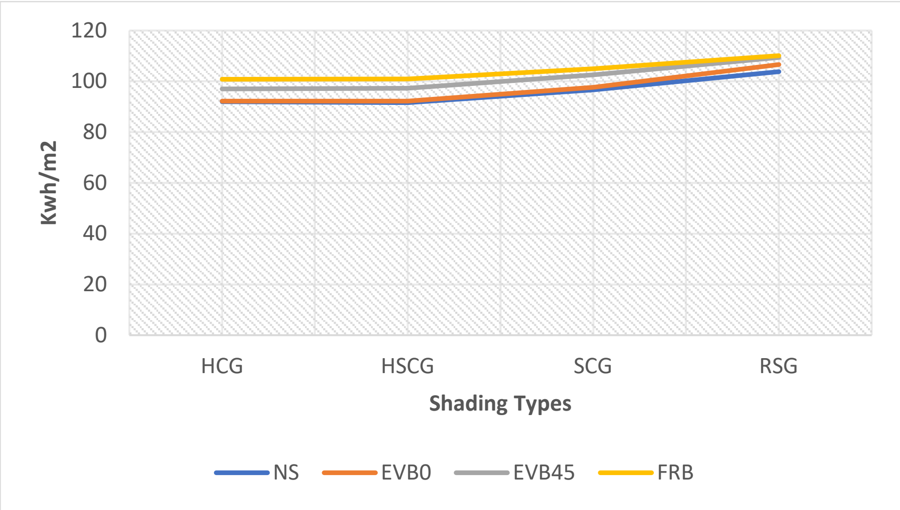

Figure 6. Annual total energy consumptions according to shading types

In terms of shading systems, it was found that compared to the alternatives without shading system (NS), using any of the three selected shading systems (FRB, EVB 0°, and EVB 45°) increased total energy consumption for each glazing type. Especially FRB shading increased it up to 10.2 % compared to NS (with HSCG). The total energy consumptions of EVB 0° and EVB 45° shading types were close to each other, however, EVB 0° consumes 2.6 % (with RSG) to 5.5 % (with HSCG) less energy compared to EVB 45°. As a result, HSCG without any shading (NS) has the lowest, while RSG with EVB 45° shadings has the highest total energy

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consumption among all 16 alternatives. When those two values were compared 16.3 % saving is possible Figure 6.

CONCLUSION

In the present study, a single patient room in Izmir with 16 different glazing and shading alternatives was simulated using DALEC. Results were compared and tested to explore how daylight and energy consumption are precisely balanced by glazing components. Although the outcome was an energy consumption comparison, the focus was based much on the change of heating, cooling and lighting consumption over glazing-shading options. Conclusions to be derived from this study can be viewed to see the energy-saving potentials through window components. The findings of the simulations are briefly listed:

- Among the three energy demands, lighting is the biggest energy consumer (48.6 % to 52.2 %) thus, to have an energy-efficient patient room, lighting demand should be minimized.
- The most energy-efficient scenario was NS with HCG and SHCG (Low-E glasses with high tau values). HCG and SHCG without any shading allow more daylight penetration which reduces artificial lighting usage, yet the possibility of glare should also be considered.
- As daylight availability increases, cooling energy demand also increases and it's the second biggest energy consumer (38.5 % to 41.2 %).
- Heating energy demand constitutes the smallest part of total energy consumption for the selected case study and scenarios (9.2 % to 12.2 %).
- Using alternative glazing and shading combinations affected total energy consumption by up to 16.3 %.

Several limitations were considered noteworthy. The first limitation concerns the selection of DALEC which also limits the glazing and shading alternatives that were used in simulations. DALEC does not allow the manual import of glazing or shading materials, so if a designer wants to check a different alternative, the interface does not enable such an option. Therefore, simulated scenarios were determined according to DALEC's material library, luckily, they are common products that can be easily found in the market. The second limitation is related to the total model scale. The simulation results fall short of representing the whole building's energy performance but only a room can be modelled with given locational and architectural features. However, the impact of different alternatives and various room types (such as circulation, polyclinic, and care areas) was eliminated. To predict a healthcare facility's total energy consumption all should be taken into consideration. Daylight is vital for humans yet it also requires optimization between various design aspects (such as facade design, internal finishes, space layout, glazing, shadings, views, glare, solar gains, etc.) in the early stages of design. Compared to other building types, healthcare buildings are more complicated and energy-saving strategies that should be applied are more layered (Ji & Qu, 2019). To design an energy-efficient healthcare building, all these variables have to be related to biological, behavioural, and comfort factors with a multidisciplinary approach and detailed evaluation. Researchers and designers can benefit from this study's findings during healthcare design and decision-making processes. This study is only a first step of a more in-depth analysis where exclusive optimization of energy performance and focus on patients' visual and thermal comforts in terms of glazing and shading preferences.

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