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ARCHITECTURAL PARAMETERS THAT AFFECT ENERGY CONSUMPTION: A SIMULATION BASED CASE STUDY OF A PATIENT ROOM

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ABSTRACT

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The fact that the majority of the human population lives in cities has increased the number of buildings with complex functions. This allowed the buildings to play an active role in energy consumption. Healthcare buildings are one of the most effective building types in energy consumption. These buildings have high-energy consumption due to many reasons such as serving different functions, long occupation hours, medical equipment requirements, providing comfort conditions for people in need of care, and providing an efficient working environment for personnel such as doctors and nurses. Most of the energy used in healthcare buildings is for lighting, heating and cooling systems. The efficiency of these systems varies according to daylight availability. Some environmental and architectural parameters affect the use of daylight in buildings. In this study, one of the most common example single patient room designs on the south façade was simulated using the DALEC software to examine the effects of glazing type, shading system and surface reflectance values of the energy consumed for lighting, heating and cooling using Izmir geographical values. Results are graphically visualized in Kwh/m^2. In the evaluation of eighty different scenarios created, it was found that the architectural parameter that has the most impact in terms of energy efficiency is the interior surface reflection values. The most effective scenario in terms of total energy consumption is the situation where there is no shading in the use of solar low-E glass type in very bright conditions.

keywords: Healthcare, total energy consumption, glazing type, shading systems, surface reflectance values, lighting, heating, cooling, DALEC

ÖZ

ENERJİ TÜKETİMİNİ ETKİLEYEN MİMARİ PARAMETRELER: SİMÜLASYON TABANLI HASTA ODASI ÖRNEĞİ

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İnsan nüfusunun büyük çoğunluğunu şehirlerde yaşaması karmaşık işlevli bina sayılarını arttırdı. Bu durum enerji tüketiminde binaların aktif bir rol oynamasını sağladı. Enerji tüketiminde en etkili olan bina türlerinden biri sağlık yapılarıdır. Bu binalar farklı işlevlere hizmet etme, uzun işgal saatleri, tıbbi ekipman gereksinimleri, bakıma ihtiyaç duyan kişiler için konfor koşullarının sağlanması, doktor hemşire gibi önem gerektiren personel için verimli bir çalışma ortamı sağlama gibi birçok nedenden ötürü yüksek enerji tüketimine sahiptirler. Sağlık yapılarında kullanılan enerjinin büyük payı aydınlatma, ısıtma ve soğutma sistemleri içindir. Bu sistemlerin verimliliğini günışığına ulaşılabilirliğe göre değişkenlik gösterir. Bazı çevresel ve mimari parametreler, binalarda gün ışığı kullanımını etkilemektedir. Bu çalışmada güney cephedeki en yaygın örnek tekli hasta odası tasarımlarından biri İzmir coğrafi değerleri kullanılarak aydınlatma, ısıtma ve soğutma için harcanan enerji miktarları Cam tipi, gölgeleme sistemi ve yüzey yansıtıcılık değerlerinin etkilerini incelemek üzere DALEC yazılımı kullanılarak simüle edilmiştir. Sonuçlar Kwh/m^2 cinsinden grafiksel olarak görselleştirilmiştir. Oluşturulan seksen farklı senaryonun değerlendirilmesinde enerji verimliliği açısından en fazla etkiye sahip mimari parametrenin iç mekan yüzey yansıtma değerleri olduğu bulundu. Toplam enerji tüketimi açısından en etkili senaryo, çok parlak koşullarda solar low-E cam tipi kullanımında gölgelenmenin olmadığı durumdur.

Anahtar Kelimeler: Sağlık yapıları, toplam enerji tüketimi, cam tipi, gölgeleme sistemleri, yüzey yansıtma çarpanları, aydınlatma, ısıtma, soğutma, DALEC

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I would like to express my enduring love to my parents, who are always supportive, loving and caring to me in every possible way in my life.

Süleyman İvgin

İzmir, 2021

TEXT OF OATH

I declare and honestly confirm that my study, titled "ARCHITECTURAL PARAMETERS THAT AFFECT ENERGY CONSUMPTION: A SIMULATION BASED CASE STUDY OF A PATIENT ROOM" and presented as a Master's Thesis, has been written without applying to any assistance inconsistent with scientific ethics and traditions. I declare, to the best of my knowledge and belief, that all content and ideas drawn directly or indirectly from external sources are indicated in the text and listed in the list of references.

Süleyman İVGİN
June 1, 2021

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SYMBOLS AND ABBREVIATIONS

ABBREVIATIONS:

WWR	Window to Wall Ratio
FRB	Film Roler Blind
EVB	External Venetian Blind
LED	Light Emitting Diode
DALEC	Day and Artificial Light with Energy Calculation
cDA	Continuous Daylight Autonomy
ASE	Annual System Efficiency
PEF	Primary Energy Factor
CO_2-F	Carbon Dioxide Emission Factor
FA1	Façade Area 1 (up to 1m from floor)
FA2	Façade Area 2 (1m to 2m)
FA3	Façade Area 3 (2m to room height)
MP3	Measurement Point 3
MP4	Measurement Point 4
MA1	Measurement Area 1 (area that near the window)
MA2	Measurement Area 2 (area that far from the window)
L1	Lighting Group 1
L2	Lighting Group 2
LDC	Light Distribution Curve
IWEC	The International Weather for Energy Calculation
LDT	Eulumdat Data File Format
ZPF	Zumtobel Product File Format
EPW	EnergyPlus Weather File Format
UV	Ultraviolet

lx	Lux
cd/m^2	Candela per square meter
Kwh/m^2	Kilowatt per square meter
CO_2	Carbon Dioxide
[1/h]	Air exchange per hour
W/(m^2K)	Watt per square meter-kelvin
W/m^2	Watt per square meter

CHAPTER 1
INTRODUCTION

Today, climate change and rapid population growth have caused high rates of urbanization and modernization. According to research, 66% of the human population will start living in cities by 2050 (Sataloff et al., 2015). Therefore, energy sources and usage has become more important. A serious increase in energy consumption has been observed in many countries recently (Graiz & Al Azhari, 2019). According to research, this situation is predicted to increase by 30% until 2035 (Ruzbahani et al., 2019). The areas where this energy is used the most in different countries of the world are buildings. In a study stating that the share of buildings in energy consumption has increased, it has been shown that 40% of the total energy use is for buildings (Berardi, 2015). According to the data of a study conducted in Malaysia, all building types use 48% of the existing energy (Hassan et al., 2014).

The perception of space in buildings is formed by the combination of elements such as structure, color, material, texture, pattern, form. Lighting is considered together with these architectural parameters in perception of space (Turgay & Altuncu, 2011). Lighting in the interior is a combination of natural and artificial lighting elements. The compatibility of this combination with each other plays an important role in affecting user comfort and annual energy consumption. The research question of this study is ‘’How do the architectural parameters such as glazing type, shading systems, and interior surface reflectance values affect lighting, heating, cooling, and total energy consumption?’’

The use of daylight for interior, which is an important part of lighting, saves energy spent for artificial lighting, and the presence of solar heat causes changes in heating and cooling loads. Some environmental and architectural parameters affect the accessibility of daylight that causes differences in these loads. Changing the proportions and presence of architectural factors influences the annual energy demand for lighting, heating and cooling. Healthcare buildings are the places where this change in architectural parameters is felt the most. For example, in the United States, healthcare buildings have twice the energy consumption of work buildings in terms of energy consumption. With this feature, hospitals are the second building that consumes the most energy (Kaiser et al., 2001). Moreover, in Brazil, the annual energy use of hospitals covers 10.6% of the country's overall energy consumption (Shen et al., 2019).

The use of appropriate natural and artificial lighting combination in healthcare buildings affects human health and psychology, patient hospitalization and recovery time, and the working performance and comfort of the staff, together with energy consumption and environmental effects. As healthcare buildings are the areas with the highest energy use per square meter, they offer great opportunities to save energy consumption (Alexis & Liakos, 2013). In areas where artificial light and daylight are insufficient in healthcare buildings, melatonin secretion slows down, leading to depression and drowsiness (Mehrotra et al., 2015). In another study, (Altimier, 2015) said that the quality of the healthcare structure interior will contribute greatly to the healing process of patients. Another similar study revealed that visually well-lit interiors affect the productivity and morale of healthcare workers (Dalke et al., 2006). For this reason, daylight accessibility in healthcare buildings affects many factors, especially energy consumption.

Daylight availability depends on various parameters; such as locational, seasonal and architectural. In this study, a selected sample single patient room type was simulated using DALEC software for eighty determined scenarios to see the effect of architectural parameters. Each scenario was examined in terms of lighting, heating and cooling loads and the results were visualized with graphs containing minimum and maximum values. The hypothesis of this study is that selected architectural parameters such as glazing type, shading system, and interior surface reflectance values affect total energy consumption in patient rooms.

1.1. Structure of Thesis

This thesis consists of six chapters with the introduction part first. It indicates the share of healthcare buildings in the energy consumption of buildings and the effect of architectural parameters that change the accessibility of daylight in the interior on energy consumption. The structure of the thesis is among the topics of this chapter.

The second chapter presents a literature review on studies examining the effects of daylight use on occupant comfort and energy consumption in healthcare facilities. It includes the investigation of environmental and architectural parameters that change daylight availability.

In the third chapter, DALEC software which was used during simulations was introduced. DALEC’s input (location, dimensions and usage, building physics, façade and artificial lighting) and output options were mentioned to provide results from the software design. In general, the DALEC software, its use and the visuals about the data obtained were explained.

The fourth part focuses on the methodology of the study. Description of the case study room is given with its target illumination levels. To improve the energy consumption values of the room, some architectural parameters are determined either as fixed or independent variables. The selected fixed variables (room geometry, location, orientation, and artificial lighting and independent variables (such as the glazing type, shading system, and surface reflectivity values) were given with their properties.

The fifth chapter includes results and evaluations of eighty different scenarios. In the chapter, lighting, heating, cooling and total energy consumption loads were analyzed and compared in terms of selected variables.

In the sixth and last chapter, the results were examined in terms of energy efficiency. The impact of selected variables on energy consumptions was indicated and conclusions were drawn in section six.

CHAPTER 2
LITERATURE REVIEW

2.1. Lighting and Architecture

People are always the target of architecture. Humans define the architectural environment with the help of sense organs. In this way, the human establishes the connection with the space (Novljan & Muros Alcojor, 2015). The perception of space emerges when the light is thought together with the architecture. The texture, color and pattern, which are the elements of architecture, create a meaningful whole with the use of light (Vidal Fontenelle, 2008).

Light is an important factor in providing vision function. Lighting is a result of the use of light, and besides aiding visual function, it affects human psychological state, sleep comfort, working performance, mood and alertness (Boyce, 2016). Successful lighting considered during the design phase increases the spatial quality perception. Lighting improves the perception of the quality of architectural equipment (Novljan & Muros Alcojor, 2015). Therefore, lighting is an element that serves to understand architectural parameters such as form, texture and color by the user and to realize the purpose of building use.

Humans provide 87% of the learning he receives from the environment with his sense of vision. For this reason, factors such as the amount, quality, and distribution of light affect lighting and vision (M. Lu et al., 2020). In addition to helping to perceive space visually, light affects human-object relationships (de Kort, 2019). The occupants due to features such as lighting amount, color, light distribution and temperature can perceive each designed space differently. Lighting has an important share in understanding and using space. In addition to providing visual performance, it is also important in adding functionality and aesthetic value. Moreover, the use of light in the space is effective in issues such as human health and psychology, employee performance and energy consumption. An indoor area that is not efficient in terms of lightness causes visual problems, behavioral disorders and glare problems in users

(Choi & Zhu, 2015). According to the research, it has been stated that improvements in the lighting equipment of the buildings will save the energy spent for artificial lighting (Wagiman et al., 2020). For this reason, one of the important factors that should be considered in detail in order to design energy-efficient buildings and to save annual energy consumption is lighting. The electrical energy used for lighting in the world constitutes 19% of the total energy. For this reason, the most effective way to save energy consumption is lighting design. In this way, a reduction in CO_2 emission caused by artificial lighting is also achieved (Han et al., 2019). Therefore, lighting is one of the most important parts of architecture not only for visual function but also for creating a perception of space and energy consumption.

2.1.1. Parameters Affecting Energy and Daylight Availability Conditions for Interiors

In energy efficient building designs, it is very important to benefit from daylight and heat most efficient way. Daylight effects were considered during the design phase plays a major role in both providing comfort conditions and energy consumption. Besides, when it comes to daylight, more is not always better due to daylight-related problems. For example, while excessive daylight availability may cause problems such as glare, overheating (especially for hot climate dominated regions) and increases the amount of energy spent for cooling. Therefore balanced daylight availability can make energy savings while obtaining user comfort. Proper daylight usage reduces energy consumption for lighting, and minimizes the damage to the environment. There are many environmental factors to consider while allowing daylight and heat to the interiors. Environmental factors such as location of the building, altitude, sky type, natural/artificial obstructions around the building, and architectural factors (such as room dimension, orientation, window to wall ratio, reflection values of interior surfaces, glazing type, shading system) affect daylight availability. Each of the mentioned factors was discussed below.

2.1.1.1. Environmental parameters

The use of daylight is an important factor in a sustainable and energy-efficient building design. The use of daylight provides the visual and thermal comfort of the occupants and saves energy consumption (Dubois & Blomsterberg, 2011). The environment in which the building is located and the characteristics of this environment affect the daylight usage conditions (Mangkuto et al., 2016). For example, factors such as the location of the building, altitude, the type of sky when it exists, horizontal and vertical obstructions change these daylight usage rates. For this reason, architects and engineers should consider environmental parameters at the design stage, to provide user comfort and to design energy-efficient buildings.

2.1.1.1.1. Location

When designing a building, it is proceeded by considering the geographical conditions of the region where it is located. Location differences cause changes in climate type, number of sunny days, and prevailing wind direction. This difference affects daylight availability and therefore annual energy consumption. There are different daylight distribution data for each location. This data consists of daylight simulations covering every day of the year. It is the expression of natural lighting for every hour of the year in the location. Different locations generate different climate types and weather data. Among the most used weather data is International Weather for Energy Calculations (IWEC). These data are formed by defining a year according to the values of the past twenty years (Bellia et al., 2015). In a study using different location data for the same location, it has been shown that there are changes in the energy consumed for artificial lighting (Iversen et al., 2013) Similarly, it was stated that climate data of different locations affect the use of indoor daylight. According to the simulation studies carried out in office buildings where the target illumination is 300 lx in the working plane in five different climatic types of Europe, it has been observed that there are differences between the results in buildings with the same architectural structural parameters and features (Bellia et al., 2015). As a result, location change causes differences in energy consumed for lighting, as it changes the results of other data required for daylight.

2.1.1.1.2. Sky Type

Sky type is one of the most effective environmental factors about region. Sky type reflects the natural lighting differences for buildings by defining daily sunlight duration, cloudiness and atmospheric movements (Darula et al., 2015). The amount of daylight entering the interior also depends on the type of sky. Sky-type values vary depending on the geographic location, the day of the year, and the time of day the measurement was taken (Seuntiens et al., 2012). In 2003 The International Commission on Illumination (CIE) determined 15 standard sky types to be used in simulations and calculations. Each sky type defines the sunlight distribution and lighting effect as a sky model (Danny H.W. Li & Lou, 2018). In a study where four different sky types were evaluated according to the satisfaction levels of the participants with the same window types, the results showed that the sky type affects the perception of daylight in the interior. Clear sky, the partly cloudy sun behind cloud, partly cloudy sun visible, overcast sky types were compared in the experiment in which people from different professions between the ages of 23 and 47 participated. 93% of the participants preferred the partly cloudy sun visible and clear sky options (Seuntiens et al., 2012). Sky type should be considered in the early stages of design to provide energy savings and user comfort.

2.1.1.1.3. Obstructions (Neighbor Buildings, Artificial/Natural Obstructions, Vegetation, etc)

While daylight availability is effective in providing visual comfort for interiors, it also reduces the annual energy demand of the building for lighting. Due to the location of the building, there can be, artificial and natural obstructions that affect the availability of daylight. These obstructions may reduce the amount of daylight entering the room and consequently may increase artificial lighting usage and energy consumption. In the research, it has been stated that one of the main factors affecting the use of daylight indoors is obstructions (Ünver et al., 2003). Neighboring buildings, one of the artificial barriers, affect the amount of daylight entering the interior positively or negatively. In this context in Hong Kong, the effect of alternative urban designs and building heights on daylight harvesting was examined. As a result of the simulation studies performed on the vertical daylight factor values, it has been found that the amount of daylight entering the building can be increased with the improvements to be made in the building heights (Ng, 2005). Similarly, the effect of buildings and urban environments on indoor daylight lighting was examined (Pereira et al., 2009). Moreover, in office buildings, the effect of environmental factors on daylight values was examined. In the results, it was stated that the environmental factor that has the most impact on accessibility to daylight will be the obstacles around the building (Munoz et al., 2014). Obstruction in the environment prevents the building from accessing daylight, causing changes in building energy consumption. In a study examining the relationship between daylight utilization and energy saving, situations designed from combinations of angles and placement of external obstruction were simulated in the Energyplus program. The data are specified in terms of the amount of energy consumed to provide visual and thermal comfort conditions according to daylight usage conditions. When the results are evaluated according to different building façades, it has shown that the more the angle of the obstructions arising from the neighboring buildings, the higher the energy used for lighting. It has been observed that there is a change in the electrical energy consumed for ventilation due to the change of the barrier angle. It has been proven that the amount of electrical energy used for lighting increases when the obstructions are placed at greater angles on the eastern façade of the building. In the combination where the angle is 50 degrees, the part of the annual electrical energy consumption for lighting reaches the maximum value with 143.8KWh (Sun et al., 2017). According to the simulations made on the working plane of an office building, the presence of external obstruction around the building reduces the daylight factor value in the interior area by 40% (Munoz et al., 2014). The presence of external obstacles affects the use of daylight as well as changes the solar heat gain. Parallel to this, it was stated that neighboring buildings act as a shading system in order to provide thermal comfort in buildings in desert climates and reduce the negative effects of daylight (Sabry, H., Sherif, A., Shawky, S. and Rakha, 2010). In regions with hot climates in summer, artificial or natural barriers prevent overheating situations (Manioğlu & Yilmaz, 2008). As the location of environmental obstruction will affect the interaction of the building with the sun, it plays an important role in energy consumption (Danny H.W. Li et al., 2017). For example, neighboring buildings create a shading system effect, as well as supporting structures to use the sun by carrying reflective properties (D. H.W. Li et al., 2006). In a simulation study investigating the effect of shading system of external obstacles in office buildings over energy consumption, it was found that changing the obstacle angle between 25° and 30° reduces the electrical energy consumption from 40 to 28 kWh/m² (Danny H.W. Li & Wong, 2007). As a result, external obstructions have a significant share in energy consumption due to the importance of buildings' access to the sun in providing thermal and visual comfort conditions.

2.1.1.2. Architectural Parameters

Annual energy consumption values change according to the daylight availability of the buildings. Efficient use of daylight in the building reduces artificial lighting loads and also saves energy spent for heating in cold climate types (Munoz et al., 2014). On the contrary, in hot climates, while the cooling loads increase due to the excessive use of daylight indoors, it may also cause problems affecting visual comfort conditions such as glare for users. For these reasons, it is important to use daylight per the building design. Various architectural parameters affect daylight availability within interiors. The room dimension, orientation, window to wall ratio (WWR), reflection values of interior surfaces, glazing type, and shading system are some of prominent architectural parameters that affect daylight availability.

2.1.1.2.1. Room Dimension

While designing the buildings, the room and building dimensions determined in line with the decision made by the architects and engineers provide the functional features of the building, as well as the use of daylight in the interior and the annual energy consumption of the building (Fang & Cho, 2019). According to research, one of the most important architectural parameters affecting building energy consumption and indoor daylight use is building shape (Caruso & Kämpf, 2015). When this shape is considered together with other architectural variables, the interior space is a helpful factor in achieving visual quality. In this context, the combination of room, corridor depth, and other simulated architectural parameters caused situations such as maximum use of daylight in the interior, glare for occupants, and energy consumption for lighting was examined (A. Zhang et al., 2017). Similarly, the effect of ceiling height and other architectural variables on indoor lighting and thermal performance was investigated (Futrell et al., 2015). Changing the amount of daylight utilization caused by the room dimensions also changes the lighting energy demand in the building. In the study of Konis et al., (2016), it was stated that indoor daylight efficiency and related energy use are affected by architectural parameters such as building shape and direction. It has been stated in many studies that this architectural factor also affects the energy values in buildings used for different functions. Additionally, Fang & Cho, (2019) in office buildings, emphasized that changing the building geometry along with other façade design options affected the values of daylight usage in the interior. Furthermore, in a study evaluating the energy consumed for lighting in classrooms and indoor daylight values in terms of daylight autonomy and daylight factor, it was shown that there are changes in daylight utilization and energy consumption values in classrooms with rectangular and square ground areas (Rubeis et al., 2018). Therefore, the room size and proportion should be considered as an architectural parameter that changes the amount of energy consumed by the building, as well as an important factor in providing interior visual comfort conditions.

2.1.1.2.2. Orientation

Deciding on the orientation of the building during the design phase helps to provide the visual comfort conditions in the interior, while contributing to the building's energy consumption in thermal terms. According to a study conducted in high-rise buildings, it was stated that orientation plays an important role in the case of a building using solar energy. Overheating caused by excessive use of solar energy increases the annual energy consumption for cooling in regions with hot climates (Park et al., 2021). Additionally investigating the effect of building orientation on energy consumption in the city of Newcastle, Australia, it was stated that proper building orientation will increase the use of daylight and heat in winter, saving energy spent for heating. In the same study, it has been shown that with the help of the building orientation, the use of active wind direction in the summer season will provide cooling and ventilation energy loads (Albatayneh et al., 2018). Avoiding problems that may occur later due to the orientation of the building will cause different results in each different climate type. Parallel to this to the results of another study conducted in regions with tropical climate type, 12% of the options identified should be located in the west, 24% in the northeast, 58% in the east, and 5% in the southeast direction to avoid the negative effects of overheating (Valladares-Rendón et al., 2017). Moreover, based on cold climate types, it was emphasized that the correct orientation is important for the building to benefit more from the sun due to heating (Carbonari et al., 2002). Indicates changes in annual energy consumption due to the appropriate building orientation, for solar utilization rate, lighting, heating, and cooling loads. In a study conducted in this context, it was stated that the orientation of the building affects the performance of the lighting and ventilation systems and therefore plays an important role in energy consumption (Abanda & Byers, 2016). Similarly to this research, it has been stated that one of the most effective passive systems to make efficient use of solar heat and light is orientation (Morrissey et al., 2011). Building orientation is one of the passive systems that provide savings in energy consumption. Since the orientation affects more than one parameter, choosing the appropriate situation provides significant energy savings. In another study conducted in China, it has been shown by using EnergyPlus that energy use can be reduced by changing the direction of the building in the city (Xu et al., 2012). Besides, when passive methods aiming to save energy consumed annually are investigated, it was stated that the shape and direction of the building will provide a 36% reduction in the energy consumed (Aksoy & Inalli, 2006). Pacheco et al., (2012), were emphasized that orientation is one of the most effective architectural parameters that play a role in the energy consumption of any building. Similarly, in a study where indoor daylight efficiency is important, it was stated that building orientation is a factor that changes this situation (Al-fahmawee, 2013). Additionally, the orientation of the building has a great effect on the natural heating of the interior in energy-efficient building design (Moakher, 2012). Furthermore, examining the effect of building orientation differences on annual energy use, a real building modeled in the Revit program is tested in different combinations in energy simulation programs. As a result of the study, it was stated that 17.056 kWh can be saved on electricity consumption with options with appropriate orientations (Abanda & Byers, 2016). Consequently, considering the orientation together with other architectural variables in the interior, it is an important method in saving energy spent for lighting, heating, and cooling.

2.1.1.2.3. Window to Wall Ratio (WWR)

The windows play an active role in the energy demand of the building, as they not only provide a visual connection between the exterior and the interior, but also affect the amount of daylight and ventilation properties in the building. The correct design of window and wall proportions is required in the design of the building envelope to ensure efficient daylight distribution in the interior, to create comfort conditions, and to calculate building energy consumption (F. Chi, Wang, Wang, et al., 2020). In the studies, the ratio of window to wall affects the annual energy consumption of the building as it changes the indoor daylight efficiency and indoor air quality (Attia et al., 2012). Determining the appropriate window to wall ratio according to the intended use of the buildings will affect the energy consumption. According to the results of a study conducted in office buildings in Italy, designing the façade with 35-45% window-wall ratio makes the annual building energy use most efficient (Goia et al., 2013). Research conducted in a school building in Eskisehir Turkey stated that the façade has a window and wall ratio of 50%, while providing a more comfortable indoor environment for the occupants, 15% of the annual energy spent on artificial lighting can be saved (Ashrafian & Moazzen, 2019). The appropriate window to wall ratios differs according to the conditions of the same building types in regions with different climatic characteristics. In a study for two common climate types, the change in energy spent for artificial lighting in buildings with different window-wall ratios was investigated.

The results showed that in cases with appropriate combinations, savings between 10% and 44% of the energy spent for artificial lighting can be achieved (Ghisi & Tinker, 2005). In this context examining the effect of window-wall ratio in office buildings on building energy use, research was carried out in hot, cold, and temperate climate types. According to the results of the study, it was stated that using appropriate window configurations in hot climate types saves between 3% and 14% in energy consumption and 1% in cold climates. It has been suggested that the required window-wall ratio on the façade should be between 50% and 80% in regions with hot climates and between 20% and 60% in regions with cold climates to achieve this gain from energy consumption (Susorova et al., 2013). In the simulations made to test the accessibility of daylight in office buildings with different climate types, it was stated that the window wall ratio between 30% and 45% is the most efficient option for lighting. In the same research, the use of the most appropriate window to wall ratio in façade design has provided a savings between 5% and 25% in annual energy consumption compared to other design options (Goia, 2016). In a study of five main Asian climate types, it was observed that the ratio of window to wall affects the annual energy consumption of the building for lighting, heating, and cooling (J. W. Lee et al., 2013). Additionally, in Turkey examining the effect of window wall ratio on building insulation properties, it was stated that designs with façades combined with different window wall ratios change the share of heating load in annual energy consumption (Özkan & Onan, 2011). Windows affect the amount of daylight indoors due to their use with other architectural equipment. In the simulation study where 162 options with different window-to-wall ratios were evaluated, it was observed that the average daylight factor of the interior increased as WWR increased. Furthermore, while the average daylight factor is 2% in the design with 0.1 window-wall ratio, this value is 15% when the WWR is 0.9 (F. Chi, Wang, Wang, et al., 2020). In another study investigating the effect of different façade designs on building energy in office buildings, it was observed that the most suitable combination was in options with a smaller window-to-wall ratio when there is no shading system (Méndez Echenagucia et al., 2015). In conclusion when the ideal window-to-wall ratio is considered together with other architectural parameters that can be used with these windows, it reduces the energy consumed.

2.1.1.2.4. Reflection Values of Interior Surfaces

Color is one of the most important architectural parameters in the interior. Interior surface colors also provide important information about the surface reflectance rate. These colors play an important role in indoor lighting by absorbing or reflecting the light coming from the sun or the lighting fixture. It is a critical architectural parameter in saving energy spent for lighting, as it affects the diffusion of light indoors (Rohini Singh & Rawal, 2011). In this context, it was emphasized that the interior surface coatings affect the spatial quality and daylight quality. It has been shown that the location, color, and distribution of the coatings affect the visual comfort of the interior (Jafarian et al., 2018). Similarly, A. Michael et al., (2017) investigated the effects of the presence of reflective and shiny surfaces on interior furniture on the amount of daylight. Apart from the furniture, the reflectivity values of the interior walls, ceiling, and floor surfaces will also cause differences in energy consumption. In another study in which the artificial lighting results of an interior are simulated, it was stated that the reflectivity properties of the interior walls find solutions to the glare problems and contribute to the distribution of the illumination (Makaremi et al., 2017). Moreover, it was stated that the reflection values of indoor surfaces are among the important factors affecting the amount and quality of lighting in terms of both artificial and natural lighting (Mangkuto et al., 2016). Additionally, in which the lighting results of a historical building were evaluated, it was stated that increasing the reflectivity values of the interior walls from 30% to 88% would cause the energy consumed for lighting to decrease from 23.5% to 19.5% (Ciampi et al., 2015). According to research, reflection values on interior surfaces are an important factor in providing visual comfort conditions and saving energy consumption. Increasing this value causes a 45% reduction in the annual energy spent on lighting (Makaremi et al., 2019). In a study, it is effective to increase the reflectivity value of the ceiling surface to distribute the daylight entering the interior evenly and to reduce the energy consumption of the lighting (Reinhart, 2002). Similarly a study conducted in offices stated that a reflection value between 50% for walls and 70% to 80% for the ceiling would be the most appropriate results for indoor natural light diffusion. In the same study, it was emphasized that the floor and work plane reflectance values should below to avoid problems such as glare for the visual comfort of the occupants (Gratia & De Herde, 2003). In Makaremi et al.'s study (2017), it was emphasized that the interior surface reflectance values are one of the important architectural factors affecting the distribution of daylight and artificial light. As a result, indoor surface reflectivity causes changes in building energy demand for heating, cooling, and lighting, as they affect daylight transport and spread, solar heat gain and loss.

2.1.1.2.5. Glazing Type

Providing natural light in the interior is mostly due to the windows. For this reason, one of the important architectural factors affecting the energy consumption values of the building is glazing. The selection and calculation of the glazing type to be used in the building design process facilitate analysis such as user comfort and energy consumption (Gosselin & Dussault, 2017). When the effects of different parameters on building energy use were tested and glazing type was determined as the second architectural parameter that caused a change in energy consumption (Raji et al., 2016). In this context, the fact that the windows have different glazing types has been evaluated in terms of annual energy consumption of the building (J. W. Lee et al., 2013). In a study conducted in the patient room of a 7-storey hospital building in Italy, where the total energy spent for heating is more than that spent for cooling, it was stated that using different glazing types in the room windows would save energy between 25% and 40% (Cesari et al., 2018). Similarly, the use of excessive and wrong glazing type windows in the building envelope causes a glaring problem that will disturb the users and increase the energy spent for heating and cooling (James & Bahaj, 2005). Using the right type of glazing increases the amount of daylight reached indoors, saves energy spent for artificial lighting, and protects the connection between indoor and outdoor (M. C. Singh & Garg, 2011). With the wrong type of glazing, glare problems occur that will cause visual comfort conditions in the interior due to exposure to direct daylight (Ramkishore Singh et al., 2015). Furthermore, the configuration of glazing types and other architectural parameters has an important share in providing interior comfort quality in office spaces (K. Kim et al., 2007). According to many studies, the harmonious working characteristics of the glazing type and shading systems used in the building should be taken into account in order to benefit from daylight more efficiently in the interior and to save building energy consumption (Nielsen et al., 2011), (Hammad & Abu-Hijleh, 2010). Baetens et al., (2010) examining different glazing technologies focused on minimizing the harmful effects of solar heat and daylight and making more use of these terms. The role of triple-glazed and double-glazed window types in building energy consumption was investigated in a study in which different window directions and sizes were taken into account (Tahmasebi et al., 2011). Another study investigated the effect of glazing combinations suitable for different climate types on the share spent for cooling in the annual energy consumption of the building (Sadrzadehrafiei et al., 2012). Moreover, in Amman, Jordan, the effect of using eight different glazing types on building energy consumption was examined (Hassouneh et al., 2010). Parallel to this, a study in which glazing types are different according to their thermal properties, the energy spent for cooling and heating was examined in three different climatic zones (Jaber & Ajib, 2011). In another study with different glazing options, combinations were compared to bringing daylight to interiors in residential buildings (Husin & Harith, 2012). According to research conducted in Canberra, Australia, the use of different types of glass on the façade is an important factor in the presence of daylight in the interior (Taylor et al., 2009). In addition, the use of different glazing types in façade designs in office buildings in two cities with different climatic characteristics in Greece differs in the amount of energy required for heating and lighting (Stegou-Sagia et al., 2007). According to the data obtained as a result of a simulation study, the use of translucent photovoltaic glass has saved 65% of the energy consumed for annual cooling compared to the use of flat glass (L. Lu & Law, 2013). Similarly, in which thermal results were taken into consideration, it was emphasized that different glazing types according to different climate types can reduce overheating by 60% (Peng et al., 2013). According to research conducted in different climatic regions of China, it has been stated that one of the two different glazing types compared in terms of energy consumption is more efficient in thermal insulation and can save 2% of the annual energy consumption of the building (Wang et al., 2017). In other studies, it has been stated that some window types reduce solar heat gain due to their thermal properties and are advantageous in terms of energy consumed during cooling periods (Hee et al., 2015). Moreover, comparing different glazing types, it was stated that vacuum glazing saves 53% of the annual energy spent for heating compared to double-pane glass (Ghosh et al., 2016). In this context, it was emphasized that the use of vacuum glazing type affects energy savings between 35% and 66% in places with different climates (Qiu & Yang, 2020). In the study of three different glass colors on the indoor daylight quality and user comfort, it was stated that the glass color has an important role in the arousal of the occupants (Arsenault et al., 2012). Besides, in an office building in Beijing, China, the effects of glazing types with different colors and permeability on human health and employee competence were examined (X. Chen et al., 2019). In summary, choosing appropriate glazing helps to obtain visual and thermal comfort, thus saving energy consumption.

2.1.1.2.6. Shading System

Shading equipment is an auxiliary system in regulating the daylight and heat needed or excessive for the building. For this reason, the use of shading systems also affects heating, cooling, and lighting loads required for the interior (Hoffmann et al., 2016). Recently, shading systems have been preferred to provide the comfort needs of indoor users, to benefit from daylight more efficiently, and to save energy (Brembilla et al., 2019). Depending on the variety of shading systems used, it provides maximum benefit from daylight and heat of the building in winter seasons, and protects the building from the negative effects of daylight in summer (Kirimtat et al., 2019). As a result of a simulation study examining the effect of shading elements on the annual energy need, the presence of these systems causes a 30% reduction in the annual energy consumption of the building (Yao, 2014). According to research, the use of shading systems in the building structure affects factors such as access to daylight and energy spent for artificial lighting (Khoroshiltseva et al., 2016). In a study based on values such as interior daylight factor and glare, it was stated that the use of vertical blinds on the façade reduces the discomfort caused by glare and improves visual comfort (Aimilios Michael & Heracleous, 2017). When using shading equipment with different geometric patterns has shown that the presence of these shading systems gives more efficient results than illuminance and daylight factor types (A. Michael et al., 2018). In addition, taking into account the results of daylight exposure and daylight autonomy measurements, the data showed that the most successful design was the design with the shading system that found solutions to glare problems (Englezou & Michael, 2020). The importance of shading equipment has been emphasized in the studies, as it affects factors such as building energy consumption and indoor daylight parameters (Sherif et al., 2012). According to E. S. Lee, (2002), with the help of shading systems, savings in building energy consumption are achieved by preventing indoor overheating and reducing electrical lighting. Moreover, it was emphasized that the use of shading systems is the most effective way to save building energy consumption (Ramkishore Singh et al., 2016). Shading equipment has been used in designs to provide physical view of the outside, to take daylight into the building, and to prevent glare problems that may occur for the user (F. Chi, Wang, Li, et al., 2020). Another study involves the evaluation of the results by simulating the amount of indoor daylight and building energy use with the presence of a shading system (L. Li et al., 2016). Similarly, it has been proven that the use of automatic shading systems maximizes the benefit of daylight indoors (Koo et al., 2010). Parallel to this, it has been shown that the shading equipment and the proposed LED artificial lighting system save the electrical energy consumed for lighting (S. H. Kim et al., 2014). Additionally, it was stated that shading systems play an active role in energy consumption in different season types, for buildings that do not prevent overheating and do not benefit from daylight sufficiently (Yu et al., 2008). Equipment such as internal roller shades, external shading, movable shading devices are the most useful ways to save energy consumption, as they affect building heat gain and daylight lighting levels (Yao, 2014). In researches conducted in different countries and cities, it has been observed that shading devices can make a difference in terms of building annual energy consumption values and indoor thermal comfort conditions (Palmero-Marrero & Oliveira, 2010). Besides, in an office building in Abu Dhabi-UAE, the effect of external shading equipment on building energy consumption for lighting was investigated. The external shading system, which can be adjusted to different angles for different time intervals, has provided energy savings between 28% and 34% (Hammad & Abu-Hijleh, 2010). Furthermore, the effect of the visual results of automatic external shading systems on user comfort was investigated. When the results were evaluated, it was stated that automatic shading equipment was more economical in terms of artificial lighting requirements compared to manual ones (J. H. Kim et al., 2009). The presence of a shading system in the buildings helps to find solutions to thermal problems and to provide visual comfort conditions in the interior.

2.2. Lighting and Healthcare Buildings

The lighting of healthcare facilities is important in terms of employee productivity, patient comfort and energy consumption. Healthcare buildings are seen as complex buildings in terms of multiple closed areas, different functions of each area, hours of use, and the services they provide (Balaras, Dascalaki, et al., 2007). Therefore, different lighting features are required for each section with different functions. Lighting levels will also differ for rooms that provide different services, such as ophthalmology, patient rooms, operating rooms, and endoscopy departments.

Successful lighting reduces errors and increases the performance of night workers (Alzoubi et al., 2010). In this way, it affects the performance of doctors and nurses working in departments with critical functions. Indoor lighting contributes to the healing process of the patient in healthcare facilities. The efficient use of natural and artificial lighting in healthcare facilities affects the physical and psychological health of patients (Alzoubi et al., 2010). In addition, successful indoor lighting contributes to the healing process of the patient in healthcare facilities, while saving energy for artificial lighting. For these reasons, lighting in healthcare buildings is an issue that architects should pay attention to in the design process.

2.2.1. Human Health and Psychology

Interior spaces have positive or negative effects on human health and psychology. While designing for healthcare buildings, factors that may adversely affect human health should be avoided. In addition to these, the healthcare building can positively affect the indoor quality of human health and increase patient psychology. When designing a healthcare room, factors such as security, privacy, and autonomy are among the things to be considered. (Schillmeier and Heinlein, 2009). The colorful rooms to be created can help patients increase their cognitive abilities and lead to a more positive life (Burzynska & Malinin, 2017). The lighting style affects the stimulation, interaction with the interior, the protection of mental and brain health, and the elimination of distraction (Daneault et al., 2014). Studies have shown that natural light is more effective in protecting human health and regulating circadian rhythms than artificial lighting (Edwards & Torcellini, 2002). In another study, it was stated that indoor lighting quality affects sleep patterns and wakefulness (Rahman et al., 2017). Therefore, healthcare structures are thought to have a positive effect on human health, as in every interior.

2.2.2. Patient Recovery and Hospitalization Time

In a well-designed hospital building, natural lighting and visual comfort can have a healing effect on patients (Harmsen, 2010). According to the research, it is known that architectural designs help the routines of dementia patients and contribute to the healing process with the help of visual memory (Regnier, 2002). In another study, it was observed that interior design has physiological effects on dementia patients and stopped the rapid progression of the disease process (Moor et al., 2010). Parallel to this, it was found that light in a well-designed room reduces fatigue and depression, benefits the recovery of hyper-bilirubinemia in babies, and plays a major role in treating wakefulness (Ulrich et al., 2004). Providing visual comfort with lighting in healthcare buildings can affect users' visual functions as well as human emotions and healing (Alimoglu & Donmez, 2005). Many studies have shown that a well-lit environment is effective in reducing seasonal affective disorder and depression (Mehrotra et al., 2015). Furthermore, it was determined that the hospitalization period of patients who were treated for depression in east-facing rooms was 3.67 less than those who stayed in west-facing rooms (Benedetti et al., 2001). In a study conducted by the Veterans Health Administration, it has been proven that the duration of the stay of patients in health institutions in locations with hot and dry climates is shorter (Federman et al., 2000). Similarly, it has been observed that recovery times increase 10% in a hospital environment where visual comfort conditions are provided (Dalke et al., 2006). As a result, to contribute to the treatment process, it is important to provide comfort in healthcare units.

2.2.3. Staff Comfort, Performance and Service Quality

Providing indoor visual and thermal comfort conditions has also an important effect on employees (Berlov et al., 2015). Many healthcare buildings are illuminated with a combination of artificial and natural lighting. These two types of light sources and visual comfort give different effects on human performance and health (Dalke et al., 2006). The most important effect of indoor lighting on users is visual functionality. Good lighting quality should be achieved to improve the performance of visual work. This situation plays an important role in eliminating the stressful working environment for doctors and nurses (Boyce et al., 2003). In a study conducted in offices, spaces with good daylight caused increased user satisfaction in the work area. In similar studies, it has been observed that the visual comfort of the environment reduces medication recommendation errors in pharmacies. For this reason, efficient use of light in health institutions has a positive effect on employee performance (Boyce et al., 2003). In addition, it has been stated that bright light can positively affect the nurse working performance in hospitals and the errors caused by this reason will be minimized (Figueiro et al., 2001). Moreover, it compared the productivity of people working in the metal industry with the value of lighting. According to the data, the improvement in the lighting quality increased the task performance by 8%. With the full provision of visual comfort, it has provided a 20% increase in employee performance (van Bommel & van den Beld, 2004). In summary, it has been observed that providing indoor comfort conditions positively affects the occupants in every building function where employee performance is required.

2.2.4. Energy Consumption of Healthcare Buildings

With the developing global economy, the energy used in buildings accounts for more than one-third of the total energy consumed (Lei et al., 2021). In recent years, due to the COVID-19 pandemic, people will spend 80% to 90% of their time inside buildings (C. fei Chen et al., 2020). For this reason, the building energy consumptions will increase even more in total energy use. Countries with a high share of building energy use in total energy consumption are listed as 47% in Switzerland, 42% in Brazil, 39% in the United Kingdom, 23% in Spain, 25% in Japan, 50% in Botswana, 28% in China and 40% in Europe (Ma et al., 2017) (Masoso & Grobler, 2010) (T. Zhang et al., 2016).

A sufficient daylight availability and obtained visual comfort conditions can save significant amount of energy (Alzoubi et al., 2010). Many parameters such as glazing type, shading system, surface reflectance values, artificial lighting and its type change energy consumption in buildings. Research show that windows used in buildings have different types of glass, affecting the lighting, heating-cooling performance, and thus changes energy consumption (Dutta & Samanta, 2018). The fact that the indoor environment is suitable for natural ventilation conditions causes a difference in the energy used for cooling. In another research, it has been proven that increasing the cooling point in buildings from 22 to 25 will result in 29% less energy consumption (Hoyt et al., 2015). Factors such as heating, cooling systems and lighting elements used to provide user comfort demand more energy consumption than other building types (Balaras, Gaglia, et al., 2007). Healthcare buildings have more working hours than other building types. For this reason, the amount of energy consumed for lighting and ventilation is more than buildings with different functions. Due to continuous use, these two loads in hospitals account for the majority of energy consumption (William et al., 2020). In addition, in an Italian hospital, it was stated that the best savings that can be made from annual energy consumption will be achieved by renewing the heating and cooling systems (Buonomano et al., 2014).

In summary, health buildings may consume more energy than other building types due to their use and requirements.

2.2.5. Daylight's Effect on Lighting Loads

One of the energy loads most affected by the presence of daylight in the interior is lighting. In a study examining the energy consumption in buildings, it was stated that the energy used for lighting is 13% of the total energy consumption of the building (Habib et al., 2016). The significant share of energy spent for lighting indicates that the most effective way to reduce building energy demand is to utilize daylight. Similarly, the energy consumed for lighting in buildings varies between 20% and 45% of the total building energy demand (Dubois & Blomsterberg, 2011). Utilizing natural lighting saves energy consumption as artificial lighting reduces the amount and time of use. In addition, there are determined amounts of illumination to realize functionality in building types designed for different purposes. (EN 12464-1). These values are the data required for the users to provide visual comfort conditions for different building types. With a well-designed balance of artificial and natural lighting, the lighting value suitable for the building function is provided. The use of daylight in the interior is also effective in the type of luminaire used in artificial lighting. The presence of lighting equipment compatible with daylight saves energy consumed for lighting. As a result, daylight cause changes in building energy consumption by affecting the energy required for lighting.

2.2.6. Daylight's Effect on Heating and Cooling Loads on Energy Consumption in Healthcare Buildings

Healthcare buildings play an important role in building energy consumption. The sections where energy is consumed differ in healthcare buildings due to their structures and multi-functionality. Most of this energy used in buildings is for lighting, heating, and cooling sections (Santamouris & Dascalaki, 2002). According to the study conducted in the hospital with a total area of 110,000 m^2 in Zhejiang, China, 66% of the annual energy consumption of the building is used for heating-cooling and lighting (Shen et al., 2019). Besides, in a hospital in Thailand, 51.36% of the building energy use is used for heating and cooling systems, while the amount of energy used for lighting is 14.12% of the total energy consumption (Thinate et al., 2017). While the efficient use of daylight in the interior changes the energy consumed for artificial lighting, it affects the heating and cooling loads. While excessive use of daylight in buildings reduces the energy consumed for artificial lighting, it causes problems such as overheating indoors. Daylight indoors not only provides natural light but also creates thermal problems such as radiation and overheating (D. A. Chi et al., 2018). This problem increases the energy consumed for cooling. In addition, the effect of daylight on user comfort also causes changes in energy consumption. For example, problems such as glare may occur for the user indoors due to the excessive presence of daylight. For this reason, any shading system to be used can change the heating and cooling energy consumption. In summary, providing daylight indoors in healthcare buildings is very important as it also affects other forms of energy use.

2.2.7. Environmental Effects

Energy consumption has increased with the use of artificial systems used for lighting, heating and cooling in buildings. This means more CO_2 emission and harm for the environment. The spread of harmful gases and pollution that occur in parallel with the increase in energy consumption causes problems in humans and the natural environment (Doğan, 2013). In a study conducted in Norway, the effect of using different heating systems in municipal buildings on CO_2 emission was investigated. In the study, the use of regional climatic conditions for heating and domestic tap water reduced the annual CO_2 emission rates (Thyholt & Hestnes, 2008). In order to reduce the harmful effects of buildings on the environment, architectural factors such as orientation, window-wall ratio and placement, passive systems, sustainable materials should be considered (Yöntem Temizer, 2016). Any factor that causes a change in energy consumption also affects the environment and human issues (Aydin, 2016). Buildings constitute an important source of pollution for the environment due to the energy they consume. 21.5% of nitrogen oxide emissions and 48.5% of sulfur dioxide emissions in the atmosphere are caused by the energy consumption of buildings. The annual energy use of the building is also effective at 35% of carbon dioxide emissions (Vine, 2003). The use of different energy sources in heating loads causes changes in energy efficiency. Except for the CO_2 emission arising from the use of electrical energy, 17% of the total emission results from the building energy consumption (Mirasgedis et al., 2004). In research, it has been stated that the use of natural gas compared to coal in building heating energy consumption causes 60% CO_2 emission per unit energy (Balaras et al., 2005). The fact that the energy used by buildings has an important place in the total world energy consumption affects the environment. Additionally, it has been emphasized that the total energy consumption of buildings is one of the factors affecting CO_2 absorption the most (Allacker et al., 2019). Moreover, the energy used in buildings constitutes 33% of the total greenhouse gas production (Spandagos & Ng, 2017). Due to energy-efficient building designs, the use of artificial energy sources and greenhouse gas emissions are reduced (Yöntem Temizer, 2016). Considering that healthcare structures play a major role in building energy demand, this consumption has a positive or negative impact on the environment. For this reason, when the energy demand of healthcare buildings is made energy-efficient and the use of artificial systems decreases, the negative impact of high energy consumption on the environment is also reduced.

CHAPTER 3
DALEC SOFTWARE

With the increase in the existence of energy efficient buildings, compliance with regulations and developing technology, pre-construction calculations in architecture have become mandatory. The most important of these calculations is the lighting design.

The permeable parts of the building façades determine how much daylight is taken into the interior, thus determining the solar energy gain of the building. Using less daylight increases the need for artificial lighting. This will increase the building's internal heat gain. This increase could mean that more energy will be required for building cooling. In addition, due to the comfort of the users, their behavior plays an important role in energy consumption. For example, a shading element used by the building occupant on the façade due to glare may cause other problems. For this reason, façade design is important in terms of energy consumption during the building construction phase. Because of the relationship between thermal and visual comfort effects, the annual energy consumption simulation should be calculated considering both components.

Simulation programs are one of the methods used to make the studies on lighting design before building construction and to evaluate the results. Lighting, which has an important effect on human life, provides important advantages to users before construction by simulating with the help of programs, together with technological innovations. Lighting simulation programs are tools that are prepared with various features, have more than one variable, and care about different calculation methods and conditions. In this way, it was possible to calculate many parameters such as annual energy consumption, heating, cooling, and light distribution of the building.

The different calculations and integration of each of these components require considerable computation and time. Therefore, a simulation program that calculates these interactions and gives fast results should be used in energy-efficient building design (Werner et al., 2017).

DALEC (Day and Artificial Light with Energy Calculation) is an software that combines lighting and thermal simulations at once. It has been developed by Bartenbach Zumtobel Lighting and the University of Innsbruck (Ebert et al., 2018). DALEC allows architects to achieve thermal and visual comfort goals in façade design and helps to examine the impact of results on energy consumption. It calculates electric lighting and heating, cooling in a very short time, taking into account the climate data of the geography of the project (Werner et al., 2017). DALEC provides the results of continuous daylight autonomy cDA, luminance limit [cd/m^2], overheating frequency, annual energy need kWh/(m²a) by entering values such as location, dimensions and usage, building physics, façade, artificial light in the interiors you create in this lighting simulation program (see Figure 3. 1).

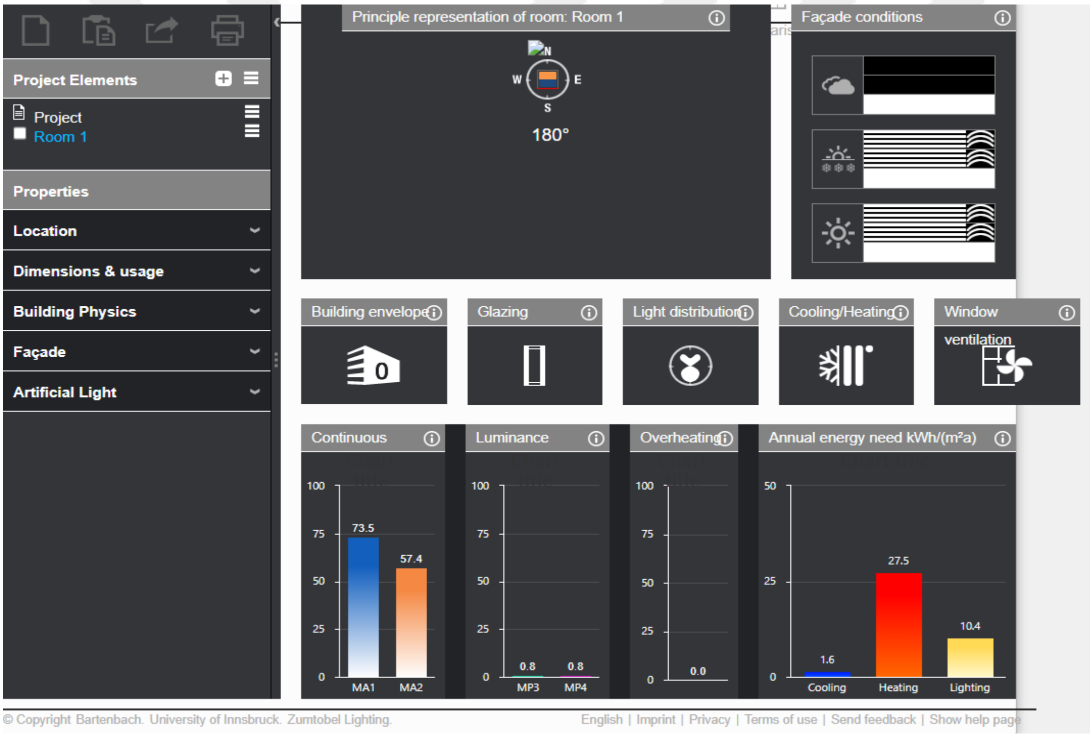

Figure 3. 1. The DALEC Web Interface – www.dalec.net

3.1. Input Parameters

For simulation, DALEC software uses already determined input factors that affect building energy consumption. The mentioned input values are; material properties, reflectivity values of surfaces, window wall ratio, shading systems, orientation, window type, window permeability rate, heating and cooling data, natural and artificial lighting amount, heat permeability rate of interior and exterior walls. (see Figure 3. 2).

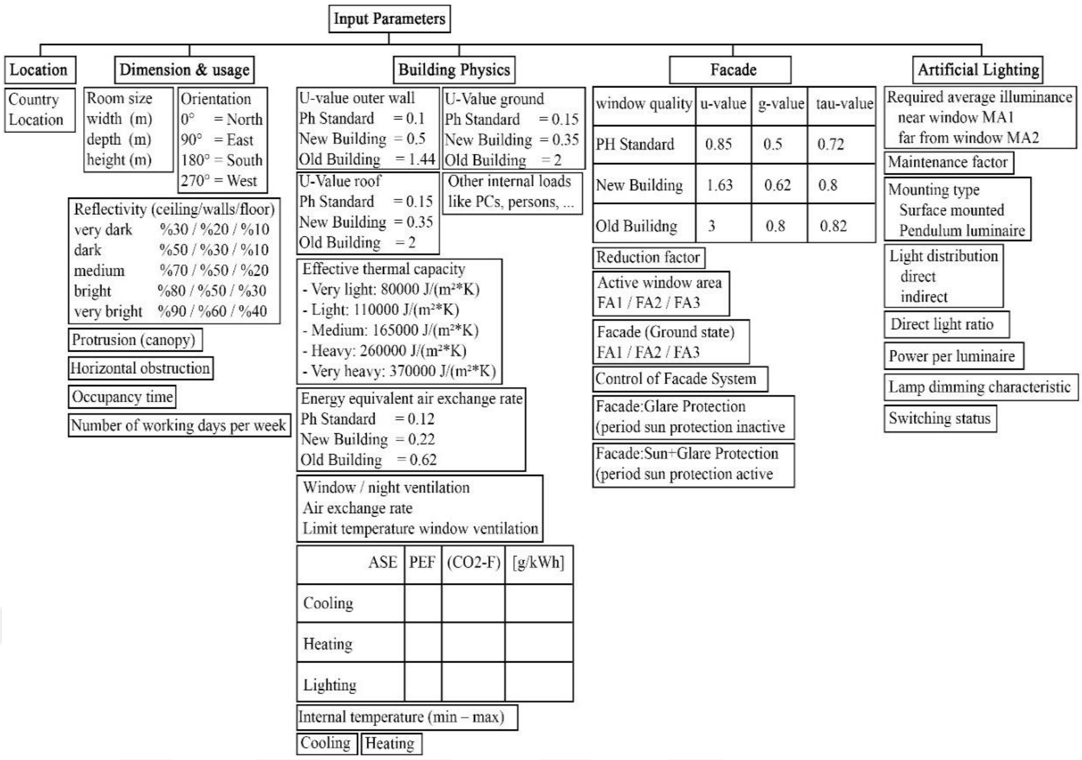

Figure 3. 2. The DALEC Input Parameters

3.1.1. Project Elements

Once the software opens, the default project is loaded. In this section, you can define, rename, duplicate, remove the name of the interior space that you will simulate, or specify the space that you will choose as the base. In this way, it is not necessary to make all the settings again for a change to be made. The software also allows you to compare different features of several different buildings or the same building (see Figure 3. 3).

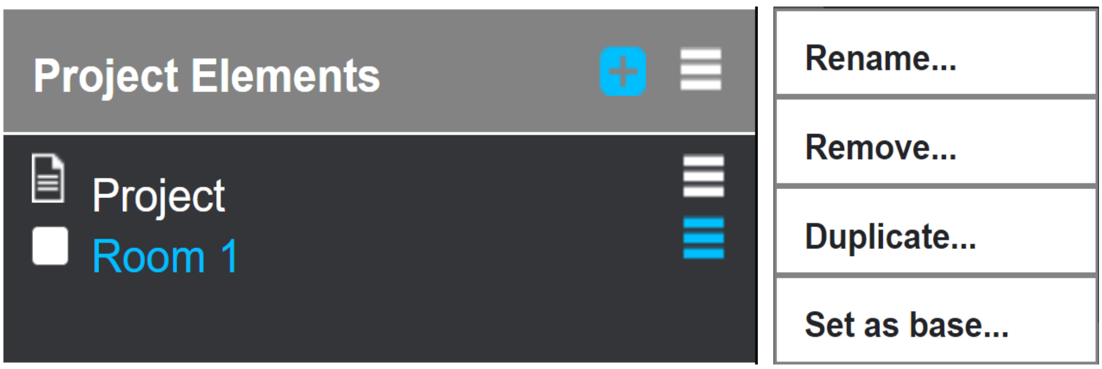

Figure 3. 3. The DALEC Project Elements – www.dalec.net

3.1.2. Properties

In this section, it makes the interior customizable by entering values such as location, dimensions and usage, building physics, façade, artificial light (see Figure 3. 4).

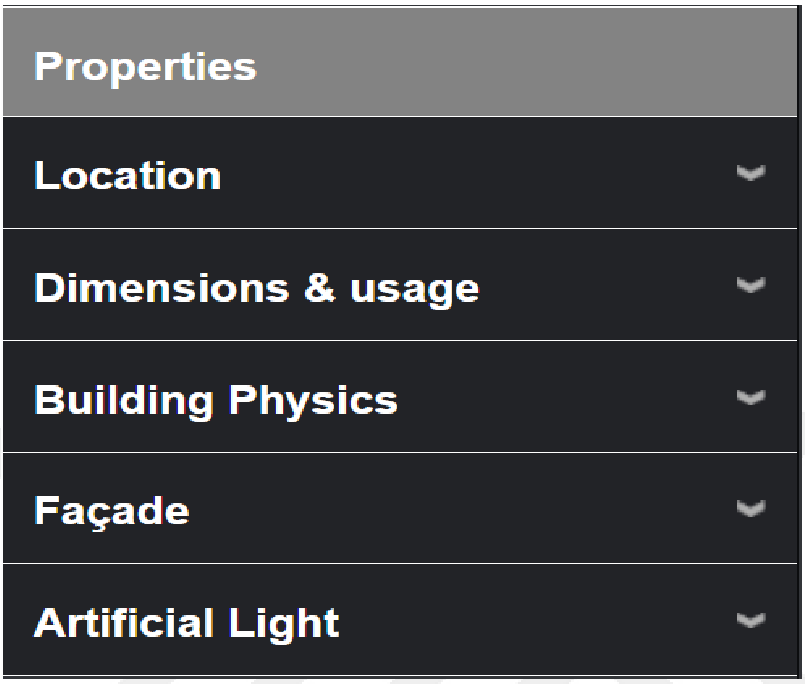

Figure 3. 4. The DALEC Properties – www.dalec.net

3.1.2.1. Location

It is the part that enables the location of the project to be entered. Indicates the country in which the project will be performed and uses the weather data of that region. Possible options depend on the weather data available. DALEC uses IWEC2 weather data in EPW format (see Figure 3. 5).

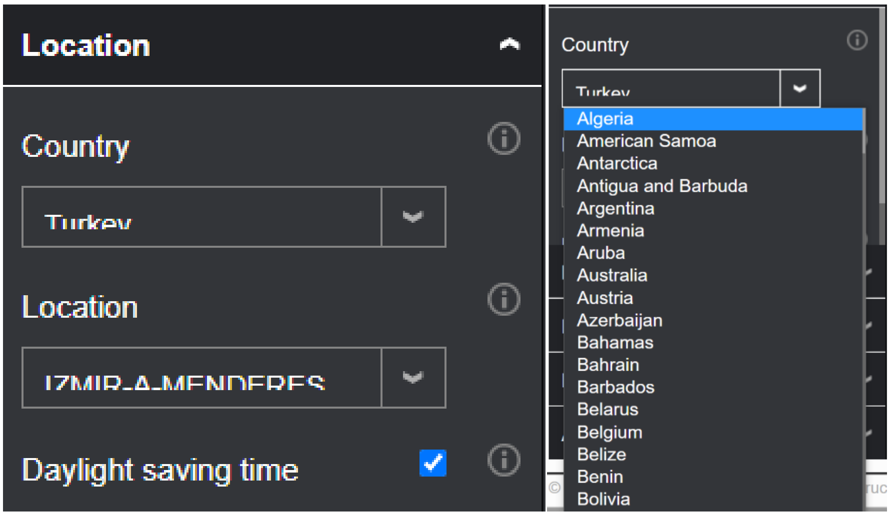

Figure 3. 5. The DALEC Location – www.dalec.net

3.1.2.2. Dimensions and Usage

The room dimensions of the simulated interior space are determined under "Dimensions and Usage" part. The values for room width, depth and height are shown in meters. In the software, the reflectance values of interior surfaces can be selected from already defined five sets of ceiling/wall/floor reflectance values which are also named as very dark, dark, medium, bright, and very bright are determined (see Figure 3. 6).

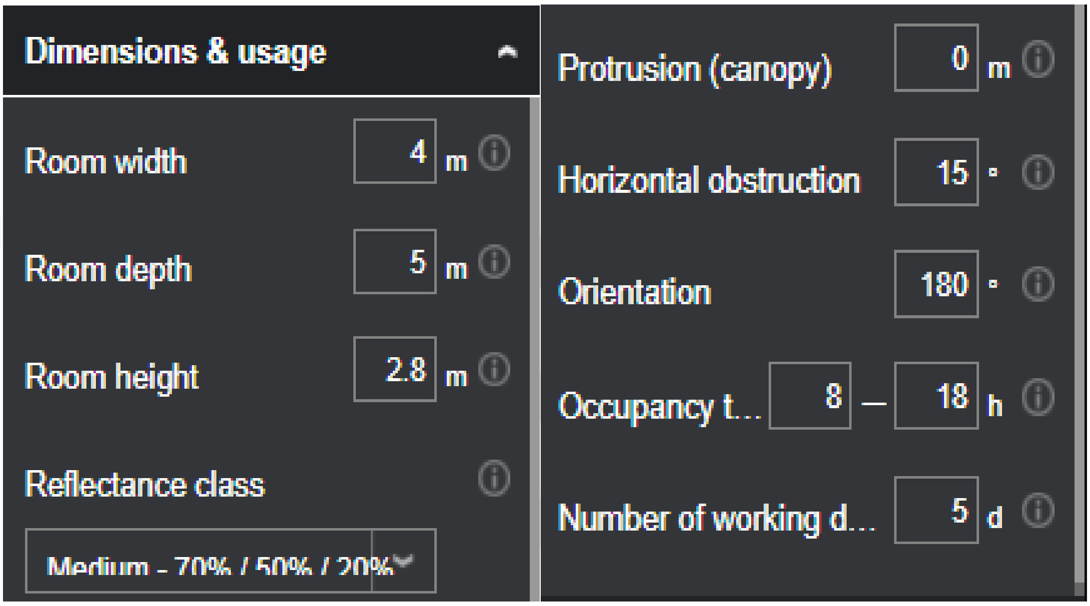

Figure 3. 6. The DALEC Dimension & Usage – www.dalec.net

For very dark condition, ceiling, wall, floor reflectance values are 30%, 20%; 10%. For dark condition, values are 50%, 30%; 10%. For medium condition, ceiling, wall, floor reflectance values are 70%, 50%; 20%. For bright condition, ceiling, wall, floor reflectance values are 80%, 50%; 30%. For very bright condition, ceiling, wall, floor reflectance values are 90%, 60%; 40% (see Figure 3. 7).

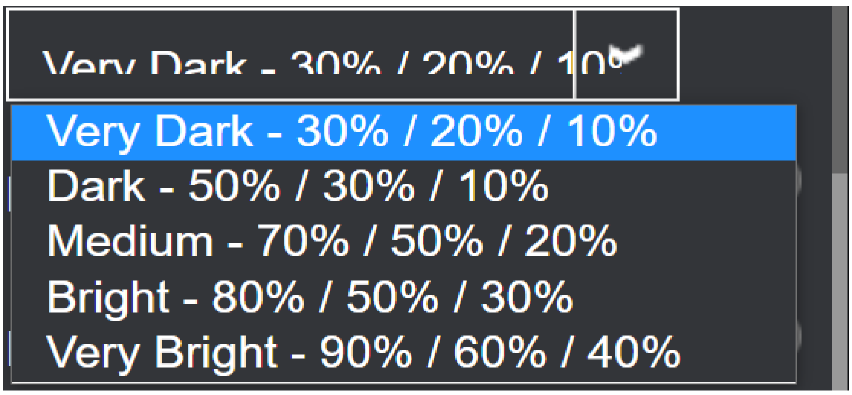

Figure 3. 7. The DALEC Surface Reflectance Values – www.dalec.net

Protrusion (canopy) describes any shade element that has the same height as the ceiling. The value in meters entered represents the depth of the canopy. Its width is considered to be infinite. Horizontal obstruction refers to a barrier related to daylight in the direction of the façade of the project by angle in degrees (see Figure 3. 8). For instance, it represents a building that causes shading against the façade. Its width is accepted as infinite in calculation. The orientation tab represents the orientation of the façade of the room in degrees such as 0°=North; 90°= East; 180° =South 270° =West. Occupancy time defines the time intervals of the day that the room is occupied. During use, artificial light is simulated according to the user's behavior. Changes in the amount of heat and light that occur depending on the use are included in the calculation (PCs, etc). The number of working days indicates how many days a week the building is used. January 1 is calculated as the first working day. Public holidays, when the building is closed for use, are not taken into account.

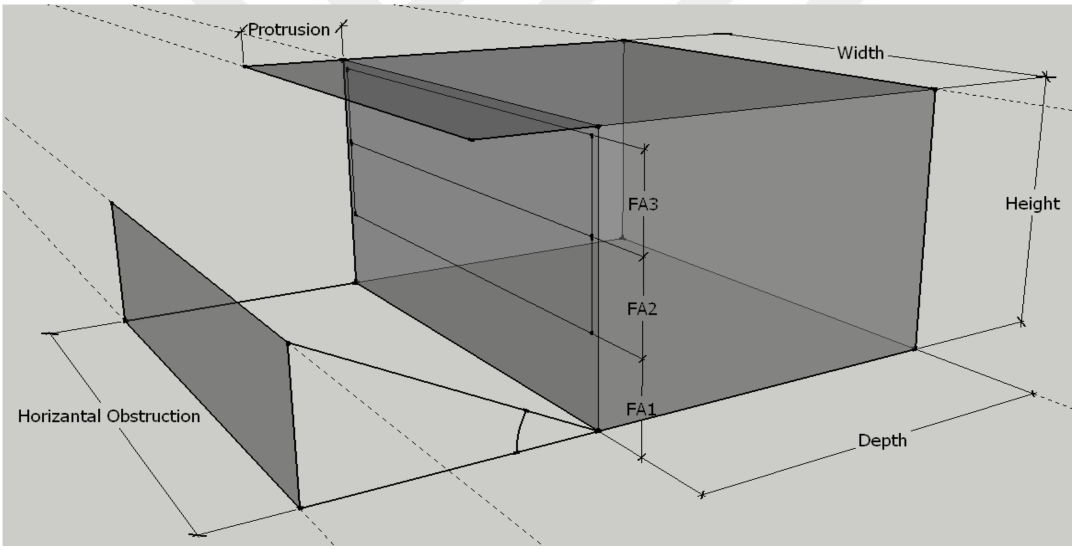

Figure 3. 8. The DALEC Building Geometry

3.1.2.3. Building Physics

This is the section where the inputs about building physics are located. The U-value outer wall defines the total heat transfer coefficient (U-value) of the outer wall in [W/(m²K)]. In the simulation, it is assumed that there is no heat and mass loss or gain of the inner walls. Except for the tab where the entries are specified by the user, three options have been selected by DALEC. The values are 0.1 for standard, 0.5 for new building, 1.44 for old buildings. Room verges on the roof defines if the room verges on a roof with an outer connection. The loss in transmission due to this field is included in the calculation. U-Values roof are 0.15 for standard, 0.35 for the new building, and 2 for the old building. Effective roof area shows the percentage of the total area that connects to the outside air (see Figure 3. 9).

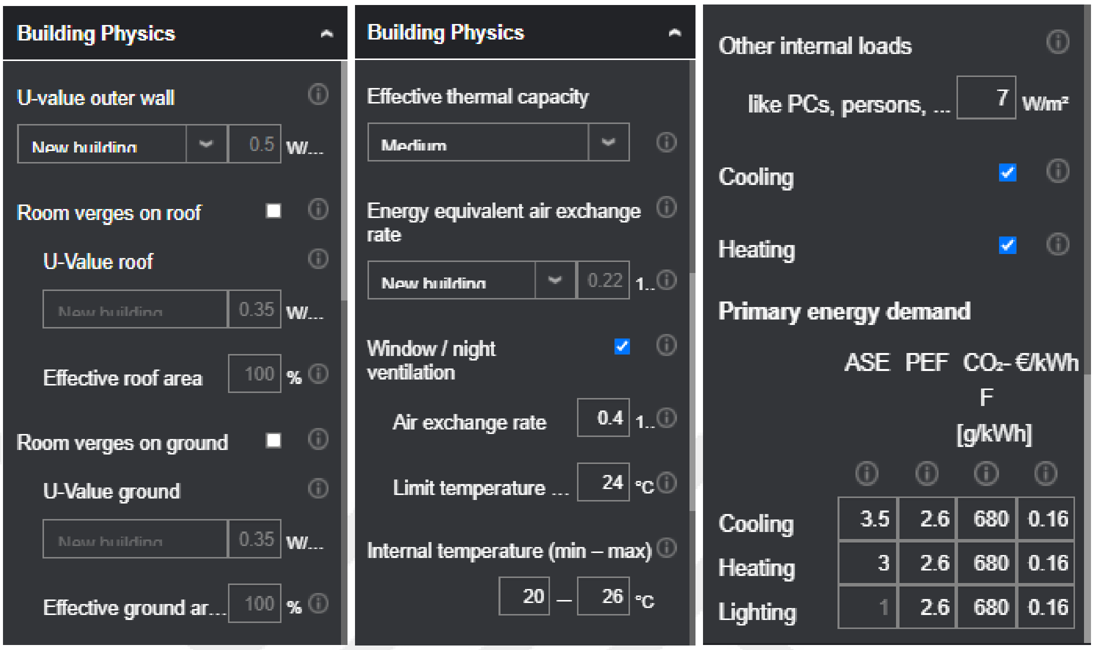

Figure 3. 9. The DALEC Building Physics – www.dalec.net

Room verges on the ground defines if the room verges on the ground with an outer connection. The loss in transmission due to this field is included in the calculation. U-Value ground is 0.15 for standard, 0.35 for the new building, and 2 for the old building (see Figure 3. 10). The effective ground area shows the percentage of the total area that connects to the outside air.

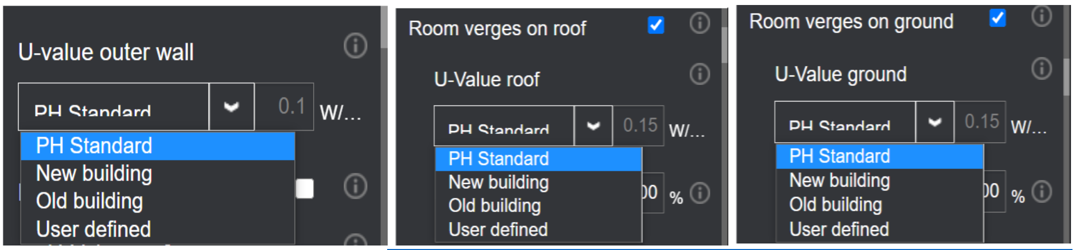

Figure 3. 10. The DALEC U-value Outer Wall, Roof, Ground – www.dalec.net

There are 5 different selections for effective thermal capacity option. Very light: 80000 J/(m²*K), Light: 110000 J/(m²*K), Medium: 165000 J/(m²*K), Heavy: 260000 J/(m²*K), Very heavy: 370000 J/(m²*K). The energy equivalent air exchange rate [1/h] indicates the energy-based air exchange rate due to the building envelope gaps and ventilation. Values are 0.12 for standard, 0.23 for new building and 0.62 for old buildings (see Figure 3. 11).

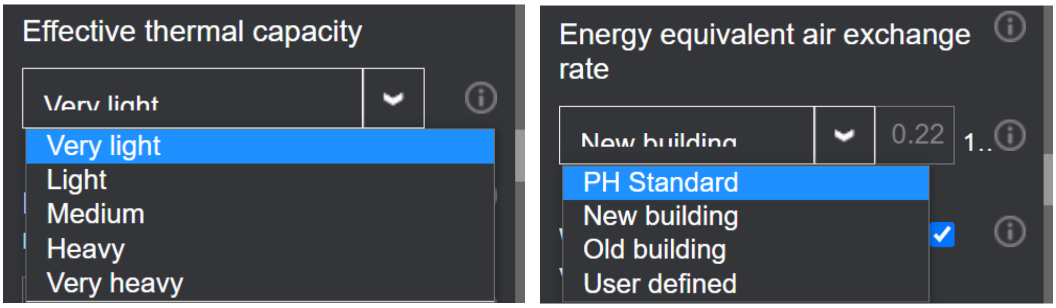

Figure 3. 11. The DALEC Effective Thermal Capacity and Energy Equivalent Air Exchange Rate – www.dalec.net

Window / night ventilation means that the windows are opened when the results are higher than the specified value. This situation becomes effective only when the outside temperature is lower than the indoor temperature. This can be thought of as a passive cooling system. The air exchange rate shows how often the indoor air is renewed through window / night ventilation.

Typical values are:

- Windows, doors closed: 0 - 0,3 [1/h],
- Tilted window: 0,3 - 1,5 [1/h],
- Window opened completely for a short time: 0,3 - 4 [1/h],
- Window opened completely : 9 - 15 [1/h],
- Opposed window completely opened (cross ventilation): <40 [1/h].

Limit temperature window ventilation defines the internal temperature at which the window/night ventilation system will be activated in °C.

Internal temperature (min - max), shows the maximum and minimum values that the building temperature can be [°C]. If the temperature goes above or below these values, the heating and cooling systems work in opposition to each other. If the active cooling system is not activated, the frequency of overheating is simulated according to the maximum temperature value.

Other internal loads define the loads in the room in terms of heat and light. These are counted only when the building is occupied by the user. For instance: PCs, persons, printers, etc.

Cooling defines whether an active cooling system affects the simulation. The cooling system must be disabled in order to calculate the frequency of overheating. Heating indicates the presence of an active heating system.

The primary energy demand category includes the following. The "Annual System Efficiency" (ASE) shows the annual average power efficiency of the heating and cooling system. With the help of this term, "Usage Energy" and "Final Energy" are simulated. The “Primary Energy Factor” (PEF) presents the percentage of energy required for conversion, generation, and distribution terms over the additional energy demand. The "CO_2 Emission Factor" (CO_2-F) specifies the amount of CO_2 produced per unit of "Final Energy" in terms of [g/kWh] of this energy source. Thanks to the result of this value, the cost of the same energy source is calculated.

3.1.2.4. Façade

DALEC has four options for window quality under the glazing heading. Three plane glazing is preferred for standard, tau-value is 0.72, g-value is 0.5, u-value glazing is 0.85. Two plane glazing is preferred for the new building, tau-value 0.8, g-value 0.62, u-value glazing 1.63. Two plane glazing is preferred for the old building, Tau-value 0.82, g-value 0.8, U-value glazing 3. For 'User defined' an own value can be defined.

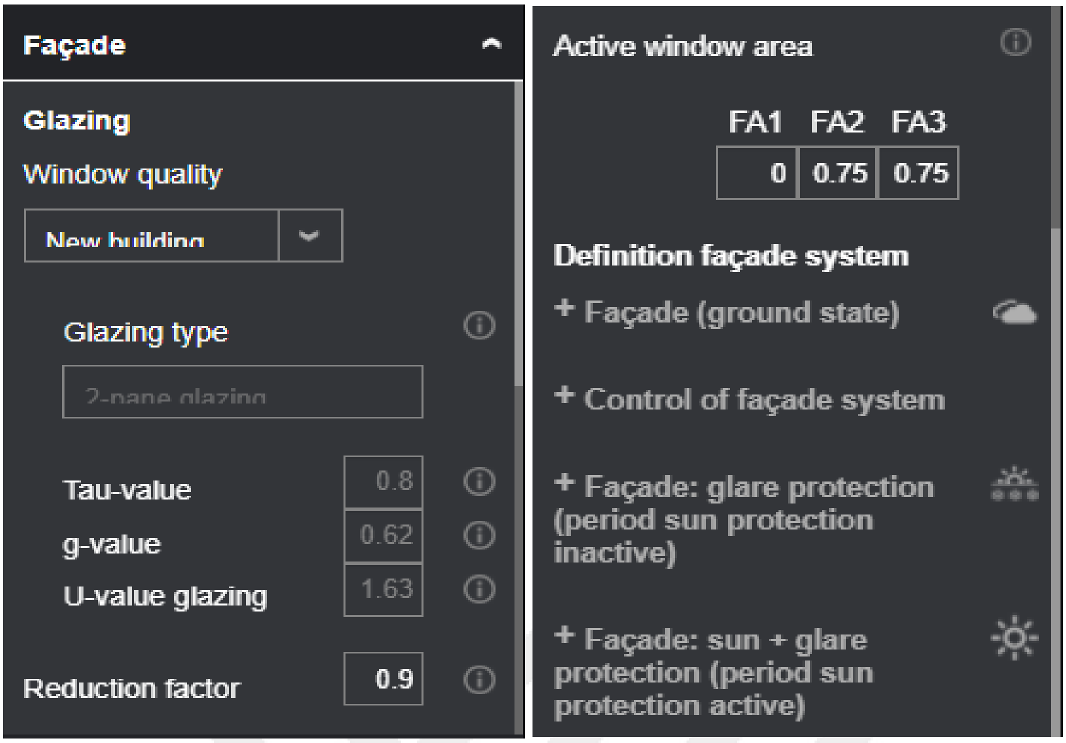

Figure 3. 12. The DALEC Façade – www.dalec.net

The glazing type determines that the insulated glass to be used in the project is double or triple-pane. Tau-value indicates the light transmittance of the selected glass under normal conditions. The software is based on the term visual transmittance to simulate daylight values. Spectral changes in daylight are not taken into account in the calculation. G-value (SHGC, g-value) indicates the solar heat gain coefficient under normal conditions. In cases where the value is not between 0.4 and 0.7, the simulation cannot give accurate results. U-value glazing shows the overall heat transfer coefficient of the glass in [W / (m²K)]. These values are 0.85 W / (m²K) for pH-Standard, 1.63 W / (m²K) for new building, 3.0 W / (m²K) for old building until 1998, and 1.7 W / (m²K) for old building since 1998. The reduction factor indicates the dirt rate of the glass used on the façade. This value is used to simulate the decrease in the permeability of the glass due to dirt. For example; 1.0 for completely new and clean glasses, 0.9 for if the glazing is cleaned biannually. The active window area describes the reduction factor used to simulate the impermeable parts of the window area on the façade as the window frame. If the façade design consists entirely of glass, this value is 1.0. Values are specified for all 3-façade areas (FA1, FA2, FA3) (see Figure 3. 12).

3.1.2.5. Definition of the Façade System

The first façade system definition (ground state) section shows the situation in which protection is not needed from excessive daylight and glare problems that may occur. The definition of the second façade system (glare protection period sun protection inactive) indicates the situation that requires protection from glare problems in winter. The definition of the last façade system (sun and glare protection period sun protection active) indicates the situation that requires protection from excessive daylight and glare problems for the summer season (Werner et al., 2017).The façade design may differ depending on the conditions such as daylight requirement, glare, heating and cooling.

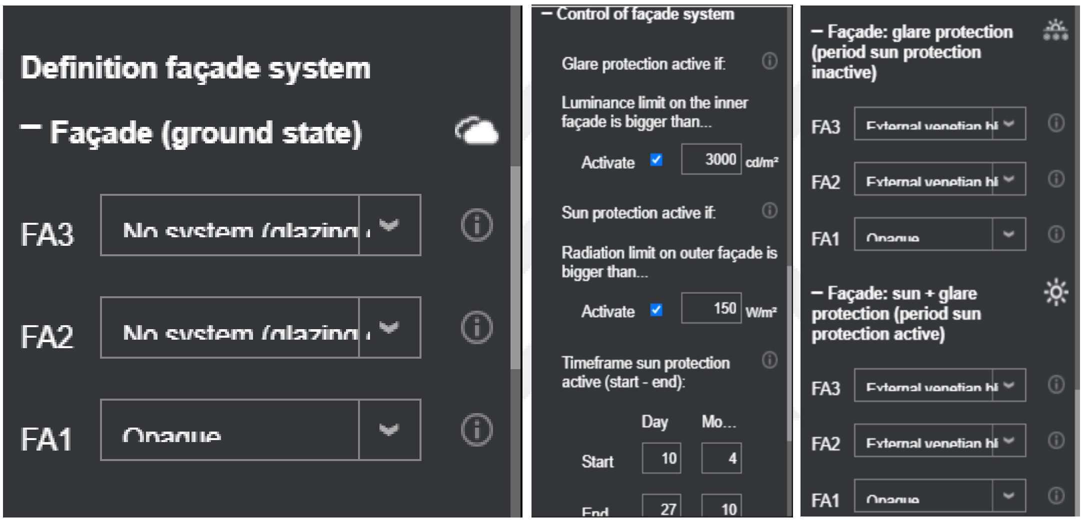

Figure 3. 13. The DALEC Definition of the Façade Systems – www.dalec.net

In the 'no shadow' condition FA3 is the specification of the façade system for frontage area 3 (2m to room height), FA2 frontage area 2 (1m to 2m), FA1 frontage area 1 (up to 1m from floor).

façade: glare protection (period sun protection inactive)

In the condition of 'shaded, heating time' FA3 is the specification of the façade system for façade area 3 (2m to room height), FA2, façade area 2 (1m to 2m), FA1 façade area 1 (floor to 1m).

façade: sun + glare protection (period sun protection active)

In the condition 'shaded, cooling time' FA3 is the specification of the façade system for façade area 3 (2m to room height), FA2, façade area 2 (1m to 2m), FA1, façade area 1 (floor to 1m) (see Figure 3. 13).

Options include: no system (glazing only), clear screen (film roller blind), diffuse screen, external venetian blinds (fixed 0 ° C), external venetian blinds (fixed 45 ° C), external venetian blinds (cut-off control) , daylight redirection blinds + protection glazing (fixed 0 ° C), daylight redirection blinds + protection glazing (cut-off), daylight redirection blinds + protection glazing (retro) (see Figure 3. 14).

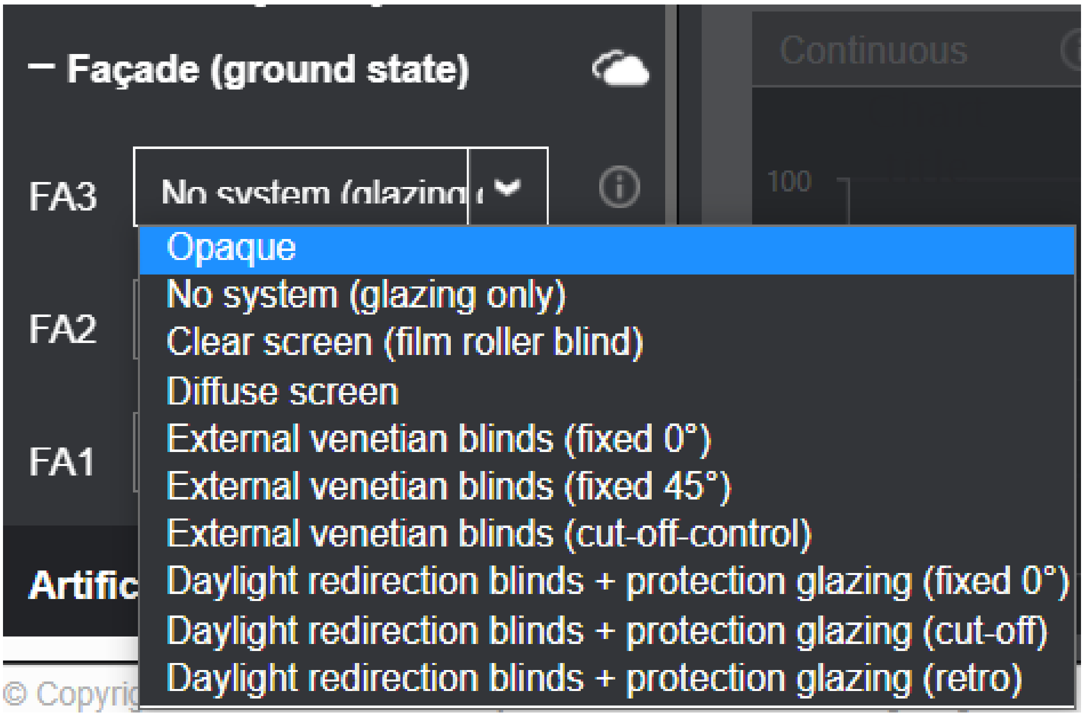

Figure 3. 14. The DALEC Façade System Options – www.dalec.net

Glare, affecting the visual comfort, shows different values depending on the intended use of the building. In the software, this value is 3000 cd/m^2 if no input is resurrected (Werner et al., 2017). In case the luminance limit [cd/m²] defined in the interior is exceeded, the determined shading system is activated. The direction of the calculated area is parallel to the façade. When the vertical external radiation limit is exceeded on the façade to protect from the sun, "shading" becomes active during the summer season. In the software, this value is 150 W/m^2 if no input is (Werner et al., 2017). Timeframe sun protection active (start - end) indicates the period of time over which an overheating condition may be likely. The shading system is activated for heating in the remaining part for cooling in the specified time period.

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3.1.2.6. Artificial Lighting

The software specified two different calculation areas, close to the window area (MA1) and far away (MA2). In addition, two lighting groups (L1 and L2) affecting them are defined. MA1 is 3m from the façade, while MA2 is the calculation area for the rest of the room. (e.g. room depth = 7 m, depth of MA1 = 3 m, MA2 = 4 m). (Werner et al., 2017). The required average illuminance shows the amount of illumination planned in terms of (lx) in the calculation area MA1 near the window and MA2 far from the window, according to the building's intended use (see Figure 3. 15).

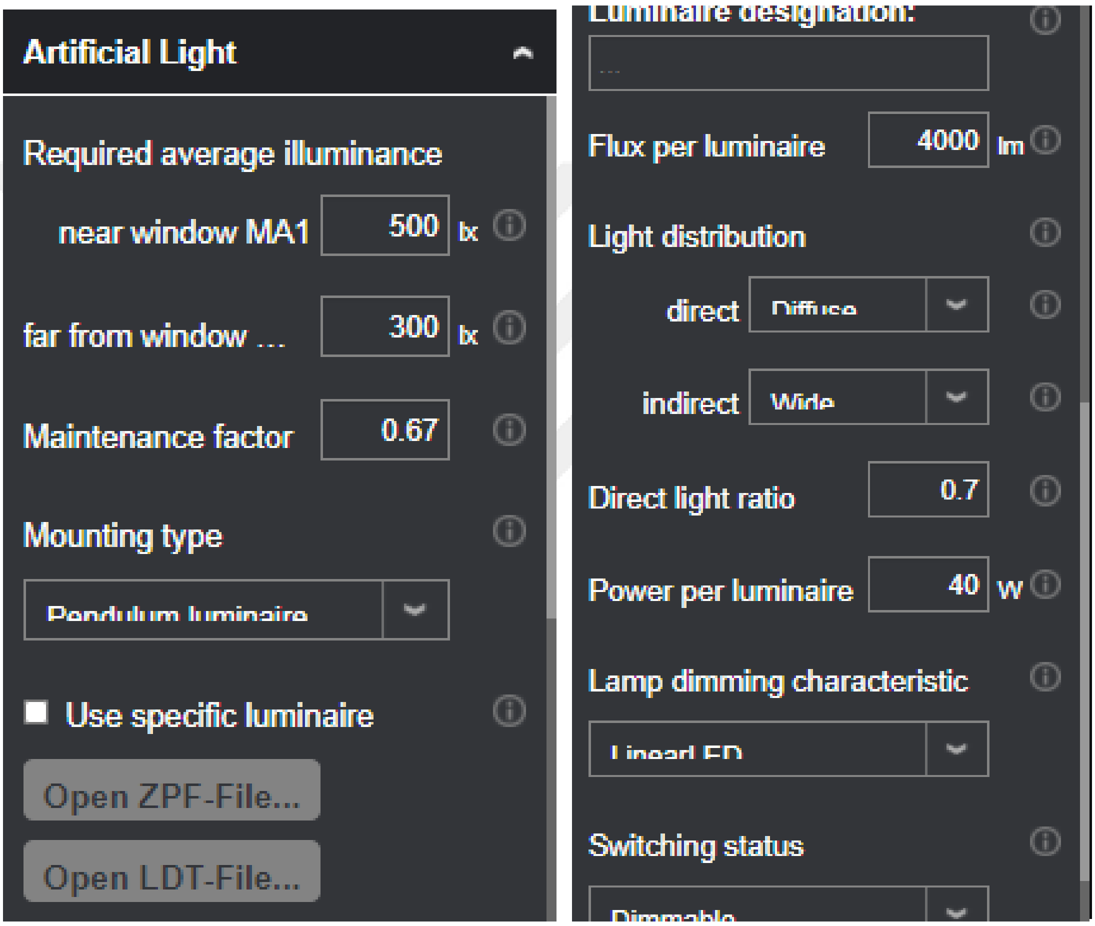


Figure 3. 15. The DALEC Artificial Lighting – www.dalec.net

Maintenance Factor defines seeing the effects of use-related aging of the luminaire over time for artificial lighting. Typical maintenance cycles values: 0.67 clean environments, for three year maintenance cycles and 8 clean environments for annual maintenance cycles.

Mounting type shows the way the lighting element is installed. "Surface mounted" is the way of installing on the ceiling. "Pendulum luminaire" is the application in which the luminaire is suspended. The suspension length varies according to the height of the room (see Figure 3. 16). Use specific luminaire means import functionality for any lighting element in .ldt or .zpf file format. The luminaire designation tab is the area for entering a luminaire definition. It will be filled automatically if loading is done in the specified file formats.

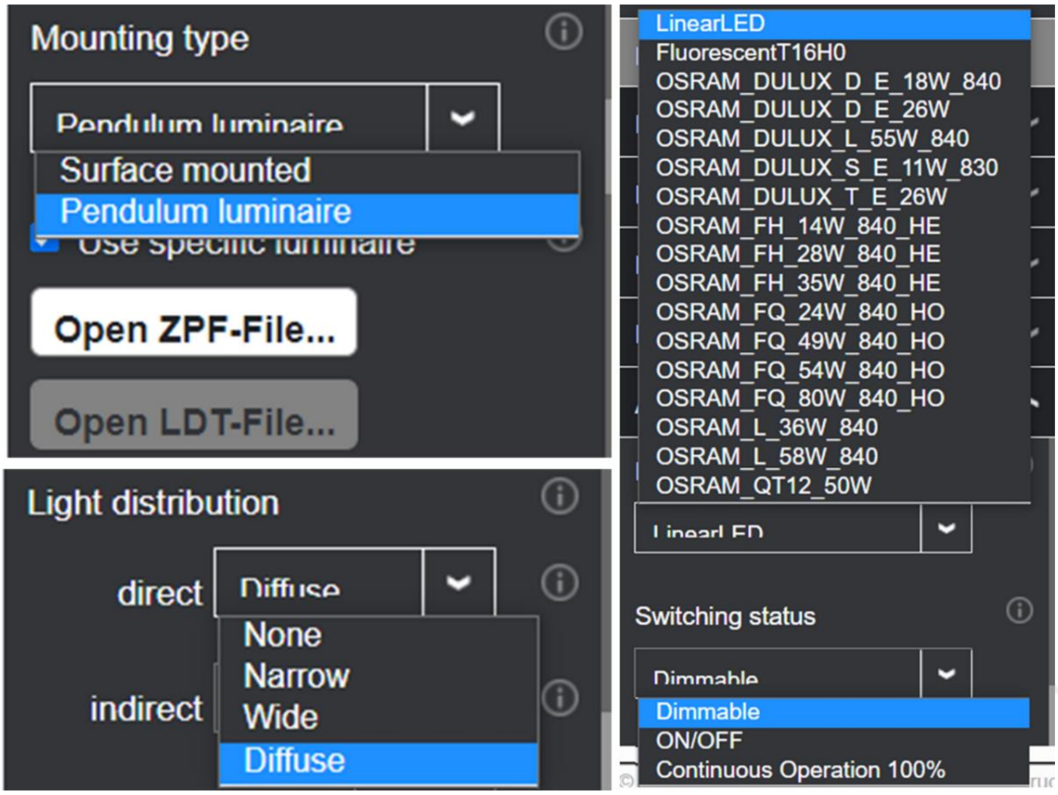


Figure 3. 16. The DALEC Artificial Lighting Mounting Type – www.dalec.net

Light distribution defines the distribution pattern of light from a fixture. Direct shows the direct distribution of the light intensity of the lighting element. This concept usually represents light scattered downwards. Indirect refers to the indirect distribution of the luminous intensity of the luminaire. This term mostly means upward lighting. There are 5 different curves showing the direct and indirect light distribution (LDC) for the lighting elements (Werner et al., 2017) (see Figure 3. 17).

Direct light ratio means the percentage of the direct distribution of the luminous flux in the total light distribution. Power per luminaire determines the amount of power in Watts per lighting element used in the design.

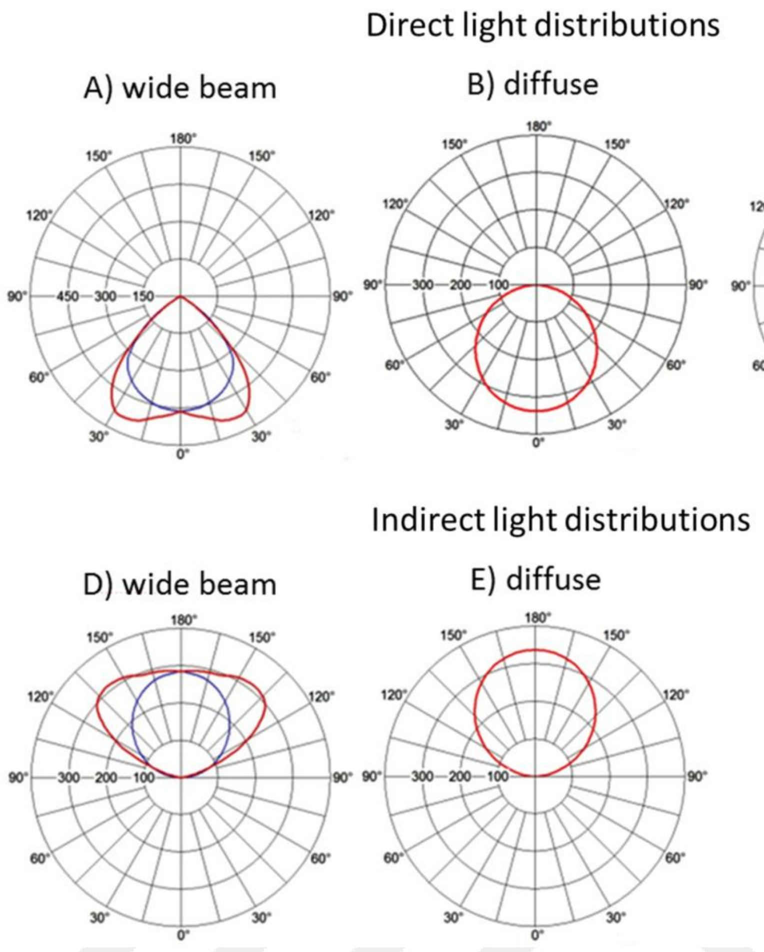


Figure 3. 17. The DALEC Available Basic LDCs. (Werner et al., 2017).

The lamp-dimming characteristic is where the type of lighting used is selected. Energy consumption varies depending on the luminaire chosen when the light is dimmed. From all these inputs, the software calculates the hourly energy consumption of the artificial lighting design and uses it for thermal simulation results (Werner et al., 2017).

Switching status shows the dimming options of a luminaire. Switchable luminaires (On / Off) is a switching status type used to simulate whether or not the intended illumination value can be reached only by daylight. Continuous operation 100% means that the artificial lighting group is always on (Werner et al., 2017).

3.2. Output Parameters

DALEC is a software that calculates the annual energy needed in a short time based on the lighting and thermal data of different façade designs. Hourly IWEC-2 weather files, preferred by the software, contain climate information of more than 3000 locations around the world (Werner et al., 2017). Thanks to the modular approach, diversity can be achieved by applying different room sizes, façade designs, weather data, lighting options, reflectivity values, building possibilities. The software can quickly simulate complex designs containing many parameters and reflect them on the graphics. In this way, it helps designers in lighting and energy calculations in façade design.

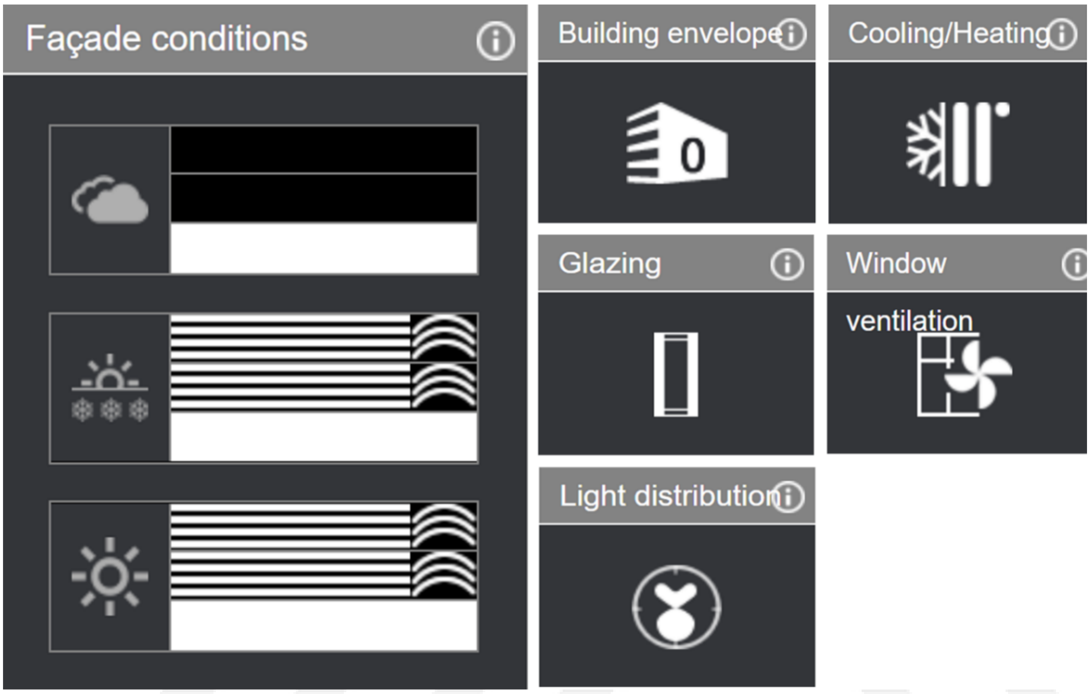


Figure 3. 18. The DALEC Simulations Conditions Graphs – www.dalec.net

Façade conditions defines the change of the façade regarding the sky type. The building envelope icon summarizes the section where the heat transmission rates of the building envelope are determined. Glazing represents the type of glass used in the project. The light distribution icon symbolizes the type of light propagation of artificial lighting elements. If there is LDT or ZPF as a shortcut, then any fixture file has been defined.

The Cooling/Heating icon represents settings related to active cooling and heating. The window icon indicates the presence of window ventilation to be taken into account in the simulation results (see Figure 3. 18).

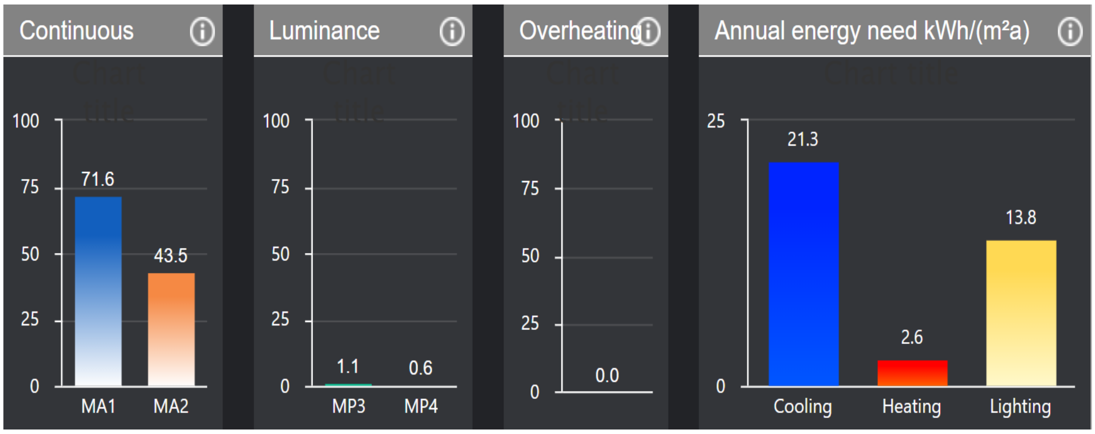


Figure 3. 19. The DALEC Simulations Results Graphs – www.dalec.net

The continuous daylight autonomy cDA shows the daylight performance at the specified working plane level. It is the percentage of the amount of target illumination specified for how long of the year it is covered by daylight alone. The cDA chart indicates the percentage of required annual lighting covered by daylight only (lux hours).

Luminance indicates the percentage of time the luminance limit [cd/m^2] is exceeded on the interior surfaces in the design. The overheating frequency defines the hours when the specified maximum indoor temperature set point is exceeded. This simulation gives results in design options that do not have an active cooling system. The annual energy need diagram describes the annual amount of energy required for heating, cooling and artificial lighting (see Figure 3. 19).

The software graphically gives the following results:

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

- luminance exceeding viewpoint,
- vertical illuminance viewpoint,
- modeling viewpoint,
- internal temperature,
- overheating hours and
- solar heat gain.

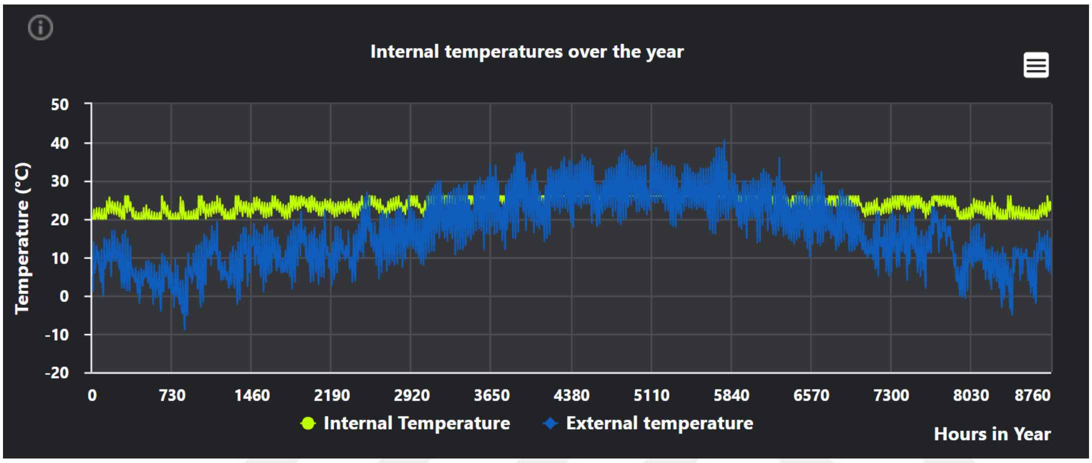
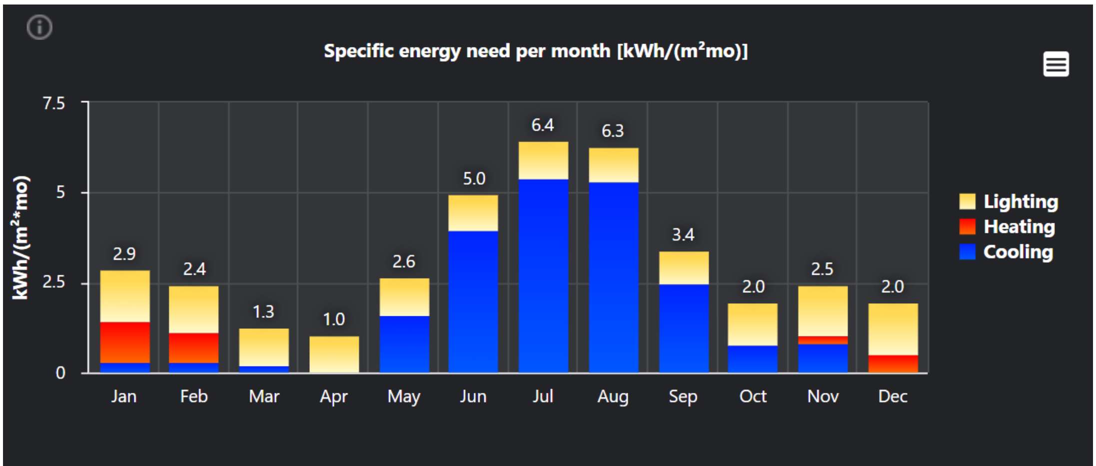


Figure 3. 20. The DALEC Internal and External Temperatures Graph – www.dalec.net

The graph of internal and external temperatures shows the indoor and outdoor temperature change throughout the year in °C (see Figure 3. 20).



Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Cooling [kWh/(m²*mo)]	0.3	0.3	0.2	0.0	1.6	4.0	5.4	5.3	2.5	0.8	0.8	0.1	21.3
Heating [kWh/(m²*mo)]	1.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	2.6
Lighting [kWh/(m²*mo)]	1.4	1.3	1.0	1.0	1.1	1.0	1.0	1.0	0.9	1.2	1.4	1.4	13.8

Figure 3. 21. The DALEC Specific Energy Need per Month Graph – www.dalec.net

Specific energy needs a per month diagram shows the monthly energy demand related to the treated floor area for cooling, heating and artificial light (see Figure 3. 21).

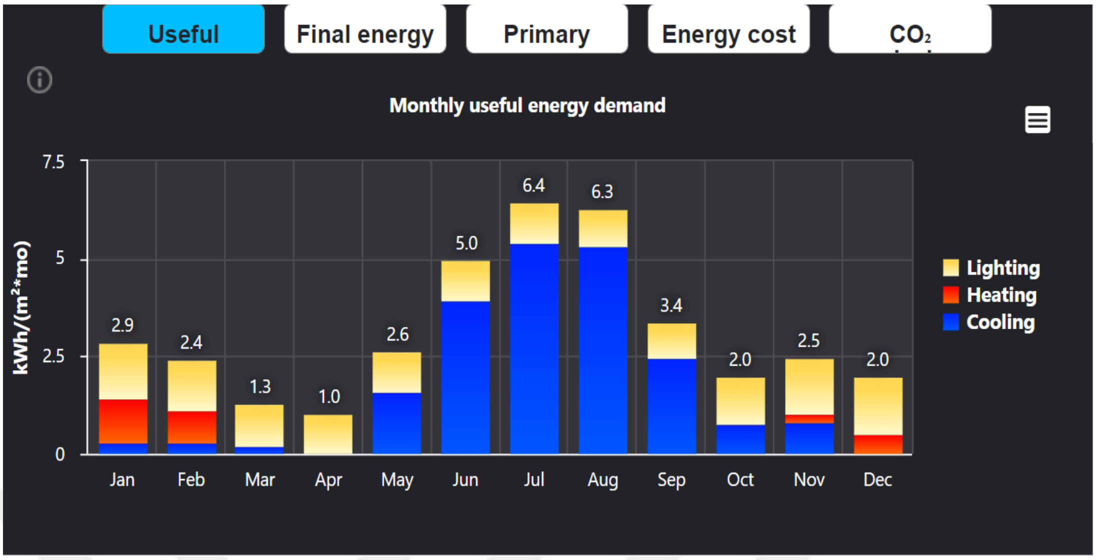


Figure 3. 22. The DALEC Specific Yearly Useful Energy Demand Graph – www.dalec.net

The monthly energy and CO_2 results graph shows these data:

The specific yearly useful energy demand describes the sum of the necessary heating, cooling and artificial light demand (see Figure 3. 22).

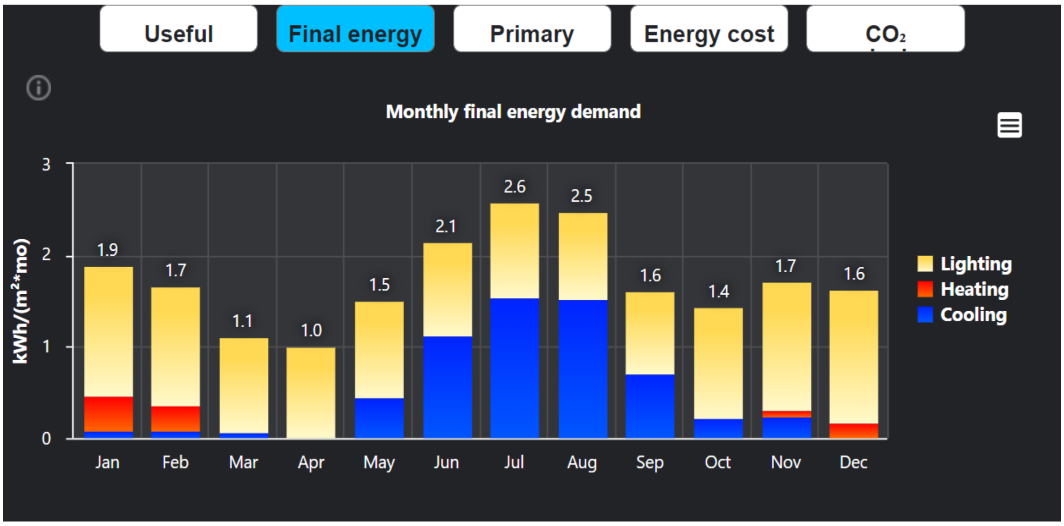


Figure 3. 23. The DALEC Specific Yearly Final Energy Demand Graph – www.dalec.net

The specific yearly final energy demand considers the useful energy demand the yearly power efficiency of the heating and cooling system (see Figure 3. 23).

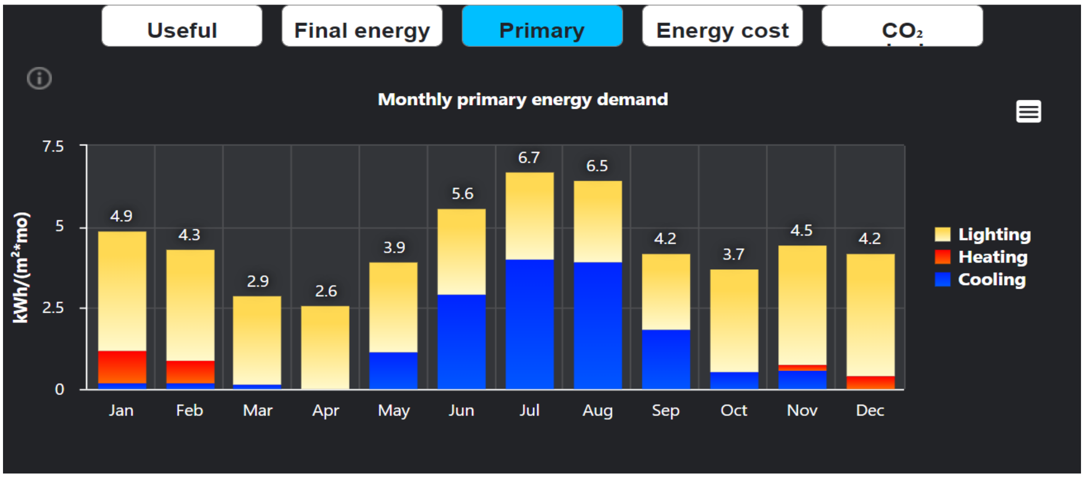


Figure 3. 24. The DALEC Specific Yearly Primary Energy Demand Graph

The specific yearly primary energy demand considers the "Annual System Efficiency" of the heating and cooling system and additionally the energy demand of the energy source for generation, conversion and distribution (see Figure 3. 24).

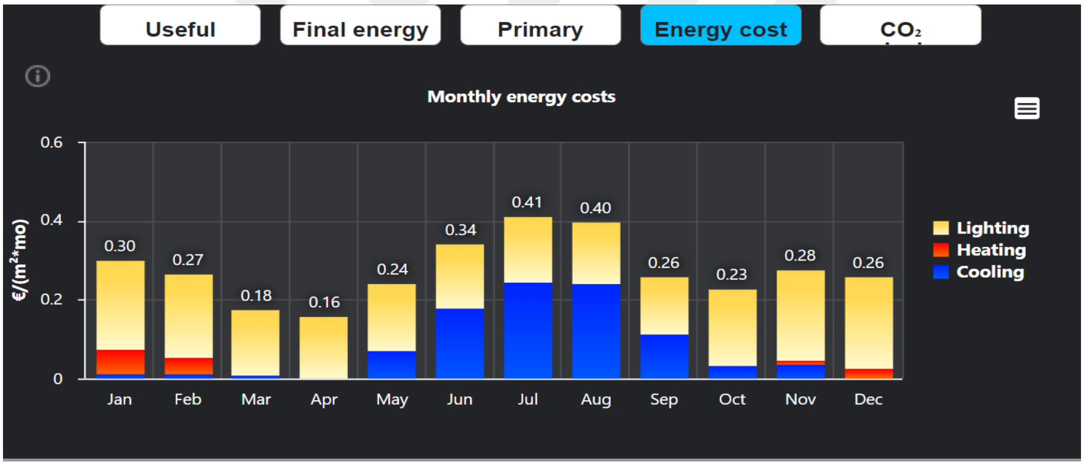


Figure 3. 25. The DALEC Monthly Energy Costs Graph – www.dalec.net

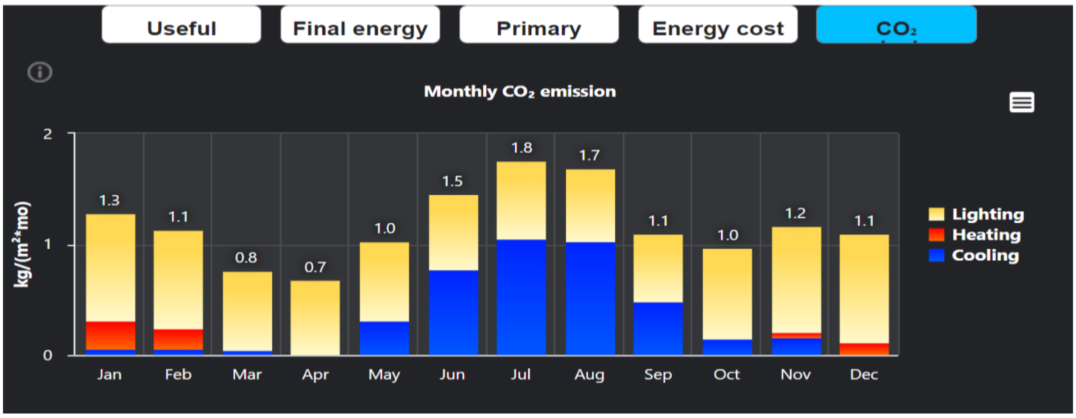


Figure 3. 26. The DALEC Monthly CO_2 Emission Graph – www.dalec.net

The energy costs (see Figure 3. 25) and The CO_2 emission (see Figure 3. 26) related to the treated floor area for cooling, heating and artificial light.

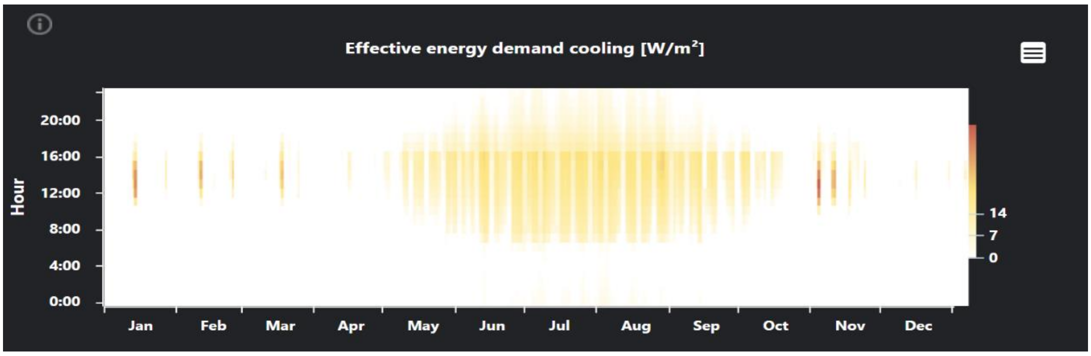


Figure 3. 27. The DALEC Effective Energy Demand Cooling and Heating Graph

Graph is hourly specific energy demand related to the treated floor area for cooling and heating in W/m² (see Figure 3. 27).

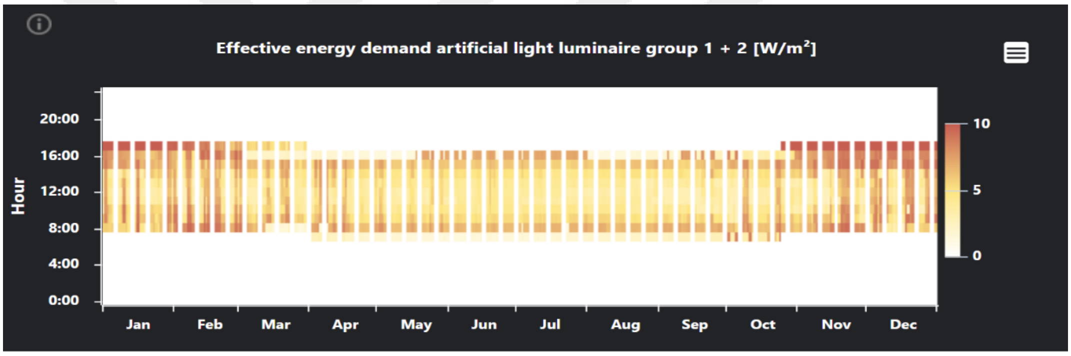


Figure 3. 28. The DALEC Effective Energy Demand Artificial Light Luminaire Group 1+2 Graph – www.dalec.net

Hourly specific electrical energy demand related to floor area for luminaire group 1 (located close to window), luminaire group 2 (located in distance to window) and luminaire groups 1 and 2 (see Figure 3. 28).

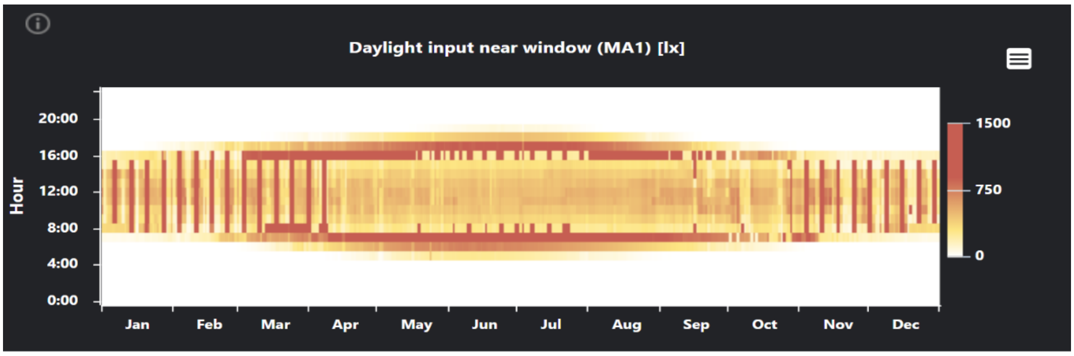


Figure 3. 29. The DALEC Daylight Input Near Window (MA1) Graph

Daylight input graph shows hourly daylight illuminance in lux in the measurement area MA1 close to the façade and MA2 in the depth of the room (see Figure 3. 29).

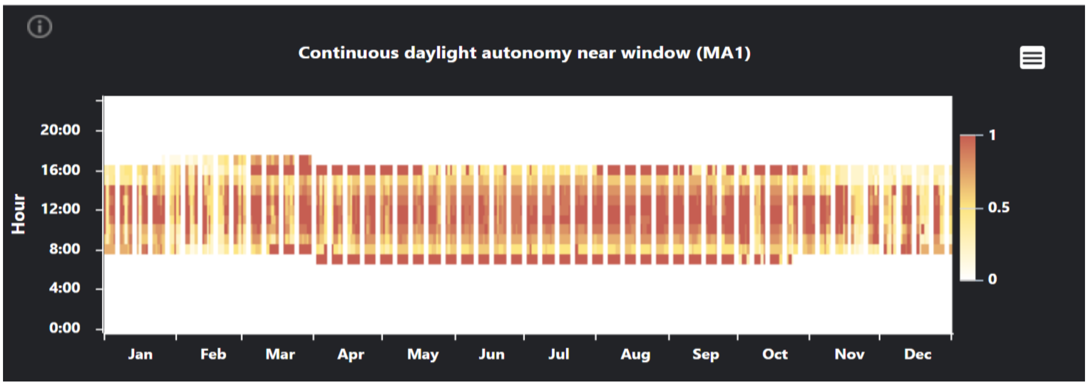


Figure 3. 30. The DALEC Continuous Daylight Autonomy Near Window (MA1) Graph – www.dalec.net

Hourly continuous daylight autonomy cDA as shown in Figure 3. 30 corresponding to the required average illuminance given for the artificial light in the measurement area MA1 close to the façade and MA2 in the depth of the room (see Figure 3. 31).

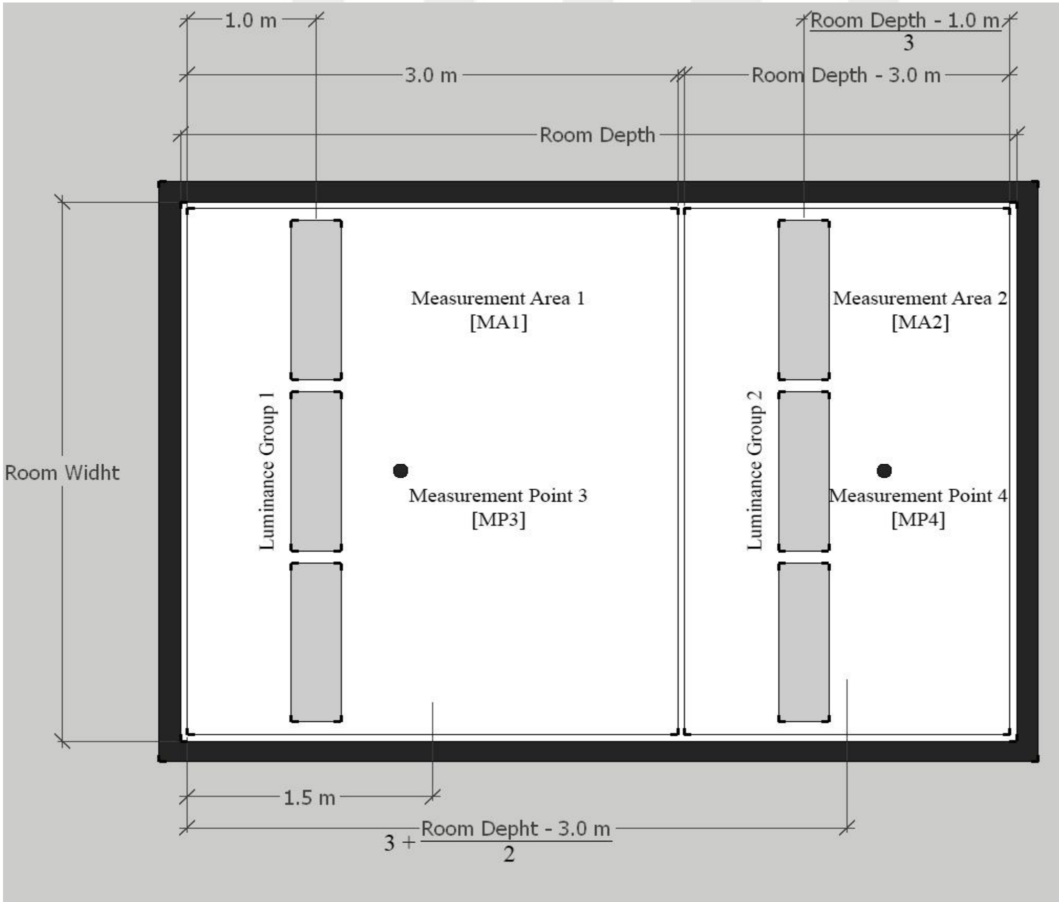


Figure 3. 31. The DALEC Electric Lighting Design Setup of the Artificial Light Module (Werner et al., 2017)

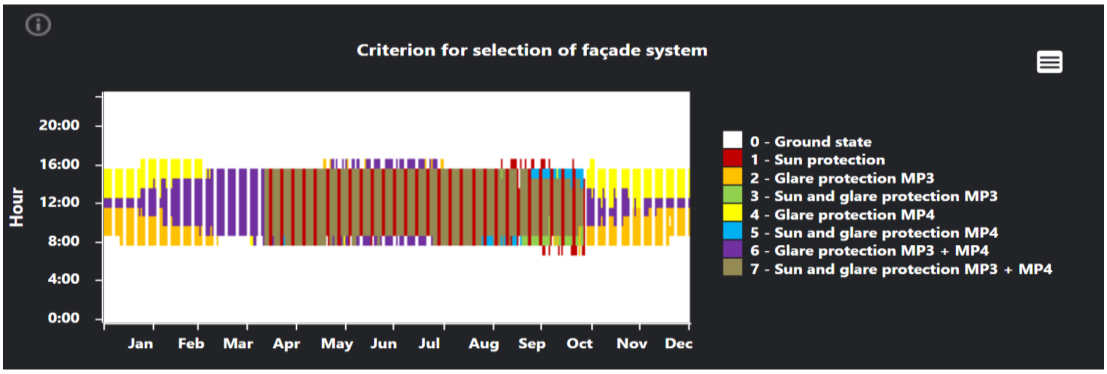


Figure 3. 32. The DALEC Criterion for Selection of Façade System Graph – www.dalec.net

The criterion for selection of façade systems, determines parameter in the control (glare protection/heat protection) that is decisive for the selection of the active façade system. The threshold values are specified in the control section (see Figure 3. 32).

0- ground state

1- sun protection

2- glare protection MP3

3- sun and glare protection MP3

4- glare protection MP4

5- sun and glare protection MP4

6- glare protection MP3 and MP4

7- sun and glare protection MP3 and MP4

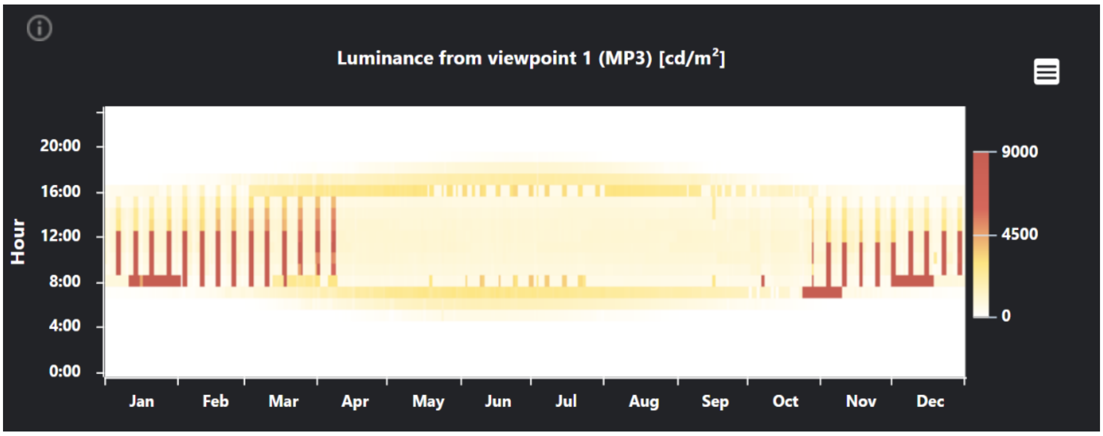


Figure 3. 33. The DALEC Luminance from Viewpoint 1 (MP3) Graph – www.dalec.net

Graph shows hourly maximum luminance in cd/m^2 at the façade seen from viewpoint MP3 and MP4 (see Figure 3. 33).

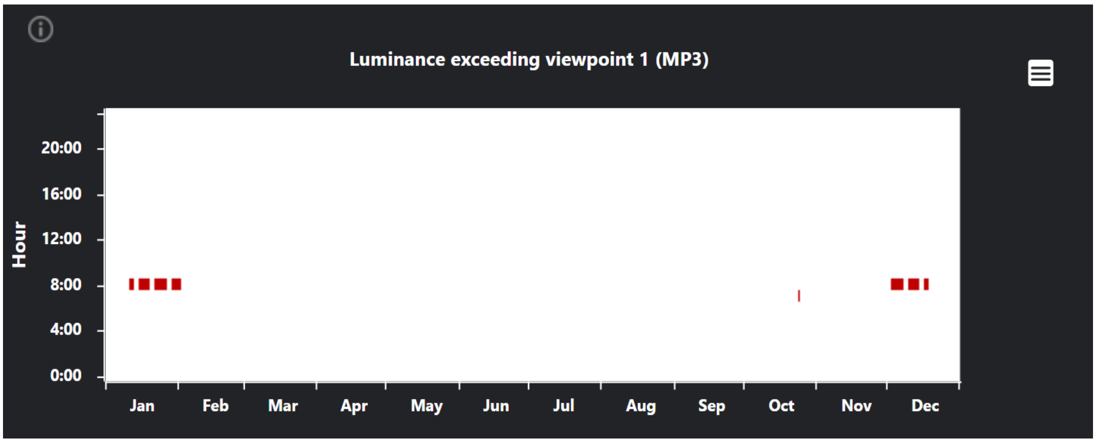


Figure 3. 34. The DALEC Luminance exceeding viewpoint 1 (MP3) Graph – www.dalec.net

Graph shows the times of the year when the threshold value for the luminance at the façade specified in the control section is exceeded from viewpoint 1 and 2 (MP3 and MP4) (see Figure 3. 34).

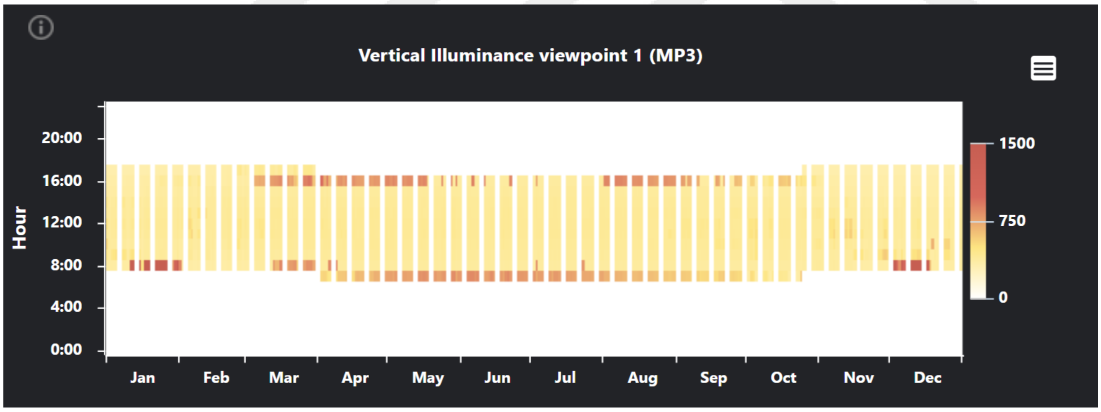


Figure 3. 35. The DALEC Vertical Illuminance viewpoint 1 (MP3) Graph – www.dalec.net

Hourly vertical illuminance shows in lux at view point 1 and 2 (measurement point MP3 and MP4) from day- and artificial light (see Figure 3. 35).

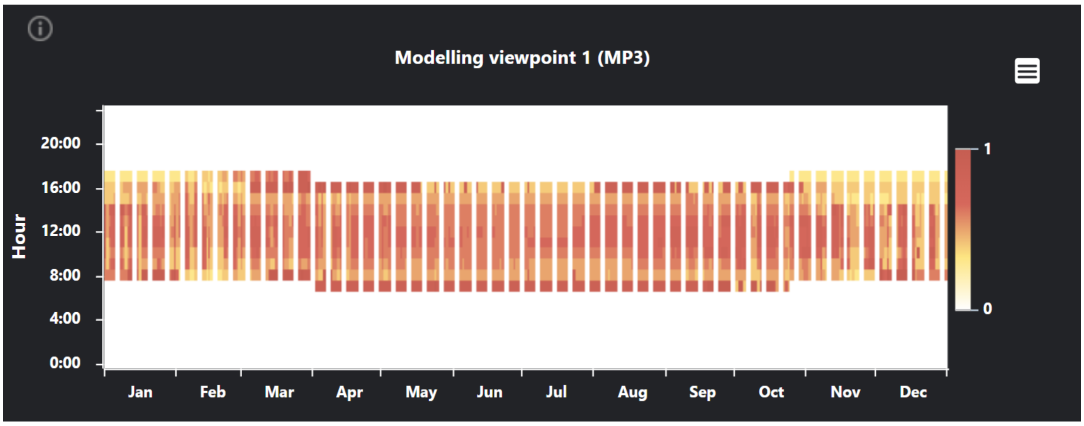


Figure 3. 36. The DALEC Modelling viewpoint 1 (MP3) Graph – www.dalec.net

Modeling viewpoint graphs show hourly Modelling value (ratio between cylindrical and horizontal illuminance) at viewpoint 1 and 2 (measurement point MP3 and MP4) from day- and artificial light (see Figure 3. 36).

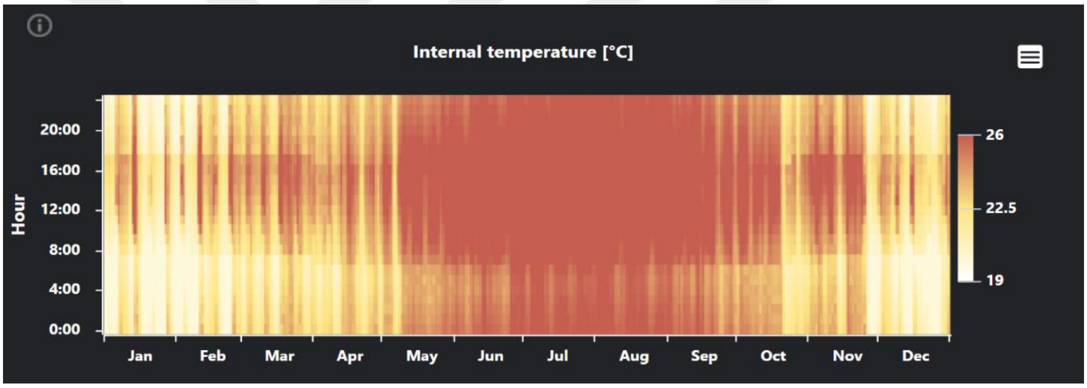


Figure 3. 37. The DALEC Internal temperature Graph – www.dalec.net

Internal temperature in ° C is the graph of the indoor temperature change by month over the year (see Figure 3. 37).

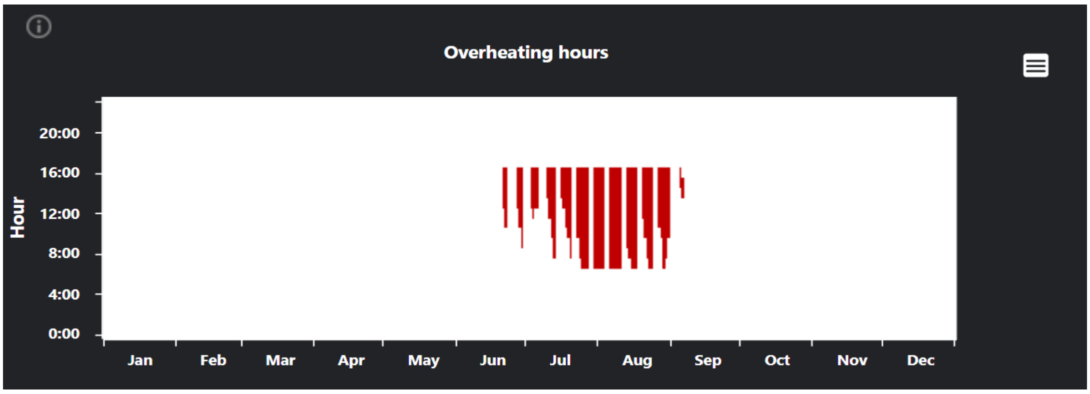


Figure 3. 38. The DALEC Overheating hours Graph – www.dalec.net

Overheating hours graph shows in which internal temperature exceeds the set point temperature (only during occupation time). This calculation is carried out only if there is no active cooling system (see Figure 3. 38).

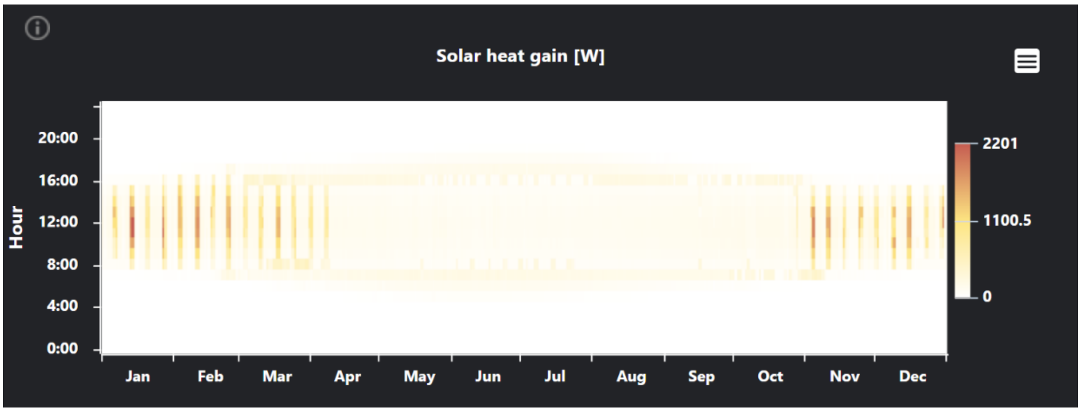


Figure 3. 39. The DALEC solar heat gain Graph – www.dalec.net

The last graph defines hourly solar heat gain in W. These values are calculated from the angle dependent solar heat gain coefficient (SHGC), the vertical external solar radiation and the transparent area of the façade (see Figure 3. 39).

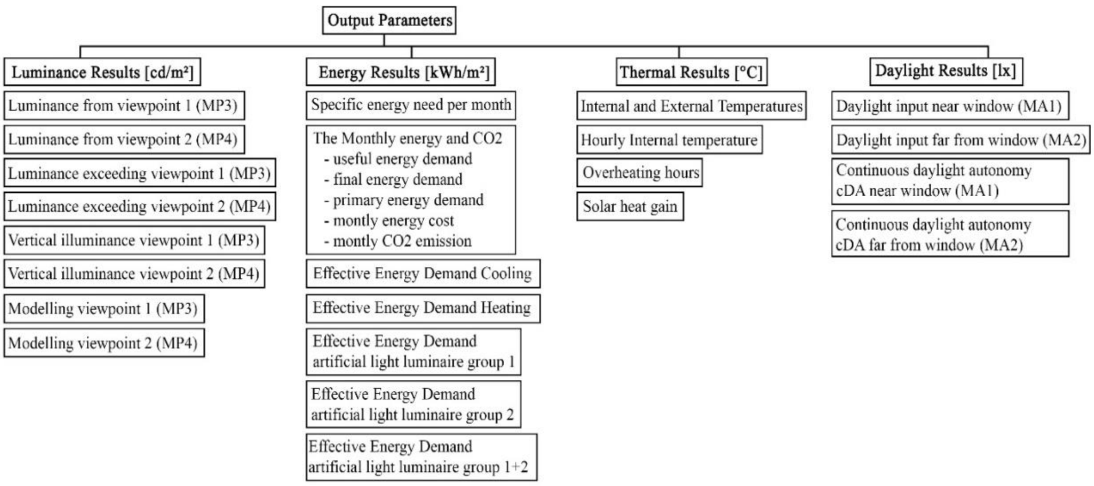


Figure 3. 40. The DALEC output parameters – www.dalec.net

The software provides the opportunity to compare many designs with different features (see Figure 3. 41). In this way, rooms designed according to different features can be evaluated in terms of primary energy demand, useful energy demand, final energy demand, CO_2 emissions, energy costs, continuous daylight autonomy, luminance exceeding, overheating frequency, number of luminaires. Graphically presents the results for heating, cooling, lighting loads and the MA1, MA2, MP3, MP4 fields.

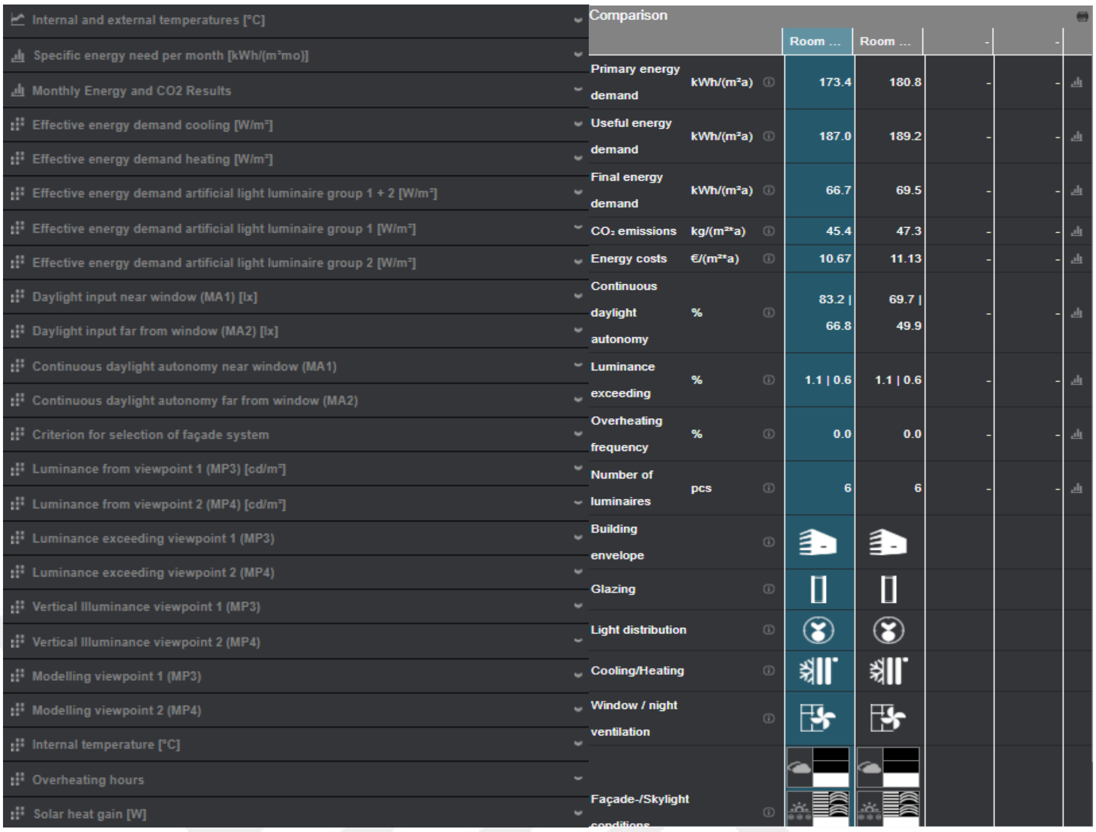


Figure 3. 41. The DALEC Result and Comparison – www.dalec.net

CHAPTER 4
METHODOLOGY

In the research, the energy performances of the planned patient room design cases were investigated in terms of alternative glass configurations, shading systems, and internal surface reflectance rate parameters DALEC software which is an software that combines lighting and thermal simulations were used for this study. This software allows to achieve thermal and visual comfort goals in façade design and helps to examine the impact of results on energy consumption (Werner et al., 2017). Façade design is important in terms of energy consumption during the building construction phase. Because of the relationship between thermal and visual comfort effects, the annual energy consumption simulation should be calculated considering both components. The different calculations and integration of each of these components require considerable computation and time (Werner et al., 2017). Therefore, DALEC, a simulation software that calculates these interactions and gives fast results, has been used within this study.

4.1. The Description of Case study of Patient Room

To test the effect of selected parameters a common regular single patient room layout was chosen as a case study (Sherif et al., 2014). The case study was located at the ground floor level of a healthcare building, with a room width of 3.66 meters and a depth of 6.99 meters and a height of 3 meters. The dimensions and layout of the simulated room are shown in Figure 4. 1. No protrusion (canopy) or horizontal obstructions were used. The calculations were made considering that the room windows face the south façade and occupied by the users at all hours of the day and seven days a week.

The sample room was simulated using İzmir Turkey's (38° 24′ 45″ N 27° 8′ 18″ E) geographical values. Studies have been conducted taking into account that the amount of lighting needed does not change according to different polyclinics of the healthcare building in patient room designs. It has been taken into account that the target illumination value is 300lx in standard patient rooms as it stated in standarts (Technical Committee CEN/TC 169 “Light and Lighting,” 2002), (EN 12464-1).

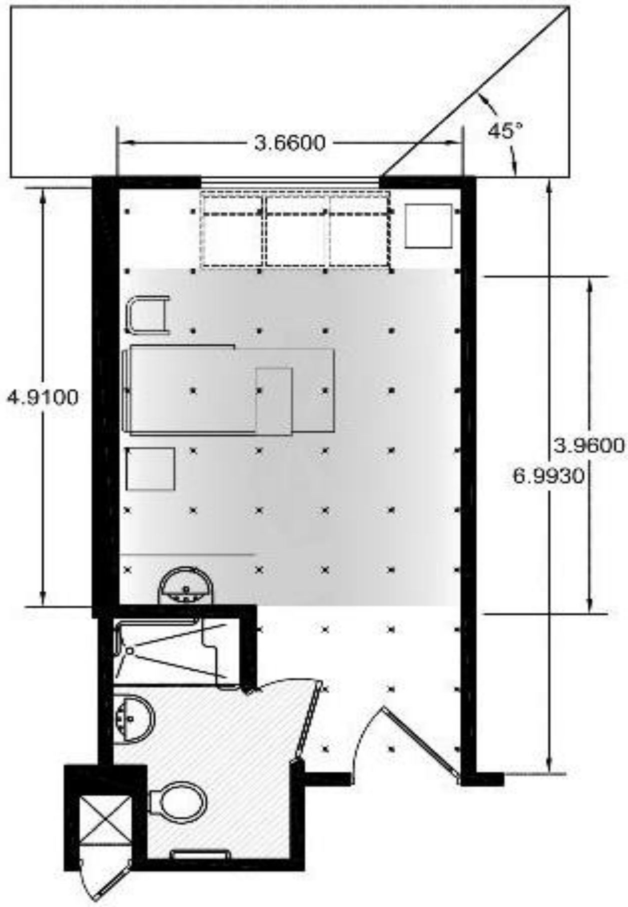


Figure 4. 1. One of the Most Common Single Patient Room Layout (Sherif et al., 2015)

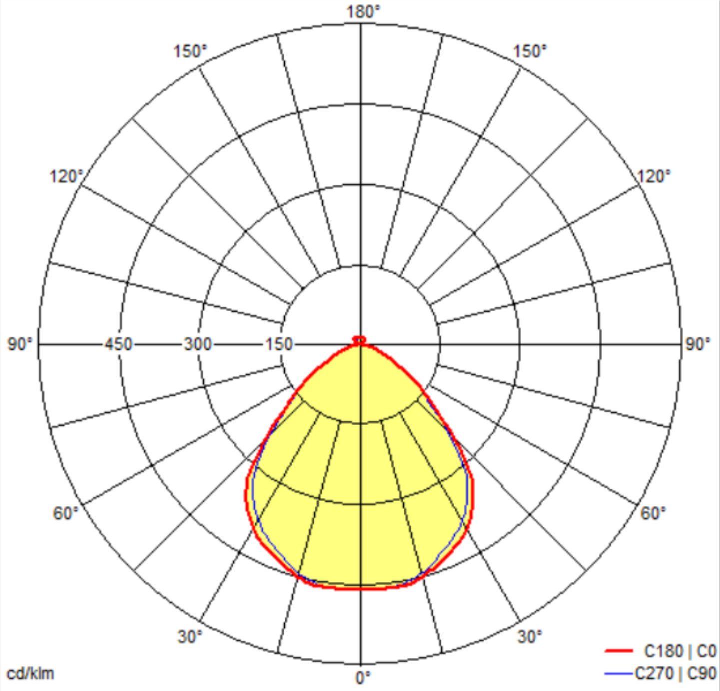
Though several factors have an affect on daylight availability for interios, within this study, the effect of glazing type, interior surface reflectance values and shading systems on lighting, heating, cooling, and total energy consumption was chosen to be investigated.

Daylight access not only influences illuminance levels and visual comfort but also has a significant effect on heating and cooling loads of interiors. In order to determine the effect of selected parameters on the heating and cooling loads following material, properties were chosen for the case study. The heat transmission coefficient (U-value) of the building exterior walls is 1.44 [W / (m^2K)]. Inner walls are considered as adiabatic. It is assumed that the room has no external connection with the roof or floor. The effective thermal capacity of the room is 165000 J/(m^2*K). The energy equivalent air exchange rate is %62. This gives the infiltration value (air exchange through gaps and cracks). It is assumed that window/night ventilation is active and windows are opened by users when the outside temperature is lower than the indoor temperature. It has been taken into account that the windows and doors are closed most of the day and the air exchange rate is 0,3. Room interior limit temperature is 24°C. When this value is exceeded, it is simulated that Window/night ventilation is activated. The set points of the range (minimal and maximal) of inner room temperature are 20 - 26°C. When the temperature is above or lower of these setpoints, the heating or conversely cooling is activated. Internal load due to other equipment such as the TV and computer in the room is assumed to be 7 W / m². It is thought that active cooling and heating systems are targeting the determined values. The reduction factor used to account for the reduction of the glass's permeability due to dirt ratio was considered to be 0,9. The active window area is 0.5 for FA3 façade area 3 (2m to room height), 0.5 for FA2 façade area 2 (1m to 2m), and 0 for FA1 façade area 1 (floor to 1m) (Table 4. 1).

PRODUCT DATA	
Description	LF3 A 1600-940 MINI LDE BK
Article no.	42 932 522
EAN number	9010299120816
Light Source	LED
Luminaire luminous flux*	1552 lm
Luminaire efficacy*	89 lm/W
Colour Rendering Index min.	90
Ballast	1 x 28000664 DRV TR LCA 17W 700mA 50V D #O4A C PRE
Miniature circuit breaker**	quantity with B16: 35 pcs.
Correlated colour temperature	4000 Kelvin
Chromaticity tolerance (initial MacAdam)	3
Rated median useful life*	L90 50000h at 25°C
Luminaire input power*	17.5 W Power factor = 0.98
Dimming	LDE dimmable to 1%; over DALI, DSI and switchDIM; DC level is adjustable
Maintenance category	D - Enclosed IP2X

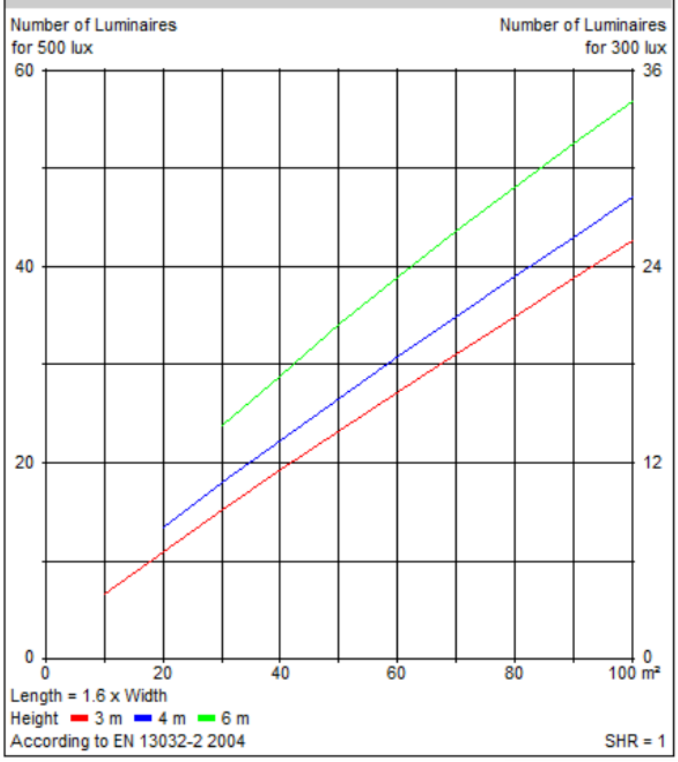
Figure 4. 2. Zumtobel 42932522 LF3 A 1600-940 MINI LDE BK Product Data – www.zumtobel.com

Zumtobel 42932522 LF3 A 1600-940 MINI LDE BK luminaire was used as artificial lighting in the simulation (see Figure 4. 2). Flux per luminaire is 1552 lm. Direct light ratio is 0,95. The lamp dimming characteristic is LinearLed. A luminaire with a dimmable switching status is used.



	C0	C90	C180	C270
0°	459	459	459	459
5°	458	458	458	458
10°	457	454	457	454
15°	449	442	449	442
20°	433	422	433	422
25°	417	403	417	403
30°	397	379	397	379
35°	367	347	367	347
40°	324	304	324	304
45°	249	236	249	236
50°	178	169	178	169
55°	137	133	137	133
60°	98	97	98	97
65°	62	60	62	60
70°	43	43	43	43
75°	28	28	28	28
80°	15	14	15	14
85°	6	5	6	5
90°	1	1	1	1
95°	2	1	2	1
100°	3	2	3	2
105°	3	2	3	2
110°	4	2	4	2
115°	6	3	6	3
120°	7	5	7	5
125°	10	6	10	6
130°	12	8	12	8
135°	15	10	15	10
140°	16	11	16	11
145°	17	13	17	13
150°	17	13	17	13
155°	16	14	16	14
160°	15	14	15	14
165°	15	14	15	14
170°	15	14	15	14
175°	15	14	15	14
180°	14	14	14	14

Figure 4. 3. Zumtobel 42932522 LF3 A 1600-940 MINI LDE BK LDCs-www.zumtobel.com



Light output ratio	
LOR	100 %
ULOR	5 %
DLOR	95 %
FFR	0.05 (5:95)
BLF	1.00

Glare Evaluation	
X = 4 H, Y = 8 H	S = 0.25 H
Reflection factors	70/50/20
UGR transversal	<19
UGR axial	<19

Classification	
LiTG	A53
EN	65°<3000cd/m²
BZ	BZ1/1/BZ2
UTE	0.95 C + 0.05 T
CIE Flux Codes	64 91 99 95 100

Figure 4. 4. Zumtobel 42932522 LF3 A 1600-940 MINI LDE BK Light Output ratio – Glare Evaluation – Classification – www.zumtobel.com

Table 4. 1. Case study parameters

Location	38° 24′ 45″ N 27° 8′ 18″ E in İzmir, Turkey
Room Dimensions	3.66m x 6.99m x 3m
Protrusion (canopy)	0m
Horizontal obstruction	0 °
Orientation	270° (South)
Occupancy time	0-24h
Number of working days per week	7
U-value outer wall	1.44 [W/(m²K)]
U-value inner wall	adiabatic
Effective thermal capacity	165000 J/(m²*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 / m²
Cooling and Heating Systems	Active
Reduction factor	0.9
Active window area FA1	0
Active window area FA2	0.5
Active window area FA3	0.5
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

4.2. The Description of Selected Interior Surface Reflectances

For each patient room design, five different conditions of interior surface reflectance were selected. For very dark condition, ceiling, wall, floor reflectance values are 30%, 20%; 10%. For dark condition, values are 50%, 30%, 10%. For medium, values are 70%, 50%, 20%. For bright condition, values are 80%, 50%, 30%. For very bright, values are 90%, 60%; 40% (Table 4. 2).

Table 4. 2. Interior surface reflectance rates

	Ceiling	Wall	Floor
Very dark	30%	20%	10%
Dark	50%	30%	10%

Medium	70%	50%	20%
Bright	80%	50%	30%
Very Bright	90%	60%	40%

4.3. The Description of Selected Glazing Types

For each patient room design, four glazing types were selected in the main headings of heat control glass, solar control glass, heat and solar control glass, and reflective solar glass. 4mm low-E glass was chosen for buildings that attach importance to thermal insulation in their design. In addition to heat and solar control, 4mm solar low-E glass was used for buildings where high light transmission is required. 6mm green float glass was preferred for the designs that change the sunlight control and permeability for the building it is located in. 6mm green tentesol was chosen for designs in areas exposed to excessive sunlight. Double glazing has been applied for all glazing types. The space between the glasses was chosen as air because it affects the heat transmission values. Glazing type configurations and values used are as in Table 4. 3. Tau-value indicates the light transmittance of the selected glass under normal conditions. G-value (SHGC, g-value) indicates the solar heat gain coefficient under normal conditions. U-value shows the overall heat transfer coefficient of the glass in [W/(m²K)].

Table 4. 3. Glazing types

	Glazing Type	Tau-value	g-value	U-value
Heat Control Glass	4mm Low-E Glass	79%	55%	1,3
Heat Solar Control Glass	4mm Solar Low-E Glass	72%	44%	1,3
Solar Control Glass	6mm Green Float Glass	66%	45%	2,7
Reflective Solar Glass	6mm Green Tentesol	29%	27%	2,7

4.3.1. Heat Control Glass (4mm Low-E Glass)

It is the type of glass used to provide heat control in the interior. Especially for small residences and medium-sized commercial buildings where thermal insulation is required. According to the researches made by Şişecam's 4mm low-E glass, it reduces the building heat loss by 50% compared to the places where normal double glazing is used. It postpones the condensation that may occur on the glass surface due to its structure and prevents the window fronts from being cold in winter. It reduces the entry of ultraviolet (UV) rays into the indoor environment by 76%. The glass system consists of a combination of 4mm Low-E glass, 16mm air filled space and 4mm colorless float glass (Isıcam, 2018) (see Figure 4. 5).

ŞİŞECAM LOW-E GLASS

HEAT CONTROL GLASS

4 mm Clear Float Glass + 16 mm Cavity + (#3) 4 mm Low-E Glass	Daylight (EN 410)			Colour Rendering Index (Ra) %	Solar Energy (EN 410)					Thermal Conductivity (U Value) W/m^{2}K (EN 673)	
	Transmittance %	Reflectance Outdoor %	Reflectance Indoor %		Direct Transmittance %	Reflectance Outdoor %	Absorption %	Solar Factor (g value) %	Shading Coefficient	Dry Air	Argon
Neutral	79	12	11	96	52	26	22	55	0,64	1.3	1.1

Figure 4. 5. Isıcam Heat Control Glass Values (Isıcam, 2018)

With its Low-E coating, its light transmittance value (Tau-value) is 79%. While it reflects 12% of the total light coming from the sun, the value reflected to the interior is 11%. The solar energy direct transmittance rate is 52%. It reflects 26% of the total solar energy to the outside and absorbs 22%. The solar heat gain value (G-value) is 55%. The heat permeability coefficient (U-value) of 4mm Low-E glazing type is 1.3 if the space between the glass is filled with dry air and 1.1 [W/(m^{2}K)] when the space between the glass is filled with argon (Isıcam, 2018).

4.3.2. Heat and Solar Control Glass (4mm Solar Low-E Glass)

It is the type of glass used in buildings where heat and solar control are required to be provided at the same time. It provides high light transmission generally combined with heat and solar control. 4mm Solar Low-E Glass reduces the heat loss of the building by 50% and the entrance of solar heat inside by 40% compared to the places where normal double glazing is used. By providing solar and thermal insulation together, it saves energy spent for heating and cooling. It prevents windows inside the building from being cold in winter and hot in summer. It reduces the entry of ultraviolet (UV) rays into the indoor environment by 91%. The glass system consists of a combination of 4mm Solar Low-E Glass, 16mm air filled space and 4mm colorless float glass (Isıcam, 2018) (see Figure 4. 6).

ŞİŞECAM SOLAR CONTROL LOW-E GLASS

HEAT & SOLAR CONTROL GLASS

4 mm Solar Control Low-E Glass (#2) + 16 mm Cavity + 4 mm Clear Float Glass	Daylight (EN 410)			Colour Rendering Index (Ra) %	Solar Energy (EN 410)					Thermal Conductivity (U Value) W/m^2K (EN 673)	
	Transmittance %	Reflectance Outdoor %	Reflectance Indoor %		Direct Transmittance %	Reflectance Outdoor %	Absorption %	Solar Factor (g value) %	Shading Coefficient	Dry Air	Argon
Neutral	72	10	11	96	41	29	31	44	0.50	1.3	1.1

Figure 4. 6. Isıcam Heat and Solar Control Glass (Isıcam, 2018)

Together with the Solar Low-E coating, its light transmittance value (Tau-value) is 72%. While it reflects 10% of the total light coming from the sun, the value reflected to the interior is 11%. The solar energy direct transmittance rate is 41%. It reflects 29% of the total solar energy to the outside and absorbs 31%. The solar heat gain value (G-value) is 44%. The heat permeability coefficient (U-value) of 4mm Solar Low-E glazing type is 1.3 if the space between the glass is filled with dry air, and 1.1 [W / (m^2K)] when the space is filled with argon (Isıcam, 2018).

4.3.3. Solar Control Glass (6mm Green Float Glass)

Solar Control Glass is the type of glass used in buildings where it is important to prevent problems such as glare caused by the sun rays entering the building. While the interior provides visual comfort, it saves on cooling costs. It is generally used in buildings with curtain walls. The glass system consists of 6mm Green float Glass, 16mm air filled space and 6mm colorless float glass combination (Isıcam, 2018).

The light transmittance value (Tau-value) of Green float glass is 66%. While it reflects 11% of the total light coming from the sun, the value reflected to the interior is 14%. The solar energy direct transmittance rate is 38%. It reflects 7% of the total solar energy to the outside and absorbs 55%. The solar heat gain value (G-value) is 45%. The heat transmission coefficient (U-value) of 6mm Green float glazing type is 2.7 [W/(m^2K)] when the space between glass is filled with dry air, and 2.6 [W/(m^2K)] when filled with argon (Isıcam, 2018) (see Figure 4. 7).

ŞİŞECAM TINTED FLOAT GLASS — SOLAR CONTROL GLASS (BODY TINTED) — SOLAR CONTROL

6 mm Tinted Float Glass + 16 mm Cavity + (#3) 6 mm Low-E Glass / 6 mm Clear Float Glass	Daylight (EN 410)			Colour Rendering Index (Ra) %	Solar Energy (EN 410)					Thermal Conductivity (U Value) W/m²K (EN 673)	
	Transmittance %	Reflectance Outdoor %	Reflectance Indoor %		Direct Transmittance %	Reflectance Outdoor %	Absorption %	Solar Factor (g value) %	Shading Coefficient	Dry Air	Argon
Green + Clear Float Glass	66	11	14	87	38	7	55	45	0.52	2.7	2.6

Figure 4. 7. Isıcam Solar Control Glass (Isıcam, 2018)

4.3.4. Reflective Solar Control Glass (6mm Tentesol)

It is the type of glass suitable for buildings where the ingress of sunlight is required to be minimized. It prevents problems that may occur due to the excessive brightness of the sun. It contributes to energy savings by reducing cooling costs. It provides integrity with the façade in buildings with curtain walls. When viewed from the direction where the light is strong, it creates a mirror effect due to its reflective surface. It is more durable than other glazing types with its hard coating (Isıcam, 2018).

ŞİŞECAM TENTESOL — SOLAR CONTROL GLASS (REFLECTIVE) — SOLAR CONTROL

6 mm Tentesol (#2) + 16 mm Cavity + (#3) 6 mm Low-E Glass / 6 mm Clear Float Glass	Daylight (EN 410)			Colour Rendering Index (Ra) %	Solar Energy (EN 410)					Thermal Conductivity (U Value) W/m²K (EN 673)	
	Transmittance %	Reflectance Outdoor %	Reflectance Indoor %		Direct Transmittance %	Reflectance Outdoor %	Absorption %	Solar Factor (g value) %	Shading Coefficient	Dry Air	Argon
Green + Clear Float Glass	29	20	35	93	19	11	71	27	0.31	2.7	2.6

Figure 4. 8. Isıcam Reflective Solar Control Glass (Isıcam, 2018)

The light transmission value (Tau-value) of Tentesol glass is 29%. While it reflects 20% of the total light from the sun, the value reflected to the interior is 35%. The solar energy direct transmittance rate is 19%. It reflects 11% of the total solar energy to the outside and absorbs 71%. The solar heat gain value (G value) is 27%. The heat permeability coefficient (U-value) of 6mm Tentesol type glass is 2.7 when the space between the glass is filled with dry air, and 2.6 [W / (m²K)] when the space between the glass is filled with argon (Isıcam, 2018) (see Figure 4. 8).

4.4. The Description of Selected Shading Types

Studies reveal the need for building shading systems to ensure indoor comfort quality and to save building energy consumption (Sharma et al., 2019). Studies have shown that shading systems applied in buildings are effective in reducing the energy consumption of the building (Raheem et al., 2015). In another study, shading equipment present outside or inside the building represents the amount of daylight entering the building, the heat gain of the building, and privacy (Gomes et al., 2014). With glazing type options and shading element combinations, daylight illumination can be increased in non-light areas of the building, indoor visual comfort can be provided and building energy consumption can be reduced (Do & Chan, 2020).

Four types were selected from ten different shading systems determined by DALEC (see Figure 3. 14) in the design of the patient room. These are; No system (glazing only), film roller blind (clear screen), external Venetian blinds 0° and 45° (Table 4. 4).

Table 4. 4. Shading Systems and Features

Shading Stystem	Shading feature
No system	Glazing only
Film Roller blind	Clear Screen
External Venetian blinds	0 °
External Venetian blinds	45 °

4.4.1. No System (Only Glazing)

It is a simulation option for the building where only glass windows are used without a shading system.

4.4.2. Film Roller Blind (Clear Screen) (FRB)

A Film roller blind is a shading equipment used to reduce the effects of daylight coming from the openings of the building and causing discomfort to the users (Do & Chan, 2020). In the research, it has been proven that 45% of the heat loss is saved with the roller blind shading system (Oleskowicz-Popiel & Sobczak, 2014). In research, roller blinds prevent problems such as glare and are effective in reducing the energy spent for cooling (Kunwar et al., 2019). In a simulations using roller blinds, the results were evaluated in the context of energy consumption and visual comfort conditions. It was stated that the glare threshold was not exceeded by 90% in all options, and the energy consumed for cooling systems was reduced by 26% (Kunwar et al., 2019).

Figure 4. 9. Film Roller Blind Shading System – www.rollaray.com

The effect of using roller blinds on energy consumption was studied in a study conducted in houses facing the south façade in Hong Kong (Zhong et al., 2020). According to the external non-movable shading elements, roller blinds allow users to control indoor features (see Figure 4. 9). The manual control of the system by the user is among the factors that will affect the energy use of the building (O'Brien et al., 2013). This shading system was chosen due to its effectiveness in providing visual comfort conditions and being user-controlled.

4.4.3. External Venetian Blind (EVB)

External Venetian blinds are used to save on cooling loads, to provide thermal and visual comfort conditions and to prevent in-room glare problems in climatic conditions dominated by the sun. External Venetian blinds have long been used as shading equipment in the building structure (Ramkishore Singh et al., 2016). In addition, it provides privacy for the people inside the building (Reinhart & Voss, 2003). In a similar study, the use of external Venetian blinds also reduces building emission rate by 6.95% (Aste et al., 2012). In another study, it was stated that this system is among the parameters that affect the building performance in terms of visual comfort and energy consumption (Ramkishore Singh et al., 2016). Studies have indicated that external Venetian blind systems are one of the main factors affecting energy use (Chan & Tzempelikos, 2013). In another study conducted in China, the effect of these systems on shading and their performance in cooling load were examined (Sharma et al., 2019). It should be used on the outside of the glass to better control the glare and the heat of the sun entering the interior (Nikoofard et al., 2014). In the study, which included two different time zones in Italian residential buildings, different configurations of the external Venetian blind were shown over the visual and thermal parameters that were inspected (Carletti et al., 2016). In another study, it was stated that the most important effect of external Venetian blind is its ability to carry daylight to the parts of the room far from the window (Chan & Tzempelikos, 2013). The EVB shading system was simulated in scenarios due to its major impact on energy consumption for lighting, heating, and cooling.

Figure 4. 10. External Venetian Blind Shading System (Alulux, 2021).

In the study, the effect of alternative indoor surface reflection, shading systems and glazing type on the energy consumption of the patient rooms in healthcare buildings was investigated using the simulation method based on the case study.

CHAPTER 5
RESULTS AND EVALUATION

Under the specified conditions, the case study room was simulated according to the parameters in Table 4. 1 using DALEC software. In this section results of the simulations are given according to the selected variables, such as glazing types, shading systems, interior surface reflectance values and total energy consumptions respectively. There are a total of eighty different scenarios and each scenario has its own lighting, cooling, and heating consumption values, only selected results were discussed under each paragraph. However, all results of each scenario are represented with graphics, and results are evaluated.

5.1. Evaluation of Results in Terms of Glazing Types

In this section, the effects of glazing type differences were examined individually according to the energy consumption for lighting, heating, and cooling. The results of the very dark and very bright scenarios where the values are maximum and minimum were visualized. Except for these two scenarios, the results from other conditions were detected as similar.

When low-e glass was used for glazing during simulations, annual energy consumption of lighting has the highest value with 63.9 Kwh/m² in FRB shading systems under very dark conditions (see Figure 5. 1). In terms of heating energy consumption, the highest consumption was observed with the EVB 45° shading system under very bright conditions. On the other hand, for cooling the lowest energy consumption was 37.1 Kwh/m² in the EVB 45° shading system under very bright conditions (see Figure 5. 2).

When solar low-e glass was used for glazing during simulations, annual energy consumption of cooling has the highest value with 36.4 Kwh/m² in the EVB 45° shading system under very bright conditions (see Figure 5. 2). In terms of lighting energy consumptions, the highest consumption was observed when the FRB shading system was used under very dark conditions with 64.4 Kwh/m² (see Figure 5. 1).

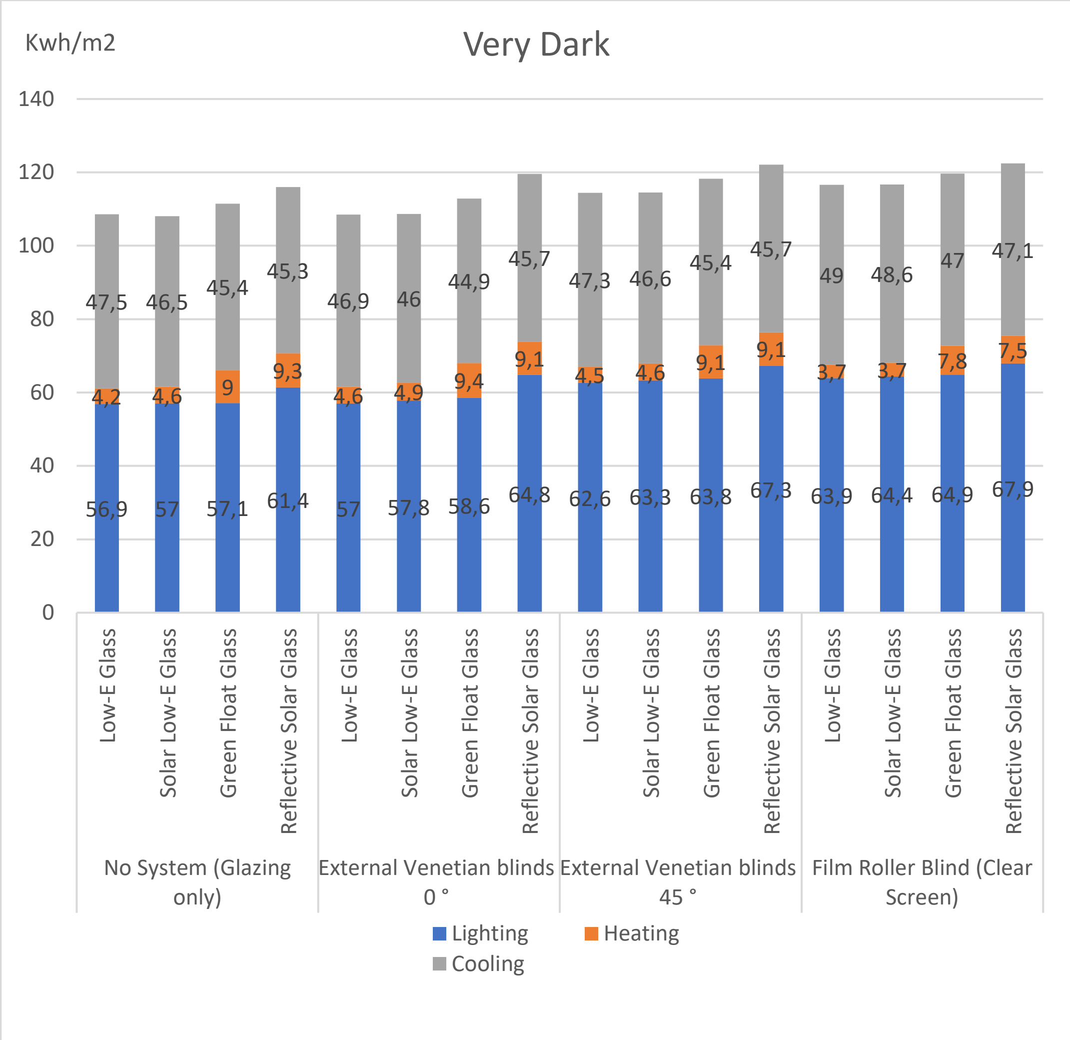


Figure 5. 1. In Very Dark Condition According to Glazing Type Annual Energy Consumption Lighting (L), Heating (H), Cooling (C)

When green float glass is used for glazing during simulations, annual energy consumption of heating has the lowest value with 7.8 Kwh/m² in the FRB shading system was used under very dark conditions. In terms of cooling energy consumptions, the highest consumption was observed when the FRB shading system was used under very dark conditions (see Figure 5. 1).

When reflective solar glass was used for glazing during simulations, annual energy consumption of lighting has the lowest value with 42.9 Kwh/m² with no shading systems under very birght conditions (see Figure 5. 2). In terms of heating energy consumptions, the highest consumption was observed with the EVB 0° shading system under very bright conditions. On the other hand, for cooling the highest energy consumption was 47.1 Kwh/m² in the FRB shading system under very dark conditions (see Figure 5. 1).

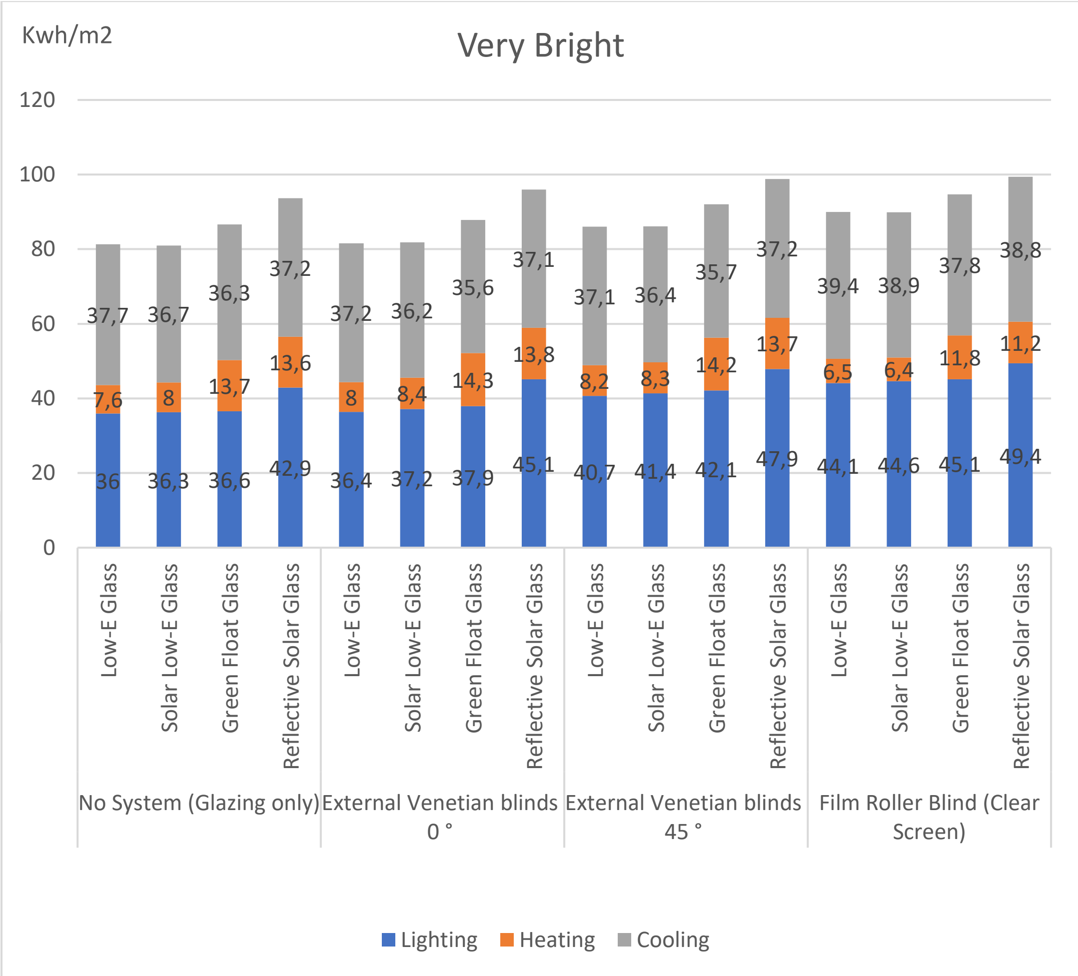


Figure 5. 2. In Very Bright Condition According to Glazing Type Annual Energy Consumption Lighting (L), Heating (H), Cooling (C)

All four glazing types and their selected peak annual energy consumptions were given above. Since the other variables (shading system and interior color reflectances) are also significantly important on consumption values, evaluations regarding that were also made. For instance when low-E glass was compared to reflective solar glass in very dark conditions and the absence of a shading system the energy consumed for lighting was reduced by 7.3%. In the same comparison, in very dark conditions and EVB 0° shading system 5.9% reduction was achieved in low-E glass (see Figure 5. 1).

When solar low-E glass was compared to reflective solar glass in very bright conditions and the absence of a shading system the energy consumed for heating reduced by 41.2%. When green float glass was compared to low-E glass in very bright conditions and FRB shading system the energy consumed for cooling reduced by 4% (see Figure 5. 2).

As a result of scenarios, it was observed that changes in glazing type cause differences in annual energy load. The results of very dark and very bright scenarios where values are maximum and minimum were visualized. Under other circumstances, the results were parallel. The most energy-efficient type of glass for lighting and heating was determined as low-E glass.

5.2. Evaluation of Results in Terms of Shading Systems

In this section, the effects of shading system differences were examined individually according to the energy consumption for lighting, heating, and cooling. The results of the very dark and very bright scenarios where the values are maximum and minimum were visualized. Except for these two scenarios, the results from other conditions were detected as similar.

When only glass was used for the shading system during simulations, annual energy consumption of lighting has the highest value with 61.4 Kwh/m² in reflective solar glass under very dark conditions. In terms of cooling energy consumptions, the lowest consumption was observed when green float glass was used under very dark conditions (see Figure 5. 3) with 36.3 Kwh/m².

When EVB 0° was used for the shading system during simulations, annual energy consumption of heating has the lowest value with 4.6 Kwh/m² in low-E glass under very dark conditions (see Figure 5. 3). In terms of lighting energy consumptions, the lowest consumption was observed when low-E glass was used under very bright conditions (see Figure 5. 4) with 36.4 Kwh/m².

When EVB 45° was used for the shading system during simulations, annual energy consumption of cooling has the highest value with 47.3 Kwh/m² in low-E glass under very dark conditions. In terms of lighting energy consumptions, the highest consumption was observed when green float glass was used under very dark conditions (see Figure 5. 3) with 63.8 Kwh/m².

When FRB was used for the shading system during simulations, annual energy consumption of lighting has the lowest value with 44.1 Kwh/m² in low-E glass under very bright conditions. In terms of heating energy consumptions, the highest consumption was observed when green float glass was used under very bright conditions (see Figure 5. 4) with 11.8 Kwh/m².

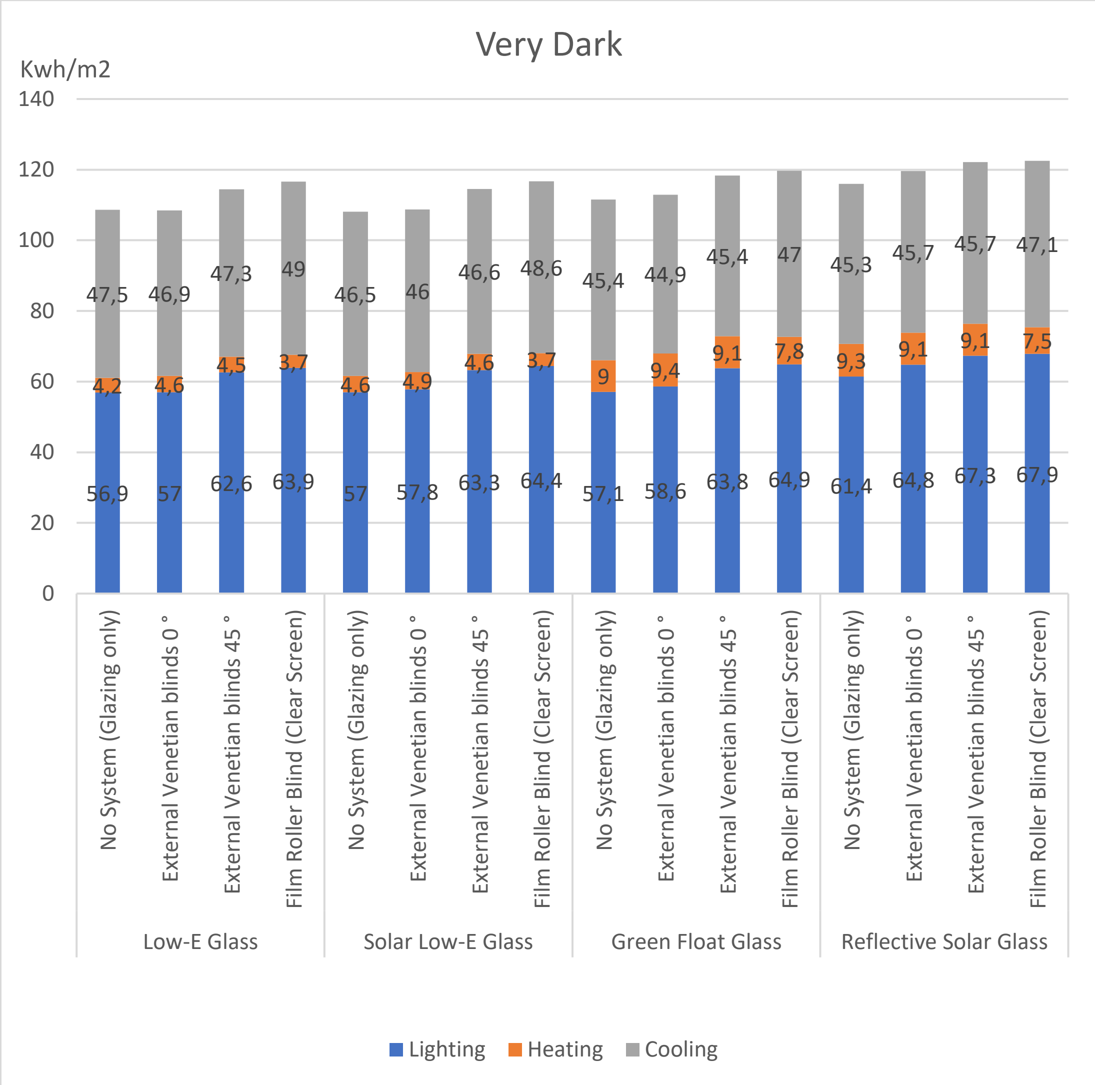


Figure 5. 3. In Very Dark Condition According to Shading System Annual Energy Consumption Lighting (L), Heating (H), Cooling (C)

All four shading options and their selected peak annual energy consumptions were given above. Since the other variables (glazing and interior color reflectances) were also significantly important on consumption values, evaluations regarding that were also made. For instance when EVB 0° was compared to the FRB shading system in low-E glass under very dark conditions the energy consumption for lighting was reduced by 10.8%. In the same glazing type under very dark conditions the energy demand for heating was decreased by 11.9% in the absence of a shading system according to an FRB. Similarly, in solar low-E glass, the energy consumed for cooling reduced by 5.3% in EVB 0° compared to FRB. Moreover, in green float glass under very dark conditions, energy consumption for lighting was reduced by 10.5% in the absence of a shading system according to EVB 45° (see Figure 5. 3).

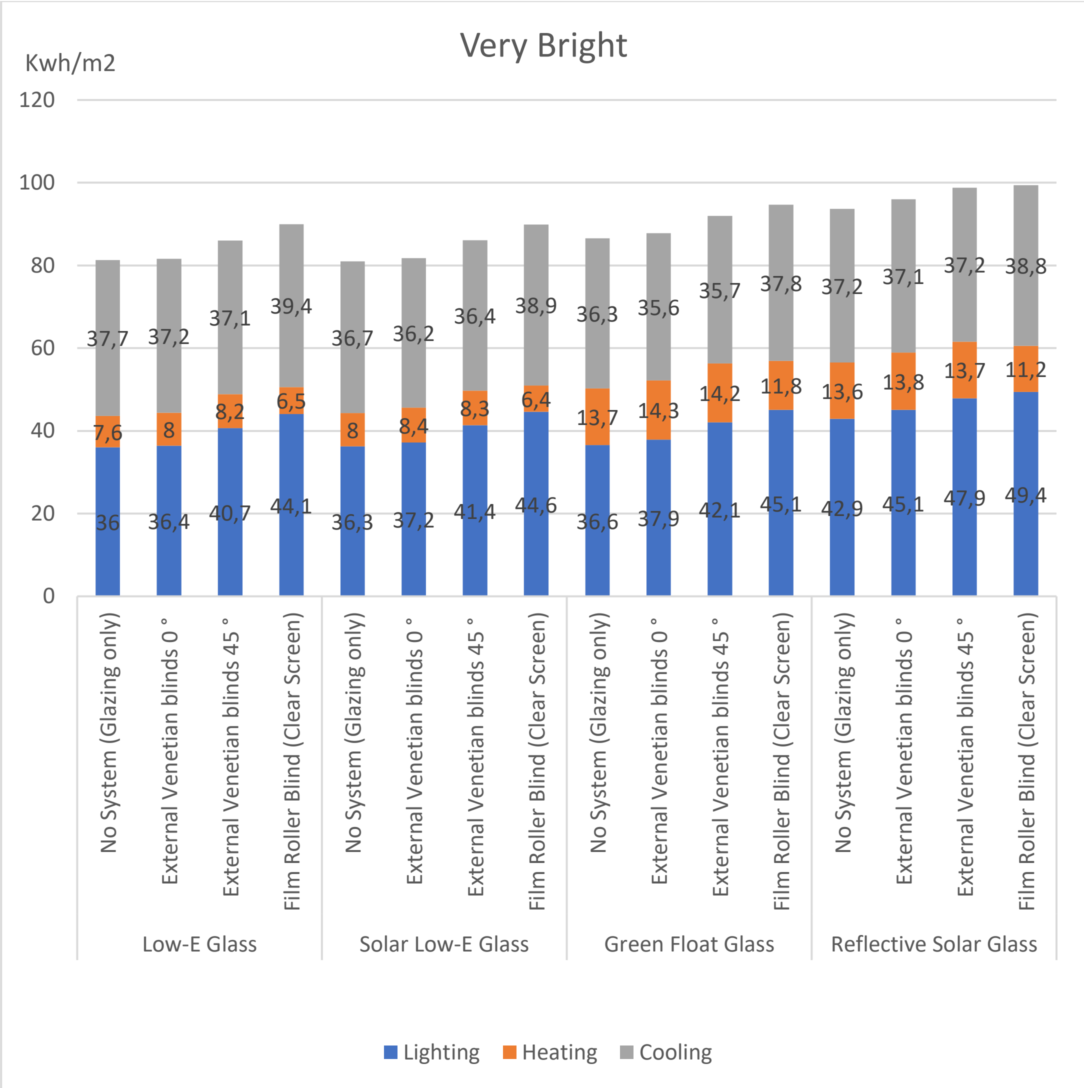


Figure 5. 4. In Very Bright Condition According to Shading System Annual Energy Consumption Lighting (L), Heating (H), Cooling (C)

When FRB was compared to the EVB 45° shading system in low-E glass under very bright conditions the energy consumption for heating was reduced by 20.7%. Similarly in green float glass under very bright conditions, energy consumption for lighting was reduced by 18.8% in the absence of a shading system compared to FRB. Moreover, in reflective solar glass under very bright conditions the energy consumption for cooling was equal to 37.2 Kwh/m² when using EVB 45° and without a shading system (see Figure 5. 4).

As a result of the scenarios, it was observed annual energy load affected by the changes in shading systems. It is possible to say that the most energy-efficient design for lighting is the case where there is no shading system and a film roller blind is used for heating energy consumption.

5.3. Evaluation of Results in Terms of Interior Surface Reflectance Values

In this section, the effects of surface reflectance values differences were examined individually according to the energy consumption for lighting, heating, and cooling.

In very dark conditions annual energy consumption of heating has the highest value with 9.4 Kwh/m² in green float glass and EVB 0° shading system. In terms of cooling energy consumptions, the lowest consumption was observed when green float glass and EVB 0° shading system was used (see Figure 5. 7) with 44.9 Kwh/m².

In dark conditions annual energy consumption of lighting has the highest value with 65.2 Kwh/m² in reflective solar glass and FRB shading system (see Figure 5. 8). In terms of heating energy consumptions, the lowest consumption was observed when in a solar low-E glass and FRB shading system was used (see Figure 5. 6) with 4 Kwh/m².

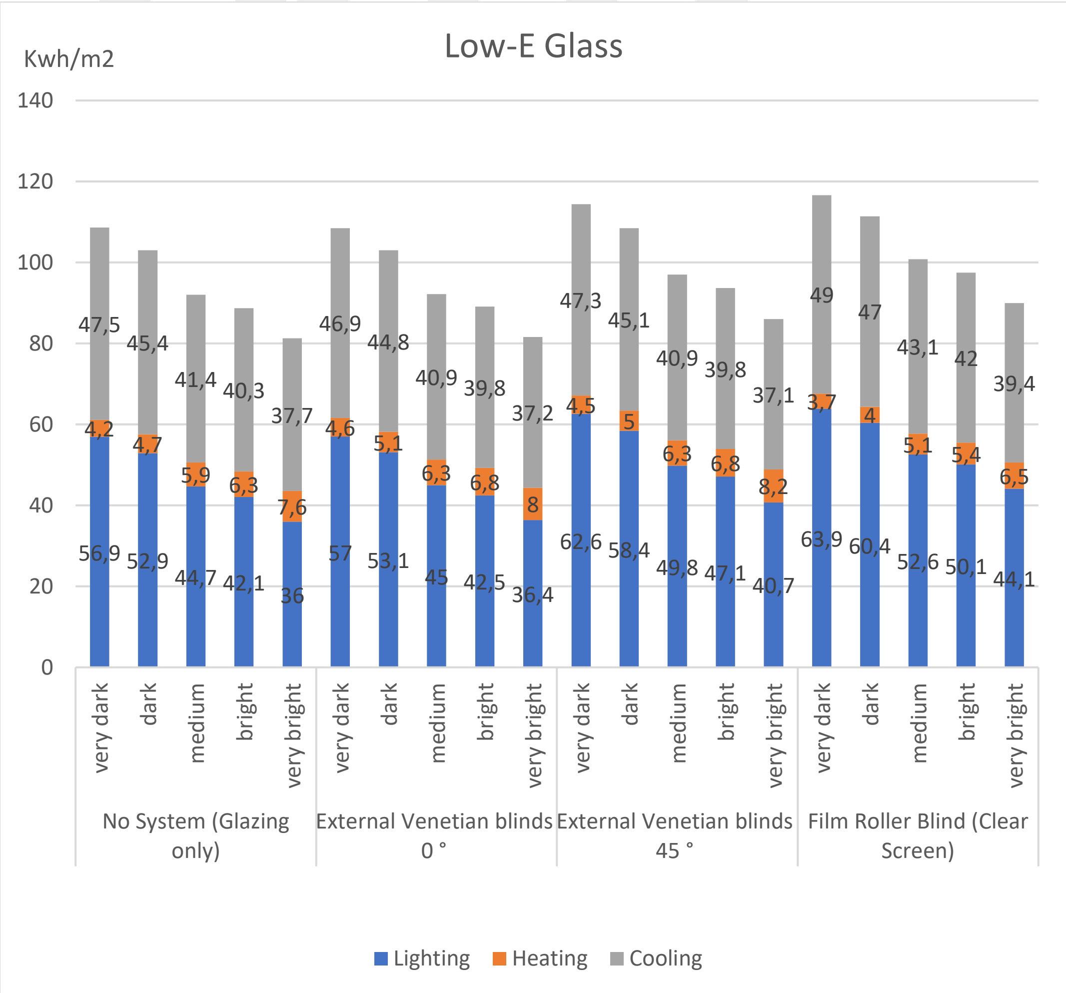


Figure 5. 5. In the use of Low-E Glass According to Reflection values Annual Energy Consumption Lighting (L), Heating (H), Cooling (C)

In medium conditions annual energy consumption of cooling has the lowest value with 39.2 Kwh/m² in green float glass and EVB 0° shading system (see Figure 5. 7). In terms of lighting energy consumptions, the lowest consumption was observed when in low-E glass was used and without a shading system (see Figure 5. 5) with 44.7 Kwh/m².

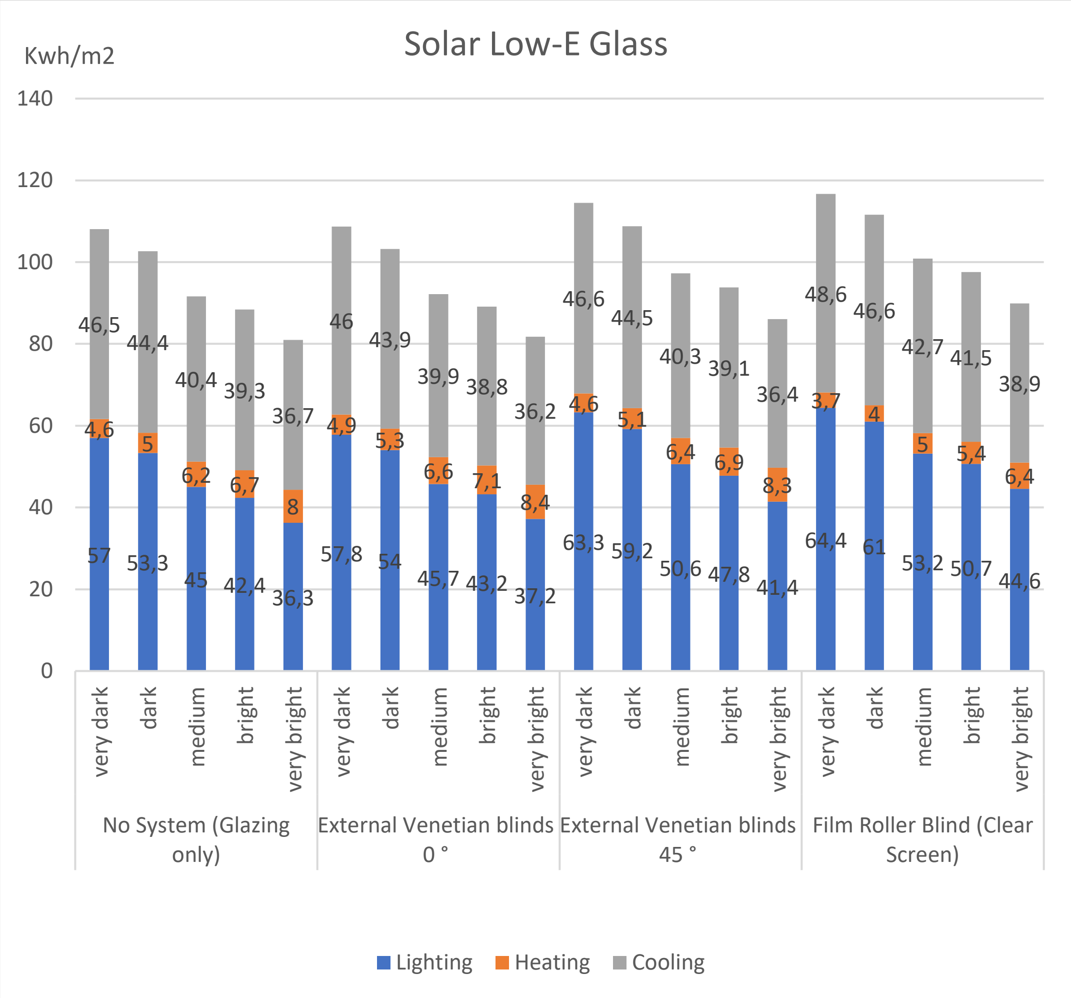


Figure 5. 6. In the use of Solar Low-E Glass According to Reflection values Annual Energy Consumption Lighting (L), Heating (H), Cooling (C)

In bright conditions annual energy consumption of cooling has the highest value with 42 Kwh/m² in low-E glass and FRB shading system. In terms of lighting energy consumptions, the lowest consumption was observed when in low-E glass was used and without a shading system (see Figure 5. 5) with 42.1 Kwh/m².

In very bright conditions annual energy consumption of lighting has the highest value with 49.4 Kwh/m² in reflective solar glass and FRB shading system (see Figure 5. 8).

In terms of cooling energy consumptions, the lowest consumption was observed when in green float glass and EVB 0° was used (see Figure 5. 7) with 35.6 Kwh/m².

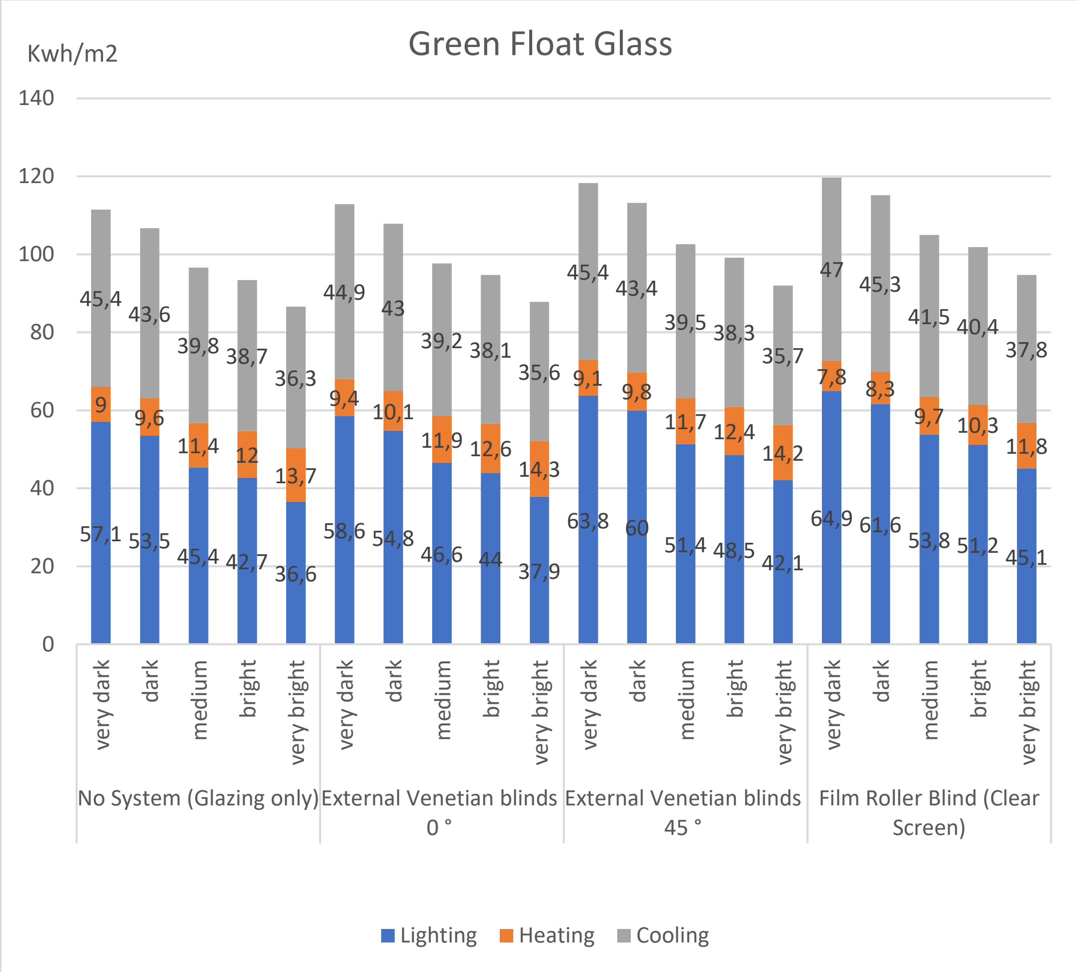


Figure 5. 7. In the use of Green Float Glass According to Reflection values Annual Energy Consumption Lighting (L), Heating (H), Cooling (C)

All five indoor surface reflectance values and their selected peak annual energy consumptions were given above. Since the other variables (glazing and shading systems) were also significantly important on consumption values, evaluations regarding that were also made. For instance when very bright condition was compared to very dark in low-E glass with no shading system the energy consumption for lighting reduced by 36.7%. In the same glazing type with EVB 0° shading element, the energy demand for heating decreased by 42.5% in very bright conditions compared to very dark conditions. Similarly in the EVB 45 ° shading element, the energy consumed for cooling was reduced by 4.6% in dark conditions compared to very dark. Moreover, in an FRB shading system under very dark conditions, the energy consumed for lighting was 27.5% more than in bright conditions (see Figure 5. 5).

When dark condition was compared to very bright conditions, heating energy consumption was reduced by 37.5% when the solar low-E glass is used with no shading system. Similarly, when dark condition was compared to the medium color reflectances, cooling energy consumption decreased by 9.1% with the EVB 0° shading element. For lighting purposes, very bright conditions saved 30% of energy compared to dark conditions in EVB 45° shading. Moreover, in FRB, the energy consumed for heating is 8.1% more in dark conditions than in the very dark (see Figure 5. 6)

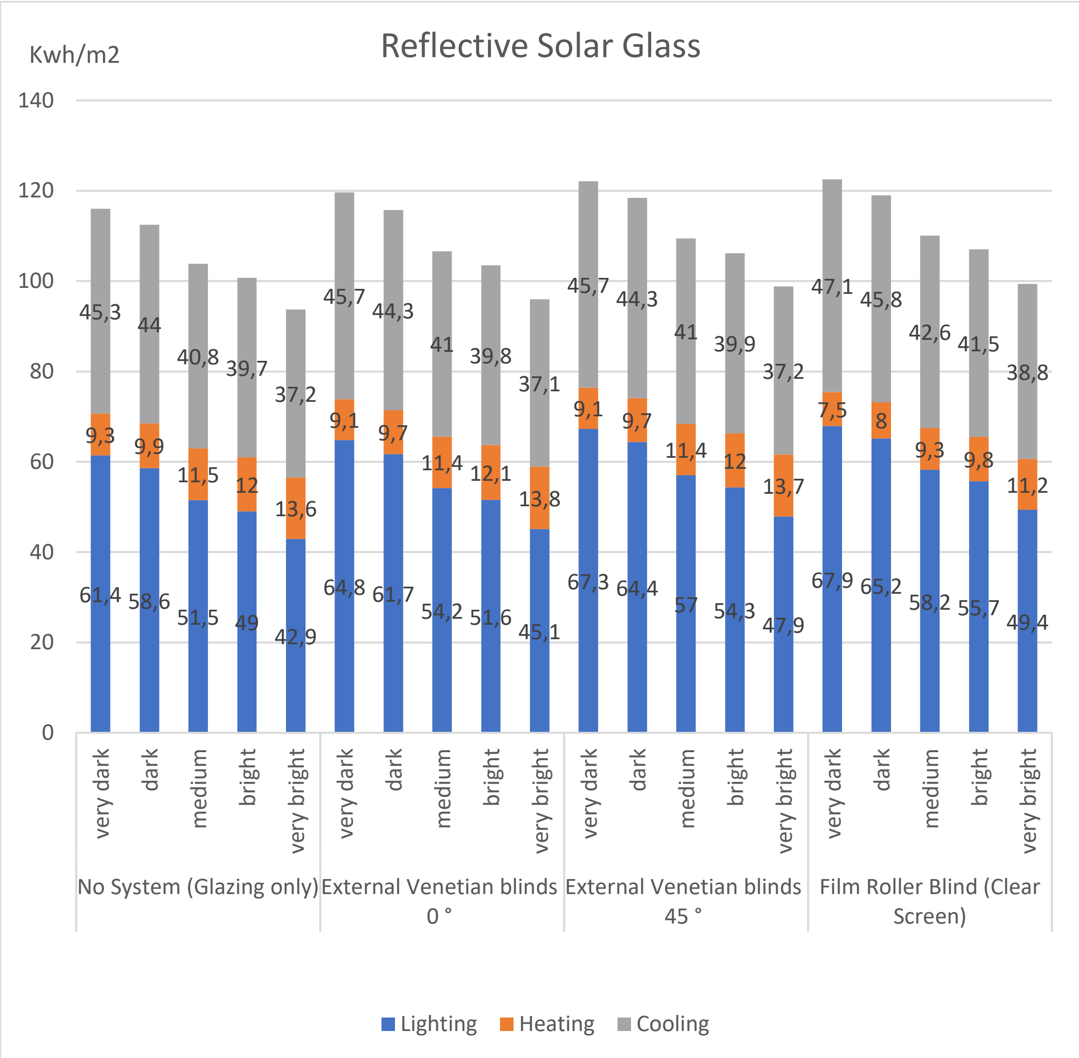


Figure 5. 8. In the use of Reflective Solar Glass According to Reflection values Annual Energy Consumption Lighting (L), Heating (H), Cooling (C)

As a result of the scenarios, it was observed that changes in the surface reflectance values cause differences in the annual energy load. The most energy-efficient results for lighting and cooling were achieved in very bright conditions and very dark conditions for heating.

5.4. Evaluation of Results in Terms of Total Annual Energy Consumption

Under the specified conditions, the case study room was simulated according to the parameters in Table 4. 1 using DALEC software. The total annual energy consumption of each scenario was shown below in Table 5. 1. The annual energy consumption of the scenarios varied between 81 to 122,5 kWh/m². The lowest amount of energy consumed annually was 81 Kwh/m², when there is no shading element, the interior surfaces have the highest reflectivity and the use of solar low-E glass. When the reflectivity value of the interior surfaces was very dark, the total energy consumption was the highest with 122.5 Kwh/m² in reflective solar glass and FRB shading system. The lowest energy consumption calculated during the year was 66.1% of the highest energy use.

Table 5. 1. Total Annual Energy Consumption (Kwh/m^2)

		Total Annual Energy Consumption (Kwh/m^2)			
IR	Glazing Type	No System (Glazing only)	External Venetian Blind 0	External Venetian Blind 45	Film Roller Blind (Clear Screen)
Very Dark	Low-E Glass	108.6	108.5	114.4	116.6
	Solar Low-E Glass	108.1	108.7	114.5	116.7
	Green Float Glass	111.5	112.9	118.3	119.7
	Reflective Solar Glass	116.0	119.6	122.1	122.5
Dark	Low-E Glass	103.0	103.0	108.5	111.4
	Solar Low-E Glass	102.7	103.2	108.8	111.6
	Green Float Glass	106.7	107.9	113.2	115.2
	Reflective Solar Glass	112.5	115.7	118.4	119.0
Medium	Low-E Glass	92.0	92.2	97.0	100.8
	Solar Low-E Glass	91.3	92.2	97.3	100.9
	Green Float Glass	96.6	97.7	102.6	105.0
	Reflective Solar Glass	103.8	106.6	109.4	110.1
Bright	Low-E Glass	88.7	89.1	93.7	97.5
	Solar Low-E Glass	88.4	89.1	93.8	97.6
	Green Float Glass	93.4	94.7	99.2	101.9
	Reflective Solar Glass	100.7	103.5	106.2	107.0
Very Bright	Low-E Glass	81.3	81.6	86.0	90.0
	Solar Low-E Glass	81.0	81.8	86.1	89.9
	Green Float Glass	86.6	87.8	92.0	94.7
	Reflective Solar Glass	93.7	96.0	98.8	99.4

In very dark conditions and using low-E glass, the total annual energy consumed reduced by 6.8% in FRB compared to EVB 0°. Under the same conditions with no shading system, the total energy demand decreased 0.4% in solar low-E compared to low-E glass. With an EVB 45° shading system and reflective solar glass, the total energy consumption was 23.5% more than very bright in very dark conditions (see Figure 5. 9).

In dark conditions and solar low-E glass, the total annual energy consumed reduced by 7.6% in the absence of a shading system compared to FRB. Under the same condition EVB 0° shading system, the total energy demand decreased 10.8% in solar low-E than reflective solar glass. In a green float glass and EVB 45° shading element, the total energy consumption was 14.1% more than bright conditions in dark conditions. (Table 5. 1).

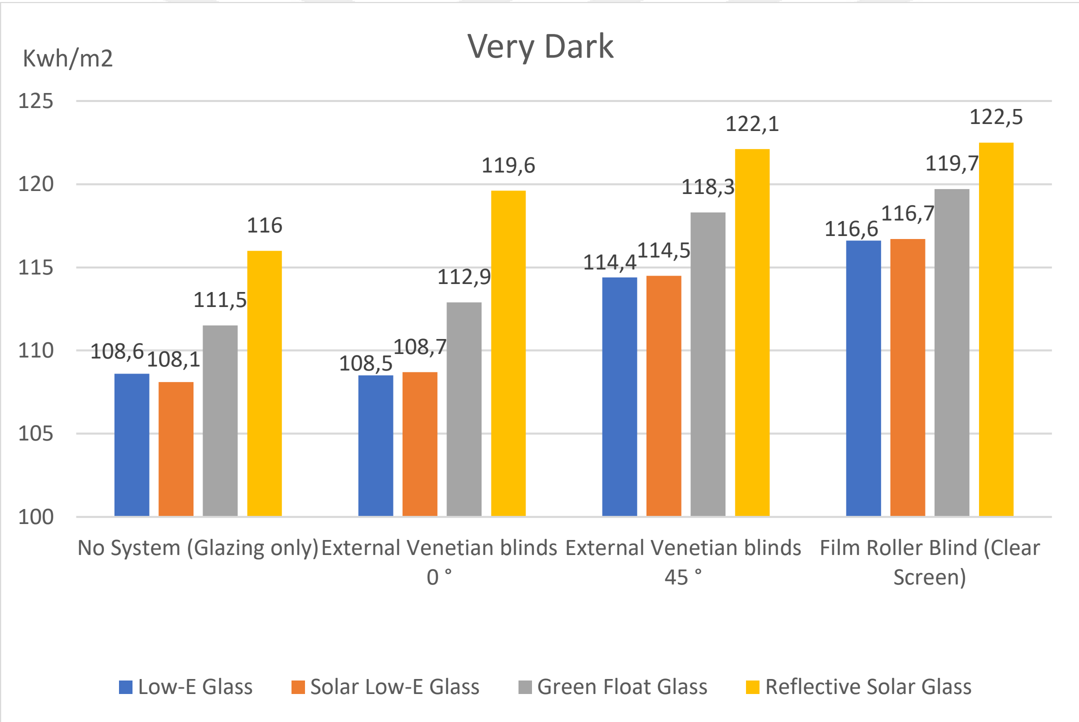


Figure 5. 9. Total Energy Consumption Graph Under Very Dark Conditions

Under medium conditions and green float glass, the total annual energy consumed reduced by 4.7% in the EVB 0° shading element compared to 45°. With the same condition and EVB 45° shading element, the total energy demand decreased 5.4% in low-E compared to green float glass. In FRB shading element and solar low-E glass total energy consumed reduced by 13.5% in the medium condition compared to the very dark (Table 5. 1).

Under bright conditions and reflective solar glass, the total annual energy consumed reduced by 5.1% in the absence of a shading system compared to EVB 45°. Under the same condition, in the FRB shading element, total energy demand decreased 4.7% in the green float glass compared to reflective solar glass. In the EVB 0° shading element and Low-E glass, the energy demand decreased 18% in bright conditions than very dark (Table 5. 1).

In very bright conditions and low-E glass, the total annual energy consumed reduced by 4.4% in the EVB 45° shading element compared to FRB. Under the same condition and no shading system, the total energy demand decreased 13.2% in low-E compared to reflective solar glass. In the EVB 0° shading system and green float glass, the total energy reduced 22.2% in very bright conditions than very dark (see Figure 5. 10).

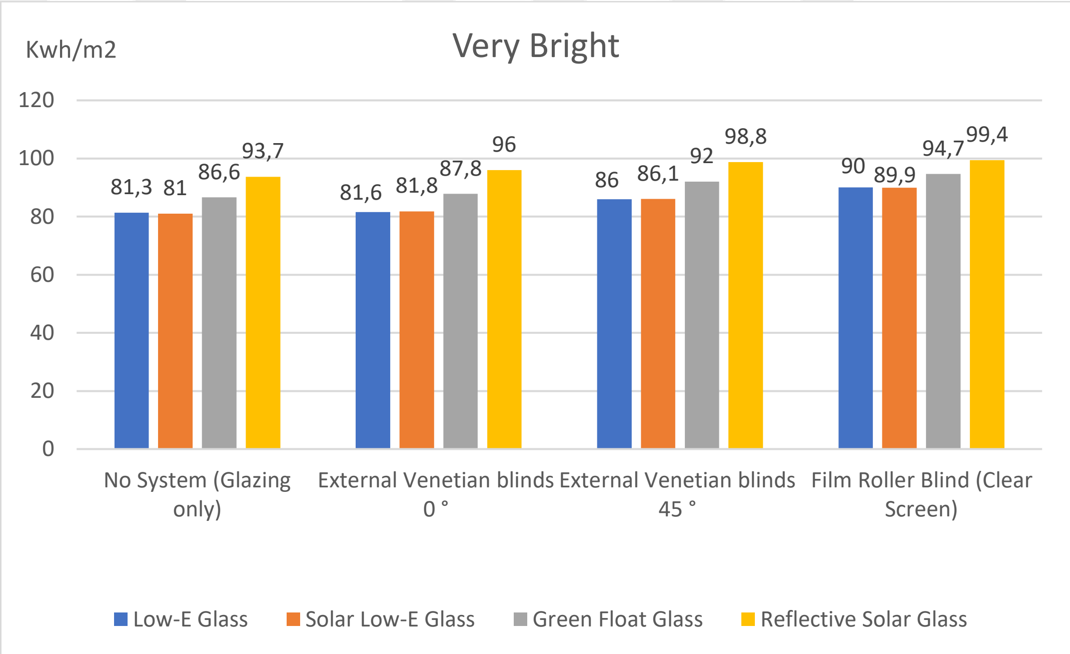


Figure 5. 10. Total Energy Consumption Graph Under Very Bright Conditions

The lowest total energy consumption was in the solar low-E glass without shading system and the highest energy in the reflective solar glass and FRB. As the interior surface reflectivity values increased, the total amount of energy consumed decreased. In all shading systems, the energy consumption was higher when reflective solar glass was used. In medium and bright conditions, energy consumption was equal for low-E and solar low-E glass when the EVB 0° shading system. It was equal under dark conditions for using a low-E glass EVB 0° and no shading system. Under very dark conditions in using low-E glass, the absence of shading was higher than using EVB

0°. As a result of the scenarios, annual energy consumption levels were affected by the changes in surface reflectance values, shading systems, and glazing types. The results of the very dark and very bright scenarios where the values are maximum and minimum were visualized. Under other conditions the results were parallel.

5.4.1. Evaluation of Results in Terms of Lighting

Annual energy consumptions of all eighty scenarios were evaluated above. In this section, only lighting energy consumption values were discussed. Considering the results obtained, the energy consumption for lighting generally has the largest share in the building's energy load. The energy consumed for lighting was the lowest for Low-E glass and the highest for reflective solar glass in all combinations.

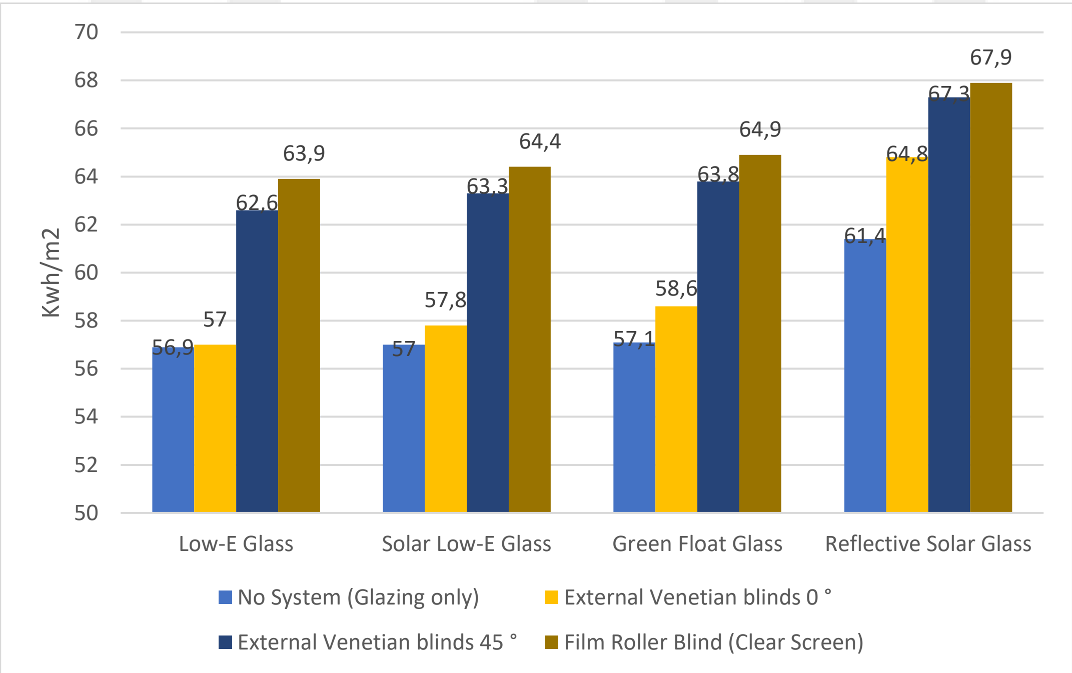


Figure 5. 11. Very Dark - Lighting Energy Consumption

Among all combinations, the highest energy consumption for lighting was 67.9 Kwh/m² in very dark (ceiling: 30%, wall: 20%, floor: 10%) with reflective solar glass and FRB shading system (see Figure 5. 11). The lowest energy consumption for lighting was 36 Kwh/m² in very bright conditions and low-E glass without a shading system (see Figure 5. 12).

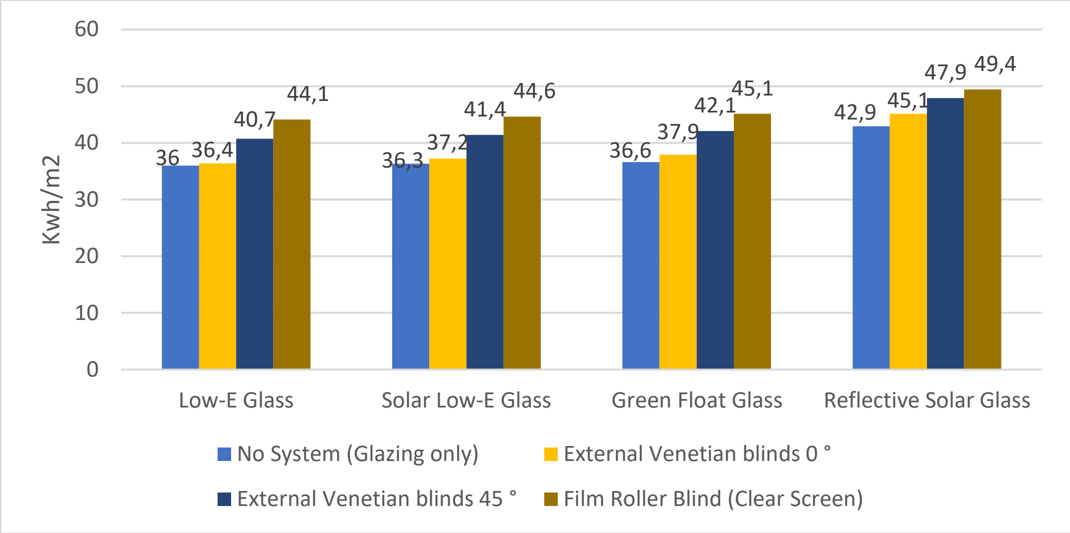


Figure 5. 12. Very Bright - Lighting Energy Consumption

As it is understood interior architectural factors affect energy consumption for lighting therefore by modifying those factors energy savings can be achieved. Especially changing the surface reflectance values has a significant role on energy consumptions of lighting.

5.4.2. Evaluation of Results in Terms of Heating

Annual energy consumptions of all eighty scenarios were evaluated above. In this section, only heating energy consumption values were discussed. Considering the results obtained, the lowest value in annual energy consumption is used for heating. In all cases, the energy consumed for heating was the least for Low-E glass. As the interior surface reflectivity increased, the energy used for heating increased.

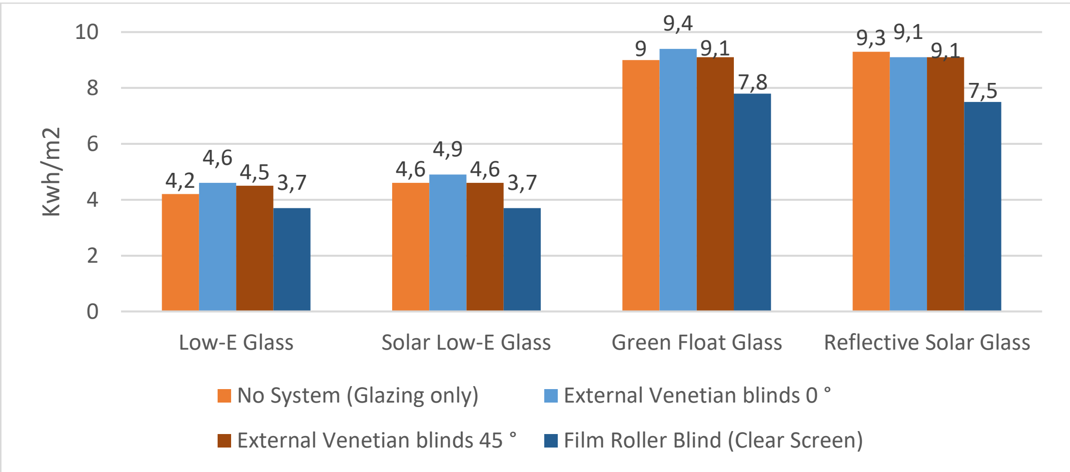


Figure 5. 13. Very Dark - Heating Energy Consumption

The lowest energy consumption for heating was 3.7 Kwh/m² in very dark conditions with a low-E and solar low-E glass and FRB shading system (see Figure 5. 13). Among all combinations, the highest energy spent on heating was 14.3 Kwh/m² in very bright conditions with green float glass and EVB 0° shading equipment (see Figure 5. 14).

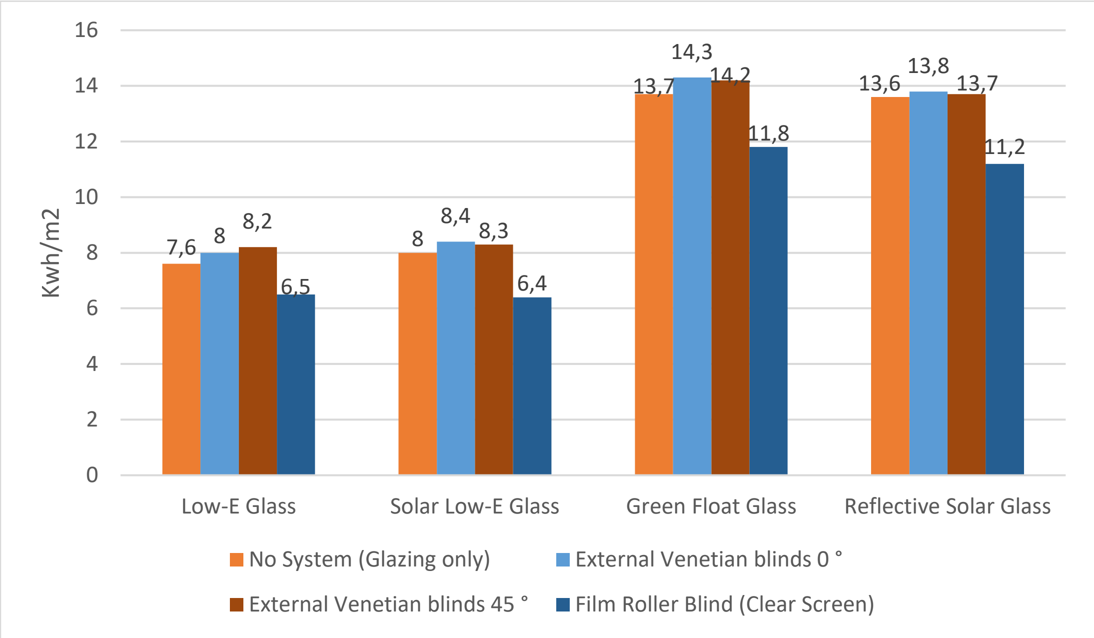


Figure 5. 14. Very Bright - Heating Energy Consumption

As can be seen from the results interior architectural factors affect energy consumption for heating therefore by modifying those factors energy savings can be achieved. In particular, the FRB shading system saved energy consumed for heating compared to other shading equipment. In contrast, reflective solar glass and green float glass cause an increase in energy consumed for heating compared to the other two types of glass.

5.4.3. Evaluation of Results in Terms of Cooling

Annual energy consumptions of all eighty scenarios were evaluated above. In this section, only cooling energy consumption values were discussed. The energy consumed for cooling was the most for Low-E glass in all cases. As the indoor surface reflectivity increases, the energy consumed for cooling decreases.

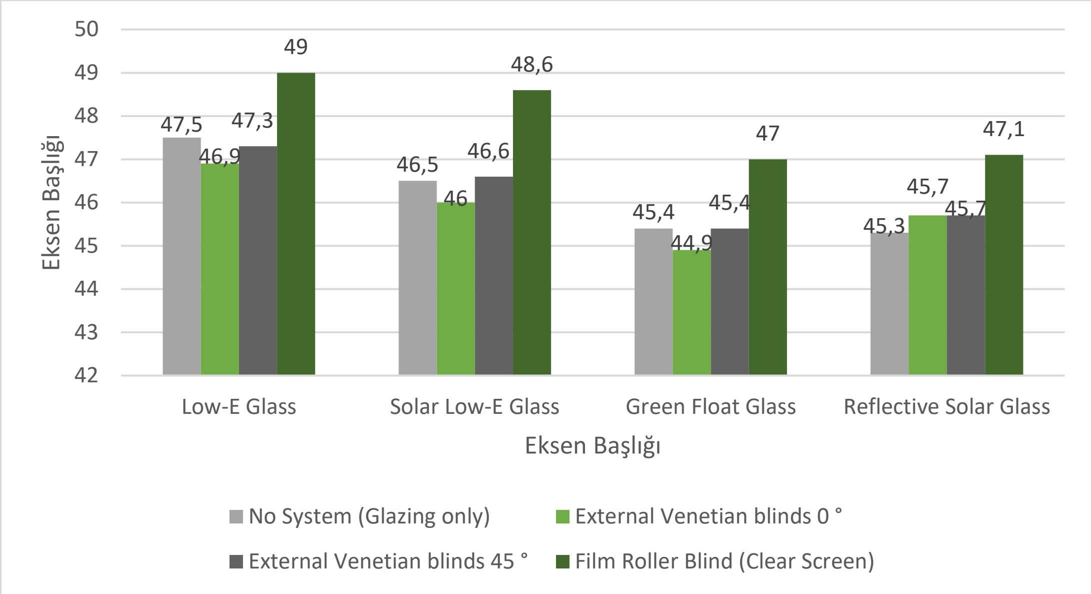


Figure 5. 15. Very Dark - Cooling Energy Consumption

The case where the energy consumed for cooling was the highest is 49 Kwh/m² in very dark conditions with low-E glass and FRB shading system (see Figure 5. 15). Among all combinations, the lowest energy spent on cooling was 35.6 Kwh/m² in very bright conditions with green float glass and EVB 0° shading equipment (see Figure 5. 16).

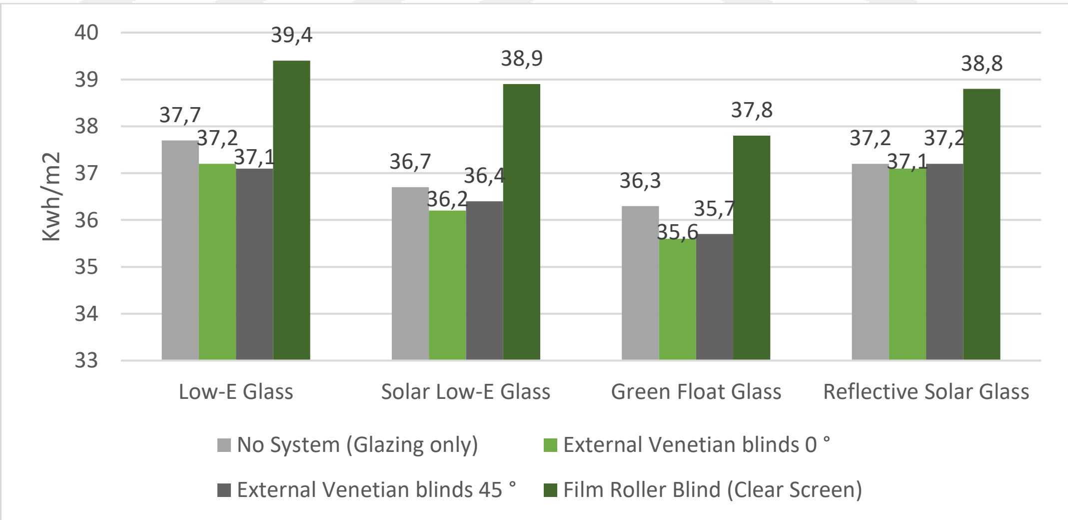


Figure 5. 16. Very Bright - Cooling Energy Consumption

As it is understood interior architectural factors affect energy consumption for cooling therefore by modifying those factors energy savings can be achieved. Especially the FRB shading system causes an increase in the energy consumed for cooling compared to other shading equipment.

Table 5. 2. Annual Energy Consumption Lighting (L), Heating (H), Cooling (C) (Kwh/m^2)

		Annual Energy Consumption (Kwh/m^2)											
		No System (Glazing only)			External Venetian blinds 0 °			External Venetian blinds 45 °			Film Roller Blind (Clear Screen)		
IR	Glazing Type	L	H	C	L	H	C	L	H	C	L	H	C
Very dark	Low-E Glass	56,9	4,2	47,5	57	4,6	46,9	62,6	4,5	47,3	63,9	3,7	49
	Solar Low-E Glass	57	4,6	46,5	57,8	4,9	46	63,3	4,6	46,6	64,4	3,7	48,6
	Green Float Glass	57,1	9	45,4	58,6	9,4	44,9	63,8	9,1	45,4	64,9	7,8	47
	Reflective Solar Glass	61,4	9,3	45,3	64,8	9,1	45,7	67,3	9,1	45,7	67,9	7,5	47,1
Dark	Low-E Glass	52,9	4,7	45,4	53,1	5,1	44,8	58,4	5	45,1	60,4	4	47
	Solar Low-E Glass	53,3	5	44,4	54	5,3	43,9	59,2	5,1	44,5	61	4	46,6
	Green Float Glass	53,5	9,6	43,6	54,8	10,1	43	60	9,8	43,4	61,6	8,3	45,3
	Reflective Solar Glass	58,6	9,9	44	61,7	9,7	44,3	64,4	9,7	44,3	65,2	8	45,8
Medium	Low-E Glass	44,7	5,9	41,4	45	6,3	40,9	49,8	6,3	40,9	52,6	5,1	43,1
	Solar Low-E Glass	45	6,2	40,4	45,7	6,6	39,9	50,6	6,4	40,3	53,2	5	42,7
	Green Float Glass	45,4	11,4	39,8	46,6	11,9	39,2	51,4	11,7	39,5	53,8	9,7	41,5
	Reflective Solar Glass	51,5	11,5	40,8	54,2	11,4	41	57	11,4	41	58,2	9,3	42,6
Bright	Low-E Glass	42,1	6,3	40,3	42,5	6,8	39,8	47,1	6,8	39,8	50,1	5,4	42
	Solar Low-E Glass	42,4	6,7	39,3	43,2	7,1	38,8	47,8	6,9	39,1	50,7	5,4	41,5
	Green Float Glass	42,7	12	38,7	44	12,6	38,1	48,5	12,4	38,3	51,2	10,3	40,4
	Reflective Solar Glass	49	12	39,7	51,6	12,1	39,8	54,3	12	39,9	55,7	9,8	41,5
Very Bright	Low-E Glass	36	7,6	37,7	36,4	8	37,2	40,7	8,2	37,1	44,1	6,5	39,4
	Solar Low-E Glass	36,3	8	36,7	37,2	8,4	36,2	41,4	8,3	36,4	44,6	6,4	38,9
	Green Float Glass	36,6	13,7	36,3	37,9	14,3	35,6	42,1	14,2	35,7	45,1	11,8	37,8
	Reflective Solar Glass	42,9	13,6	37,2	45,1	13,8	37,1	47,9	13,7	37,2	49,4	11,2	38,8

CHAPTER 6
CONCLUSION

One of the building types with the highest share in energy consumption is healthcare buildings. Daylight is very important in these building types to reduce energy consumption and ensure indoor comfort conditions. The presence of appropriate daylight in hospital rooms; Along with visual function, it affects human health and psychology, patient recovery time, healthcare staff performance, and annual energy consumed for lighting, heating and cooling.

There are environmental and architectural parameters affecting daylight access in the interior. Environmental parameters are related to the geographical features of the building such as orientation, obstructions, sky type, location. In addition, there are architectural parameters decided by designers that affect daylight accessibility. Within the scope of this study, glazing type, shading system and interior surface reflectance values, which are among the architectural parameters that affect the accessibility of daylight in the interior, are discussed. Daylight is taken into the interior from the openings of the building. Windows in particular play an important role in daylight management. The difference in the glazing types in the windows affects the daylight accessibility as it changes the permeability value. Using glazing types suitable for environmental conditions provides significant savings in indoor air conditioning. Similarly, the presence of shading systems in these openings prevents glare problems for the user. In addition, it minimizes overheating in hot climates. For this reason, it is effective in saving energy used for cooling. One of the most important factors affecting indoor daylight is surface reflectance values. Light-colored surfaces are important in natural lighting as they reflect more daylight. As the use of daylight increases in indoor lighting, the need for artificial lighting will decrease, and the negative effects of the building on the environment will be reduced. To examine the effect of these architectural parameters that change the accessibility of daylight in the interior; Using the DALEC software, energy consumption simulations of a south-facing hospital room in Izmir were made for lighting, heating, and cooling in line with the options offered by the program.

When the sample room was simulated for changing architectural parameters the annual energy consumption for lighting, heating and cooling changed significantly. Though the detailed evaluations are given in Chapter 5, in Table 6. 1 the minimum and maximum values for each are summarized.

Table 6. 1. Lowest and Highest Annual Energy Consumption Lighting, Heating, Cooling

	Combination	Kwh/m^2	Shading System	Glazing Type	Reflection
Lighting	Lowest	36	No System (Glazing only)	Low-E Glass	Very Bright
	Highest	67,9	Film Roller Blind (Clear Screen)	Reflective Solar Glass	Very Dark
Heating	Lowest	3,7	Film Roller Blind (Clear Screen)	Solar Low-E, Low-E Glass	Very Dark
	Highest	14,3	External Venetian blinds 0°	Green Float Glass	Very Bright
Cooling	Lowest	35,6	External Venetian blinds 0°	Green Float Glass	Very Bright
	Highest	49	Film Roller Blind (Clear Screen)	Low-E Glass	Very Dark

In designs using Low-E glass and solar low-E glazing types, it was observed that there are equations and very small differences in the amount of energy consumed for lighting, heating and cooling. Results were similar for other shading system combinations and reflection values. Therefore, it was found that the choice of solar low-E glass and Low-E glass does not have a radical effect on the energy consumed for lighting, heating and cooling.

In the designs using green float glass and reflective solar glazing types, it was observed that there is no big difference in the energy consumed for heating. Results were similar for other shading system combinations and reflection values. Therefore, it was found that these two glass choices do not have a radical effect on the energy consumed for heating. However the most energy-efficient glazing type for lighting and heating was low-E glass and green float glass for cooling.

In designs using EVB 0° and 45° shading systems, equations and small differences were observed in the energy consumed for heating and cooling. Results were similar for other glazing type configuration and reflection values. For this reason, it was demonstrated that the choice of EVB 0° and 45° shading system does not make a big difference in heating and cooling loads. The most energy-efficient shading system for lighting was only glazing, FRB for heating, EVB 0° shading equipment for cooling.

In all design combinations, as the interior surface reflectance values increase (from very dark to very bright), the energy consumed for lighting and cooling decreases and increases for heating. In parallel with this, the total annual energy consumed decreases. In addition, the parameter that changes the energy consumption the most for lighting, cooling, and heating is the interior surface reflectance values. The most energy-efficient surface reflectance value in energy consumed for lighting and cooling is very bright and very dark conditions for heating.

The results of scenarios should be evaluated considering some limitations. For example, the selected patient room is one of the most common single patient room layouts and is located in İzmir on the south façade measuring 3.66x6.99x3m. Different room sizes, locations, and orientation can produce different results. Another limitation of the research is related to the software in which the simulation study is performed. Among the selected architectural parameters, the interior surface reflectance values are the most extreme values determined by the DALEC software and are valid only for walls, ceilings and floors. Moreover, the suitability of these values in terms of design criteria has not been taken into account. Other reflective furniture and objects in the interior were not included in the simulation results. Similarly, shading systems whose effects are examined are limited to the parameters provided by the DALEC software. Different indoor reflectance values and shading systems may cause different results. Each value to be selected in energy consumption simulations is reflected in the results. Since a scenario cannot be created for each value, some choices have been made within the scope of this study. For example, four glazing types given in chapter four were selected for the window type, while four different shading systems provided by DALEC software and five different indoor surface reflectance values offered by DALEC were selected for shading. The values used for this simulation are shown in detail in Table 4. 1. It should be noted that each value used other than the specified values will differentiate the results.

The most effective scenario in terms of total energy consumption is the situation where there is no shading in the use of solar low-E glass type in very bright conditions. Although this combination is the most efficient scenario, user comfort was not evaluated in the simulations. In this study, glare indexes of the patient room were not simulated. Within the scope of further studies, the results can be detailed by considering factors such as user comfort and glare in the interior.

According to the simulation results of eighty different scenarios of the case study prepared using different architectural parameters, it was concluded that the most effective architectural parameter in energy consumption is interior surface reflection values. However, the compatibility of the interior surface reflectance values specified by DALEC with the architectural design criteria is debatable. Architects, designers have to consider the consequences of their decisions and wise decisions should be given in the early phases of design.

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