Journal of Contemporary Technology and Applied Engineering (JCTAE)
Home Page: https://jctae.journals.ekb.eg/
Published by: Faculty of Engineering, Kafrelsheikh University

Volume: 3 Issue: 2 Year: 2025
Pages: 82 – 92
DOI: 10.21608/jctae.2025.360965.1043

Print ISSN: 2812-5797
Online ISSN: 2812-5800

ENERGY EFFICIENCY OF HOSPITAL PATIENT ROOMS USING AGTS AND SHADING SYSTEM – CASE STUDY: EMERGENCY HOSPITAL, KAFR EL SHEIKH UNIVERSITY, EGYPT

Received: 16-02-2025
Accepted: 25-02-2025

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ABSTRACT. The global issue of energy consumption in buildings is great importance. In general, healthcare buildings are among the most energy-intensive categories of structures. The majority of hospital space is devoted to patient accommodations, which require a substantial quantity of energy to maintain climate control through heating and ventilation. The external walls of patient rooms are the most critical component of the exterior surfaces of these buildings in order to reduce energy consumption. The provision of daylight and the ability to view the outside can substantially contribute to the healing process, as well as the reduction of suffering and the duration of hospital stays. Contemporary structures are becoming more prevalent with fully glazed facades. Further, they are desired for hospitals where it is believed that more connected to external views will improve the health and well-being of patients. Nevertheless, the utilization of wide windows may occasionally result in a negative impact on the energy consumption of a building. This study aimed to put a proposed strategy to improve energy performance in patient room by, integrate intelligent glazing and shading devices. Allowing the window to remain more hours in a clearer state to achieve the balance of reduction of energy consumption and achievement of proper day-light distribution in patient room. To test this, intelligent glazing material (AGT_T) was identified and modelled with horizontal shading device. A typical patient room located in emergency hospital in Kafr El sheikh, Egypt with a southern orientation and fully glazed southern wall was investigated using design builder and energy plus software to make the simulation. The results showed that reduction of energy consumption of applied AGT_T glass and the horizontal shading devices reached to 15.9% as compared to existing state.

KEYWORDS: Healthcare buildings; Hospitals; Patient room; AGTs; Energy saving; Shading system; Design Builder.

1. INTRODUCTION

Healthcare buildings require substantial energy continuously for illumination, ventilation, and the operation of medical equipment. So, there is increasing apprehension regarding the sustainability of energy consumption by healthcare buildings globally [1]. Hospital patient rooms, operating continuously throughout the year, necessitate exceptionally high requirements for space heating and cooling [2]. Due to their typical location along the building's perimeter to maximize lighting and views, patient rooms constitute a significant proportion of the hospital's external surface area. This factor leads to elevated energy usage, which increased with the building envelope's age [3]. In addition to accounting the most vulnerable component of the envelope, window dimensions have consistently posed a significant challenge in architectural design, owing to their negative impact on the building's heating and cooling needs. Wider windows, equipped with suitable low-emission coatings, may diminish thermal transmission losses during winter and solar gains in summer. Furthermore, the increased influx of natural sunshine into the room diminishes electricity use for lighting by up to 25% [2]. A substantial body of literature has shown that exposure to natural light and views of nature significantly enhance the psychophysical well-being of both patients and staff [4,5]. Patients in rooms with enhanced natural lighting report reduced discomfort, require fewer analgesics [6]. Furthermore, exposure to natural light might enhance staff vigilance and reduce stress levels [7]. Enhancing care delivery efficiency, decreasing the patient Average period of stay, and minimizing hospital energy use can significantly lower hospital expenses through increased solar exposure [6]. Nevertheless, only a limited number of studies have thoroughly examined the impact of glass type, dimensions, and orientation on the energy efficiency of patient rooms. Therefore, the aim of the work was to present a proposal for the optimal use of a type of glass with horizontal shading to improve the energy performance of the patient room by adopting wider windows.

2. HEALTHCARE BUILDINGS AND ENERGY

Healthcare buildings have a unique status due to their continuous operation, year-round. Hospitals exhibit substantial energy consumption due to lighting, air-conditioning systems, medical equipment, general workplace devices, elevators, and heating and ventilation systems. HVAC (heating, ventilation, and air conditioning) systems account for the largest energy consumption rates in hospitals, ranging from 30% to 65%, followed by lighting systems, which use 30% to 40% [8,9].

Various design principles may be used to optimize energy flows in healthcare buildings. Its diverse methodologies may be used to diminish energy utilization. As seen in Fig. 1, This subitem encompasses two distinct components and focuses on strategies derived from literature pertaining to healthcare buildings. The first subitem addressed design considerations, focusing on aspects directly associated with the architectural project, including site location, materials, passive heating and cooling techniques, windows, and glazing, among others. The last subitem addressed the use of renewable energy sources, including solar systems, wind turbines, and geothermal energy [10]. Hospital spaces are varied, including patient units, diagnostic and treatment facilities, non-clinical areas, general services, and other spaces. Patient units are regarded as important spaces inside hospitals, constituting a significant amount of the conditioned floor space in contemporary healthcare buildings [11].

2.1. PATIENT ROOM AND WWR

Patient rooms exhibit substantial energy use for heating and cooling, attributed to the need for elevated ventilation rates and more stringent microclimatic control standards [12]. The exterior walls of patient rooms constitute the predominant portion of the structure's external surface area. Windows may substantially enhance the healing process, alleviate pain, and decrease hospital stay duration by allowing daylight entry and providing an exterior view. Nonetheless, they may also adversely impact the energy usage of these structures. The window-to-wall ratio (WWR) is the external wall surface area that is comprised of glazing (windows) and influences several building attributes. The dimensions of a window provide a physical and visual link to the outside and influence the environmental effects related to material use. It significantly influences the equilibrium between daylight and energy [13].

Based on patient room size, window sizes should be carefully examined. Patients' rooms may have a wide room depth and a small exterior wall surface area, or a greater surface area and a shallower workspace. Patient room windows should limit sun penetration, reduced warming, and enhance daylighting and exterior view. the aim is reducing energy use while preserving comfort and quality health care [13]. A study was conducted in Cairo using simulation the energy and daylighting performance of three patient room designs. For each room design, Window-to-Wall Ratios (WWRs) were tested. Also recognized were balanced WWRs that meet energy and daylighting standards. This study found that in patient rooms with design c, WWR is 30:40% and will increase energy usage if broader [13]. Table 1 lists the WWRs suggested for each patient room design.

Another research examines how window sizes and glass affect hospital patient room heating and cooling energy consumption. To determine the best glazing options and energy savings from bigger openings. Different commercial glazing systems were simulated. In Bologna, Italy, rooms with four orientations, the authors tested the energy efficiency of a base case window with 25% Window-to-Wall Ratio (WWR) and a wall-to-ceiling window with 77% WWR. The most relevant energy demands for each place must be determined using meteorological data. The findings show that a city with climatic data like Bologna requires glazing types with 1 to 2 Wm-2K-1 U-value and g-value around 0.55. Results revealed that bigger windows with proper glass reduce heating and cooling energy [14].

Sadek and Mahrous suggest adaptive glazing technologies (AGTs) that adjust their optical and thermal properties in response to environmental factors for fully glazing walls [15]. This Cairo hospital case study examines seven AGT kinds. This paper examined a rarely considered approach for integrating shading devices with full-height intelligent glazing technologies to balance glazing performance, focusing on improving visibility outside the building while maintaining energy consumption and day lighting availability. Energy performance for seven AGTs was initially simulated separately in a typical southern-oriented Cairo hospital waiting room. To test performance improvements, three shading devices were mixed with each AGT. AGTs reduced yearly energy usage by 17.25% to 56% compared to the basic scenario. The lowest energy consumption was recorded by AGT_T (41.29 kWh/m2-yr) and AGT_EC1 (52.59 kWh/m2-yr). In comparison to the basic scenario, the energy savings for both glazing types were 56% and 44%, respectively. The horizontal shading contribution to the most efficient glazing (AGT_T and AGT_EC1) varied between 6.8% and 16% in extra savings, respectively. The use of This can be noted in the increased number of hours that the AGTs spent in clearer states [15].

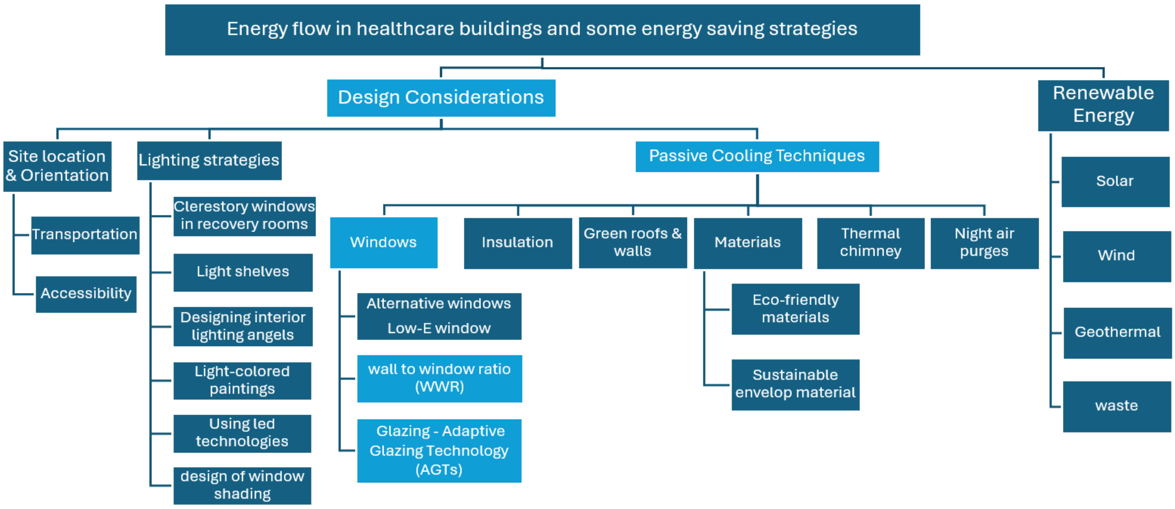
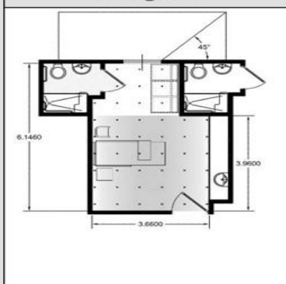
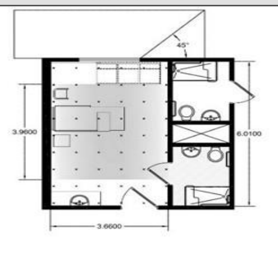
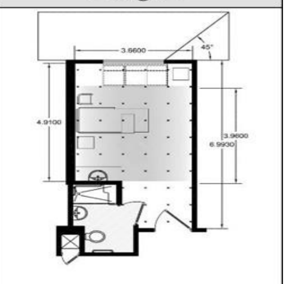


*Fig. 1. Energy flows in healthcare buildings [**Source**: Authors].*

Table 1. Recommended WWR for patient room designs [13]

	Design A	Design B	Design C
Patient Room Designs			
Energy	**40% - 90%**	**30% - 45%**	**30% - 40%**
Daylighting	**70% - 90%**	**30% - 90%**	**30% - 90%**
Balance	**70% - 90%**	**30% - 45%**	**30% - 40%**

3. ADAPTIVE GLAZING TECHNOLOGY (AGTS)

Intelligent or adaptable glazing technologies (AGTs) are new sun control systems that have significant promises to enhance visual and thermal comfort in buildings. AGTs possess the ability to dynamically alter their optical and thermal characteristics based on fluctuations in several governing factors, including thermal load, surface temperature, and sunlight, as seen in Figs. 2 and 3. These modifications allow the window to prevent an excessive amount of solar radiation and superfluous light from entering by progressively transitioning from a clear to a dark/tinted state, hence enhancing environmental comfort and diminishing the building's energy requirements [15].

A broad variety of current intelligent glazing choices are available, including electrochromic, gasochromic, photovoltaic integrated glazing, thermochromic, liquid crystal devices, spectrally selective solar control devices, and suspended particle devices. Although these products operate similarly via a self-dimming technique, their ultimate performance varies depending on the material technical characteristics such as overall heat transfer coefficient (U-value), visible transmittance (Tv), and solar heat gain coefficient (SHGC). Other important aspects include the switching range between clear and dark states, as well as the selected parameters that regulate their functioning [17].

The most effective AGTs material for reducing energy usage is AGT_T glass [15], which comprises a triple glazing unit (sageglass). The properties of AGT_T glass are shown in Table 2. The primary element of AGT is SageGlass sr2_60 (dynamic glass). Sage Glass Classic uses electrochromic technology to consistently color the whole window glass in harmony with sunlight, so improving occupant comfort while preserving a connection to the outdoors. Sage Glass has four distinct hue states: clear, light, medium, and full [18], as seen in Table 3 and Fig. 4.

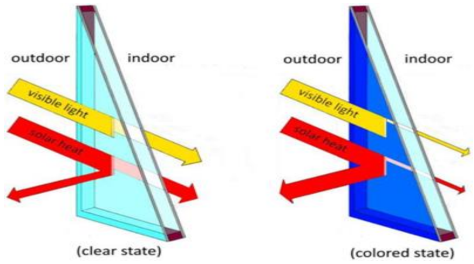


Fig. 2. Typical smart windows operating modes [16]

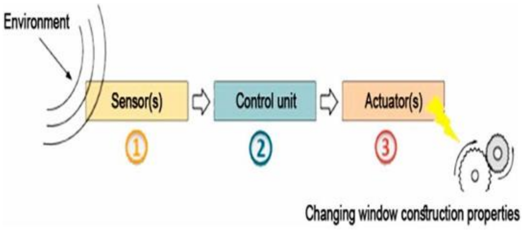


Fig. 3. Components for controlling dynamic window construction [15]

Table 2. Visual and thermal specifications of applied AGTs [15]

Visual and thermal specifications of the applied AGTs.

AGTs code	AGTs description	AGT Centre properties			Window components_Glass (GL) and Gaps				
		U-value W/m²k	SHGC range 0-1	Tv range 0-1	GL1	GAP1	GL2	GAP2	GL3
AGT_D.G	Double-glazing unit (Sage glass)	1.62	0.43	0.64	Sage Glass_ classic_7_64	Argon	Clear_6	–	–
AGT_EC1	EC with low-SHGC	1.67	0.32	0.45	Clear_3	Air	SageGlass_7_SR2	–	–
AGT_EC2	EC with high-SHGC	1.57	0.41	0.60	SageGlass7_sr2_60	Argon	Clear_3	–	–
AGT_P	Pleotint glazing	2.47	0.51	0.29	Suntuitive_05C	Argon	Clear_3	–	–
AGT_T	Triple-glazing unit (Sage glass)	1.11	0.41	0.53	Clear_6	Air10%/ Argon90%	SageGlass7_sr2_60	Air10% Argon90%	Clear_6
AGT_TC	Thermochromic glazing (TC)	2.66	0.22	0.49	Thermochromic2_24	Air	Clear_3	–	–
AGT_TC (b-in)	Thermochromic glazing (TC) built in Energy Plus as example file	1.60	0.42	0.52	Built in Energy Plus as example file				

Table 3. The properties of switching states of SageGlass clear with SR2.0 [18]

SageGlass Clear with SR2.0

6 mm Clear with SR2.0, 0.76 mm PVB, 2.2 mm SageGlass, 10 mm air space with 90% Argon fill, 6 mm Clear

Level of Tint	%Tvis	%Rf Ext.	%Rb Int.	SHGC	U-factor Btu/hr.ft²°F	%Tuv	%Tdw-K	STC	OITC
Clear State	60%	16%	15%	0.41	0.29	<1%	14%	37	30
Light Tint	18%	10%	10%	0.16	0.29	<1%	5%	37	30
MediumTint	6%	10%	9%	0.11	0.29	<1%	2%	37	30
Full Tint	1%	11%	9%	0.09	0.29	<1%	1%	37	30


Fig. 4. Switching states of SageGlass [18]

4. METHODOLOGY

The energy efficiency of the building was estimated using Design Builder software. It is one of the most convenient in the field of environmental modeling [19]. According to literature it is valid in Egypt, in its analysis, it depends on the Energy Plus software, which brings the findings closer to reality than any other software. Data may simply be added to construct a model of the building to acquire precise data and a realistic simulation. Then the software analyzes the data to acquire actual information about the entire energy use in the building, whether for cooling, heating, lighting, or electrical appliances. A healthcare building in Kafr

El-Sheikh city, located in Kafr El-Sheikh governorate, was selected for a case study. The glass types in the southern-facing glass facades of a patient room were altered, and the effect on energy consumption efficiency was analyzed using Design Builder software.

4.1. Case Study Description

The case study locates in Kafr El Sheikh Governorate, located in the northern region of the country, along the western branch of the Nile. The climate is characterized by hot and humid summers, and cold, dry, and windy winters. This building operates as an emergency hospital at Kafr El Sheikh University. The hospital has 78 patient rooms: 21 in the north, 18 in the south (9 with a window-to-wall ratio (WWR) of 100% and 9 with a window-to-wall ratio of 40%), and 39 in the west. The southern patient rooms constitute 23% of the overall room count, as seen in Fig. 5.

The research selected a southern patient room with 100% WWR as a case study to implement the AGTs glass and evaluate the effects on the current state of as seen in Figure 6. The selected southern patient room was designed according to design c, as referenced in prior literature, and includes an indoor bathroom. The literature research indicates that to reduce energy consumption, the window-to-wall ratio (WWR) of patient room design C should be 30:40%, but the patient room in the case study has a window-to-wall ratio of 100%. The study aims to minimize energy use while creating a balance with daylighting by using AGT-T glass, since literature suggests that AGT-T is the most effective replacement glass for reducing energy usage [15].

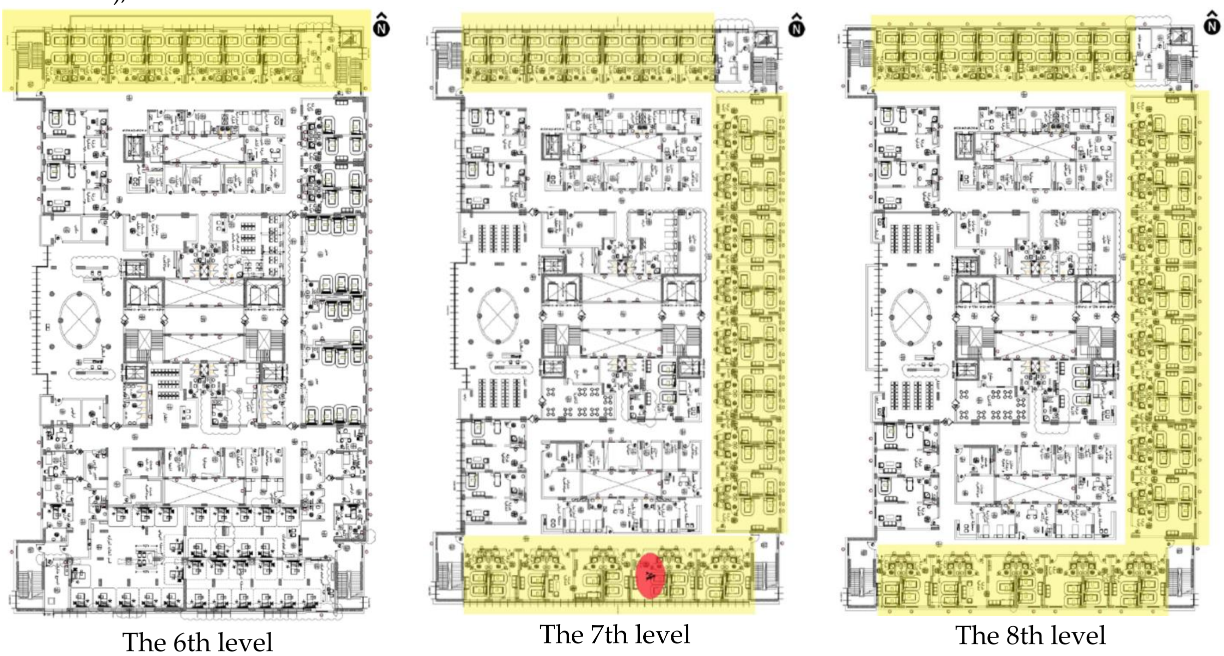


Fig. 5. Plans for emergency hospital in Kafr El Sheikh university [20]

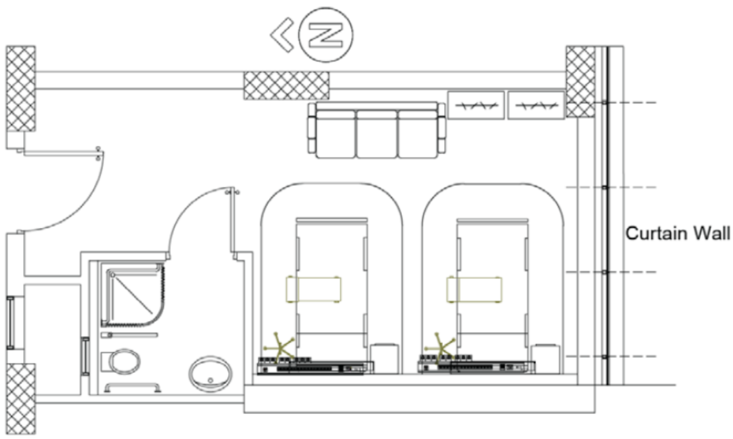


Fig. 6. A southern patient room of the emergency hospital at Kafr El-Sheikh university [20]

4.2. LOCATION DATA

The energy consumption efficiency of the building in its current state was assessed using Design Builder software, commencing with the selection of the location: Baltim, Egypt. It is the closest energy station to Kafr El Sheikh. Baltim is a default location template in Design Builder software, sourced from ASHRAE. The climatic zone is 2A, located at latitude 31.55 and longitude 31.1, with a standard pressure of 101.3 kPa, a wind speed of 2.4 m/s, a wind direction of 180 degrees, a maximum dry bulb temperature of 32.3°C, and a minimum design temperature of 22°C.

4.3. MODELLING PROCESS

The research began to draw building into the software through some steps began with import 2D drawing file of the patient room as AutoCAD DXF file and attach it at height 35.13m. Then selected add new building and from drawings options selected building type: building, form: extrude, and height: 4.64m. data for the encased building, which consists of (activity- construction- openings) were entered. The activity entered as building area type, hospital, template, 24*7-bedroom unit (patient room. The area of patient room: 27m2 and entered workday profile as 24/7 hours/days. The building's walls consist of 25cm thick pumice sand bricks. The bricks are covered with two layers of cement mortar, 2cm thick on both sides. From command opening, it was entered the WWR 100%fully glazed and chose Aluminum window frame. It was selected to visualize the buildings in render as 3D models, as shown in Fig. 7. Simulating variables are summarized in table 4.

4.4. SIMULATION SCENARIOS

The simulation was conducted during a one-year period, from January 1, 2024, to December 31, 2024. The researchers conducted a simulation in the southern patient room on the seventh floor of emergency Hospital at Kafr El Sheikh. The patient room has one south-facing window with a window-to-wall ratio of 100%. The researchers conducted the simulation across three situations.

The first, patient room, in its current state, has conventional exterior windows composed of a reflecting 6mm thick outer layer of glass and a 6 mm thick transparent interior layer of glass [20]. Second, researchers replaced the exterior window glass with AGT-T glass and inputted the layer specifications of this glass into the software, using data according to Sadek and Mahrous [15], as shown in Table 3. Subsequently, the software calculated the properties of AGT_T glass, and it conducted the simulation using AGT-T glass in a general scenario (clear case) and ignored other switching states during the day—clear to dark—to make the simulation in static state. The latter, it used AGT-T but added horizontal shading. The properties of both types of glass are shown in Table 5.

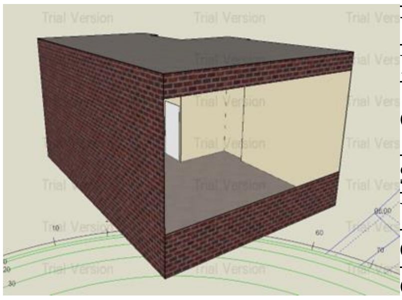


*Fig. 7. 3D modeling of the case study of the southern patient room [**Source**: Authors based on Design Builder software data]*

***Table 4.** Simulation variables of the current state of patient room*

Variables	Energy Plus Values
Location	Baltim, Egypt
Climate	EGY_Al ISKANDARIYAH_ALEXANDRIA_ETMY
Space type	Patient room in an existing hospital
WWR	100 %
Glazing	Double glazing, reflective, clear no shading
Conditioned	Zone HVAC four pipe fan coil system
Occupancy Schedule	Hosp-24*7_Bed_Occ
Light schedule	Building-Specific Space, Healthcare Facility – Patient room, 6.7 W/m2

Table 5. ***Table 5.*** *The main properties of the types of glass used in simulation [**Source**: Authors].*

Current state of glass used in the patient room

Data Report (Not Editable)	
General	
Dbl Blue 6mm/13mm Arg	
Source	EnergyPlus dataset
Category	Double
Region	General
Colour	
Definition method	
Definition method	1-Material layers
Layers	
Number layers	2
Outermost pane	
Pane type	Generic BLUE 6MM
Flip layer	No
Window gas 1	
Window gas type	ARGON 13MM
Innermost pane	
Pane type	Generic CLEAR 6MM
Flip layer	No
Outside Surface	
Fix convective heat transfer coefficient	No
Inside Surface	
Fix convective heat transfer coefficient	No
Calculated Values	
Total solar transmission (SHGC)	0.494
Direct solar transmission	0.373
Visible transmittance	0.505
U-value (ISO 10292/ EN 673) (W/m2-K)	2.549
U-Value (W/m2-K)	2.511
Apply enhanced surface coefficents to achi...	No
Cost	
Cost per area (GBP/m2)	180.000
Radiance Daylighting	
Diffusing	No

AGT-T Glass

Data Report (Not Editable)	
General	
AGT_T	
Source	
Category	Triple
Region	General
Colour	
Definition method	
Definition method	1-Material layers
Layers	
Number layers	3
Outermost pane	
Pane type	Generic CLEAR 6MM
Flip layer	No
Window gas 1	
Window gas type	ARGON 12MM
Pane 2	
Pane type	SAGE Electrochromic
Flip layer	No
Window gas 2	
Window gas type	ARGON 12MM
Innermost pane	
Pane type	Generic CLEAR 6MM
Flip layer	Yes
Outside Surface	
Fix convective heat transfer coefficient	No
Inside Surface	
Fix convective heat transfer coefficient	No
Calculated Values	
Total solar transmission (SHGC)	0.411
Direct solar transmission	0.258
Visible transmittance	0.535
U-value (ISO 10292/ EN 673) (W/m2-K)	1.160
U-Value (W/m2-K)	1.109
Apply enhanced surface coefficents to achi...	No
Cost	
Cost per area (GBP/m2)	100.000
Radiance Daylighting	
Diffusing	No

5. RESULTS

The results showed the effect of using the AGT-T glass on reducing energy consumption for patient rooms in hospitals. Using the Design Builder software, a simulation of patient room at the emergency hospital at Kafr El Sheikh university was created. The results showed the energy consumption of (room electricity, lighting and cooling) of the patient room in 3 scenarios. The first, in the current case with two layers of glass, outer layer is reflective glass 6 mm thick and inner layer is clear glass with 6 mm thick. The second, when using the AGT-T glass as alternative glass. The latter used AGT-T but added horizontal shading. After the software analyzed the entered data of the patient room under study in the three scenarios energy consumption data appeared in kilowatt hours, whether resulting from (lighting, cooling, or room electricity).

5.1. THE CURRENT STATE

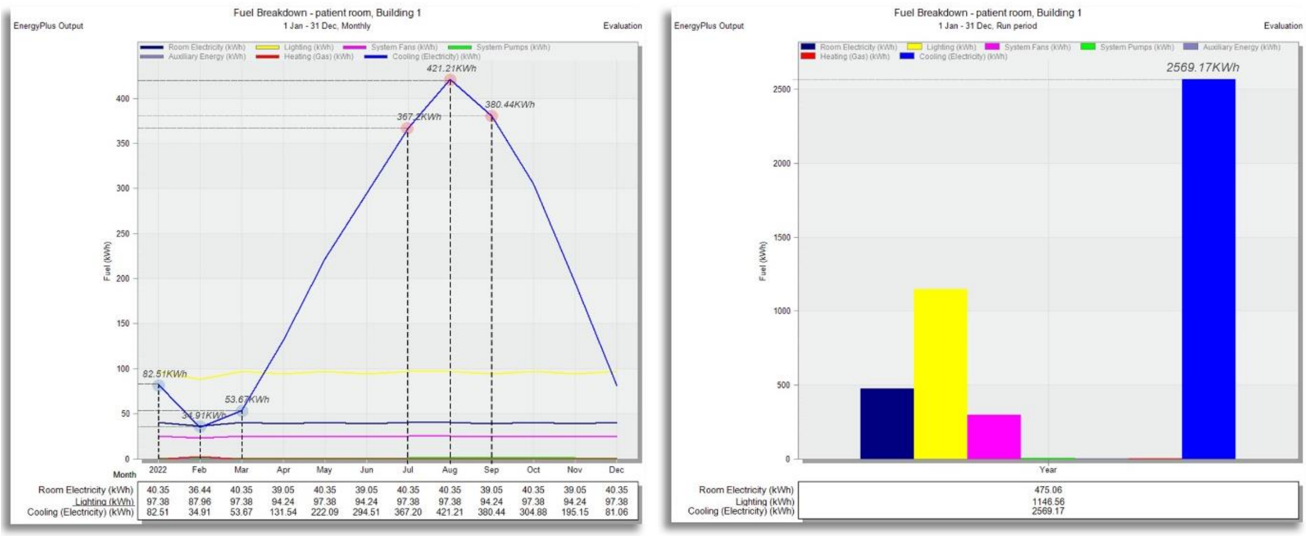
In the first scenario (current state) as shown in figure 8, Results divided into two graphs and charts, per month over a year and totally in the run period (year). First, the graph (Fig. 8, A) shows that the highest percentage of energy consumption for cooling was 421.21 kwh in August followed by 380.44 kwh in September. It was almost non-existent in the months of December 81.06 kwh, January 82.51 kwh and February 34.91 kwh. Second, the graph (Fig. 8, B) shows that, highest energy consumption comes from cooling 2569.17 kwh, followed by lighting 1146.56 kwh.

5.2. AGT-T

In the second scenario, AGT-T glass in the general case was used as an alternative of current glass. The results are also divided into two graphs and charts as shown in figure 9. The first graph (Fig. 9, A) shows that the highest energy consumption for cooling was 395.8 kwh in August followed by 356.09 kwh in September and 348.3 kwh in July. The lowest energy consumption for cooling was 34.3 kwh in February, 53.94 kwh in March and 77.8 in January. Second graph (Fig. 9, B) shows that cooling consumed energy of 2460.93 kWh in one year, which is the largest energy consumption followed by lighting consumed energy of 1146.56 kwh. The reduction of energy consumption of cooling in the patient room reached 4.17% for the AGT-T glass compared to current glass.

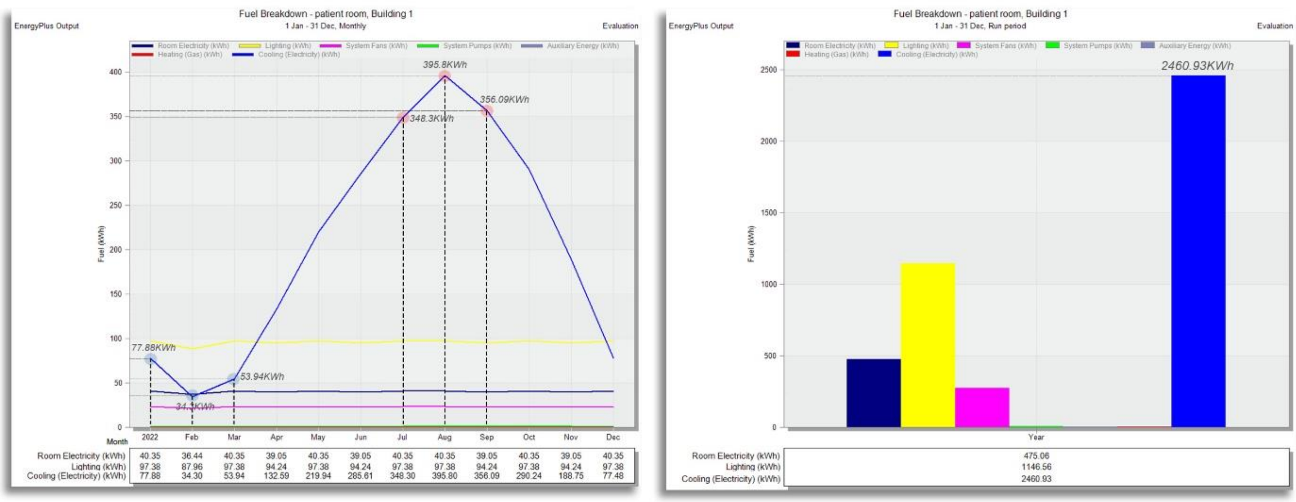
5.3. AGT-T GLASS WITH HORIZONTAL SHADING

The results of simulation of energy consumption in the patient room in the third scenario, shown in Fig. 10. In this state, using horizontal shading (SHD-horizontal) with the AGT-T glass. The results showed in graph (figure 10, A), The highest energy consumption for cooling was 375.1 kWh in August followed by 336.38 kwh in July. The lowest energy consumption was 15.36 kwh in February followed by March was 40.91 kwh and January was 49.18 kWh. In the period between (1 Jan – 31 Dec) as shown in graph (Fig. 10, B), The highest energy consumption came from cooling 2160.12 kwh followed by lighting 1146.56 kwh. The implementation of horizontal shading with AGT_T glass resulted in a 15.9% decrease in cooling energy usage in the patient room compared to the existing glass.



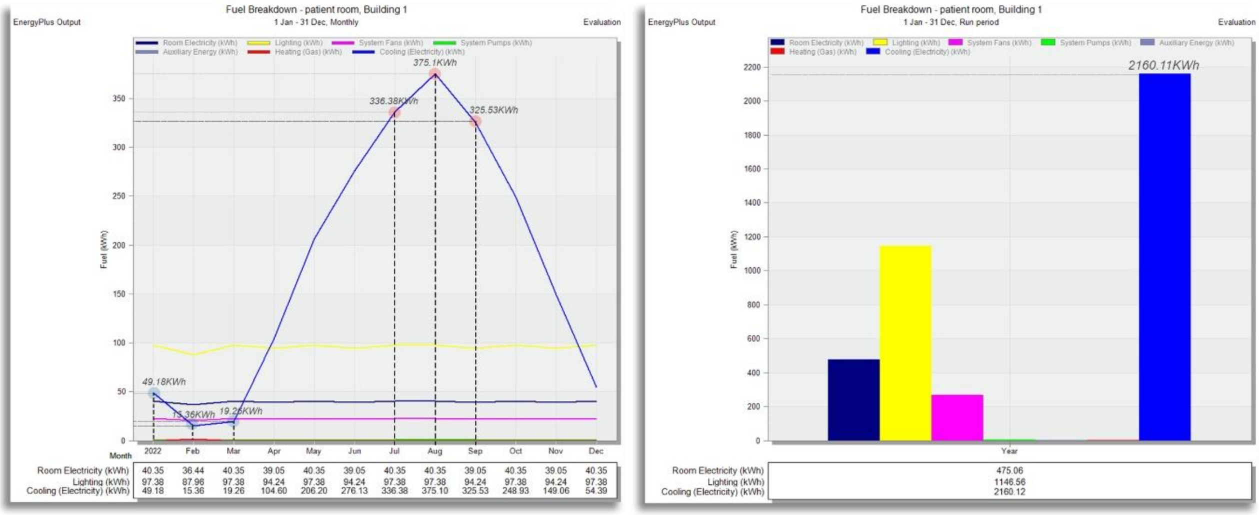
(A) (B)

Fig. 8. (A) Graph of energy consumption per a month over a year in the patient room under study in the current state; (B) Graph of energy consumption per a year in the patient room in current state ***[Source****: Authors].*



(A) (B)

Fig. 9. Graph of energy consumption monthly over a year in the patient room AGT-T glass, (B) graph of energy consumption in a year in the patient room using AGT-T glass ***[Source****: Authors].*



(A) (B)

*Fig. 10. (A) Graph of energy consumption per month over a year in the patient room when using horizontal shading with the AGT-T glass; (B) Graph of energy consumption per year in patient room in the third scenario [**Source**: Authors].*

6. Discussion

The results indicate that, largest energy consumption used for cooling was in months July, August and September to reduce the temperature. The lowest energy consumption was in months from December to March. The energy consumption in south façade is too high and in the period between (1 Jan: 31 Dec) the highest energy consumption came from cooling in the patient room. In line with hypothesis, as shown in Table 6, when using AGT-T and horizontal shading the percentage of energy consumption decrease clearly. The reduction percentage was 4.1% when using AGT-T glass. While, adding the horizontal shading to the AGT-T glass the reduction percentage was 15.9%. Applying horizontal shading system enhanced the total energy savings by additional 11.8%. and allowed the glass to remain all day in the clear state (simulated state). The energy consumption resulting of lighting was stable in the three cases (current and alternative cases).

From Fig. 11, it noticed that the lower the total solar transmission (SHGC) of the glass the lower the energy consumption. The higher the light transmission of the glass the lower the energy consumption. AGT-T triple glazing with a gap filled with an inert gas achieves better results in reducing energy consumption than double glazing. This is consistent with what was mentioned in case studies. The data contributes a clearer understanding of the effect of using AGT-T glass and horizontal shade system in the patient rooms. This simulation occurred in only one patient room in the south of the 7th floor of the emergency hospital of Kafr El Shiekh university. Most of data which entered to the software was limited by default template because the simulation was done using a free trail 30 days version of design builder software by using AGT-T glass in the clear case and ignoring the turning of AGT-T glass during the day from clear to dark. For more realistic results, using horizontal shading system to allow the glass to remain all day in the clear state (simulated state).

*Table 6. Comparison of the percentage of cooling load reduction for the patient's room in the current case and the proposed alternative case [**Source**: Authors].*

Glass type	Total solar transmission (SHGC)	Light transmission	U- value	Applied shading	Total energy consumption of cooling in hall 402 (kWh)	The percentage of reduction in hall 402 (southwestern hall)
Current case, DBL blue 6mm/13mm Arg	0.494	0.505	2.5	------	2569.17	-----
AGT_T glass	0.411	0.535	1.160	------	2460.93	4.1%
AGT_T glass with horizontal shading	0.411	0.535	1.160	Horizontal shading	2160.12	15.9%

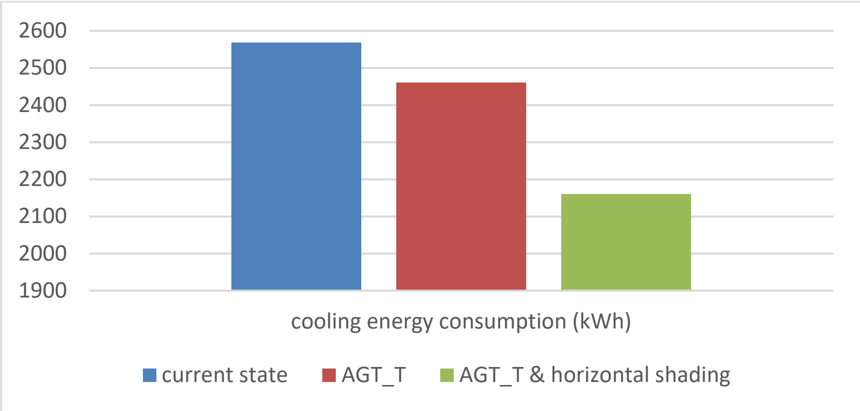


*Fig. 11. A comparison between the results of cooling energy consumption in the three scenarios [**Source**: Authors].*

7. CONCLUSION AND RECOMMENDATIONS

This study concludes that windows are the primary factor in the energy efficiency of the building envelope, as it has the capacity to significantly reduce energy consumption. In this century, there has been a substantial increase in the development of smart materials technologies. Therefore, this investigation demonstrated the efficacy of AGT_T as an alternative to conventional glass in hospitals. The design Builder software has been employed to simulate the patient room in the south facade of the emergency hospital at Kafr El Sheikh University. The results of this study demonstrate that the utilization of AGT_T glass and horizontal shading system resulted in a 15.9% reduction in energy consumption for the patient room. In comparison to the current situation of double glass, this simulation has been conducted in three scenarios, utilizing AGT_T glass and horizontal shading devices. This simulation was for only one patient room on the southern facade of the hospital, and if this change is applied to all patient rooms inside the hospital, which are about 76 patient rooms, the energy consumption in healthcare buildings will be significantly saved.

The energy savings are expected to vary with the use of different types of glass, such as Single Glass, which exceeds 40% in energy savings. Therefore, it is recommended to use AGT_T glass with shading to enhance thermal performance and achieve balanced and efficient energy consumption in healthcare buildings. This implies that the architects and government are encouraged to incorporate AGT_T glass and horizontal shading into future healthcare buildings to reduce energy consumption, as the opportunities for reducing cooling energy are evident. It is advisable to extend the use of these technologies to additional healthy buildings to diminish energy consumption and attain sustainability objectives. Additional research is advised to evaluate alternative materials that integrate superior energy efficiency with augmented user comfort. This research is a significant stride toward emphasizing the significance of incorporating sustainable design and innovative materials to enhance the quality of life and reduce the environmental impact of healthcare buildings..

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