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Study on Improving Energy Performance in Patient Rooms at Existing Hospitals in Cairo

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Abstract

The research involves a practical study using the simulation software Design Builder 4.7 for patient rooms in an existing hospital, specifically Ain Shams Specialized Hospital. This choice was made because hospitals are high-energy-consuming buildings. The study takes into consideration design parameters and variables such as orientation, window-to-wall ratio, type of glass used, and building materials. A comparison is then made between different window ratios, aiming to determine the optimal orientation for patient rooms and how to enhance their energy performance. The study focuses on analyzing current energy consumption and providing recommendations to enhance energy efficiency. The proposed measures include improving thermal insulation and upgrading air conditioning and lighting systems to strike a balance between patient comfort and energy efficiency. In this way, the study aims to drive improvements in energy performance, with a focus on the health and comfort of patients, and the promotion of environmental sustainability in the healthcare sector in Cairo.

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Keywords: Existing Hospitals, Energy Saving, Patient Rooms.

1. INTRODUCTION

With the increasing awareness of climate considerations, a new generation of energy-efficient hospital buildings is emerging, adhering to green design standards and providing a good indoor environment for patient rooms. In this context, the focus will be on improving energy performance within hospital buildings, with practical application to an existing hospital

1.1. The research problem

The research problem lies in the increased energy consumption within hospital buildings, attributed to the inefficiency of the building envelope. This inefficiency results in significant energy use, leading to damages and, consequently, the inability to provide a conducive indoor environment for patient rooms.

1.2. Aim of research

This study aims to assess the impact of energy-saving systems and how to enhance them within hospital buildings, utilizing the simulation software Design Builder 4.7. The study focuses on elucidating the role of physical properties of materials, window-to-wall ratios, and building orientation in improving the thermal performance of the external envelope for patient rooms in hot climates, ultimately aiming to enhance energy efficiency in existing hospital buildings.

1.3. The research hypothesis

The orientation of the building and methods for treating the external envelope are considered among the most crucial solutions that can be proposed to enhance energy efficiency within spaces. Additionally, it serves as a solution to reduce energy consumption within spaces, subsequently decreasing the reliance on mechanical heating and cooling systems.

1.4. Research Methodology

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A theoretical approach was adopted to achieve aims of the research by depending on displaying previous studies; the results found from these studies and how these results impact the current study. It also showed the necessity of the research at hand and studying the concepts followed. A statistical approach was used to deduce a stereotype which was studied for patient rooms in The Greater Cairo region. An applied approach was followed that used the study and style of environmental aspects (Design Builder 4.7). The simulation was done by computer using the simulation tool program and prevailing patterns by changing the orientation, thickness and type of wall used in the facade and by changing ratio of slots and type of glass followed by the results of simulation for each individual case and then clarification of the results and comparing them with each other, thus achieving the aims of the research, and previous studies and their results.

And the main steps for the simulation were as follows:

a. Evaluation of the proposed environmental model by using the simulation program Design Builder 4.7:
- Analysis of climatic data.
- Analysis of solar radiation.

b. Recognition of energy consumption (thermal performance, cooling loads) depending on the following patterns:
- orientation- slot ratios- type of glass used- occupancy rates-building materials used
- Thermal resistance- R-value- of different building materials, density, wall thickness.

2- Case study:

A study was made for patient rooms in an actual hospital: Ain Shams Specialized Hospital, located in The Greater Cairo Region, from which the properties of the model for the patient rooms were specified. Patient rooms were of a standard rectangular shape that differed in the placement of toilets within the rooms and number of beds available, whether single or double or triple, as is shown in the following figures that adhere to the standards of the Egyptian Code for designing hospitals. The Ain Shams Hospital project consists of a basement, ground floor, first floor, second floor and third floor, a water tank and electricity and security rooms, in addition to service work and site coordination. The ground floor primarily includes service units, such as: laboratories, X-Ray rooms, sterilization unit, observation wards, laundry and kitchen. The first floor includes the surgical wards, operating rooms, Intensive Care Unit and administrative offices, whereas patient rooms are located on the second floor. (3)

Table (1) Information on Ain Shams Specialized Hospital building:

Project name	**Ain Shams Specialized Hospital**	**Space:**	**66000 m2**
Owner:	Ain Shams University	Climate:	Hot-dry
Location:	Cairo	Date of completion:	1984
Architect:	G. Belmon & B. Fotron		
Building type:	Specialized university hospital	Number of beds:	825 beds

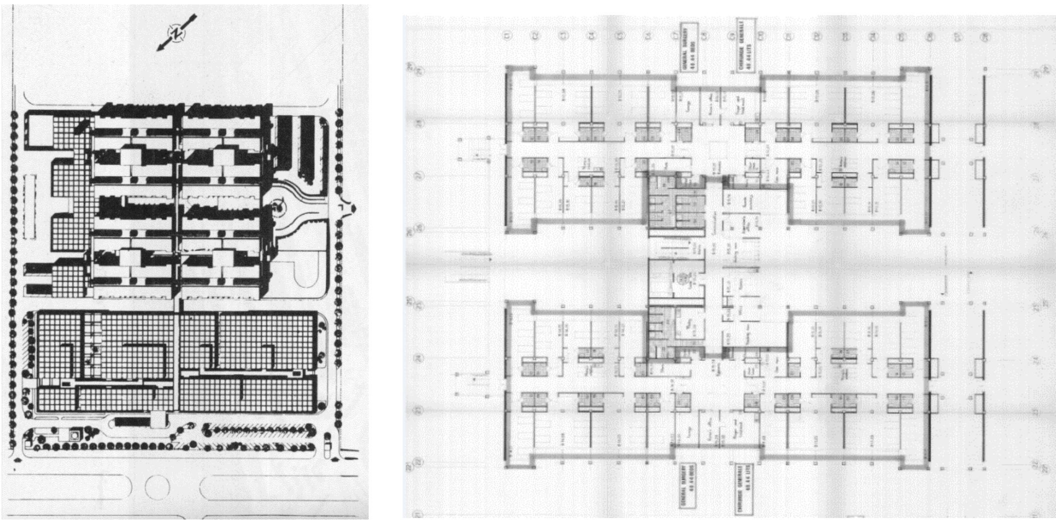


Figure (1) shows plans of the floor plan for the patient rooms and the general location of Ain Shams Specialized Hospital.

Figure (2) shows plans and section for models of patient rooms in the case study

2-1- Thermal performance evaluation for the case studies:

The thermal performance evaluation of patient rooms in the hospital building can be considered an indicator of achieving voids for thermal comfort affected by the choice of material, and which must be fulfilled by the facade. Following clarification of the foundations of green design of the hospital building and analysis of the building materials implemented in them, a comparison is drawn to state how well thermal comfort within patient rooms is achieved by the materials used in the facade; whether those used in walls, glass or slot ratios. This aims to achieve energy efficiency in patient rooms in the hospital building.

2-2- Foundations for choosing the case study:

The Greater Cairo Region is characterized by having a hot-dry climate, and non environmental treatment of hospital buildings nor transforming them to green buildings has resulted in lack of thermal comfort within spaces inside patient rooms, thus negatively impacting patients.

To achieve aim of the study, the following must be considered:

- Presence of the case study in a specific climatic area i.e., The Greater Cairo Region.
- Providing the required information needed to prepare it for the simulation phase followed by the evaluation.
- Choosing projects that require research into the effect of building materials in achieving efficiency standards which are environmentally friendly.
- The need for these models in the environmental design and studying the materials used and their effect on thermal comfort.

2-3- The technical method used in collecting and documenting chosen case studies' data:

The following measures were taken in gathering case studies' data:

- Field trips, photographic documentation and researcher's notes.
- Architectural and aerial mapping for the case studies.
- Previous studies and research which included the case studies.

2-4- Applied study methodology:

a- Climatic data analysis of the study region.

b- Analytical description of the hospital building used in the study as follows: (Architectural description, description of current building materials, occupancy rate, slot ratio, and orientation.)

c- Evaluation of the principle case by using simulation, and likewise for patient room models in the hospital used in the study by using the simulation program 4.7 Design Builder, then evaluating it.

d- Giving alternatives by testing the suggested methodology for the case studies by using the convenient treatments, followed by studying the orientation, then the materials then the slot ratios. This is to assure achievement of the best results by using the simulation program to analyse thermal performance of the building and obtaining results.

e- Comparison and discussion of the results. by doing this, evaluating the different alternatives and material alternatives is possible, hence choosing the optimum solution for achieving patient comfort and providing a good environment.

The main aim of this simulation was as follows:

a. The study of the effect of building materials on thermal comfort inside patient rooms in the hospital building.

b. Analysis of the materials used in patient rooms in the actual hospital building and how highly they affect the internal environment.

c. Making a simulation of the required cooling loads in the current building and providing alternatives.

d. Estimating the percentage of energy saved by using the different alternatives, whether design or material related.

2-5- Analysis of patient room models in Ain Shams Specialized Hospital:

a- Analysis of climatic data of the area of the study: Greater Cairo Region.

Climatic data of Greater Cairo Region was determined by 6.0 climate consultant program.

- A psychometric chart

A psychometric chart defines the relationship between temperature and relative humidity on the horizontal and vertical axes, respectively. It determines characteristics of Greater Cairo climate by defining the area of thermal comfort in relation to the temperature and humidity as well as occupancy rate, and all it encompasses, such as type of clothing and level of activity, as shown in figure (3):

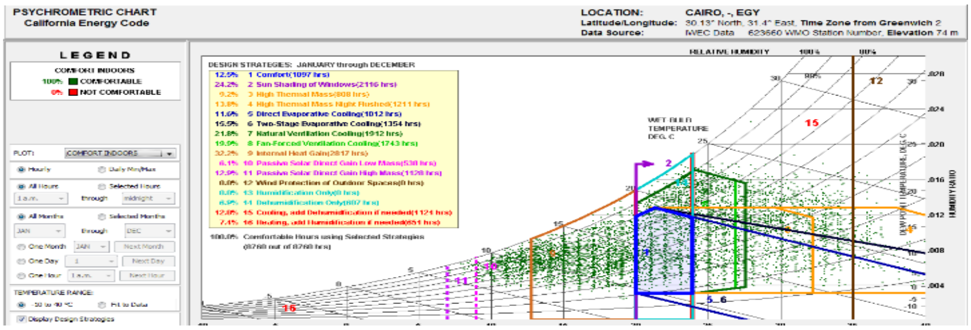


Figure (3) illustrates the psychrometric chart for thermal comfort in the case study using Climate Consultant 5.5 program

b- Patient room models' data:

- Architectural design data:

The aim of studying patient room models in hospitals before and after adjusting building materials is to determine the effect of the materials on thermal performance, orientation and slot ratios at the different architectural angles of the patient rooms. A comparison will be drawn between the current state of the patient rooms in the hospital and the adjustment after placing the alternatives. The comparison will discuss the most important elements of design such as: (horizontal projections- slot ratios-walls- building materials used in every element.)

- Heat gain:

There are two sources for heat (internal and external). Internal heat arises from: working people and lighting, whereas external heat comes from heat of the sun, which leaks into space through the building envelope.

2-6- Evaluation of patient room models through simulation:

a- Simulation methodology:-

Description and dimensions of the building are inputted into the program, and a 3d simulation model is created to simulate the actual building and its total energy consumption that is clear from the following 3d model taken from the program, Design Builder 4.7 which analyses all the input regarding the case study.

b- Building operation data:

Activities:

- Building operation time: Daily operation time, 24 hours and throughout the year.
- Density 0.55.
- Clothing: In winter= 0.9 clo, and in summer= 0.49 clo (4)
- Metabolism of patients (standing/walking) =0.1
- Computers or medical devices.
- Setting operation schedule: 24 hours a day, every day of the week.

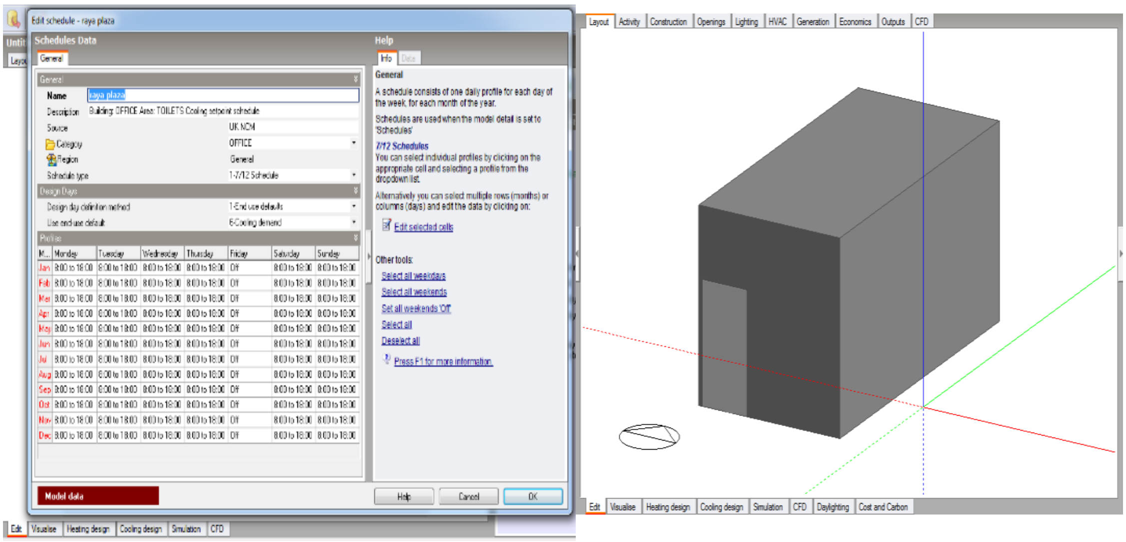
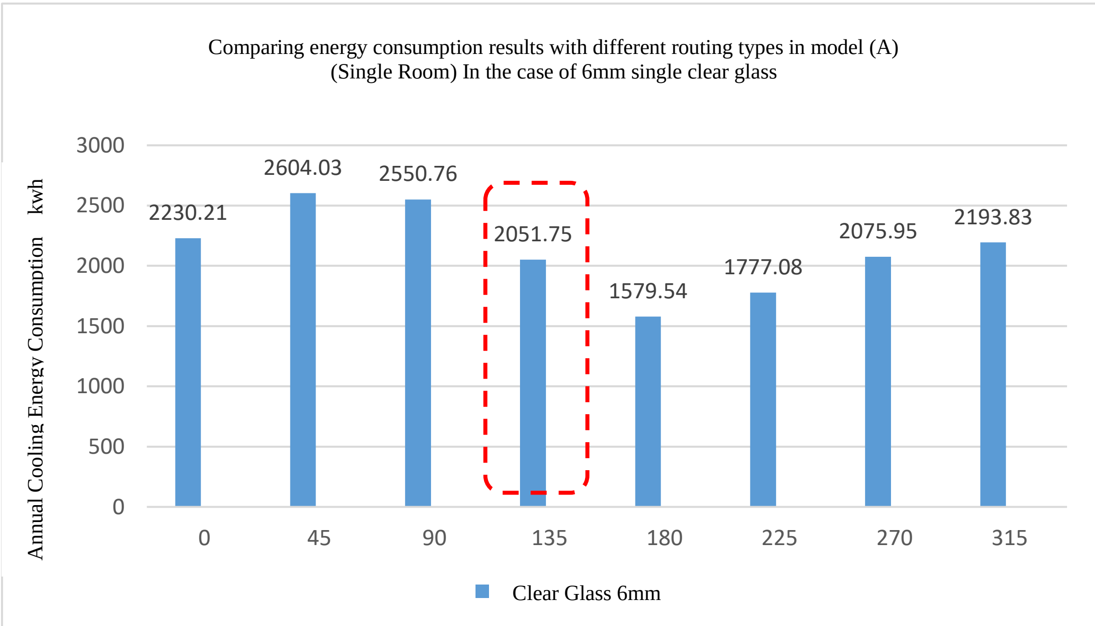


Figure (4) depicts a 3D model of the case study in the Design Builder 4.7 program

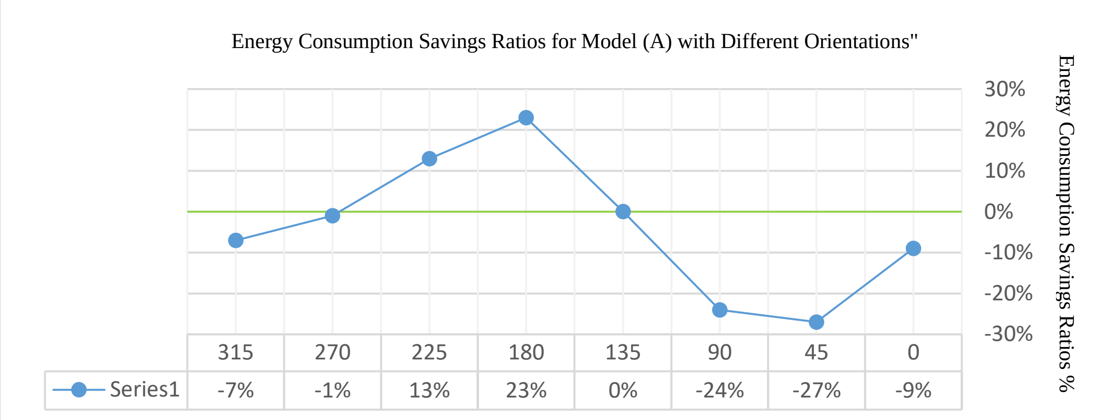
2-7- Discussion of the results:

- Results of energy consumption for the simulation case with differing orientation types for model (A) (Single room): In the case of single-paned 6mm clear glass where orientation of the case within the study (northwest) at an angle of 135 o, as is shown in figure (5)



"Figure (5) illustrates the energy consumption results for patient rooms in the baseline condition with variations in orientation for model (A)."

- Comparison of energy consumption savings percentages based on different orientations in model (A) (individual room) is depicted in Figure (6):



"Figure (6) illustrates the average annual energy consumption savings for the first model (A) of patient rooms."

Simulation of the orientation was done at an angle of 45 degrees ((south=. O), (south west= 45 O), (west =90 O), (north west =135 O), (north =180 O), (south east= 225 O), (east= 270 O), (north east= 315 O)) in the case of single-paned clear glass with the criteria ((UV) = 5.70), ((LT) = 0.88), ((SHGC) = 0.82) and the least annual energy consumption for orientation results was found at a 180 degree angle with a percentage of 23%, while the orientation of the simulation case was at a 135 degree angle (north west.)

- Comparison of different material types in model (A) (individual room) is depicted in Figure (7):

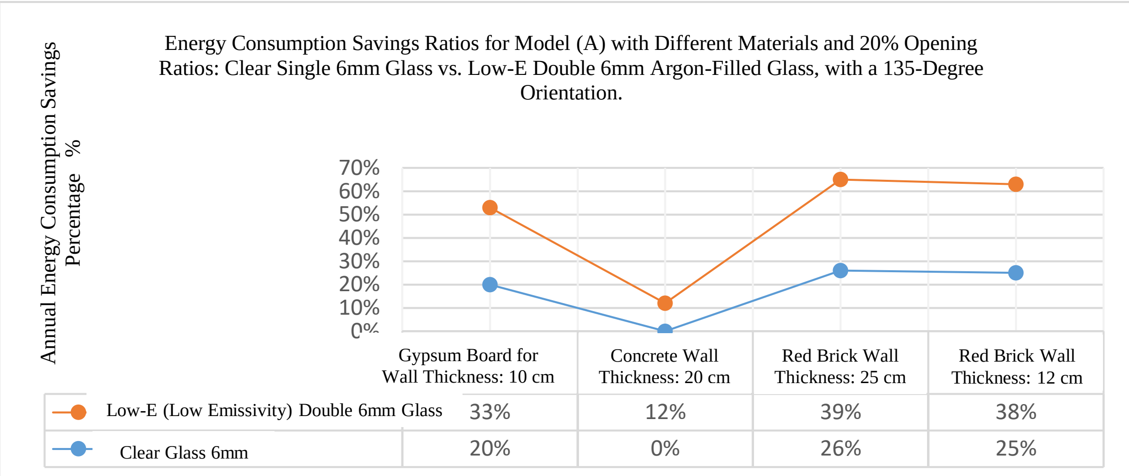


Figure (7) illustrates a comparison of energy consumption savings in model (A) (individual room) based on different materials

A group of different materials of different thermal resistance were tested, and these are shown in the results of figure (6), which give the average annual energy consumption of the materials when clear glass is used ((SHGC = 0.82), ((LT) = 0.88), ((UV) = 5.70), and double-paned 6 mm low emission glass with criteria ((SHGC = 0.23), ((LT) = 0.42), (U vale (UV) = 1.55.) The simulation was placed at a 135 o angle, and was oriented with the slot ratios in the case of the simulation, representing 20% of the building envelope of patient rooms. The results indicated that using low emission glass decreased preservation of energy consumption by 12 to 39% more than using clear glass did. And with thermal resistance of materials, the results of 25 thickness walls in the case of clear glass achieved a 26% greater preservation of energy, while using low emission glass showed a 39% greater preservation of energy than the simulation case of patient rooms.

"Figure (8) illustrates a comparison of opening percentages in model (A) (individual room):

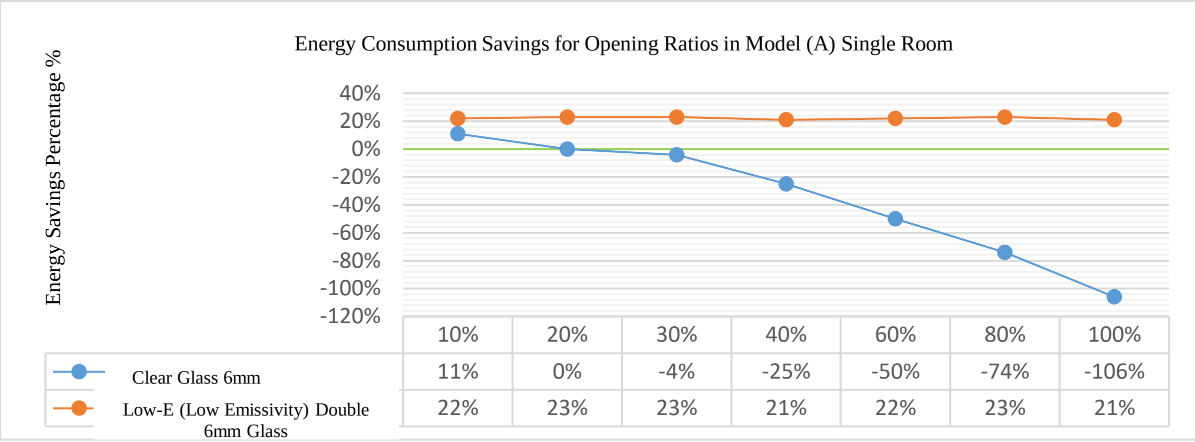
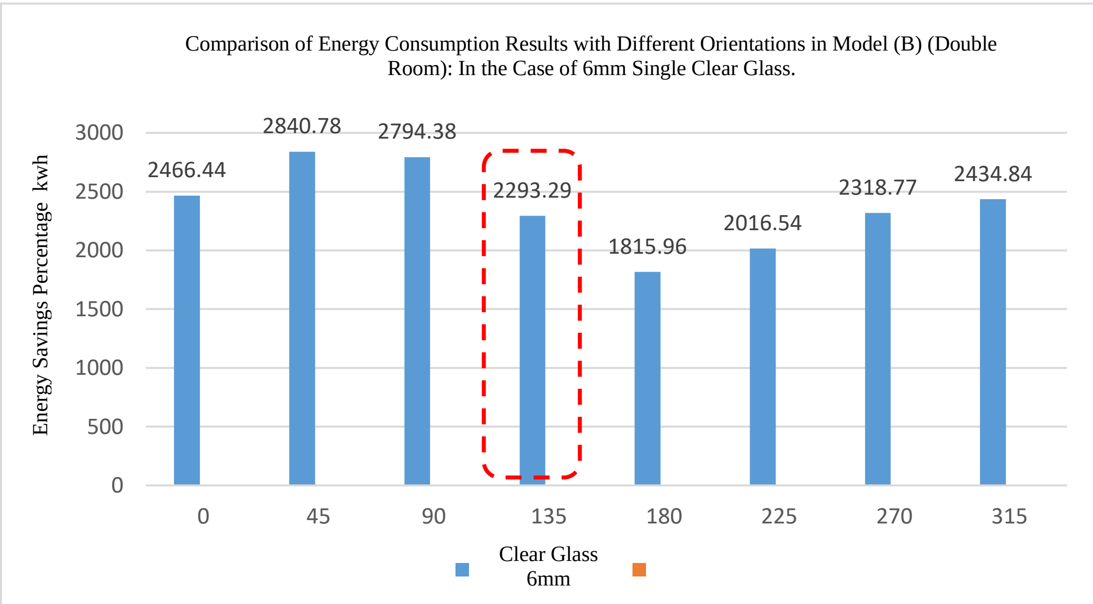


Figure (8) shows that the results of the simulation for the slot ratios of the building envelope of patient rooms for model (A) in the simulation case at a 135degree angle.

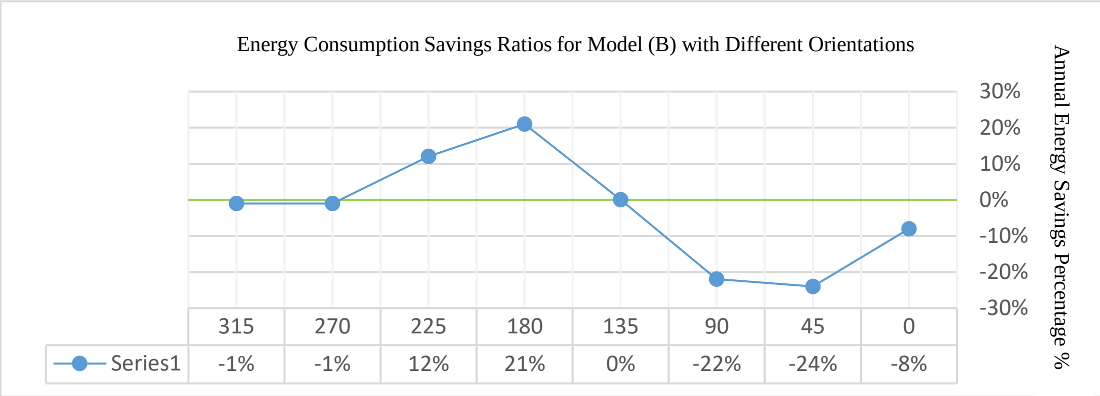
indicate that the rate of preservation of energy consumption decreases as slot ratios increase. The more slot ratios increase, the greater the rate of energy consumption is with 6 mm clear glass including criteria ((SHGC) = 0.82), (LT) = 0.88), (UV) = 5.70)). The lowest rate of preserving energy consumption is shown with double-paned low emission glass with criteria ((SHGC) = 0.23), (LT) = 0.42), (U Value (UV) = 1.55)). It is noteworthy that the more slot ratios decreased, the more energy was preserved in patient rooms.

- The energy consumption results for the baseline condition with variations in orientation in model (B) (double room) are presented in Figure (9). In this case, transparent single-pane glass with a thickness of 6 mm was used, and the study area was oriented at (Northwest) with an angle of 135 degrees:



"Figure (9) illustrates the energy consumption results for patient rooms in the baseline condition with variations in orientation for model (B).

- Comparison of energy consumption savings results based on different orientations in model (B) is depicted in Figure (10):



"Figure (10) illustrates the average annual energy consumption savings for the second model (B) of patient rooms."

Simulation of the orientation was done at an angle of 45 degrees ((south=. O), (south west= 45 O), (west =90 O), (north west =135 O), (north =180 O), (north east= 225 O),), (east= 270 O) (south east= 315 O)) in the case of single-paned clear glass with the criteria ((UV) = 5.70), ((LT) = 0.88), ((SHGC) = 0.82) and the greatest annual energy preservation for orientation results was found at a 180 degree angle with a percentage of 21%, while the orientation of the simulation case was at a 135 degree angle.

- Figure (11) illustrates a comparison of different materials in model (B) (double room):

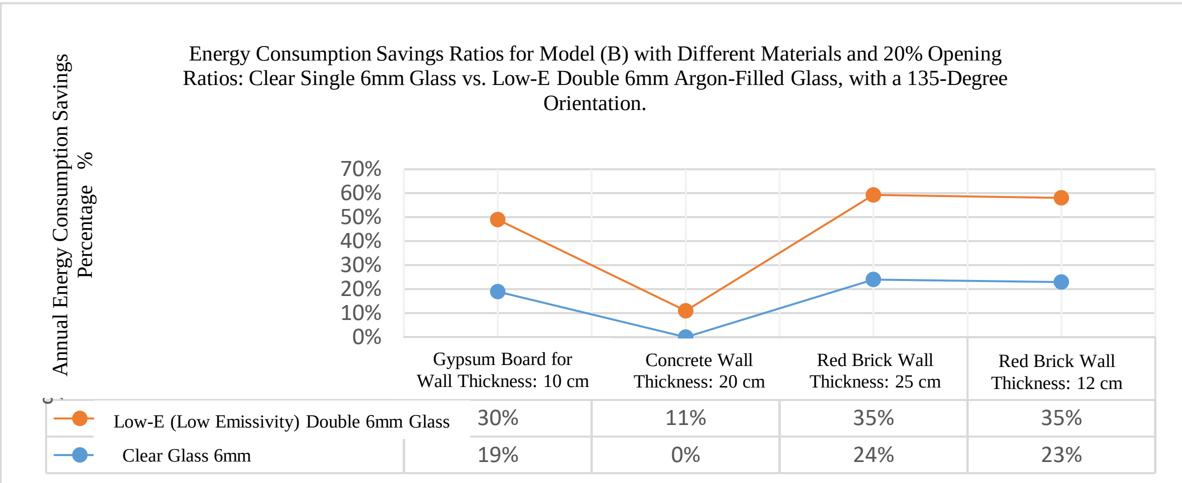
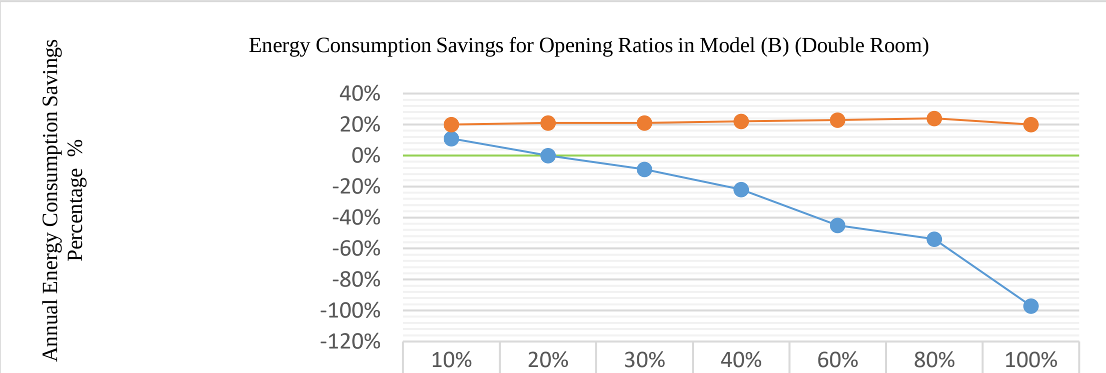


Figure (11) depicts a comparison of energy consumption savings in model (B) (single room) based on different materials.

A group of different materials of different thermal resistance were tested, and these are shown in the results of figure (10) which give the average annual energy consumption of the materials when clear glass is used ((SHGC = 0.82), ((LT) = 0.88), ((UV) = 5.70), and double-paned 6 mm low emission glass with criteria ((SHGC = 0.23), ((LT) = 0.42), (U vale (UV) = 1.55.) The simulation was placed at a 135 o angle, and was oriented with the slot ratios in the case of the simulation, representing 20% of the building envelope of patient rooms. The results indicated that using low emission glass increased preservation of energy by at least 11% more than using clear glass did. And with thermal resistance of materials, the results of 25 thickness walls in the case of clear glass consumed less energy, while using low emission glass showed less energy consumption in patient rooms.

- Figure (12) illustrates a comparison of opening percentages in model (B) (double room):

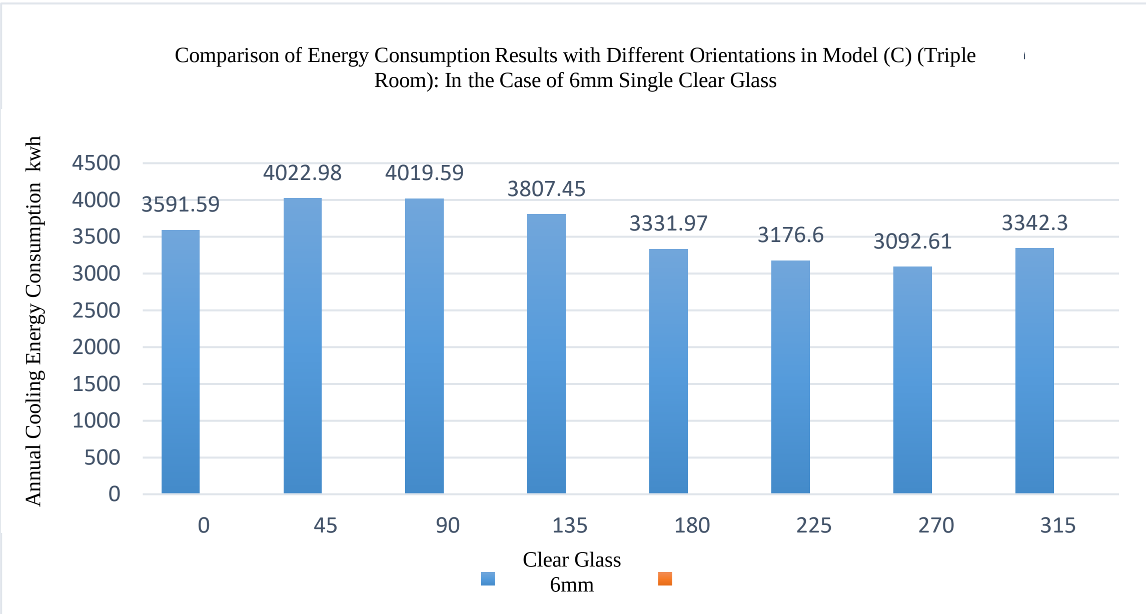


	10%	20%	30%	40%	60%	80%	100%
Clear Glass 6mm	11%	0%	-9%	-22%	-45%	-54%	-97%
Low-E (Low Emissivity) Double 6mm Glass	20%	21%	21%	22%	23%	24%	20%

Figure (12) shows that the results of the simulation for the slot ratios of the building envelope of patient rooms in the simulation case at a 135degree angle

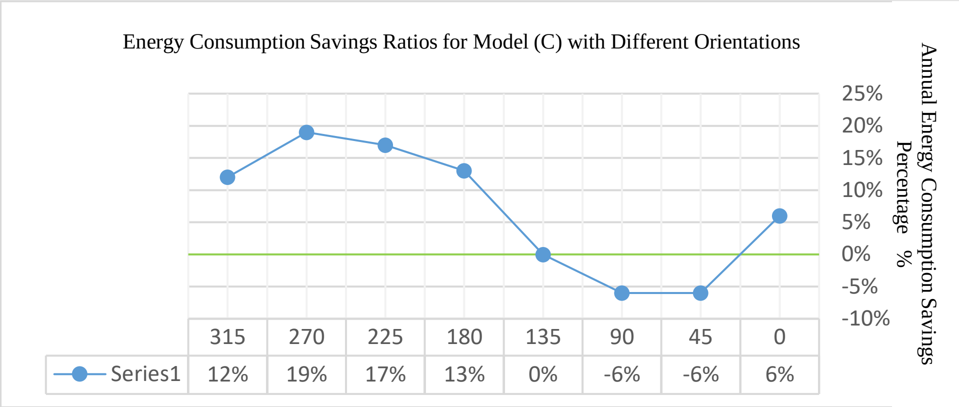
indicate that the rate of preservation of energy consumption decreases as slot ratios increase. The more slot ratios increase, the greater the rate of energy consumption is with 6 mm clear glass including the criteria ((SHGC) = 0.82), (LT) = 0.88), (UV) = 5.70)). The lowest rate of preserving energy consumption is shown with double-paned low emission glass with criteria ((SHGC) = 0.23), (LT) = 0.42), (U Value (UV) = 1.55)). It is worthy to note that the more slot ratios decreased, the more energy was preserved in patient rooms.

-The energy consumption results for the baseline condition with variations in orientation for model (C) (triple room) are shown in Figure (13). In this case, single-pane transparent glass with a thickness of 6 mm was used, and the study area was oriented at (Northwest) with an angle of 135 degrees:



"Figure (13) illustrates the energy consumption results for patient rooms in the baseline condition with variations in orientation for model (C)

- "Comparison of energy consumption savings results for the baseline condition with variations in orientation in model (C) (triple room) is illustrated in Figure (14)."

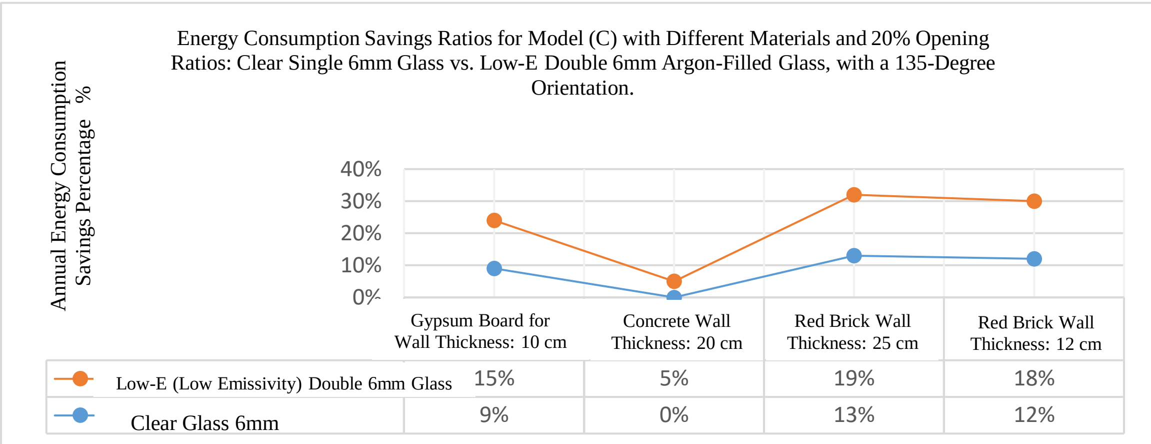


"Figure (14) illustrates the average annual energy consumption savings percentages for model (C) of patient rooms."

Figure (14) shows the average annual energy preservation rate of model (C) for patient rooms.

Simulation of the orientation was done at an angle of 45 degrees ((south=. O), (south west= 45 O), (west =90 O), (north west =135 O), (north =180 O), (north east= 225 O),), (east= 270 O) (south east= 315 O)) in the case of single-paned clear glass with the criteria ((UV) = 5.70), ((LT) = 0.88), ((SHGC) = 0.82) and the greatest annual energy preservation for orientation results was found at a 270 degree angle with a percentage of 19% preservation rate more than the simulation case, where the orientation of the simulation case was at a 135 degree angle.

- Comparison of different material types in model (C) (triple room) is depicted in Figure (15):



"Figure (15) illustrates a comparison of energy consumption savings in model (C) (single room) based on different materials."

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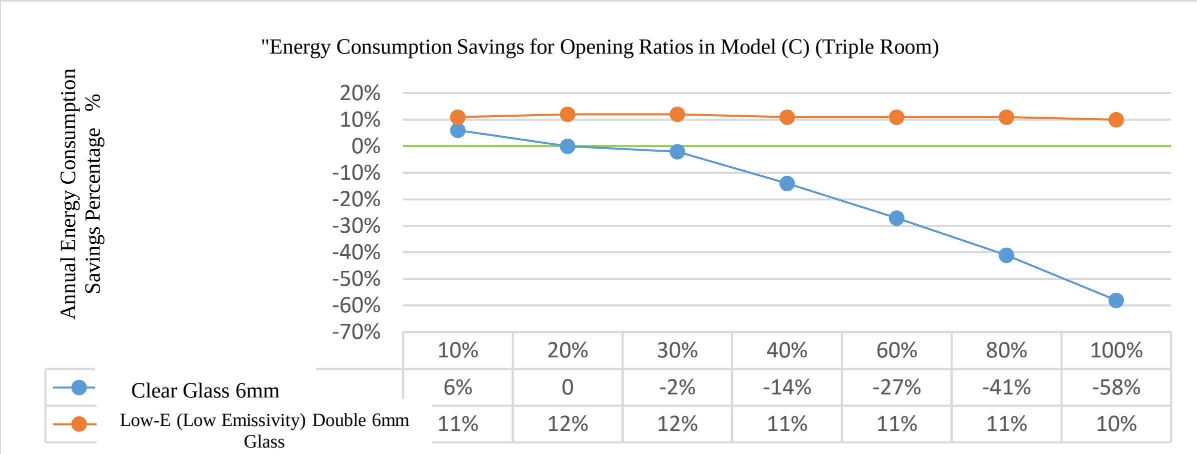
A group of different materials of different thermal resistance were tested, and these are shown in the results of figure (14), which give the average annual energy consumption of the materials when clear glass is used ((SHGC = 0.82), ((LT) = 0.88), ((UV) = 5.70), and double-paned 6 mm low emission glass with criteria ((SHGC = 0.23), ((LT) = 0.42), (U vale (UV) = 1.55.) The simulation was placed at a 135 o angle, and was oriented with the slot ratios in the case of the simulation, representing 20% of the building envelope of patient rooms. The results indicated that using low emission glass increased preservation of energy consumption by 5 to 19% more than using clear glass did. And with thermal resistance of materials, the results of 25 thickness walls in the case of clear glass achieved a 13% greater preservation of energy, while using low emission glass showed a 19% greater preservation of energy than the simulation case of patient rooms for model (C).

- Figure (16) illustrates a comparison of opening percentages for model (C) (triple room):

Figure (16) shows that the results of the simulation for the slot ratios of the building envelope of patient rooms in the simulation case at a 135degree angle



indicate that the rate of preservation of energy consumption decreases as slot ratios increase. The more slot ratios increase, the greater the rate of energy consumption is with 6 mm clear glass including the criteria ((SHGC) = 0.82), (LT) = 0.88), (UV) = 5.70)). The lowest rate of preserving energy consumption is shown with double-paned low emission glass with criteria ((SHGC) = 0.23), (LT) = 0.42), (U Value (UV) = 1.55)). It is worthy to note that the more slot ratios decreased, the more energy was preserved in patient rooms.

3- Conclusion:

- Slot ratios: They should be no less than 40% to 60% to achieve connection with the external environment in order to improve patients' psychological state and provide natural lighting that helps in saving energy and speeding up patients' healing time, as shown by previous research and studies.
- The type of glass: used in slots helps in saving more than 20% of energy consumption when using double-paned low emission glass of the criteria ((SHGC) = 0.23), ((LT) = 0.42), (U Value (UV) = 1.55)) than when using single-paned clear glass with the criteria ((SHGC) = 0.82), ((LT) = 0.88), ((UV) = 5.70.))
- Using computer programs for making a simulation at the design or renewal stage of the hospital building. It is considered an important factor in evaluating and achieving the principles of green architecture as well as identifying the optimum energy consumption in actual hospital buildings and improving them.
- The ability to apply results of the research and simulation studies on patient room models built by specialized organizations in those areas to achieve thermal comfort inside patient rooms and reduce energy consumption there. And it becomes clear to us that both the architectural and material dimensions greatly affect the consumption of energy, and if architects took these dimensions into consideration at the design or renewal stage, a reduction in energy consumption would be achieved.
- Energy consumption in a building is a result of design-related decisions; and in the research four architectural dimensions were studied and analysed. These dimensions are (orientation, building materials, thickness of building materials and slot ratios,) and they were chosen for their importance and effect on energy consumption of patient rooms in the hospital building. To conclude, the results indicated the impact of the architectural and building materials' dimensions, and their effect on thermal comfort and energy consumption in patient rooms' space through the study of the building envelope.
- The results showed that cooling demands are much higher than heating demands of patient rooms in actual hospitals in Greater Cairo Region, where temperatures less than 21oC are almost neglected in comparison to temperatures above 28 oC. Thus, the best alternatives needed for reducing thermal gain of the building envelope should be tested during summer.
- The results of thermal performance of the building elements of the actual hospital building indicated and focused upon thermal transfer (U-values) as an indicator of thermal performance of building elements in the building envelope of patient rooms(walls and slots.) The main aim of the simulation was evaluation of thermal performance of patient rooms in the actual hospital building and confirmation of how greatly building materials affect thermal comfort and energy consumption.
- The main focus was to give alternatives for building materials used in walls and slots, and the simulation was made taking into consideration, building materials, their thickness, slot ratios and type of glass used.

4- Recommendations of the applied study:

a- General recommendations on how to improve energy efficiency in hospital buildings:

- Enhancing Thermal Insulation and Ventilation: By improving the thermal insulation of the building and enhancing the ventilation system to maintain appropriate temperatures without the need for excessive energy consumption for heating or cooling.
- Utilizing Smart Technology: By employing automated control systems and sensors to regulate energy usage more efficiently, such as smart lighting systems that operate based on motion and provide illumination only when needed.
- Replacing Appliances with More Efficient Ones: By updating heating, cooling, and lighting equipment to more energy-efficient appliances. For example, replacing traditional bulbs with LED lights that consume less energy and have longer lifespans.
- Energy Consumption Management: By applying energy consumption management techniques such as smart energy-saving and load control to reduce energy consumption during inactive periods.
- Promoting Energy Awareness: By raising awareness among staff and patients about the importance of energy conservation and how they can contribute, such as turning off unnecessary devices when not in use and considering the use of high-efficiency equipment.
- Renewable Energy Generation: By installing renewable energy generation systems such as solar panels or wind turbines to generate a portion of the energy used in the hospital.

By implementing these strategies, you can achieve energy savings in the hospital building.

b- Executive recommendations for designing energy-efficient hospitals:

- Using smart control systems and modern technologies in hospitals to improve energy consumption management, such as intelligently regulating lighting, ventilation, and cooling systems according to actual needs.
- Utilizing computer simulation techniques: Employing simulation and computer modeling software to evaluate the performance of hospital buildings, analyze energy consumption, and identify areas for effective improvement.
- Adopting green building standards: Implementing green building standards in the design and construction of hospitals, including the use of sustainable building materials and designing energy-efficient buildings that preserve the environment.
- Providing continuous training and education for employees, engineers, and architects on the use of computer programs and simulation to assess and improve hospital performance in terms of energy efficiency.
- Conducting periodic assessments of hospital performance in terms of energy usage and continuously improving operations and systems to ensure maximum energy efficiency.
- Enhancing collaboration with technology companies and specialized engineering firms to develop innovative solutions for energy savings in hospitals, and exchanging knowledge and expertise to improve energy performance.
- Supporting scientific research in energy-saving techniques and technology application in hospitals, and encouraging innovation to develop new and efficient solutions in this field.
- Reviewing and updating policies and regulations related to energy efficiency and sustainability in hospitals, and ensuring their effective implementation to achieve defined goals.
- Investing in developing green infrastructure in hospitals, such as installing solar energy systems and improving heating and cooling systems to reduce energy consumption.
- Providing financial and tax incentives for hospitals adopting energy-saving practices and sustainability measures, and encouraging investment in updating technology and green infrastructure.
- Participating in national and international initiatives and programs related to energy efficiency and sustainability, and collaborating with relevant authorities to achieve sustainable development goals

c- Special recommendations for architects and architecture students:

- Using innovative designs for the building structure and properly directing it to reduce the energy needs for heating and cooling, by improving thermal insulation and reducing heat loss and cooling.
- Adopting renewable energy technologies such as solar energy and wind energy reduces reliance on traditional energy sources and decreases harmful emissions.
- Designing buildings to allow for maximum natural lighting and adequate ventilation.
- Using sustainable building materials containing renewable resources, including advanced thermal insulation and double-glazed windows, to improve energy efficiency.
- Implementing smart control systems and automation technologies leads to reduced energy consumption by improving energy management within the building.

- Encouraging architects and architecture students to learn about the latest technologies, simulation programs, and practices related to energy efficiency and sustainability, and how to effectively apply them in their projects.
- The building should be oriented in a way that allows for maximum utilization of natural light and reduces reliance on artificial lighting.
- Workshops and training courses can be offered to architects and architecture students on best practices in designing environmentally friendly and energy-efficient hospitals.
- Encouraging research and innovation in the field of hospital design to find new and effective solutions for energy saving.
- Architects and architecture students should collaborate closely with medical and technical teams in the hospital design process. Understanding the needs of patients and how to achieve a comfortable and medically efficient environment contributes to developing innovative energy-saving designs.
- Architects and architecture students should stay informed about the latest developments in sustainability and energy saving and apply them in hospital design. They can attend specialized workshops and training courses and read scientific research in this field.
- Careful site analysis should be conducted by architects to determine how to best utilize local climatic conditions and natural resources in hospital design.
- Continuous assessment and improvement: Architects and students should continuously monitor and evaluate the performance of buildings after completion and look for opportunities for continuous energy efficiency improvement.
- Experienced architects can guide and educate new students on best practices in designing environmentally friendly and energy-efficient hospitals to spread awareness and enhance knowledge in the field.

5-References:

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