INTERNATIONAL JOURNAL OF
ARCHITECTURAL ENGINEERING AND URBAN RESEARCH
PRINT ISSN 2785-9665 ONLINE ISSN 2785-9673
VOLUME 6, ISSUE 1, 2023, 246 – 273

Improving Energy Performance in Hospital Buildings Using Nanotechnology

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Abstract

Nano-technology plays a pivotal role across various fields, particularly in architecture and construction. Leveraging nanotechnology is of utmost importance in improving energy efficiency in buildings. With growing concerns about local energy consumption, particularly electricity, research aims to develop a range of nanomaterials for exterior cladding or therapeutic interiors to enhance thermal performance. This involves studying nanomaterials, their properties, and the impact of nanotechnology on the exterior cladding, especially for hospital buildings. Furthermore, the research focuses on examining a range of models for implementing nanotechnology to illustrate its impact on enhancing the thermal performance of hospital buildings. This includes conducting simulations using design builder software and comparing the thermal performance under normal conditions versus when nanotechnology-infused materials are incorporated. the study demonstrated a 16% reduction in energy consumption in the studied hospital building when nanotechnology was employed in coatings and glass applications. The study concludes by presenting a set of results and recommendations affirming the efficacy of utilizing nanotechnology to improve energy efficiency and thermal performance in buildings

Key Word

Energy efficiency - nanotechnology - hospitals - outer shell - thermal performance

1- Introduction

Egypt is experiencing significant climate change and faces concerns regarding the depletion of local energy resources, especially electricity, due to its extensive use in industrial sectors and the expansion of new urban areas, particularly in construction and infrastructure. The energy conservation ratio is a major issue across all Egyptian cities, making the need for energy-efficient and environmentally friendly buildings a critical consideration in the design process.

The energy performance of architecture holds great importance in minimizing its impact on the surrounding environment and enhancing user comfort. Through high-efficiency systems, material selection, and optimal use of new and renewable energy technologies, the energy issue can be addressed. This has led to the development of building materials with new features designed to preserve natural resources, meet sustainability standards, and integrate nanotechnology into architectural facades, thus giving rise to a new architecture based on the use of nanotechnology-treated materials (Desouky, Etal, 2019).

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ARCHITECTURAL ENGINEERING AND URBAN RESEARCH
PRINT ISSN 2785-9665 ONLINE ISSN 2785-9673
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This study also examines the significant benefits of utilizing nanotechnology to reduce energy consumption in hospitals in Egypt, aiming to understand the impact of nanomaterials, their use, and the optimal methods for obtaining the best results. Nanomaterials possess numerous unique properties and functions, notably in reducing emissions from greenhouse gases through different methods that positively impact the environment and users, significantly contributing to energy conservation

1-1- Research Problem:

The absence of established principles for implementing energy-saving and improving the efficiency of healthcare buildings using nanotechnology, resulting in a lack of specific requirements or considerations to evaluate the environmentally and functionally sound designs for these buildings.

The lack of a clear thermal design methodology for existing healthcare building facades that achieves suitable thermal efficiency.

Absence of specific methods that integrate nanotechnology with architecture, particularly in finishing materials, and delineate the impact of nanomaterials on energy consumption inside hospital buildings

1-2- Research Objective

The aim is to identify a range of nanomaterial finishes that impact energy efficiency, whether for the exterior envelope or interior of healthcare buildings, to enhance their thermal performance.

This objective is pursued through several secondary goals, including:

Managing energy by understanding the applications of modern nanotechnology and how to leverage it.

Identifying different methods to improve energy efficiency in existing healthcare buildings (hospitals) through exterior cladding treatments.

Using modern nanotechnology materials to achieve environmental safety.

Integrating technology with architecture and its applications in various life domains, especially in architecture, and its impact on sustainability and green architecture

1-3- research methodology

Theoretical Framework: This involves a set of concepts and theories related to thermal performance and its requirements within healthcare buildings, exploring nanotechnology techniques utilized in thermal insulation, and assessing their environmental and functional impact on various building materials and their influence on energy consumption within healthcare buildings.

Analytical Framework: This relies on analyzing a range of materials used in nanotechnology applications to determine their impact on improving the thermal performance of hospital buildings.

Applied Framework: This involves utilizing suitable materials in nanotechnology applications and conducting simulations using the design builder software to evaluate the impact of these materials on enhancing the efficiency of healthcare buildings, particularly the exterior envelope, using nanotechnology techniques.

1-4- Literature review

- A study illustrates the role of technology in developing traditional architectural elements in terms of design, performance, usage, construction methods, and materials. This aims to utilize them as fundamental and contemporary components in the design and construction of modern, technologically advanced buildings. The study recommends embracing modern global construction methods to keep pace with the continuous technological advancements and developments in the context of economy and sustainability. The study is titled "The Role of Technology in Developing Traditional Architectural Elements" (Mohamady, 2011).
- The mechanism of nanotechnology and its relationship with the fields of physics and architecture involves the understanding of how nanotechnology can be utilized in architectural engineering. The study recommends the utilization of nanomaterials, such as aerogels like "NANOGEL," in the ceilings of stairwells in residential buildings and other spaces to provide natural lighting instead of artificial lighting, thus contributing to energy conservation. Additionally, due to its fire-resistant properties, the researcher suggests its use in certain components of emergency exits, while adhering to the specific building codes and regulations. (Elhagery, 2014)
- A methodology to enhance energy efficiency in existing hospital buildings through exterior cladding treatments for patient rooms and the selection of material type, thickness, and percentage of openings to improve the thermal performance of the exterior envelope. Among the recommendations is for the state to adopt a green building approach in the national strategic plan, particularly for existing hospital buildings, as they serve as an environmentally friendly model, contributing significantly to reducing economic burdens, conserving energy and water, achieving indoor environmental quality, reducing pollution, and other benefits that the state strives to achieve (Ateya, 2018).

- A study was conducted to highlight the importance of using nanomaterials, comparing the impact of nanogel and phase change materials (PCM) in the exterior glass of a multi-story office building in the Smart Village area in Egypt on the annual energy consumption performance compared to traditional double-glazed

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panels. The simulation was performed using DesignBuilder (6.0.1), and a cost analysis was conducted to evaluate the long-term economic feasibility of nanomaterial alternatives. The results showed that the Nanogel Airgel glazing reduced annual energy consumption by 11.71%, while PCM glazing led to a 10.86% reduction in the current office building's energy consumption. The most efficient and cost-effective alternative in terms of energy consumption and cost effectiveness is the Nano Airgel glass (Abuhenidy, 2019).

- The proper use of glass in office buildings plays a crucial role in efficient energy utilization, especially with the application of nanotechnology. The main objective of this paper was to assess the potential of different types of glass used in building envelopes to reduce energy consumption in office buildings. Various types of glass were integrated with different window-to-wall ratios (WWRs) and orientations to verify their effectiveness. The use of double-glazed SB R100 Clr 6mm/13mm air glass in offices can significantly save energy compared to other types of glass windows. The recommended glass type also provides natural lighting levels that exceed Egyptian Energy Code requirements (Abden, 2017).

2- Nano-architecture technology

is the science that focuses on studying nanomaterials and characterizing their mechanical, chemical, and physical properties, as well as studying the phenomena resulting from scaling materials down to the nanoscale (dealing with measurements between 0.1 and 100 nanometers), 10^-9 (Ahmeda, 2017). The aim is to produce new materials known as nanomaterials with properties that meet the requirements of advanced technology (Elaskandary, 2010). The significance of nanotechnology lies in the fact that when materials are broken down into extremely small pieces (at the nano level), these materials exhibit completely different properties from those of the bulk material, potentially leading to the development of more efficient devices at lower cost (Saber, 2020).

In simplified terms, architecture translates human needs into three-dimensional functional structures. It is considered a collective art that effectively combines elements to create more complex forms. The architectural evolution has introduced new performance requirements, energy efficiency for facilities, and building sustainability (Boras, 2018). Architecture is the science of designing, planning, and constructing buildings and other structures. Nano-architecture involves integrating nanotechnology into architecture, not only through the use of nanomaterials, various processing techniques, and systems but also by altering and enhancing design practices and methods in numerous ways to achieve high-performance building designs (Parthenopoulou, 2020).

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2-1- The role of nanotechnology in maintaining health and the environment

Nanomaterials are utilized to replace some traditional materials that require rawer materials for production and may cause environmental damage during manufacturing processes, or are known to be environmentally harmful. Nanotechnology has the ability to reduce energy consumption and assist in environmental protection, improving pollution detection, and enhancing non-traditional and renewable energy generation technologies, such as solar and wind power. Integrating nanotechnology with smart architecture works to enhance intelligent performance efficiency, improve the building's indoor environment, and enhance its overall performance towards the natural environment (ElQasem, 2020). This integration between nanotechnology and smart architecture ultimately aims to contribute to preserving health and the environment

2-2- Clean (green) nanotechnology and its goals

Clean nanotechnology relies on environmentally safe principles of chemistry and engineering. Theoretically, clean nanotechnology is expected to enhance process efficiency and replace current compounds and processes that threaten human health with safer alternatives (Rajpoot, 2021). It also provides the opportunity to improve energy production and various materials. There are two main goals for clean (green) nanotechnology as illustrated in Figure 1.

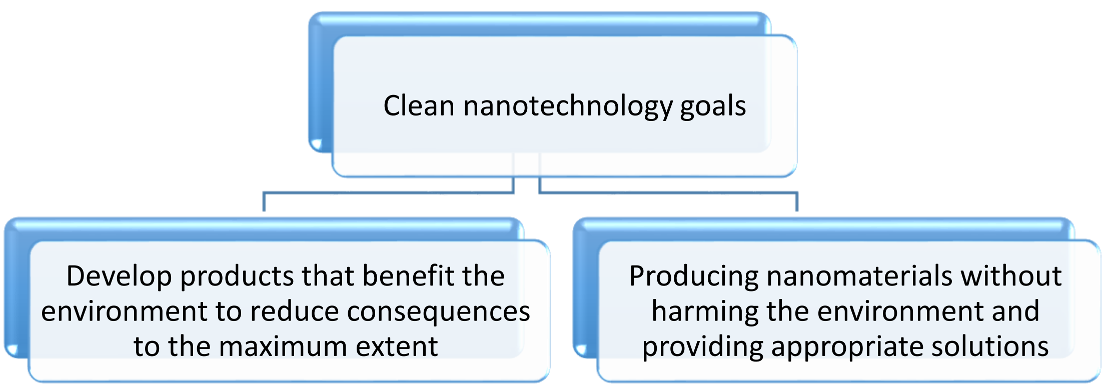

Fig.1 Clean nanotechnology goals

2-3- Distinctive properties of nanomaterial

Nanomaterials exhibit a variety of chemical, physical, and mechanical properties that distinguish them from non-nanomaterials. Some of these properties include:

Electrical conductivity: Certain insulating materials transform into excellent electrical conductors due to their nanoscale dimensions, and vice versa.

Hardness: Nanoparticle hardness surpasses that of non-nanoscale particles of the same material by hundreds of times. For example, nanoparticles made of silicon exhibit significantly higher hardness compared to bulk silicon.

Color change capability: The color of nanoparticles changes with variations in their size. This phenomenon is particularly evident in nanoparticles of gold and silver.

Transparency: Nanoparticles with dimensions smaller than the visible light wavelengths do not reflect visible light, resulting in high transparency. This property makes them suitable for coating various products without affecting their color, such as clear coatings and cosmetics (Abdelrazek, 2022).

Waterproof properties: It acts as a barrier between water and the building structure, preventing the passage of water.

3- The impact of nanotechnology on improving the exterior envelope in hospitals

The building envelope is widely recognized as the most effective indicator of energy used for heating, cooling, lighting, and ventilation in buildings. It significantly influences and responds to the reduction of energy consumption. The building envelope serves as the boundary between the interior and exterior environment of the building. Due to its direct interaction with external environmental conditions, it governs heat exchange processes, the amount of heat received by the envelope, and the energy required to operate the building.

The majority of hospital buildings in Egypt suffer from inadequacies in the design and performance of the building envelope, with some lacking environmental treatments

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Nanotechnology has contributed to the introduction of numerous applications aimed at optimizing energy consumption by enhancing lighting efficiency, insulation materials, coatings, and other applications to address the issue of increased energy consumption in buildingsFig.2. Below are some nanomaterials used in exterior finishes:

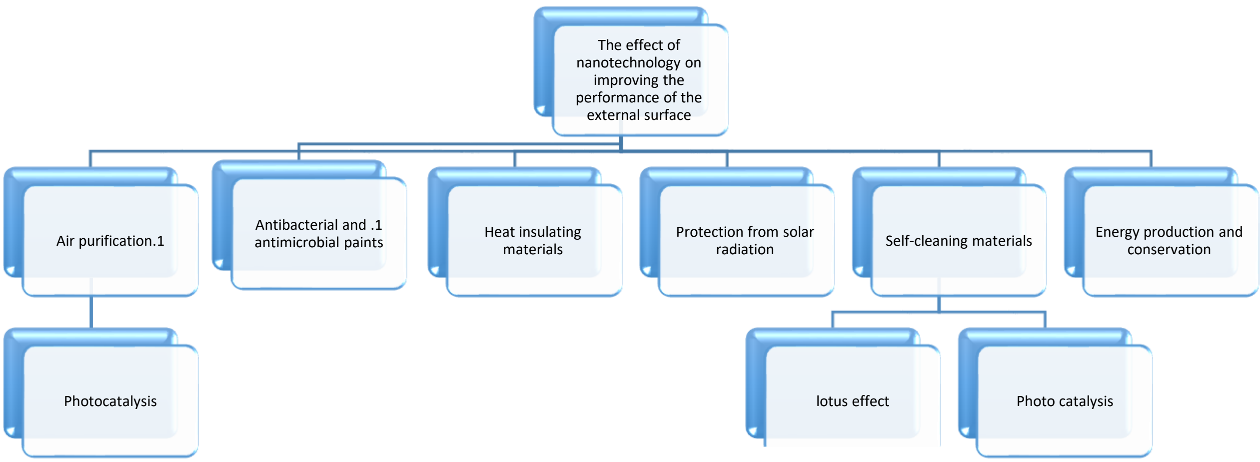

Fig.2 The effect of nanotechnology

3-1- Air purification

Nanotechnology works to rid the air of harmful organic substances and eliminate unpleasant odors and pollutants by chemically breaking them down into simpler, non-harmful compounds. The air purification technology, Air Purifying, utilizes photocatalysis, and this method has been employed at the Hyundai exhibition in Germany. Gypsum panels with self-cleaning properties and purification capabilities were utilized (Elkasem, 2020).

Furthermore, air purification and the reduction of pollutants have been implemented at the "Torre de especialidades" hospital in Mexico City. The hospital's facades were designed using panels consisting of cement and titanium dioxide, which also serve as a canopy for the hospital's façade shown in Fig.3.

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figure (3) illustrates the hospital façade of (Torre de especialidades)

3-2- Antibacterial and antimicrobial paints

The paints that target and destroy bacteria, reducing the need for disinfectants, are effective in hospitals where harmful bacteria, including disinfectants and antibiotics, are prevalent (Tharwt, 2023). For example, in a hospital in Jusler, operating rooms use ceramic units containing TiO2 coating with photocatalysis and antibacterial properties (Basyony, 2019). For example, in a hospital in Jusslar, TiO2 coating with photocatalytic and antibacterial properties is utilized in the operating rooms (Basyony, 2019).

3-3- Heat insulating materials

It works to form a specialized and advanced layer using nanotechnology, which consists of precise crystalline and molecular structures without voids. This structure aids in scattering and reflecting solar radiation and heat, resulting in a temperature decrease of up to 20 degrees Celsius compared to normal conditions. By employing the ANZ material, which functions as a thermal insulating layer(Ezat,2022) .See Fig.4

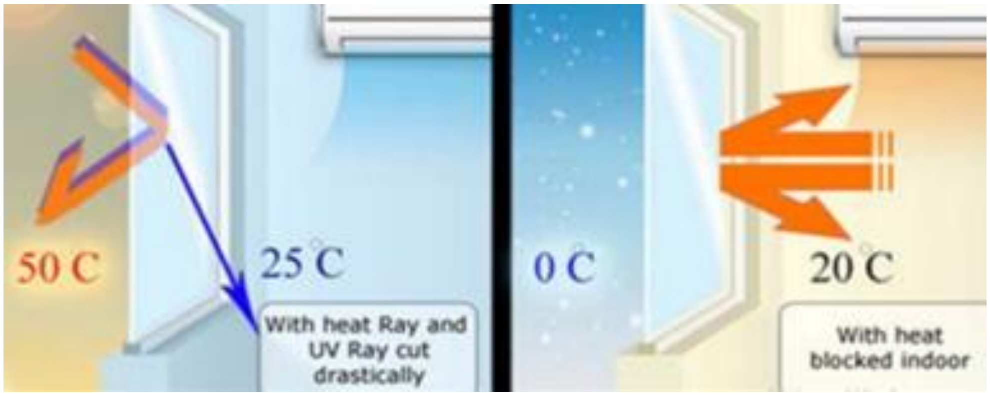

Fig.4 It demonstrates maintaining a warm temperature in the winter and a cool one in the summer

3-4- Solar Proection

For window protection from solar radiation, a technology is utilized where the glass automatically darkens, transforming into tinted glass without the need for continuous electricity. This technology takes the form of films applied to the surface of the window glass, preventing heat from penetrating indoors while allowing pure, healthy sunlight to enter. It possesses a unique ability to significantly reduce internal heat by a high percentage, reaching up to 95%.

- Anti-reflective coating

Furthermore, the reduction of sunlight reflection is achieved through nanotechnology, wherein the refractive index can be altered to allow a maximum of 90% light transmission. This is accomplished by using multi-layered glass that is anti-reflective (Abdelrazek, 2022).

- Additionally, protection from ultraviolet (UV) rays is provided. (eleskandry,2010)

The nano-coated ultraviolet protection paint is utilized

3-5- Self-cleaning materials

Nanotechnology can be utilized for environmental pollution remediation, where solar-powered microscopic machines can facilitate the reduction of carbon dioxide emissions. Over the course of several years of operation, these machines have the potential to convert all the accumulated carbon dioxide into either carbon or oxygen once again

- Self-cleaning nano coating shed dirty through photo catalysic

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Surfaces coated with titanium dioxide (TiO2) containing paint exhibit self-cleaning properties compared to untreated surfaces.

- Self-cleaning water-based paints

The Lotus Effect is demonstrated in the application of exterior surface coatings with water-repellent properties. This effect mimics the behavior observed in lotus leaves, where the textured surface minimizes the contact area for water, thereby preventing water accumulation (Abdelmoez, 2020).

- Anti-fog coating The treatment of glass facades in air-conditioned rooms in tropical areas and bathroom mirrors can be achieved through the use of anti-fog coating, employing nanotechnology to apply a layer of titanium dioxide. This nano-scale coating transforms water droplets and fog into a thin, invisible layer (Desouky, 2019)

3-6- Production and provision of energy

Nanotechnology offers the potential to produce, store, and optimize energy. Coating windows with nanomaterials can lead to reduced energy consumption and improved indoor air quality in buildings. Rhiel (2009) highlights the ability of nanotechnology to enhance energy efficiency and management in buildings by providing new solutions. This includes optimizing energy consumption, energy storage, and energy generation.

Nanomaterials play a crucial role in enhancing the effectiveness of materials used for exterior facades. The control of material properties, such as density and temporal delay, impedes the transfer of heat from external to internal spaces, thus contributing to thermal comfort within the building (Hanafy, 2023).

Utilizing solar cells in glass to harness solar energy contributes to cost savings in capital equipment, energy control, operational expenses, and climate monitoring equipment Fig.5 (Hanafy, 2023).

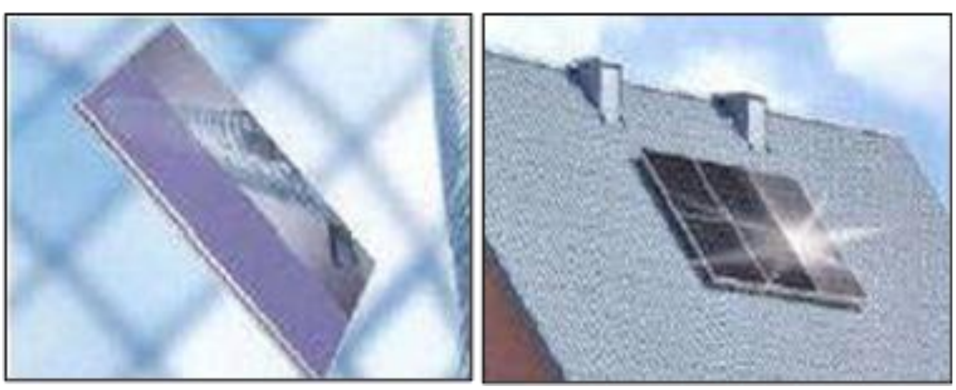

Fig.5 Use of solar cells

Nanotechnology coatings,

The main product of energy, similar to how plants absorb sunlight and convert it into chemical energy, is the coating which would eliminate the need for electrical wires. This is achieved through coating on a nanoscale and injecting a pigment of titanium dioxide, which transforms into flexible materials that absorb energy from the sun and indoor light and convert it into electrical energy. Additionally, they are resistant to rust and environmental changes, thus extending the lifespan of the property. (Abdelrazek,2022)

4- Examples of nanotechnology applications to enhance energy efficiency in hospital

4-1- (Nanogel) Aerogel

Nanogel Aerogel exhibits high thermal and acoustic insulation properties, as well as providing natural lighting. It can be utilized to fill the gaps between glass panels and in the external envelope of buildings and glass windows. Moreover, it features self-cleaning photocatalytic technology and has demonstrated effectiveness in reducing noise, as evidenced in its application in the MSV Football Stadium in Duisburg, Germany.

4-1-1- Spaceloft

This product is a fabric-like material with a thickness of 10-5 mm, as depicted in Fig.6 It stands out for its effective heat insulation capability and flexibility. Additionally, its thermal conductivity is 2 to 2.5 times lower than traditional insulation materials, making it ideal for pressure resistance. (Baetens,2011)

Fig.6 Spaceloft

4-1-2- SOl - Gel:

It is a thin coating used for insulating and protecting glass by integrating infinitesimally small particles into multiple layers on the glass surface. It provides protection by adding a layer of titanium dioxide (TiO_2) for self-cleaning properties and represents Sol Gel

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insulation as a protective shield against harmful sunlight rays. It also enhances natural lighting and improves light dispersion within architectural spaces

4-1-3- "Vacuum insulation panel (VIP)"

The evacuated insulation panels provide thermal protection that exceeds six times what conventional insulating materials offer, making them the superior choice for achieving excellent thermal insulation with significantly less thickness than traditional panels.

Additionally, they are utilized in insulating windows and glass facades by placing them between two layers of glass. Their application in the Seitzstrasse mixed-use building, a residential and administrative building in Munich, Germany, marks the first large building entirely insulated with evacuated panels, surpassing the efficiency of conventional materials by over tenfold **Fig.7.(Arif,2020)**

Fig.7 The Seitzstraße apartments with Vacuum Insulated Panels.
(Arif,2020)

4-2- Thin-film solar cell

It prevents sunlight and reduces the internal space temperature by (2-3 degrees) compared to conventional materials (Tharwt, 2022).

It utilizes nanoscale particles of titanium dioxide (TiO_2) in solar cells.

Its application is evident in the Solar Ark building.

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There are multiple approaches to cost reduction using thin film and nanotechnology to produce thin, flexible, and eco-friendly solar cells.

4-3- Passive smart nano glass

It does not rely on electrical stimulation but interacts with other influences such as light, heat, or others.

4-3-1- Photochromic

Photochromic glass relies on a technology that changes its color when exposed to light, becoming either transparent or opaque as a result of the photochromic materials absorbing electromagnetic energy from ultraviolet radiation.Fig.8 It is also used to reduce strong sunlight penetration and allow weak sunlight to pass through (Zafarani, 2006)

Fig.8 The effect of lighting on the color and transparency of glass used with photochromic technology.
https://www.bdcnetwork.com/ppg-pleotint-co-market-environmentally-adaptive-glazing-technology-low-e-glass

4-3-2- Thermochromic

It is a type of liquid crystals that changes its arrangement and light transmittance due to temperature fluctuations. This means that the window will be transparent in the cold part and opaque in the hot part, as depicted in (5-34). When thermal energy is introduced to the material, it undergoes partial structural changes, leading to a modification in the spectral reflection of the material's original molecular structure, resulting in a change in the reflected radiation color within the visible range of the electromagnetic spectrum. Here, it is thermochromic, providing thermal insulation while preserving sufficient illumination (Zafarani, 2006).

It has been utilized in the Children's Learning Adventure center in Keller, USA

4-3-3- Low emission nano glass:

Emissivity refers to the glass's ability to reflect heat, which is enhanced by using low-emissivity glass. This type of glass is thin and coated with a transparent layer of nanosilver between anti-reflective metal oxide layers. This glass reduces heat transfer through the window on hot days, thus preserving the internal glass panels' temperature.Fig.9 This type of glass has been utilized at the Tom Bradley International Terminal at Los Angeles Airport and in The Dar Building in Abu Dhabi.

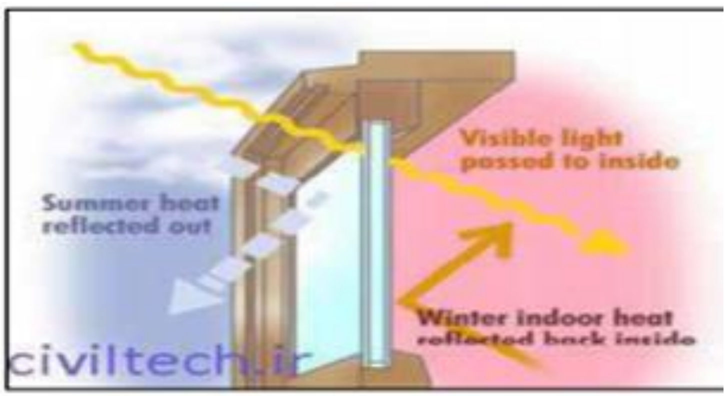

Fig.9 Allowing sunlight and controlling heat in low-emissivity glass. (Abdelrazek,2022)

4-3-4- self - cleaning glass – photocatalytic

Self-cleaning glass features a very thin layer of titanium dioxide that responds to daylight. This reaction serves to repel and remove dirt particles. (Abdelrazek,2022)

4-3-5- Anti-reflective glass:

It is a transparent nanoscale glass composed of particles smaller than the wavelength of visible light. It is not only innovative but also cost-effective, making it an ideal solution for resisting reflection and glare. It consists of silicon dioxide (SiO_2) spheres with a thickness of 30-50 nanometers. It is known for providing clarity and visibility at all times, offering clear and pure vision, as depicted in the figure 10

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Fig.10 anti–reflection glass and reflective glass

4-3-6- Thesolar cells - Organic Light Emitting Diode (OLED)

This technology consists of very thin flat lighting units, with a thickness not exceeding 1 micron, characterized by their lightweight nature as they require fewer manufacturing materials and do not emit heat when operated, thus presenting an aesthetic form. It comprises solar power units that work to collect solar energy during the day, and on the other side, Organic Light Emitting Diode (OLED) lamps that illuminate at night using the gathered energy from the day, as depicted in Figure (5-15) (Khanna, 2014)

4-4- Positive smart nano glass

Also known as Switchable Glass, positive smart nano glass is a type of glass that changes its light transmission properties when an electric voltage is applied. Certain types of smart glass enable users to control the amount of light and heat passing through them by pressing a button, altering their transparency from clear to opaque. Other types of smart glass provide privacy and are classified as positive smart glass.

4-4-1- Electrochromic glass

Electrochromic materials are capable of changing their color when an electric current is applied, as a chemical reaction occurs in this type of material, altering its properties. These materials can reflect and absorb light and heat, as depicted in Figure 5-46. They have been utilized in the Chabot College Community and Student Services Center (CSSC).

There are several types of electrochromic glass, including electric glass.

- Liquid Crystal

Some types of glass utilize liquid crystal applications, which consist of organized liquids that are sensitive to an electric field. In this technology, the glass is composed of two layers of polarizing materials with liquid crystals placed between them.

- Suspended Particle Display

This technology is similar to liquid crystals, but it differs in that it relies on microscopic particles of a light-absorbent solid material. This liquid is confined between two glass plates coated with a transparent, electrically conductive material. When an electric current is passed through the conductive plates, these particles align in an organized manner, altering the glass's transparency according to the operating conditions.

- The color of the glass changes electrically by ion injection.

The concept of this glass relies on the presence of a layer of a chemical substance with distinctive optical properties that change color and characteristics when exposed to an electric current due to the presence of ions from another substance. The substance returns to its original state when the ions are no longer present.

4-5- The addition of nano titanium dioxide (TiO2) to materials

Titanium dioxide is a white powder, which tends to create non-transparent surfaces when applied to glass, thereby obstructing visibility. To address this issue, a thin layer, approximately 15 nanometers thick, is used to produce completely transparent glass. This technology is expected to reduce the use of environmentally damaging cleaning agents and enhance worker safety by eliminating the need for climbing and cleaning building facades (Elkazaz, 2019).

The presence of a catalyst substance aids in the transformation of reactive materials. The industrial catalyst works to produce a very strong oxidizing agent that breaks down organic materials, dust, and bacteria when exposed to sunlight or even ordinary light, converting them into environmentally beneficial substances, as illustrated in Figure (://www.hazemsakeek.org). Considered one of the best photocatalytic semiconductor materials, titanium dioxide is most suitable for use as a photocatalyst among semiconductor materials.

4-6- Phase change materials (PCMs)

Phase Change Materials (PCMs) are substances capable of altering their specific heat capacity in response to ambient temperatures. This property is achieved by storing energy in the form of latent heat within the materials, causing the substance to change phase from solid to liquid and vice versa. The transition temperature depends on the specific materials used, as illustrated in Figure 10 (Torgal, 2011). As it uses in Molecular Engineering and Sciences Buildingin the University of Washington Fig.11 and "Sur Falveng" housing for elderly people

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Fig.11 Molecular Engineering and Sciences Buildingin the University of Washington

4-7- Nano silica (Silica Nanoparticles) (NS)

By incorporating 2% nano silica (SiO_2), as depicted in Figure (3-2), into concrete, the mechanical properties of the concrete are improved, resulting in a 15-20% increase in density and compressive strength. The addition of nano silica to cementitious materials aids in preventing water penetration into the concrete, consequently producing highly durable concrete.

A selection of models for nano applications will be chosen to demonstrate their impact on improving the thermal performance of hospital buildings through simulation in the DesignBuilder software. A comparison will be conducted between the thermal .performance in the standard state and when adding nanotechnology materials

5- The Base case

The southern west side on the 2nd, 3rd, and 4th floors of the building was chosen for the current study. It represents a side bedroom department of the Hospital. the zones range in cooling between air conditioning and natural ventilation; furthermore. The southern west facade was concerned with the study to demonstrate the results with more contrast and realism Fig 12, Fig13. Therefore, the current department considers most factors affecting the energy performance of the building and represents a sample model of the rest of the buildings.

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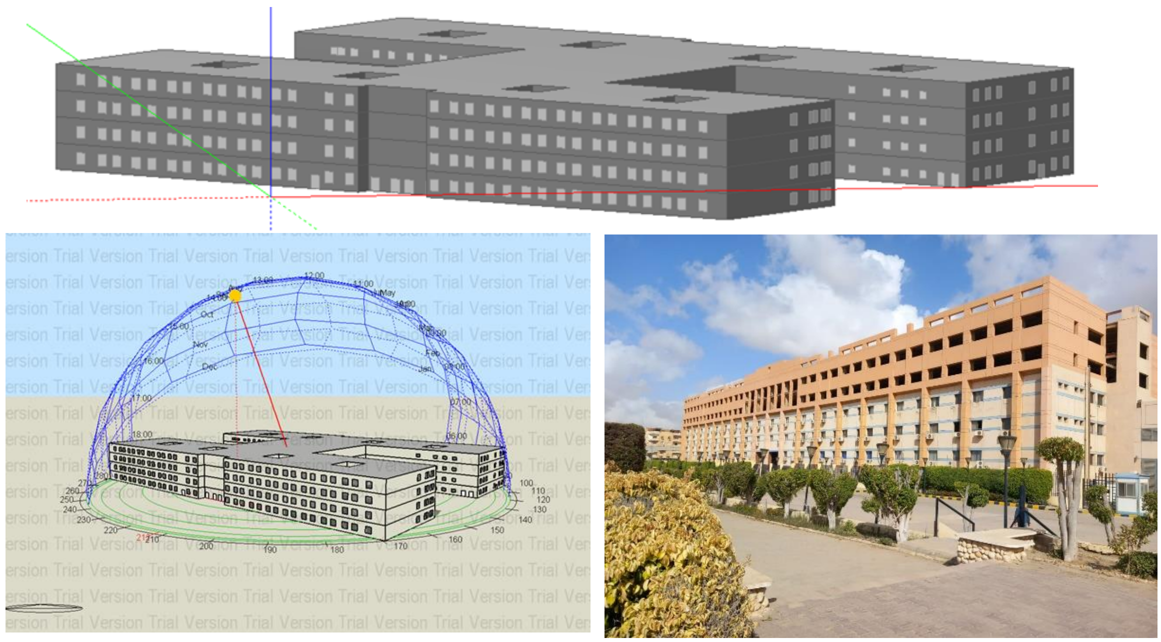

Fig.12 The base case simulation thermal model (3D Model)

Fig. 13 Southern west side of the typical level floors plan

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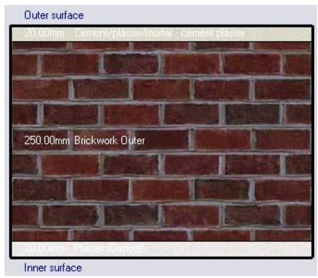
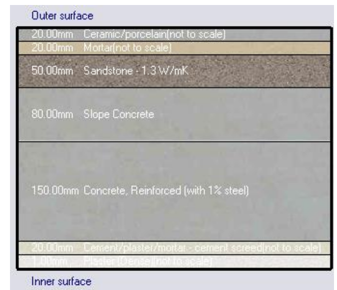
5-1- Base Case

5-1-1- Base Case Constructions

The building has non-insulted brick masonry walls 250 mm thick covered with a 20 mm thick cement plaster on the exterior and interior, providing a calculated U-value of 1.81 W/m^2 K.



The base case materials of external walls



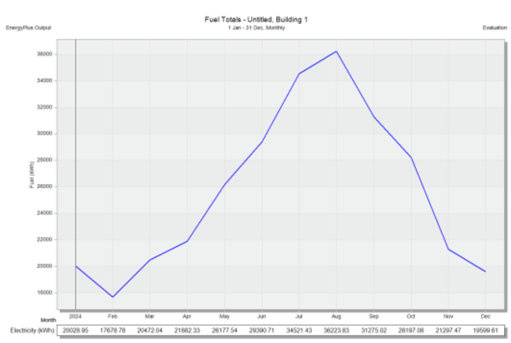
The base case materials of Roof

The exterior windows of the building are Aluminum frames with a single clear 3 mm glazing. The original window has a U-value of around 5.89 W/m2K,

Base case windows characteristics. (Source: Design Builder)

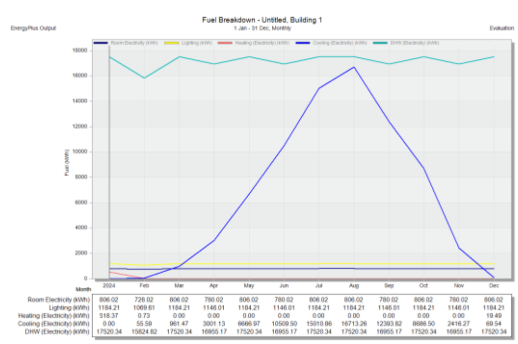
Window glazing	Solar Transmission (SHGC)	Direct Solar transmission	U-value
Single Clear	0.858	0.837	5.89

5-1-2- Base Case Simulation:



Electricity (monthly)

Annual Electricity = 306.74 MWh



Fuel breakdown (monthly)

Annual Cooling = 76.48 MWh

Annual Lighting = 13.94 MWh

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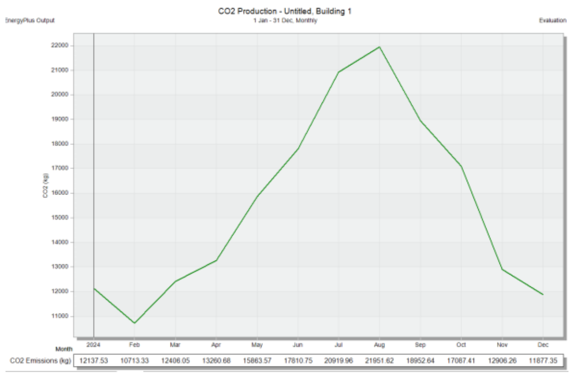
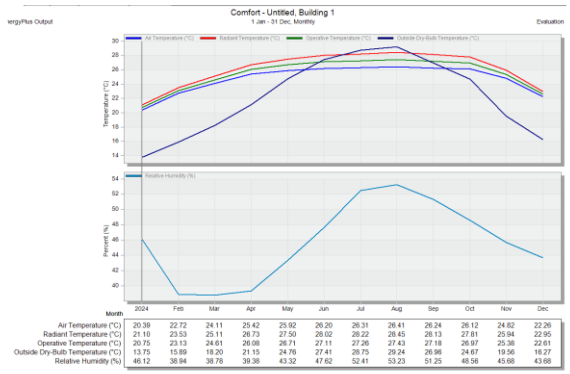
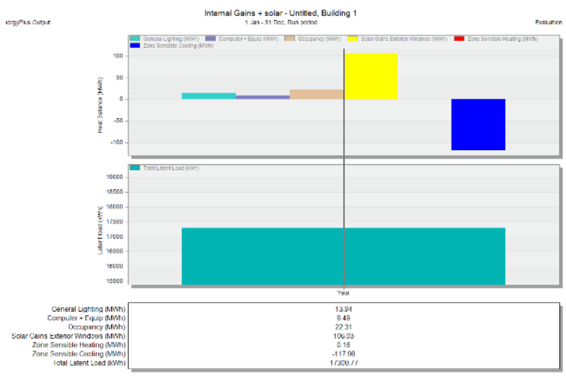


CO_2 Emissions (monthly)

Annual Emission = 185.89 x10^3 kg

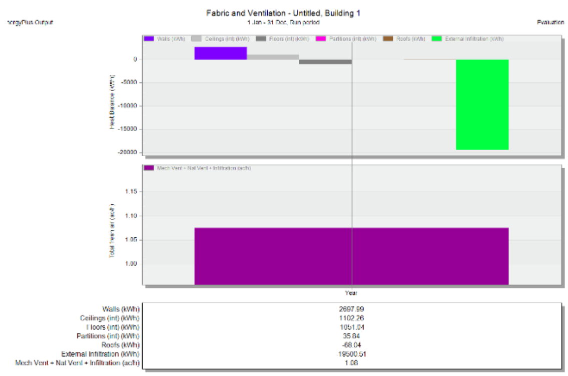


Radiant Temperature



Solar Gains Exterior Windows

Annual = 106 MWh



Fabric (walls and roof)

Wall heat balance = 2697.9

Roof heat balance = -68.04

5-2- The Nano materials interventions in building’s Construction:

The vacuum insulation panel with expanded polystyrene cover layers were selected for thermal insulation of the building’s envelope, where the expanded polystyrene cover layers were applied to decrease the thermal bridging produced by the VIP metal envelope. The VIPs’ thermal conductivity is 0.002 – 0.008 W/(m.K), and the specific heat capacity is 850 J/(kg.K).

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5-2-1- Results of the external wall insulation

Materials	Electricity	Cooling	CO_2
Base case	**306.74 MWh**	**76.48 MWh**	**185.89 MWh**
Vacuum insulation panels	296.08 MWh 3.4%	67.60 MWh 11.6%	179.43 MWh 3.4%
TiO_2 (Cladding)	302.98 MWh 1.2%	71.84 MWh 6%	183.61 MWh 1.2%
Vacuum insulation panels and TiO_2 Cladding	295.87 MWh 3.5%	67.4 MWh 11.87%	179.3 MWh 3.5%

5-2-2- Results of the roof insulation

Materials	Electricity	Cooling	CO_2
Base case	**306.74 MWh**	**76.48 MWh**	**185.89 MWh**
Vacuum insulation panels	302.53 MWh 1.37%	72.58 MWh 5.09%	183.33 MWh 1.37%

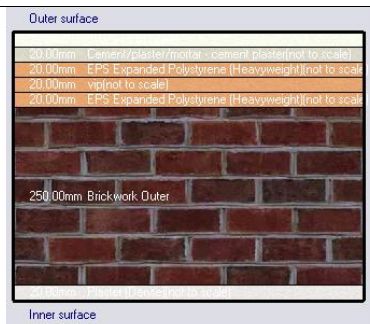

Fig (14) External walls after adding nano insulating material
R-Value = 6.67 m^2-K/W

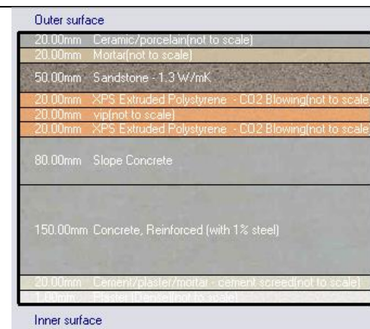

Fig (15) Roof after adding nano insulating material
R-Value = 6.53 m^2-K/W

5-2-3- The Nano insulating materials interventions in building's windows

Materials	Electricity	Cooling	CO_2	Solar G.
Base case	**306.7 MWh**	**76.48 MWh**	**185.89**	**106 MWh**
Dbl - Elec Ref. Bleached 6mm/13mm - Arg	299.4 MWh 2.3 %	69.2 MWh 9.5%	181.43 2.4%	64.86 MWh 38.8%
Dbl - LoE (e2=.2) Clr 6mm/13mm Arg	298.6 MWh 2.6%	68.44 MWh 10.5%	181 2.6%	62.52 MWh 41%
Dbl - LoE Elec Abs Bleached 6mm/13mm - Arg	293 MWh 4.4%	62.36 MWh 18.4%	177.59 4.46%	42.21 MWh 60.1%

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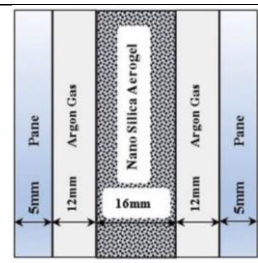
Thermochromic	**292.9 MWh 4.5%**	**62.42 MWh 18.3%**	**177.5 4.5%**	**33.12 MWh 68.7%**
Dbl - Elec Ref. Colored 6mm/13mm - Arg	281.6 MWh 8.1%	50 MWh 34.6%	170.68 8.1%	9158.9 kwh 91.3%
Dbl - LoE Elec Abs Colored 6mm/13mm Arg	281.52 MWh 8.2%	47.8 MWh 37.5%	170.60 8.2%	5736.9 kwh 94%
5mm clr, 12mm arg, 16mm aerogel, 12mm arg, 5mm clr	281.50 MWh 8.24%	47.63 MWh 37.7%	170.59 8.24%	4874.9 kwh 95%

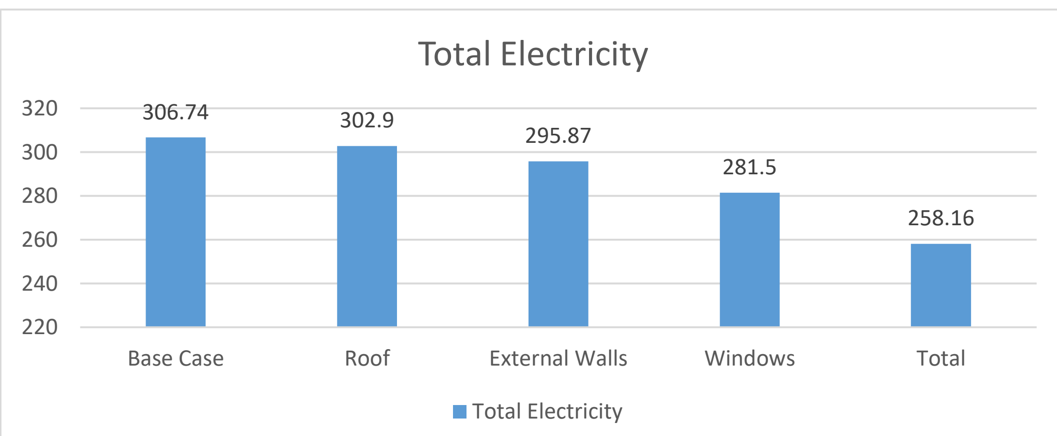
This stage investigated the impact of nano-glazing materials on the studied building energy consumption. Simulation results revealed various improvements in the electricity, with the highest improvement percentage of approximately 8.2% for the double glazed with an Aerogel layer and two layers of argon. At the same time, 6mm double electrochromic reflective bleached 13mm Argon scored a minimal impact on electricity intensity by 2.3%.



Nano Aerogel window panel section

6- The Results of nano insulating materials in walls and windows:

All the interventions were applied to the final simulation to determine the total energy saving. Accordingly, the double-glazed with a nanogel layer and two layers of argon was chosen as it achieved the most significant improvement. VIPs were used on the external walls and roof and TiO2 cladding in the walls.



The results of adding VIPs to the external wall insulation and TiO2 Cladding showed that total energy use was reduced by more than 3.5%. the adding VIPs to the roof reduce about 1.37%.

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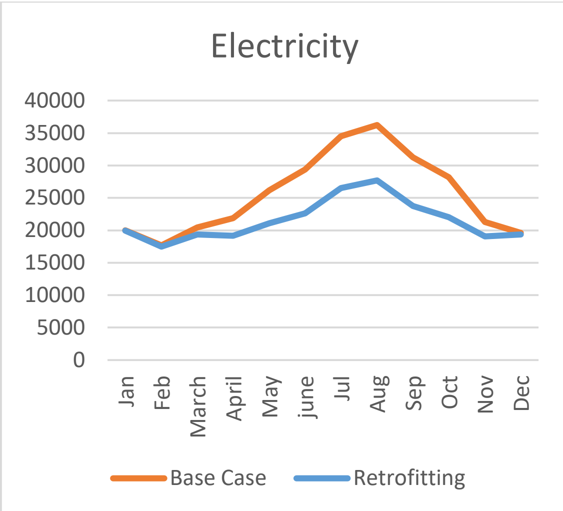
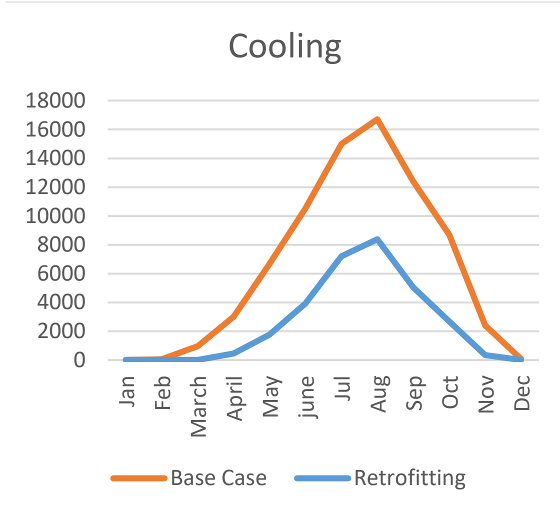
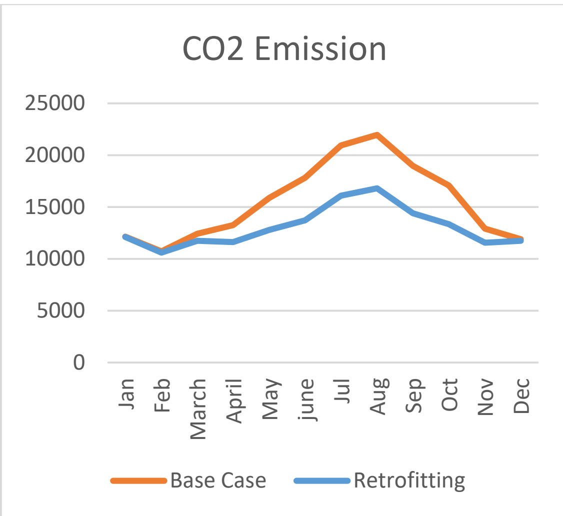
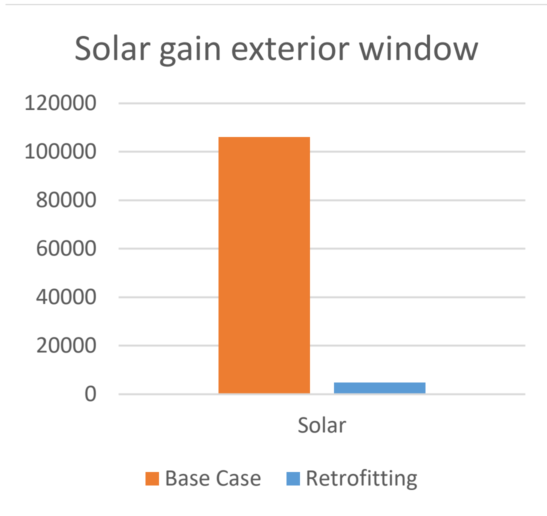




Total Electricity = 258.16 MWh
Before = 306.74 MWh
Decrease = 16%

Cooling = 76.48 MWh
Before = 29.76 MWh
Decrease = 61%





Total CO_2 Emission = 156.44 x10^3 kg

Before = 185.89 x10^3 kg
Decrease = 16%

Solar gain exterior window = 4874.98 KWh

Before = 106030 KWh
Decrease = 95%

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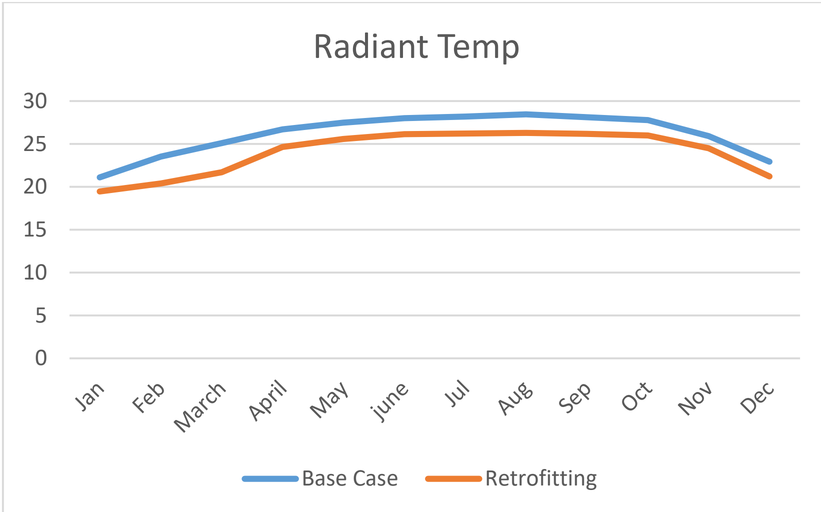

Radiant Temp = The highest radiant temperature recorded was 28.45°C which, in turn, decreased by 2.14°C.

7- Conclusion

The research emphasizes the significant benefits of using nanomaterials in improving the efficiency of existing hospital buildings and optimizing energy consumption, as opposed to traditional materials. It highlights the substantial impact of nanotechnology on the properties of building materials, increasing their durability, resistance, and service life, thereby influencing the quality and cost-effectiveness of architectural products. Notably, the study demonstrated a 16% reduction in energy consumption in the studied hospital building when nanotechnology was employed in coatings and glass applications. Recommended materials for use in hospital buildings include:

- Self-cleaning coatings based on nanotechnology, such as lotus coatings and photocatalytic coatings utilizing titanium dioxide, reduce the necessity for cleaning and maintenance of building facades and interior spaces. These coatings create surfaces that repel dirt and debris, facilitating easier and reduced maintenance efforts for building exteriors and enclosed spaces.
- Utilizing aerogel, a highly porous and lightweight material, between glass layers
- Vacuum Insulated Panels (VIPs).

8- Recommendation

- Emphasizing nanotechnology can lead to numerous solutions that contribute to energy efficiency.
- Encouraging the organization of conferences focused on the utilization of nanotechnology and its applications.
- Utilizing nano-insulating materials to retrofit existing buildings in order to support them and work on reducing their energy consumption.

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