Nanotechnology Perceptions
ISSN 1660-6795
www.nano-ntp.com

Methodology to Improve Energy Efficiency in a Low-Cost Residential Buildings in Egypt Residential Building within an Existing and Frequent Government Housing Project - A Case Study

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One of the most significant problems facing the world at large and the Middle Eastern countries, including Egypt, in particular, is the rising energy consumption brought on by annual global warming. Egypt experiences high summer temperatures, which lead to high energy consumption, so it is imperative to use applications that help Egypt's buildings use less energy. The state has chosen one of the current government housing projects that it provides to residents in multiple governorates. Because there is less use of internal or external insulation, bricks and concrete are typically used in its construction, which causes these buildings to develop poor internal climatic characteristics. The goal of this paper is to increase the efficiency of these built structures by lowering their detrimental effects on the climate while consuming the least amount of energy possible to provide users with more interior comfort.

Aerogel insulation, vacuum insulation panels, mineral wool, and expanded polystyrene panels are the four types of insulation that are available in Egypt for the building's facades. To accomplish the aforementioned goal, an energy simulation was carried out for this existing residential building using the Design Builder to compare the energy consumption. The findings demonstrated that vacuum insulation panels and air-insulating materials provide the lowest energy consumption, resulting in lower electricity consumption and higher thermal comfort levels. In contrast, expanded polystyrene panels and mineral wool provide a lower degree of thermal comfort and a higher level of electrical energy consumption than the earlier materials.

Keywords: Residential buildings, Energy consumption, Building envelope, Thermal insulation; Thermal comfort.

1. Introduction

There is a consensus that the energy consumption of residential buildings in Egypt is approximately 22% of total energy use [1], and heating and cooling energy consumption is 45% It was found that the building envelope is the main source of energy consumption [2]. Globally, the construction industry accounts for 40% of global energy consumption and contributes to carbon emissions. In countries with restricted growth, this percentage rises to approximately 80% [3] So, it is crucial to understand that a building's energy consumption is determined by its design and continues throughout its life until it is destroyed or its virtual life ends [4].

It is quite common that the real measured building energy consumption is much higher than the predicted consumption during design [5,6].

Many factors lead to an increase in the building's internal temperature, such as the use of building materials or materials that are not good thermally or do not insulate heat, especially in hot areas, air leaks from the building's openings through the windows, and external doors or building connections (thermal bridges), internal user movement, etc. Therefore, all previous points must be placed within the design parameters of buildings, especially residential ones, so that they are designed on environmental foundations that make them more energy efficient [7]. The main objective of the research is to improve living spaces' thermal comfort of residential buildings, reduce energy consumption—especially for cooling—and pinpoint the environmental restrictions imposed according to the Egyptian building codes, particularly as they pertain to thermal comfort and how it impacts buildings' energy consumption.

2. Building Envelope

The building envelope protects the building's occupants and controls the building's internal environment. It consists of the building's walls, including openings (doors and windows), in addition to the roof [8]. The good design of this envelope, especially in new projects, reduces the loads required for cooling and heating operations. Therefore, the high costs of its design and implementation can be compensated for through the reduced use of cooling and heating equipment it will save [9].

The building envelope is an essential part of the building, so it has the same effect, whether it is on the consumption of resources, or on the environmental impact that it causes [10]. Consumption is based on the building materials used in the building envelope, which are mostly derived from natural sources, which results in the consumption of more energy during the various stages of building construction [11,12], and environmental change occurs during the manufacture or transportation of the building materials used, which results in environmental gases that are harmful to the environment, which It results in increased degrees of thermal warming, as well as what is produced during construction, renovation, and demolition operations of building material waste that all remains in the ground [13,14], So, the building envelope has many positive effects on the users' internal environment, but it has several harmful effects on humans and their surrounding external environment, especially on plants and animals as well.

2.1 Retrofitting the Building Envelope Optimizes

Thermal comfort is defined by international standards as "a condition of mind which expresses satisfaction with the thermal environment" [15]. The thermal comfort of a building is achieved by its ability to provide the largest amount of improved air within its spaces, or by using as low energy as possible. This is achieved by creating a building envelope designed in sustainable ways that achieve this, or by its sustainable retrofit [16]. According to [17], a sustainable retrofit is the upgrading of a building's parts or components to enhance the structure's environmental performance. It is also described as any type of improvement made to the building's controls, systems, or structure to raise the property's energy efficiency [18].

The building's external walls play the largest role in achieving internal thermal comfort, so they must be well studied, especially knowing their thermal resistance values, which greatly affect the building's energy consumption, especially in multi-story buildings [19]. In the past, the exterior wall of a building was named based on the building material. The wall was called stone if the building material was stone, wood, or metal. But other names have emerged for improved walls, such as thermally insulated walls, light concrete walls, and double walls [20].

The results conducted by [21] after studying a group of retrofit experiments carried out on the envelopes of several buildings in Europe showed that the best environmental benefits for those buildings and their users result from improving their thermal insulation.

Physically, external insulation of the building envelope is the ideal solution because the insulating layers used reduce the condensation of thermal bridges, especially if they are continuous around the building without interruptions that lead to thermal condensation. The external insulating layers also help the building maintain its internal temperature so that heat gain in winter and heat loss in summer are reduced. It completely packs off the building's thermal mass, which helps increase thermal comfort, while internal insulation leads to increased thermal bridging, and increased thermal pressure on the external walls in addition to more condensation processes [22].

Vacuum insulation panels, rock wool, mineral wool, expanded polystyrene panels, double walls, and Aerogel Insulation Boards are the most frequently utilized external insulation materials. Many cutting-edge insulation products, such as vacuum insulation panels and air gel have been created in recent years. Innovative insulation types have demonstrated significant promise in improving building energy performance when compared to conventional insulation materials, notwithstanding their existing market niche. In this investigation, simulations and tests of these materials were carried out [23].

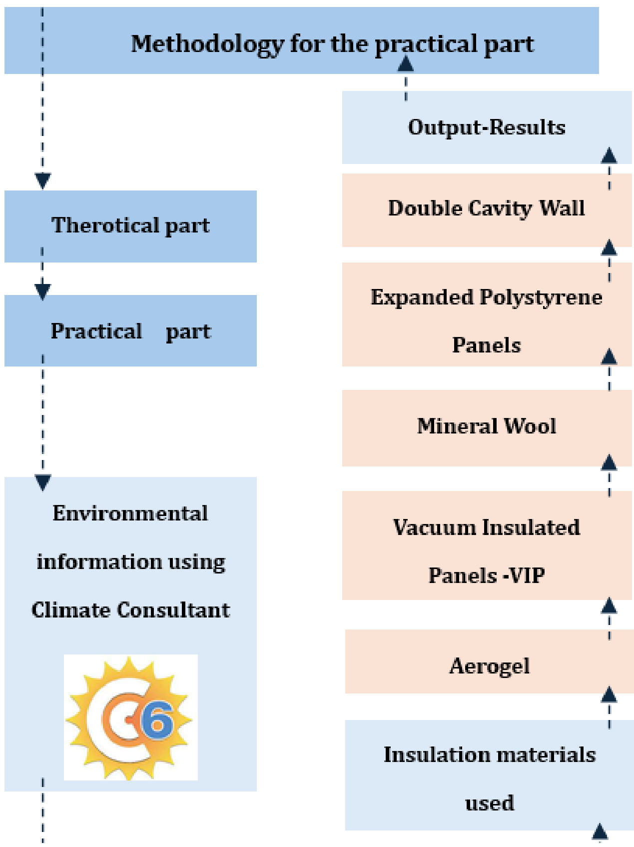
3. Material and Method

3.1 Objectives

The study's primary goal is to create a vision for residential building Retrofitting for government housing projects in Egypt to lower energy consumption and increase residential building efficiency as a strategic goal to be attained given that all new construction must be zero-energy sustainable buildings. On the other hand, Energy that results in a building using as much energy as it produces, producing more energy than it consumes, or vice versa, saving energy that can be used for other purposes, is thought of as a starting point for achieving sustainability in existing residential buildings.

3.2 Methodology

The research is based on a hypothesis to create a vision of using various thermal insulation materials and applying them to the various facades of the building, which primarily considers the energy consumption of the residential building before and after insulation using the design-builder programmer. This study focuses on the energy performance of residential buildings and includes comparing different types of thermal insulation materials, and then comparing the results of the simulation conducted using this program, See Figure 1.



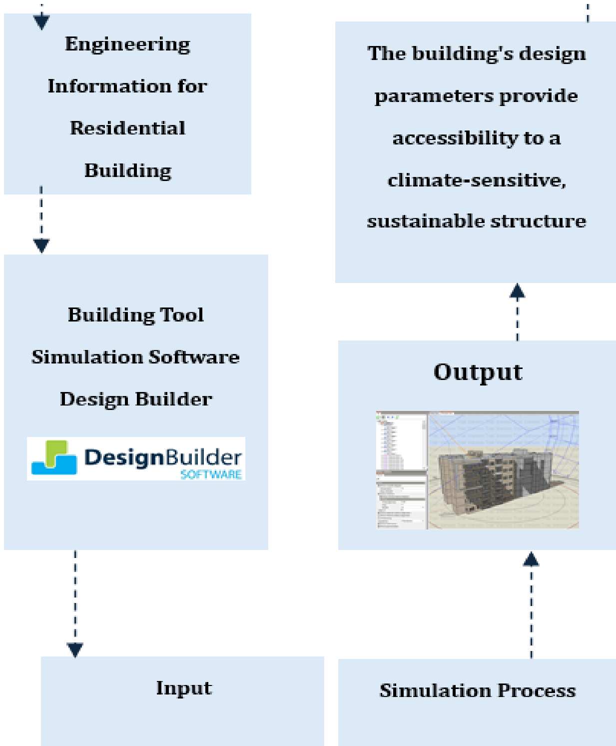


Figure 1. Methodology of Research.

3.3 Study Sample

The sample study was selected from one of the frequent government housing projects in one of the neighborhoods of Greater Cairo (6th of October area). In terms of energy consumption, it was found that residential projects are the ones that occupy the first place in energy consumption, and therefore a six-story residential building built within this government project was chosen, and the Design Builder V.7 simulation program was chosen to apply the design variables to it, See Figure 2.

Figure 2. The general plan of the project sites in 6th of October City, Cairo total buildings number (194), Zone (A): 2304 buildings units, Zone (B) 2320 buildings units.

4. Reasons for choosing the model for the study.

The 'Sakan Misr' project is one of the projects of the New Urban Communities Authority that is widely spread in most cities of the Arab Republic of Egypt as one of the means currently used by the state to provide suitable housing for the middle-income classes. The number of units offered by this project so far reaches about 100,000 units in ten stages for sale.

4.1 Data for the model under study

The study model is a residential building consisting of a ground floor + 5 recurring floors, the area of the recurrent floor is 470 square meters, and the model is repeated in the general location of each project in different directions, as the model is symmetrical in the four directions. Each floor consists of four units that are almost identical in design, composition, and area, and these units differ only in the direction of each unit (as in the following figure1 and 2). Buildings are distributed in the public site by repeating the previously mentioned model with different directives according to the shape and nature of the site as well as in proportion to the urban design of each project as shown in Figure 3. The entire building has been selected to represent the applied model of the study.

Figure 3. The horizontal projection and interfaces of the model under study.

The applied study includes measuring the level of thermal comfort, total energy consumption, and carbon dioxide levels within the internal spaces to reach a building that considers the ambient climatic conditions within the four residential units on the entire residential floor level, See Figures 4 and 5.

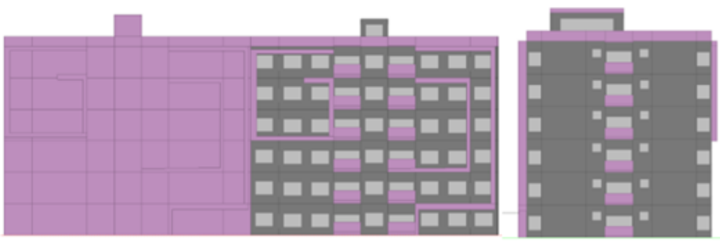


Figure 4. South Façade of the residential building on the Design Builder program Screenshot.

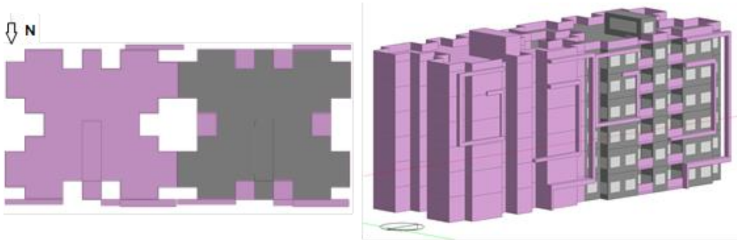


Figure 5. The architectural drawings of the unit under study and the three-dimensional shape of the unit after it was built on the Design Builder program.

4.2 Climatic analysis of the area under study

According to the climate reports issued by the monitoring station located at Cairo International Airport ETMY 623660 and the ENERGYPLUS website and the climate files available on it, and using the Climate Consultant 6.0 application, it was found that the percentage of humidity throughout the year ranges between 45% to 65%, ranging summer temperatures from 35 degrees to 41 degrees Celsius, as well as a decrease in temperatures until they reach 6 degrees Celsius in winter in the north of Upper Egypt and 8 degrees in the south, which indicates that temperatures in Egypt reach the point of exhaustion. Hot in the summer and very cold in the winter, See Figure 6.

Since the average relative humidity varies according to the different temperatures, we find that it is affected by the air temperature, so it can change to less than 20% after the peak of the temperature and up to 40% during the night. It is worth mentioning that the average relative humidity ranges at the level of the cities of Egypt from 59% to 61%.

Wind direction varies according to seasons, seasons of the year, and city locations. The winds have their effect in changing the shape of the terrain, and it is noted that they are weak in speed at the beginning and end of the day.

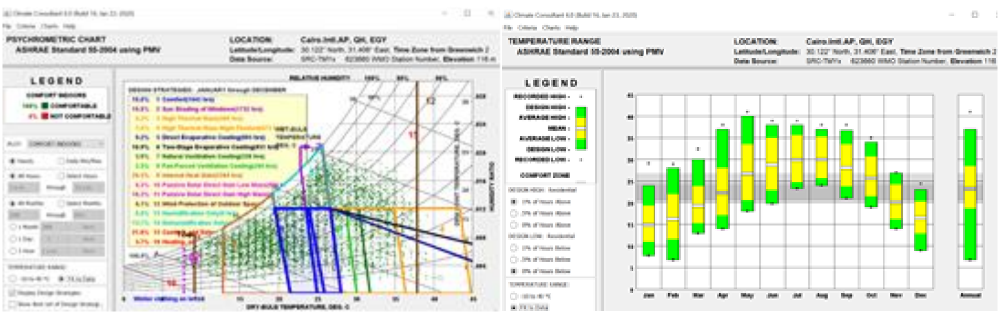


Figure 6. Cairo air temperature and psychrometric chart map throughout the year.

5. Study/ Simulation tools (Design Builder-Energy Plus)

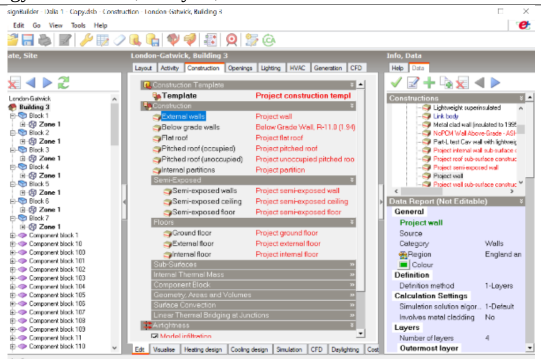
It is known that this program, in turn, provides an experimental medium through which we can build a model for the housing units under study as it is on the ground with the same construction building materials and finishing materials, and activate the model according to the climate of the specified area to give the results of the building's operation and consumption of energy throughout the year, and then we suggest adding Some design variables on the building, then simulate the operation of the building throughout the year, and compare the consumption results before and after the addition, to reduce the building's energy consumption.

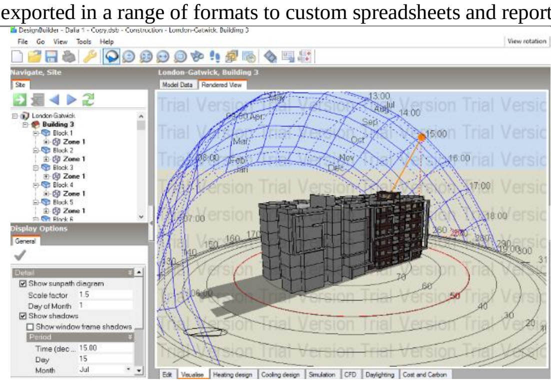
Design builder (Design Builder Software Ltd - V. 7.0.0.116 – Educational Version) provides a detailed analysis based on simulation for energy assessment based on the characteristics of the specific building, which allows the user to benefit from it to develop systems after analyzing, studying, and measuring their effectiveness, by trying out the proposed hypotheses and testing the results before applying them on the ground, which is a modeling environment that provides the necessary information about the building's environmental performance, including the building's energy consumption, thermal comfort data, and the volume of heating, ventilation, and air conditioning operation in the building as shown in Table 1.

Consumption values are accurately output according to the hours of the day. Based on the type of HVAC, natural ventilation, daylight control on the building, the quality of the building facades, their duplication, and shading strategies, as well as the cooling and heating rates in the building.

Table 1. Input and output parameters of the simulation tool (Design Builder Simulation), author.

Input Data	**Output Data**
The location of the model was determined, and then its elements were built in a three-dimensional field and given the real thickness, materials, and functions of the building, using the options available in the program and Shell: • Activities, materials, and quality • Lighting systems. • Air conditioning systems. • Openers, glass quality, and other fine details of the building.	A comprehensive set of data is shown in an annual simulation: • Energy consumption according to its source as fuel and its use. • Indoor air, radiation, temperature, and humidity. • Comfort outcomes include temperature distribution curves, comfort parameters, and discomfort indices. • Location weather data.
Choosing an effective tool at each design stage of the building to simulate its impact. The program consists of several elements, the most important of which is: the possibility of 3D modeling, and it consists of an integrated library of raw materials and their physical and thermal properties, and energy simulations, analysis, and thermal comfort rates are simulated.	Heat transfer through building fabric including ceilings, walls, infiltration, and ventilation. Heating and cooling loads and calculating the sizes of their stations using weather data design, and carbon dioxide emissions. The information produced can be displayed graphically, in tabular or group form, and can be exported in a range of formats to custom spreadsheets and reports.





5.1 Determine the proposed division of residential plots.

It depends on dividing residential areas into three main sections according to typical planning criteria, including middle housing - economic housing, and middle housing areas will be selected as a case for the research study as follows, as shown in Tables 2,3 and 4.

Table 2. Planning criteria for dividing residential lands into medium housing areas.

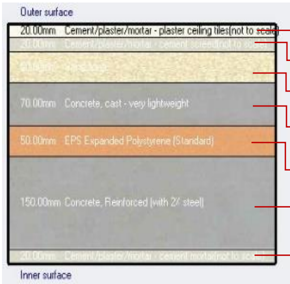
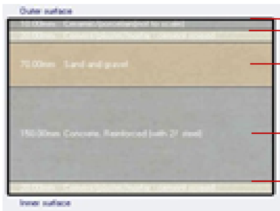
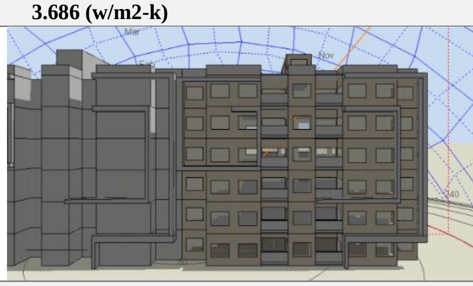
Structural requirements for medium housing areas	
Land Area	300:400 m2
Buildings Ratio	60 %
Units per Floor	4 Residential Units
The average Floor Area of the Housing Unit	90:120 m2
Suggested Design variables	First: The height of the building and the inter-spaces between opposite buildings. Second: The outward protrusions. Third: The layers of the solid outer cover. Fourth: The dimensions and proportions of the external openings. Fifth: The interior residential skylights.

Table 3. Unit occupancy characteristics were entered for the simulation application.

Space Name	Living and reception space
Occupancy Rate	0.1 person /m2
Activities	Traditional residential activities for the family
Cooling temperature	24-28o C
Heating temperature	20-23o C
Relative Humidity	Acceptable limits range from 20-55%.
Air Conditioning used Type	SPLIT (No Fresh Air)
Natural Ventilation	Natural ventilation is relied upon according to operating schedules based on internal and external temperatures and the difference between them. Natural ventilation is not relied upon above 28 degrees in the summer and less than 20 degrees in the winter.

Table 4. Structural layers of the building for each element and thermal transfer used in the Design-Builder program.

External Walls (250 mm + 45 mm finishing)	**Outer** Surface  **5 mm** Screeds and render **20 mm** Cement/ Plaster/ mortar **250 mm** Brick wall **20 mm** Cement/ Plaster/ mortar **Inner** Surface
U-Value(w/m2-k)	**1.852 (w/m2-k)**

Internal Walls (120 mm + 40 mm finishing)		**20 mm** Cement/ Plaster/ mortar **120 mm** Brick wall **20 mm** Cement/ Plaster/ mortar
U-Value(w/m2-k)	**2.281 (w/m2-k)**	
Roofs From top to bottom		**20 mm** Ceiling Tiles **20 mm** Cement/ Plaster/ mortar **60 mm** Sand and Gravel **70 mm** Concrete, Cast - Very lightweight **50 mm** E.P.S (Expanded Polystyrene) **150 mm** Reinforced Concrete (2% Steel) **20 mm** Cement/ Plaster/ mortar
U-Value(w/m2-k)	**2.010 (w/m2-k)**	
Floors From top to bottom		**10 mm** Ceramic/ Porcelain **20 mm** Cement/ Plaster/ mortar **70 mm** Sand and Gravel **150 mm** Reinforced Concrete (2% Steel) **20 mm** Cement/ Plaster/ mortar
U-Value(w/m2-k)	**3.686 (w/m2-k)**	
External Openings External doors and windows with an aluminum frame and 60% single reflective glass with a thickness of 3 mm		
U-Value(w/m2-k)	**5.894 (w/m2-k)**	

5.2 Monitoring the results of the climate analysis of the residential model using the Design Builder program for the reference case without treatments

In this study, the number of hours of discomfort in the natural ventilation mode and the amount of energy consumed for cooling are compared in the case of the mixed mode between natural ventilation and industrial cooling, according to the Egyptian code for the rationalization of energy consumption, and according to the variables derived from the study of the status of the unit under study, See Figure 7.

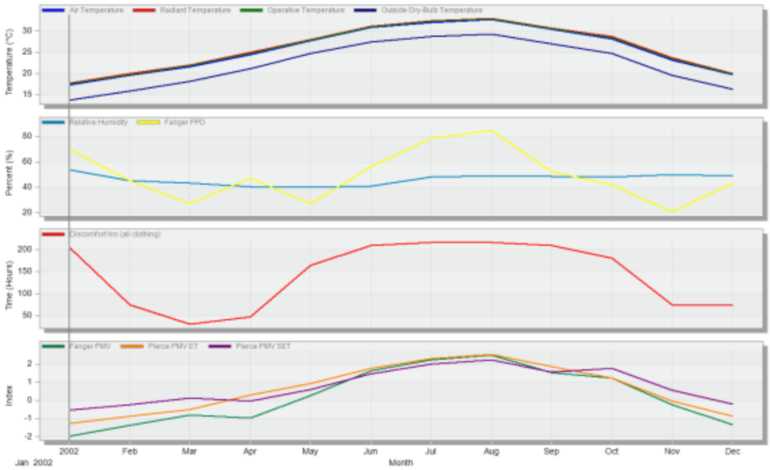


Figure 7. The results extracted from the program indicate the variables affecting the level of comfort.

Table 5. External factors affecting the building, such as temperature, humidity, and PMV.

Date/Time	**Relative Humidity %**	**Fanger PMV**	**Fanger PPD %**	**Air Temperature °C**	**Operative Temperature °C**	**Discomfort hrs. (All clothing)**	**Outside Dry-Bulb Temperature °C**
June	48.07	0.422	78.54	32.05	**32.20**	217	**28.75**
July	49.07	0.530	84.81	32.63	**32.79**	217	**29.24**
August	48.84	0.211	52.29	30.39	**30.58**	210	**26.95**
				Winter Months			
Dec	49.27	-1.31	43.31	19.64	19.80	73.06	16.27
Jan	53.83	-1.95	70.35	17.32	17.51	206.6	13.74
Feb	45.31	-1.35	45.30	19.56	19.77	73.94	15.88

Table 6. Thermal loads on each of the Glass surfaces, Walls, Interior Ceilings, Floors, and Roof.

Date/Time	**Glazing**	**Walls**	**Ceilings**	**Floors**	**Roofs**
June	1470.219	219.8629	567.647	547.2789	**679.2092**
July	1971.052	394.5406	628.566	649.58	**761.8486**
August	1526.97	184.2817	81.6571	117.8764	**206.8242**
			Winter Months		
Dec	-11851.2	585.4042	517.5651	517.5651	**-934.34**
Jan	-7451.52	-611.618	726.3839	726.3839	**-987.718**
Feb	-7451.52	-1060.36	705.2636	705.2636	**-839.478**

The previous Table 5 shows the thermal comfort factors affecting the building from internal and external temperatures, relative humidity, the internal thermal comfort index of architectural spaces, PMV, and the external comfort index PPD, where we find the current study of the building recording the highest temperatures inside the space, ranging from 30 to 32 0C.

Heat is gained from the outside through thermal loads on each (glass surfaces, walls, interior ceilings, floors, roofs, and other external intrusions) as shown in the next Table 6.

Table 6. Thermal loads on each of Glass surfaces, Walls, Interior Ceilings, Floors, and Roof.

5.3 Electricity Consumption rates throughout the year -Base Cae.

Table 7 shows the result of simulating energy consumption for the hypothetical situation of the study model throughout the year, where the month of August records the highest values of electric energy consumption, reaching 30485.67 kWh, and gradually decreasing from September to February to reach 10214.94 kW/h, so that The total energy consumed during a full year reaches 218170.5 kW/h, and this is illustrated by the form of the total annual electric energy consumption rates for the default mode of the model as illustrated in Figure 8.

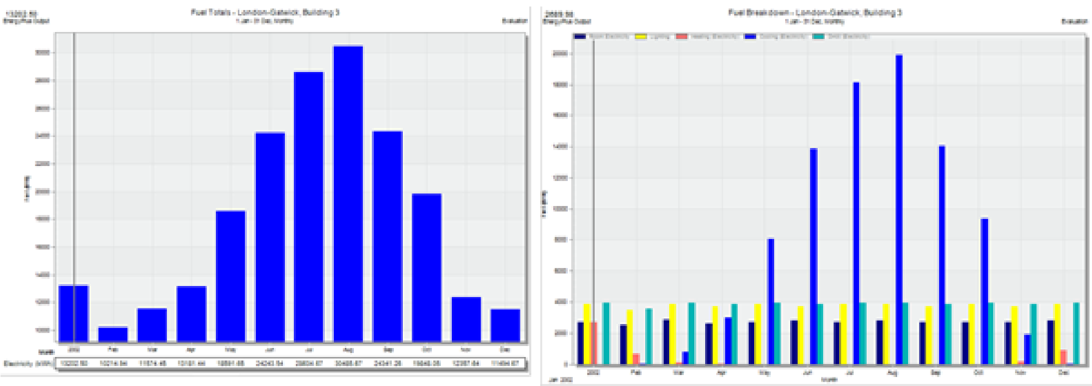


Figure 8. Left: Total electric energy consumption rates throughout the year for the proposed building. Right: Total energy consumption rates of electricity, lighting, cooling, and heating system used in the proposed building.

Table 7. Electrical Energy Consumption Rates used in the proposed building.

Electricity loads used in space, except for lighting	Electricity = 2500 kWh
Electricity loads are consumed by lights.	Lighting = 3900 kWh
Cooling Loads	Cooling = 20000 kWh
Domestic Hot Water Consumption	DHW = 4000 kWh

Table 8. Properties of the Aerogel Insulating Material for the Proposed Building.

	Insulation Type				
	Aerogel	**Vacuum Insulated Panels -VIP**	**Mineral Wool**	**Expanded Polystyrene Panels**	**Double Cavity Wall**
Structural layers in the simulation program (Design Builder Software)					
Conductivity (W/mk)	0.014	0.014	0.014	0.036	0.840
Density (kg/m3)	150	150	48.0	20.0	1700
Specific heat (J/kg-k)	1000	1000	840	1500	800
Total Surface Area-South Façade:283.5 m2					
Cost	379,050 L. E	397,232 L. E	65,500 L. E	301,209 L. E	80,790 L. E

5.4 Carbon Dioxide Emissions (CO_2)

The total carbon dioxide emissions of buildings, available data at the building level during the months of the year, where the total carbon dioxide emissions reach 12041 Kg.

5.4.1 Cooling Rate for the Building

The effect of the total cooling required on the study area (the required air that is introduced to the interior spaces through the heating, ventilation, and air conditioning system (HVAC) where the total consumption for cooling the interior spaces is 13101.51 kWh.

6. Analysis of Energy Consumption Rates for the study variables after developing the proposed architectural solutions.

At that stage, the effect of the change occurring after the use of thermal insulation materials on energy consumption (used for cooling) and the most monthly consumption within the space under study is studied, with a study of the feasibility of the type of insulation material on them. Therefore, (Aerogel, Vacuum Insulation Panels, Mineral Wool, Expanded Polystyrene Panels, and Double Walls) were chosen as shown in Table 8. These insulating materials were also applied to three facades, which are the western, eastern, and southern facades, as they are the most exposed to the sun.

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7. Result

7.1 Analysis of energy consumption and thermal performance of the study variables.

At that stage, the changes in the use of thermal insulation materials on energy consumption (used for cooling and heating), thermal comfort indicators, and carbon dioxide emissions within architectural spaces are studied, along with changing the type of insulation material. The following table shows the thermal properties of the insulation materials used according to the general specifications for the items of thermal insulation works, which are guiding values for the used insulation materials. The study is based on the measurement of energy consumption and the level of thermal comfort in the case of natural ventilation, and the consumption of cooling energy to measure energy consumption in the case of reliance on air conditioning systems.

The following is a presentation of the simulation results a comparison of the test results of the insulation materials selected for the study, and the values of the effective ability to save energy with the thickness of the samples fixed to be 20 mm in all directions.

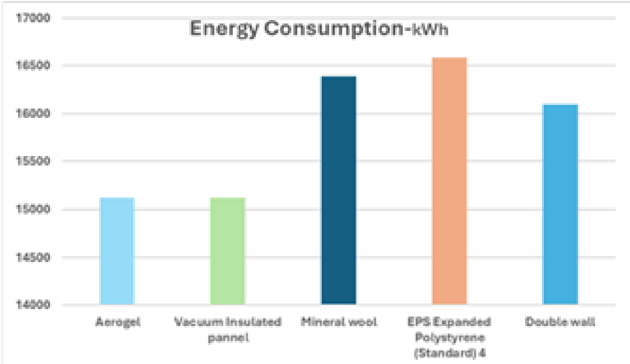

Figure 9. A comparison between the different types of insulation for total energy consumption throughout the building.

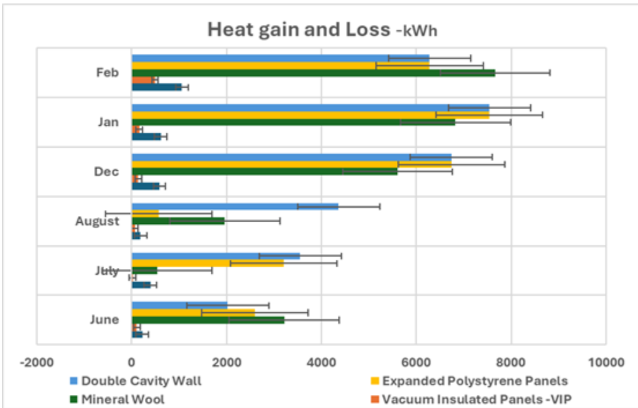

Figure 10. A comparison between the different types of insulation for the heat gain and loss inside the unit throughout the building

Electricity: The result of simulating energy consumption for the hypothetical situation of the study model after laying the Aerogel insulation boards, vacuum insulation panels, Mineral Wool Expanded Polystyrene Panels (Standard), and finally the Double Cavity Wall throughout the year indicates that the energy consumption reached 2570 kWh, 2634 kWh 2791.5 kWh,2820 kWh and 2718.3 kWh respectively compared to the total electricity during a whole year for the basic situation of the building, which reached 218170.5 kW, See Figure 9.

Indoor Energy Consumption: Indoor energy consumption rates including equipment, lighting, occupancy, heating, and air-conditioning after laying the Aerogel insulation boards, vacuum insulation panels, Mineral Wool Expanded Polystyrene Panels (Standard) and finally the Double Cavity Wall are as follows:

- Energy consumed for cooling: 10977 kWh,10954 kWh, 11281 kWh,11482 kWh, and 11112 kWh respectively.
- Consumption rate because of external glazing: 15566 kWh,15572 kWh, 16362 kWh, 16430 kWh, and finally 16135 KWh respectively.

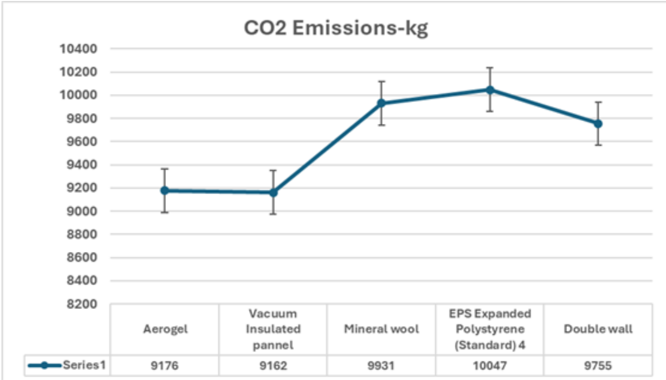

Figure 11. CO2 Emissions for the different types of insulation throughout the building.

Annual operational electricity consumption: energy consumption is divided according to the usage category of electricity, cooling, heaters, and internal and external lighting, where the average total consumption of electricity reaches 2570 KWh, 2634 kWh, 2791.5 kWh, 2820 kWh, and finally 2718.3 KWh respectively compared to the basic condition of the residential building without any architectural treatments, See Figure 10.

The total mass of carbon dioxide emissions after adding Mineral Wool reached 9178 kg, 9162 kg 9331 kg,10047 kg, and 9755 kg respectively compared to the current situation of the study without treatments, which amounted to 12041.86 k, See Figure 11.

8. Conclusions

The results of the effect of the insulation materials used on the thermal performance of the building

The design of the external wall sector has an important and effective effect on the extent to which thermal comfort is achieved for the users of the internal spaces, and its effect appears whenever the thermal transition of the sector becomes more appropriate according to the climatic interface.

From the results of the study using insulating materials for the residential model (Aerogel, Hollow insulation panels, Mineral wool, Expanded polystyrene panels, and Double cavity wall), we find that the Aerogel insulation material provides the lowest energy consumption for the building with the highest level of thermal comfort and one of its advantages is that it can be used in urgent cases or When merging more than one material on the wall to achieve an increase in the savings rate.

The effect of the total cooling required on the study area (the required air that is introduced to the internal spaces through the heating, ventilation, and air conditioning system (HVAC), where the total consumption for cooling the internal spaces was 10976.74 KWh, unlike the total consumption rate for heating the spaces in the season winter, which reached 141.31 kWh as can be seen in the previous tables, as the consumption rates required for operation after adding Aerogel material were lower than the basic condition of the building by 13.5%.

From the study, we also find that the Aerogel and vacuum insulation panels give the lowest energy consumption and thus provide the lowest level of electricity consumption and the highest level of thermal comfort for the entire residential building, while the mineral wool and expanded polystyrene panels give the highest electrical energy consumption and the lowest level of thermal comfort.

By comparing the simulation results, we find the percentages of energy savings for high-performance insulating materials, as the results show that the best materials, in general, are Aerogel and vacuum insulation panels, as they converge in their results. We also find that the high-efficiency insulation panels (Aerogel) and the vacuum insulation panels record the highest efficiency in energy consumption throughout the year.

Although the cost of Vacuum Insulated Panels -VIP and aerogel is still much higher than that of traditional materials, once the technology is fully developed, it may be able to compete and provide the performance needed from the standpoint of zero energy building.

9. Recommendation

In addition to assisting any specific project for residents who utilize solar energy in their houses, work on adopting strategies to rationalize energy conservation and researching the best approaches.

People's acceptance of the concept of lowering energy consumption and adopting renewable energy is greatly influenced by efforts made to raise environmental consciousness among residents and to help them realize the importance of energy conservation and the concept of sustainability. Mineral Wool is not a good insulator for interior spaces and should be avoided because it increases the energy needed for air conditioning.

References

[1] Arab Republic of Egypt, Ministry of Environment. 2020; doi: https://www.eeaa.gov.eg/portals/0/eeaaReports/SoE2007Ar/10-energy.pdf

[2] Ministry of Energy and Electricity. 2010; doi: https://www.researchgate.net/figure/Electricity-consumption -in Egypt-Ministry-of-Energy-and-Electricity-2010_fig1_332061223

[3] Mahsa T., Mohammad J., M. Past and Future Trends on the Effects of Occupant Behavior on Building Energy Consumption. Journal of Sustainable Architecture and Civil Engineering, 29/2/2021; 83-101. doi: http://dx.doi.org/10.5755/j01.sace.29.2.28576

[4] Agugliaro, F., Montoya, F. G., Sabio-Ortega, A. & García-Cruz, A., Review of bioclimatic architecture strategies for achieving thermal comfort. Renew Sust Energ Rev, 49; 2014. doi: https://doi.org/10.1016/j.rser.2015.04.095

[5] de Wilde, P. The gap between predicted and measured energy performance of buildings: A framework for investigation. Automation in Construction 41; 2014. doi: 40–49. https://doi.org/10.1016/j.autcon.2014.02.009.

[6] Desideri, U., Yan, J., Menezes, A.C., Cripps, A., Bouchlaghem, D., Buswell, R. Predicted vs. actual energy performance of non-domestic buildings: Using post-occupancy evaluation data to reduce the performance gap. Applied Energy 97; 2012. 355–364. doi: https://doi.org/10.1016/j.apenergy.2011.11.075

[7] Thanun Srithongchai. The Role of Layout in Improving Building Thermal Performance in Bangkok. Journal of Sustainable Architecture and Civil Engineering; 29/2/2021; 189-204. doi:

http://dx.doi.org/10.5755/j01.sace.29.2.29410
[8] IEA. Transition to Sustainable Buildings: Strategies and Opportunities to 2050. Paris: International Energy Agency (IEA); 2013.
[9] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program Greening Federal Facilities, "An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers and Designers", Second edition, Building Green, Inc., Brattleboro, Vermont; 2001.
[10] R. Tiong & I. Lee. “Examining the Role of Building Envelopes towards Achieving Sustainable Buildings”; International Conference on Whole Life Urban Sustainability and its Assessment, Glasgow; 2007; P: 1- 2, 10, 11. doi: Lee.pdf (sue-mot.org)
[11] P.F.G. Banfill; M. Monkiz; & G. F. Menzies. “Life-Cycle Assessment and the Environmental Impact of Buildings: A Review”; Sustainability 2009. doi: (hw.ac.UK)
[12] A. Acheampong; J. Ayarkwa; J.K. Hackman & K. Agyekum. “Environmental Impact of Construction Site Activities in Ghana”; Africa Development and Resources Research Institute (ADRRI) Journal; vol.9, no.9(2); 2014. doi: (researchgate.net)
[13] WD Re-Thinking Ltd. “The Impacts of Construction and the Built Environment”; WILLMOTTDIXON; 2010.
[14] C. Aigbavboa; M. Mbala & J. Aliu. “Reviewing the Negative Impacts of Building Construction Activities on the Environment: The Case of Congo”; International Conference on Applied Human Factors and Ergonomics; 2018. doi: SpringerLink
[15] Mounira B.; Yasmina B. " A Study of Indoor Environment of Large Glazed Office Building in Semi-Arid Climate" Mahsa Torabi, Journal of Sustainable Architecture and Civil Engineering, 29/2/2021; 175-188. doi: http://dx.doi.org/10.5755/j01.sace.29.2.28008
[16] Shamout, S. Energy retrofit of the existing building Envelope in Jordan: A Study on Mixed-use Buildings (Retail and Office) in Amman. New Zealand, Auckland: University of Auckland; 2016.
[17] Tan, Y., G. Liu, Y. Zhang, C. Shuai, and G. Q. Shen. “Green Retrofit of Aged Residential Buildings in Hong Kong: A Preliminary Study.” Building and Environment, Volume 143, 1 October 2018; 89-98. doi: PolyU Scholars Hub
[18] P. Brown, W. Swan, and S. Chahal. “Retrofitting Social Housing: Reflections by Tenants on Adopting and Living with Retrofit Technology.” Energy Efficiency; 2014; 7 (4): 641–653. doi: University of Huddersfield Research Portal.
[19] Sadineni, Suresh B., Srikanth M., and Robert F. Boehm. “Passive Building Energy Savings: A Review of Building Envelope Components.” Renewable and Sustainable Energy Reviews; 2011; 15(8):3617–31. doi: https://doi.org/10.1016/j.rser.2011.07.014.
[20] Bandana Jha and Bishwajit Bhattacharjee, Tool for Energy Efficient Building Envelope Retrofitting, Building Performance Analysis Conference and SimBuild co-organized by ASHRAE and IBPSA-USA Chicago, IL, September 26-28, 2018. doi: C001.pdf (ashrae.org)
[21] Ardente, Fulvio, Marco Beccali, Maurizio Cellura, and Marina Mistretta. “Energy and Environmental Benefits in Public Buildings as a Result of Retrofit Actions.” Renewable and Sustainable Energy Reviews; 2011; 15(1):460–70. doi https://doi.org/10.1016/j.rser.2010.09.022.
[22] Yixiao Ma and Han Vandevyvere, Building Envelope Retrofit, Solution Booklet, EU and SCIS Smart Cities Information System; April 2020. doi: scis_solution_booklet_building_envelope_retrofit.pdf (Europa. EU)
[23] Xinrui Lu and Ali M. Memari. " Performance Evaluation of Building Envelope Systems Incorporating Conventional and Innovative Insulation Materials.", Department of Civil and Environmental Engineering, Penn State University, University Park, United States; 2019. doi: https://dx.doi.org/10.7492/IJAEC.2019.011