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Comparing Retrofitting Techniques by Energy Cooling Loads Analysis: Simulation-Based Model Study for Residential Building in Egypt

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ABSTRACT

Today, the world suffers from rapid climate change such as; high temperatures, Cooling Loads, and less thermal comfort in Buildings that affect the energy efficiency of buildings and the health of citizens. The problem is increasing cooling load values in buildings and energy consumption during the summer season to make thermal comfort in Spaces. The research discussed two parts of theoretical studies on the importance of using retrofitting techniques that are considered suitable solutions in buildings to reduce energy consumption. Therefore, the research aims to use retrofitting techniques to improve and reduce cooling loads and develop proposals for possible solutions to achieve energy efficiency through the second part of using the simulation program to reach the appropriate results to reduce the energy consumption of cooling loads. It is applied by selecting a project of an existing residential building in Egypt and using a simulation program such as; Design Builder in three Phases that can be compared with the base case with three cases through various techniques and parameters of suitable materials to study and calculate cooling load from the high value to low value. The simulation result shows the maximum cooling load value of 4.53 KWh/m^2 in the Base case without any insulation materials or retrofitting techniques, therefore retrofitting techniques were used to reach a minimum cooling load of 2.56 KWh/m^2 in the third case. So the best result is the third case of minimum cooling loads that achieves energy efficiency to make existing buildings sustainable.

Keywords: Simulation; Cooling Loads; Insulation Materials; Windows Glazing; Retrofitting Techniques

NOMENCLATURE

KWh/m^2	Kilo watt hours per meter square

ACRONYMS

3D	Three-Dimensional
EECRB	Egyptian Energy Code for Residential Buildings
EEHC	Egyptian Electricity Holding Company
HBRC	Egyptian Housing and Building National Research Center
IEA	International Energy Agency
CO_2	Carbon Dioxide

1. INTRODUCTION

The world suffers today as a result of population and rapid growth increases each year which led to increasing high consumption of energy and non-renewable resources of oil and gas, so they need to use renewable sources of energy for suitable adequate housing and more sustainable with thermal comfort by using alternative solutions in construction, especially in the residential sector, where consumption is about 40%, and 27% respectively of energy consumption annually [1,2].

This shows the annual energy consumption rates according to the International Energy Agency's (IEA) report every year as shown in figure 1.

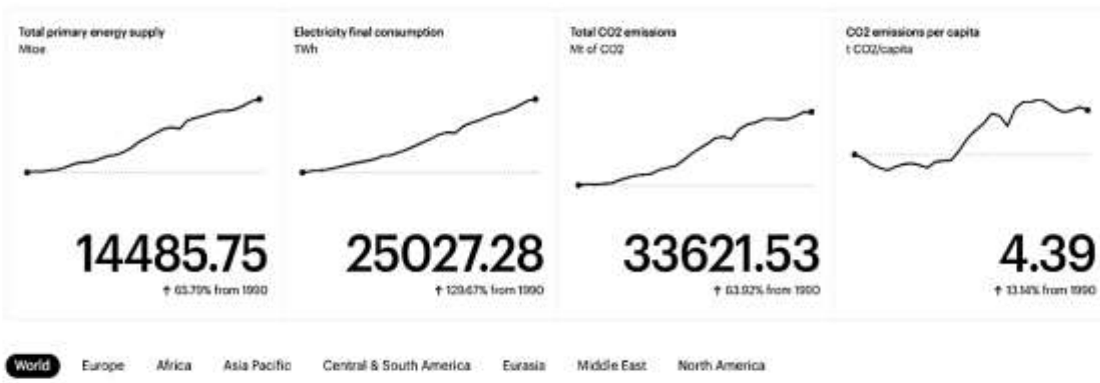


Figure 1: Key energy statistics in the Global World, 2022 according to the International Energy Agency's impact index. Source: International Energy Agency, 2022 [3]

In particular, Egypt suffers from annual energy consumption every year as a result of population increase, urban growth, and high consumption of energy that led to an increase in the annual need for energy sources for suitable living for users. The state suffers from fewer resources and increasing costs that affect the increasing consumption of non-renewable energy sources that are largely consumed until they expire and are not continuously renewable, unlike renewable energy resources [4].

Therefore, the Egyptian government resorted to developing appropriate solutions to control those factors and negative impacts that affect the residential sector to reduce energy consumption and costs that enhance and develop the sustainability of buildings and cities [6]. Egypt has adopted and made attention to this issue of nationalism for all citizens from all sides and state institutions to reduce pressure on those resources and control consumption in the past years and so far [7]. The Egyptian Energy Code for Residential Buildings (EECRB) has been developed by the Egyptian Housing and Building National Research Center (HBRC), which is a regulation that all participants must work with to reach the design of sustainable and low-cost residential buildings [8].

The problem is increasing cooling load values of buildings due to the use of traditional building materials without the use of appropriate treatments and solutions to reduce the rate of heat flow through walls and openings in facades of buildings, and users resort to using electromechanical equipment from cooling devices to cool the place during the summer period, thus increasing the rate of energy consumption and non-renewable energy sources. So it is a critical issue, most probably neglected by architects & designers in the early stages of the design process, therefore; residential buildings suffer the same negligence, and they focus on the function aspects trying to make attention to the environmental issues. So using retrofitting techniques can optimize, and reduce Cooling Loads and develop possible solution proposals such as; the window ratio of walls, insulation materials, and type of glass to achieve energy efficiency through using a simulation program to reach appropriate results and compare them to reduce energy consumption cooling loads and make existing buildings sustainable [9].

So, the research question is:

-How can retrofitting techniques improve the environmental efficiency of the building to reduce cooling loads?

-What are the methods and parameters of retrofitting techniques that can be used in the buildings?

The research aims to use retrofitting techniques to improve and reduce cooling loads that benefit from the use of appropriate insulation materials and the appropriate type of glass to achieve energy efficiency through the simulation program to reach the appropriate results to reduce the energy consumption of cooling loads and make existing buildings more sustainable.

The research structure was designed to explain three phases of work in a simulation program. It includes two parts: The first part explains the theoretical study and the second part explains the applied study as shown in figure 2.

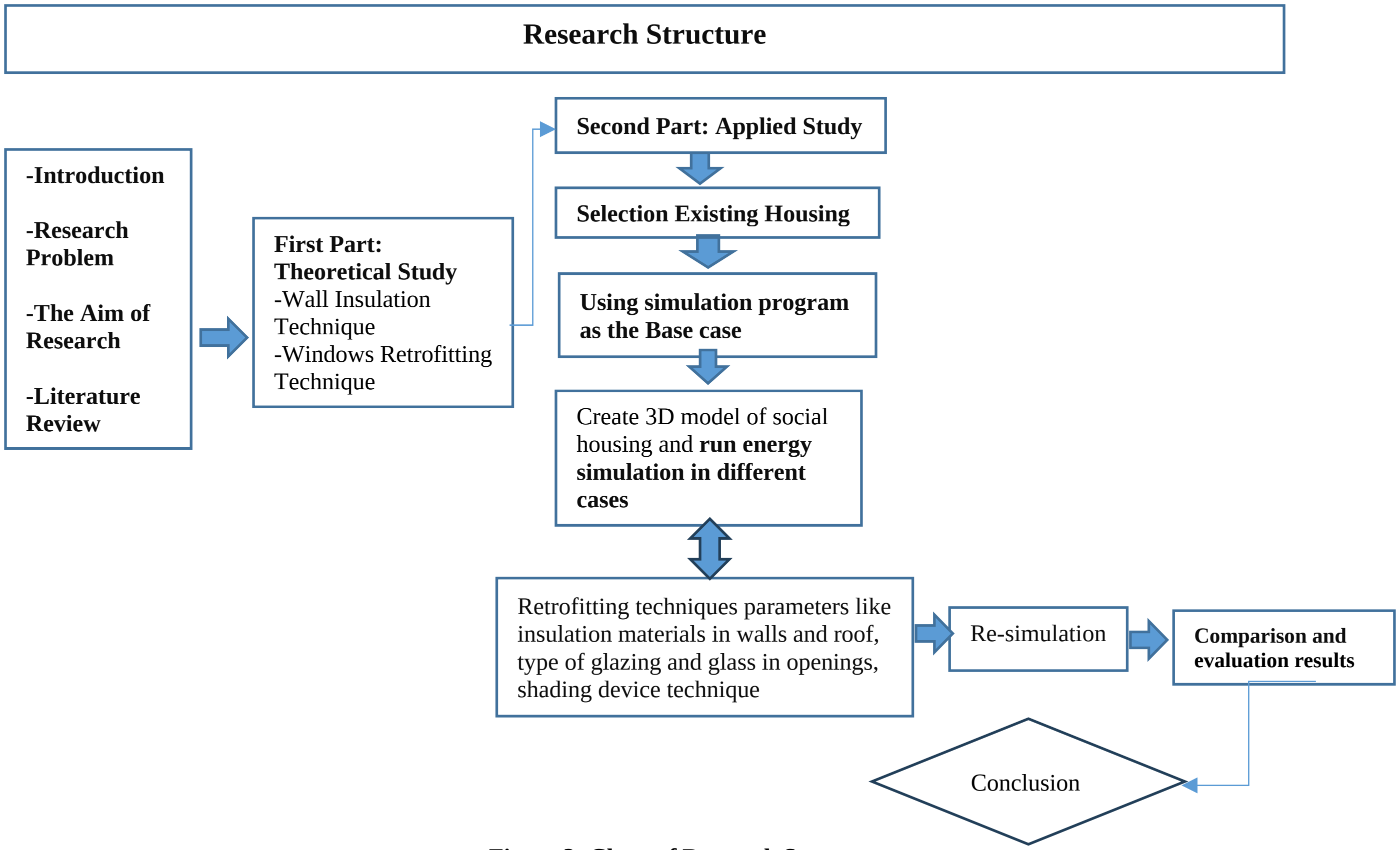


Figure 2: Chart of Research Structure
Source: The Author

1.1 Literature Review

This part of the theoretical study presents the background of the importance of retrofitting techniques through some references and applications that have been used in previous research to reduce energy consumption, achieve thermal comfort and natural lighting inside buildings. Retrofitting is defined as the development and modification of some of the technologies used after conducting experiments to improve them, manufacture them, and use them again more efficiently to improve and provide comfort for users, increase the environmental efficiency of buildings, more sustainable, and reduce sources of energy consumption, especially non-renewable resources, to keep them from extinction and depletion [10]. These technologies can transform traditional buildings into sustainable buildings to preserve the environment surrounding them, optimal use of resources, and reduce consumption and costs [11]. Many countries have begun to set laws and regulations that are concerned with the environment and climate change in setting codes that compel designers to use them and develop innovative solutions by adhering to energy laws and standards to achieve the minimum energy consumption according to the type of buildings, various activities, and the number of hours the building operates [12,13].

Pilechiha and others began research in improving energy efficiency by using retrofitting techniques in the office building, where they focused on designing windows and openings in office buildings hype algorithm mutates by using the quality and thickness of windows to reduce energy loads and achieving natural lighting within the spaces [14]. Bu and others presented some appropriate proposals and literature reviews of the Green Retrofit Design (GRD) process mode for applying retrofitting techniques in buildings and studying all aspects related to energy and its consumption to spread these ideas in buildings and develop them to be sustainable [15]. Ashraf and Almaziad studied the effect of facades in educational building in Saudi Arabia using an energy simulation tool as Design Builder simulation for calculating cooling load to reduce energy consumption by retrofitting techniques in the facades [16]. Al-Rashed and Asif studied the different variants and put some factors of retrofitting techniques to reduce energy by 30% in residential buildings from different air-conditioning systems inside the dwelling depending on the climate and different weather conditions [17].

Evans and others investigated the study of building energy laws and how to apply them using retrofitting techniques in buildings through the appropriate elements in 22 countries that represent 70% of global energy consumption, which takes into account the type of building, age, and location to discuss appropriate methods of appropriate building materials that the methods can be testing and evaluating them to implement those in buildings and confront climate change [18].

Jacobsen and Cochin presented a new and different methodology to improve energy efficiency in the United States of America, specifically in the state of Florida, to implement the regulations of energy laws in residential buildings, study prices during the three years before and after the application of energy laws, and monitor the results to introduce appropriate treatments in residential buildings to reduce energy consumption by 4% of electricity consumption and 6% of natural gas, and a study of payback periods from 4 to 6 years to reduce costs and carbon dioxide emissions [19].

Hana studied the development of an appropriate solution to the energy problem in Egypt how to apply the Egyptian code for energy in residential buildings, and its impact on the efficiency of buildings by introducing appropriate treatments of materials for walls, roofs, and windows and applying that in one of the computational programs from the requirements of the code from the use of retrofitting techniques in residential buildings using of insulation materials in walls, roofs and choose the type of glass layers to improve energy efficiency and reduce cooling load to 60% [20].

1.2 Retrofitting Techniques Methods

Existing cities, especially in residential buildings suffer from design problems such as small spaces, wrong orientation, direct exposure of the facades to sunlight, which led to increasing high temperatures in spaces, and the use of cooling devices in the summer to reduce the high temperature inside. So energy consumption is increasing and non-renewable resources because the buildings didn’t use retrofitting techniques like insulation materials, shading devices, and types of glasses to allow only natural light to pass through. These methods help to reach the Zero-Energy requirement of a sustainable building [21]. The retrofit in the construction process is one of the factors that improve the building’s thermal insulation to reduce energy consumption, achieve thermal comfort, and enhance lighting and natural ventilation within residential spaces. Some parameters help the designer to make the building more efficient such as; the orientation of the building and windows, the ratio windows of walls, insulation materials, and shading devices [9, 22]. Some retrofitting techniques will be used in a simulation program in the building to examine and reduce energy consumption.

1.2.1 Wall Insulation Techniques

Wall insulation is one of the methods of retrofitting techniques, and the most important factor for developing building facades and insulating them to reduce high sunlight, and using more operating hours for electromechanical devices that include cooling devices in buildings [23, 24]. The main role of choosing the best building materials is to achieve the appropriate thermal performance by determining the type and thickness, which can save between 20% and 55% of energy [24, 25]. It is also possible when choosing the appropriate materials to reduce the proportion of carbon dioxide (CO_2) emissions to 40%, and it can reach 60% at most [26]. Therefore, the efficiency of the walls can be improved by selecting insulation materials and increasing the layers to reduce heating flow and cooling load, by searching for the U value of those materials in the walls to choose the best insulation materials that can be implemented [2].

1.2.2 Windows Retrofitting Techniques

Openings in the facades are one of the main reasons that cause increasing high temperatures in spaces in buildings as a result of the entry of sunlight throughout the day, and therefore users resort to using cooling devices to cool their effect and thus increase energy consumption and cooling loads.

Therefore, taking into account the type of glass, glazing, layers of glass, and the ratios of openings to the wall are among the most important factors that reduce the negative impact inside the building and prevent the entry of increased sunlight while allowing the passage of natural light [27,28,29,30,31]. Also, one of the innovative solutions to treat openings is shading such as; overhangs, blinds and side fins that reflect parts of the sun’s rays by the refraction of a certain mile and the rest of the light passes indoors, as well as double glazing, which is two layers of glass, including a vacuum, either an insulating material or air [28, 32] as shown in figure 3.

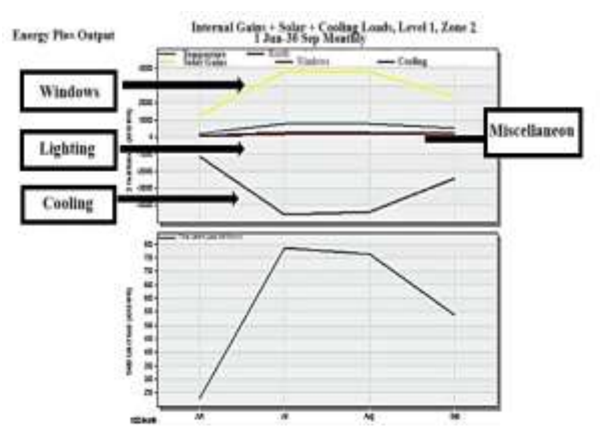


Figure 3. Chart of the impact of Windows and Cooling.
Source: Danial, C. Ezzat, et al, 2023 [32]

2. METHODOLOGY

The study consists of two main parts: The first part consists of an inductive and theoretical study of the concept of retrofitting techniques for walls and openings. The second part includes an applied study of the use of a simulation program in one of the projects implemented in Egypt to apply these techniques and test the behavior of the building by setting different variables and appropriate solutions for the materials used to reduce cooling loads and increase thermal comfort inside the building.

In this part, this study conducts the selection of the existing residential building project, called Ibny Beitk project, which was established in many governorates, as these buildings face design problems in the spaces and facades. The study used the simulation program of Design Builder to conduct a simulation of the building energy and study the behavior of the building in terms of calculating the cooling loads that consume energy annually, especially in the summer season as Shown in figure 4.

The study area for the project was determined in the simulation program using the Design Builder program, where the Giza governorate location was identified and determined in October 6th city. The project was established in 2005 and is located in the Greater Cairo region [33], then the climate study was determined by the Energy Plus program plug-in in design builder simulation that is linked with the simulation program, as in figure 5 and figure 6. The three-dimensional building was drawn in the program that simulated in three different phases in different cases and alternatives were studied in the program through different treatments and solutions using retrofitting techniques for walls, ceilings, and openings for various materials to create simulations specifically in the summer period months from May to September, in which the heat intensity increases during that period, which increases hours of operation of Cooling Devices to provide thermal comfort.

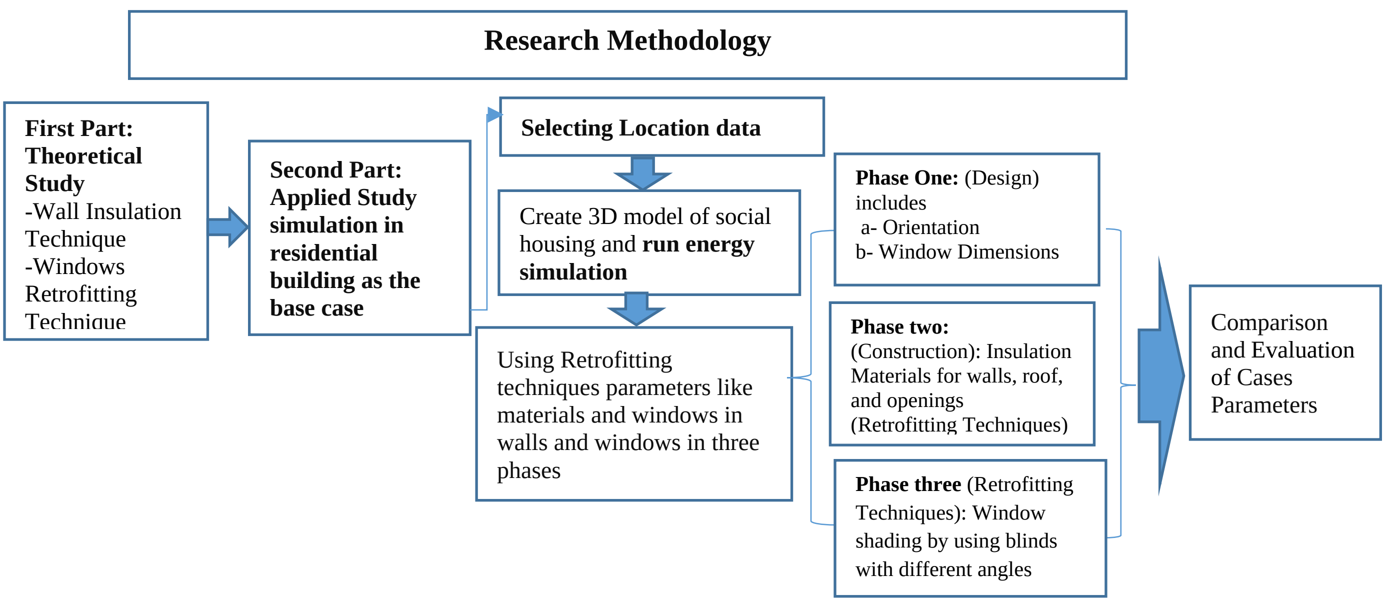


Figure 4: Chart of Research Methodology
Source: The Author

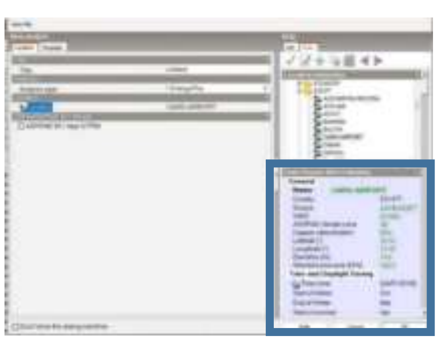


Figure 5: Climate Data by Energy Plus Plug-in in Design Builder Simulation
Source: The Author

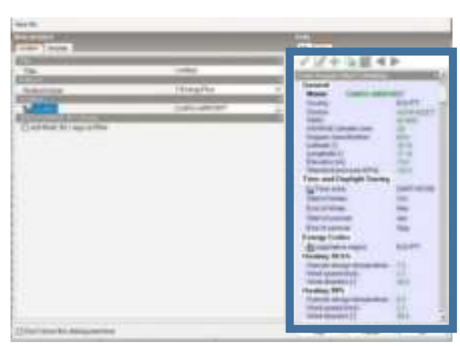


Figure 6: More Detailed Climate Data in Design Builder Simulation
Source: The Author

2.1 Building description: Ibny Beitk Project.

In 2005, the Egyptian government developed plans and strategies to solve the housing problem in Egypt and provide adequate housing for citizens at the lowest possible cost. The project of Ibny Beitk was Located in Cairo to provide suitable housing for citizens as shown in figure 7.

Figure 7: Location of Ibny Beitk project

This comes through community participation and encouraging the Egyptian citizen to build his house according to the specifications set by the state in terms of capabilities and materials used in construction, but this project did not succeed in providing the appropriate needs, as it suffers from problems in building materials and the appearance of cracks in concrete and the weakness of those materials, and also the lack of the suitable of treatments for walls and openings to isolate facades and roofs that led to high temperature and cooling loads inside spaces due to the user use cooling devices to cool small spaces to reduce high temperature and make thermal comfort [33,34]. The building consists ground floor and two typical floors, the area of these units is 63 m^2 as shown in figure 8 and figure 9

Figure 8: Ibny Beitk Project in 6th October, Giza

Source: Azzam, Mai, M., 2014 [34]

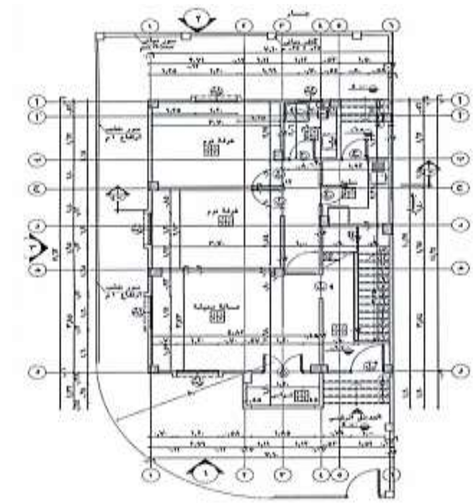


Figure 9: Plan of the Ground floor of Ibny Beitk project

Source: Ahmed, M. N., and Mousa, M. A., 2014 [35]

2.2Create a 3D model and Inputs

At this stage, the model is drawn in the Design Builder simulation program, and the location of the place was determined on the 6th of October City, Giza Governorate that can be simulated in different phases by using parameters in walls, windows, type of shading, Orientation….etc. as shown in figure 10, figure 11 and table 1.

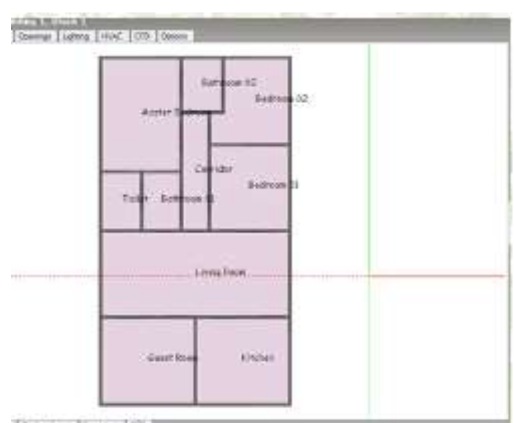


Figure 10: Plan of the Ground floor of Ibny Beitk project
Source: The Author

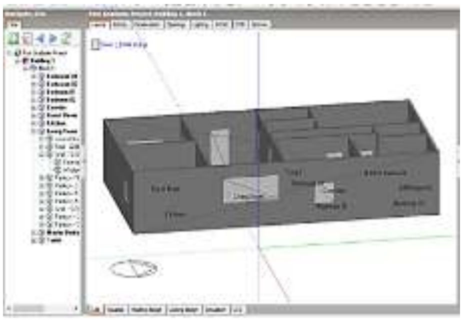


Figure 11: The 3D model of the building by Design Builder simulation program
Source: The Author

Table 1: Specifications of the elements of the existing building [34,35]

Elements	Walls	Roof	Openings
Finishing Materials	Screed (0.02m)-Concrete Brick (0.25m)-Screed (0.02m)	Concrete Tiles (Roofing) (0.05m)-Screed (0.02m)-Concrete Reinforced (0.25m)	Sgl Clr 6mm, no glazing and shading

2.3 Simulation analysis of Retrofitting Techniques of energy efficiency in different Phases

The following table shows the application of the building model in the simulation program, where the behavior of the building was studied and the cooling loads were calculated in three different Phases:

-Phase One (Design) includes:

a-Orientation
b- Window Dimensions

-Phase two (Construction): Insulation Materials for walls, roof, and openings (Retrofitting Techniques) include:

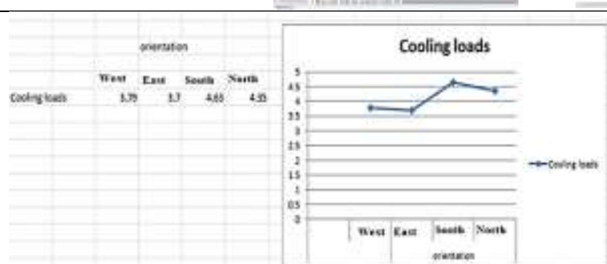
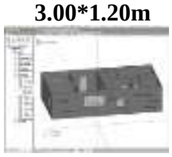
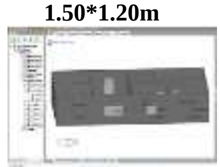
a-External Walls
b-Roof
c-Openings

-Phase three (Retrofitting Techniques): Window shading by using blinds with different angles

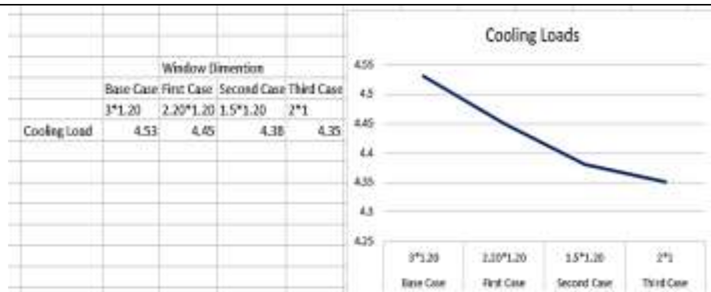
3. RESULTS

After the simulation process in the building, they can be summarized in the form of a table and graphs for each of the three Phases and the results for each of them after Simulation in different cases, as shown in table 2

Table 2: Results Simulation of cooling loads in three different phases
Source: The Author

Location: 6th of October City, Giza Governorate				
Phase One (Design): **a- Orientation**	**West** 	**East** 	**South** 	**North** 
Result of this phase (KWh/m^2)		 		
Phase One (Design): **b- Window Dimensions**	**BaseCase: Window 3.00*1.20m** 	**Case one: Window 2.20*1.20m** 	**Case two: Window 1.50*1.20m** 	**Case three: Window 2.00*1.00m** 

Result of this phase (KWh/m²)



Phase two: Construction: Insulation Materials for walls, roof, and openings:

A- External Walls

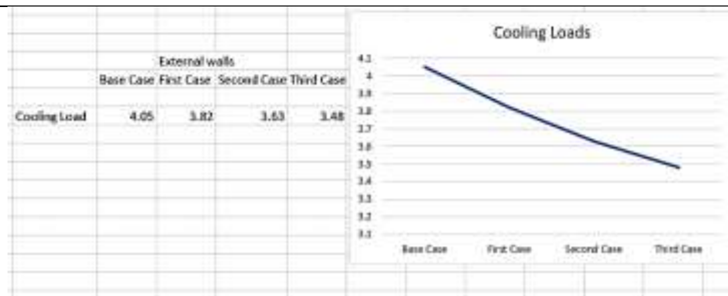
Base Case: Screed (0.02m)- Concrete Brick (0.25m)- Screed (0.02m)

Case one: PVC (0.02m)- Morter (0.02)- Polyvinylchloride (PVC) (0.05m)- Concrete block (lightweight) (0.12m)

Case two: Foam slag (0.05m)-UF Foam (0.02m)- Concrete Brick (0.25m)

Case three: PVC (0.02m)- Morter (0.02)-Polyethylene Foam(0.05m)- Concrete Brick (0.25m)- PVC (0.02m)

Result of this phase (KWh/m²)



Phase two: Construction: Insulation Materials for walls, roof, and openings:

b- Roof

Base Case: Concrete Tiles (Roofing) (0.05m)- Screed (0.02m)- Concrete Reinforced (0.25m)

Case one: PVC (0.02m)- Polyethylene foam (0.05m)- Concrete Reinforced (0.25m)

Case two: Foam slag (0.05m)-UF Foam (0.02m)- Concrete Reinforced (0.25m)

Case three: Green plants roofing (0.2m) - Concrete Reinforced (0.25m)

Result of this phase (KWh/m²)

Phase two: Construction: Insulation Materials for walls, roof, and openings:

c-Openings

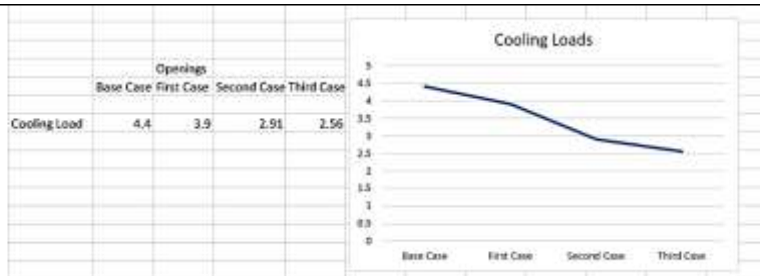
Base Case: Sgl Clr 6mm, no glazing and shading

Case one: Dbl Ref-A-L Clr 6mm/13mm Arg, Single glazing and no shading

Case two: Dbl Elec Abs Bleached 6mm/13mm Air

Case three: Dbl LoE Spec Sel Tint 6mm/ 13mm Air

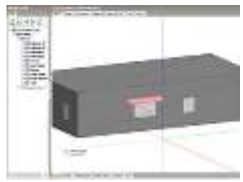
Result of this phase (KWh/m^2)



Phase three (Retrofitting Techniques): Window shading by using blinds with different angles

Base Case, No shading

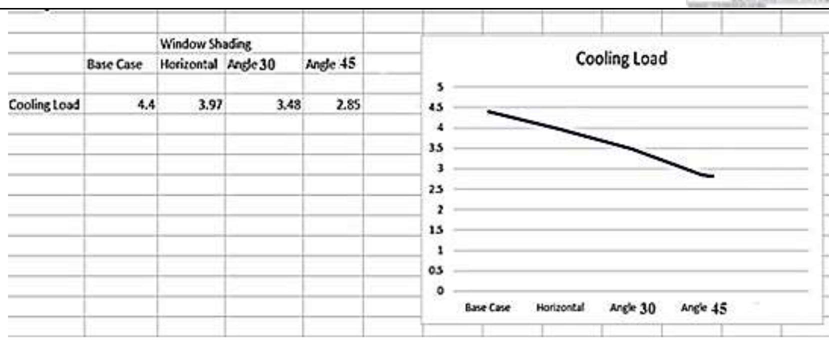
Horizontal



Angle 30^0

Angle 45^0

Result of this phase (KWh/m^2)



The previous table shows the results and graphs in three phases, where cooling loads were calculated:

- **Phase One (Design) includes:**

a- Orientation

For Orientation: The result in this phase show a high value of cooling load in the south direction is 4.63 KWh/m^2 because due to the movement of the direction of the sun, it is vertical at noon during this period, which exposes the buildings to the hot rays of the sun and therefore needs treatments and solutions to protect them from environmental impacts. Also, the north direction result is 4.35 KWh/m^2 and buildings are exposed to environmental impacts like sunlight, winds, etc.

b- Window Dimensions

The results of changing dimensions of the windows must be designed because it's the one of factors to control high temperature and sunlight, which the cooling loads increase with the increase in the window area.

The result shows the high value of cooling load when the area of window 3.00*1.20m is 4.53 KWh/m^2

This is what was mentioned before, the solution cannot be to increase the area of the openings, so it is designed in other cases to the area of window 2.00*1.00m in the third case which leads to the low value of cooling load 4.35 KWh/m^2.

- **In Phase Two (Construction): Insulation Materials for walls, roof, and openings (Retrofitting Techniques) include:**

a- External Walls

The results show the high value of cooling load in the base case is 4.05 KWh/m^2 when using materials Screed (0.02m)- Concrete Brick (0.25m)- Screed (0.02m) without any solutions and insulation materials to reduce high temperature and cooling loads, so in other cases used insulation materials and retrofitting techniques to reduce high cooling load in the best case three that used PVC (0.02m)- Morter (0.02)-Polyethylene Foam(0.05m)-Concrete Brick (0.25m)- PVC (0.02m) and led low value of cooling load 3.48 KWh/m^2.

b- Roof

The results show the high value of cooling load in the base case is 4.4 KWh/m^2 when using materials Concrete Tiles (Roofing) (0.05m)- Screed (0.02m)- Concrete Reinforced (0.25m) without any solutions and insulation materials to reduce high temperature and cooling loads, so in other cases used insulation materials and retrofitting techniques to reduce high cooling load in the best case three that used green plants roofing (0.2m) - Concrete Reinforced (0.25m) and led low value of cooling load 2.84 KWh/m^2.

c- Openings

The results show the high value of cooling load in base case is 4.4 KWh/m^2 when using the type of glasses and glazing of openings of Sgl Clr 6mm, no glazing and shading to reduce high temperature and cooling loads, so in other cases used of retrofitting techniques for openings to reduce high cooling load in the best case three that used Dbl LoE Spec Sel Tint 6mm/ 13mm Air and led low value of cooling load 2.56 KWh/m^2.

- **Phase three (Retrofitting Techniques): Window shading by using blinds with different angles**

The results show the high value of cooling load in the base case is 4.4 KWh/m^2 without any glazing and shading devices to reduce high temperature and cooling loads, so in other cases used of retrofitting techniques for openings to reduce the high cooling load in the best case three that used shading device with angle 45^0 and led low value of cooling load 2.85 KWh/m^2.

4. DISCUSSION

After the simulation process for four Cases in three phases, the results can be reached and compared between the three Phases of the simulation in the building:

4.1. The Main Findings of Phase One (Design) include:

a-Orientation

The simulation result shows the maximum cooling load value of 4.63 KWh/m^2 on the southern facade, which means that the building is exposed to high intensity of sunlight on the façade, and therefore; the spaces are exposed to the intensity of lighting and heat, which need some treatments and isolating the facade like insulation materials and controlling ratio of openings reduce the high sunlight. Also, the cooling load rises to 4.35 KWh/m^2 on the north facade, and it needs also some treatments and isolating the facade like insulation materials and controlling the ratio openings of walls to reduce the high sunlight.

b- Window Dimensions

The simulation result shows the maximum cooling load value of 4.53 KWh/m^2 in the Base Case when the area of the openings increases to (3.00*1.20m). When we started to reduce the area of openings, the result in the First case was less than the Base case reducing the value of the cooling load to 4.45 KWh/m^2 with the area (2.20*1.20m), and so in the Second case to reach 4.38 KWh/m^2 with the area (1.50*1.20m), and reach the lowest value of 4.35 KWh/m^2 in the Third case with the area (2.00*1.00m). Therefore, it can be said that the design and selection of the area of the openings are very important in the design of the building, which has an important impact on controlling the entry of sunlight, when the area of openings increases, the higher sunlight, and temperature that led to increase the cooling load and energy consumption in Buildings.

4.2. The Main Findings of Phase Two: Construction: Insulating walls, roof, and openings (Retrofitting Techniques) including:

a- External Walls

The simulation result shows the maximum cooling load value of 4.05 KWh/m^2 in the base case without any insulation materials or retrofitting techniques, therefore; insulation materials or Retrofitting Techniques with different layers were used in the other cases, to reach a minimum cooling load of 3.48 KWh/m^2 in the third case.

b-Roof

The simulation result shows the maximum cooling load value of 4.4 KWh/m^2 in the base case without any insulation materials or retrofitting techniques, therefore; insulation materials or retrofitting techniques with different layers were used in the other cases, to reach a minimum cooling load of 2.84 KWh/m^2 in the third case.

c-Openings

The simulation result shows the maximum cooling load value of 4.4 KWh/m^2 in the base case without any insulation materials or retrofitting techniques, therefore; Glazing or retrofitting techniques with different types of Glasses were used in the other cases, to reach a minimum cooling load of 2.56 KWh/m^2 in the third case.

4.3. The Main Findings of Phase Three (Retrofitting Techniques): Window shading by using blinds with different angles

The simulation result shows the maximum cooling load value of 4.4 KWh/m^2 in the base case without shading, therefore we used blinds with different angles in other cases to reach a minimum cooling load of 2.85 KWh/m^2 in the third case with the shading angle 45^0. So the best result is the third case. These results can be summarized in three phases as shown in table 3 and figure 12.

Table 3: Comparing Results Simulation of cooling loads in different cases
Source: The Author

	Comparing results summary of Simulation cooling loads in different cases			
Type of Cases	**Base Case**	**First Case**	**Second Case**	**Third Case**
Window Dimensions	4.53	4.45	4.38	4.35
External Walls	4.05	3.82	3.63	3.48
Roof	4.4	3.23	2.99	2.84
Openings	4.4	3.9	2.91	2.56
Window shading	4.4	3.97	3.48	2.85

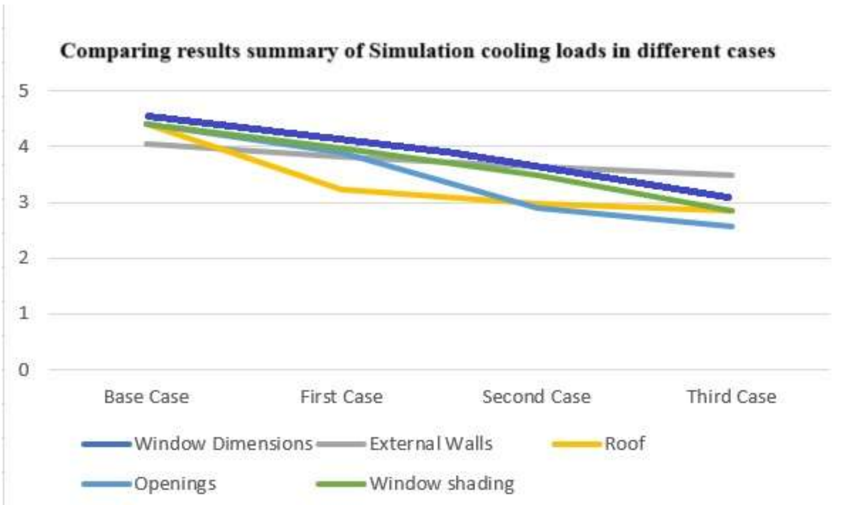


Figure 12: Comparing results summary of Simulation cooling loads in different cases

Source: The Author

5. CONCLUSION

The research has studied the importance of saving energy consumption, which the world today and Egypt also suffer from that increase in the consumption of non-renewable resources to produce electricity resulting from the use of cooling devices to reduce high temperatures, the impact of high sunlight, cooling spaces to make thermal comfort for users, which requires search other Possible solutions to reduce the negative impact of the building .Therefore; the residential building was studied and applied in the simulation program to solve problems like reducing high temperatures and cooling load values by using retrofitting techniques and calculating the cooling loads in different phases in different alternatives and parameters to reach the lowest value of cooling load. The research also presented the benefit of retrofitting techniques to improve energy efficiency by studying the orientation, area of openings, insulation materials for walls and roofs, openings as well as modern techniques for shading facades, and their direct impact on reducing cooling loads. The study presented the importance of a simulation program that helps the architect develop creative solutions and ideas to solve energy consumption problems and reduce the use of cooling devices that increase the consumption of electricity and non-renewable energy resources. One of the residential models in Egypt was chosen, which is considered one of the most energy-consuming sectors, which increases cooling loads in the summer to cool the place and achieve comfort for users. Therefore, techniques of retrofitting the materials in the walls and openings as well as shading methods were used to test the behavior of the building and simulate it in its various stages until reaching the maximum thermal load for the building and achieving thermal comfort for the users.

After the simulation process, results show the maximum cooling load value of 4.53 KWh/m^2 in the Base case without any insulation materials or retrofitting techniques, therefore retrofitting techniques were used to reach a minimum cooling load of 2.56 KWh/m^2 in the third case. So the best result is the third case of minimum cooling loads that achieves energy efficiency to make existing buildings sustainable.

The Research discussed the importance of using retrofitting techniques to reduce energy consumption and Cooling Loads by applying the simulation program in selecting housing projects in the summer period to reduce cooling Loads. The research recommends the following points:

1. Raise awareness and culture among architects and people in this direction to avoid environmental problems and achieve user comfort by searching for more alternatives of techniques to reduce high temperatures and cooling load in the summer season.

2. Conducting courses and seminars on the importance of rationalizing energy consumption and how to develop solutions and alternatives through the requirements of users and buildings.

3. Explain the importance of using smart systems, new developments of technologies and materials to apply the codes of Energy, and keeping links with modern technology, especially in the facades and roofs of residential buildings, and the methods of implementing them that have a significant impact on energy conservation.

4. Make available research and reports among the public in general, and increase interest in publishing scientific research in publications, scientific journals, and the media, as well as in how to preserve the environment from climate change.

5. Encouraging companies producing these systems and modern technology to apply them in buildings and encouraging businessmen to invest in green and smart architecture to rationalize energy consumption and reduce costs for states.

Finally, the research will discuss in more detail of application of retrofitting techniques like smart materials, and PV in buildings by using simulation programs to reduce cooling loads in Buildings and make more efficient energy.

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Declaration of competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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6. REFERENCES

[1] Zervos A. Renewables, 2018, global status report. Renewables global status report (GSR). 2018.

[2] Adly, B., El-Khouly, T., 2022, Combining retrofitting techniques, renewable energy resources and regulations for residential buildings to achieve energy efficiency in gated communities, Ain Shams Engineering Journal, Volume 13, Issue 6, Faculty of Engineering, Ain Shams University, Egypt, DOI: https://doi.org/10.1016/j.asej.2022.101772

[3] International Energy Agency, 2022, Transition to sustainable buildings, strategies and opportunities to 2050, https://www.iea.org/countries/egypt, [Last Accessed 28/6/2022].

[4] EEHC. 2016. Retrieved 11 10, 2017, from Egyptian Electricity Holding Company. http://www.eehc.gov.eg/eehcportal/Eng/, [Last Accessed 26/6/2022].

[5] U.S. Energy Information Administration based on data 2021 Statistical Review of World Energy

[6] Metwally M, Abdalla SS., 2011, Impact of gated communities on the urban development of new cities in Egypt. J Al-Azhar Univ Eng Sector.

[7] Ghonimi I, El Zamly H, Khairy M, Soilman M., 2011, The Contribution Of Gated Communities To Urban Development In Greater Cairo Region. New Towns: Al Azhar University Engineering Sector.

[8] HBRC. 2005. Retrieved 10 3, 2020, from Housing and Building Research Centre: www.hbrc.edu.eg.

[9] Albadry S., 2016, Feasibility of converting existing residential buildings to net study in Cairo. The American University in Cairo Center of Sustainable Development.

[10] Khairi M, Jaapar A, Yahya Z. 2017. The application, benefits and challenges of retrofitting the existing buildings. IOP Conference Series: Materials Science and Engineering, The application, benefits and challenges of retrofitting the existing buildings -

IOPscience, vol. 271; Nov. 2017. p. 012030, Doi: 10.1088/ 1757-899x/271/1/012030.

[11] Siew CC, Che-Ani AI,Tawil NM, Abdullah NAG, Mohd-Tahir M. 2011. Classification of Natural Ventilation Strategies in Optimizing Energy Consumption in Malaysian Office Buildings, Advanced energy retrofit projects (researchgate.net) Elsevier Enhanced Reader. Proc Eng 2011;20:363–371. Doi: 10.1016/j. proeng.2011.11.178.

[12] Gann DM, Wang Y, Hawkins R. 2010. Do regulations encourage innovation? – the case of energy efficiency in housing. Build Res Inf 2010:280–96.

[13] Sheta W. 2018. The potential of residential energy standards in Egypt:a comparative study with the code for sustainable homes. J Al Azhar Univ Eng Sector 2018;13 (49):1608–16.

[14] Pilechiha P, Mahdavinejad M, Pour Rahimian F, Carnemolla P, Seyedzadeh S. 2019. Multi-objective optimisation framework for designing office windows: quality of view, daylight and energy efficiency. Appl Energy 2020;261:114356. Doi: https://doi.org/10.1016/j.apenergy.2019.114356.

[15] Bu S, Shen G, Anumba CJ, Wong AKD, Liang X. 2015. Literature review of green retrofit design for commercial buildings with BIM implication. Smart Sustain Built Environ 2015;4(2):188–214.

[16] N. Ashraf, F. Almaziad, Effects of facade on the energy perfor-mance of education building in Saudi Arabia, World SustainableBuilding, Barcelona, Spain, 2014, ISBN: 978-84-697-1815-5.

[17] F. Alrashed, M. Asif, Trends in residential energy consumption in Saudi Arabia with particular reference to the Eastern Province,J. Sustain. Dev. Energy Water Environ. Syst. 4 (2014) 376–387.

[18] Evans M, Roshchanka V, Graham P., 2017, An International Survey of Building Energy Codes and their Implementation. Journal of Cleaner Production. Volume 158, August 2017, Pages 382-389.

[19] Jacobsen GD, Kotchen M. Are building codes effective at saving energy? Evidence from residential building data in Florida. National Bureau of Economic Research; 2010. p. 1–35.

[20] Hanna GB. Energy Efficient Residential Building Code for Arab Countries. In: The Tenth International Conference for Enhanced Building Operations, Kuwait; 2010. p. 1–7.

[21] Adly B, Sabry H, Faggal A, Mahmoud A., 2019, Retrofit as Means for Reaching Net-Zero Energy Residential Housing in Greater Cairo. In: Architecture and Urbanism: A Smart Outlook. Egypt: Springer; p. 1–10.

[22] Albadry S, Tarabieh K, Sewilam H., 2017, Achieving Net Zero Energy Buildings Through Retrofitting Existing Residential Building Using PV Panels. Elsevier; p. 195–204.

[23] Abanda, F.H., Byers, L., 2016, An investigation of the impact of building orientation on energy consumption in a domestic building using emerging BIM (Building Information Modelling). Energy 97, 517e527

[24] Bataineh, K. and Al Rabee, A., 2022, A cost-effective approach to design of energy efficient residential buildings, Frontiers of Architectural Research, Department of Mechanical Engineering, Jordan University of Science and Technology, Irbid, 22110, Jordan, Volume 11, Issue 2, Pages 297-307, DOI: https://doi.org/10.1016/j.foar.2021.10.004

[25] Binici, H., Aksogan, O., Demirhan, C., 2016, Mechanical, thermal and acoustical characterizations of an insulation composite made of bio-based materials. Sustainable Cities and Society 20, 17e26.

[26] Yuan, J., Farnham, C., Emura, K., 2017, Optimum insulation thickness for building exterior walls in 32 regions of China to save energy and reduce CO2 emissions. Sustainability 9 (10), 1e13.

[27] Hee, W.J., Alghoul, M.A., Bakhtyar, B., Elayeb, O., Shameri, M.A., Alrubaih, M.S., Sopian, K., 2015. The role of window glazing on daylighting and energy saving in buildings. Renew. Sustain. Energy Rev. 42, 323e343.

[28] Zinzi, M., Ruggeri, P., Peron, F., Carnielo, E., Righi, A., 2017, Experimental characterization and energy performances of multiple glazing units with integrated shading devices. Energy Procedia 113, 1e8.

[29] Ye, Y., Xu, P., Mao, J., Ji, Y., 2016, Experimental study on the effectivenessof internal shading devices. Energy Build. 111, 154e163.

[30] Lau, A.K.K., Salleh, E., Lim, C.H., Sulaiman, M.Y., 2016, Potential of shading devices and glazing configurations on cooling energy savings for high-rise office buildings in hot-humid climates: the case of Malaysia. Int. J. Sustain. Built Environ. 5 (2), 387e399.

[31] Huang, H., Zhou, Y., Huang, R., Wu, H., Sun, Y., Huang, G., Xu, T., 2020, Optimum insulation

thicknesses and energy conservation of building thermal insulation materials in Chinese zone of humid subtropical climate. Sustainable Cities and Society 52, 101840.

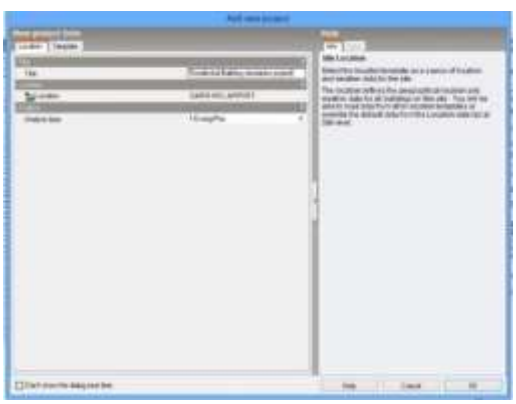
[32] Danial, C. Ezzat, Mahmoud, A., H., Tawfik, M., Y., 2023, Methodology for retrofitting energy in existing office buildings using building information modelling programs, Ain Shams Engineering Journal , Volume 14, Issue 6, June 2023, 102175, DOI: https://doi.org/10.1016/j.asej.2023.102175.

[33] Ibny Beitk Project," www. Urban-com.gov.eg/2asp, [last accessed 30/6/2022].

[34] Azzam, Mai Mahmoud Salah El-Din, 2014, Criteria for the Selection of Local Building Materials for Green Architecture in Egypt, Ph.D. Thesis, Faculty of Engineering, Ain Shams University, Egypt.

[35] Ahmed, M. N., Mousa, M. A., 2014. Study and analysis of the experience of the new city of Assiut in providing suitable housing for low-income people (Evaluating the project of Ibny beitk one of the axes of the National Housing Project) ", Journal of engineering science, Assiut university, Egypt, Vol.42, No. 6, PP.1462- 1491.

APPENDIX A: All raw data and results (inputs and outputs) of the simulation program

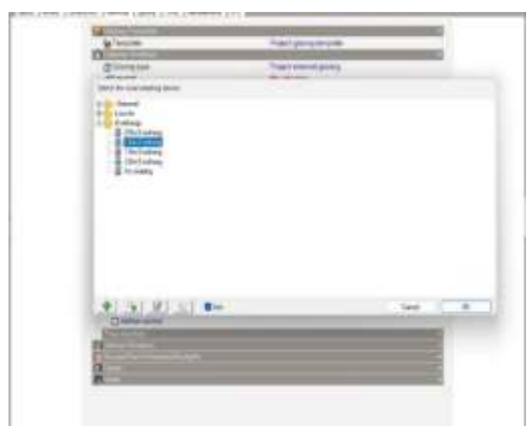


Location data

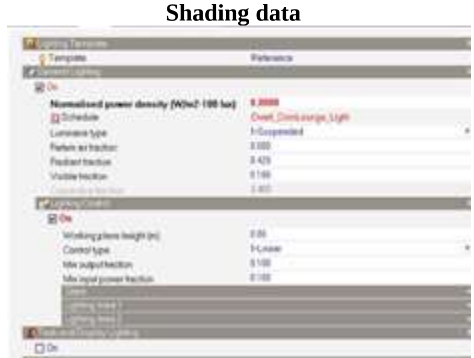
Activity data

Construction walls data

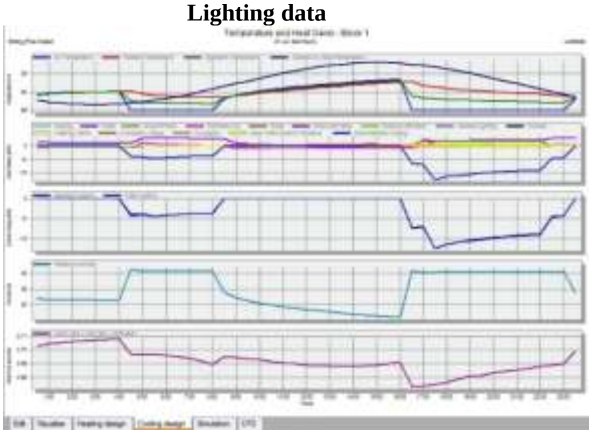
Openings walls data



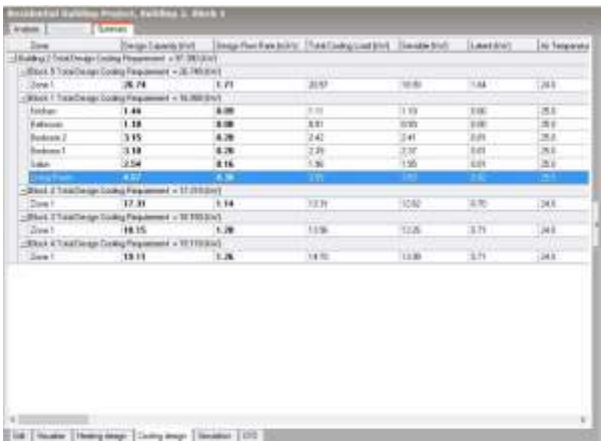
Shading data



Lighting data



Outputs data Results



Outputs data Results

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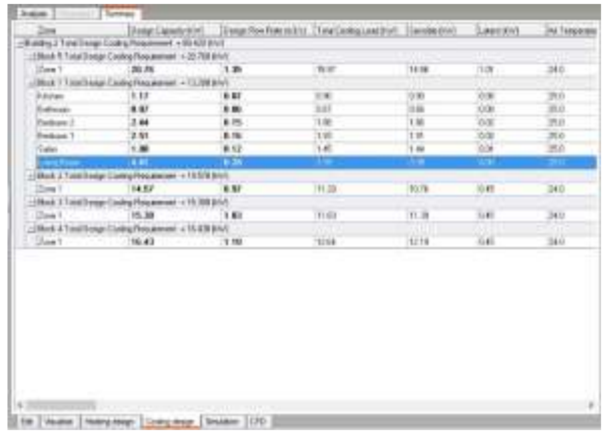
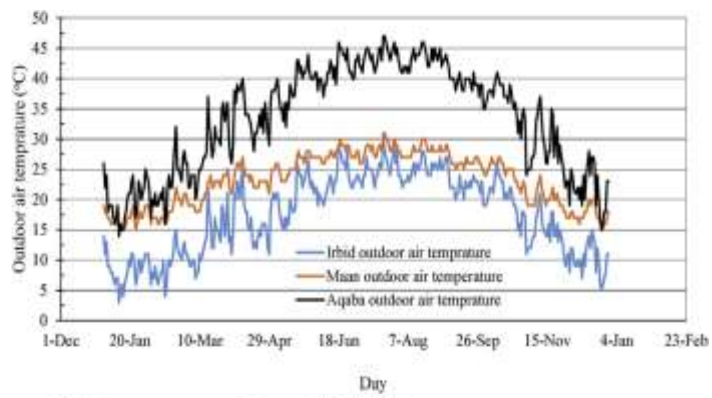
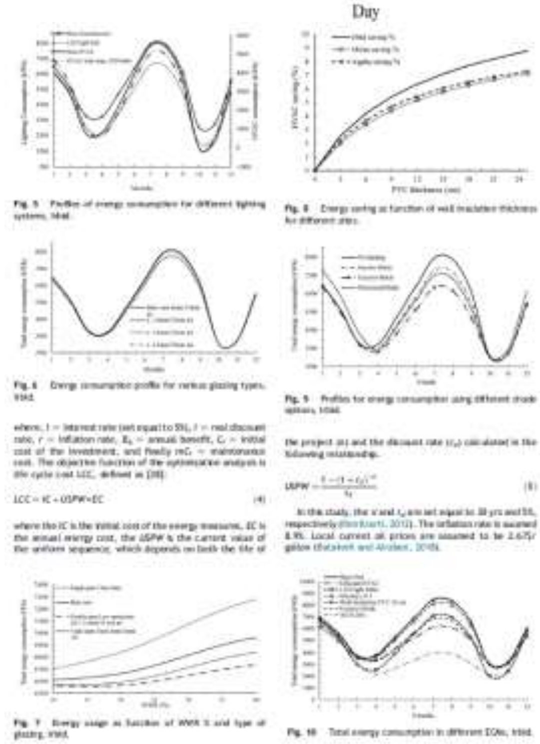
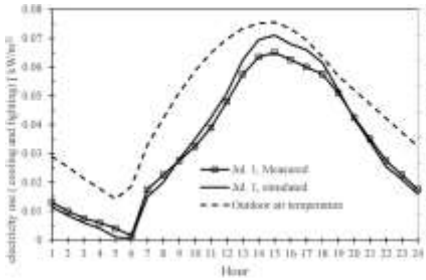


Outputs data Results

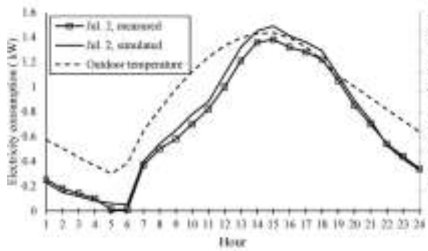
APPENDIX B: All results compared with international published articles to ensure that all results are aligned with the international results (Bataineh, K. and Al Rabee, A., 2022) [24]







(a) Solar radiation blocked (shade is on)



(b) Normal operation (shade is on/off)

Table 2 Distribution of reference building energy consumption.

	Ma'an		Irbid		Aqaba	
	consumption (kWh)	End use %	consumption (kWh)	End use %	consumption (kWh)	End use %
Lighting	18,572	22.3	18,572	27.4	18,572	12.7
System miscellaneous	17,023	20.4	17,023	25.1	17,023	11.7
Heating	2414	2.9	10,958	16.1	70	0.0
Cooling	45,254	54.4	21,334	31.4	110,170	75.5
Total energy consumption (kWh)	83,263	100.0	67,887	100.0	145,835	100.0