Green Building Information Modelling to Raise the Efficiency of a Residential Building in the New Administrative Capital

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Green Building Information Modelling to Raise the Efficiency of a Residential Building in the New Administrative Capital

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Abstract Recent economic and population growth patterns in Egypt almost guarantee that energy consumption and emissions will continue to rise rapidly if nothing changes. According to the United Nations Development Program, Egypt's energy demand will have been triple by 2030. Additionally, Egypt's total emissions from energy use have been increased eightfold since 1971. The construction industry has been pushed to adopt sustainable building strategies, and the consensus among researchers and practitioners is that the most important phase to make decisions about is during the early stages of design. Arguably, high-performance buildings require a different design mechanism than traditional methods to achieve a holistic, sustainable outcome. Indeed, Building Information Modelling (BIM) can greatly facilitate the informed sustainability in buildings. Although BIM and sustainable design emerge from different underlying factors, they share an important common thread: the success of both depends on large part of building design philosophy loaded from the start. In fact, BIM can greatly facilitate the informed sustainability in buildings. Within the framework of reviewing the literature, researchers concluded the importance of BIM in the early stages of building design. The authors conducted an applied case study to evaluate a residential building in the new Administrative Capital in Cairo, Egypt, and concluded a set of design upgrades to raise the energy efficiency of the building and reduce carbon emissions from operating energy.

Keywords: Building Information Modelling, Green Building Information Modelling (Green BIM), Energy Performance Analysis, Building Energy Modelling (BEM), Energy efficiency, high-performance buildings.

1- Introduction

The current urban expansion wave is the greatest in human history ever, and by 2060, the world's total building stock will have been doubled [1]. According to a United Nations report, the number of people living in urban areas is expected to be increased to 6.3 billion in 2050 from 3.6 billion in 2011 [2]. 35 percent of the world's energy was consumed by buildings in 2019. Around 55% of all electricity used worldwide is consumed by buildings [3]. According to the estimates from the International Energy Agency, Egypt's overall energy-related emissions have been grown eight times since 1971, while per-person emissions have quadrupled during that time.

It is almost guaranteed that Egypt's energy demand and emissions will continue to be increased rapidly if nothing changes, given the country's current demographic and economic growth tendencies. In fact, the United Nations Development Programme predicts that Egypt's energy demand will have been tripled by 2030 if current trends continue. Therefore, conservation efforts are necessary to avoid potential energy shortages that could impede economic development as well as to minimize emissions [4]. Furthermore, global warming is posing a serious threat to Egypt's environmental health. According to the Arab Environment Climate Change report, the most cautious projections of global sea level rise predict that 34% of the Nile Delta will be flooded, uprooting around 7 million people and resulting in significant economic harm owing to the loss of the fertile soils. Egyptians must be concerned about this hazard posed by high carbon emissions at least as much as everyone else [4]. Making decisions about a building's sustainable elements early in the design process is crucial [5].

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Thinking about designing energy efficiency and sustainable high-performance buildings requires a design mechanism and design approach that are different from traditional buildings to achieve a more sustainable result. By thinking about specific issues at the right time in the design process, the design team is empowered to minimize negative impacts, maximize building performance, and keep design-build-operate-demolish or renovate costs low. McGraw-Hill Construction conducted an online survey of a variety of industry professionals who use BIM tools to deliver green buildings, and the results revealed that BIM could significantly facilitate green construction and is anticipated to be widely used in the future if pertinent challenges could be identified and successfully addressed [6].

Although BIM and sustainable design have emerged from somewhat different underlying market factors, they share a significant common thread. The success of both initiatives heavily depends on a front-loaded, deeply integrated building design philosophy that seeks to involve all team members from the very beginning of a project [7]. Evaluation of energy use during the initial design phases is made possible by connecting the building model to energy analysis tools.

2- Literature Review

2-1 Energy and Emissions

Buildings will have a significant impact on the decarbonisation of the global economy through increased energy efficiency to lower energy demand, reduced material use and lower embodied carbon levels, and support for the deployment of distributed low-carbon and renewable energy sources.

The embodied carbon from the production and processing of building materials and construction, as well as the operational carbon from their energy usage, make up a building's total lifetime carbon footprint. Through evaluating the whole life cycle of a building, whole-life carbon is defined as operational carbon plus embodied carbon. Operational emissions are the highest over the life of the building, exceeding approximately 50%, as shown in Figure 1. We will not start reducing emissions from the building sector over all until we stop producing CO_2 emissions from new building operations [8].

Egypt currently has relatively high levels of supply security, with electricity available 96 percent of the time on average. But as a result of skewed investment decisions in energy-intensive industries brought on by the substantial energy policy subsidies, stress on the electrical sector is also growing. In 2014, the nation's power emission factor was 443.76 g CO_2/kWh. However, Gas and petroleum continue to be the primary fuels used in power generation [9].

Innovative architectural, engineering, and construction techniques have a huge chance to improve building energy performance. By using sustainable design concepts, construction professionals can significantly lessen the adverse effects of new and restored structures on the environment [10].

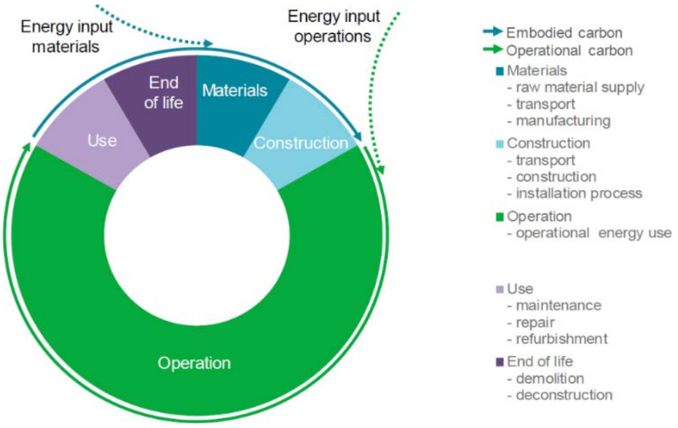

Figure 1: Whole-life carbon
Source: [11]

2-2 Building information modeling (BIM)

No one definition of "BIM" is sufficient [12]. Instead, it needs to be examined as a multifaceted, historically developed, complex phenomenon. A widely referenced definition was given by Succar (2009), who defined BIM as "BIM refers to a set of interacting policies, processes, and technologies that generate a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle." [13].

Building Information Modelling (BIM), which is a computer-readable method of exchanging building information in design amongst disciplines, is seen to be one option to overcome the deeply ingrained fragmentation issue in the AEC industry [14]. It is believed that this represents the first step toward the long-term goal of integrated project delivery (IPD). Additionally, it provides the opportunity to handle project information throughout the whole life cycle of the structure, from conception to final disposition [5].

BIM technology can offer a practical means of enabling integrated energy efficiency design and the evaluation of energy use throughout the course of the building's life. The BIM model can be linked to a tool for making decisions and to sustainability metrics to help with early project design decisions and to enable detailed sustainability trade-off analyses using actual project data. Using multi-dimensional visualisation technologies, this approach offers a way to model the effects of decisions on design, operations, maintenance, and occupant behaviour modification. This promotes a sustainable built environment. With such a method, designers may also evaluate alternative sustainable design options that encourage resource conservation and energy efficiency in relation to project costs [15]. In order to smoothly include sustainability analyses into conventional design, construction, and operation processes, a number of BIM applications have been proposed and built [16].

2-3 Green BIM

The idea of "green BIM," which connects BIM and green buildings, has been investigated by prior studies based on a number of pertinent topics, including green buildings, sustainable design, and sustainable construction [16]. Wong and Zhou (2015) defined green BIM as "a model-based process of generating and managing coordinated and consistent building data during its project lifecycle that enhances building energy efficiency performance and facilitates the accomplishment of established sustainability goals" [15].

BIM and green buildings are the two things that make up green BIM. The "BIM attributes" dimension in the taxonomy, which reflects the analytical services that BIM software may offer to the built environment, represents the key characteristics of BIM. The four aspects of document management, visualising analytical processes and outcomes, integrating with diverse databases, and delivering sustainability studies and simulations can be used to summarise the key components of BIM [16].

Any green project goes through a lifetime process that begins with project design and finishes with the demolition phase. The "green characteristics" component comprises sustainability factors including energy, thermal comfort, carbon emissions, water, material waste, daylighting, natural ventilation, and acoustics analysis that could be addressed by using BIM software [16].

2-4 BIM-supported designs of green buildings

Rebitzer's analysis reveals that while design does not directly cause many environmental effects, it does determine almost 70% of those effects over the course of a building's lifetime [17].

During the early stages of creating a new building, BIM can assist designers in optimising the default setup for building performance simulations using the already-existing building data sets [18]. Contractors see BIM as the most beneficial for sustainable projects [19]. For the design process, a variety of BIM tools have been created to address sustainability concerns. The bulk of green BIM applications are for building performance analyses and simulations, including integrated building performance optimization, energy performance assessments, CO_2 emission analyses, and lighting simulations. In the early stages of design, these BIM applications support designers by offering better integrated and visual perspectives of building performance [16].

2-5 Building Performance Modeling Tool

There are many different types of building simulation software programmes available nowadays. However, because of the complexity, energy simulations are typically left until the very end of the design process, leaving out easy and affordable chances to save energy in the first phases of the process. The creation of web-based energy modelling tools has been a fascinating area of study in recent years thanks to more accessible cloud computing and huge amounts of data from various sources. The primary objective of the next generation of simulation tools is to increase their usability for engineers and architects, particularly for early design comparisons. Simplified methods for modelling and interface design may enable non-technical designers to make better design decisions [20]. Based on the literature, we have found energy modellers are expensive. The cove.tool will significantly save money thanks to their time savings. The two primary categories in the field of energy modelling are as follows:

• Models at the Early Stages for Design Decision Making
• Modeling for Later Stage Compliance

Cove.tool often fits the first group pretty well [21]. Cove.tool has a distinct advantage over other software because any software is only as useful as the outcomes it generates. It takes less than ten times as long to produce models that are within 5% of the complexity of the Energy Plus models [21]. However, less specific inputs enable them to be effective for early design stages and suited for a wider range of audiences [20].

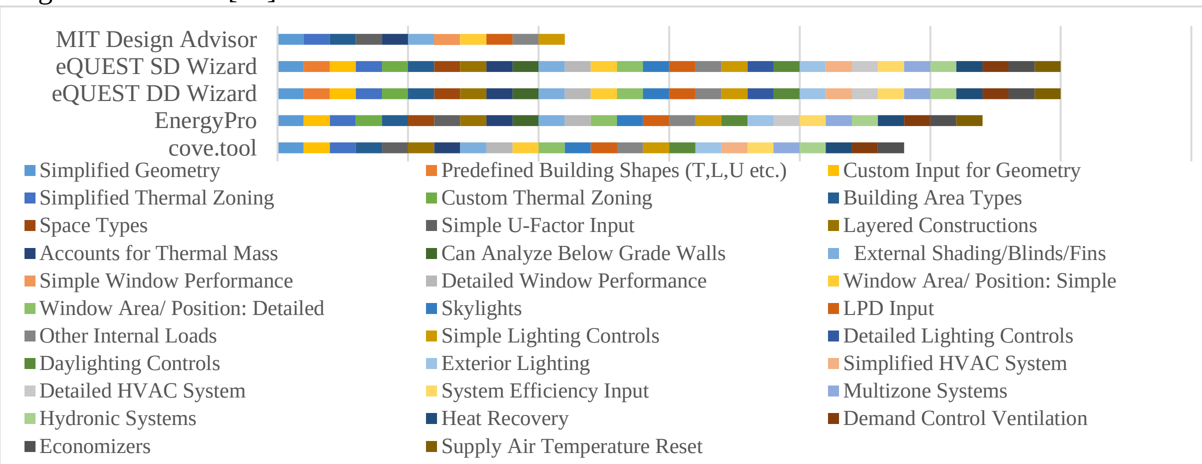

Figure 2: Summary of S-BPM Tool Geometry and Building Envelope and Lighting and HVAC Capabilities
Source: [22]. Edited by Author

3- Methodology

Based on what has been studied and concluded in the theoretical study during the literature review, we conducted an applied study of energy simulation for a study sample where the researchers conducted an analysis to determine the study area and then determined the model after fixing some of the main factors that affect the energy consumption of residential buildings. The purpose of building energy modelling is to know the importance of energy modelling at the design stage to reduce energy consumption and carbon dioxide emissions within the requirements of environmental sustainability. This was based on several steps, the first of which was a case study analysis to build the relevant detailed data needed to track energy consumption levels and areas for improvement. Second, it was a simulation based on the "Cove Tool" cloud software, where this simulation runs on three simulations: first a baseline model of the actual building condition; updated Scenario 1 based on Egyptian code to increase residential buildings' energy efficiency; and Scenario 2 based on additions proposed by the researchers. Finally, a comparison of the results is made to verify the change in consumption levels and CO_2 emissions.

3-1 Selection of residential building

This study focused on the newly developed areas to monitor the government's role in applying energy conservation during the construction of modern buildings in the newly developed areas. Therefore, the new administrative capital was chosen.

The New Administrative Capital Project emphasises sustainability as one of its key components. It is one of the city's objectives to have solar or green roofs on 70% of all rooftops. The current concept, however, might quickly fall into the same reoccurring patterns that many communities in Egypt are experiencing if it is not improved beyond its initial objectives. In many instances, sustainability seems to be reduced to the bare minimum by merely adding rooftop solar panels, green roofs, and/or grey water systems. The straightforward installation of these systems is not, however, a complete answer to sustainability.

In the first phase of the new administrative capital, the district of the Ministry of Housing is the residential district R03. By making an inventory of residential buildings, we found the largest percentage of midrise buildings (22%).

The study sample selection method was based on previous research work conducted by Attia and Evrard [23]. In their research, they classified models based on size. Accordingly:

- **First,** we made an inventory of the most frequent residential models in the residential district R03, where Table 1 shows the data of the most frequent models in the district.
- Second, in order to find the most prevalent model with the same factors as those listed in Table 3, we restricted the selection by stabilising some factors.

Table 1: Inventory of residential models for buildings in the residential district R03

Model type	Code	Repetition number	floors number	Building area of the residential ratio
Buildings	A6	117	Ground + 5 floors	16%
	B6	131		22%
	A8	99	Ground + 7 floors	14%
	C8	121		16%

As a result, we found that the most widespread models with the same surrounding conditions are (A8) oriented to the northeast with a value of 17 degrees in a clockwise direction, and it has a neighbour from one side in the northwest direction, as shown in Figure 3.

Figure 3: Study sample of building A8 on Google maps

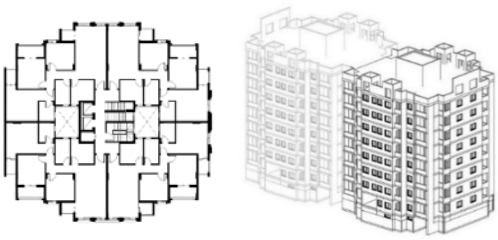

Figure 4: Typical floor plan and simulation model

3-2 Building description

Attia (2012) claimed that no attempt has been made to categorise residential structures in Egypt based on their functionality or type and suggested categorising the residential building stock into five classes based on its performance [24]. The building selected for this study is in Performance Group III (RC Skeleton with masonry and no thermal mass), as is the case for all residential buildings in Residential District R03. Edeisy (2020) claimed that that Since the 1950s, reinforced concrete column and beam structural systems with bricks (slit, clay, and cement) for walls and interior partitions have been the predominant method used for residential construction [25].

Model (A8) is an eight-story building block measuring 27m x 26m x 30.7m. The total floor area of the building is 590 m^2. The total area of the apartment is 152 m^2, with a net air-conditioned area of 90 m^2, representing three rooms and a reception hall for each apartment. The structural construction of the building is a structure of reinforced concrete. The exterior walls are made of hollow clay bricks with a thickness of 0.25 m without insulation and aluminium windows with 3 mm single glass.

Table 2: A description of A8 building geometry

Height (m)	Roof Area (m^2)	Floor Area (m^2)	Wall Area (m^2)				Glazing Area (m^2)			
			North-East	South-East	South-West	East-West	North-East	South-East	South-West	East-West
30.7	545.8	4344	515	639	516	0	227	33	227	0

3-3 Important Factors Affecting Residential Buildings' Energy Use

Numerous important elements influencing the energy usage of residential structures have been studied. These factors can be broadly split into four categories [26].

Table 3: Important Factors Affecting Residential Buildings' Energy Use

Category	Key Factor
Building's Physical Characteristics	*Building Type (Single Family House, Multifamily House)
	*Architectural Design
	*Age
	*Shape
	*Size
	*Area
	*Height
	*Number of Rooms
	*Number of Floors
	**Building Insulation
	*Building Orientation (North, East, …)
	**Building Materials (Wall, Roof, …)
	**Construction Materials (Brick, Wood, …)
Appliances and Systems Characteristics	*Age
	**Frequency of Use
	**Automatic or Manual Control*
	Source of Energy (Electricity, Natural Gas, …)
Occupants, Energy Behavior Characteristics	*Household Size
	*Number of Adults
	*Material Status
	*Occupant Age
	*Ownership Type
	*Job
	*Income
	*Education level
	*Race
	*Energy Related Behavior (Energy-Saving Behavior, …)
	*Desired Indoor Temperature for Residents (Daytime/Night)
Climate Characteristics	*Outdoor Temperature (Daytime/Night)
	*Building Surrounding Area

*Factors we fixed to choose the most frequent model with the same factors.
**Factors that are changed in the study model.

Source: [26]

4- Building Energy Modelling Results

The simulation of the prototype (A8) was performed to evaluate the current baseline energy model, followed by the implementation of the modification to the two scenarios. The first scenario is based on the recommendations of the Egyptian Code to Improve Energy Efficiency in Residential Buildings (BEEC), and the second scenario was developed by the researchers based on identifying the best performance interventions for this case. This is to improve operational energy consumption performance and reduce operational carbon dioxide emissions.

Table 4: Building description for energy model

Model Input Measures			Baseline model	Scenario 1	Scenario 2
Envelope	Openings	WWR	32% NE & SW, 5% SE	32% NE & SW, 5% SE	32% NE & SW, 5% SE
		Description of the glass	Single Grey 3mm	Single dark Grey 6mm	Double green 6mm/12mm air
		U-Value (W/m² K)	7.24	5.7	2.8
		Solar Heat Gain Coefficient (SHGC)	0.81	0.44	0.5
		Tvis	0.85	0.14	0.66
	Wall	U-Value (W/m² K)	1.7	0.7	0.7
	Roof	U-Value (W/m² K)	0.5	0.3	0.3
Ventilation and Air Conditioning	COP		2.34	2.34	3.5
	Temperature set point (ºC) - Adaptive		24	24	24
Lighting	Type		CFL	CFL	LED
	power density (W/m²)		3.4	3.4	2.8
Plug Loads	Average Installation power density (W/m²)		6	6	6
Occupancy density	(persons/m²)		.04	.04	.04
DHW	Period 1 (October-April) (l/m²/day)		0.35	0.35	0.35
	Period 2 (May-September) (l/m²/day)		0.05	0.05	0.05

Source: The Egyptian energy efficiency code (BEEC), [24]. Edited by authors.

4-1 Existing Baseline Energy Model Consumption

As shown in Figure 5, simulation results for the baseline model showed a total energy consumption of the building of 604,000 kWh/y. We found that cooling was responsible for 35% of this amount, followed by lighting at 17%. Total CO_2 emissions are 268,000 kg per year, which is a remarkably high amount.

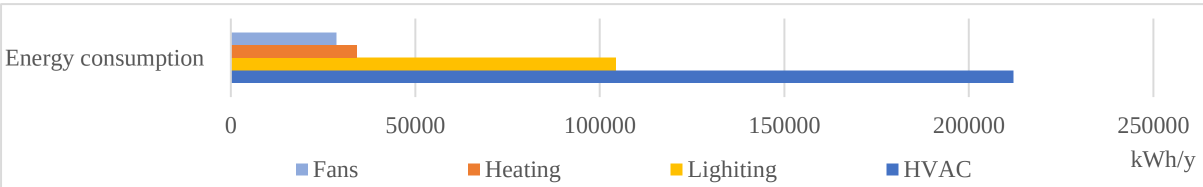

Figure 5: Annual energy consumption of baseline model

4-2 Scenario 1 Upgrades: Energy Model Breakdown

Scenario 1 of the simulation is a modified model, where the data was changed based on the recommendations of the Egyptian Energy Efficiency Code (BEEC), introduced by the Egyptian government in 2005 to indicate the minimum design requirements The application for residential buildings and these data were simulated by using the cloud simulation software tool "Cove.tool" to build the physical and energy characteristics as shown in Table 4. For walls, a thermal insulation filler of 0.02 m of polystyrene plates (EPS) was added, then brick walls with a thickness of 0.12 m. The insulation layer in the ceiling of polystyrene boards (EPS) is present with a thickness of 0.05 m. It is desirable that this thermal insulation layer be 0.1 m thick to reach the value of the total thermal resistance required in the code.

Simulation results for Scenario 1 showed a total energy consumption of 527,000 kWh/y, compared to the baseline model. We find that it reflects an overall saving of 13% in total energy consumption. Cooling was responsible for 22% less value than the baseline model, and air conditioning was responsible for 59% of the reduction in the total energy consumption of the building, and this was due to improvements in the building envelope and therefore less energy loss. Heating decreased by 72%.

The consumption of fans were also decreased by 23% less than in the baseline model. Total CO_2 emissions for Scenario 1 were a decrease of 13% compared to the baseline model.

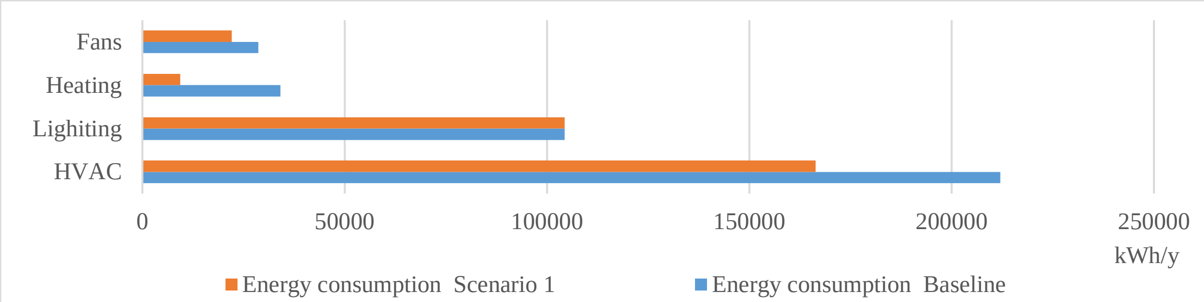

Figure 6: Comparison of annual energy consumption for scenario 1 and the baseline model

4-3 Scenario 2 Upgrades: Energy Model Breakdown

Finally, we chose to keep the external walls and ceiling at the same Scenario 1 values, to highlight the effect of detected changes to windows, lighting, daylight sensors, occupancy sensors, the efficiency of air conditioning units, and their impact on the overall consumption of the building compared to the baseline model.

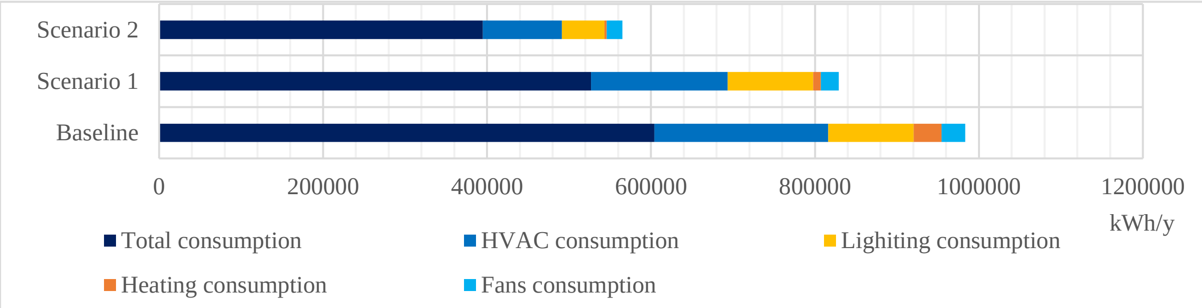

Figure 7: Comparison of annual energy consumption for the baseline model, scenario 2 and scenario 1

Compared with the baseline model, the total power consumption decreased by 35%, and we find that the most influential reduction in power consumption was for cooling, which decreased by 55%. Followed by the power consumption for lighting, which reached a 50% reduction. Fans' consumption decreased by 33%, and we found a 93% reduction in energy consumption for heating. The results indicate that the total CO_2 emissions for scenario 2 from operational energy consumption were decreased by 25% compared to the amount of operational emissions for scenario 1, and decreased by 35% compared to the baseline model.

5- Financial Analyses

With mounting economic pressure, the government began a reform plan in 2014 in order to gradually end energy subsidies. In order to accelerate the liberalisation of its power industry and draw in foreign investors, the government then released the new Electricity Law N.87 in 2015. In the years that followed, those actions combined with low global oil prices did result in a reduction of energy subsidies. In actuality, energy subsidies are just half of what they were in 2014. Energy subsidies, however, returned to their all-time high in 2013 following the abrupt devaluation of the Egyptian pound in 2017. On average, the Egyptian government paid EGP 25 billion annually to support the country's power sector between 2010 and 2017. If energy subsidies are calculated based on total economic costs from supply to distribution, they could cost up to EGP 58 billion per year, or nearly 3% of average GDP from 2010 to 2017 [9].

5-1 Energy cost in Egypt

Energy prices were calculated based on three energy cost states [9]:

- **First state:** it is the average price of energy for the year 2015, where the price of energy (0.01USD/kWh) for electricity.
- **Second state:** where the energy price subsidy will be removed in the coming years, the minimum energy price if energy subsidies are removed (0.013USD/kWh).
- **Third state:** It is the maximum price of energy if energy subsidies are removed (0.038USD/ kWh).

To determine the rates of increase in both consumption levels and prices annually, the researchers assumed a rate of increase in prices of 15% every 5 years, based on the calculation of the average increase in the past ten years for the periods (2010-2015) and (2015-2020), which was 11% and 19% for Egypt's electricity. As for consumption levels, Attia and Evrard (2013) in their research indicated that results from a survey indicated an annual increase in consumption of 1.5% [23].

Table 5: The three states of energy cost with an increase of 15% every five years

energy cost states	rate of increase every five years		energy cost (USD/kWh)
First state	First five years		$ 0.010
	15%	5 years later	$ 0.0115
		10 years later	$ 0.013
		after 15 years	$ 0.015
Second state	First five years		$ 0.013
	15%	5 years later	$ 0.015
		10 years later	$ 0.017
		after 15 years	$ 0.020
Third state	First five years		$ 0.038
	15%	5 years later	$ 0.044
		10 years later	$ 0.051
		after 15 years	$ 0.059

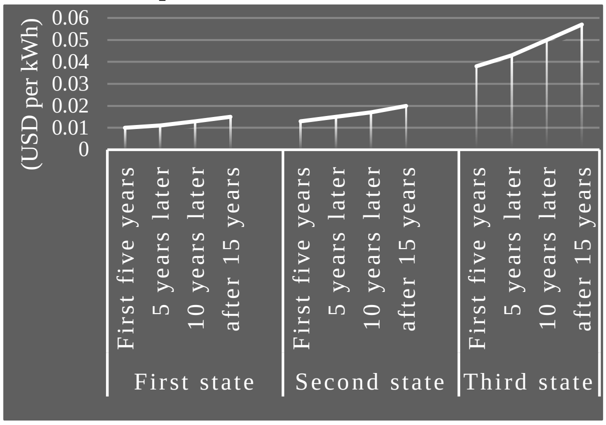

Figure 8: Comparison of the three states of energy cost with an increase of 15% every five years

5-2 Capital Costs VS Operational Energy Savings

The cost of the proposed modifications and additions to the building, minus the cost of the current materials, to know the increase in the cost of materials.

Table 6: Cost of the proposed modifications and additions and the percentage of energy savings

		Scenario 1	Scenario 2
Roof	Modification Adjustment cost difference (US Dollar) Reduce energy	Change the insulation thickness from 5cm to 10cm $ 2,020 0.35%	
Wall	Modification Adjustment cost difference (US Dollar) Reduce energy	Increasing the external walls with a layer (heat insulation (EPS) thickness of 2 cm + clay bricks thickness of 12 cm) $ 12,000 7%	
Openings	Modification Adjustment cost difference (US Dollar) Reduce energy	change type of glass $ 1,850 4%	change type of window $ 50,500 11%
Lighting	type Adjustment cost difference (US Dollar) Reduce energy	No modification	LED $ 790 8%
Daylight and Occupancy Sensors	Modification Cost Reduce energy		$ 7,400 13%
HVAC	Suggest imposing it on the user Reduce energy		$ 0 15%
Total Adjustment cost difference (US Dollar)		$ 15,870	$ 72,710
Total reduce energy		13%	35%

The total cost of modifications for scenario 1 to achieve the requirements of the Egyptian Code for Energy Efficiency in Residential Buildings amounted to approximately 15870 US dollars, and the cost of scenario 2 by changing windows is approximately 72,710 US dollars. When noticing which modifications are more expensive, we find changing the windows, so the payback period for both modifications will be studied separately (glass change-window change) with Scenario 2 to see which one has the best effect on the proposed modifications. When comparing the effect of changing the type of glass only on total energy consumption, we find a 4% decrease from the basic model, and the effect of changing the entire windows was 11%, also a decrease from the basic model. Which makes us wonder whether choosing to change windows to reduce energy consumption will cover the high cost or not? This will become clear to us from a study of the payback period.

5-3 Payback period

5-3-1 Payback period for scenario 1. By studying the payback period for scenario 1, as shown in Figure 9, we note that the payback period for the first state of energy cost is 15 years, the payback period for the second state of energy cost is 12 years, and the payback period for the third state of energy cost is 5 years.

5-3-2 Payback period for scenario 2 (changing window). By studying the payback period for scenario 2 (changing window) as shown in Figure 9, we note that for the first state of energy cost, the payback period exceeds 20 years; the payback period for the second state of energy cost is 19 years; and the payback period for the third state of energy cost is 8 years.

5-3-3 Payback period for scenario 2 (changing glass). By studying the payback period for scenario 2 (changing glass) as shown in Figure 9, we note that the payback period for the first state of energy cost is 10 years, the payback period for the second state of energy cost is 8 years, and the payback period for the third state of energy cost is 3 years.

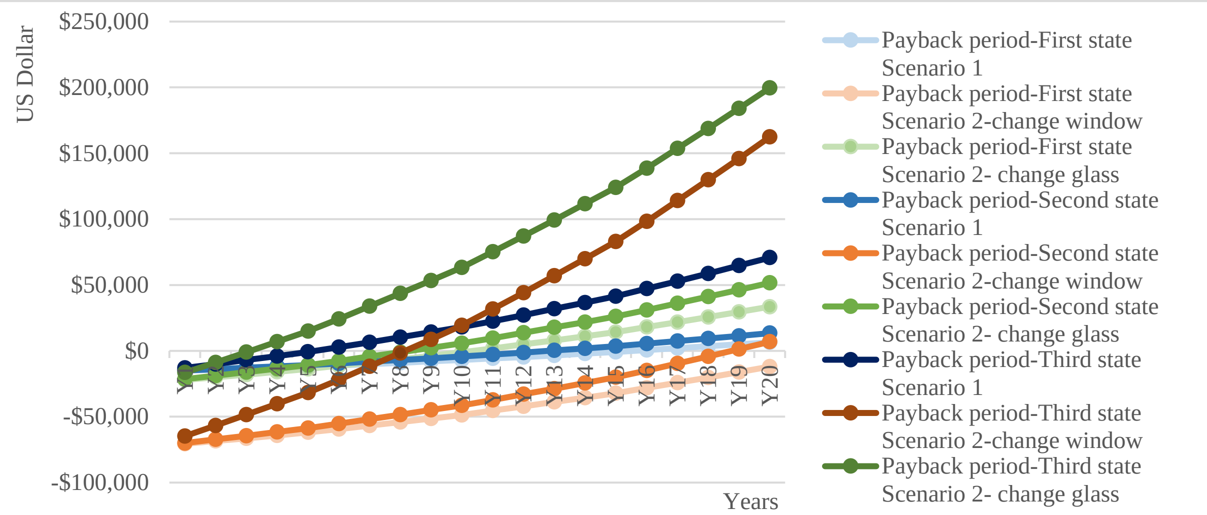

Figure 9: Comparison of payback periods for (scenario 1, scenario 2 (changing window), scenario 2 (changing glass)) based on the three energy cost states

6- Discussion

The following section discusses the effect of using each modification separately to know the importance of each of them. By comparing the effect of each modification individually with the basic model, we find the following:

- Change the lamps to LEDs with an average intensity of 2.8 W/m^2
- instead of the BEEC recommended lighting devices for use in residential buildings. It was affected by a decrease in the total energy consumption by 8%, and the energy consumption for cooling decreased by 13%, and we found that the percentage of the decrease in lighting consumption had the highest impact, as it decreased by 18%.

- The addition of sensors for daylight and occupancy of 100% of the building affected a decrease in the total energy consumption by 13%, and the energy consumption for cooling was reduced by 17%, and we found that the percentage of the most effective reduction in lighting consumption was decreased by 39%.
- Changing the windows has an effect of a decrease in the total energy consumption by 11%. The energy consumption for cooling has been decreased by 14%, and we find that the lighting consumption is constant as it has not been changed.
- The effect of using split air conditioning units with better performance with a coefficient of performance factor (COP) of (3.5) instead of (2.34) affected the total energy consumption decrease to 15%, and we find that the percentage of the highest effective reduction in energy consumption for cooling was 40%. Lighting consumption remained fixed.

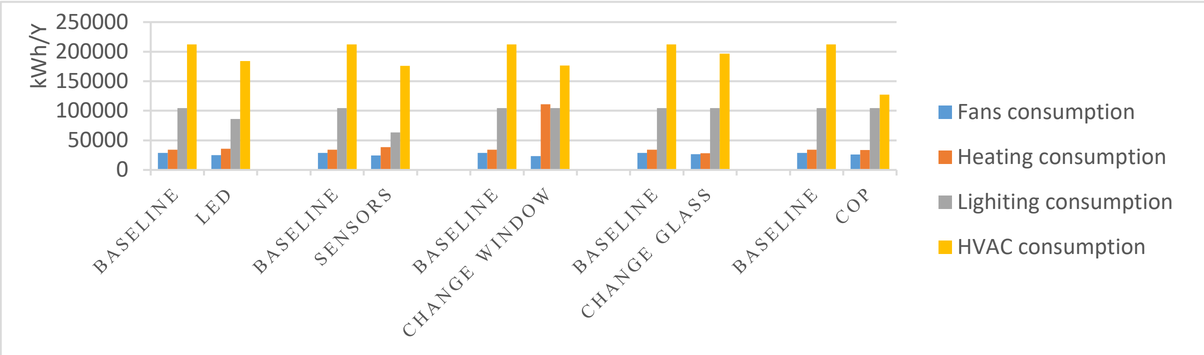

Figure 10: comparing the effect of each modification individually with the basic model

7- Summary of Financial Analyses Results

From the analysis of payback periods, we find that scenario 2 (changing glass) has the largest percentage of energy savings and the least payback time for the three energy cost states.

Table 7: Summary of financial analyses results

		baseline model	Scenario 1	Scenario 2 (changing window)	**Scenario 2 (changing glass)**
EUI (kWh/m²/y)		139	121	91	93
Total consumption (kWh/y)		604,000	527,000	395,000	405,000
Total CO_2 emissions (kg co_2/y)		266,000	232,000	174,000	178,000
Saving energy			13%	35%	33%
Payback period (years)	First state		15	more than 20 years	10
	Second state		12	19	8
	Third state		5	8	3

Through the study, we find that energy modelling for sustainable buildings is a matter of great economic dimensions, so choosing the best solution in the early stages of design is to avoid repetition of the design and to avoid wasting time, money, and effort.

8- Conclusion

One of the key ideas emphasised by the New Administrative Capital project is sustainability. The installation of solar panels or green roofs on 70% of all rooftops is one of the city's objectives. The most basic forms of sustainability seem to be achieved by adding rooftop solar panels, green roofs, and/or grey water systems. The straightforward installation of these systems is not, however, a complete answer to sustainability. However, the housing sector for the buildings in the residential district R03 was built in the new administrative capital in a way that neglects the improvement of the building envelope. Where building walls and floor slabs contain absolutely no insulation (except for rooftops, bathrooms, and kitchens), the windows are single glazed with an aluminium frame and are not covered by any shading systems, which causes poor resistance of the building envelope to heat and, consequently, an increase in energy consumption. The present issue falls into the same recurring patterns that many cities in Egypt are dealing with, and if it is not grown beyond its initial objectives, it might easily fail to achieve sustainability measures.

The government institutions which are responsible for construction are still using the same methods of using building materials for residential buildings from the fifties until now, neglecting the work of the Egyptian code for energy efficiency in residential buildings until now. As there are no strict laws to apply the Egyptian Code to improve energy efficiency and they have not been implemented in the New Administrative Capital.

It was also noted that the importance of adding daylight sensors and occupancy sensors in reducing the final demand for energy. As the behaviour of users is one of the factors affecting energy consumption, with the presence of these sensors we save a large amount of wasted energy. Through this, we find the importance of educating users about the need to save energy and involving them in responsibility so that their behaviour affects the final energy consumption.

9- Recommendation

To entice investors to this sector and, consequently, to its implementation and development, government authorities should simplify the processes and licences for structures that are planned sustainably and according to environmental principles.

We are resorting to international expertise and providing it to train specialized engineers due to the presence of local expertise that we have recourse to.

Paying attention to energy modelling and its entry into the licensing procedures, due to the necessity of applying it to know the annual consumption of the building and its impact on the environment.

The need to develop and renew the Egyptian Code for Energy Efficiency in Residential Buildings, as it has not been developed since its issuance in 2005, is therefore in line with global developments and the need to renew the values of the materials currently used.

The government continues to build new buildings in the Administrative Capital that neglect the environmental aspects, so we recommend the competent governments consider the proposed modifications, which will positively affect energy consumption and thus reduce carbon emissions.

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10- References

[1] OECD (forthcoming) 2019, 'Global Material Resources Outlook to 2060', *Glob. Mater. Resour. Outlook to 2060*, doi: 10.1787/9789264307452-en.

[2] Han Y, Taylor J, and Pisello A 2015, 'Exploring mutual shading and mutual reflection inter-building effects on building energy performance', *Appl. Energy*, vol. **185**, pp. 1556–1564, 2017, doi: 10.1016/j.apenergy.10.170.

[3] UN Environment Programme 2020, '2020 Global Status Report for Buildings and Construction', *Glob. Status Rep*., pp. 20–24, [Online]. Available: www.iea.org.

[4] Elgendy K, 'The State of Egypt's Sustainability Agenda | Carboun: Advocating Sustainable Cities in the Middle East and North Africa'. https://www.carboun.com/energy/the-state-of-the-egyptian-sustainability-agenda/ (accessed Jul. 16, 2022).

[5] Zanni M, Soetanto R, and Ruikar K 2013, 'Exploring the potential of BIM-integrated sustainability assessment in AEC'. http://radar.gsa.ac.uk/5613/1/016ZanniSoetantoRuikar%20-%20final%20author%20version.pdf

[6] Eastman C, Teicholz P, Sacks R, and Liston K 2011, BIM Handbook A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors, (John Wiley & Sons, Inc., Hoboken, New Jersey), vol. **4**, no. 1.

[7] Moakher E, Pimplikar S 2012, 'Building Information Modeling (BIM) and Sustainability – Using Design Technology in Energy Efficient Modeling', *IOSR J. Mech. Civ. Eng*., vol. **1**, no. 2, pp. 10–21, doi: 10.9790/1684-0121021.

[8] A. 2030 Initiative., 'WHY THE ZERO CODE?' https://zero-code.org/ (accessed Jul. 01, 2022).

[9] Schimschar S, Schröder J, Bhar R, Comaty F, Petersdorff C, Pohl A, Schäfer M, Steinbacher K 2020, 'Accelerating zero-emission building sector ambitions in the MENA region (BUILD _ ME)', no. April. Available: https://www.buildings-mena.com/files/BUILD_MECountryReport-Egypt_.pdf
[10] Autodesk 2009, 'Sustainable Design Analysis and Building Information Modeling', pp. 1–10. http://images.autodesk.com/adsk/files/sustainable_design_analysis_and_building_information_modeling_white_paper.pdf
[11] GlobalABC/IEA/UNEP 2020, 'GlobalABC Regional Roadmap for Buildings and Construction in Africa 2020-2050', *Glob.* Alliance *Build. Constr*., p. 150, [Online]. Available: https://globalabc.org/sites/default/files/inline-files/GlobalABC_Roadmap_for_Buildings_and_Construction_in_Africa_FINAL2_0.pdf.
[12] Miettinen R and Paavola S 2014, 'Beyond the BIM utopia: Approaches to the development and implementation of building information modeling', *Autom. Constr*., vol. **43**, pp. 84–91, doi: 10.1016/j.autcon.2014.03.009.
[13] Succar B 2009, 'Building information modelling framework: A research and delivery foundation for industry stakeholders', *Autom. Constr*., vol. **18**, no. 3, pp. 357–375, doi: 10.1016/j.autcon.2008.10.003.
[14] Sacks R, Kaner I, Eastman C. M, and Jeong Y. S 2010, 'The Rosewood experiment - Building information modeling and interoperability for architectural precast facades', *Autom. Constr*., vol. **19**, no. 4, pp. 419–432, doi: 10.1016/j.autcon.2009.11.012.
[15] Wong J. K. W and Zhou J 2015, 'Enhancing environmental sustainability over building life cycles through green BIM: A review', *Autom. Constr*., vol. **57**, pp. 156–165, doi: 10.1016/j.autcon.2015.06.003.
[16] Lu Y, Wu Z, Chang R, and Li Y 2017, 'Building Information Modeling (BIM) for green buildings: A critical review and future directions', *Autom. Constr*., vol. **83**, no. August, pp. 134–148, doi: 10.1016/j.autcon.2017.08.024.
[17] Liu S, Meng X, and Tam C 2015, 'Building information modeling based building design optimization for sustainability', *Energy Build*., vol. **105**, pp. 139–153, doi: 10.1016/j.enbuild.2015.06.037.
[18] Hiyama K, Kato S, Kubota M, and Zhang J 2014,'A new method for reusing building information models of past projects to optimize the default configuration for performance simulations', *Energy Build*., vol. **73**, pp. 83–91, doi: 10.1016/j.enbuild.2014.01.025.
[19] Shrivastava S and Chini A 2012, 'Using building information modeling to assess the initial embodied energy of a building', *Int. J.* Constr. *Manag*., vol. **12**, no. 1, pp. 51–63, doi: 10.1080/15623599.2012.10773184.
[20] Forouzandeh N, Tahsildoost M and Zomorodian Z 2021, 'A review of web-based building energy analysis applications', *Cleaner Production journal.*, vol. **306**, doi: 10.1016/j.jclepro.2021.127251.
[21] Padwal A, 'Comparison Between OpenStudio (EnergyPlus) and cove.tool | Cove.tool Help Center'. https://*help*.covetool.com/en/articles/2673641-comparison-between-openstudio-energyplus-and-cove-tool (accessed Jul. 08, 2022).
[22] Tillou M, Goel S, Rosenberg M. Simplified Performance Rating Method - Review of Existing Tools, Rulesets, and Programs. Published online 2020. https://www.osti.gov/biblio/1814644
[23] Attia S and Evrard A 2013, 'Benchmark models for air conditioned residential buildings in hot humid climate', *Proceedings of BS 2013: 13th Conference of the International Building Performance Simulation Association*. pp. 3112–3119.
[24] Attia S 2012, 'A Tool for Design Decision Making Zero Energy Residential Buildings in Hot Humid Climates', no. May, doi: 10.13140/RG.2.2.33501.23522.
[25] Edeisy M 2020, 'Environmental Analysis of the Residential Sector in Cairo', *Proceedings of REAL CORP 2020, 25th International Conference on Urban Development, Regional Planning and Information Society*. pp. 261-272. ISSN 2521-3938.
[26] Rafsanjani H and S.M.ASCE 2016, 'Factors Influencing the Energy Consumption of Residential Buildings: A Review' *Conference: Construction Research Congress 2016*, DOI: 10.1061/9780784479827.114.