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Toward Economically Viable Climate-Responsive Envelope Solutions for Social Housing in Egypt: A Comparative Study

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Abstract Improving energy consumption and internal comfort in social housing in Egypt has become an increasing priority for architects and decision-makers as one of the important solutions to the problem of population growth and the government's interest in providing affordable housing for the youth, and in the face of climate change and rising energy demand. This study examines the impact of climate-responsive envelope design modifications on both thermal performance and economic feasibility in social housing models in two distinct Egyptian climatic regions. The selected case studies are from the new fourth-generation cities: Capital Gardens in the New Administrative Capital (a hot-dry region) and Salam East Port Said (a hot-Mediterranean region). Several options were tested to enhance the envelope using modelling tools, including increasing wall thickness, improving thermal mass, and adding insulation layers. Simulations were used to evaluate the improvements in internal thermal comfort. In parallel, an economic analysis was conducted to determine the costs of constructing the envelope and the payback periods based on the expected energy savings. The results show that policymakers, designers, and developers can gain accurate insights by identifying appropriate envelope solutions for each climatic zone and achieving a balance between thermal efficiency and economic feasibility. This study contributes to the ongoing discussion on sustainable design by integrating environmental performance assessment and economic decision-making for social housing in Egypt.

Keywords Social Housing, Building Envelope Design, Thermal Performance, Cost-Efficiency, Payback Period

1. Introduction

As global energy consumption keeps increasing, it is an important issue, and it has become a major focus of global research and analysis. Buildings account for 34% of global final energy use and contribute 37% of CO_2 emissions linked to energy, highlighting the urgent need for sustainable and energy-efficient housing solutions [1]. The housing sector globally is one of the main reasons for energy consumption and carbon emissions. Housing constitutes about 60% of urban land use, while cities are responsible for approximately 39% of global carbon emissions, highlighting the crucial role of designers and architects in developing housing to shape sustainability outcomes [2]. Conduct a comprehensive assessment of thermal efficiency, performance, economic feasibility, environmental impact, and update methods and challenges associated with using local building envelope materials such as bricks, vacuum insulation panels, and reflective heat coatings to upgrade energy in residential structures [3]. Recent studies in Egypt provide analytical experiments confirming that various alternative housing patterns, urban fabrics and building envelope design strategies can achieve improvements in thermal performance and energy efficiency. A case study in Agha, Egypt showed that adopting housing clustered around a courtyard built with compressed earth block (CEB) in outer walls can enhance environmental performance, achieving reductions in air temperature, mean radiant temperature, cooling energy consumption, and carbon dioxide emissions compared to traditional housing patterns and urban fabric [4]. Also, research on sustainable building in hot-arid environments indicates that employing compressed earth block (CEB) wall systems can substantially decrease energy consumption and carbon emissions, achieving a reduction in peak heat gain by around 25% relative to conventionally designed projects [5]. These findings highlight the critical role of urban fabric compactness and alternative residential typologies in achieving sustainable energy goals, with priorities like the shortest payback period, the lowest cost, or the highest energy savings. Social housing is recognized as a key factor influencing the quality of life for disadvantaged populations, contributing to the preservation of social cohesion. Nevertheless, its development continues to face constraints due to limited investment [6]. In recent years, Egypt has experienced repeated electricity crises, driven by the effects of climate change and the global energy shortage. A significant increase in electricity demand has emerged, largely due to rising temperatures and the widespread use of air conditioning for thermal comfort. Among all sectors, the residential sector in Egypt is characterized by poor thermal performance [7,8]. In the last 10 years, the building and residential sectors were responsible for approximately 40% and 27% of global energy consumption, respectively. Consequently, enhancing energy efficiency within the housing sector represents one of the most effective approaches to mitigating this trend [9,10]. Determining viable economic options is done by evaluating the initial costs against the expected savings or the payback period through energy conservation [11]. The United Nations Sustainable Development Goals (SDGs), particularly Goal 12, confirm the responsibility of consumption and resource reduction. In this context, strategies such as reconfiguring building envelopes and improving heating, ventilation, and air conditioning (HVAC) systems represent an effective approach to enhancing energy efficiency -consumption and sustainability in residential buildings sector [12]. The rise in consumption can be attributed to several key factors, most notably population growth, climate change accompanied by record-high temperatures, and ongoing urban expansion [13]. Sustainable practices in urban and architectural design are essential not only for improving energy efficiency but also for minimizing the contribution of buildings to greenhouse gas emissions. In this context, the importance of ensuring that the built environment harmonizes with the impacts of climate change emerges as a vital priority for users within the spaces. Regrettably, social housing units in Egypt have been developed with insufficient attention to thermal performance and energy efficiency. This neglect has led to indoor environments that lack occupant comfort and generate elevated energy consumption, thereby increasing electricity costs and exacerbating environmental degradation. Egypt is progressing in parallel with the global efforts to enhance energy efficiency in the building sector. The country’s Vision 2030 is aligned with several of the United Nations' Sustainable Development Goals, especially those focused on enhancing energy performance in buildings [14]. Given the constrained budget allocated for social housing development, it is essential to improve building performance by adopting suitable envelope design strategies that effectively address these limitations. Unlike typically complex residential buildings, social housing aims to meet the fundamental living needs of vulnerable populations by employing cost-effective design strategies and maintaining straightforward, functional spaces [15]. As part of the MENA region, Egypt is actively striving to enhance energy efficiency in buildings, in line with global efforts. This initiative is driven by the increasing energy demand of the construction sector, especially within the residential domain. The emergence of a new generation of Egyptian cities highlights the necessity of climate-responsive neighborhood planning and housing design in arid regions, integrating eco-friendly materials and architectural identity into sustainable development strategies. The New Administrative Capital in Egypt is anticipated to represent a significant leap forward for the national economy, offering substantial opportunities for economic development. Additionally, the establishment of a new capital is expected to help alleviate the overpopulation pressure currently experienced in Cairo [16].

2. Methods and Methodology

For investigating the research problem, the researcher selected two case studies from the new fourth-generation cities: the Capital Gardens in the New Administrative Capital (6 floors) and the Salam East Port Said (5 Floors). The models were selected on the basis that they represent some of the most recent social housing projects in Egypt as a Multifamily mid-rise housing typology and a pointed urban fabric; moreover, they are located in different climatic regions while maintaining identical external envelope components. Climatic conditions for each region were analyzed using EPW files (Table 1).

Table 1. The Selected Case Studies and Their Climatic Conditions

Case Study	**Capital Gardens**	**East Port Said (Salam)**
Building		
Housing typology	mid-rise / 6 Floors	mid-rise/ 5 Floors
Air Temperature	6 to 43 ℃	7 to 37 ℃
Relative Humidity	45 to 62%	67 to 75%
Wind speed	3 to 4 m/s	4 to 6 m/s

The research methodology is based on a comparative analysis of two main dimensions: (1) the difference in environmental performance, and (2) the economic aspect, represented by both the construction cost of the building envelope and the electricity consumption cost of the building. The comparison was conducted between the two case-study models under both the current condition and the modified condition of the building envelope (brick–insulation–cement–paint). This approach enables the calculation of the payback period for the additional cost resulting from the envelope modification (Figure 1).

In the first dimension, which examines the environmental performance of the building envelope of the two models in their current condition, the software Design Builder (V6.1.2) was employed to construct the models (Table 2) and input the required data regarding envelope components, function of spaces, openings, ventilation, and lighting systems. Based on these parameters, thermal comfort levels within the indoor spaces were assessed, and the R-value of the building envelope was determined and compared against the requirements of the Egyptian Energy Efficiency Code for Residential Buildings in each climatic region, to establish the target R-value for the modification stage. Additionally, the amount of electricity consumption (kWh) was calculated, serving as the basis for the second dimension of the analysis.

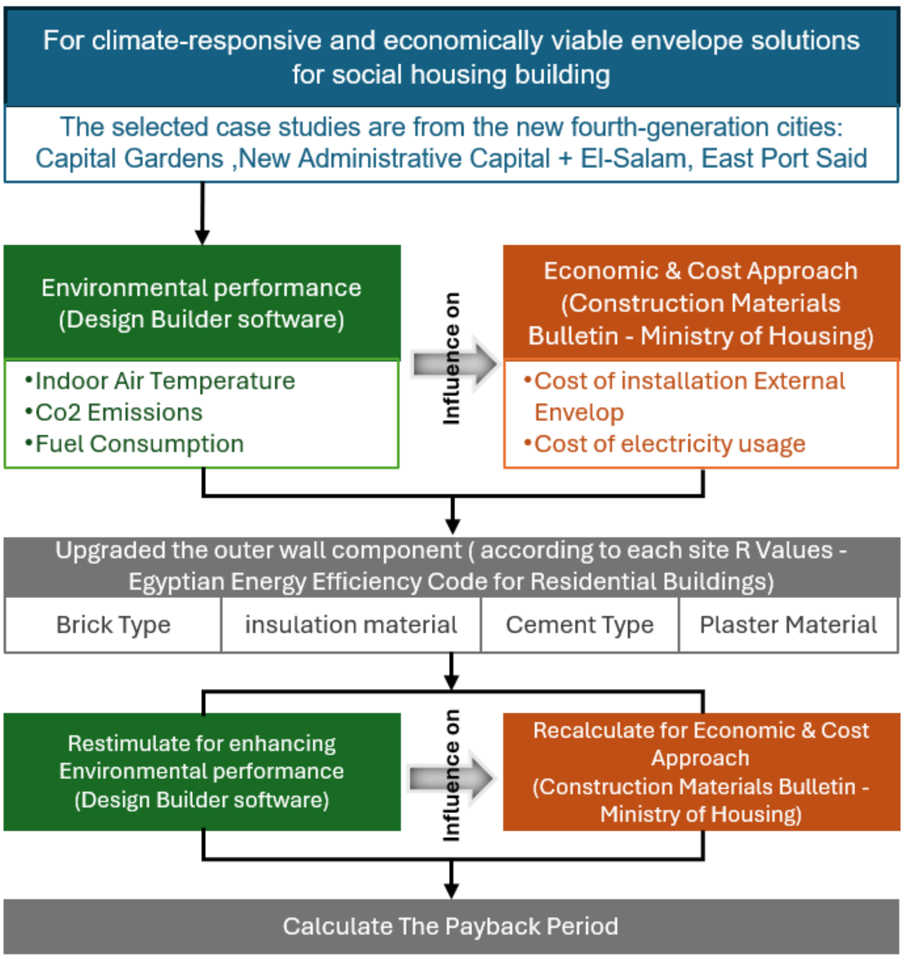
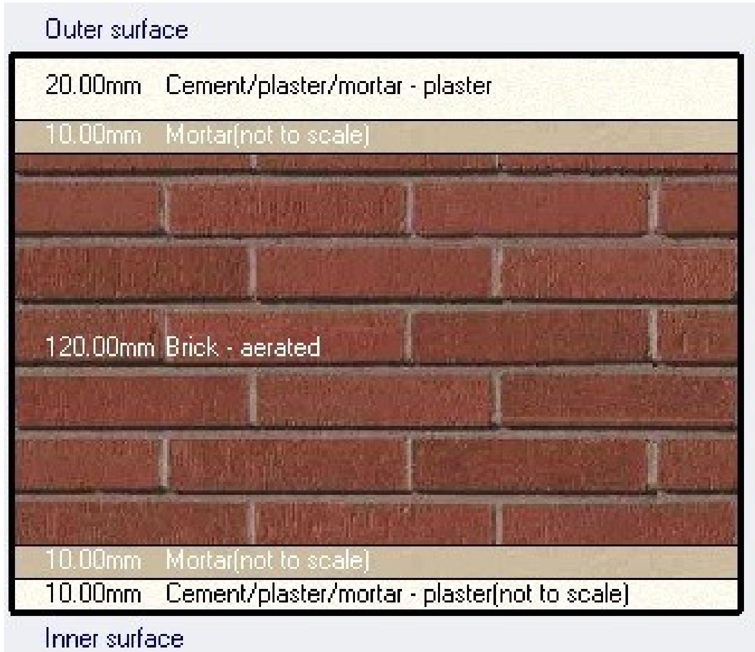


Figure 1. Research Methodology

Table 3. The Current Cases Design & Outer Wall Components

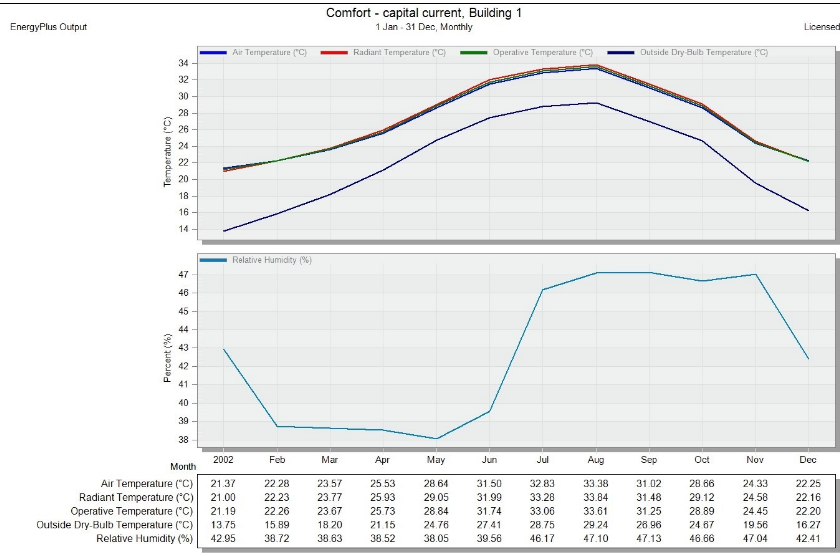
	Building Plan (North Orientation)	**Unit Plan Example**	**Wall Section**
Capital Gardens	Multifamily mid-rise housing / 6 Floors	Rec – 3 bedroom – kitchen - Bath	
East Port Said	Multifamily mid-rise housing / 5 Floors	Rec – 3 bedroom – kitchen - Bath	

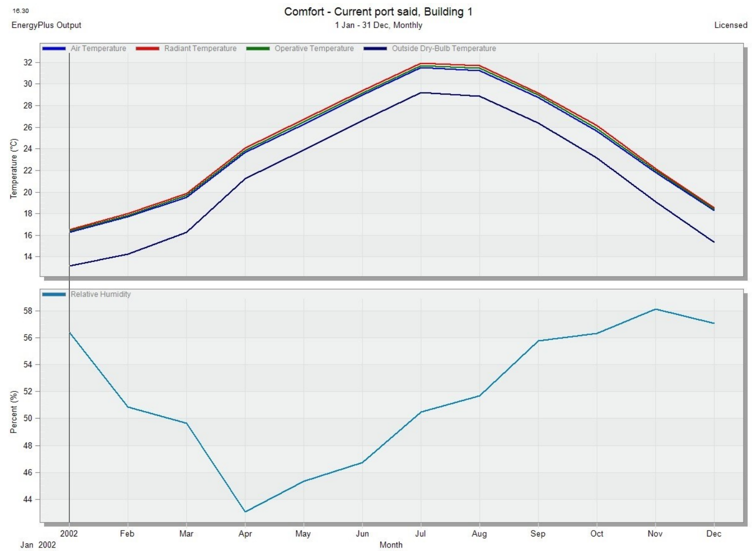
Table 4. Current Outer Wall Details & R-Value according to Design Builder Inputs Flowchart

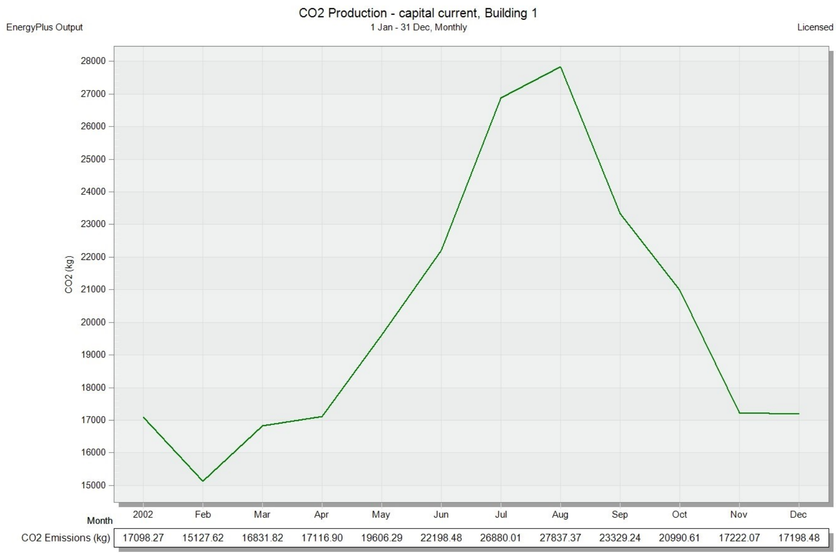
<table>
<tr><th rowspan="2"></th><th rowspan="2">The Requirements R-Value</th><th colspan="4">Design Builder Inputs Flowchart</th></tr>
<tr><th>Outer Wall Components</th><th>Openings</th><th>Lighting</th><th>HVAC</th></tr>
<tr><td>Capital Gardens</td><td>R-Value for outer wall = 0.67 m ^{2}K/W
The requirements 0.7 m ^{2}K/W up to 1.5 m ^{2}K/W</td><td rowspan="2">

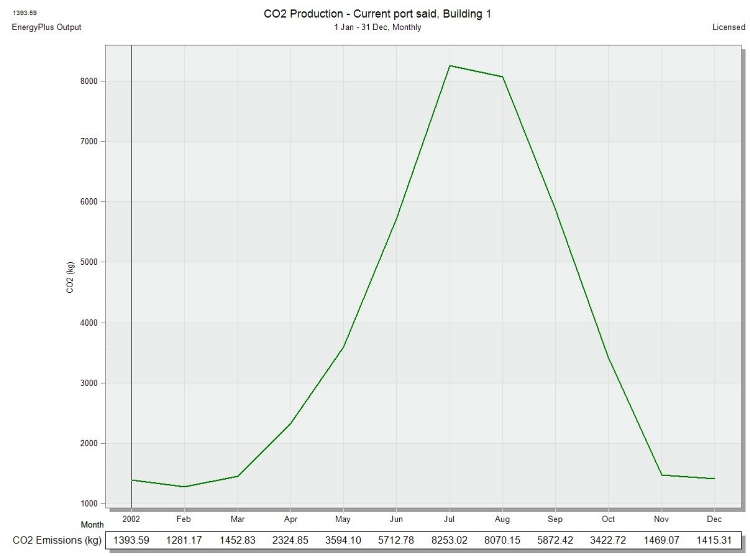
Activity: Residential -Dwelling unit</td><td rowspan="2">- Single glazing, Clear
- sgl Clr 6mm
- Aluminum window frame</td><td rowspan="2">- Schedule: Residential Light
- Task and display lighting on desks and counters light</td><td rowspan="2">- Template: Split + Separate Mechanical Ventilation
- Shedule: Residential Shedule.
- Natural Ventilation
With Average ACH from 0.5 to 2, and that's a low average.</td></tr>
<tr><td>East Port Said</td><td>R-Value for outer wall = 0.67 m ^{2}K/W
The requirements 0.69 m ^{2}K/W up to 1.3 m ^{2}K/W</td></tr>
</table>

Table 5. The effect of the current outer wall components on thermal performance

<table>
<tr><th></th><th>Capital Gardens</th><th>East Port Said</th></tr>
<tr><td>Thermal Performance (℃)</td><td>

TA up to 34 ℃</td><td>

TA up to 32 ℃</td></tr>
<tr><td>Carbon Dioxide Emissions (KG)</td><td>

</td><td>

</td></tr>
</table>

As shown in the section of the building's exterior envelope (Table 4), it does not contain any insulation (sound or thermal), and this is what we will see the results of on the building's thermal performance (Table 5). And this confirms the importance of this study for human health within spaces.

As a result of the external envelope components made from used materials (Table 5), there was an increase in thermal gain inside the spaces, leading to higher temperatures than the normal comfort level for humans (up to 34 ℃ in capital garden and 32 ℃ in East Port Said) and the lack of moderate humidity inside the spaces (from 39% to 52% in capital garden and from 43% to 58% in East Port Said). Additionally, the materials used in construction, combined with the use of air conditioning to operate the building, have contributed to an increase in carbon dioxide emissions in the atmosphere, which harms both the environment and human health.

As for the economic aspect, according to the residential model of the case studies, which was constructed using Revit software to calculate the surface areas of the materials comprising the external envelope, the external envelope area for Capital Garden building (excluding openings) is 2,577.46 m², and the external envelope area for East Port Said building (excluding openings) is 1956.23.46 m². By calculating the quantities of brick, cement, sand, plaster, and paint required for each model, and using the Building Materials Bulletin issued by the Ministry of Housing (February 2025 edition) as a reference, the cost of each component was estimated. Labor costs were excluded from the assessment to focus solely on material expenses. The cost of each execution item (bricks, plaster, paints) was calculated to determine the approximate final cost of constructing the exterior shell for each of the two models, as shown in Table 6.

According to the study model and using Design Builder (V6.1.2), the amount of energy consumed was calculated based on the devices used, lighting, and air conditioning. Based on this, the following was concluded. Since the exterior envelope has a low thermal resistance value, it has shown higher cooling requirements inside the spaces, leading to increased energy consumption in the building and consequently higher electricity costs. These results highlight the importance of selecting environmentally exterior envelope elements according to the climatic region from the code of energy efficiency to improve energy efficiency under different climatic conditions.

First, the Capital Gardens building, according to the energy analysis in Design Builder software, has an annual electricity consumption of 372,869.53 kwh according to Design Builder simulation (Table 7). As per the Ministry of Electricity for February 2025, the electricity tariffs consist of 6 tiers based on consumption. To ensure the approximation and effectiveness of the result, the third tier was selected as the average usage, which is priced at 2.23 EGP per kWh. The annual cost of electricity consumption for the residential building = 372,869.53 *2.23 = 831,499 EGP.

Second for East Port Said case study, Annual electricity consumption per building = 74,387.7 kwh according to Design Builder simulation (Table 7). The annual cost of electricity consumption for the residential building = 74,387.7 * 2.23 = 165,884.6 EGP, as shown in Table 7, a summary of the energy consumption analysis results. In the baseline condition, the analysis revealed that both models exhibited high levels of electricity consumption.

3.2. Proposed Alternatives for the Building Envelope

Evaluating the locally available construction materials in the Egyptian market (Table 8), with a particular focus on the differences across climatic regions, formed the basis for proposing alternative design solutions for the building envelope. And by using the Egyptian Code for Energy Efficiency in Residential Buildings, four alternative envelope models were designed to achieve the recommended R-value for each climatic zone (Table 9). These models are designed not only to enhance thermal performance but also to respond to the regional context by incorporating materials available in local markets. To ensure greater economic savings, the alternative with the most widely available materials in the market was chosen to minimize overall construction costs as much as possible.

Thus, the possibility of integrating environmental considerations with economic feasibility emerges, especially in the most important part of the housing sector, such as social housing.

The results indicate that modifying the building envelope composition and adding an additional insulating layer to ensure compliance with the required R-value significantly improves thermal performance by linking thermal requirements to the availability of local resources.

Table 6. Approximate Total Cost of the Current External Envelope

Materials	Capital Gardens		East Port Said	
	Quantity	Cost (EGP)	Quantity	Cost (EGP)
Clay bricks (half-brick wall)	154,647.6 pcs	303,109	117,373.8 pcs	292,378
Portland cement	49.68 tons	168,912	38.75 tons	131,750
Fine sand	138 m³	17,250	104.08 m³	10,640
Paint (primer + textured finish)	6,826.3 kg	89,765	4,969.1 kg	65,343
Total Cost	**579,037.15** EGP		**500,111.87** EGP	

Table 7. Approximate Cost of Current Energy Consumption

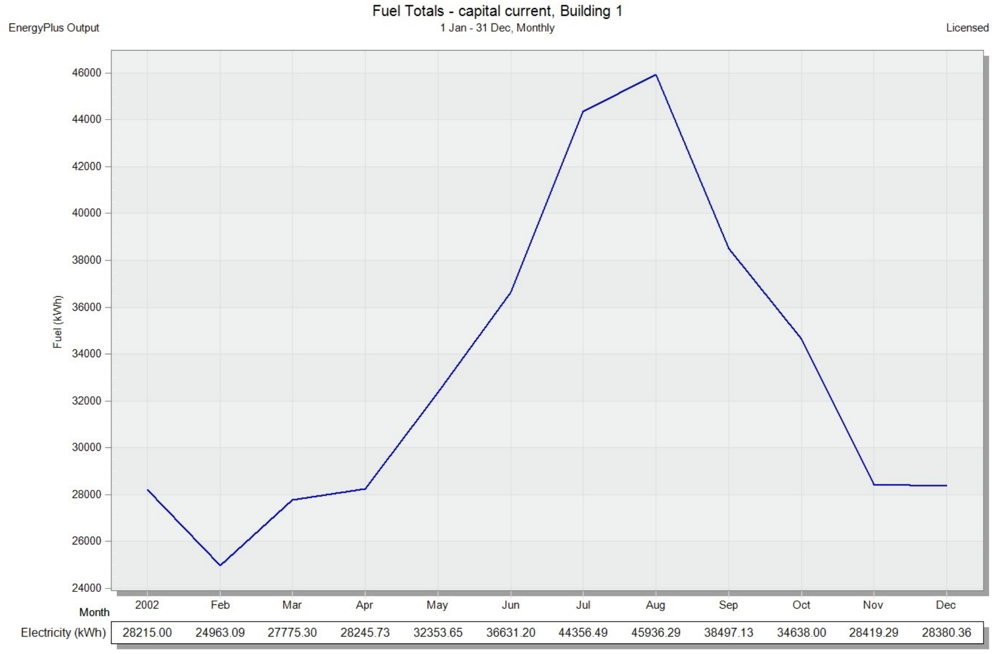
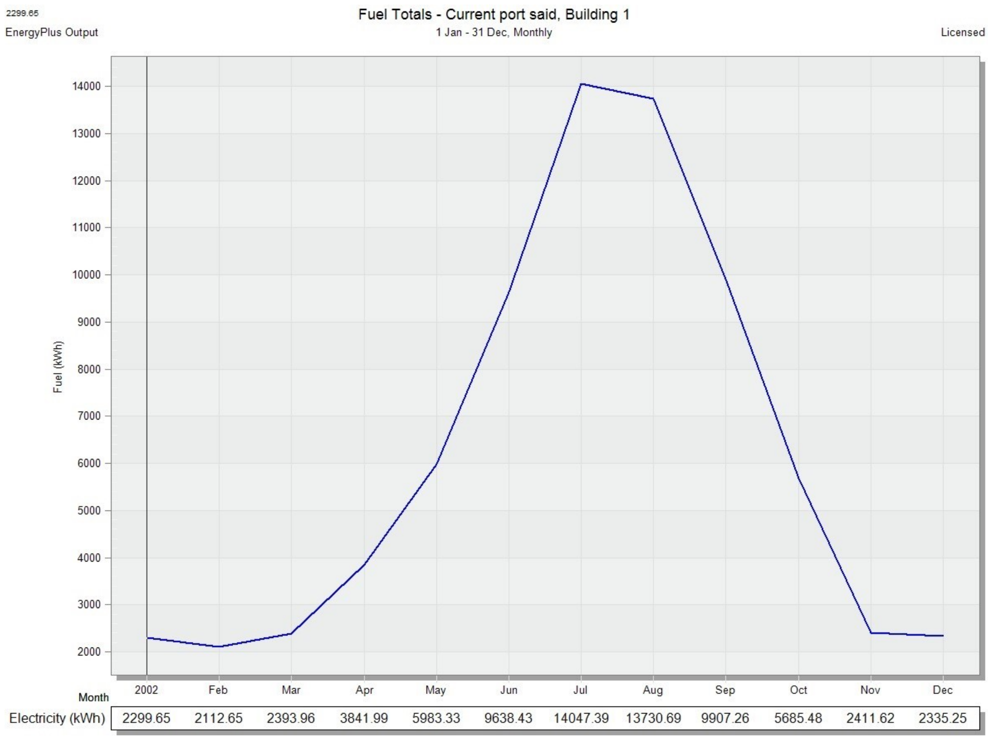
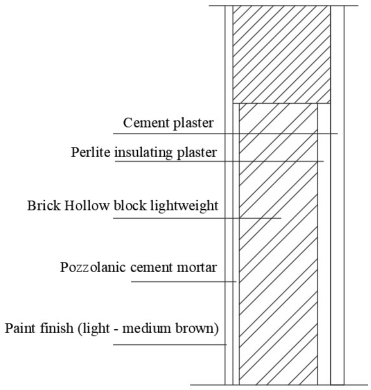
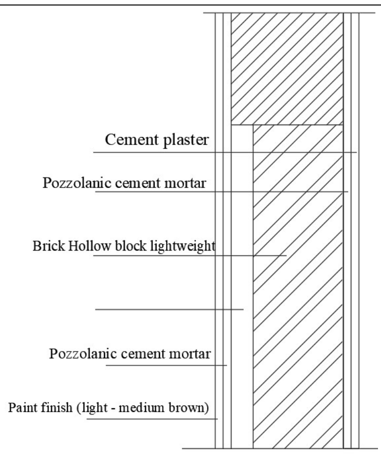
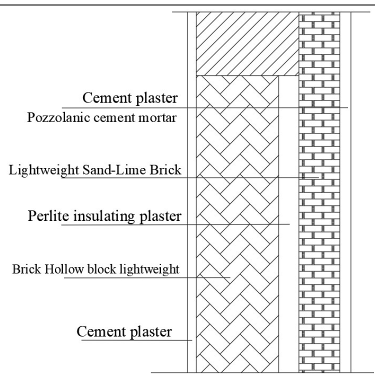
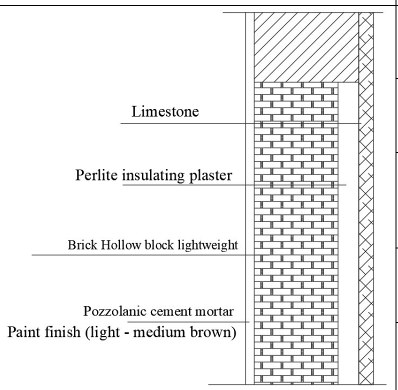
<table>
<tr><th></th><th>Annual Electricity Consumption</th><th>Cost of Energy Consumption</th></tr>
<tr><td>Capital Gardens</td><td>
</td><td>- Annual consumption = 372,869.5 kwh
- Annual cost = 831,499 EGP</td></tr>
<tr><td>East Port Said</td><td>
</td><td>- Annual consumption = 74,387.7 kwh
- Annual cost = 165,884.6 EGP</td></tr>
</table>

Table 8. Comparison of the Thermal Physical Characteristics of the Proposed Type of Brick versus the Current Type of Brick

<table>
<tr><th colspan="8">Specifications and characteristics according to the Building Materials Bulletin issued by the Ministry of Housing (February 2025 edition)</th></tr>
<tr><th colspan="2">Material</th><th>Density kg/m ³</th><th>R-value m ²k/w</th><th>Fire Resistance at 1000 ℃</th><th>Energy Saving</th><th>Water Absorption</th><th>Dimension (m)</th></tr>
<tr><td>Current Brick</td><td>Clay Brick</td><td>1850</td><td>0.42</td><td>80 min</td><td>-</td><td>25%</td><td>0.06*0.11*0.24</td></tr>
<tr><td>Proposed Brick</td><td>Hollow Clay Bricks (Lightweight)</td><td>880</td><td>0.59</td><td>120 min</td><td>25%</td><td>20%</td><td>0.10*0.20*0.30</td></tr>
</table>

Table 9. The Proposed Alternatives for the Building Envelope

<table>
<tr><th colspan="2">Wall Section</th><th>Material</th><th>Thickness (m)</th><th>Conductivity W/m ·℃</th><th>R-Value m ^{2}·℃/W</th><th>Total R-Value</th></tr>
<tr><td rowspan="5">1</td><td rowspan="5"></td><td>Cement plaster</td><td>0.03</td><td>0.9</td><td>0.03</td><td rowspan="5">1.58 m ^{2}K/W</td></tr>
<tr><td>Perlite insulating plaster</td><td>0.02</td><td>0.055</td><td>0.9</td></tr>
<tr><td>Hollow Clay Bricks (Lightweight)</td><td>0.25</td><td>0.6</td><td>0.59</td></tr>
<tr><td>Pozzolanic cement mortar</td><td>0.02</td><td>0.53</td><td>0.037</td></tr>
<tr><td>Paint finish (light –medium brown)</td><td>0.02</td><td>0.84</td><td>0.023</td></tr>
<tr><th colspan="2">Wall section
Material</th><th>Material</th><th>Thickness (m)</th><th>Conductivity W/m ·℃</th><th>R-Value m ^{2}·℃/W</th><th>Total R-Value</th></tr>
<tr><td rowspan="6">2</td><td rowspan="6"></td><td>Paint Finish (light–medium brown)</td><td>0.02</td><td>0.84</td><td>0.023</td><td rowspan="6">1.5 m ^{2}K/W (Selected)</td></tr>
<tr><td>Pozzolanic Cement Mortar</td><td>0.02</td><td>0.53</td><td>0.037</td></tr>
<tr><td>Hollow Clay Bricks (Lightweight)</td><td>0.25</td><td>0.6</td><td>0.59</td></tr>
<tr><td>Thermal Insulation (Polystyrene Board)</td><td>0.01</td><td>0.03</td><td>0.84</td></tr>
<tr><td>Pozzolanic cement mortar</td><td>0.02</td><td>0.53</td><td>0.037</td></tr>
<tr><td>Paint finish (light –medium brown)</td><td>0.02</td><td>0.84</td><td>0.023</td></tr>
<tr><td rowspan="6">3</td><td rowspan="6"></td><td>Cement plaster</td><td>0.03</td><td>0.9</td><td>0.03</td><td rowspan="6">1.86 m ^{2}K/W</td></tr>
<tr><td>Pozzolanic Cement Mortar</td><td>0.02</td><td>0.53</td><td>0.037</td></tr>
<tr><td>Lightweight Sand-Lime Brick</td><td>0.10</td><td>0.35</td><td>0.28</td></tr>
<tr><td>Perlite insulating plaster</td><td>0.02</td><td>0.055</td><td>0.9</td></tr>
<tr><td>Hollow Clay Bricks (Lightweight)</td><td>0.12</td><td>0.60</td><td>0.59</td></tr>
<tr><td>Cement plaster</td><td>0.03</td><td>0.9</td><td>0.03</td></tr>
<tr><td rowspan="5">4</td><td rowspan="5"></td><td>Limestone</td><td>0.20</td><td>2.8</td><td>0.07</td><td rowspan="5">1.62 m ^{2}K/W</td></tr>
<tr><td>Perlite insulating plaster</td><td>0.02</td><td>0.055</td><td>0.9</td></tr>
<tr><td>Hollow Clay Bricks (Lightweight)</td><td>0.25</td><td>0.6</td><td>0.59</td></tr>
<tr><td>Pozzolanic cement mortar</td><td>0.02</td><td>0.53</td><td>0.037</td></tr>
<tr><td>Paint finish (light –medium brown)</td><td>0.02</td><td>0.84</td><td>0.023</td></tr>
</table>

With the implementation of this strategy and the proposed modifications, and their environmental and economic testing on the two models (Capital Gardens - East Port Said), it has been confirmed that the methodology not only aligns with the goals of energy efficiency but also contributes to the broader objectives of reducing carbon emissions and promoting the use of locally available eco-friendly materials, which benefits the improvement of the international economy.

Therefore, if architects and decision-makers choose locally produced eco-friendly materials, this will encourage manufacturing plants to start producing these materials, which will eventually lead to a reduction in their prices due to their essential presence in the construction materials market.

3.3. After the Modification Assessment

The proposed alternatives were tested by Design Builder software for the environmental aspects (thermal performance and energy consumption) and economic evaluation. The environmental assessment confirmed the modified envelope component's ability to improve energy efficiency and thermal comfort according to regional climatic conditions.

At the same time, the economic analysis, including cost comparisons and payback period calculations, confirmed that the use of locally sourced, environmentally friendly, and energy-efficient materials could represent a viable financial solution.

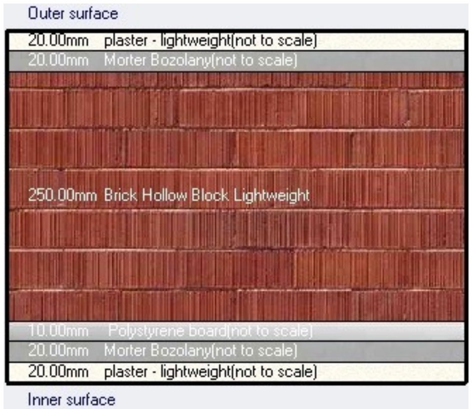
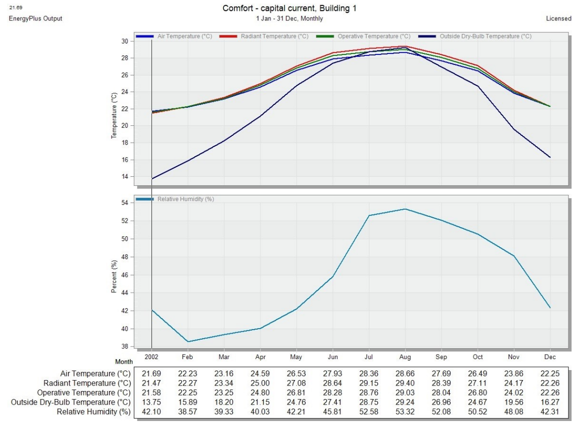
These results confirm that sustainable design strategies not only provide appropriate thermal and environmental performance but also contribute to achieving economic sustainability, as shown in Table 10, where thermal performance improvement, carbon emissions reduction, and energy consumption cost reduction are highlighted. This encourages designers to adopt this strategy to achieve economic sustainability in future social housing projects in Egypt.

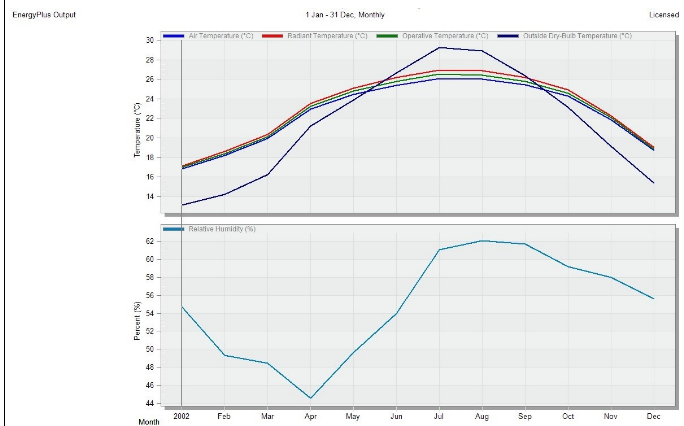
According to the Egyptian Code for Energy Efficiency in Residential Buildings, a building envelope model was developed to achieve the required R-value using locally available, environmentally friendly materials. The use of pozzolanic cement resulted in a 40% reduction in carbon emissions, while brick was identified as an eco-friendly material with excellent sound insulation up to 50 decibels, insulation for heat and humidity increases by more than 60%, which saves energy by up to 25%. The environmental performance analysis (Table 10) demonstrated notable improvements in both temperature regulation and carbon emissions. Specifically, the maximum recorded temperature in the Capital Gardens model decreased from 34 ℃ to 28 ℃, while in the East Port Said model it was reduced from 32 ℃ to 26 ℃. A significant reduction in carbon emissions was also observed.

From an economic perspective, recalculating the construction cost of the modified building envelope revealed an increase in overall cost, primarily due to the use of certain materials and the addition of insulation (excluding labor costs) (Table 11).

However, when calculating the payback period for those case studies, it was found to be 3.7 years for the New Capital Gardens model and 3.3 years for the East Port Said model. Moreover, the energy consumption analysis (Table 12) indicated that the modification resulted in approximately 60% savings in electricity costs for the New Administrative Capital model and 33% for the East Port Said model, confirming the effectiveness of the modification. These results support the research objectives (Fig.2) by demonstrating the effectiveness of designers' interest in the environmental and economic outcomes of the proposed envelope modification in residential buildings. Additionally, it confirms the feasibility of applying this strategy in the diverse climatic regions of Egypt, providing a practical framework to enhance thermal comfort and reduce construction costs in social housing projects in Egypt, in line with Vision 2030.

Table 10. The Effect of Updated Outer Wall Components on Thermal Performance

<table>
<tr><th></th><th>Updated Outer Wall Components</th><th>Capital Gardens</th><th>East Port Said</th></tr>
<tr><td>Thermal Performance</td><td rowspan="2">
</td><td>

TA up to 28 ℃</td><td>

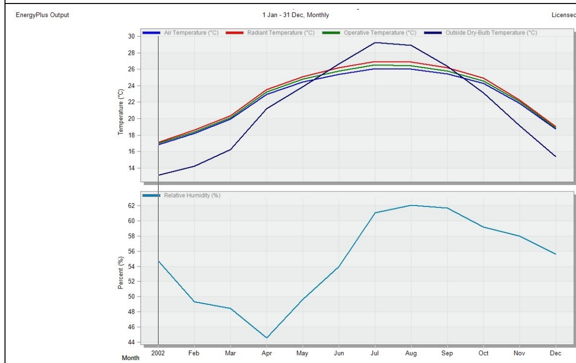
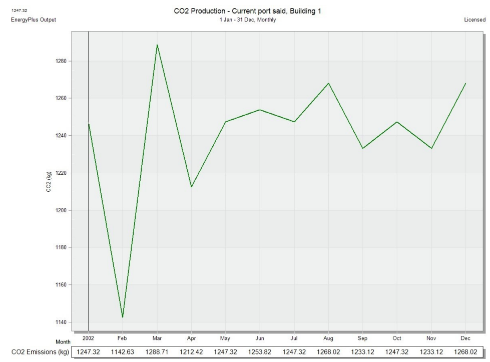
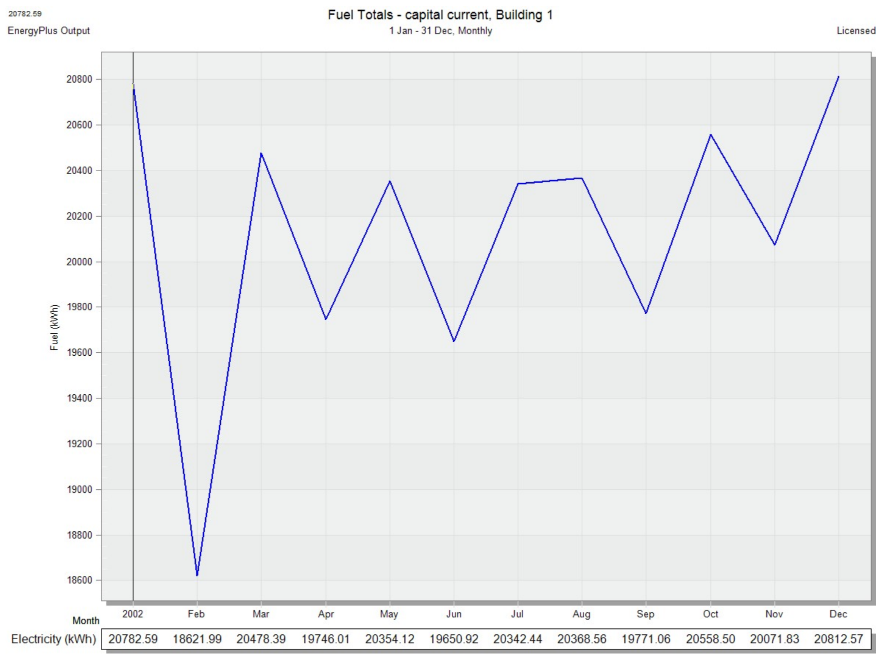
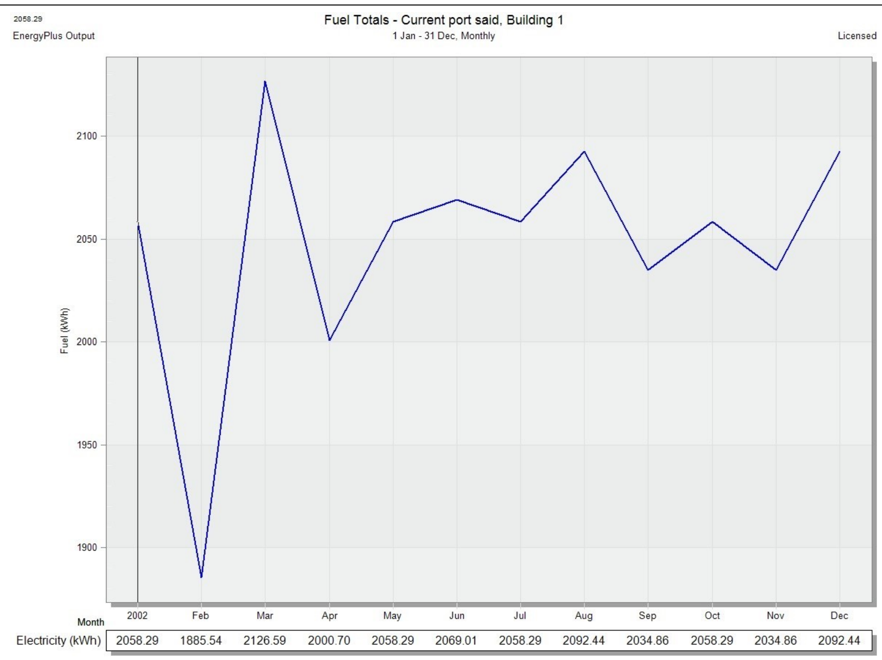
TA up to 26 ℃</td></tr>
<tr><td>Carbon Dioxide Emissions</td><td>
</td><td>
</td></tr>
</table>

Table 11. Approximate Total Cost of the Upgraded External Envelope

Materials	Capital Gardens		East Port Said	
	Quantity	**Cost (EGP)**	**Quantity**	**Cost (EGP)**
Brick Hollow block lightweight	128,873 pcs	885,845	97811.5 pcs	649,566
Pozzolanic Cement	50,112 tons	108,242	38.016 tons	82,114
Fine sand	139 m ³	17,400	105.6 m ³	10,796
High durability plaster paint	6,826.3 kg	186,358	4,969.1 kg	65344
Thermal Insulation (Polystyrene-Board)	17654 sheets	471,198	1340 sheets	64,052
Total Cost	**1,669,044 EGP**		**871,873 EGP**	

Table 12. Approximate Cost of Upgraded Energy Consumption

<table>
<tr><th></th><th>Annual Electricity Consumption</th><th>Cost of Energy Consumption</th></tr>
<tr><td>Capital Gardens</td><td>


</td><td>- Annual consumption = 241558.9 kwh
- Annual cost = 538,676.5EGP</td></tr>
<tr><td>East Port Said</td><td>


</td><td>- Annual consumption = 246,69.6 kwh
- Annual cost = 55013.2 EGP</td></tr>
</table>

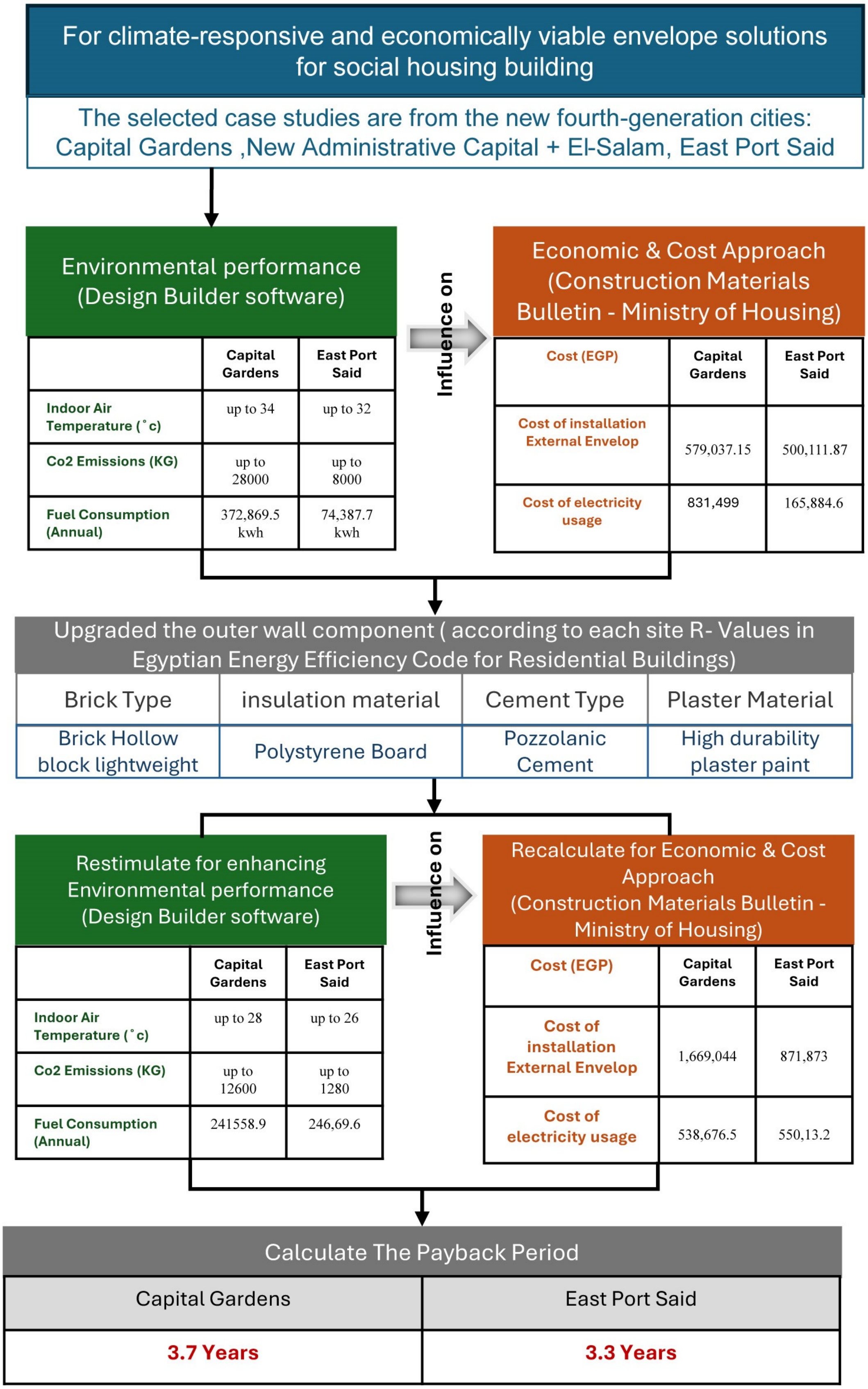


Figure 2. Results Support the Research Methodology and Its Objectives

4. Conclusions

This study showed that modifying the building envelope according to the Egyptian code for energy efficiency in residential buildings and using locally eco-friendly materials such as pozzolanic cement and lightweight hollow bricks can achieve the required environmental and economic goals (Table 13).

The results showed a decrease in indoor temperatures of about 6 degrees Celsius in both models, and consequently, with the change in the materials used, there was a significant reduction in carbon emissions. And despite the increase in initial construction costs resulting from the choice of materials and the addition of thermal insulation, the payback periods for the increase in construction costs were 3.7 years for the Capital Gardens model and 3.3 years for the East Port Said model, demonstrating economic feasibility, which is a short period compared to the building's expected lifespan, reflecting the effectiveness of the materials used. Moreover, energy savings were significant, with energy costs decreasing by 60% and 33% for the two models (Capital Gardens - East Port Said). The results confirm the effectiveness of designing and constructing sustainable residential building envelopes in Egyptian social housing to reduce carbon emissions, improve thermal comfort, and ensure economic feasibility, and the necessity for decision-makers and architects to pay attention to this approach.

Therefore, the use of this strategy in social housing policy and the commitment of designers and decision-makers to these goals can significantly contribute to Egypt's transition to a more resilient and sustainable built environment.

The comparative evaluation of the models of the Capital Gardens and East Port Said highlights the importance of environmental and economic considerations in designing the building's exterior envelope. The improved R-value according to the Egyptian code for residential building efficiency has led to a noticeable decrease in indoor air temperature by approximately 6 degrees Celsius.

Carbon emissions have been reduced, especially with the highest percentage reduction observed in the East Port Said model, where they decreased from 8000 kg to only 1280 kg. Although the upgraded envelope increased initial construction costs, the operational savings were substantial, with monthly energy expenditures reduced by 35% in Capital Gardens case study and nearly 67% in East Port Said case study. The payback periods of 3.7 and 3.3 years in the two case studies emphasize the importance of focusing on the economic aspect, as these results highlight the significance of studying various alternatives for the building's exterior envelope in sustainable buildings as a design strategy to save energy, reduce carbon emissions, and enhance thermal comfort in the social housing sector in Egypt. This study aims to change the perception of architects, urban designers, and decision-makers in the social housing sector in Egypt by demonstrating that environmentally friendly solutions have a significant economic impact and can be applied to all climatic regions.

The findings reaffirm the potential for enhancing thermal performance and mitigating heat gain through building envelopes when alternative housing patterns are adopted to reduce the transfer of thermal loads into interior spaces.

Therefore, the focus in building new cities for future generations should be on these environmental and economic strategies. This focus will not only contribute to improving thermal comfort but also to combating climate change in the context of urban growth.

Table 13. Comparison of the Study Results between the Two Models on the Environmental and Economic Aspects

		Capital Gardens		East Port Said	
		Current Case	**Upgraded Case**	**Current Case**	**Upgraded Case**
Environmental Aspects	**R-Value (m^2K/W)**	**0.67**	**1.5**	**0.67**	**1.5**
	TA-indoor air temperature (℃)	up to 34 ℃	up to 28 ℃	up to 32 ℃	up to 26 ℃
	CO_2 emissions (KG)	up to 28000	up to 12600	up to 8000	up to 1280
Economic Aspects (EGP)	**Cost of the external envelope**	579,037.15	1,669,044	500,111.87	871,873
	Cost of energy consumption (Annual cost)	831,499	538,676.5	165,884.6	550,13.2
Payback Period		**3.7 Years**		**3.3 Years**	
Payback Period when	**Error Propagation in cost/energy +10%**	**5.3 Years**		**4.3 Years**	
	Error Propagation in cost/energy -10%	**2.6 Years**		**2.4 Years**	

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