

A simulation study of energy use rates using Building Information Modeling (BIM) tools on social housing building in Alexandria Governorate.

Fatma El Zahraa Abdullah Mohamed^{1*}, Youssef Omar Mohamed Elrefaey², Algendy Shaker Algendy³

¹Architecture Department, Faculty of Engineering, Al-Azhar University, Nasr City Campus, Cairo, Egypt Lecturer,

* Corresponding Author Email: fatmaelzahraa_abdullah@yahoo.com- ORCID: 0009-0009-0364-653X

²professor of Architecture Department, Faculty of Engineering, Al-Azhar University, Nasr City Campus, Cairo, Egypt

Email: Yousefrafie@gmail.com- ORCID: 0009-0005-5278-6775

³professor of Architecture Department, Faculty of Engineering, Al-Azhar University, Nasr City Campus, Cairo, Egypt

Email: a.shaker@azhar.edu.eg - ORCID: 0000-0003-1180-8171

Article Info:

DOI: 10.22399/ijcesn.3925

Received : 05 July 2025

Accepted : 29 August 2025

Keywords

Energy efficiency
Social housing buildings
Building Information Modeling (BIM)
Nano Glass.

Abstract:

With the increasing concept of sustainability around the world, and the problems arising from climate change and global warming, there is an important role to play in improving energy performance as a basic requirement in environmental design processes of buildings, especially residential buildings, as they are the highest consumers of energy. This requires giving effective environmental treatments to rationalize energy and preserve residents' comfort. The aim of the research was to improve energy efficiency in social housing buildings in New Borg El Arab City in Alexandria Governorate as a treatment of the building envelope. This was done through an applied study using the simulation program Design Builder 0.7. An applied study used the Design Builder 0.7 simulation program to explore the energy performance of social housing buildings. The strategy was simply to optimize the building envelope with the following changes: adding 6 cm of thermal insulation to 25 cm thick walls, replacing old windows with double glazed windows modified by nanotechnology, and 8 cm of thermal insulation to the roof. The results showed that using the environmental treatments proposed in the study to improve the outer envelope resulted in a significant improvement in energy performance of approximately 20% compared to the base case.

1. Introduction

As sustainability agendas gain traction at a global level, the assessment of energy efficiency has become an increasingly important component of design and operational practices. Residences are statistically some of the largest consumers of energy, which, in turn, presents a need to identify new methods of optimizing energy use without jeopardizing the comfort and quality of the living experience. This study is focused on the energy use of social housing buildings located within New Borg El Arab City, in the Alexandria Governorate. On the North Coast of Egypt, the research area has a unique climate that has a significant impact on thermal performance of

the buildings, requiring further investigation into the implications of such impacts.[1] This research focuses on leveraging Building Information Modeling (BIM) to perform in-depth simulation studies addressing the energy efficiency of residential buildings. The adoption of BIM enables a thorough analysis of various factors influencing energy use, including the characteristics of the building envelope, HVAC systems, and the effects of surrounding climatic conditions. By evaluating simulation outcomes, opportunities for optimization can be pinpointed, allowing for the introduction of design adjustments or technical solutions aimed at minimizing energy usage. These improvements benefit users by

lowering operational costs while enhancing the overall quality of living in residential spaces.

2. Study Background

In the Middle East jurisdictions with most of its land area considered subtropical (Csa) and partly semi-arid to semi humid (Bsh), majority of modern built residential buildings without the use of mechanical air conditioning systems are not appropriate for present and future climatic change projective, particularly within densely built urban areas [2]. Most of these buildings position architectural design in high-rise buildings to eliminate natural elements and comforts found in traditional built buildings, potentially leading to a disassociation of space conditioned indoor environments from the outdoors, as intended to develop a reliance on and allow for effective natural ventilation of each occupied space [3]. Much of the literature has also mentioned the degree of reliance on mechanical air conditioning systems and resulting in high electricity use to facilitate thermal comfortable indoor conditions of air temperature, particularly where outside environmental conditions are warm and humid [4]. Similarly, and for example to conclude, hot and warm climate areas—which have projective similarities to intra-Mediterranean bounded and regions—such as Mediterranean countries in south-eastern Europe with Egypt have high domestic consumer prices in respective summer months consuming electricity with reliance on domestic cooling appliances, through weekdays to weekends [5] is a point worth note and emphasis. Conversely, those same households in summers have a financial expenditure due to a high dependence on domestic cooling appliance use on summer weekdays and weekends: and regrettably to say, with little thought to fossil fuel assimilation, climate change and sustainability. The increasing awareness of the significance of the environment and the effects of climate change has led architects and designers to use sustainable building design strategies to improve quality within their project. Bioclimatic design is an approach to the built environment that strives to develop comfortable and energy-efficient structure by

applying local climate data and natural resources.

1- Study Problem: Increased energy use in social housing building in Borg El Arab City, Alexandria Governorate, due to the lack of treatment of the building envelope.

2- Study Questions:

1. What are the effective environmental design approaches to achieve thermal comfort and lower energy use, improve design quality, and analyze the energy efficiency of the external envelopes of residential buildings in Alexandria Governorate?
2. How effective is the use of BIM in analyzing and improving the design quality and energy efficiency of the building envelopes of residential buildings in Alexandria Governorate?

3- Hypotheses:

The study proposes a primary hypothesis: the BIM model will contribute to improving the design quality and energy performance evaluation of the exterior envelopes of residential buildings in Alexandria Governorate.

4- Study Objectives:

This study seeks to:

- Assess the value of the BIM model as a strategy to enhance the design of the external envelope of residential buildings in the Alexandria Governorate.

5- Methodology:

The methodology used in this research is structured in three parts:

1- The Inductive Approach: The theoretical part addresses climate-related challenges and the resulting major energy challenges in Egypt and globally. It also addresses the role of Building Information Modeling (BIM) technology in improving the design of residential buildings, particularly for the social housing sector. The research examines how systems can be developed to mitigate environmental impacts while enhancing thermal comfort within residential buildings, focusing on bioclimatic design strategies.

2- The Deductive Approach:

This section focuses on the climatic conditions and data specific to the study area. Analysis and

interpretations are conducted to reveal the regional environment and align with it, leading to the required accuracy in addressing the local environment of the case study.

3- The Applied Approach:

This section uses energy simulation tools using Building Information Modeling (BIM) technology to evaluate the energy performance of the proposed case study. The goal is to improve the design of the building envelope and identify effective treatments and strategies to achieve thermal comfort within residential buildings while improving energy performance. This comprehensive three-part framework balances theoretical data exploration, practical application, and comparative data analysis, providing a comprehensive approach to addressing the challenges of residential building envelope design in the Egyptian environment.

6- Technology Adoption and Innovation Diffusion Theories

The examination of new digital technologies including Building Information Modeling (BIM) is usually effectively situated through models like the Technology Acceptance Model (TAM), or the Unified Theory of Acceptance and Use of Technology (UTAUT). TAM proposes the acceptance of a technology is mainly determined by perceived utility and ease of use [6]. UTAUT has expanded on TAM by including other dimensions, such as social influence and facilitating conditions. Viewing professional engagement with digital tools through these lenses can provide unique and valuable information on the role of digital technologies in engineering and construction, particularly in contexts where digital literacy and organizational conditions vary.

Understanding these psycho-sociological motivators is essential to support greater BIM uptake, particularly in developing markets [7],[8]. Rogers' Diffusion of Innovations theory contextualizes the process of adoption by classifying adopters as innovators, early adopters, early majority, late majority and laggards. In construction, adoption is understandably mostly towards the late majority due to the nature of inertia common in projects of ambiguity, the collaborative challenges with suppliers, regulations affecting workflows and the capital costs involved [9],[10]. For example, workplaces that are resistant to BIM adoption may view it as a

complex technology, have long payback periods, or fear costly disruptions to their creative processes, considering it a specialized tool. Alternatively, disrupting traditional practices in the built environment, with systematic iterations of technologies and processes, could involve collaborative work and investment. Diffusion and adoption processes could be accelerated using effective mechanisms such as pilot projects, peer-to-peer learning opportunities, or professional certification programs [11]. It would be useful to understand how innovation flows across different types of professional networks to facilitate the uptake and diffusion of digital technologies within professional teams.

Emerging economies face distinct obstacles to BIM adoption, shaped by regulatory constraints, socio-cultural dynamics, and foundational infrastructure challenges. Issues such as fragmented supply chains, inadequate infrastructure, and inconsistent digital policy frameworks often impede successful technology integration in these contexts.[12].

8.1. Conceptualizing BIM-Architecture Integration

8.1.1 BIM as the Enabler of System-Wide Sustainability in Design

While Building Information Modeling (BIM) can be seen as an information management technology tool, it is a necessary piece of informed and sustainable decision-making. To this end, BIM serves as a vehicle to be able to combine different datasets, model the impacts of design, and understand the project from a lifecycle perspective. Where BIM becomes transformative is the ability to move beyond its conventional understanding as a repository of design information into a system that considers environmental, economic, and social trade-offs.[13] This is particularly important to the limitations of constraints to sustainability in developing economies as they often lack resources and have complex regulations. BIM can be used as a framework to apply sustainability principles from the onset of the design process, allowing design teams to make decisions based on evidence that aligns to national aspirations and the global sustainability context.

On a more practical level, BIM can effectively combine energy modeling, assessing material efficiency, and economic analyses. By using building performance simulation tools, design can begin earlier in the energy use assessment process based on daylighting and indoor climate comfort. Digital materials inventories can also be leveraged in BIM to better identify environmentally friendly materials. Finally, cost-benefit analyses can encourage stakeholders to prioritize future savings over initial costs. [14,15] BIM establishes a link between feasible sustainability alternatives and available, distinguishable information. These processes potentially support the triple bottom line: environmental thinking, inclusive participation and empowerment, and economic resilience. From an environmental perspective, BIM supports energy-efficient designs and, consequently, carbon emissions monitoring. From a social perspective, shared resource constraints can be modeled for accessibility and comfort as part of overall design. [16] BIM supports lifecycle cost estimation and the reduction of downside risks associated with certain future costs. In the future, BIM may better support sustainability by promoting it as an investment in its realization and providing a collective infrastructure for informed decision-making [17]. BIM is also a powerful and intelligent lever through which building developers can align their practices with overarching government goals such as Egypt Vision 2023. Therefore, BIM has the potential to anchor new expectations for a proactive and systems level of thinking in sustainability approaches within architectural practice.

8.1.2 Roles of Design Professionals in ESG Transformation

The growing emphasis on sustainability and ESG (Environmental, Social and Governance) in design brings a fundamental change to the methods of the professionals involved in the programmers for the development of architecture and infrastructure [18]. Architects, engineers, and urban planners are becoming more than simply isolated technical experts and being drawn into collaborative partnerships in digital productive and purposeful design environment [19]. Those same professionals are increasingly being asked to develop

strategies that balance ecological realities, economic limits, and social objectives [20]. Building Information Modeling (BIM) is important as a part of change, in that BIM establishes a common ground, or collaboration, whereby contributions from multiple disciplines can be aggregated and visualized, which enhances accountability and clarity in knowledge-based choices throughout the phases of a project.

Role theory is a theorization on how responsibilities change in processes that centre on ESG. In essence, individuals take up roles defined by not only institutional norms, but also their professional identities, and the responsibilities of their specific context. In an etiquette ethos about sustainability brought through digital aware BIM, architects might take on the role of sustainability strategists; engineers may play performance analysts, and planners might act as equity assessors. Actor-network theory further illustrates how both human and non-human elements including digital tools like BIM—interact within socio-technical networks. These interactions highlight how BIM acts as a mediator that redefines professional boundaries and encourages collaboration across traditional divisions [21],[22].

The capacity of BIM to function as a common language and coordination mechanism is pivotal to achieving ESG ambitions in realization of design outcomes [23]. BIM facilitates all actors working from the same 'truth' and a collaborative space in which communication challenges can be addressed. This is highly relevant in developing economies, where fragmented governance often inhibits interdisciplinary connectivity [24]. The capacity of BIM models to include codes of regulations, sustainability and stakeholder requirements, means that all actors share and evolve their collaboration with a common understanding of goals for the project. With these collaborative conditions, the design team can act per the agency of ESG transformation, enabled and coordinated through a digital construction platform [25].

8.1.4 Conceptual Framework for Integration

The theoretical model presented in this paper proposes a holistic view of BIM architecture as an interrelated system of dynamic inputs, processes, and outputs connected through feedback loops. The inputs are sustainability regulations, national development frameworks, climate objectives, and ESG performance criteria [26]. Together, these define the normative and policy framework affecting design choices. The processes are BIM-enabled workflows of energy modeling, material analysis, lifecycle costing potential, and stakeholder coordination. These workflows leverage real-time data integration and iterative simulations that align with systems thinking principles.

The outputs are infrastructure projects that achieve ESG benchmarks and contribute to sustainable national change. [27]. A central component of this conceptual model is the introduction of feedback loops to enable continuous learning and adaptive design. Feedback can be utilized from post-occupancy evaluations, performance audits or compiling consultation during the planning phase of the design process. Continuous feedback is important to refine digital models and enhance performance in projects in the future [24]. Continuous feedback also reinforces the dynamism of the model, as it changes with actual performance data and stakeholder feedback. Thus, BIM becomes an important part of an adaptation governance approach in infrastructure development where the design outcomes are constantly realigning with sustainability objectives [11]. The model is based on explicit conceptual boundaries and assumptions. It also anticipates a design ecosystem where digital literacy, regulations and institutional support exist or are developing. The text acknowledges the differences in effectiveness of integration of BIM in different contexts since the methods applied that worked in one case may work in a typically ineffective manner in another context. It notes but does not fully develop direct links between design phases and sustainability indicators: modeling in the early-phase affects energy and material outcomes, modeling in the construction-phase is helpful for risk and cost management, and modeling operations is key to realizing improvements in long-term

performance. This methodology presents a theoretical and scalable way to effectively bring sustainability in the architectural domain, leading to practical and strategically delivered sustainability specifically for developing economies, using BIM in the context of buildings. [10]

8.2. Barriers and Theoretical Mitigation Strategies

8.2.1 Systemic and Institutional Barriers in Emerging Economies

The barriers to digital transformation and Building Information Modeling (BIM) adoption, especially in developing countries, are fundamentally related to issues of policy, fragmentation of regulatory frameworks, and lack of infrastructure. Many developing countries do not have policies and strategies that clearly outline their total commitment to promoting and mandating industries, such as architecture, and construction, to transition into using more advanced technology, digitally. For example [10], Egypt's Vision 2030, is about to push for serious change; however, the gap between policy intention and action usually remains inept and does not trigger actions. The absence of BIM standards, sustainability benchmarks, and digital data sharing protocols maintains fragmentation and incoherence in the design and construction process and undermines compliance and collaboration. As well as policy inertia there is an obvious reluctance and inertia to digital transformation from within the architectural compiling itself. Small practice architects very often see BIM as a disruptive negative, rather than an opportunity for positive innovation and progress. High costs of software, the lack of maturity in digital infrastructure, and unreliable internet connectivity only further restricts willingness to transition. In addition, living with legacy dependence on manual drafting, making love with fragmentation in the workflow, has created soft cultural influences to avoid technological progress and replacement. Along with regulating ambiguity, and the diminishing effect of cybersecurity, clients are increasingly requesting sustainability, and technology, with low demand for digital sustainability, as the condition for few clients requesting

sustainability, is solidifying recessive behaviors, and has created a reluctance change. There is one more barrier to deal with in terms of the professional development and accreditation gap that limits practitioners' use of the value B.I.M. has to offer. Some of the emerging markets' higher education system in architecture are still attempting to assimilate digital skills required to conduct the current state of infrastructure. While the education system in case of BIM related work often excludes sustainability assessments, integrated modelling processes, or co-design processes; and the lack of an accreditation body to rationalize assessment of accreditation of B.I.M. skills or examining training accreditation for the digital skills; all place practitioners in positions that come to rely on the relational capacity to element and ignore new opportunities in an increasing technological context.. Without institutional support to promote up skilling and maintain knowledge standards, the workforce is left unprepared to implement BIM on a large scale, which ultimately slows down our progress toward sustainable infrastructure goals.

7- Case Study:

A study was conducted on social housing building in Borg El Arab City in Alexandria Governorate, which belongs to the North Coast region. The model characteristics of the housing building were determined.

- General Information:

Project Name and Area: Borg El Arab Social Housing Project in Alexandria Governorate.

Climate: Alexandria enjoys a moderate, The Mediterranean Sea experiences a climate characterized by dry, hot summers and mild, humid, rainy winters.

Location: Borg El Arab City in Alexandria Governorate.

The social housing project depends on a ground floor and five floors. Each floor includes four buildings, each consisting of a living room, three rooms, a kitchen, and a bathroom. As shown in Figures (2) and (3):

8- Evaluation of thermal performance of case Study: -

Assessing the thermal performance of social housing buildings serves as a key measure of

effectively interior spaces maintain thermal comfort. Achieving this comfort is closely tied to the selection of building materials, especially those comprising the external envelope. By examining the design principles underpinning these housing buildings and analyzing the properties of the materials used, a comparative study is undertaken to evaluate the efficacy of these materials, whether in wall construction or glazing, in meeting thermal comfort objectives. The aim of this study is to optimize the energy efficiency of social housing building while enhancing design quality, thereby fostering a comfortable and sustainable indoor environment.

9- Basis for Selecting the Case Study:

The case study was selected in Borg El Arab City, located in Alexandria, within the North Coast region, known for its moderate climate. However, the failure of social housing buildings to address environmental challenges resulted in a lack of thermal comfort within the spaces, negatively impacting users. To achieve the study objectives, the following points were considered:

- Identifying the project case study within a distinct climatic zone, specifically the North Coast region.

- Gathering essential data and information to support the simulation process and subsequent evaluation phases.

- Choosing projects that focus on assessing the influence of building materials in achieving both efficiency and environmental suitability.

10- Technical Methods for Collecting and Documenting Data:

Several methods were used to collect information related to the case studies, including:

- Drawing on previous research and studies.

- Conducting subject trips with photographic documentation.

- Obtaining architectural drawings, designs, surveying maps and geographical studies for the project.

11- Applied Methodology:

Identifying and thoroughly analyzing the local climate data for this specific study. -

Describing the social housing buildings under study with a detailed analytic description including the style of the architectural design, characteristics of the existing building envelope assemblies, occupancy nature, area/percentage of openings, and orientation. - Analyzing the baseline using Design Builder V7.0 simulation program using modeled versions of the social housing buildings under study.

- Testing the proposed treatment method considering the orientation of the building, the material of the components, and the type of glazing of the openings to mitigate the thermal performance overall.

- A comparison of the simulation results and discussion of finding to assess the effectiveness of the alternatives proposed, selecting options that provide the best environmental comfort.

The focus of this simulation is:

A. To assess the capacity of various construction materials for thermal comfort in the social housing buildings.

B. Analyze the materials used in social housing buildings and their impact on the indoor environment.

C. Conduct a simulation of the required cooling loads in the current building and develop alternatives.

D. Estimate the percentage of energy savings using various design and material alternatives.

1- Assessment of Social Housing Models: Evaluation is determined through the following tasks: A. All climate information for Borg El Arab City, Alexandria Governorate: The study examines the climatic conditions of Alexandria Governorate, located along Egypt's North Coast, using the software Climate Consultant 6.0 for data interpretation. - Psychrometric Chart: The psychrometric chart exhibits the relationship between temperature, plotted horizontally, and relative humidity (vertical axis), allowing for proximity to the climate conditions in Alexandria Governorate which were utilized for the distance from the thermal comfort zone based on changing temperature and humidity in the figures to follow.

1- Assessment of Social Housing Models: Evaluation is determined through the following tasks:

A. All climate information for Borg El Arab City, Alexandria Governorate: The study examines the climatic conditions of Alexandria Governorate, located along Egypt's North Coast, using the software Climate Consultant 6.0 for data interpretation.

- **Psychrometric Chart:** The psychrometric chart exhibits the relationship between temperature, plotted horizontally, and relative humidity (vertical axis), allowing for proximity to the climate conditions in Alexandria Governorate which were utilized for the distance from the thermal comfort zone based on changing temperature and humidity in the figures to follow (4).

B- Data for a Social Housing Model Building:

- Architectural Object Data:

The objective of analyzing a social housing model building, both before and after implementing proposed adjustments, is to assess the influence of materials on thermal performance, orientation, glazing openings, and architectural features — all of which directly affect energy use. This analysis will involve comparing the current condition of the housing building to its state after applying the proposed changes. Additionally, the study will measure energy use rates in each scenario, factoring in aspects such as spatial orientation and thermal insulation for walls that are 6 cm thick and roofs with an 8 cm thickness. The investigation will also calculate the range of energy savings by determining the difference between the highest and lowest savings values, along with identifying the savings attributed to each proposed modification compared to the existing case.

- Heat Gain:

There are two main sources of heat gain: internal and external. Internal heat is generated by the occupants inside the building and lighting sources, while external heat is generated by the building's exposure to sunlight, which penetrates the interior space through the building's outer envelope.

- Evaluating the social housing building model using simulation:

The evaluation process is carried out through:

A- **Simulation Methodology:** This methodology relies on entering the building specifications and dimensions into a specialized program to create a three-dimensional model that realistically simulates the building. This model provides a comprehensive visualization of all aspects of energy use within the building. Design Builder v7.0 is used, which analyzes all inputs related to the case study and provides precise details about the building's performance

and the effectiveness of the architectural design..

The project consists of 166 buildings, comprising a total of 3,984 housing buildings. Additionally, the layout includes essential service facilities such as a nursery, a commercial market, and areas designated for places of worship.

12- Simulation Methodology:

The process begins by entering the building specifications and dimensions into the program, which creates a mock-up and simulation model that reflects the actual building. This model provides an accurate visualization of everything related to the building energy use. The model is also shown using Design Builder 7.0, which analyzes all inputs related to the case study in a comprehensive manner.

13- Discussion of the results:

1- Figure (7): Demonstrates a comparison of results for energy use based on the basic case with different types of orientation for the modeling of the social housing building in Burj Al Arab City in Alexandria governorate with a wall thickness of 12 cm red brick and 3 mm plane single transparent glass.

The energy use analysis for the base case in Borg El Arab City in Alexandria Governorate evaluates the performance of a social housing building with red brick walls 12 cm thick, single transparent class (3 mm thick) across multiple orientations. In examining the southeast orientation, the Yearly cooling energy use is 53.85 kWh/m² and the heating energy use is 11.51 kWh/m², indicating the orientation consumes more energy than the north orientation at 43.43 kWh/m² for cooling demand and 18.13 kWh/m² for heating demand. The second-best orientation in terms of cooling energy demand is the northeast orientation, with values of 48.52 kWh/m² for cooling and 17.12 kWh/m² for heating, resulting in a cooling reduction ratio of 19.35% to the north orientation. The cooler temperatures in the northwest orientation did not improve the cooling demands relative to the other orientations, as the Yearly cooling demand for the east orientation was 53.52

kWh/m² and the heating demand was 14.23 kWh/m² the second highest cooling energy use orientated from all occupied orientations considered in the study. The south orientation shows the cooling use of 50.14 kWh/m² combined heating energy use, at 10.34 kWh/m². The southwest orientation shows similar behavior with cooling use values at 51.51 kWh/m² and heating use at 11.88 kWh/m². The western orientation has a cooling usage of 50.92 kWh/m² and a heating rate of 14.9 kWh/m² Yearly. Finally, we note the northwest orientation, with a cooling use of 47.15 kWh/m², and heating use of 17.8 kWh/m², once again demonstrating the moderate use compared to the other orientations evaluated in this study.

2- Figure (8): Demonstrates an analysis comparing the energy use outcomes for **the second scenario** based on different orientation types of the social housing building model. The construction specifications include a 25 cm red brick wall thickness, 8 cm of thermal insulation applied to the roof, and 3 mm single transparent glass for the windows.

Looking at the energy use results for the second case, southeast orientation: shows average Yearly cooling energy use of 46.7 kWh/m² and average heating energy use of 2.4 kWh/m². Corresponding to the highest energy use rate in comparison to the north orientation, where the energy use results indicated average Yearly cooling energy use of 35 kWh/m² and average heating energy use of 7 kWh/m² for the north orientation. Approximately 25% higher than the north orientation for cooling energy is evidenced in the review of all energy use for the various orientations testing in the second example, with the northwest orientation at a lower Yearly cooling energy use than all except the 38.6 kWh/m² mentioned. The average heating energy use for northwest orientation was 6.9 kWh/m². In comparison, the northeast orientation showed the higher Yearly cooling energy use at 40.2 kWh/m², while showing the least heating energy use at 6.1 kWh/m². The analysis at east orientation shows the highest Yearly cooling energy use at 54.7 kWh/m²; while showing the least amount of heating energy use at 3.9 kWh/m². The south orientation case: shows APRU cooling energy use operating was 43.4 kWh/m², while the

heating energy use was significantly reduced to 2.03 kWh/m². For the cool orientation, the cooling energy use for the year was 44.02 kWh/m² and the heating energy use was 2.9 kWh/m² which does reflect balance to components when comparing to the east, south and northwest orientations. For the energy use respective to case two, direction (west), we retrieve the following: the cooling energy use was 42.7 kWh/m² Yearly, and the heating energy use was 4.6 kWh/m².

3- Figure (9): Presents a comparison of energy use results for **the third scenario**, analyzing various orientations of the social housing building model. The case is based on specific construction characteristics, including a wall thickness of 25 cm made from red brick, 8 cm of thermal roof insulation, and double low-e glass measuring 6 mm.

The energy use analysis for the third scenario, featuring a southeast orientation of the social housing model in Borg El Arab City, Alexandria Governorate, incorporates specific building design elements: 25 cm thick red brick walls, 8 cm roof thermal insulation, and 6 mm low-emissivity double glazing. In this configuration, the average Yearly cooling energy use is 43.02 kWh/m², while the average Yearly heating energy use stands at 2.45 kWh/m². These values represent a comparatively higher energy use rate when compared to the north-facing building orientation, where cooling demand averages 33.18 kWh/m² and heating demand averages 6.7 kWh/m² Yearly. The northeast-oriented building in the third scenario exhibits a 22.9% lower cooling energy use compared to the north-facing configuration, with average Yearly cooling energy demand at 34.56 kWh/m² and heating energy at 5.9 kWh/m². This makes it the second most efficient orientation in terms of cooling demand among the analyzed scenarios. For the east-facing building, the Yearly cooling energy use is calculated at 42.49 kWh/m², with heating demand averaging 3.9 kWh/m² Yearly. The south-oriented building consumes slightly less energy for cooling at 39.9 kWh/m², alongside a heating demand of 2.16 kWh/m² Yearly. Similarly, the southeast-oriented configuration records an Yearly average cooling energy demand of 40.4 kWh/m² and heating energy demand of 3.02 kWh/m². The west-facing scenario demonstrates an Yearly average cooling

energy requirement of 39.25 kWh/m² and a heating demand of 4.7 kWh/m² Yearly. However, the northwest-facing building orientation incurs the highest energy use levels among all studied scenarios, with an Yearly average cooling energy demand of 50.74 kWh/m² and heating demand reaching 12 kWh/m².

4- Figure (10): Shows a Compares the energy usage outcomes for **the fourth scenario** based on various orientations of the social housing building model. This analysis assumes a wall constructed with 25 cm red brick, 6 cm thermal insulation incorporated into the wall, 8 cm thermal insulation for the roof, and double low-e glass panels measuring 6 mm.

For the fourth scenario (south-east), energy use results for a social housing building model located in Borg El Arab City, Alexandria Governorate with a 25 cm thick red brick wall, 6 cm thermal insulation to the wall, 8 cm thermal insulation to the roof, and 6 mm low-e double glazing shows it had an average Yearly cooling energy use of 30.54 kWh/m² and an average heating energy use of 0.99 kWh/m². This is the highest energy use rate for an orientation compared to the north. For the north orientation, it shows an average Yearly cooling energy use of 24.89 kWh/m², which is still 18.5% lower than the north for cooling energy, and an average heating energy use of 2.4 kWh/m². The energy use results for the fourth scenario show different results of energy use depending on orientation. In the north-eastern orientation it has an Yearly cooling energy use of 26.68 kWh/m², which is the second lowest achieved. The average heating energy use was 2.16 kWh/m². Looking at the east orientation, while in the same scenario, the cooling energy use rose to 29.82 kWh/m², while the heating energy rate was slightly lower, at 1.5 kWh/m². For the south facing, under the fourth scenario, the cooling energy use was 29.68 kWh/m² and the heating energy rate was the full and lowest at 0.7939 kWh/m². For the southwest, the Yearly cooling energy use was the greatest in this scenario, at 30.05 kWh/m², with a heating rate of 0.92 kWh/m², with an increase from the south orientation on both metrics. The energy use results for the fourth case, facing west, are 50.74 kWh/m² of Yearly cooling energy use and 1.5 kWh/m² of heating energy use. The

energy use results for the fourth case, facing northwest, are 26.67 kWh/m² of Yearly cooling energy use and 2.34 kWh/m² of heating energy use.

5- Fifth case: Comparing energy use results with different windows to wall ratio (WWR) For the social housing building model, the specified construction materials include a wall thickness of 25 cm red brick combined with 6 cm of thermal insulation within the wall. The roof incorporates 8 cm of thermal insulation, while the windows feature 6 mm double low-e glass for enhanced energy efficiency.

The energy use results for the fifth case, with a 10% opening ratio, for the social housing building model in Borg El Arab City, Alexandria Governorate, with 25 cm of red brick wall thickness, 6 cm of wall insulation, 8 cm of roof insulation and 6 mm low-emissivity double glazing were an average of Yearly cooling energy use is 40.34 kWh/m² and heating energy use is 3.02 kWh/m². The energy use result for the fifth case was for a case with a 20% WWR opening ratio, a Yearly average cooling energy use is 48.13 kWh/m² and heating energy use is 2.32 kWh/m². The energy use result for the fifth case, with a WWR of 30% on windows and walls, is an average of 57.47 kWh/m² of Yearly cooling energy use and 1.88 kWh/m² of heating energy use. The fifth case, with a WWR of 40%, had a cooling energy use of 68.68 kWh/m² per Year and heating energy use of 1.5 kWh/m². The fifth

case, with a WWR of 50% for windows and walls, had a cooling energy use of 81 kWh/m² per Year and heating energy use of 1.31 kWh/m².

6-Sixth case: Comparing the results of energy use with **different types of thermal insulation and normal thermal insulation aerogel nano** for a model of a social housing building in the case of a wall depth of 25 cm red brick and 6 cm thermally insulating in the wall and 8cm thermally insulating to roof and 6 mm double low-e glass.

For the scenario where the walls are 25 cm thick with red brick construction combined with 6 cm of nano-aerogel thermal insulation, 8 cm of nano-aerogel thermal insulation for the roof, and 6 mm low-emissivity double-glazed glass, the yearly cooling energy use rate is recorded at 27.08 kW/m², while the heating energy use rate is notably low at 0.59 kW/m². In comparison, using 6 cm of regular thermal insulation in the walls, paired with 8 cm of conventional thermal insulation for the roof and the same 6 mm low-emissivity double-glazed glass setup, results in a yearly cooling energy use rate of 30.01 kW/m² and a heating energy use rate of 0.92 kW/m². These findings underline the superior performance of nano-aerogel insulation in reducing cooling and heating energy demands, making it a more efficient choice for enhanced thermal comfort and energy efficiency within similar building designs.

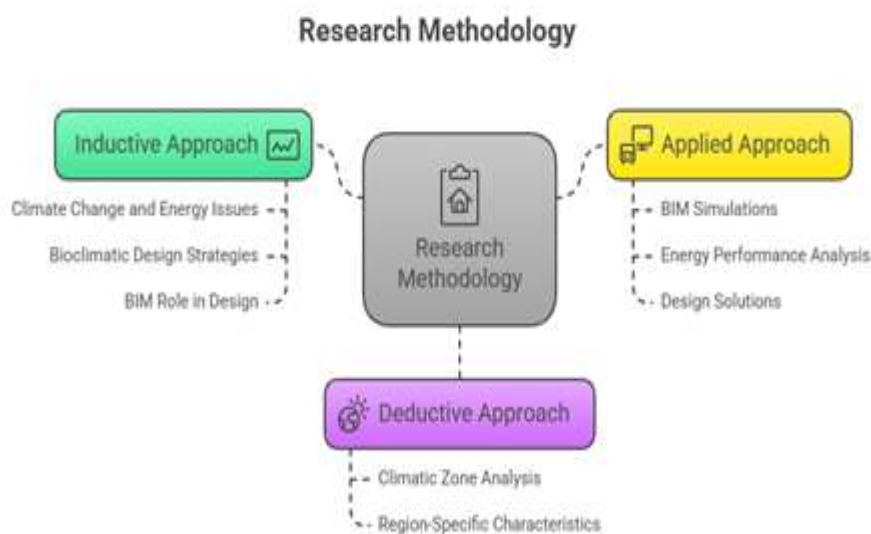


Figure 1.Research Methodology



Figure 2 a model of a residential social housing building consisting of 4 units per floor. Source: Researcher



Figure 3 The plans of a model of 90-meter residential units with services - social housing plan - Borg El Arab City in Alexandria

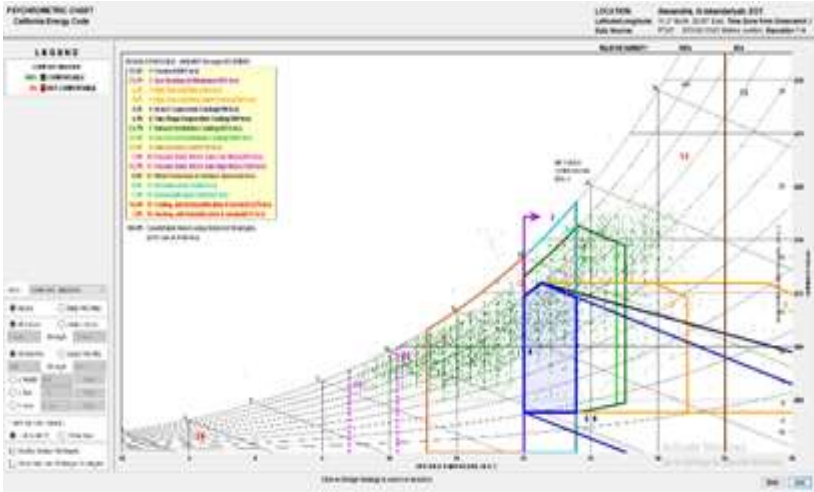
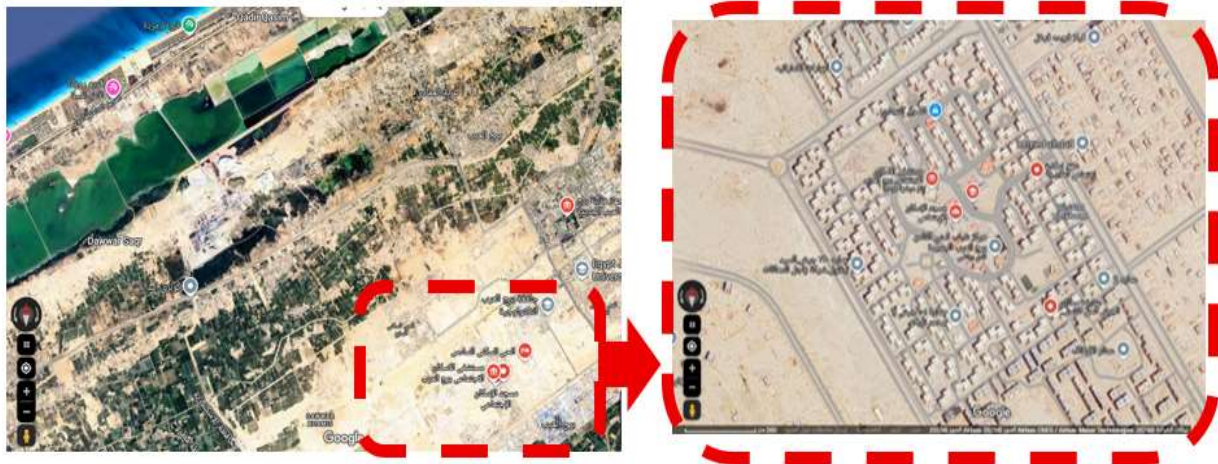


Figure 4 The psychrometric chart of thermal comfort for the study case using the Climate Consultant 6.0 program. [29]



Picture 5 illustrates the arrangement of social housing building in New Borg El Arab City, located in Alexandria Governorate

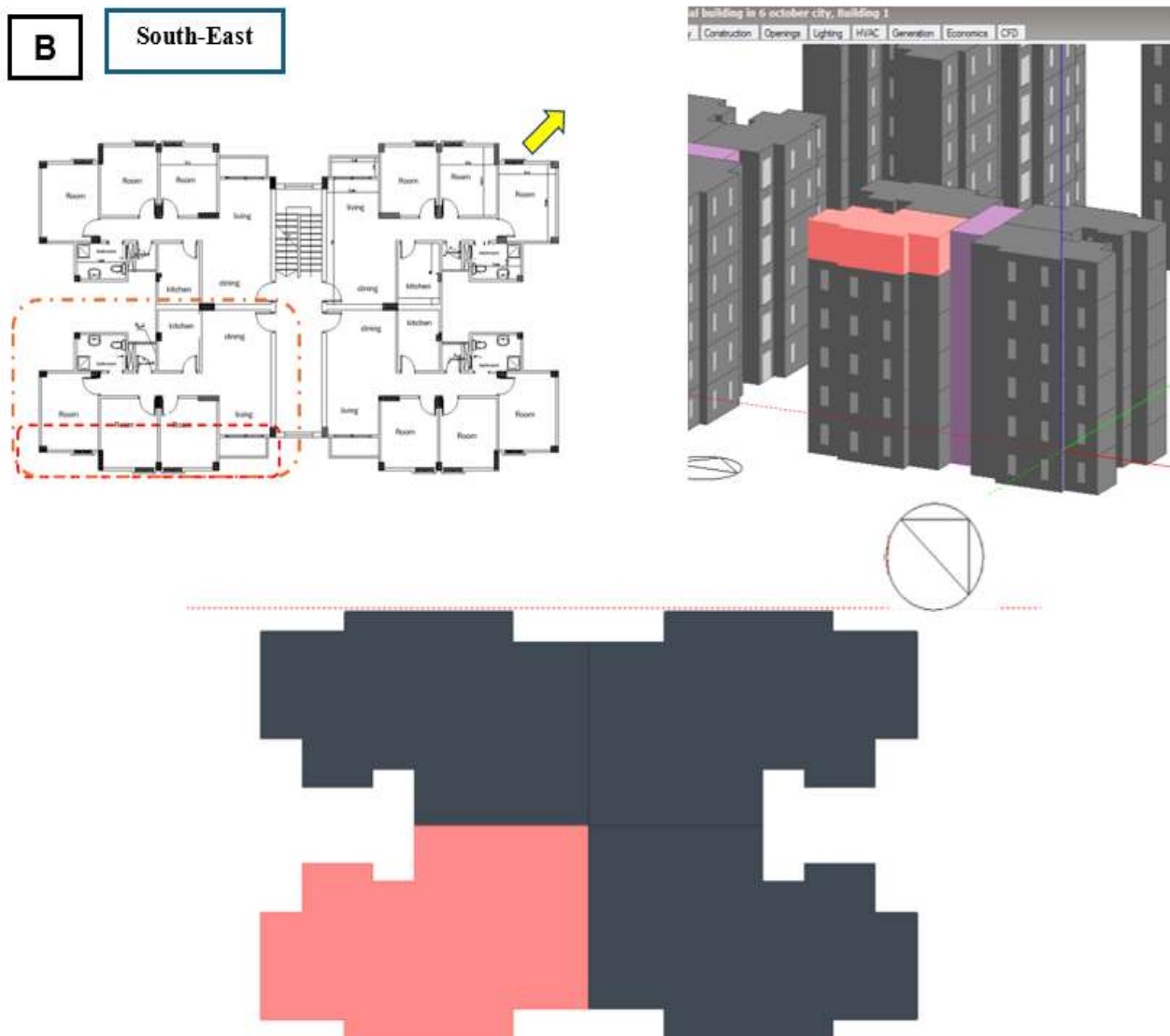


Figure 6 (a) a model of the study case in the V 7.0 Design Builder program. Source: Figure (b) shows a layout for the social housing building model for the base case with a wall depth of 12 cm and without thermal insulation of the roof, and where the base case orientation is **South-East**.

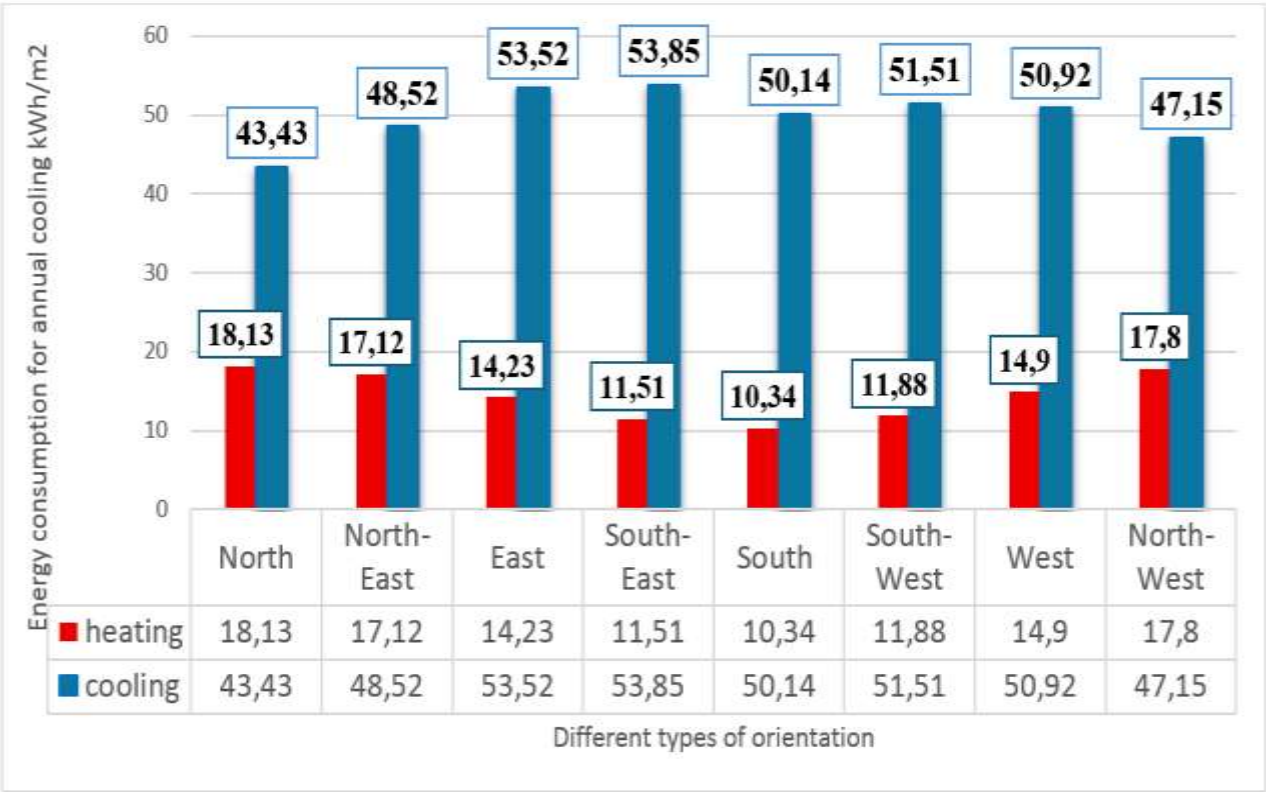


Figure 7 as shown in the first case: Comparison and Analyzing energy use results for the base scenario across various orientation configurations in the social housing building model reveal specific findings. This assessment is based on using a 12 cm thick red brick wall combined with 3 mm single glass windows.

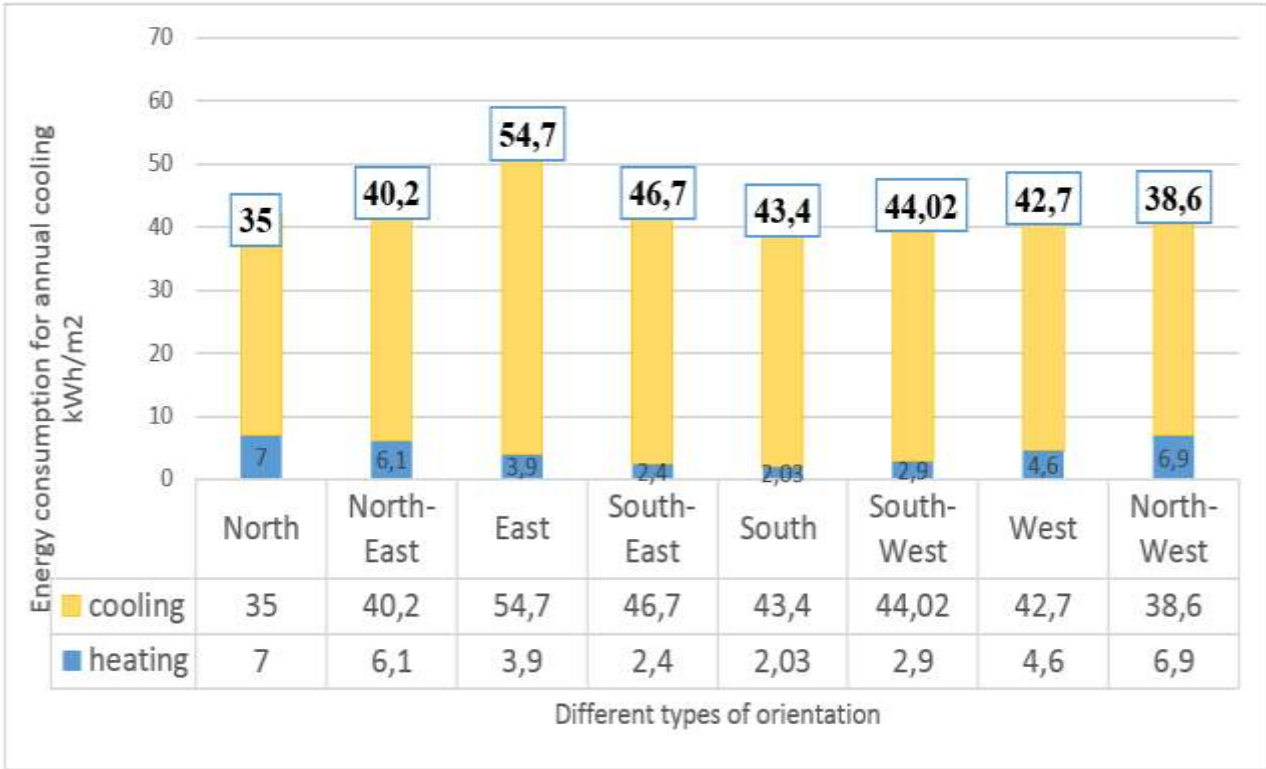


Figure 8 illustrates a comparison of energy use results of the second scenario with respect to orientations of the social housing building model. This comparison considered a wall thickness of 25 cm of red brick, a roof that involved 8 cm of thermal insulation, and single transparent glass with a thickness of 3 mm.

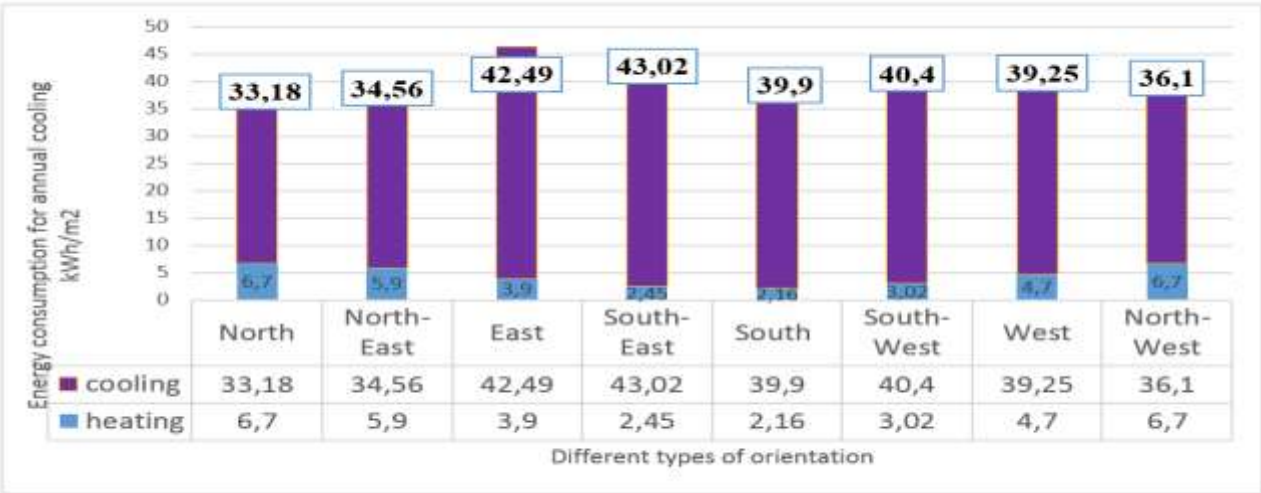


Figure 9 illustrates the third case, showcasing various orientations of the social housing building model. This analysis considers a configuration with 25 cm thick red brick walls, 8 cm of thermal insulation on the roof, and 6 mm double low-e glass.

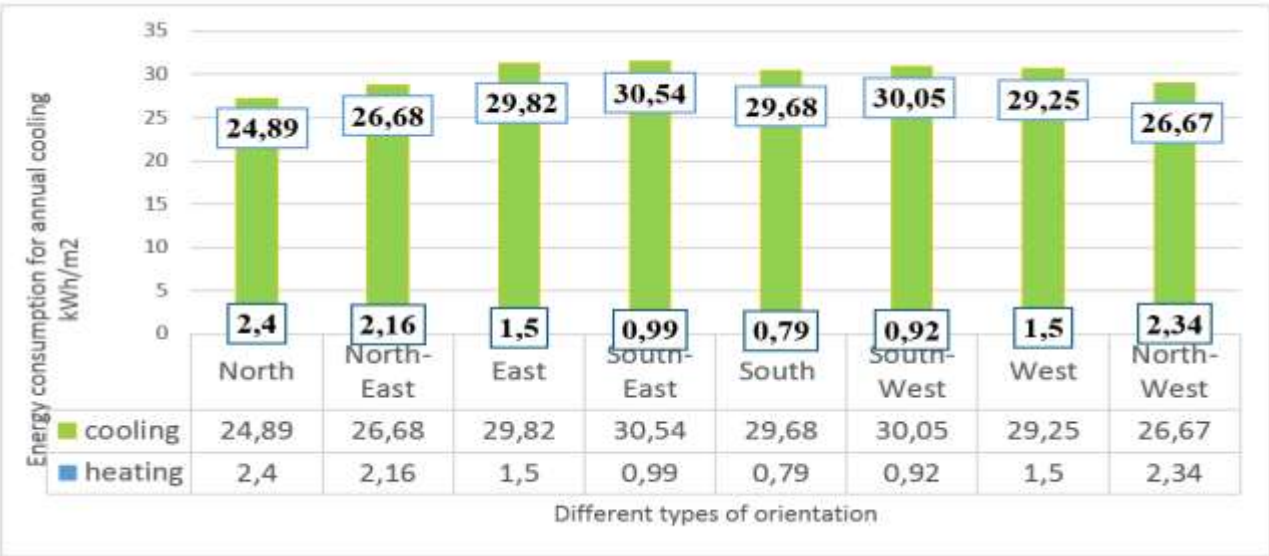


Figure 10 illustrates the energy use results for the fourth scenario, comparing various orientation configurations of the social housing building model. In this analysis, the building features a wall with 25 cm red brick thickness, 6 cm of thermal insulation within the wall, 8 cm of thermal insulation on the roof, and double low-e glass of 6 mm thickness.

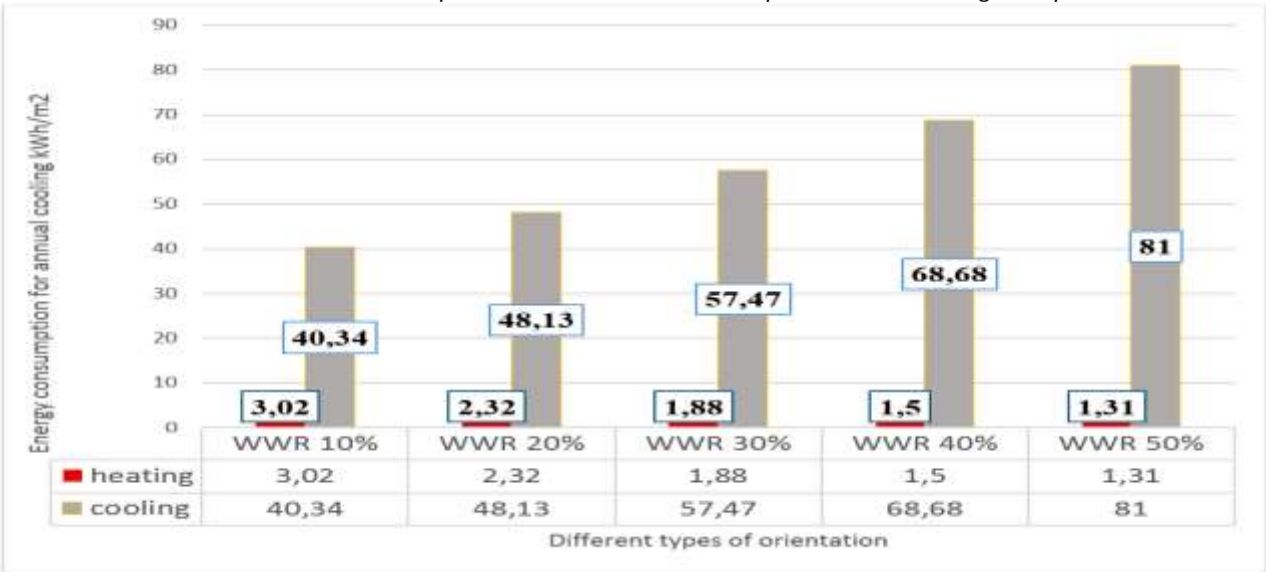


Figure 11 illustrates the fifth case, which compares energy consumption outcomes for a social housing building model with varying window-to-wall ratios (WWR). The analysis is based on a structure featuring 25 cm thick red brick walls, 6 cm of wall insulation, 8 cm of roof insulation, and 6 mm low-emissivity double glazing.

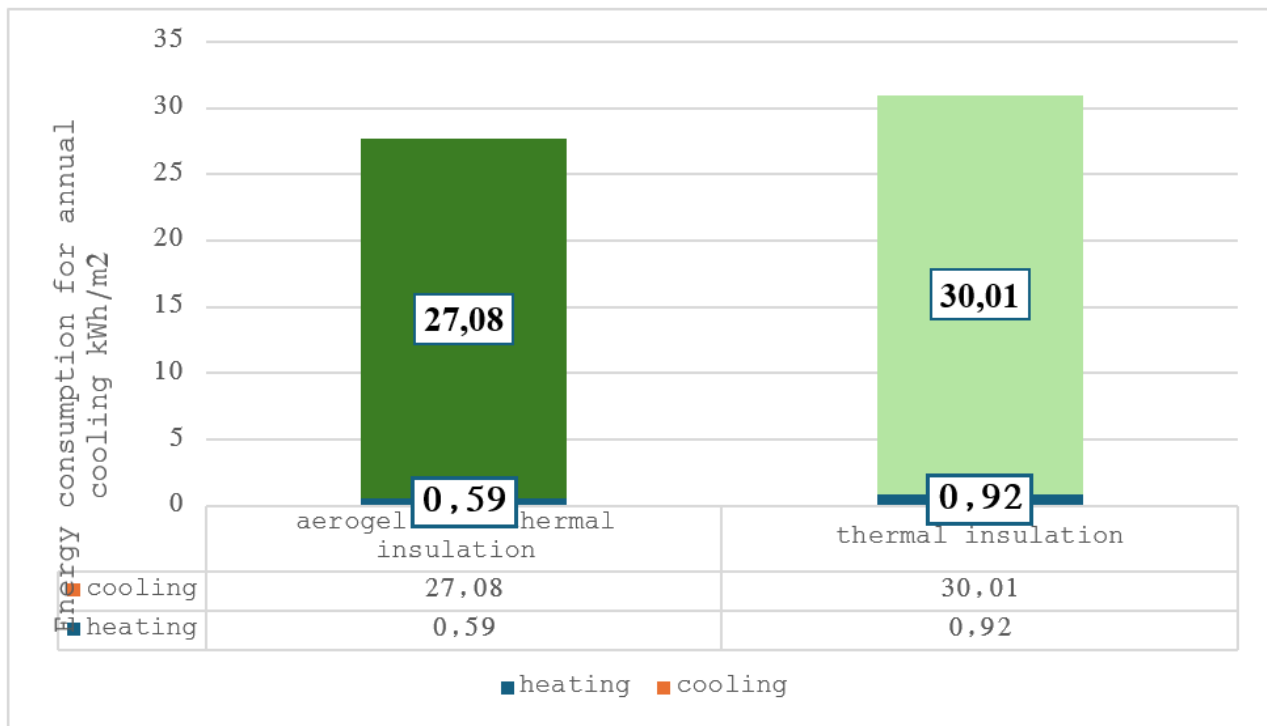


Figure 12 illustrates **the sixth case**: an analysis of energy consumption when comparing various types of thermal insulation, including standard thermal insulation and aerogel nano insulation. The study examines a social housing model featuring 25 cm thick red brick walls, augmented by 6 cm wall insulation, 8 cm of roof insulation, and 6 mm double low-e glass.

4. Conclusions

- Mediterranean and Coastal Zones: The design strategies focus on maximizing natural ventilation and effective shading to combat the hot, dry summers while taking advantage of the mild winters. Specific standards for indoor temperatures, window specifications, and shading methods ensure that buildings remain comfortable and energy efficient.
- Energy use results for the third case, the south-east orientation, for a social housing building model in Borg El Arab City, Alexandria Governorate, with a 25 cm red brick wall thickness, 8 cm roof thermal insulation, and 6 mm low-emissivity double glazing. The average Yearly cooling energy use is 43.02 kWh/m², and the average heating energy use is 2.45 kWh/m². This is a higher rate of energy use compared to the north orientation, where the energy use results are (north orientation). The average Yearly cooling energy use is 33.18 kWh/m², and the average heating energy use is 6.7 kWh/m². With a cooling energy use ratio of 22.9% compared to the northward orientation, energy use results for the third scenario, facing northeast

14- Recommendations:

- 1- Efforts should focus on enhancing the energy efficiency of social housing structures, particularly in Borg El Arab City within the Alexandria Governorate, by employing environmental treatments. Improving the building envelope helps reduce energy consumption and elevates indoor environmental quality.
- 2-Initial findings underscore the significance of incorporating thermal insulation measures, specifically adding 6 cm of insulation to walls combined with 6 mm double-glazed nano-treated glass. Additionally, applying at least 8 cm of insulation to roofs yields the highest energy savings for social housing buildings in Borg El Arab City, achieving reductions surpassing 20% compared to current standards.
- 3- Leveraging BIM simulation technology offers valuable preliminary insights that assist in identifying suitable environmental interventions to enhance energy performance in residential buildings, with a particular emphasis on social housing building in Borg El Arab City.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of 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
- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.
- **Author contributions:** The authors declare that they have equal right on this paper.
- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

- [1]Ozarisoy, B., & Altan, H. (2021). Systematic literature review of bioclimatic design elements: Theories, methodologies and cases in the South-eastern Mediterranean climate. *Energy and Buildings*, 250, 111281.
- [2]Bachtiar, A. A. F., Hamzah, B., Asmal, I., & Jamala, N. (2024). A Model for Determining the Thermal Comfort of Fishermen's Houses on Coasts with Humid Tropical Climate. In *Proceeding of International Conference on Multidisciplinary Research for Sustainable Innovation* (Vol. 1, No. 1, pp. 431-440).
- [3]Mahmoud, A. H. A. (2011). Analysis of the microclimatic and human comfort conditions in an urban park in hot and arid regions. *Building and environment*, 46(12), 2641-2656.
- [4]Jalia, R. Bakker, and M. Ramage, (2019). "The Edge, Amsterdam," ed: Centre for Digital Built Britain, University of Cambridge: Cambridge, UK.
- [5]Zoure, A. N., & Genovese, P. V. (2022). Development of bioclimatic passive designs for office building in Burkina Faso. *Sustainability*, 14(7), 4332.
- [6]Hewavitharana, T., Nanayakkara, S., Perera, A., & Perera, P. (2021, November). Modifying the unified theory of acceptance and use of technology (UTAUT) model for the digital transformation of the construction industry from the user perspective. In *Informatics* (Vol. 8, No. 4, p. 81). MDPI.
- [7]Howard, R., Restrepo, L., & Chang, C. Y. (2017). Addressing individual perceptions: An application of the unified theory of acceptance and use of technology to building information modelling. *International Journal of Project Management*, 35(2), 107-120.
- [8]Nnaji, C., Okpala, I., Awolusi, I., & Gambatese, J. (2023). A systematic review of technology acceptance models and theories in construction research. *Journal of Information Technology in Construction*, 28.
- [9]Onifade, O., Ochuba, N. A., Eyeregba, M. E., Kalu, A., & Ezech, F. S. (2024). A Conceptual Model for Policy-to-Practice Alignment in Financial Reporting and Operational Oversight.
- [10]Osho, G. O., Omisola, J. O., & Shiyabola, J. O. (2020). A Conceptual Framework for AI-Driven Predictive Optimization in Industrial Engineering: Leveraging Machine Learning for Smart Manufacturing Decisions. *Unknown Journal*.
- [11]Lawal, C. I., Adanigbo, O. S., Ezech, F. S., Friday, S. C., & Ugbaja, U. S. (2025). Advances in Business Entrepreneurship for Driving International Financial Technology Platform Expansion.
- [12]EZEANOCHIE, C. C., AFOLABI, S. O., & AKINSOOTO, O. (2022). Advancing Automation Frameworks for Safety and Compliance in Offshore Operations and Manufacturing Environments.
- [13]Abisoye, A., Udeh, C. A., & Okonkwo, C. A. (2022). The Impact of AI-Powered Learning Tools on STEM Education Outcomes: A Policy Perspective. *Int. J. Multidiscip. Res. Growth Eval*, 3(1), 121-127.
- [14]Abisoye, A. (2023). AI Literacy in STEM Education: Policy Strategies for Preparing the Future Workforce.
- [15]Kisina, D., Akpe, O. E. E., Owoade, S., Ubanadu, B. C., Gbenle, T. P., & Adanigbo, O. S. (2022). Advances in Continuous Integration and Deployment Workflows across Multi-Team Development Pipelines. *environments*, 12, 13.
- [16]Ezeanochie, C. C., Afolabi, S. O., & Akinsooto, O. (2023). A Data-Driven Model for Automating RFQ Processes in Power Distribution and Data Center Infrastructure.
- [17]Ezeanochie, C. C., Afolabi, S. O., & Akinsooto, O. (2024). Designing a Framework to Enhance Workforce Productivity Using Digital Gemba Audits and Signage Solutions.
- [18]Anyanwu, C. S., Akinsooto, O., Ogundipe, O. B., & Ikemba, S. (2024). Net-zero energy buildings: a path to sustainable living. *Engineering Heritage Journal (GWK)*, 5(1), 81-87.
- [19]Ezeanochie, C. C., Afolabi, S. O., & Akinsooto, O. (2024). Designing a Framework to Enhance Workforce Productivity Using Digital Gemba Audits and Signage Solutions.
- [20]Abisoye, A., Akerele, J. I., Odio, P. E., Collins, A., Babatunde, G. O., & Mustapha, S. D. (2025). Using AI and machine learning to predict and mitigate cybersecurity risks in critical infrastructure. *International Journal of Engineering Research and Development*, 21(2), 205-224.
- [21]Dada, E. A., Eyeregba, M. E., Mokogwu, C. H. U. K. W. U. N. W. E. I. K. E., & Olorunyomi, T. D. (2024). Advanced economic modeling for sustainable development and policy innovation in Nigeria. *Journal of Economic Policy and Innovation*, 12(2), 45-60.
- [22]Ezeife, E., Eyeregba, M. E., Mokogwu, C., & Olorunyomi, T. D. (2024). A conceptual framework for data-driven business optimization: Enhancing operational efficiency and strategic growth in US small enterprises.

- [23]Erinjogunola, F. L., Sikhakhane-Nwokediegwu, Z., Ajirotutu, R. O., & Olayiwola, R. K. (2025). Navigating multi-national construction projects: Overcoming challenges. *International Journal of Multidisciplinary Research and Growth Evaluation*. 2025b, 6(2), 52-67.
- [24]Oluokun, O. A., Akinsooto, O., Ogundipe, O. B., & Ikemba, S. (2025). Policy and technological synergies for advancing measurement and verification (M&V) in energy efficiency projects. *Gulf Journal of Advance Business Research*, 3(1), 226-251.
- [25]Oluokun, O. A., Akinsooto, O., Ogundipe, O. B., & Ikemba, S. (2025). Policy strategies for promoting energy efficiency in residential load management programs. *Gulf Journal of Advance Business Research*, 3(1), 201-225.
- [26]Gbenle, P., Abieba, O. A., Owobu, W. O., Onoja, J. P., Daraojimba, A. I., Adepoju, A. H., & Chibunna, U. B. (2025). A Privacy-Preserving AI Model for Autonomous Detection and Masking of Sensitive User Data in Contact Center Analytics.
- [27]Lawal, C. I., Adanigbo, O. S., Ezech, F. S., Friday, S. C., & Ugbaja, U. S. (2025). Advances in Business Entrepreneurship for Driving International Financial Technology Platform Expansion.
- [28]Bestara, A. K. (2022, July). Bioclimatic Architecture as a Design Approach for High School in Gedebage, Bandung City. In *International Webinar on Digital Architecture 2021 (IWEDA 2021)* (pp. 270-273). Atlantis Press.
- [29]<http://www.energy-design-tools.aud.ucla.edu/climate-consultant/request-climate-consultant.php> 10-5-2025