Modeling Sustainability Standards and Assessment Systems in High-Rise Buildings

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Abstract

With the rapid growth of major cities, sustainability in construction has become a fundamental aspect of modern building development, particularly in high-rise residential buildings which are increasingly important in urban expansion. This research aims to analyze how to model energy efficiency improvement criteria in high-rise buildings through a case study of a residential tower using the Revit software. The study begins by developing a comprehensive framework for assessing the environmental, social, and economic impacts of high-rise residential buildings, with a specific focus on energy efficiency as a key criterion in sustainability evaluation. By analyzing data obtained from Revit modeling, the research explores how modeling tools can be utilized to improve building design and enhance energy efficiency. The methodology includes a bibliometric content analysis to review relevant studies and leverage current sustainability assessment frameworks. These principles are applied to a real-life residential tower case study to illustrate the positive impact of improving energy efficiency on the tower's environmental performance. The results indicate that applying energy efficiency criteria using Revit can lead to significant reductions in energy consumption, decreased carbon emissions, and enhanced resource management in residential buildings. Additionally, these criteria contribute to the overall environmental, social, and economic benefits of high-rise buildings. The research concludes with recommendations on how to effectively integrate sustainability criteria into the design of residential towers, emphasizing the importance of using advanced modeling tools like Revit to achieve sustainable and effective outcomes in the construction field.

Keywords: Sustainability in Construction; Energy Efficiency**;** Revit Modelling; Sustainability Assessment Systems; Building Information Modelling (BIM); Sustainable Design; Green Building Standards; Building Performance Analysis; Sustainable Development; Efficiency Improvement Criteria

1. Introduction

With increasing environmental challenges and the growing need for more sustainable building solutions[1], improving energy efficiency in high-rise buildings is gaining significant importance in the field of design and construction. Residential towers, which have become an integral part of the urban fabric in major cities[2], require innovative strategies to reduce their environmental impact and enhance their energy efficiency. In this context, the use of advanced modeling tools[3] such as Revit is crucial for optimizing building performance in this domain. This research aims to present a practical case study of a residential tower in Basilea City, focusing on how to model and improve energy efficiency using Revit. It will analyze how sustainability criteria and energy efficiency improvements can be applied through advanced design strategies and the benefits of specialized software for building design and analysis. The study begins with a comprehensive review of the theoretical framework for assessing the environmental, economic, and social impacts of residential towers, highlighting the vital role of energy efficiency in achieving sustainability[4]. Through this case study, the research will explore how Revit can be used to analyze and develop design solutions that enhance the tower's energy[5] performance and contribute to reducing energy consumption and associated environmental impacts.

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2. Literature Review

The literature indicates that sustainability in construction has become a central focus in the development of modern buildings[6], aiming to reduce environmental impacts and improve resource efficiency. Residential towers are an integral part of the urban fabric in major cities, requiring innovative strategies to enhance their energy efficiency[7]. In this context, Building Information Modeling (BIM)[8] and tools such as Revit play a crucial role in improving building design and energy performance. Previous studies, such as Lundberg (2018), have shown that the application of thermal insulation techniques, high-performance windows, and renewable energy can significantly reduce energy consumption in high-rise buildings[9]. Sustainability assessment systems like LEED, BREEAM, and DGNB also represent important tools for guiding design towards sustainability[10] standards, providing a comprehensive framework for evaluating the environmental, economic, and social impacts of buildings. Smith and Tardif (2019) point out that using Revit can provide accurate data on energy consumption and environmental impacts, helping engineers make informed design decisions[11]. Furthermore, case studies such as One Central Park highlight notable improvements in energy efficiency when using BIM technologies[12], emphasizing the importance of integrating modern technological tools into sustainable design. However, there are still gaps in current research regarding the comprehensive and effective integration of sustainability standards in residential towers, which requires further research and development to address challenges[13] related to the compatibility between different assessment systems and the lack of precise data. Therefore, this research aims to address some of these gaps through a practical case study of a residential tower in Baselia City, focusing on how Revit can be used to analyze and develop design solutions that enhance the tower's energy performance[14].

3. Methodology

An experimental applied methodology was used in this research to analyze and improve energy efficiency in residential towers[15] through a case study of a residential tower in Baselia City, using Revit as the primary analytical model. The research began by identifying the main objectives and key criteria, such as energy consumption, carbon emissions, and resource management, based on sustainability assessment systems like LEED and BREEAM. Primary data were collected through field surveys, interviews, and analysis of the building's architectural drawings, with a focus on heating, ventilation, air conditioning, and lighting systems. Revit was then used to model the building[16] and analyze its energy performance by creating a three-dimensional model and simulating various design scenarios to improve energy efficiency, including enhancing thermal insulation, installing high-efficiency windows, and utilizing natural lighting. After identifying potential improvements, the impact of these modifications on the building's energy performance was assessed by testing different scenarios and comparing them to the current performance. The study concluded with a discussion of the results obtained from the analysis, highlighting the environmental and economic benefits of the proposed design improvements, and providing recommendations for implementing similar strategies in future projects, thereby offering a practical framework for achieving sustainability in the design of residential towers.

3.1 Data Analysis

Key Steps: Model the building in Revit, Describe the types of spaces in the building, Export the model to Autodesk Insight, Extract energy values and efficiency of the building

Figure 1. The modeled tower in the Revit environment

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The energy efficiency of the tower will be studied. The first step is to define the Rooms for all the spaces in the tower.

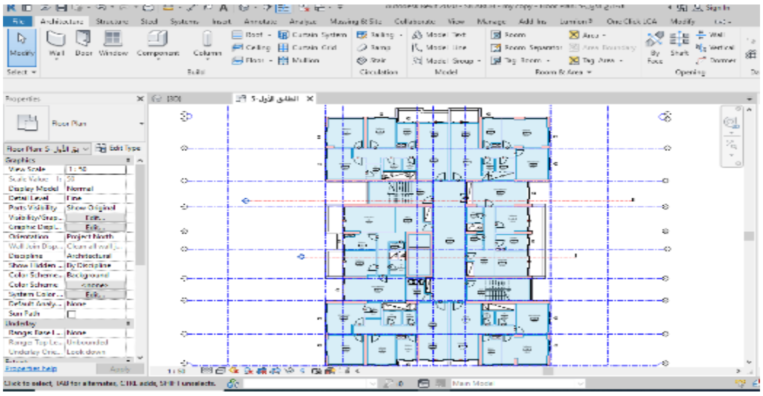

Figure 2. The image shows the first floor after defining the room for each space and naming them according to the original plans.

After defining the rooms, we will now describe the spaces and their properties for building analysis and include the information in the model. From the Analyze window, select "Space."

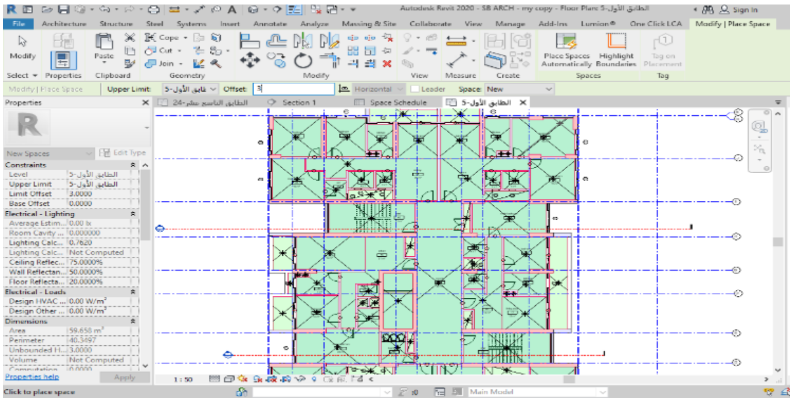

Figure 3. Describing the spaces and their properties for building analysis

The settings to be entered for the thermal study have been specified. Then, an energy model is created and the model is uploaded to the Insight site.

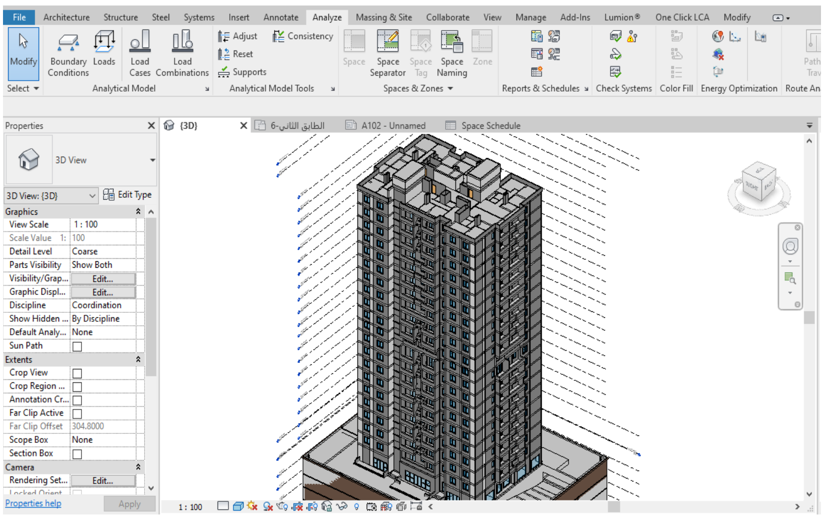

Figure 4. 3D model of the building

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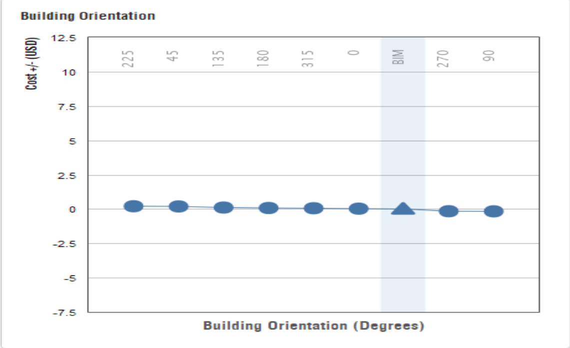
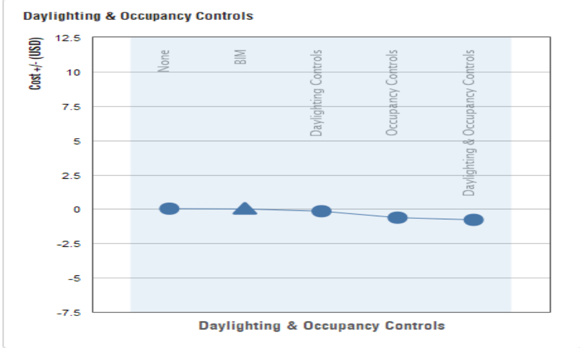
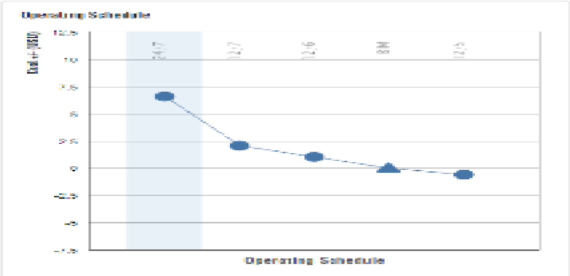
After uploading the model, the site begins to analyze the building, energy efficiency, and energy consumption, providing a set of values that show the analysis of various elements of the building. Each card is designed to provide specific information about building elements and the effectiveness of each element in reducing or increasing energy consumption.



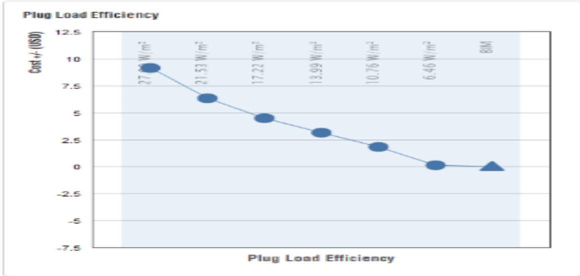
The card shows a diagram for the optimal building orientation that can reduce energy consumption in the spaces. The range is defined at the triangle marker since the required values are known.



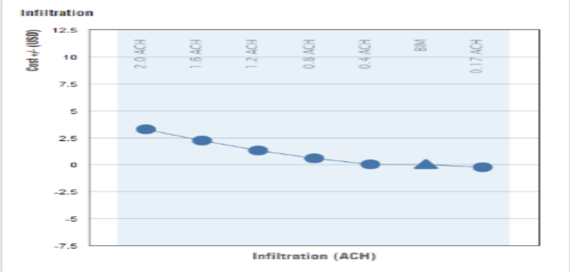
The card shows daylight control and the occupancy sensor system, with the entire range specified.



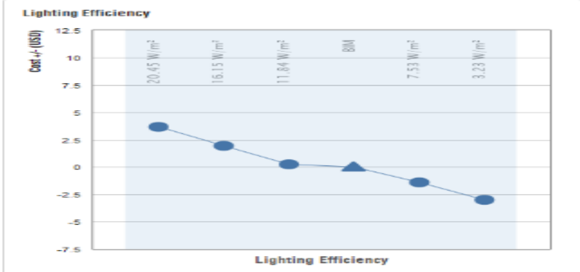
The number of hours per day throughout the entire week is used for reference.



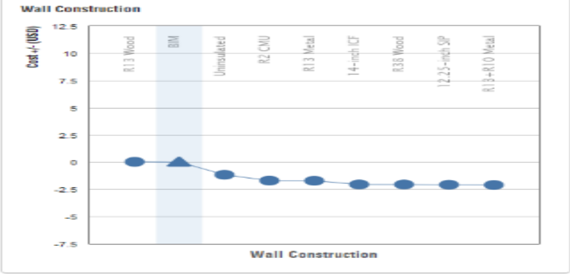
It represents the energy used by electronic devices, excluding lighting, and includes the building's usage hours by occupants, as well as the range for heating and cooling systems. These are electrical inputs, so we assumed the full range.



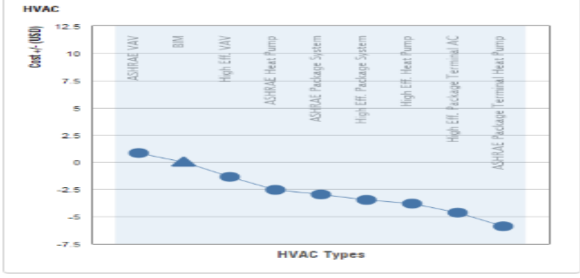
It includes building airtightness and air leakage to the spaces. These are mechanical inputs, so we assumed the full range.



It includes the heat emitted by lighting fixtures and the energy consumed per square meter. These are electrical inputs, so we assumed the full range.



Details of the walls and their construction materials.



Heating and cooling system .

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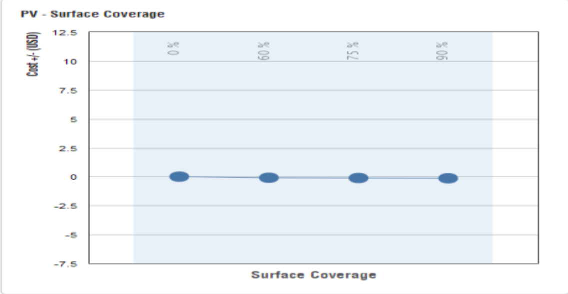
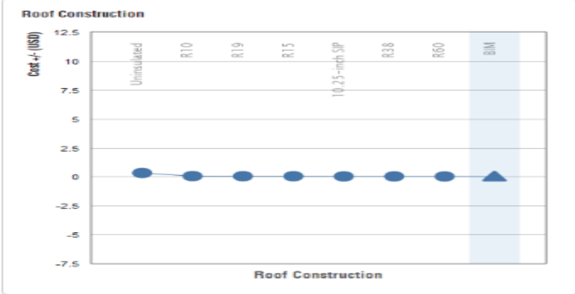
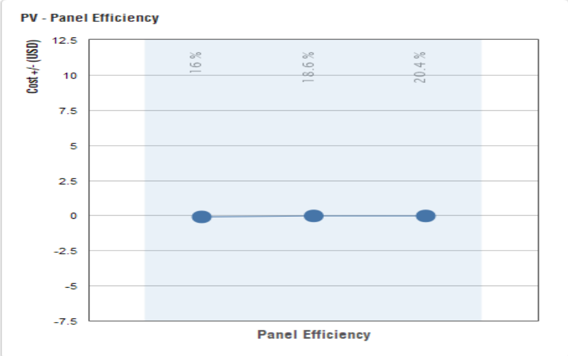


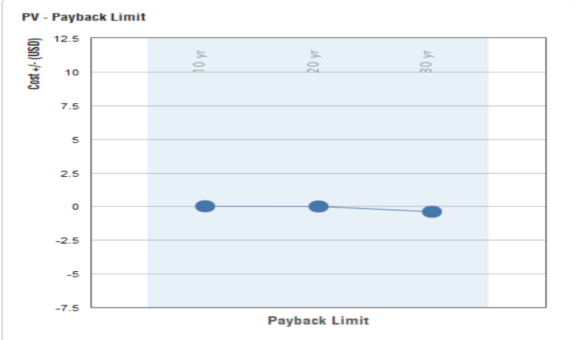
The area covered by solar panels.

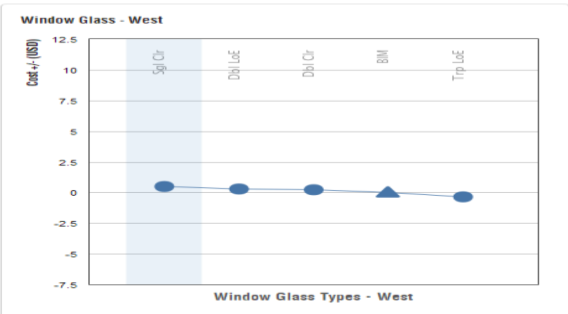


Details of the roof and its construction materials.

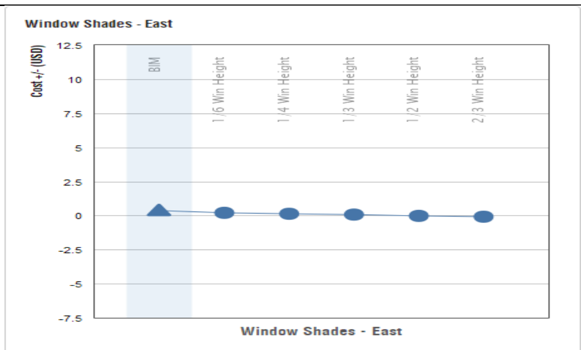


The efficiency of solar panels in converting solar energy

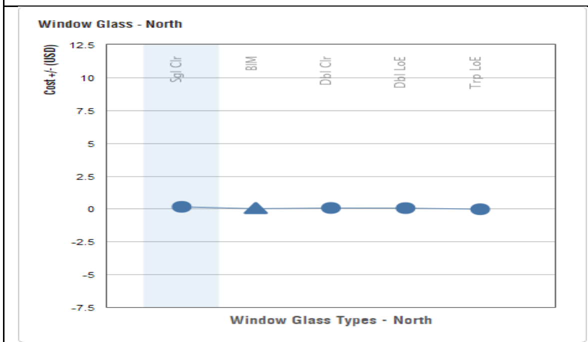




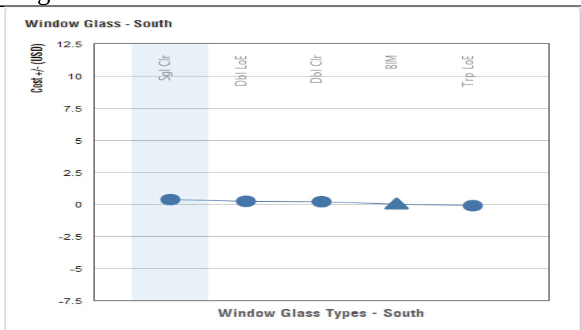
The type of glass used in the western façade.



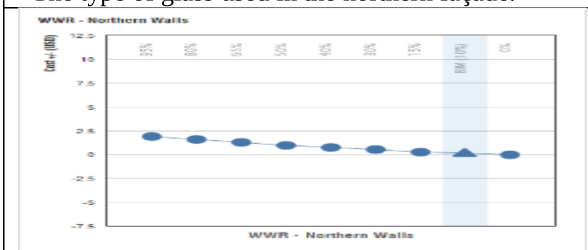
The extension of the shading devices relative to the height of the windows in the eastern facade windows.



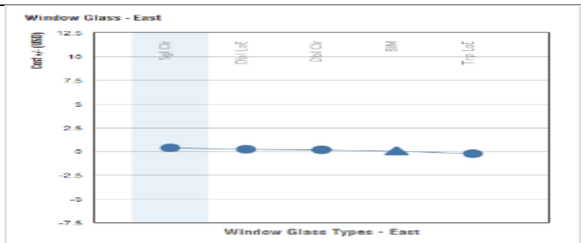
The type of glass used in the northern façade.



The type of glass used in the southern façade.



The percentage of glazing in the northern facade



The type of glass used in the eastern facade

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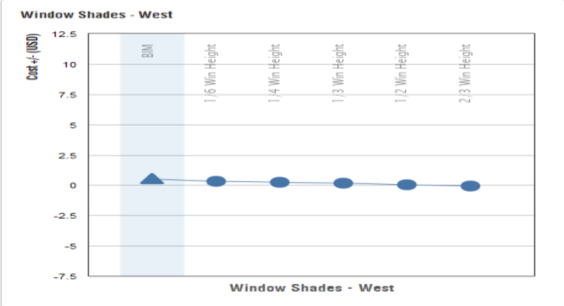
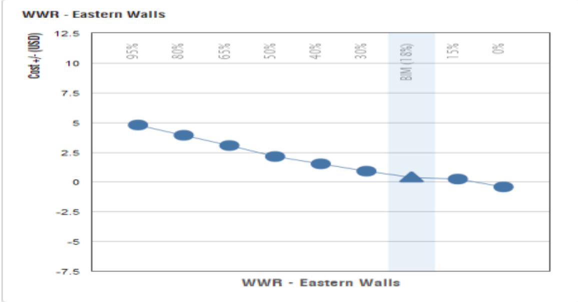
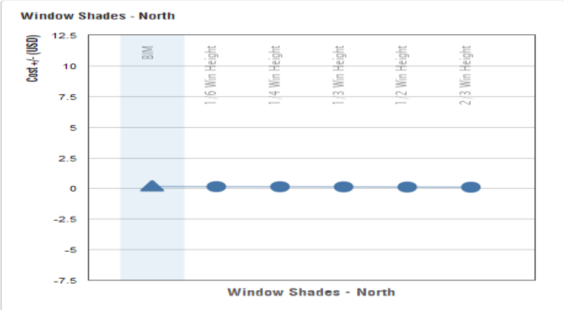


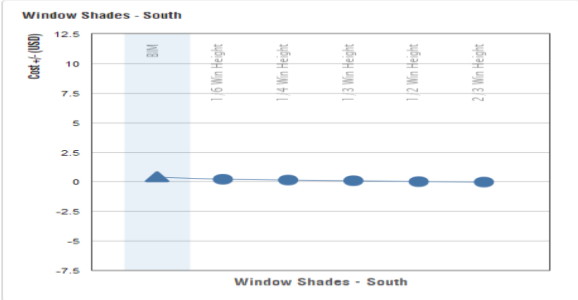
The extension of the shading devices relative to the height of the windows in the western facade windows



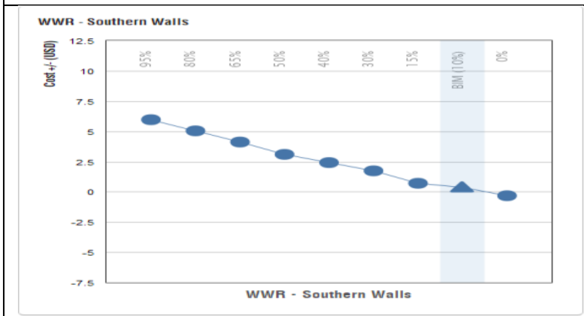
The percentage of glazing in the eastern facade



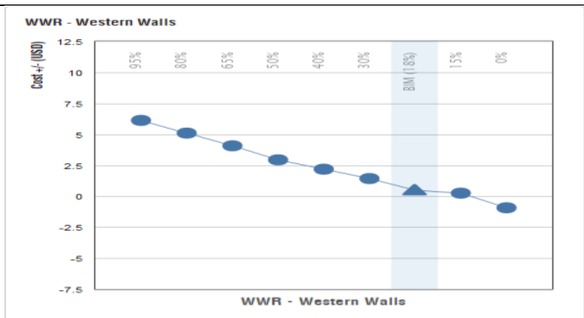
The extension of the shading devices relative to the height of the windows in the northern facade windows.



The extension of the shading devices relative to the height of the windows in the southern facade windows.

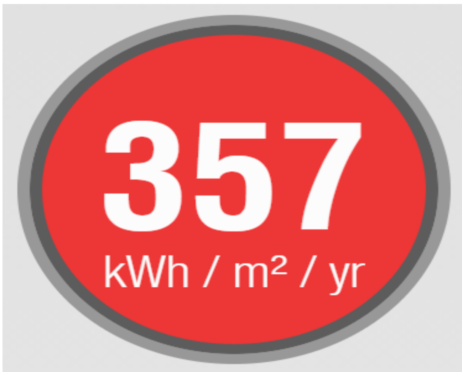


The percentage of glazing in the southern façade.



The percentage of glazing in the western façade.

The range has been defined for the specified and known elements, and all options have been considered for the undefined elements. As a result of the analyses, we obtain a figure that indicates the energy efficiency per square meter of the building throughout the year.



The model will now be re-evaluated by changing certain ranges and elements to see the impact of these changes.

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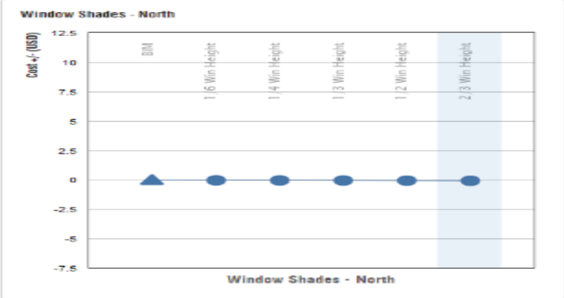
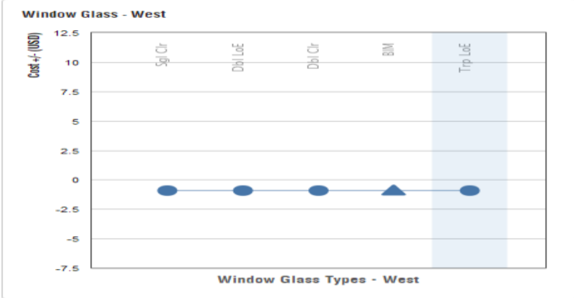
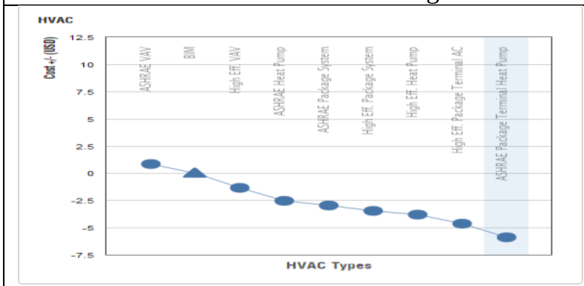


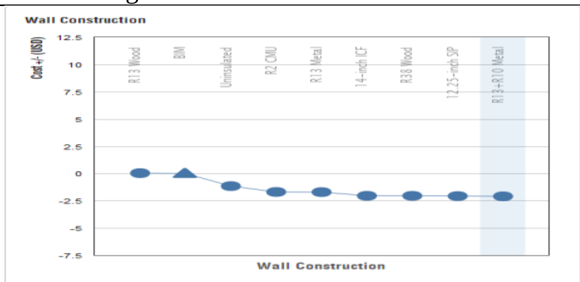
According to the plan, we selected the lower range that reduces energy consumption in the building and the optimal shading ratio for the northern facade, where a ratio of 2/3 of the window height is the best.



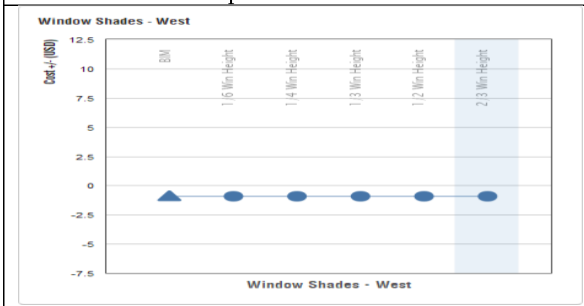
According to the plan, we selected the lower range that reduces energy consumption in the building, and the best type of windows for reducing energy consumption are double-glazed windows.



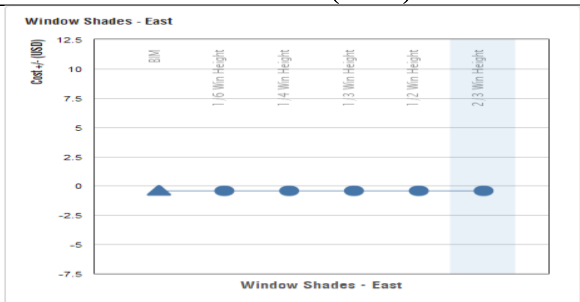
According to the plan, we selected the lower range that reduces energy consumption in the building, and the best system to adopt is the ACASHRAE Package Terminal Heat Pump.



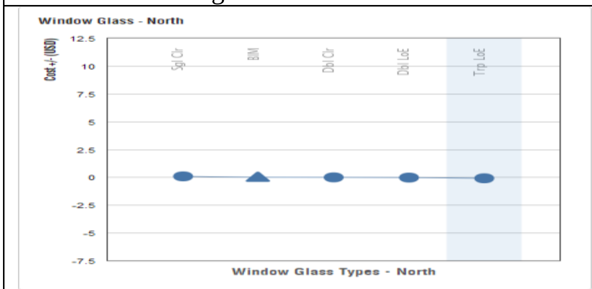
According to the plan, we selected the lower range that reduces energy consumption in the building, and the best wall type to adopt, which achieves a thermal transmittance of U=0.3316W/ (M2.K)



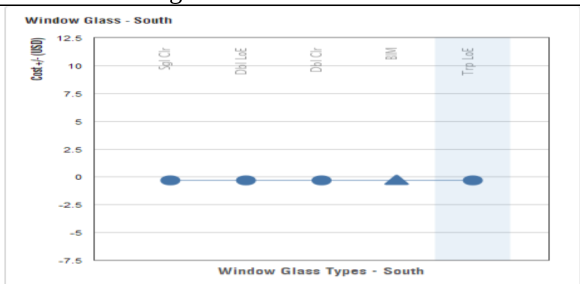
According to the plan, we selected the lower range that reduces energy consumption in the building, and the optimal shading ratio for the western facade is 2/3 of the window height.



According to the plan, we selected the lower range that reduces energy consumption in the building, and the optimal shading ratio for the eastern facade is 2/3 of the window height.



According to the plan, we selected the lower range that reduces energy consumption in the building, and the best type of windows for reducing energy consumption in the northern facade is double-glazed windows.



According to the plan, we selected the lower range that reduces energy consumption in the building, and the best type of windows for reducing energy consumption in the southern facade is double-glazed windows.

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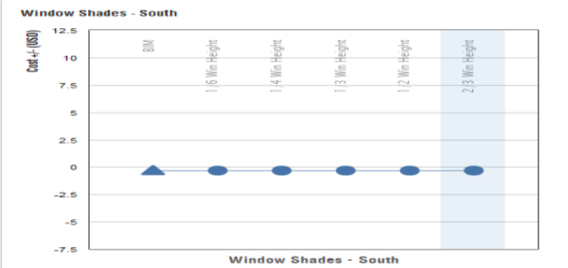
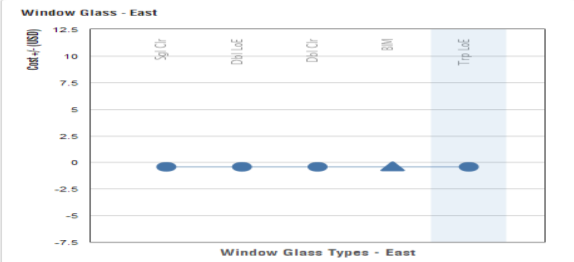
 According to the plan, we selected the lower range that reduces energy consumption in the building, and the optimal shading ratio for the southern facade is 2/3 of the window height.	 According to the plan, we selected the lower range that reduces energy consumption in the building, and the optimal shading ratio for the southern facade is 2/3 of the window height.

Several elements were changed in the study to observe the difference in results, including:

- HVAC System
- Type of Windows Used
- Shading Ratios on Windows
- Wall Types and Their Thermal Transmittance

Figure 4: As a result of the analyses, we obtain a figure that indicates the energy efficiency per square meter of the building throughout the year.

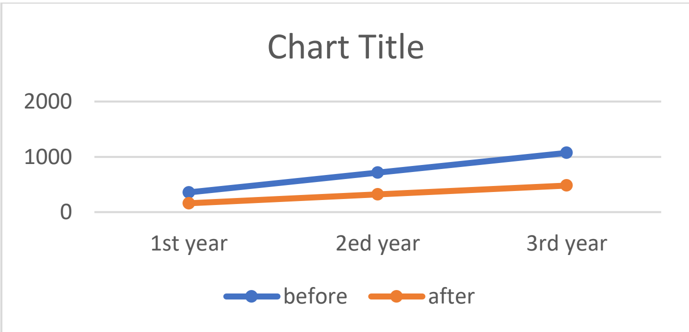


Figure 5. It shows the comparison between the current design and the modified design regarding energy savings.

The percentage difference in energy consumption per square meter between the current and modified designs of the building is calculated as:
((New Value−Old Value)/ Old Value)×100=55.1%
This indicates that the reduction in consumption between the two cases is more than half.
We find that regulating the exchange between internal and external spaces is crucial for achieving energy efficiency in the building by ensuring airtightness of openings and designing an external envelope with low thermal transmittance.

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The heating and cooling system must be carefully studied. Protecting spaces from solar radiation is essential, and shading studies should be conducted to block or capture solar rays as needed. BIM tools provide the capability to include information that simulates the local environment in the adopted design and study the relationship between them. This integration allows for determining whether the design is harmonious or discordant with the local environment and what adjustments should be considered.

Further studies can include more detailed information about the design and more accurate modeling of building elements and systems, along with a more thorough description of the surrounding environment, such as wind, climate, and equipment used. This creates results that more closely reflect reality.
The more comprehensive the information included in the model, the more accurate the results, and this provides reports that can help reduce the costs of design modifications in the early stages.

4. Discussion

The results of the data analysis using Revit demonstrate that significant improvements in energy efficiency in residential towers can be achieved through well-considered design modifications. The findings indicate that the energy efficiency of the building under study reached 160 kWh per square meter per year, reflecting the improvements resulting from the implementation of various design strategies. The graph shows a substantial reduction in energy consumption following the proposed modifications, with a decrease of more than 55% compared to the original design. Through the creation of an energy model using Autodesk Insight, it became evident that key elements contributing to enhanced energy efficiency include improved thermal insulation, the use of double-glazed windows for better thermal performance, and the application of a more efficient air conditioning system such as the ACASHRAE Package Terminal Heat Pump. Additionally, controlling the ratio of openings and shading on facades, such as setting the optimal window shading ratio at 2/3 of the window height, effectively reduced thermal loads and energy consumption. Moreover, integrating techniques like Building Information Modelling (BIM)[17] provides the capability to incorporate data regarding the local environment and design elements, allowing us to verify the design's compatibility with local climatic conditions. However, challenges remain concerning the alignment of precise data and achieving effective integration of different assessment systems. It is crucial to continue research to enhance modeilling accuracy and simulate various scenarios that can offer a clearer perspective on the extent to which the design achieves actual sustainability in different environments. The results underscore that using advanced modelling tools can led to significant improvements in energy performance and cost savings in the long term.

5. Conclusion

5.1 Summary of Key Findings:

Current research focusing on improving energy efficiency in residential towers using Building Information Modelling (BIM) [18]techniques and Revit software has highlighted several key findings that emphasize the effectiveness of sustainable design strategies in reducing energy consumption and achieving environmental goals. A significant reduction in energy consumption by over 55% was achieved in the residential tower after design optimization, indicating the effectiveness of the measures taken to enhance energy efficiency. The results demonstrated that using materials with low thermal conductivity and installing high-performance double-glazed windows plays a crucial role in reducing thermal loss and increasing the building's energy efficiency. The ACASHRAE Package Terminal Heat Pump HVAC system showed notable efficiency in reducing energy consumption while maintaining thermal comfort, underscoring the importance of selecting appropriate heating and cooling systems to improve energy performance. Natural light utilization was enhanced, and reliance on artificial lighting was reduced through the design of building facades that allow effective natural light entry, with appropriate shading ratios for windows identified as a critical factor in reducing thermal loads. The research confirmed that integrating BIM [19, 20]techniques into the design and analysis process provides a comprehensive framework for evaluating and improving building performance by simulating different scenarios and identifying design strengths and weaknesses. Despite the positive results, the research noted some challenges related to system integration and the need for accurate and comprehensive data to achieve more precise outcomes, requiring the development of more complex analytical models that consider additional environmental and technical factors. The improvement in energy efficiency positively impacts the environment by reducing carbon emissions and conserving natural resources, as well as contributing to lower operational costs for buildings in the long term. These results demonstrate that adopting sustainable design techniques and relying on Building Information Modelling[16, 21] [22]can offer effective solutions to energy consumption challenges in high-rise buildings, contributing to sustainable development and achieving global sustainability goals.

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5.2 Concluding Remarks:

The current study highlights the importance of applying energy efficiency improvement strategies in high-rise buildings through the modelling of sustainability criteria and evaluation systems using Revit software. Analysis of a case study of a residential tower in Basel confirmed that the use of advanced modelling techniques, such as Revit and Autodesk Insight, can significantly enhance energy efficiency in high-rise buildings. The study demonstrated that well-considered design modifications, such as improving thermal insulation, using double glazing, and implementing a more efficient HVAC system [23]like the ACASHRAE Package Terminal Heat Pump, resulted in a notable reduction in energy consumption by over 55% compared to the original design. These improvements not only reduced energy consumption but also contributed to lower carbon emissions and better resource management, enhancing the environmental and social benefits of high-rise buildings. By integrating Building Information Modelling (BIM)[24] techniques, the study provides a comprehensive framework for evaluating and improving the energy performance of buildings, enabling effective integration of local environmental data and design elements. However, challenges related to data accuracy and the integration of evaluation systems remain, necessitating further research to develop more complex analytical models. The findings indicate that improving energy efficiency requires a holistic design approach that considers all influencing factors, such as controlling openings and shading on facades and selecting appropriate building materials. Additionally, the study shows that using advanced modelling tools contributes to effective solutions for energy consumption challenges, providing a practical framework for achieving sustainability in high-rise building design. In conclusion, the research recommends continuing research and development of modelling tools to include more details about design and surrounding environment, which will contribute to more accurate results and reduce costs associated with design modifications in the early stages, providing a strong foundation for applying sustainability strategies in high-rise buildings, thus promoting sustainable development and achieving global sustainability goals[25,26].

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