SUSTAINABLE RETROFITTING OF CULTURAL HERITAGE BUILDINGS, A CASE STUDY: THE POLYTECHNIC UNIVERSITY OF TIRANA

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Approval sheet of the Thesis

This is to certify that we have read this thesis entitled **"Sustainability in heritage building retrofits: A case study of the Polytechnic University of Tirana, Albania"** and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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ABSTRACT

SUSTAINABLE RETROFITTING OF CULTURAL HERITAGE BUILDINGS, A CASE STUDY: THE POLYTECHNIC UNIVERSITY OF TIRANA

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Sustainable design is often seen as conflicting with heritage conservation due to the invasive measures required for new technologies, challenging the principle of minimal intervention. However, heritage conservation is also a form of sustainable development, protecting social and cultural resources. Research shows that heritage buildings can achieve high energy efficiency while preserving their value. Adaptive reuse projects, like the 1940-built Polytechnic University of Tirana, exemplify this by maintaining heritage integrity while meeting modern standards.

The goal of this thesis is to create a simulation of the Polytechnic University of Tirana using building energy modeling software to understand its current energy usage. This serves as our baseline. Additionally, we aim to explore the potential benefits of various sustainable measures. These measures include adding thermal insulation, installing double-glazed windows, adding shading to the facade, implementing internal lighting controls, using natural ventilation, and installing solar panels on the roofs. According to the thermal analysis of the object, the most efficient intervention for enhancing energy performance is the implementation of photovoltaic (PV) panels. This intervention leads to a significant energy saving of 49.10% compared to the base case.

Using DesignBuilder software, we found that sustainable interventions reduced energy consumption by 20.18% on average, showing that heritage buildings can be made sustainable without compromising their historical and cultural significance.

Keywords: *retrofit, heritage, conservation, adaptive-reuse, energy efficiency, sustainability, simulation, Polytechnic University of Tirana*

ABSTRAKT

RIKONSTRUKSIONI I QËNDRUESHËM I NDËRTESAVE TË TRASHËGIMISË KULTURORE, STUDIMI I RASTIT: UNIVERSITETI POLITEKNIK I TIRANËS

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Dizajni i qëndrueshëm shpesh shihet në konflikt me ruajtjen e trashëgimisë për shkak të masave invazive të kërkuara për teknologjitë e reja, duke sfiduar parimin e ndërhyrjes minimale. Megjithatë, ruajtja e trashëgimisë është gjithashtu një formë e zhvillimit të qëndrueshëm, duke mbrojtur burimet shoqërore dhe kulturore. Projektet e ripërdorimit adaptiv, si Universiteti Politeknik i Tiranës i ndërtuar në vitin 1940, e ilustrojnë këtë duke ruajtur integritetin e trashëgimisë ndërsa përmbushin standardet moderne.

Qëllimi i kësaj teze është të krijojë një simulim të Universitetit Politeknik të Tiranës duke përdorur softuer për modelimin e energjisë së ndërtesave për të kuptuar përdorimin aktual të energjisë. Kjo shërben si baza jonë fillestare. Gjithashtu, synojmë të eksplorojmë përfitimet e mundshme të masave të ndryshme të qëndrueshme. Këto masa përfshijnë shtimin e izolimit termik, instalimin e dritareve me xham të dyfishtë, shtimin e hijeve në fasadë, zbatimin e kontrollit të brendshëm të ndriçimit, përdorimin e ventilimit natyral dhe instalimin e paneleve diellore në çatitë. Sipas analizës termike të objektit, ndërhyrja më e efektshme për përmirësimin e performancës energjetike është implementimi i paneleve fotovoltaike (PV). Kjo ndërhyrje çon në një kursim të konsiderueshëm energjie prej 49.10% krahasuar me rastin bazë.

Duke përdorur softuerin DesignBuilder, zbuluam se ndërhyrjet e qëndrueshme reduktuan konsumin e energjisë mesatarisht me 20.18%, duke treguar se ndërtesat e trashëgimisë bëhen të qëndrueshme pa kompromentuar rëndësinë e tyre historike.

Fjalët kyçe: *përditësim, trashëgimi, mbrojtje, efikasitet i energjisë, qëndrueshmëri, simulim, Universiteti Politeknik i Tiranë*

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CHAPTER 1

1. INTRODUCTION

1.1 Sustainability and Conservation

Expanding on the intersection of heritage preservation and sustainability in the context of existing buildings reveals a nuanced landscape of challenges and opportunities [1]. One significant aspect to consider is the evolving definition of sustainability itself. As our understanding deepens, we recognize that sustainability extends beyond environmental concerns to encompass social and economic dimensions. Therefore, any retrofitting or conservation efforts must be holistic, addressing not only energy efficiency but also factors like community engagement, economic viability, and equitable access.

The objective of this thesis is to conduct a simulation of the Polytechnic University of Tirana using building energy modeling software to establish a baseline reference for its current energy consumption. Furthermore, the study aims to evaluate the potential effects of various sustainable interventions. These interventions include the incorporation of thermal insulation, the installation of double glazing on exterior openings, the implementation of facade shading, the application of internal lighting controls, the utilization of natural ventilation, and the installation of photovoltaic panels on the rooftops.

The role of technology in heritage conservation is an area ripe for further exploration. Modern advancements present exciting opportunities to enhance energy efficiency and reduce environmental impact, but integrating these technologies into historic structures requires a delicate balance. Preservation purists often advocate for minimal intervention to maintain a building's authenticity, while others support adaptive reuse and innovative retrofitting techniques [2]. Achieving consensus among stakeholders with diverse priorities is essential in navigating this complex issue.

Heritage buildings hold cultural significance that extends beyond their physical attributes. They serve as tangible connections to collective memories, identities, and traditions. Therefore, conservation efforts must also consider the intangible heritage associated with these buildings, including their social importance and symbolic value within communities [3]. Engaging diverse stakeholders—such as local residents, historians, architects, and policymakers—is crucial to ensure that sustainability initiatives align with the cultural values and aspirations of the community.

Additionally, financing mechanisms are critical for implementing sustainable retrofitting projects for heritage buildings. Despite growing recognition of the long-term benefits of energy-efficient upgrades, securing funding for these projects remains challenging [4]. Public-private partnerships, innovative financing models, and incentives for heritage conservation could help overcome financial barriers and encourage stakeholders to adopt sustainable solutions [5].

This thesis explores methods to enhance the energy efficiency of heritage buildings, using the Polytechnic University of Tirana as a case study. The research focuses on several key areas.

First, we'll establish a baseline by using DesignBuilder software to simulate the current energy usage of the Polytechnic University of Tirana. This involves documenting the building's existing conditions and energy consumption patterns to create a reference point for comparison.

Various sustainable interventions will be evaluated to assess their potential impact on energy efficiency, including the addition of thermal insulation to the building's envelope for enhanced thermal performance, installation of double-glazed windows to reduce heat loss and improve comfort, implementation of shading devices on the facade to mitigate solar heat gain, examination of advanced lighting control systems to optimize energy usage, exploration of strategies for natural ventilation to enhance air quality and reduce dependence on mechanical cooling, and assessment of the feasibility of installing photovoltaic panels on the roofs for renewable energy generation.

Simulations will be conducted using DesignBuilder to model the building's energy performance incorporating each of these interventions. By comparing these results with our baseline, we aim to quantify the potential energy savings and efficiency improvements.

The next chapter will include a literature review to understand the methodology underlying the project. The project will be dissected step by step, examining the design methods utilized in software tools such as Revit and DesignBuilder. Additionally, the historical background of the selected building will be explored, with a focus on its architecture and structural design. Finally, in the last chapter, the proposed interventions and their effects on energy consumption and efficiency will be examined.

1.2 Degrees of Intervention

Heritage buildings, cherished for their historical and cultural significance, often fall under strict planning controls to protect them from inappropriate development. These controls aim to facilitate the conservation of these structures. The International Council on Monuments and Sites (ICOMOS) defines conservation as "the processes of caring for a place to safeguard its cultural heritage value" [3]. According to ICOMOS, the most effective conservation is achieved through minimal intervention.

Adopting a lower degree of intervention in historic buildings aligns well with sustainability goals. This approach preserves the unique character and historical integrity of these structures while also being economically beneficial. It reduces costs associated with materials, transportation, energy consumption, and pollution compared to constructing entirely new buildings.

Choosing the appropriate level of intervention for historic buildings is a nuanced process, guided by the extent of alteration needed. This process ranges from the most conservative approach, which focuses on preventing deterioration, to the most radical approach, which involves reconstruction. This strategic selection ensures a delicate balance between preserving the intrinsic value of heritage buildings and implementing sustainable practices that align with modern environmental and economic considerations.

1.2.1 Minimal Intervention and Sustainability

The principle of minimal intervention is central to both conservation and sustainability. By preserving as much of the original structure as possible, we maintain the building's historical significance while minimizing the need for new materials and extensive labor. This approach conserves resources and reduces the carbon footprint associated with construction activities. Furthermore, retaining the original materials and craftsmanship of heritage buildings enhances their longevity and durability, which often surpasses that of modern buildings in terms of quality and sustainability.

1.2.2 Economic and Environmental Benefits

From an economic perspective, minimal intervention in heritage buildings can lead to significant savings. Preserving existing structures reduces the need for new construction materials, thereby lowering transportation and energy costs. This approach also minimizes waste and pollution, contributing to a more sustainable environment. Additionally, heritage buildings often possess unique architectural features and craftsmanship that are expensive and difficult to replicate in new constructions. By conserving these features, we not only preserve the cultural and historical value of the buildings but also enhance their economic value as assets to the community.

1.2.3 Strategic Selection of Interventions

The selection of appropriate interventions is crucial for achieving a balance between conservation and sustainability. This process involves assessing the building's condition, historical significance, and potential for sustainable adaptation. For example, a conservative approach might focus on preventing further deterioration by repairing structural damage and addressing issues like dampness or decay. On the other hand, more extensive interventions could involve retrofitting the building with modern energy-efficient systems, ensuring that these upgrades do not compromise the building's historical integrity.

1.2.4 Implementing Sustainable Practices

Implementing sustainable practices in heritage buildings can range from simple fixes to high-tech upgrades. For example, adding better insulation, installing energy-efficient lighting and heating systems, and using renewable energy sources can greatly improve the building's energy performance. These changes not only help the environment but also make the building more comfortable and functional for its occupants.

Sustainability efforts can go beyond just saving energy. They can also include conserving water, reducing waste, and using eco-friendly materials. By adopting these practices, heritage buildings can become shining examples of how we can blend historical preservation with modern environmental goals. This not only preserves the past but also paves the way for a greener future.

1.2.5 Community and Cultural Impact

Heritage buildings hold a special place in the hearts of their communities. They connect us to our past, telling the stories and preserving the memories of our history. By using minimal intervention and sustainable practices to preserve these structures, we ensure that future generations can continue to enjoy and learn from these cultural landmarks.

These buildings are more than just old structures; they are symbols of community identity and pride. They can boost the local economy by attracting tourists and supporting nearby businesses. Well-maintained heritage buildings can also become hubs for cultural events, educational programs, and community activities, enriching the lives of everyone in the area.

1.2.6 Policy and Regulatory Support

Preserving heritage buildings effectively requires strong support from policies and regulations. Governments and heritage organizations need to create clear guidelines and offer incentives to encourage conservation efforts. These policies should promote minimal intervention and sustainable practices, while also providing the resources and expertise needed to carry out these initiatives.Financial incentives, like grants, tax credits, and low-interest loans, can really motivate property owners to invest in the upkeep and preservation of heritage buildings. Additionally, the rules and regulations should make it easier to incorporate modern sustainable technologies into these buildings, ensuring that upgrades respect and enhance their historical value.

Implementing eco-friendly initiatives in heritage buildings often requires financial support to carry out interventions that preserve their historical integrity while also meeting environmental goals. Sometimes, ensuring a positive heritage outcome can be more expensive than other methods, highlighting the need for subsidies to balance conservation with sustainable practices.

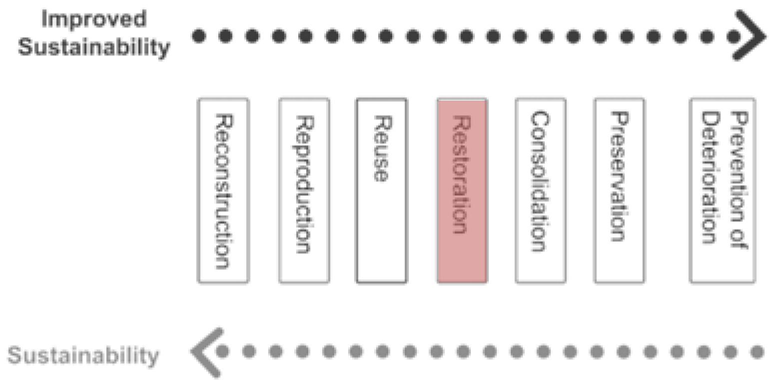

Figure 1. The levels of involvement and ecological responsibility to existing structures, particularly concerning sustainability [3].

The relationship between heritage preservationists and the green building movement should ideally be collaborative, but it has sometimes faced conflicts. Despite these differences, it's essential for both sides to recognize the potential for cooperation. Resolving these conflicts is crucial to unlock the mutual benefits that can come from aligning heritage conservation with sustainable development. Disagreements may arise when approaches to sustainable development vary, but these differences should be seen as opportunities for dialogue and collaboration.

The Venice Charter, also known as the International Charter for the Conservation and Restoration of Monuments and Sites, was adopted in 1964 to provide principles for conserving and restoring cultural heritage, particularly historical monuments. For Category 1 monuments (those of exceptional universal value), the Venice Charter emphasizes minimal intervention and reversibility in interventions.

Minimal intervention means that any changes to the monument should be kept to the absolute minimum necessary to preserve it, retaining its historical and aesthetic integrity. Any additions or alterations should be distinguishable from the original structure to ensure that its historical authenticity is not compromised. Reversibility means that interventions should, as far as possible, be reversible, allowing changes to be undone without causing damage to the original fabric of the structure. This allows future generations the opportunity to restore the monument to its original state if required.

The dialogue between heritage preservationists and the green building movement should focus on finding innovative solutions that respect both environmental and historical values. For example, implementing energy-efficient systems, such as solar panels or advanced insulation, should be done in a way that does not detract from the building's historical aesthetics. This might involve using discreet or reversible installations that can be removed without damaging the original structure.

CHAPTER 2

2. LITERATURE REVIEW

2.1 SUSTAINABLE CONSERVATION

Historic buildings come in a variety of styles, sizes and purposes which means that finding economically feasible solutions depends on the specific type of building and how it is used [14]. It's important to address each case than taking a one size fits all approach because each historic structure is unique and requires customized solutions.

When it comes to reuse of buildings, we need to consider the complex goals and methods involved in preserving cultural heritage. Sustainability, in terms of architectural heritage involves not environmental considerations but also the sustainable transformation of both the physical aspects and the intended function of the building [15]. Therefore, achieving sustainability requires a balance between repurposing the asset and conserving its value.

In a study conducted by the Royal Institution of Chartered Surveyors (RICS) and Cyril Sweett in 2007 they explored ways to improve sustainability performance for existing buildings such, as offices, hotels, retail spaces and industrial structures [7]. The study identified enhancements that can be tailored to suit each building types characteristics. Key actions included improving the quality of windows installing measures to prevent drafts enhancing insulation, in the roof, floor and walls and switching to energy lighting solutions. The use of shading devices proved effective in reducing heat from entering.

Other improvements, depending on the building type and user profile, included attempts to optimise heating and cooling system efficiency, delineate energy-use zones, improve lighting control, and integrate water-saving sanitary fixtures. Retrofitting existing structures with renewable energy sources, such as solar panels, wind turbines, or photovoltaic cells, was considered a possible augmentation strategy [15].

The holistic rehabilitation of buildings, especially heritage structures, requires looking at the entire building as a whole. This approach helps us better understand all the issues and allows for an integrated way to solve problems. When it comes to historic buildings, we need to consider their intrinsic value, their importance to the community, and how to preserve them for the long term. At the same time, we have to weigh these factors against the economic costs and environmental impacts, particularly in terms of energy and water use. This complex balancing act highlights the need for a multidisciplinary approach and a collaborative team, as noted by Rambelli, van Staden, and İpek Kunt [17].

As we plan for the future, there are several key aspects to address:

Firstly, preserving historic buildings means acknowledging the effects of climate change, such as more intense rainfall, flooding, droughts, heat waves, and rising sea levels. Secondly, we need to reduce the buildings' contribution to climate change by cutting down on greenhouse gas emissions. Thirdly, it's important to keep costs reasonable, balancing the need to preserve historical integrity with the reality of rising energy expenses.

When it comes to making historic buildings more energy-efficient, there are two main types of solutions. Passive solutions involve design changes and encouraging different user behaviors. Active energy solutions focus on improving energy efficiency technologies and using renewable energy sources for electricity, heating, and cooling.

By adopting a comprehensive approach that considers both preservation and sustainability, we can ensure that historic buildings remain valuable assets for future generations while also being environmentally responsible. Critical to note is the contextual dependency and efficacy of specific solutions, contingent upon factors such as the type and use of the building, prevailing climate, material composition, adherence to national and local heritage protection regulations, energy planning considerations, and the availability of funds. The intricate interplay of these variables underscores the need for a tailored approach in navigating the delicate balance between heritage preservation, energy efficiency, and economic sustainability.

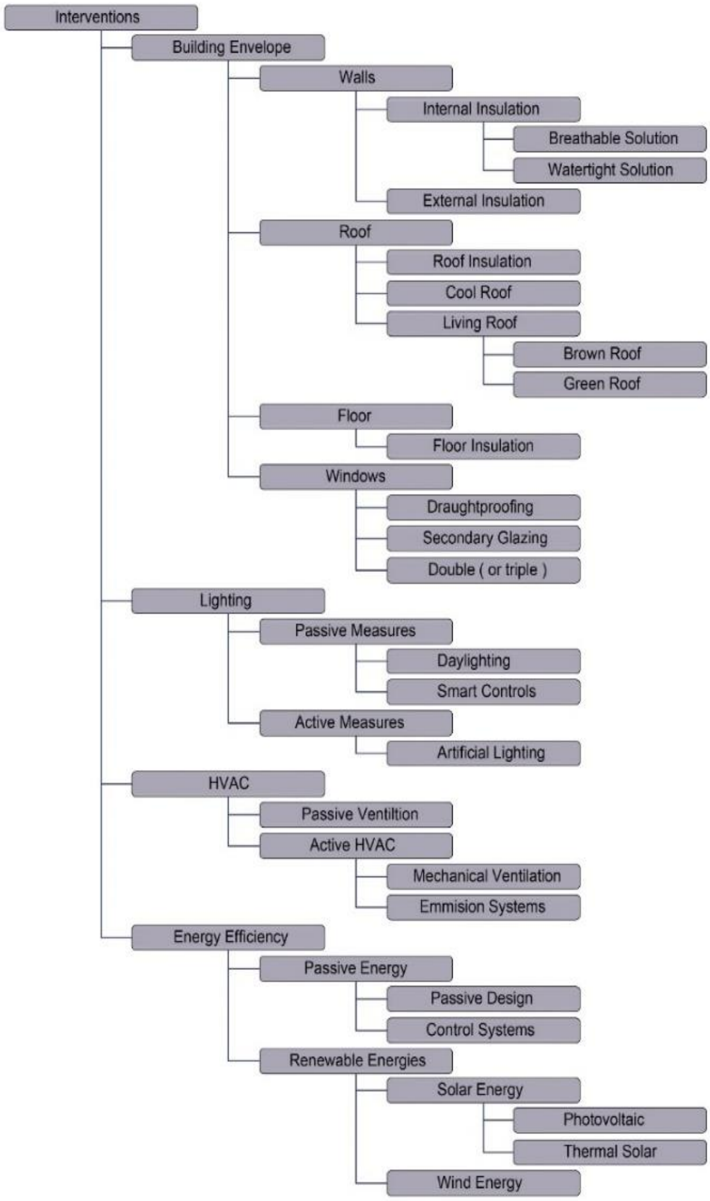

Figure 2. Passive and active energy retrofitting intervention solutions (Generated with Revit Software)

Table 1. Impacts of Interventions on Sustainability and Conservation (Energy Efficiency and Renewable Energy: Buildings Database) [16]

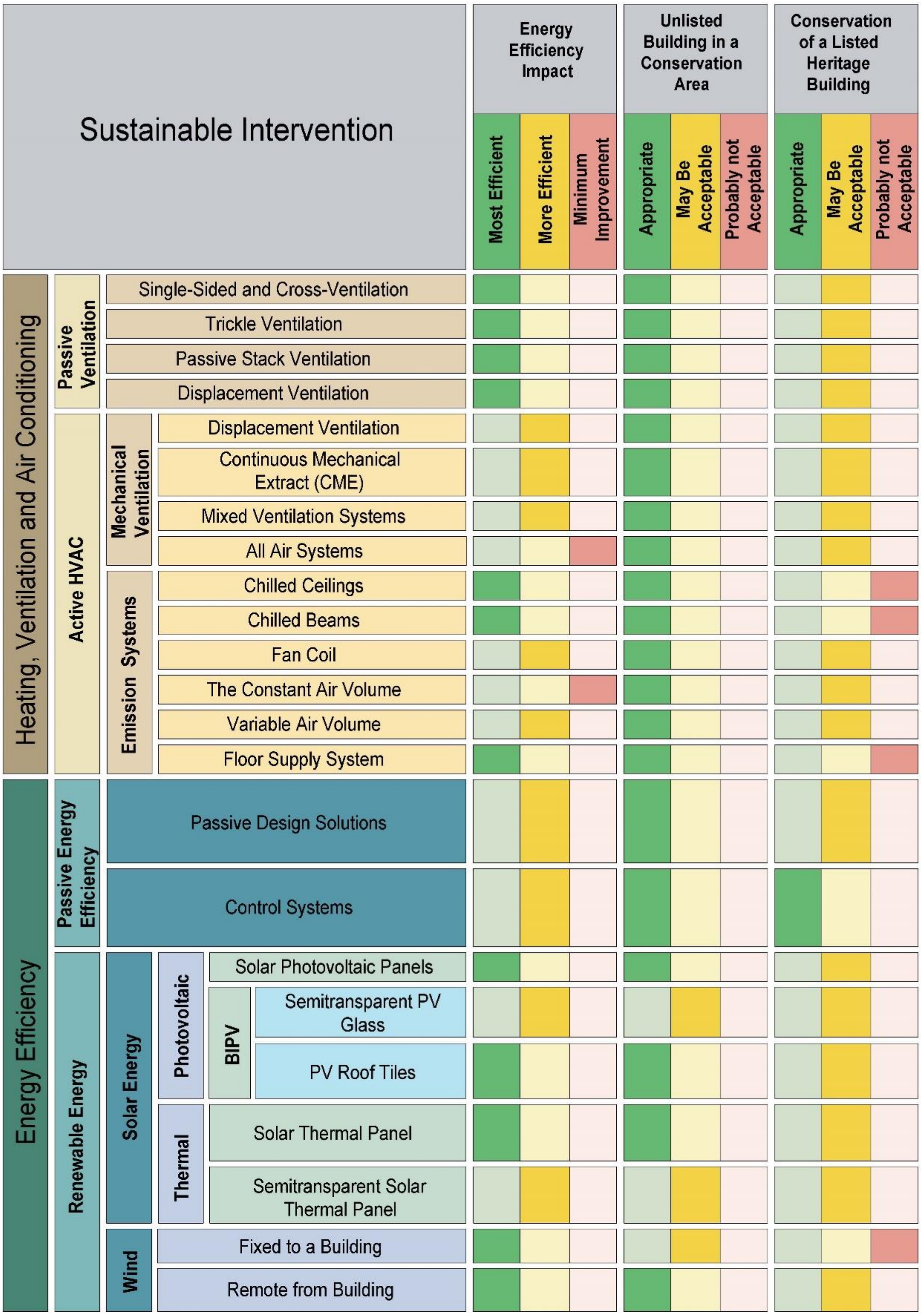

Table 2. Impacts of Interventions on Sustainability and Conservation (Energy Efficiency and Renewable Energy: Buildings Database) [16]

2.2 Examples of sustainable conservation of heritage buildings

2.2.1 Adaptive reuse of historic buildings in Salerno (Italy)

Salerno, with a population of 127,186 as per the 2023 ISTAT data, stands as the second-largest municipality in the Campania region of southern Italy. Nestled along the Gulf of the Tyrrhenian Sea, Salerno's strategic geographic location has historically positioned it as a central hub for crucial maritime exchanges, fostering a unique confluence of diverse cultures. This distinctive geographical setting has significantly contributed to the development of a rich medical tradition influenced by the teachings of the Greek Hippocrates, leading to Salerno being revered as "Urbs graeca" and "Hippocratica civitas." Notably, Salerno was home to the Salerno Medical School, Europe's first and most influential medical institution during the Middle Ages, often regarded as a precursor to modern universities [18].

The historic center of Salerno is adorned with the 'Garden of Minerva,' a site that dates back to the early 14th century where medicinal plants have been meticulously cultivated. Recognized for its exceptional cultural value, this garden functioned both as a botanical garden and an educational space, displaying plant names and properties to students. Today, Salerno's development strategy revolves around preserving and promoting these vital elements of its identity [10]. The Garden of Minerva has garnered international acclaim, leading to the establishment of the first network of historic therapeutic botanical gardens. Additionally, the University of Salerno's Department of Pharmacy has inaugurated the Plantae Medicinales Mediterraneae UNESCO Chair, while the Municipality of Salerno actively pursues UNESCO Intangible Heritage status for the Salerno Medical School [19].

In alignment with the city's vision for heritage-led regeneration, the 2005 Municipal Urban Plan emphasized the refurbishment and adaptive reuse of built heritage. This strategic approach aims to elevate the quality of life by adhering to three core principles: prioritizing reuse over mere preservation, designing empty spaces rather than creating new properties, and fostering creative initiatives over restrictive regulations [19]. The 2018 review of the Municipal Urban Plan reaffirmed these guiding principles, underscoring the importance of environmental and landscape sustainability, maintaining the plan's structural integrity, introducing regulatory innovations, simplifying administrative processes, and enhancing municipal real estate. This rich historical and strategic backdrop serves as the foundation for the collaborative development and evaluation of alternative adaptive reuse scenarios explored in this study. The focus is specifically on the 'Edifici Mondo,' a complex of four sizable abandoned historic buildings located in Salerno's historic city center. These buildings include the San Massimo Palace, the ex-Convent of San Francesco, the ex-Convent of San Pietro a Maiella and San Giacomo, and the ex-Convent of Santa Maria della Consolazione, collectively encompassing approximately 20,000 square meters.

The adaptive reuse of heritage buildings like the 'Edifici Mondo' not only signifies a pivotal moment for architectural transformation but also provides a unique platform to pioneer sustainable retrofitting methodologies, significantly enhancing the structures' energy efficiency [18]. This approach to conservation is particularly suitable due to its inherent flexibility in implementing sustainable techniques, transcending mere environmental considerations to encompass economic and socio-cultural sustainability. Its adaptability allows for the seamless integration of sustainable interventions while preserving the historical fabric of these heritage buildings, thereby highlighting their cultural and social significance. Additionally, this approach ensures the continuity of the buildings through ongoing maintenance.

Figure 3. The condition of deterioration observed in the 'Edifici Mondo' is attributed to Mariarosaria Angrisano, Martina Bosone, and Antonia Gravagnuolo [18].

CHAPTER 3

3. METHODOLOGY

3.1 Framework for analyzing the object

Sustainable design in Albania is still in its early stages. Plus, there's not much interest from building owners and architects in making Albanian's buildings more eco-friendly, and even less when it comes to preserving heritage buildings in a sustainable way.

For this research, we're looking at the adaptive-reuse project of Polytechnic University of Tirana. This project will serve as a case study to see how various sustainability measures could be applied. The goal is to determine if it's possible and practical to incorporate green practices into the conservation of Albanian's historic buildings.

For this thesis, we will take a step-by-step approach to reach our final results. We will begin by creating a detailed model of the building in Revit, a powerful tool that allows us to accurately capture the architectural and structural features of the heritage building. This model will be our foundation.

After building the model in Revit, we will move on to analyzing it in DesignBuilder, an advanced software for energy modeling. DesignBuilder will help us thoroughly examine the building's thermal behavior and energy performance. Through this process, we will simulate different energy-saving measures and evaluate their impact on the building's overall sustainability.

By combining the strengths of Revit and DesignBuilder, we can create a detailed and accurate picture of the building's current state and explore how various sustainable interventions could improve its energy efficiency. This method ensures a thorough and practical assessment, leading us to meaningful conclusions and actionable recommendations for making heritage buildings more sustainable.

3.2 Software's description

Revit and DesignBuilder are powerful tools that work together to design and analyze buildings for better energy efficiency. Revit is a software that helps create detailed 3D models of buildings, allowing us to capture all the architectural and structural elements accurately. For this project, we use Revit to build a precise digital model of the heritage building, including details like walls, windows, and roofs. This model serves as a comprehensive representation of the building, which we can then use for further analysis.

DesignBuilder is a software used to analyze the energy performance of buildings. We take the detailed model from Revit and import it into DesignBuilder. Here, we can simulate how different energy-saving measures, such as improved insulation, better windows, shading devices, natural ventilation, and solar panels, will affect the building's energy use and comfort levels.

By using Revit to create an accurate model and DesignBuilder to analyze it, we can thoroughly evaluate the building's energy efficiency and identify the best ways to make it more sustainable.

3.2.1 Revit Modeling

Modeling an object in Revit is about creating a detailed and accurate 3D digital representation of a building or structure. The process starts with setting up a new project in Revit, where you specify the project's location, units of measurement, and other initial settings. Once that's done, you begin by modeling the building's basic structural components, like walls, floors, and roofs. We can draw and define these elements with precise dimensions and materials.

Next, we add architectural features such as doors, windows, stairs, and railings. Revit offers a library of pre-designed components that you can customize and place into your model. We then include structural elements like beams, columns, and foundations to ensure the model accurately represents the building's structure.

Moving inside, we model the interior elements, such as walls, partitions, ceilings, and fixtures, making sure the indoor spaces are accurately depicted. Materials are assigned to different parts of the model to reflect the building's construction and finishes accurately. This includes specifying textures, colors, and other material properties.

We then create various views of the model, such as floor plans, elevations, sections, and 3D perspectives. These views are essential for generating detailed construction documents, including drawings and schedules.

Finally, we perform various analyses on the model, such as structural analysis, energy analysis, and daylight simulation. Revit supports working with other software tools for more advanced simulations. By following these steps, Revit enables the creation of a comprehensive and detailed digital model that serves as a central reference for design, analysis, and construction throughout the building's lifecycle.

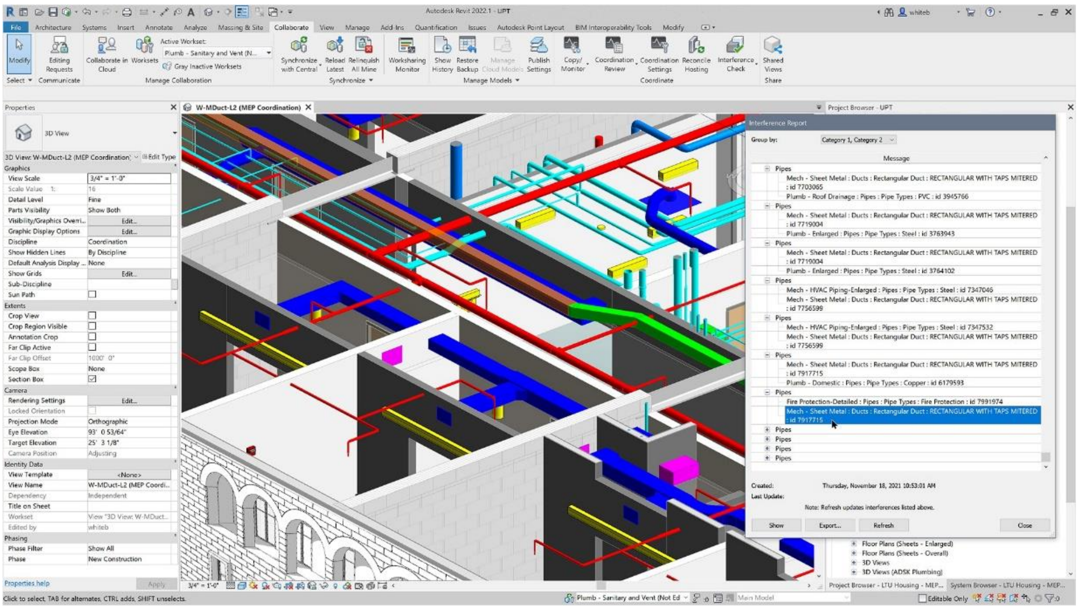

Figure 4. Hvac system designet in Revit software.

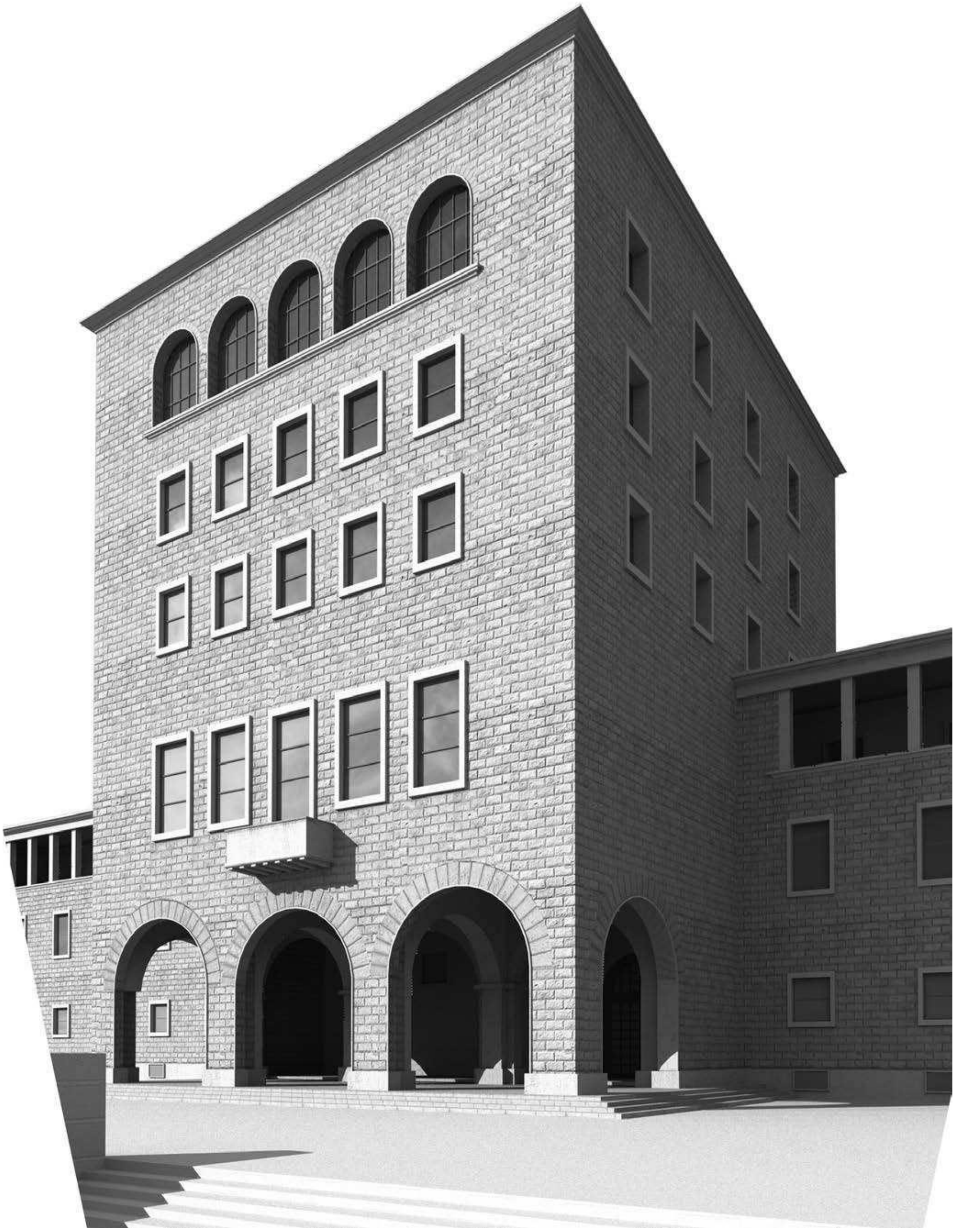

Figure 5. G. Bosio, Casa del Fascio in Tirana. 1939-40, the view of the tower (Revit Model)

3.2.2 DesignBuilder Modeling

Analyzing the efficiency of a building in DesignBuilder involves using the software to simulate and evaluate various aspects of the building's energy performance. We start by importing the building model, which is often created in software like Revit, into DesignBuilder. This model includes all the necessary architectural and structural details.

Once the model is in DesignBuilder, we set up the simulation parameters. This involves defining the building's location and climate data, which are crucial for accurate energy modeling. We also input details about the building's usage, such as how often and how many people use the spaces, as well as the energy used by lighting, equipment, and heating/cooling systems.

Next, we assign materials and constructions to different parts of the building. DesignBuilder has a library of materials, each with specific properties. By choosing the right materials for walls, roofs, windows, and floors, we can simulate how heat flows through the building.

With the setup complete, we run various simulations to see how the building performs. We look at how well the building maintains comfortable temperatures throughout the year, how much energy it uses overall, the levels of natural light in different areas, and how well the ventilation systems work.

DesignBuilder also lets us test different energy-saving measures. We can see the impact of adding insulation, installing double-glazed windows, using shading devices, adding advanced lighting controls, utilizing natural ventilation, and installing solar panels. We can test each measure on its own or combine them to see the overall effect on energy efficiency.

By using DesignBuilder, we get detailed insights into potential energy savings, cost reductions, and improvements in comfort and air quality. This comprehensive analysis helps us make informed decisions about the best strategies for making the building more energy-efficient and sustainable. This way, we ensure that any changes we make are effective and aligned with our performance goals.

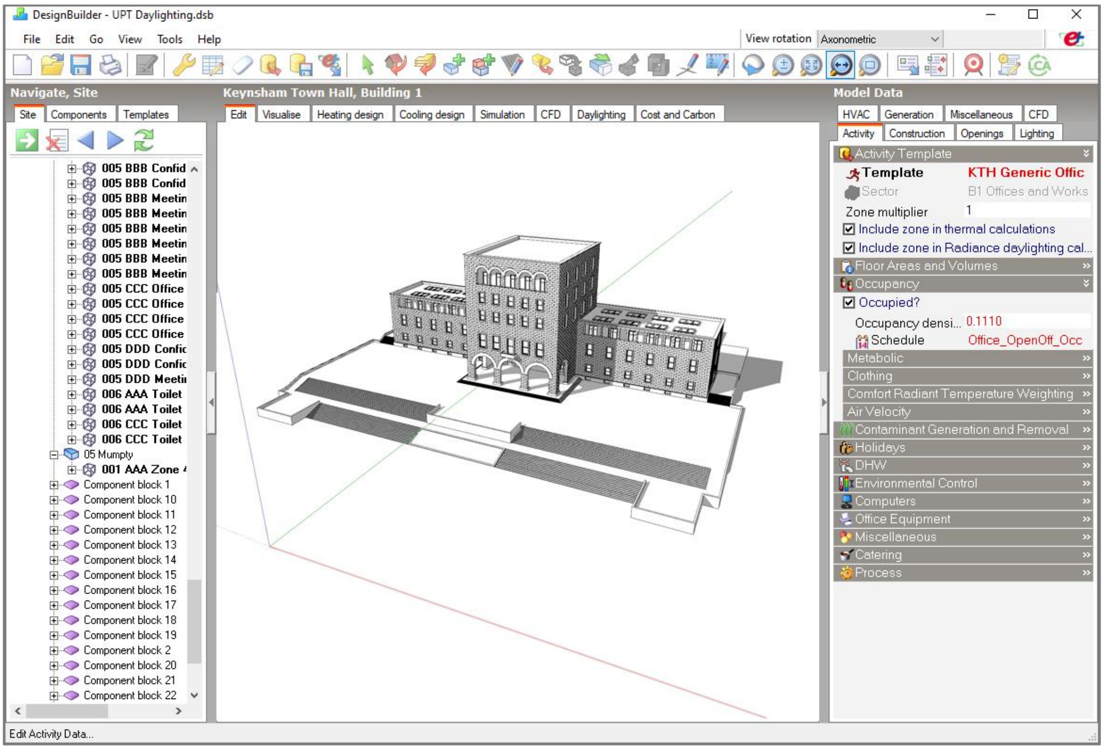

Figure 6. 3D volume of the object in DesignBuilder software.

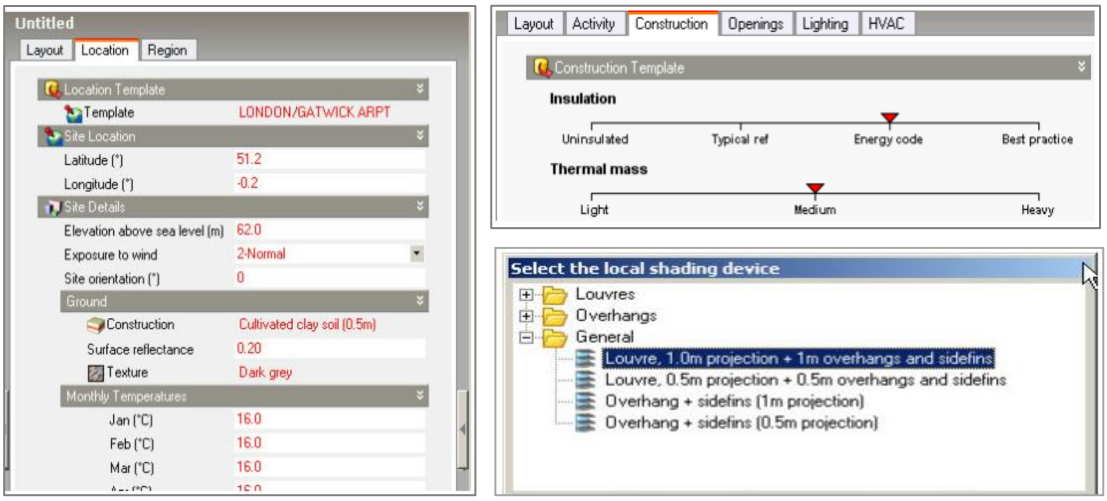

Figure 7. Site parameters, Pre-design Construction, glazing and shading.

3.3 Project Simulations

The utilization of simulation software like "Design Builder" offers a powerful tool for assessing the thermal behavior and energy performance of architectural projects. In the case of this heritage building transformation, the software facilitated a comprehensive analysis of various factors, including thermal comfort, energy consumption, and energy use intensity. Introducing six specific interventions aimed at enhancing energy efficiency demonstrates a proactive approach to sustainability. Let's delve into each intervention:

1. **Incorporating Thermal Insulation:** By adding thermal insulation to the building envelope, heat transfer through walls and roofs is minimized.
2. **Installing Double Glazing on Exterior Openings:** Double glazing provides better insulation than single-pane windows, reducing heat loss in winter and heat gain in summer, thus improving overall energy efficiency.
3. **Implementing Shading for Facade:** External shading devices, such as awnings or louvers, help control solar heat gain and glare, thereby reducing the demand for cooling and enhancing occupant comfort.
4. **Employing Internal Lighting Control:** Automated lighting controls, such as occupancy sensors and dimmers, optimize lighting usage by adjusting light levels based on occupancy and daylight availability, leading to energy savings.
5. **Utilizing Natural Ventilation:** Harnessing natural ventilation reduces reliance on mechanical cooling systems, improves indoor air quality, and lowers energy consumption associated with HVAC operations.
6. **Installing Photovoltaic Panels on the Roofs:** Solar photovoltaic panels generate renewable electricity from sunlight, offsetting grid electricity consumption and reducing the building's carbon footprint.

Using simulation to analyze these interventions helps stakeholders make informed decisions. By modeling all the suggested changes, we can see and measure improvements in energy efficiency.

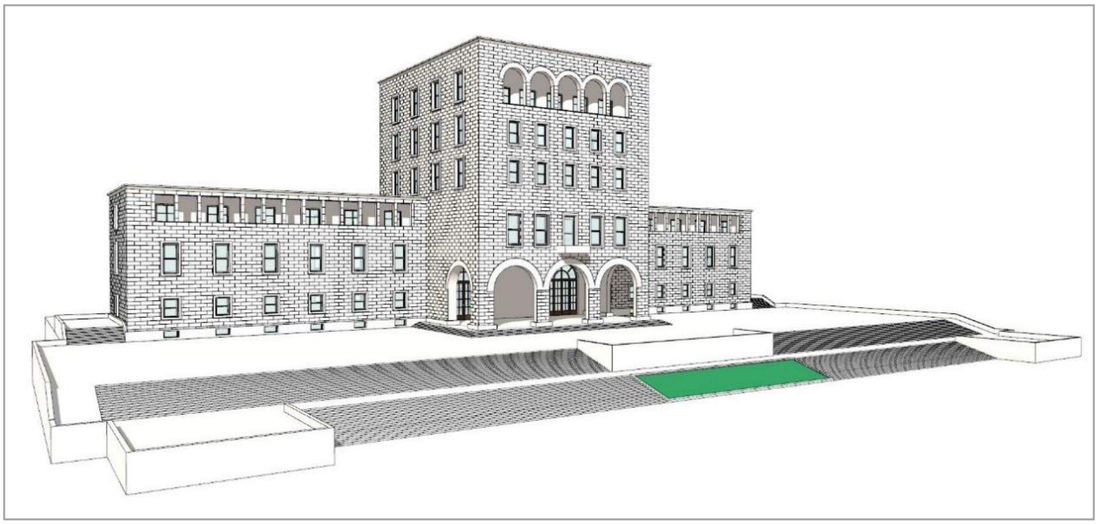

Figure 8. Architectural model reworked in Revit v.07, after the process of the survey.

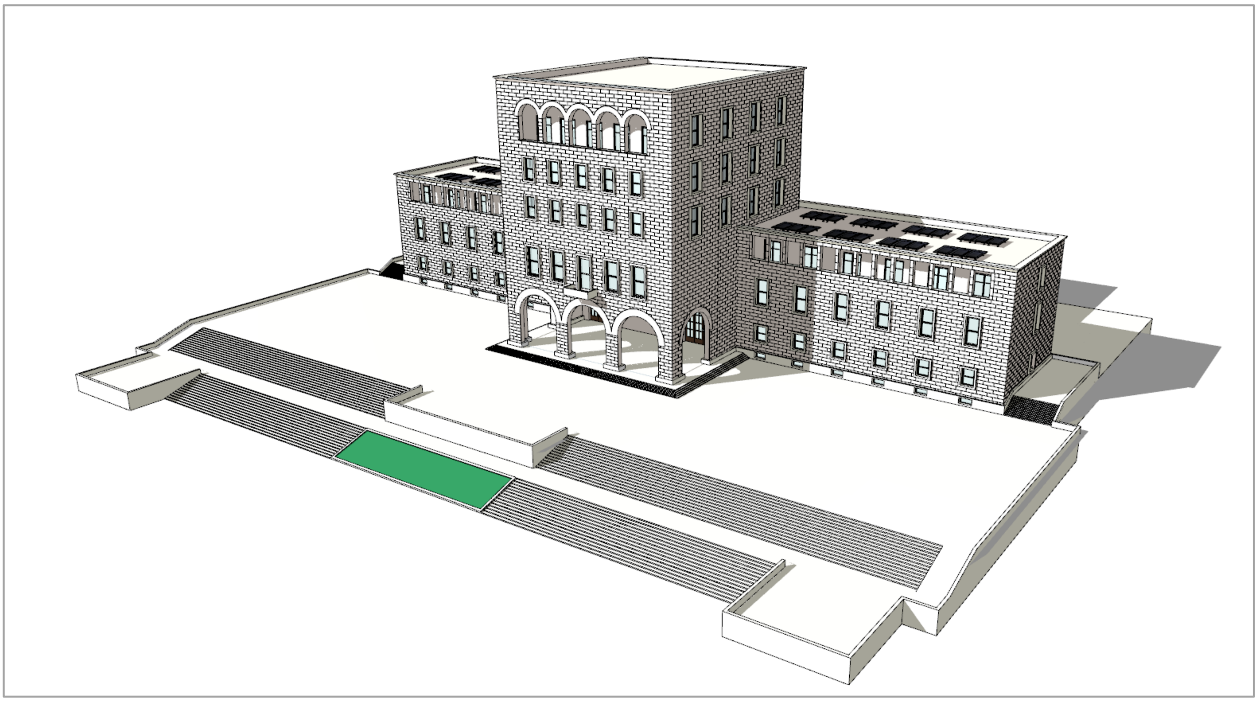

Figure 9. Architectural model reworked in Revit v.07, after the process of the survey.

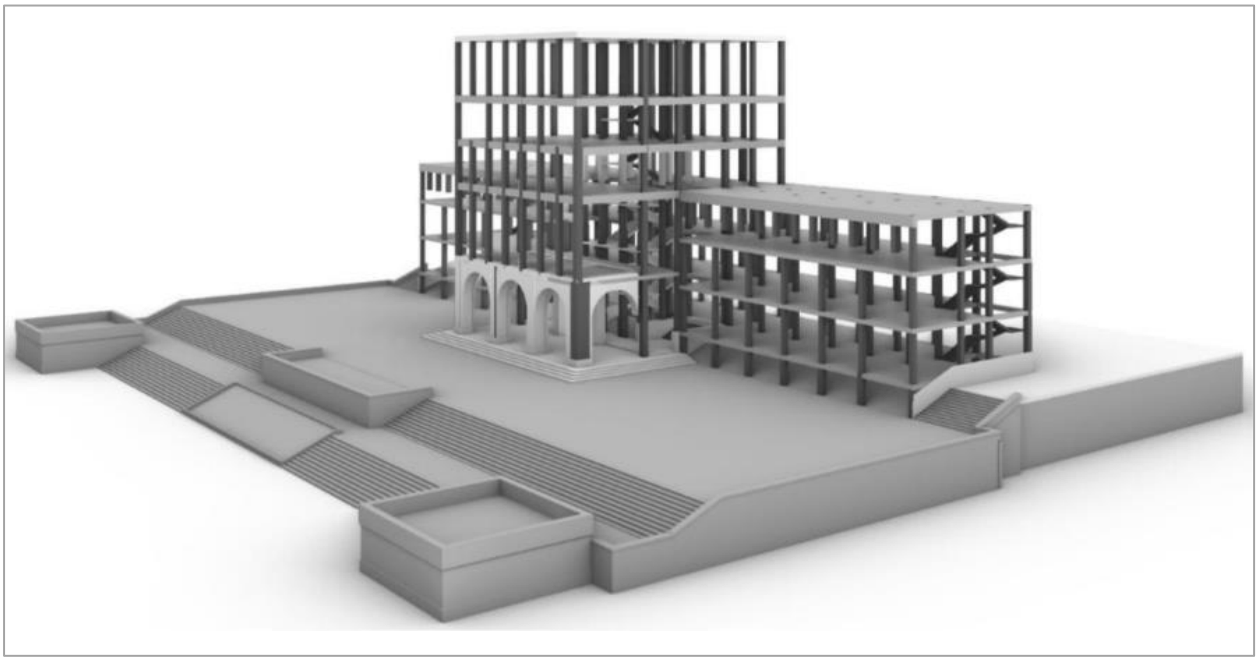

Figure 10. The 3D model design has been revised using Revit v.07 following the completion of the survey process.

CHAPTER 4

4.1 HISTORICAL BACKGROUND

Within a period of just over a year, Gherardo Bosio's contributions represent one of the most significant phases in Italian architecture in Albania during the late 1930s and early 1940s. His arrival and presence in Albania weave together two narratives: a historical one, stemming from the fascist invasion, and a personal one, connected to his untimely death at the age of thirty-eight. Gherardo Bosio was born in Florence on March 19, 1903, into a prosperous family with backgrounds in banking and the military. He graduated from the Royal Higher School of Engineering in Rome in 1926. Particularly noteworthy in his professional career are the master plans he created for Italian East Africa, including Gondar, Gimma, and Dessié, as well as various architectural projects for Italian colonies in Africa.

On April 7, 1939, Italian troops occupied Albania, leading to King Zog I's exile and the transfer of the Albanian crown to Vittorio Emanuele III. Despite the king's efforts to forge alliances with France and Britain, Mussolini's inflexible stance resulted in Albania's economic dependence on Italy and its annexation to the House of Savoy. Subsequently, the Italian government increased its expenditure on public works in Albania, financing the completion of Tirana's new center, which included the complex of ministries and the City Hall, designed by Florestano Di Fausto.

Bosio's work in Albania thus stands as a testament to this turbulent historical period, reflecting both the political dynamics of the time and his architectural legacy.

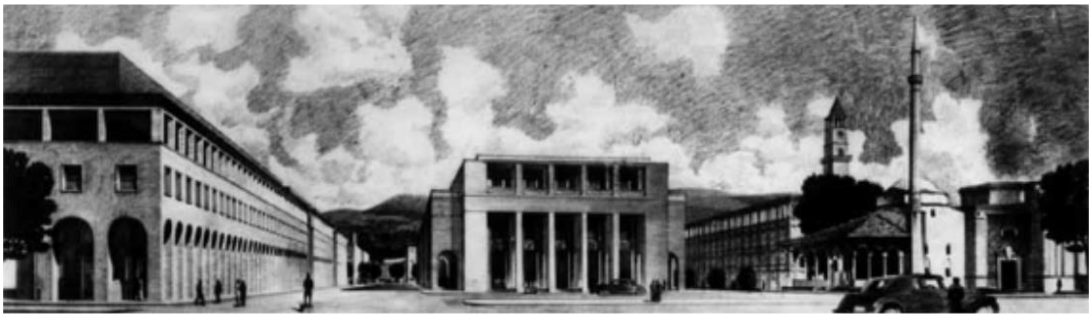

Figure 11. G. Bosio, Urban Plan of Tirana, 1939-40, arrangement of Scanderbeg Square, perspective view (Pelago, Archive of Gherardo Bosio's heirs) [7]

4.1.1 The Urban Plan of Tirana and the Projects for the Completion of the Center

Upon arriving in Tirana, Gherardo Bosio and his team faced the formidable challenge of creating a master plan for the burgeoning Albanian capital and redesigning its central area, specifically the monumental administrative complex. This task required them to harmonize their proposals with existing plans for Tirana's center developed by Brasini and Di Fausto during King Zog I's reign.

Bosio conducted a thorough analysis of the city, which, unlike other Albanian cities, lacked a historically significant core except for a few key structures: the Eth'hem Bej Mosque, the former royal villa, and the old Bazaar. Tirana was characterized by white, plastered pisé houses with projecting roofs, private gardens, and winding streets—elements strongly influenced by oriental traditions due to its long Ottoman rule. Bosio described it as: "Lying in the valley around the Lana stream, Tirana is a cluster of pisé houses, with only a few rising to two floors, ending with wide projecting eaves to protect the crumbling walls. Modern houses are built without urban planning or good construction quality." Recognizing the city's rapid population growth, the new master plan for Tirana projected an increase to about 100,000 inhabitants.

Bosio first addressed the city's circulation patterns, solving two key issues: managing the radial traffic arteries from Durrës, Vlorë, Elbasan, and Dibër towards the center, and organizing the traffic into two ring roads, from which residential neighborhood roads branched out with limited sections.

To facilitate these radial routes, wide streets like Via Principe Umberto, Viale Mussolini, Viale Vittorio Emanuele, and Via Xhemal were designed for direct access to the city center. Following the principles of the cardo and decumanus, two orthogonal axes were established for urban traversal: a north-south axis formed by Viale Vittorio Emanuele and Viale dell'Impero, and an east-west axis formed by Viale Mussolini and Piazza Scanderbeg, extending with a newly designed street. Bosio and his team aimed to give Tirana a "Western" appearance while enhancing its identity as a "garden city."

He also ensured the preservation of the entire old city core "not to lose the traces of the Muslim city."

Preserving the landscape features of existing neighborhoods and connecting with tradition, while respecting the inhabitants' way of life, were the guiding principles for the master plan concerning the pre-existing city. Bosio’s work in Tirana reflects his ability to balance modern urban planning principles with respect for historical and cultural contexts.

Bosio’s approach was unique in that it sought to integrate modern urban planning with the preservation of traditional elements. This dual focus aimed to create a city that embraced contemporary developments while respecting its historical roots. His vision for Tirana included modern infrastructure and public amenities designed to improve the quality of life for its residents. This included the introduction of new public buildings, parks, and recreational areas, enhancing the city’s functionality and aesthetic appeal. The master plan also took into account socio-economic factors, aiming to foster economic development while ensuring social cohesion. By designing public spaces and facilities that catered to the needs of all citizens, Bosio’s plan promoted inclusivity and accessibility. This approach was intended to not only boost the local economy but also to improve the overall social fabric of Tirana, making it a more vibrant and cohesive community.

In addition to socio-economic factors, environmental sustainability was a key consideration in Bosio’s plan. By maintaining green spaces and integrating natural elements into the urban landscape, the plan aimed to create a sustainable urban environment. The concept of a "garden city" was central to this vision, promoting green areas that would enhance the city’s aesthetic appeal while also providing ecological benefits.

Bosio’s work in Tirana left a lasting legacy that influenced future urban planning in Albania and beyond. His approach demonstrated that it was possible to modernize a city while preserving its historical and cultural heritage. This balance between tradition and innovation has become a model for urban planners who seek to create sustainable and culturally rich urban environments.

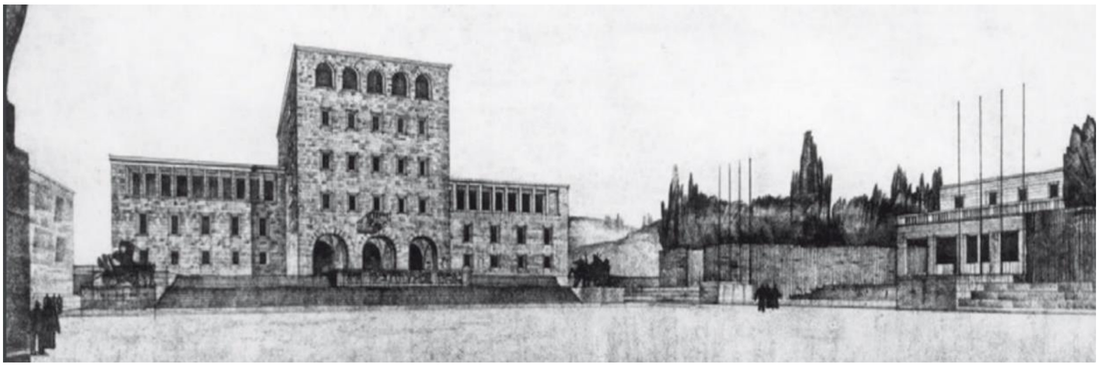

Figure 12. G. Bosio, Littorio Square in Tirana. Preliminary Design, 1939-40, perspective view (Tirana, Central Technical Construction Archive) [7]

Upon arriving in Tirana, Gherardo Bosio faced the formidable challenge of crafting a zoning plan for the Albanian capital, characterized by three distinct zones: intensive, semi-intensive, and extensive. These zones originated from the central monumental axis and Scanderbeg Square and extended towards the city's periphery. He also clearly delineated different neighborhoods. The upscale residential area was planned for the hills towards Elbasan, dominated by the large park of Villa Luogotenenziale. On the slopes to the west and east, "bourgeois" residences were planned, arranged in flexible subdivisions to adapt to the irregularities of the terrain. Meanwhile, workers' quarters were situated on a plain in the west, near the designated airport area. Adjacent to these quarters, in areas "downwind and under the rain shadow," industrial zones were planned. Apartment buildings, at least three stories high, were designed for the southern plain, which had a less favorable and less healthy exposure compared to the hills.

In terms of military facilities, Bosio proposed the creation of "two military nuclei to the west and south of the city, situated in sufficiently large areas and connected by fast and secure routes to house all military services." He suggested eliminating the market along the ring road next to the cattle market and relocating the hospital zone towards Dibër. Given the urgent need for new infrastructure, it was crucial to establish the general layout of the main roads for the master plan to follow. Concurrently, Bosio developed Urban Planning regulations (December 1939-January 1940), detailing construction rules tailored to the regime's needs.

A key project was the redesign of Scanderbeg Square, where major arteries like Viale Vittorio Emanuele, Viale Mussolini, and Viale Principe Umberto converged. Bosio reorganized the square, retaining all of Di Fausto's buildings except the municipal building, proposing a more compact design. The Et'hem Bej Mosque, the most important building in the system, was given a more prominent presence by the volumetric adjustments of the new surrounding buildings. Additionally, Bosio planned a significant reconstruction project for the Old Bazaar, preserving its original layout and naturally integrating it with the existing urban fabric. Inside the Bazaar, he envisioned semi-covered courtyards and internal squares to facilitate trade and provide shaded areas. Externally, the facades, raised to three stories, would feature a base with rounded arches, aligning with the architectural style of the old center. The ground floor would become a distinctive element of all new constructions on the main streets near the Bazaar.

For Viale Vittorio Emanuele (now Bulevardi Zogu I), a wide traffic axis with buildings of modest interest, Bosio planned constructions of a certain 'decorum,' with a building density suitable for its width and traffic function, requiring buildings to be set back to create a green strip with tall trees. For Viale Mussolini (now Rruga e Kavajës) and Viale Principe Umberto (now Rruga e Durrësit), high-quality buildings were planned due to their important location, with urban planning regulations formulated to prevent disorderly construction. Multi-story apartments, office buildings, shops, and public facilities were planned for these avenues. For Viale dell'Impero (now Bulevardi Dëshmorët e Kombit), Bosio ensured a harmonious appearance for the overall developments by providing instructions on cladding materials and intended uses. To guarantee the avenue's representative character, the floor plan defined the lengths of the building fronts with multiple modular inter-axes of 4.00 meters, ensuring separate and uniform buildings of the same height.

Bosio also envisioned creating a second political-sports center, Piazza del Littorio, which would serve as a celebratory hub of fascist ideology, separate from the existing old center and distinct from the nearly completed Piazza Scanderbeg with the ministries complex by Florestano Di Fausto. Piazza del Littorio (now Mother Teresa Square) would be the terminal point in the southern part of Viale dell'Impero. For this new center, Bosio personally designed and immediately executed the Casa del Fascio, which served as a dominant presence with its dual role as a scenic backdrop for the square and Viale dell'Impero. It was flanked by the ODA (Opera Dopolavoro Albanese) building and the GLA (Gioventù Littorio Albanese) headquarters, with the new Tirana stadium being constructed behind them. Along Viale dell'Impero, Bosio planned representative buildings such as the Lieutenant Governor's Offices and the grand Dajti Hotel.

Bosio’s comprehensive urban plan for Tirana aimed to modernize the city while preserving its cultural heritage, reflecting a careful balance of innovation and tradition. His vision laid the groundwork for Tirana’s development, integrating modern urban planning principles with respect for historical and cultural contexts.

4.1.2 Detailed Breakdown of Urban Planning

Bosio's zoning plan detailed three distinct zones radiating from the city center, each with specific characteristics and functions. The intensive zone, closest to the central monumental axis and Scanderbeg Square, was designed for high-density developments, including major public buildings, commercial areas, and high-rise apartments. This zone was intended to be the city's vibrant core, supporting a bustling urban life with ample amenities and services.

The semi-intensive zone, extending further out, was envisioned as a mixed-use area with a balanced combination of residential, commercial, and recreational spaces. This zone would accommodate mid-rise buildings, offering a transition from the densely built city center to the more spread-out suburbs. The planning regulations for this zone emphasized maintaining a harmonious urban fabric while allowing for moderate population density.

The extensive zone, located on the city's periphery, was planned for low-density residential areas and green spaces. This zone aimed to provide a serene living environment with ample open spaces, parks, and gardens. It included upscale residential neighborhoods on the hills towards Elbasan, featuring luxurious villas and private gardens. The careful planning of these neighborhoods ensured that the natural landscape was preserved and enhanced, creating a picturesque and sustainable living environment.

4.1.3 Socio-Economic and Environmental Considerations

Bosio's plan also incorporated socio-economic and environmental considerations. By situating industrial zones downwind and under the rain shadow of residential areas, he aimed to minimize the environmental impact on the city's inhabitants. The placement of workers' quarters near industrial zones ensured that workers had convenient access to their workplaces, reducing commuting times and fostering a sense of community.

The introduction of green strips and tree-lined avenues throughout the city was a key element of Bosio's vision. These green spaces not only enhanced the city's aesthetic appeal but also contributed to environmental sustainability by improving air quality and providing natural cooling. The "garden city" concept was central to his plan, promoting a harmonious blend of urban development and nature.

4.1.4 Preservation of Cultural Heritage

A crucial aspect of Bosio's urban plan was the preservation of Tirana's cultural heritage. By retaining and enhancing historical landmarks like the Et'hem Bej Mosque and the Old Bazaar, he ensured that the city's rich history remained an integral part of its modern identity. The careful reconstruction of the Old Bazaar, with its semi-covered courtyards and traditional architectural features, created a vibrant commercial hub that respected the city's historical roots.

Bosio's commitment to preserving the old city core while integrating modern urban planning principles exemplified his ability to balance tradition and innovation. His work demonstrated that historical preservation and contemporary development could coexist, enriching the city's cultural and architectural landscape.

4.1.5 Legacy and Influence

Gherardo Bosio's master plan for Tirana left a lasting legacy, influencing urban planning in Albania and beyond. His approach to zoning, infrastructure development, and cultural preservation set a precedent for future urban projects. By addressing the city's immediate needs and anticipating future growth, Bosio's plan provided a sustainable blueprint for Tirana's development.

Figure 13. G. Bosio, Piazza del Littorio in Tirana. 1939-40, perspective view (Tirana, Central Technical Construction Archive) [7]

His work highlighted the importance of comprehensive urban planning that considers socio-economic, environmental, and cultural factors. The principles he applied in Tirana have since been adopted in various contexts, demonstrating the universal applicability of his ideas.

4.2 THE CASE STUDY: OVERVIEW

Designed by Gherardo Bosio between 1939 and 1940, the Casa del Fascio exemplifies a strong connection to the Littorio style, representing the regime’s chosen architectural expression in the late 1930s. This building, conceived in 1939, embodies this architectural approach, especially in its urban context. The drawings for the Master Plan of Tirana highlight a significant maturation in volumetric composition, considering various aspects from the urban perspective.

The Master Plan for Tirana builds on the frameworks established by Giulio Bertè and Armando Brasini, who laid out a major organizing avenue to showcase the country's main organizational headquarters. Bosio aligned his work with these pre-1939 interventions, successfully developing an urban fabric suitable for the capital's growth. His experience from urban planning projects in Africa and Italy informed his approach to Tirana, where he not only defined zones and densities but also shaped architectural elements and urban furnishings, integrating plans and perspectives into cohesive living spaces.

The Casa del Fascio was envisioned as the central element of Tirana’s structural framework. It was designed not as an isolated structure but as part of a comprehensive compositional language, establishing new figurative references that would symbolize both the city and the nation. The Littorio complex, conceived as an urban theater surrounded by robust travertine terraces, positioned the Casa del Fascio as a scenic element against the natural backdrop of the hill. This design engaged citizens, making them feel integral to the urban representation.

The varying altimetric movements of the ground, created by the terraces and the stylobate of the Casa del Fascio, provided multiple viewpoints of the square and organically connected the buildings, creating a monumental podium for the architecture to rise above. The Casa del Fascio, characterized by compact intersecting rusticated parallelepipeds, evokes the impression of a fortress. While some see it as reminiscent of the traditional Albanian tower, it is more likely inspired by the type of Renaissance palace in Florence, reinterpreted in a modern style.

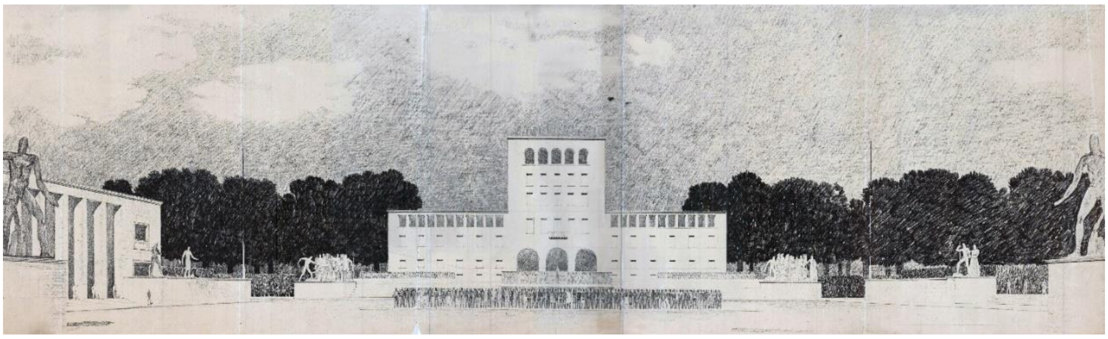

Figure 14. G. Bosio, Casa del Fascio in Tirana. 1939-40, perspective view (Tirana, Central Technical Construction Archive) [7]

The varied altimetric movements of the ground, shaped by the terraces and the stylobate of the Casa del Fascio, offered multiple viewpoints of the square and organically linked the buildings, forming a monumental podium from which the architecture ascends. The Casa del Fascio, with its compact intersecting rusticated blocks, gives the impression of a fortress. While some perceive it as reminiscent of the traditional Albanian tower, it is more likely inspired by the Renaissance palaces of Florence, reinterpreted in a modern style.

This design became an emblem of New Tirana, replicated in the same year for the Albanian pavilion at the Fiera del Levante in Bari and the Triennial Exhibition of the Lands Overseas in Naples. The nearly identical reproduction of its form in Bosio's project for Government Square in Gondar that same year is noteworthy. This formal repetition underscores Bosio's reflections on the character of places and their relationship with local cultures.

The uniform rustication treatment transcends the traditional vertical stratification of the facade into base-elevation-conclusion, imbuing the building with an almost metaphysical purity. The temple of the new Albania exists in a state of formal abstraction compared to other buildings in the Littorio complex, evoking a sense of symmetry, massiveness, elevated position, seriality, and material uniformity akin to the EUR and Palazzo della Civiltà in Rome.

Constructed with a reinforced concrete structure filled with solid brick masonry, the Casa del Fascio's windows were framed by cement and covered with Carrara white marble. The travertine-covered podium was built with a reinforced concrete structure that housed some underground rooms.

Today, the building serves as the Rectorate of the Polytechnic University of Tirana, with expansions at the rear added shortly after its original 1939 construction.

The design of the Casa del Fascio integrates architectural and urban planning elements that create a cohesive and dynamic urban environment. The altimetric variations, created by the terraces and stylobate, enhance the spatial experience by providing diverse viewpoints and organically connecting the surrounding buildings.

This design approach not only emphasizes the architectural prominence of the Casa del Fascio but also fosters a sense of continuity within the urban fabric.

The Casa del Fascio's architectural style, characterized by its compact rusticated blocks, evokes a fortress-like impression. While some interpret this as a nod to traditional Albanian towers, it is more likely influenced by Renaissance palaces from Florence, adapted into a modern architectural language. This fusion of historical inspiration and contemporary design elements underscores Bosio's ability to blend tradition with modernity.

The building's iconic status was further cemented by its replication for significant exhibitions, such as the Albanian pavilion at the Fiera del Levante in Bari and the Triennial Exhibition of the Lands Overseas in Naples. This consistent architectural language across different projects highlights Bosio's reflections on the cultural and contextual significance of architecture. The near-identical reproduction in the Government Square project in Gondar exemplifies his approach to creating a cohesive visual and cultural identity.

The uniform rustication treatment of the Casa del Fascio's facade surpasses traditional vertical stratification, imparting a metaphysical purity to the building. This abstraction aligns with the broader architectural language of the Littorio complex, characterized by symmetry, massiveness, elevated positioning, seriality, and uniformity of materials, reminiscent of the EUR and Palazzo della Civiltà in Rome.

The building's construction utilized a reinforced concrete structure with solid brick masonry, framed windows covered with Carrara white marble, and a travertine-clad podium housing underground rooms. This robust construction method ensured the building's durability and aesthetic coherence.

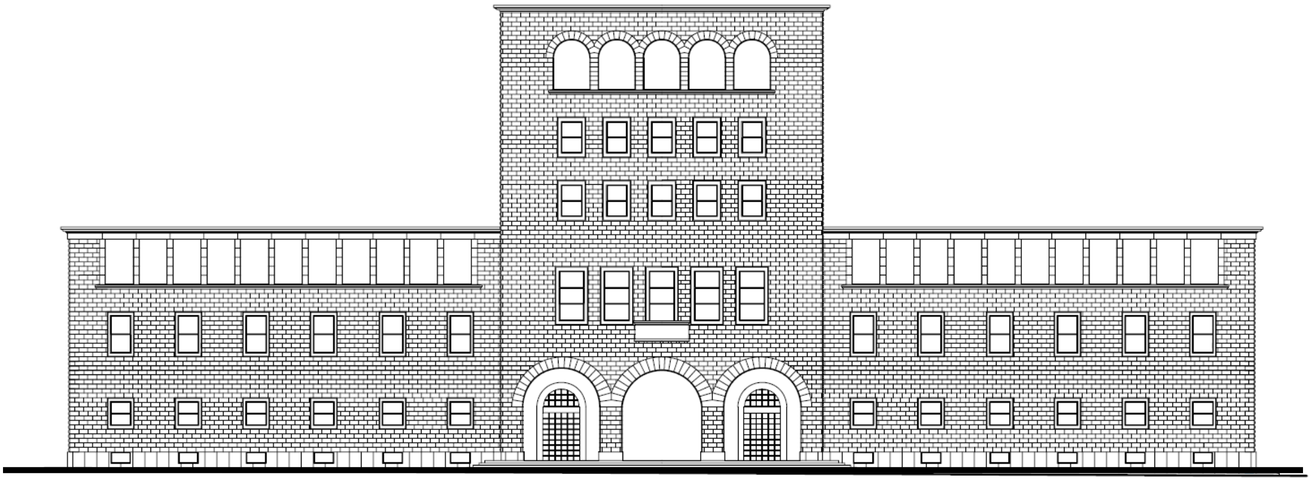

Figure 15. G. Bosio, Casa del Fascio in Tirana. 1939-40, the elevation, and view of Piazza del Littorio (Tirana, Central Technical Construction Archive) [7]

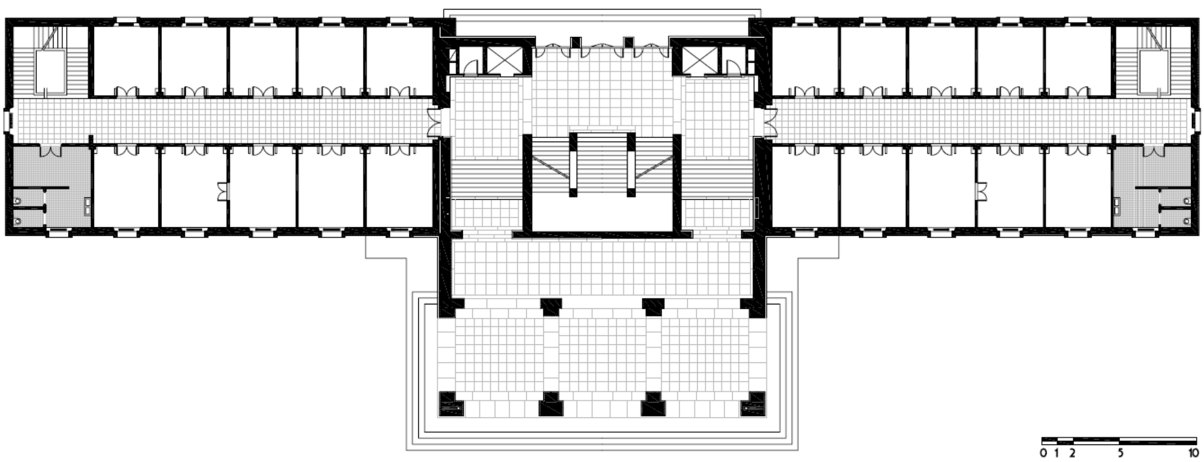

Figure 16. G. Bosio, Casa del Fascio in Tirana. 1939-40, the ground floor plan, (Tirana, Central Technical Construction Archive) [7]

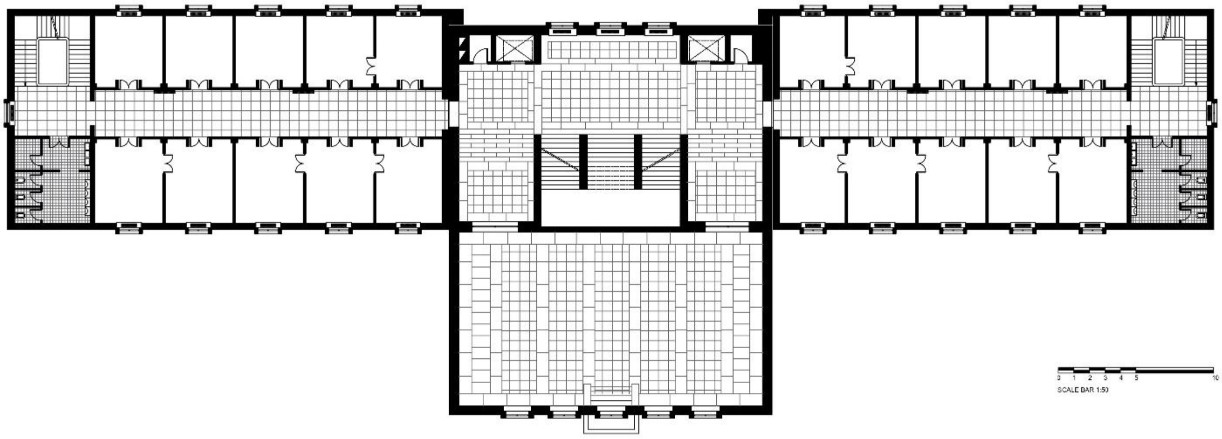

Figure 17. G. Bosio's design for the Casa del Fascio in Tirana, dated 1939-40, includes the second-floor layout, sourced from the Central Technical Construction Archive in Tirana [7].

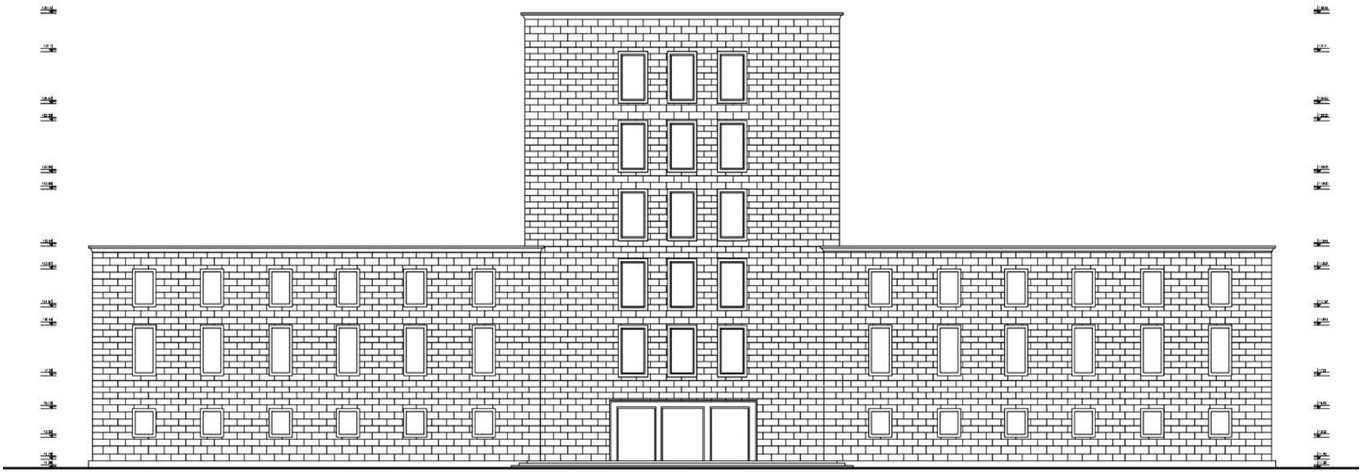

Figure 18. G. Bosio's architectural work on the facade of the Casa del Fascio in Tirana, completed between 1939-1940, is documented in the archives of the Central Technical Construction Archive in Tirana. [7]

4.2.1 Architectural Condition

Bosio made two trips to Tirana in late winter and early spring of 1939 to urgently begin studying initial solutions for the Casa del Fascio. Construction commenced the same year and concluded in late 1942, according to the final drawings signed by

Ferrante Orzali and the late Bosio. Initial sketches revealed a method akin to those proposed for Gondar, indicating from the outset that the overall project extended beyond the Casa del Fascio, encompassing the entire square and establishing connections with the buildings for the Albanian Littorial Youth and the Opera Dopolavoro. Numerous quick pencil and ink sketches, some only partially developed, attempted to define the building. It became clear, much like other projects, that the approach involved seeking a composition that relied on the synthesis of multiple building bodies rather than a singular one.

From the initial studies grouped for identification, those leading to the final project were singled out. Bosio developed at least two hypotheses and two variant proposals, complete with plans, elevations, and sections. This allowed the Ministry and the commission to select the final solution, which was subsequently implemented. The square, now a central element of the Viale dell'Impero and a symbolic destination in the new Italian Tirana, was structured as a perspective system, featuring the Casa del Fascio at the center on a raised platform, the Opera Dopolavoro building with the theater on the right, and the Gioventù Littoria building on the left.

After an extensive series of preliminary studies showcasing various forms of the building, Bosio outlined the final system. The design envisioned a tower that evolved from an oratory or independent scenic element into a standalone building. The tower, in its development, preceded the static space of the large linear volume housing the offices, accentuating its role as a backdrop through a prominent volumetric contrast. The tower's evolution was defined first as an object with regular fronts apparently divided according to a structural mesh, then as a solid monoblock with few rhythmically spaced openings, and finally approached the realized structure, featuring arches on the ground—initially seven, then five, and ultimately three in the definitive configuration. Numerous closed and regular openings were hypothesized, decreasing in number and increasing in size, characterizing the first floor with a balcony and leaving a system of five arches to terminate the volume at its peak.

For the long and lower body, window openings aligned with those of the main structure, while a colonnade composed of square-based columns and lintel replaced the arch system on the top floor. Although all surfaces were covered in roughly cut stone, paying homage to the culture of civil palaces in the homeland, the window openings were marked by thick frames in light stone projecting beyond the front edge. As with the volumetric composition and the definition of the fronts, an extensive quantity of drawings for the floor plans accompanied the journey to the final proposal. They sometimes followed the formal evolution of the building bodies but not always. In some instances, they presented independent proposals for the distribution of internal functions and the relationship between space and load-bearing structure, overseen by Bosio himself. In the final project, space was divided between the two main bodies—the tower accommodating the primary and monumental distribution, including representative spaces such as the double-height council chamber, spanning five floors; and the long, lower body housing offices, two vertical service connections, and deputies' studies with a continuous loggia system overlooking the square. The spatial layout was determined based on the structural grid, establishing the dimensional step for internal spaces and the patterns of voids in the elevations

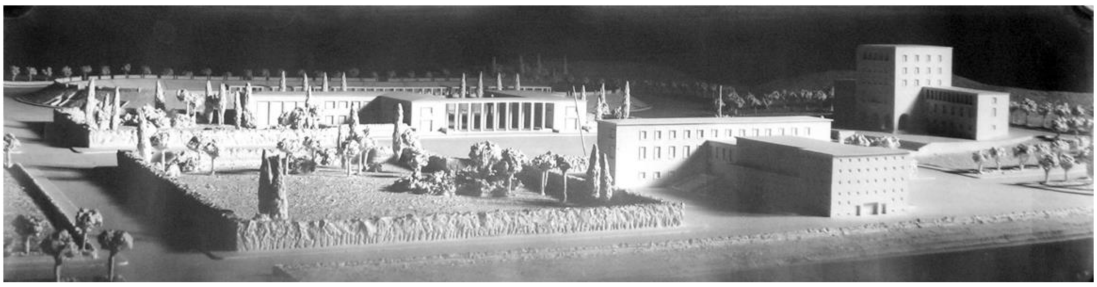

Figure 19. Gherardo Bosio, Progetto edifici e Piazza del Fascio, 1939/40 [7].

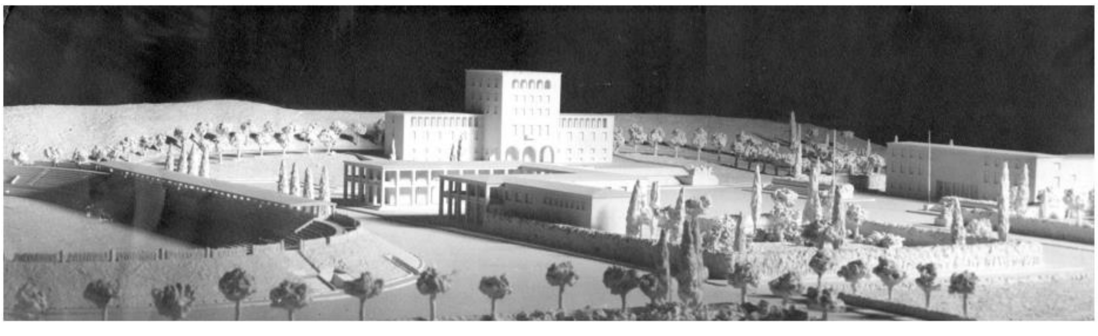

Figure 20. Gherardo Bosio, Progetto edifici e Piazza del Fascio, 1939/40. Photo of the maquette [7]

Figure 20. An architectural survey of the facade is conducted within the framework of investigating pathologies, analyzing the distribution of cracks, and identifying fractures.

Figure 21. A compilation of photographs displaying the current condition and degradation of various architectural elements and materials.

4.2.2 Structural Condition

The structural integrity of the building is achieved through a judicious combination of load-bearing brick walls, reinforced concrete columns, and reinforced concrete ceilings. This amalgamation forms a robust and resilient framework that has proven its stability over time.

Delving into the intricacies of the masonry structures within the object, they can be aptly described as assemblies of interconnected elements. These elements, held together by mortar, perform a dual role—contributing to the formation of the walls while withstanding external forces. The mortar serves as the unifying agent, seamlessly connecting these elements and filling the interstitial spaces, ensuring structural cohesion.

This interplay of interconnected elements results in the creation of not only vertical walls but also cylindrical structures such as minarets, wells, and chimneys. The versatility of this construction method, coupled with skilled craftsmanship, extends its application to the formation of arches, bridges, and curved coverings like domes. These architectural elements, resembling cylindrical shells or even spheres, showcase the adaptability and artistry inherent in masonry construction.

Remarkably, despite facing the challenges posed by two significant earthquakes, the object stands tall in good structural condition. This resilience underscores the effectiveness of the chosen structural system in withstanding seismic forces and reinforces the enduring quality of the construction.

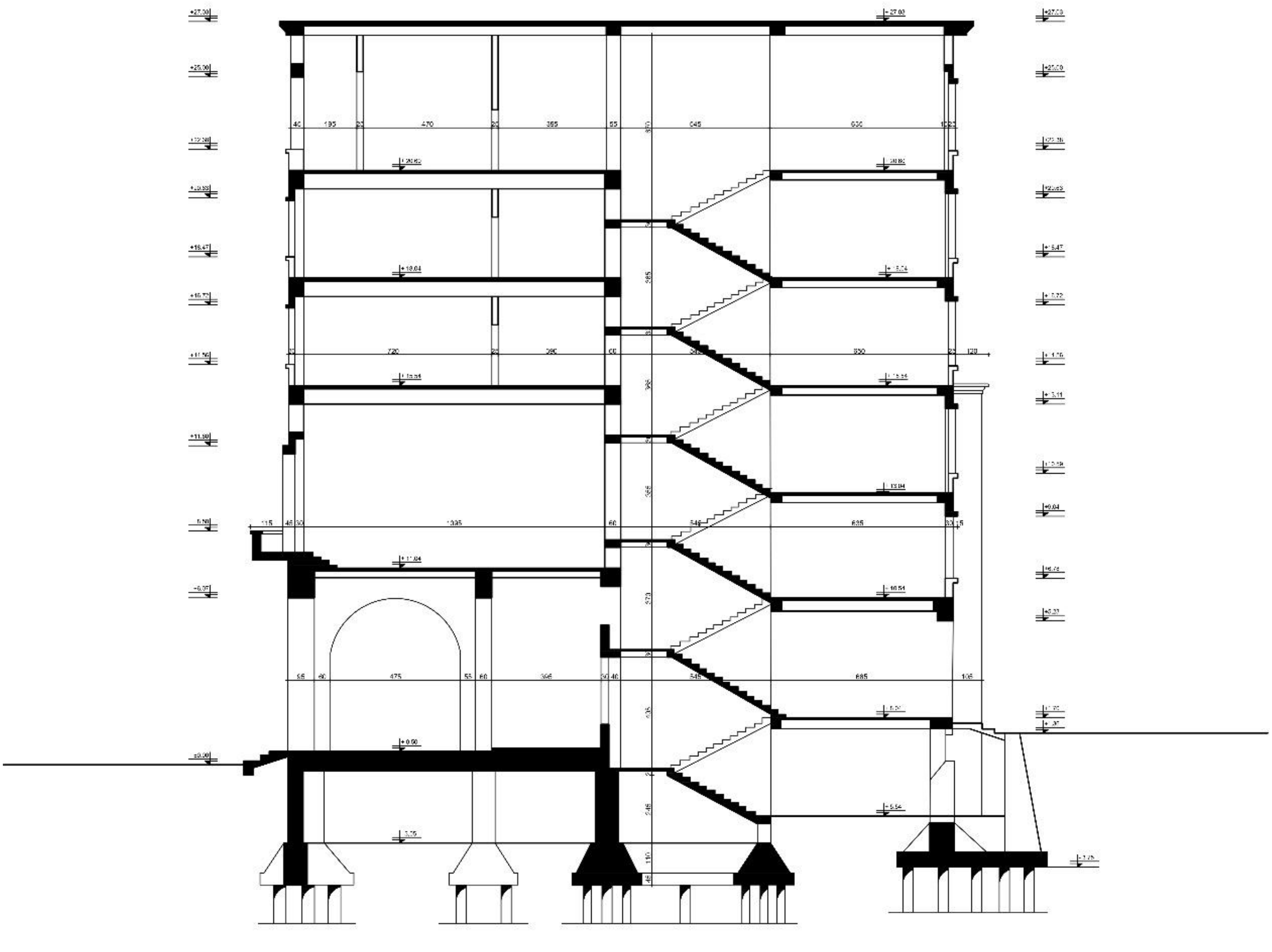

Figure 22. G. Bosio, Casa del Fascio in Tirana. 1939-40, section view [7]

CHAPTER 5

5. ANALYSES AND INTERPRETATION OF RESULTS

5.1 THE BASE CASE

Modeling the building within the "Design Builder" software to align with the current adaptive reuse project, including its underground extension, is essential for accurately assessing its thermal behavior, energy consumption, and overall performance. By incorporating all elements of the proposed project, such as form, materials, openings, and intended function, the simulation results provide a realistic depiction of how the building will function once transformed.

The inclusion of the underground extension is particularly significant, as it adds complexity to the building's thermal dynamics and energy usage. Underground spaces have unique challenges and opportunities in terms of temperature regulation and ventilation, making it crucial to model them accurately within the simulation software. By doing so, the impact of the extension on the building's overall energy performance can be properly evaluated.

Furthermore, modeling the building's form and materials ensures that the simulation takes into account factors such as solar heat gain, thermal mass, and insulation properties. This allows for a more nuanced analysis of how different design choices affect energy consumption and thermal comfort within the building.

Additionally, accurately representing the building's intended function within the simulation allows for the assessment of occupant behavior and energy usage patterns. For example, if the building is to be used as office space, the simulation can account for factors such as occupancy schedules, equipment loads, and lighting requirements to provide a more accurate prediction of energy consumption.

In summary, modeling the building within the simulation software to align with the adaptive reuse project, including its underground extension, ensures that the results of the analysis are reliable and actionable. This holistic approach allows designers and stakeholders to make informed decisions about energy-efficient design strategies and optimizations that will maximize the building's sustainability and performance.

a) Activity:

The building is designed to accommodate a variety of functions, requiring each space to have customized settings tailored to its specific activities.

Center offices:

- Occupancy density: 0.111 person/m2
- Schedule: For Weekdays

From 12:00 am, Until: 07:00 am,	0% Occupancy
From 07:00 am, Until: 08:00 am,	25% Occupancy
From 08:00 am, Until: 09:00 am,	50% Occupancy
From 09:00 am, Until: 12:00 pm,	100% Occupancy
From 12:00 pm, Until: 02:00 pm,	75% Occupancy
From 02:00 pm, Until: 05:00 pm,	100% Occupancy
From 05:00 pm, Until: 06:00 pm,	50% Occupancy
From 06:00 pm, Until: 07:00 pm,	25% Occupancy
From 07:00 pm, Until: 12:00 am,	0% Occupancy

- Metabolic rate per person : 123 W/person
- Equipment gains: 11.17 W/m2

Classrooms:

- Occupancy density: 0.175 person/m2
- Schedule:

From 12:00 am, Until: 09:00 am,	0% Occupancy
From 09:00 am, Until: 10:00 am,	75% Occupancy
From 10:00 am, Until: 12:00 pm,	100% Occupancy
From 12:00 pm, Until: 02:00 pm,	75% Occupancy
From 02:00 pm, Until: 05:00 pm,	100% Occupancy
From 05:00 pm, Until: 06:00 pm,	75% Occupancy
From 06:00 pm, Until: 12:00 am,	0% Occupancy

- Metabolic rate per person: 140 W/person
- Equipment gains: 2 W/m2
- Equipment schedule:

From 12:00 am, Until: 09:00 am,	5% Working
From 09:00 am, Until: 10:00 am,	76% Working
From 10:00 am, Until: 12:00 pm,	100% Working
From 12:00 pm, Until: 02:00 pm,	76% Working
From 02:00 pm, Until: 05:00 pm,	100% Working
From 05:00 pm, Until: 06:00 pm,	76% Working
From 06:00 pm, Until: 12:00 am,	0% Working

b) Construction:

CROSS SECTION

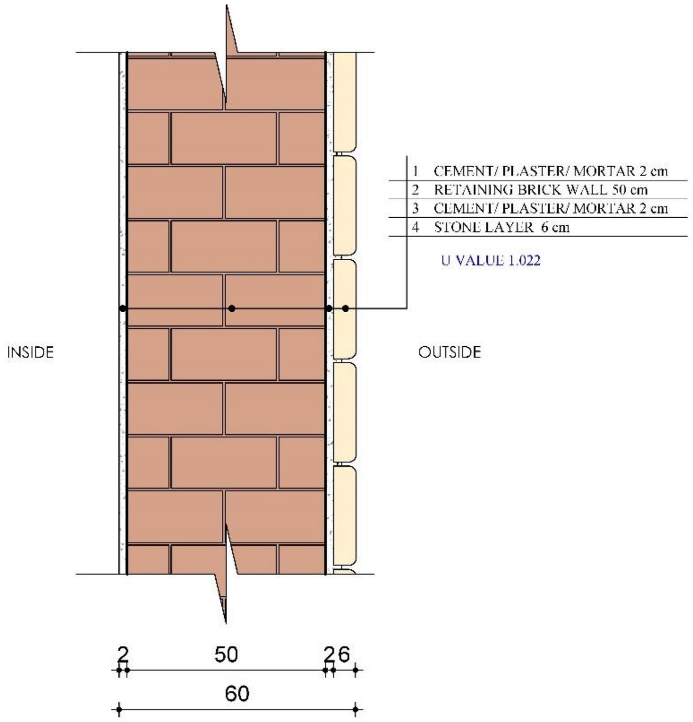

Figure 23. External 50 cm thick brick walls (Existing)

CROSS SECTION

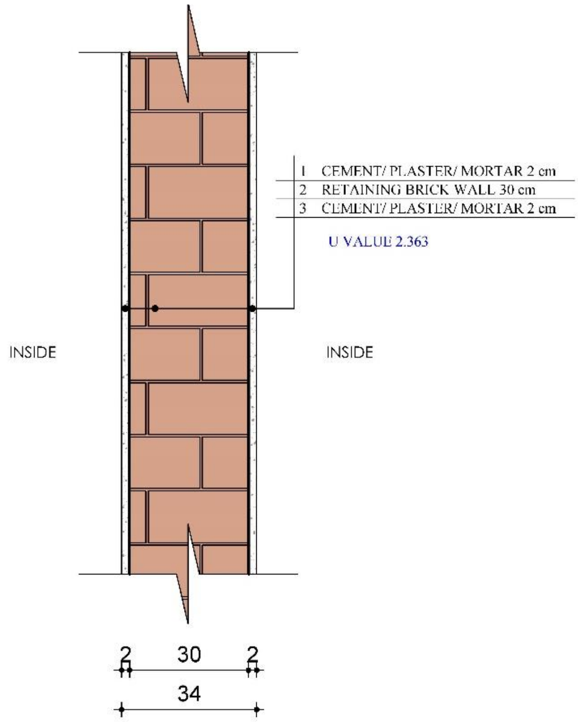

Figure 24. Internal 30 cm thick brick walls (Existing)

CROSS SECTION

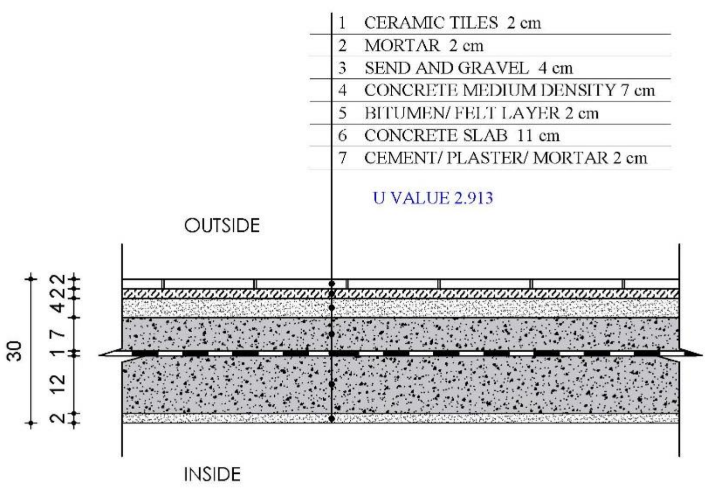

Figure 25. Roof layers (Existing)

CROSS SECTION

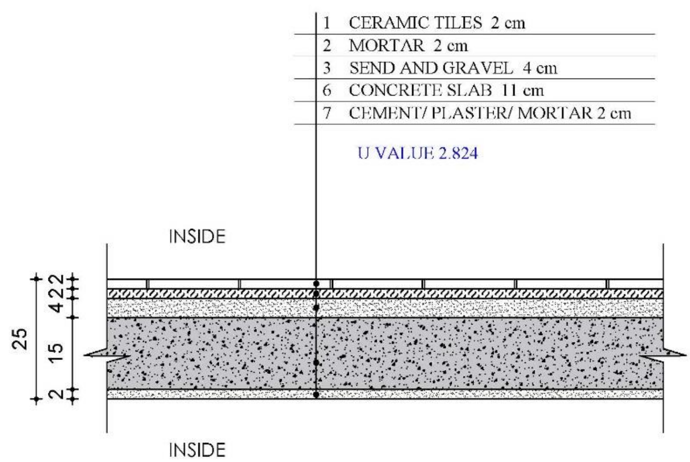

Figure 26. Thick concrete slab in the underground (Existing)

c) Openings:

The proposed windows for the base case feature aluminum frames with single clear 6mm glazing.

d) Lighting:

- Normalized power density(1): 5 W/m2/100 lux
- Target Illumination:
  a) Offices: 400 lux
  b) Classrooms, Working Spaces: 300 lux
  c) Laboratory, Exhibition & Mechanical rooms: 200 lux
  d) Lounges, library & multi-purpose hall: 300 lux
  e) Service rooms, bathrooms, Corridors & Stairs: 100 lux

d) HVAC:

- Heating set point(2): 22°c
- Heating set back(3): 5°c
- Cooling set point: 24°c
- Cooling set back: 45°c
- Heating system CoP: 0.83
- Cooling system CoP: 2.5

e) Results

The results are represented by the Energy Use Intensity (EUI) (4) for the heating, cooling and lighting energy as they are the factors affected by the upcoming proposed interventions. The simulation results indicate that cooling, heating, and lighting Energy Use Intensity (EUI) together account for 71% of the building's total energy consumption, highlighting the substantial impact of these components on overall energy usage.

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1 **Normalized power density** is the energy consumed for lighting a square meter to 100 lux.
2 **Set Point** is the temperature at which the cooling or heating system starts, during the working hours.
3 **Set Back Point** is the temperature at which the cooling or heating starts, outside the working hours.
4 **Energy Use Intensity (EUI)** is the annual energy use per square meter, measured in kWh/m².

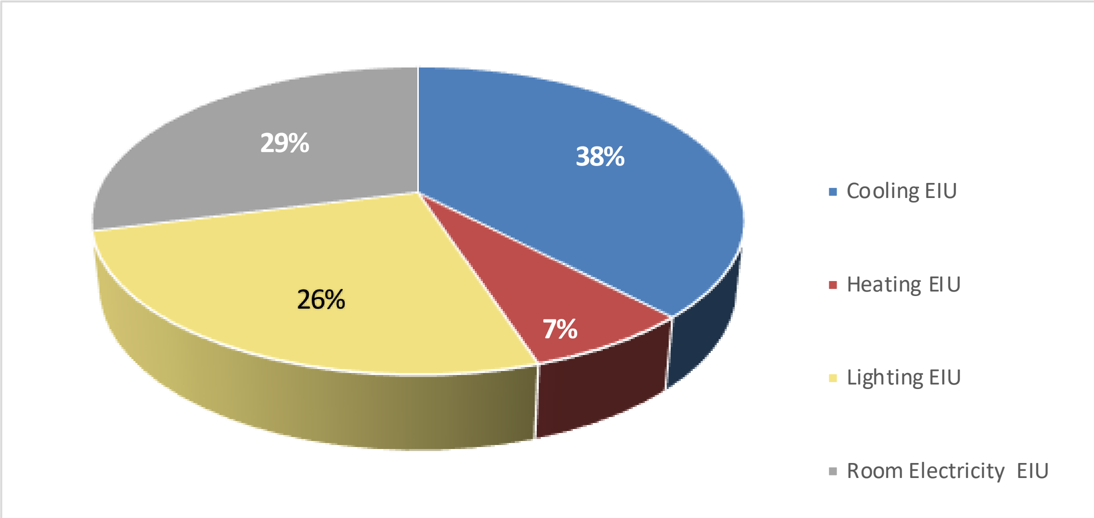

Figure 27. The Energy Use Intensity (EUI) breakdown for the Polytechnic University project shows that cooling, heating, and lighting together account for 71% of total energy consumption.

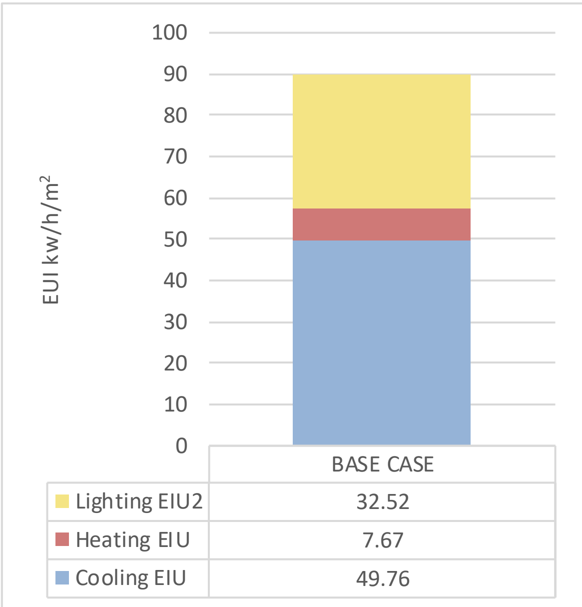

Figure 28. The Cooling, Heating, and Lighting Energy Use Intensity (EUI) of the Base Case amounts to a total of 89.95 kWh/m^2.

5.1.1 Thermal Insulation Case

a) Intervention

The building is a listed structure, and its historically significant facades must be preserved, rendering external insulation options infeasible. Given the necessity for structural consolidation, the interior of the building will undergo alterations. To address insulation needs within these constraints, it is proposed to install 5cm thick glass fiber board as internal insulation. This solution will help improve the building's thermal performance while maintaining the integrity and appearance of the exterior facades. Additionally, the use of glass fiber board will provide effective insulation, enhancing the energy efficiency of the building without compromising its historical value.

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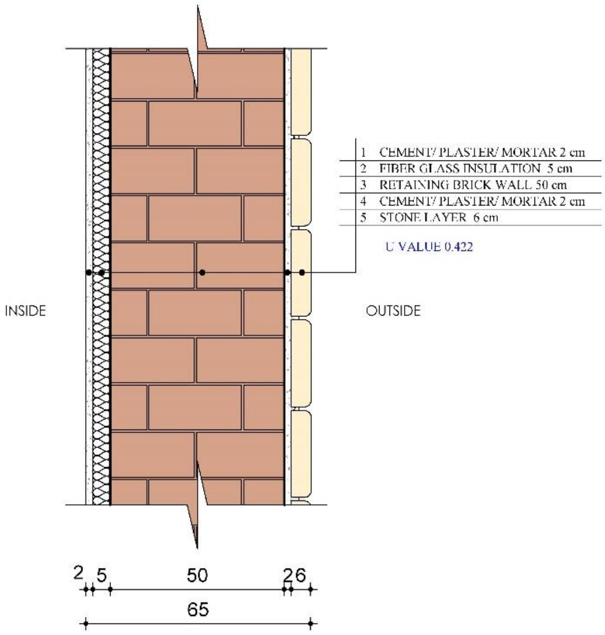


Figure 29. External 30 cm thick concrete wall with internal fiber glass board insulation

CROSS SECTION

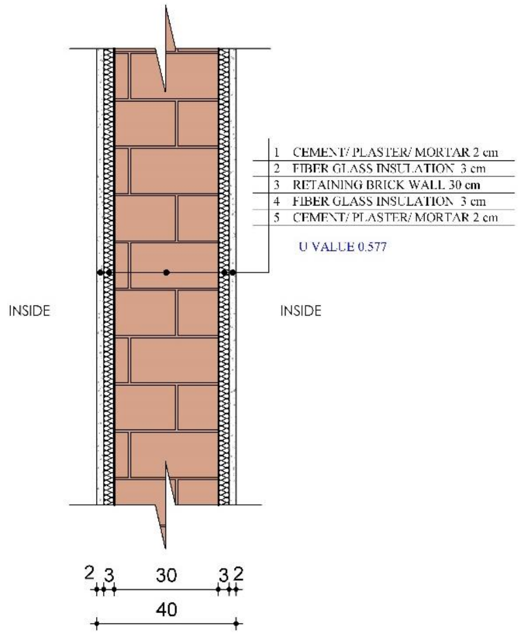


Figure 30. Internal 30 cm thick brick wall with internal fiber glass board insulation

c CROSS SECTION

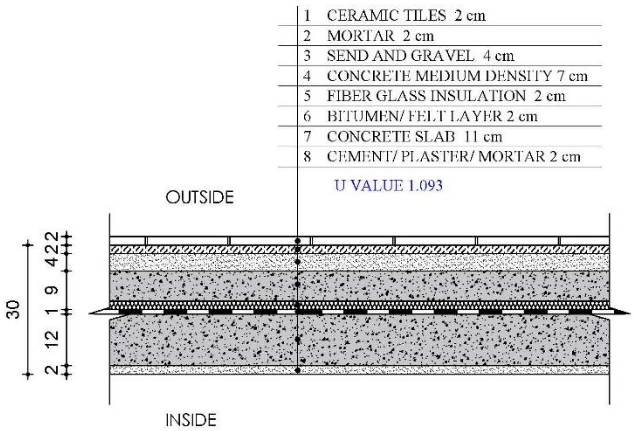


Figure 31. Roof layers with thermal insulation

CROSS SECTION

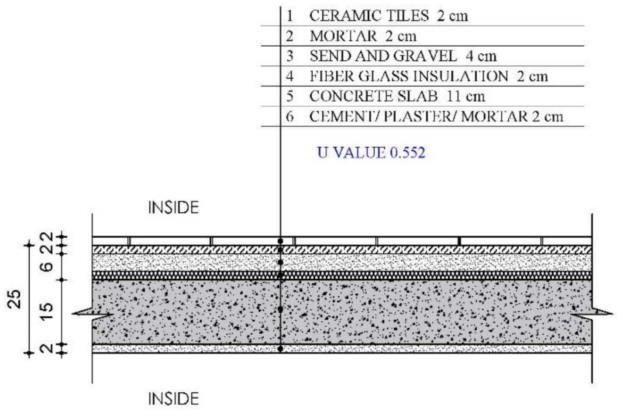


Figure 32. Concrete slab 30 cm thick with internal fiber glass board insulation

b) Results

The minor improvement in cooling and heating Energy Use Intensity (EUI) compared to the base case could indeed be influenced by various factors specific to the building and its environment. Let's explore some potential causes:

- **Existing Wall Insulation:** If the existing walls of the building already provide adequate insulation, the additional insulation material introduced during the retrofitting process may offer diminishing returns in terms of energy savings. The law of diminishing returns suggests that at a certain point, the benefits gained from adding more insulation may not justify the cost and effort involved.
- **Moderate Climate of Tirana:** Tirana's moderate climate may contribute to lesser heat gain or loss compared to regions with more extreme temperatures. In such climates, the heating and cooling loads on the building may already be relatively low, reducing the potential for significant improvements in cooling and heating EUI through retrofitting measures alone.
- **High Window-to-Wall Ratio:** A high window-to-wall ratio can increase the building's susceptibility to heat gain or loss through openings. In warmer climates, this can lead to greater cooling demands as solar heat enters the building through windows. Conversely, in cooler climates, it can result in increased heating requirements as heat escapes through windows. Therefore, addressing the impact of windows on overall energy performance becomes crucial in optimizing cooling and heating EUI.

In light of these factors, it's important to conduct a detailed analysis to identify the most effective energy-saving strategies tailored to the specific characteristics of the building and its location. This may involve optimizing the building envelope, upgrading HVAC systems, implementing efficient lighting solutions, and considering passive design strategies such as shading devices and natural ventilation. By addressing these considerations holistically, significant improvements in energy efficiency can be achieved, even in moderate climates like Tirana.

Figure 33. The comparison of Cooling, Heating, and Lighting Energy Use Intensity (EUI) and energy savings between the Insulation Case and the Base Case reveals a decrease of 0.43%.

5.1.2 Lighting Control Case

a) Intervention

Lighting control was activated to decrease the interior artificial lighting according to the available natural lighting in order to ensure that every space has its needed amount of illumination without wasting energy.

b) Results

The results show 56% improvement in lighting energy consumption. While cooling energy consumption decreased by 9.1% and heating energy consumption increased by 16.8% due to the decrease of the heat gain produced from artificial lighting. However, the overall energy use intensity is improved by 23.9%.

Figure 34. The comparison of Cooling, Heating, and Lighting Energy Use Intensity (EUI) between the Lighting Control Case and the Base Case demonstrates a savings of 24.18%.

5.1.3 Double Glazing Case

a) Intervention

Replacing the clear 6mm single glazed windows in the base case with various double-glazing options can significantly enhance the building's energy performance. Double-glazing offers superior insulation properties compared to single glazing, reducing heat transfer and minimizing energy loss. The clear 6mm single glazed windows in the base case were replaced with the following double-glazing configurations, each designed to address specific energy efficiency and comfort goals:

- **6mm clear glass, 13mm air gap, and 6mm clear internal glass:** This basic double-glazing option offers a substantial improvement in thermal insulation over single glazing, reducing heat loss in the winter and heat gain in the summer.

- **6mm blue-tinted glass, 13mm air gap, and 6mm clear internal glass:** The blue-tinted glass helps to reduce solar heat gain, which can lower cooling loads during hot weather, while still providing adequate daylight.
- **6mm clear glass, 13mm argon-filled void, and 6mm clear internal glass:** Filling the void with argon gas rather than air enhances the insulating properties, further reducing heat transfer and improving the overall energy efficiency.
- **6mm blue-tinted glass, 13mm argon-filled void, and 6mm clear internal glass:** This combines the benefits of tinted glass and argon gas, providing both improved insulation and reduced solar heat gain.
- **6mm clear glass, 13mm air gap, and 6mm clear internal glass with fixed internal louvers:** Fixed louvers help to control the amount of direct sunlight entering the building, thereby managing solar heat gain and glare without compromising natural light.
- **6mm clear glass, 13mm air gap, and 6mm clear internal glass with internal louvers that activate when solar radiation exceeds 120 W/m²:** These automated louvers respond to solar radiation, providing dynamic shading to prevent overheating and reduce cooling loads when sunlight is intense.
- **6mm clear glass, 13mm air gap, and 6mm clear internal glass with internal louvers that activate when solar radiation exceeds 400 W/m²:** Similar to the previous option, but set to activate at a higher threshold of solar radiation, these louvers balance energy savings with maximum daylight use.
- **6mm clear glass, 13mm air gap, and 6mm clear internal glass with internal louvers that activate when solar radiation exceeds 600 W/m²:** This option allows for the most daylight penetration and is designed for climates or building orientations where excessive solar heat gain is less of a concern.

Implementing these various double-glazing options can lead to significant improvements in the building's overall energy performance. Double-glazing helps to maintain a more consistent indoor temperature, reducing the need for heating and cooling. The use of argon-filled gaps and tinted glass enhances these benefits by providing additional insulation and solar control. Internal louvers, whether fixed or responsive to solar radiation, add another layer of control. Collectively, these measures contribute to lower energy consumption, and a more comfortable indoor environment for occupants.

b) Results

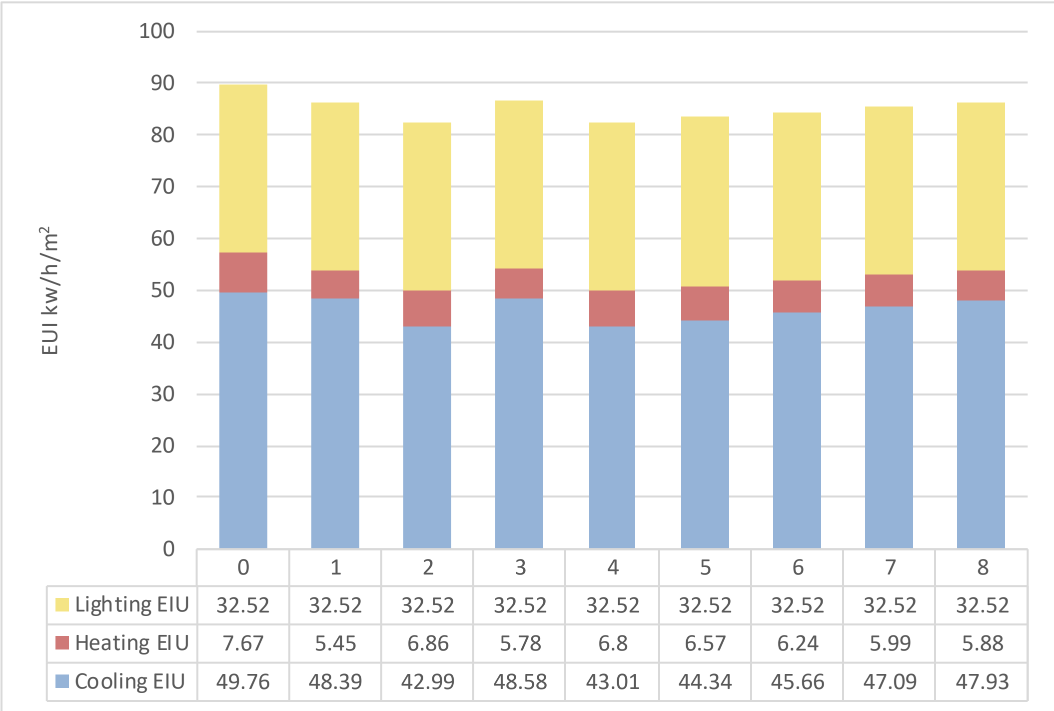


Figure 35. The Cooling, Heating, and Lighting Energy Use Intensity (EUI) of the Double-Glazing Cases compared to the Base Case.

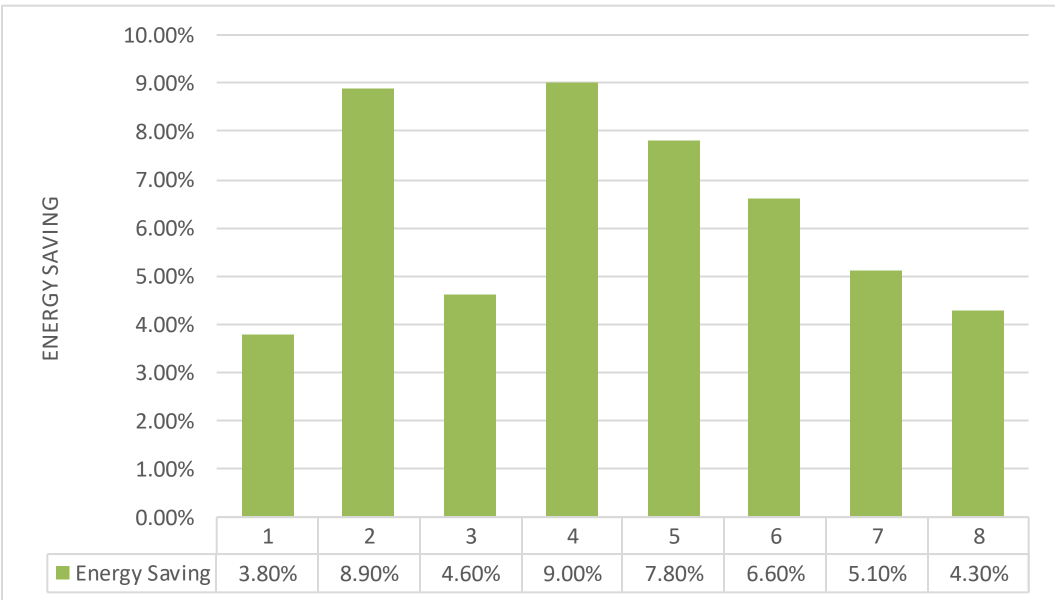


Figure 36. Energy saving percentage.

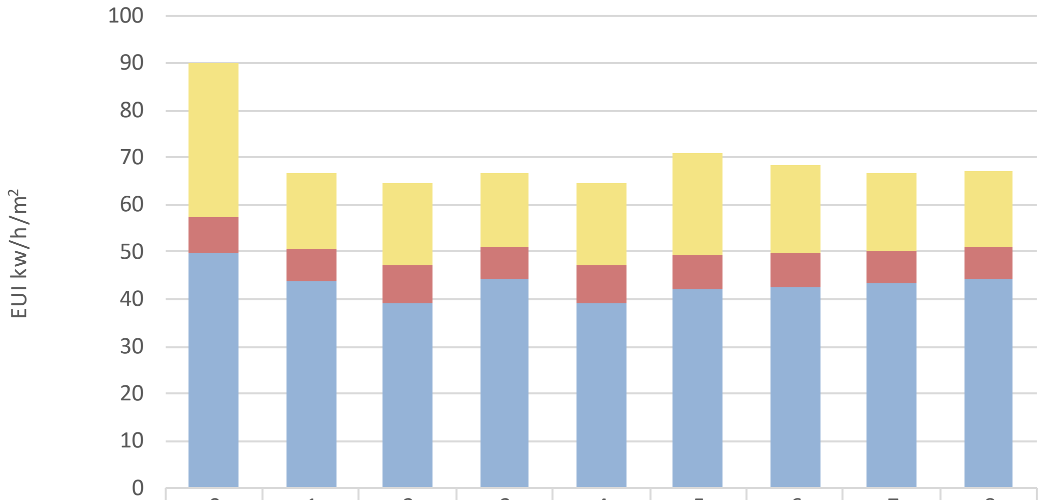
The results demonstrate varying improvements in cooling and heating Energy Use Intensity (EUI), with the highest improvements observed in the tinted glass cases (9%) and internal louvers cases (7.7%). However, these options could impact daylighting levels, potentially increasing lighting energy consumption if lighting controls are in place. Therefore, simulations for the different glazing scenarios were rerun with internal lighting control to accurately measure the required lighting energy and assess the combined potential energy savings for cooling, heating, and lighting.

Conducting these simulations with internal lighting control is a prudent strategy to evaluate the total energy consumption for cooling, heating, and lighting. Internal lighting control systems adjust artificial lighting based on the availability of daylight and occupancy, offering a more precise depiction of overall energy use and potential savings. This thorough analysis is essential for understanding the full benefits of various double-glazing options and their impact on the building's energy performance.

Integrating internal lighting controls into the simulations can provide a more holistic view of energy consumption. These controls optimize the use of natural daylight and adjust artificial lighting accordingly, which can lead to substantial energy savings. For instance, on bright days, the need for artificial lighting diminishes, reducing energy usage. Conversely, on cloudy days or during evening hours, the system ensures sufficient lighting is maintained, balancing comfort and efficiency.

Additionally, evaluating the combined impact of advanced glazing options and lighting controls can highlight the interplay between these systems. For example, while tinted glass and internal louvers can reduce cooling and heating demands, they might slightly diminish natural light penetration. By compensating for this with smart lighting controls, the building can achieve a balance that maximizes overall energy efficiency.

Furthermore, this comprehensive approach allows for the identification of optimal configurations that deliver the greatest energy savings without compromising occupant comfort. It also provides valuable insights for future retrofitting projects or new building designs, emphasizing the importance of an integrated strategy for energy management.



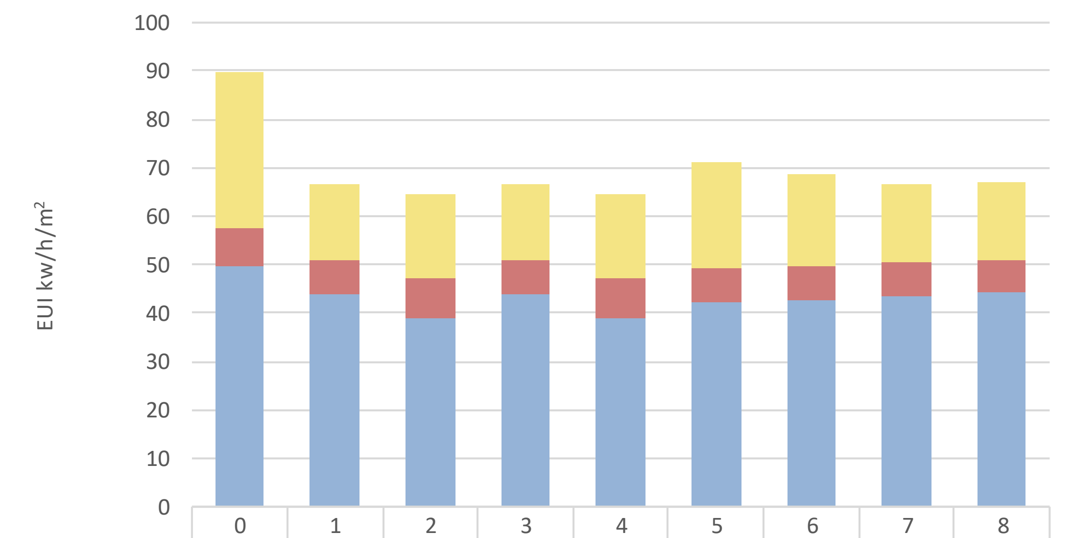
	0	1	2	3	4	5	6	7	8
Lighting EIU	32.52	15.94	17.54	15.94	17.54	21.84	18.74	16.41	16.06
Heating EIU	7.67	6.86	8.14	6.71	7.99	7.16	7.1	6.87	6.71
Cooling EIU	49.76	43.92	39.01	44.09	39.04	42.04	42.67	43.49	44.34

Figure 37. The Cooling, Heating & Lighting Energy Use Intensity (EUI) of the Double-Glazing Cases with lighting control, compared to the Base Case, and the energy saving percentage.

1. Clear double glass with air gap.
2. Tinted double glass with air gap.
3. Clear double glass with argon gap.
4. Tinted double glass with argon gap.
5. Clear double glass with air gap and internal louvers always on.
6. Clear double glass with air gap and internal louvers turns on when solar radiation exceeds 120 w/m^2.
7. Clear double glass with air gap and internal louvers turns on when solar radiation exceeds 400 w/m^2.
8. Clear double glass with air gap and internal louvers turns on when solar radiation exceeds 600 w/m^2.

In this phase of re-evaluation, a detailed examination was undertaken to delve deeper into the intricate interplay among tinted glass, internal louvers, and daylighting intensity. By analyzing the nuanced interactions of these elements, we aimed to gain a comprehensive understanding of how their combined effects influence lighting energy consumption. This analysis illuminates how the choice of glazing and shading strategies can significantly impact the overall energy performance of a building, either enhancing efficiency or potentially introducing inefficiencies. Incorporating internal lighting control into our simulations allowed us to navigate the complex dynamics between natural and artificial lighting sources. This integration not only facilitates the optimization of energy usage but also ensures that visual comfort and quality within the building are maintained at optimal levels. Striking a delicate balance between maximizing energy savings and safeguarding occupant well-being is paramount, and our approach endeavors to achieve this equilibrium.

Moreover, our comprehensive simulations extend beyond mere energy considerations to encompass factors such as thermal comfort and glare control. By holistically evaluating these aspects, we equip architects, engineers, and building owners with a robust framework for decision-making that prioritizes sustainability and occupant satisfaction.



	0	1	2	3	4	5	6	7	8
Lighting EIU	32.52	15.94	17.54	15.94	17.54	21.84	18.74	16.41	16.06
Heating EIU	7.67	6.86	8.14	6.71	7.99	7.16	7.1	6.87	6.71
Cooling EIU	49.76	43.92	39.01	44.09	39.04	42.04	42.67	43.49	44.34

Figure 38. The Cooling, Heating & Lighting Energy Use Intensity (EUI) of the Double-Glazing Cases with lighting control, compared to the Base Case

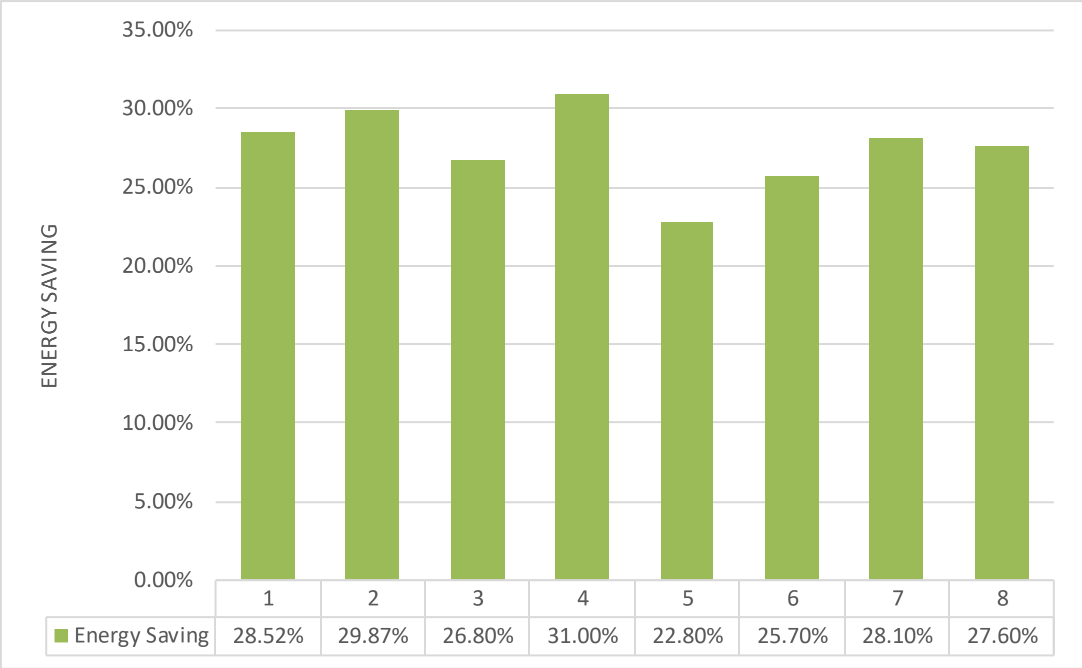


Figure 39. The energy saving percentage.

Our integrated approach to simulation and analysis goes beyond traditional energy metrics, offering a comprehensive view of the intricate interactions among various building elements. This perspective enables stakeholders to make well-informed decisions that support environmental goals and enhance user comfort. These choices not only reduce environmental impact but also improve the livability and functionality of the built environment for occupants.

The study's final results highlight the significant benefits of different glazing and shading strategies. Tinted glass, in particular, demonstrates a 30% energy saving, effectively reducing energy consumption by limiting solar radiation entering the building and decreasing the need for artificial cooling. However, while tinted glass provides substantial energy savings, it may not be suitable for heritage buildings, where maintaining the original appearance of facades is essential.

In such cases, alternative solutions must be considered. Our analysis indicates that using clear double glass with internal louvers that activate when solar radiation exceeds 400 w/m² is a viable and effective solution, achieving a 27.7% energy saving. This approach balances the need for energy efficiency with the preservation of the building's aesthetic and historical integrity. Internal louvers can effectively manage solar gain and improve thermal comfort without altering the building's exterior appearance.

Moreover, using internal louvers, which adjust based on real-time solar radiation levels, offers additional benefits. This adaptive shading strategy allows for greater control over the internal environment, enhancing both thermal and visual comfort for occupants. By dynamically responding to changes in solar radiation, the internal louvers help maintain a consistent and comfortable indoor climate, reducing reliance on artificial lighting and HVAC systems. Our comprehensive simulations also considered factors such as thermal comfort and glare control, ensuring that the proposed solutions not only save energy but also enhance the overall comfort and satisfaction of building occupants. Managing glare and improving thermal comfort is particularly important in work environments, where these factors can significantly impact productivity and well-being.

By integrating these findings into the decision-making process, architects, engineers, and building owners can develop more sustainable and occupant-friendly building designs. The insights from our analysis provide a robust framework for making informed choices that prioritize environmental sustainability and human comfort. This balanced approach ensures that buildings are not only energy-efficient but also conducive to the well-being and productivity of their occupants.

5.1.4 Implementing shading for façade Case

a) Intervention

Window shading is an effective strategy to reduce direct sunlight and heat gain through windows. However, traditional shading louvers may not be suitable for heritage buildings due to their impact on historic facades. The new proposal for the Polytechnic University involves modifying the inner courtyard facade to cover the eastern face with glazing. This raises concerns about the potential greenhouse effect caused by the large glazing area. To address this issue, it is recommended to install inner shade louvers. These louvers will prevent direct sunlight from entering the building, thereby reducing unnecessary heat gain and preserving the integrity of the historic structure.

b) Results

The simulation results show a 14.4% improvement in the building's cooling Energy Use Intensity (EUI) and a 6.5% reduction in heating EUI. These gains are mainly due to the decrease in heat gain from using tinted glass and internal louvers. However, this reduction in heat gain might lead to increased heating energy use during the winter months, potentially offsetting some of the heating energy savings achieved.

Despite this potential offset, the overall energy consumption for heating and cooling still shows an 11.6% improvement, indicating a net reduction in energy usage for maintaining thermal comfort throughout the year. When considering the total EUI for heating, cooling, and lighting, there is a 7.4% improvement. This suggests that the implementation of double glazing and internal lighting controls significantly enhances the building's overall energy efficiency.

It's important to note that while the improvements in cooling and heating EUI are significant, a comprehensive approach to energy management, including lighting control, is essential for achieving optimal energy performance. By balancing various energy-saving strategies and considering their combined effects, the building can achieve substantial reductions in energy consumption while maintaining occupant comfort and visual quality.

In addition to the tangible energy savings, there are several ancillary benefits associated with these measures. The internal louvers provide flexibility to adjust shading according to the time of day and seasonal variations, enhancing the building's adaptability to changing environmental conditions.

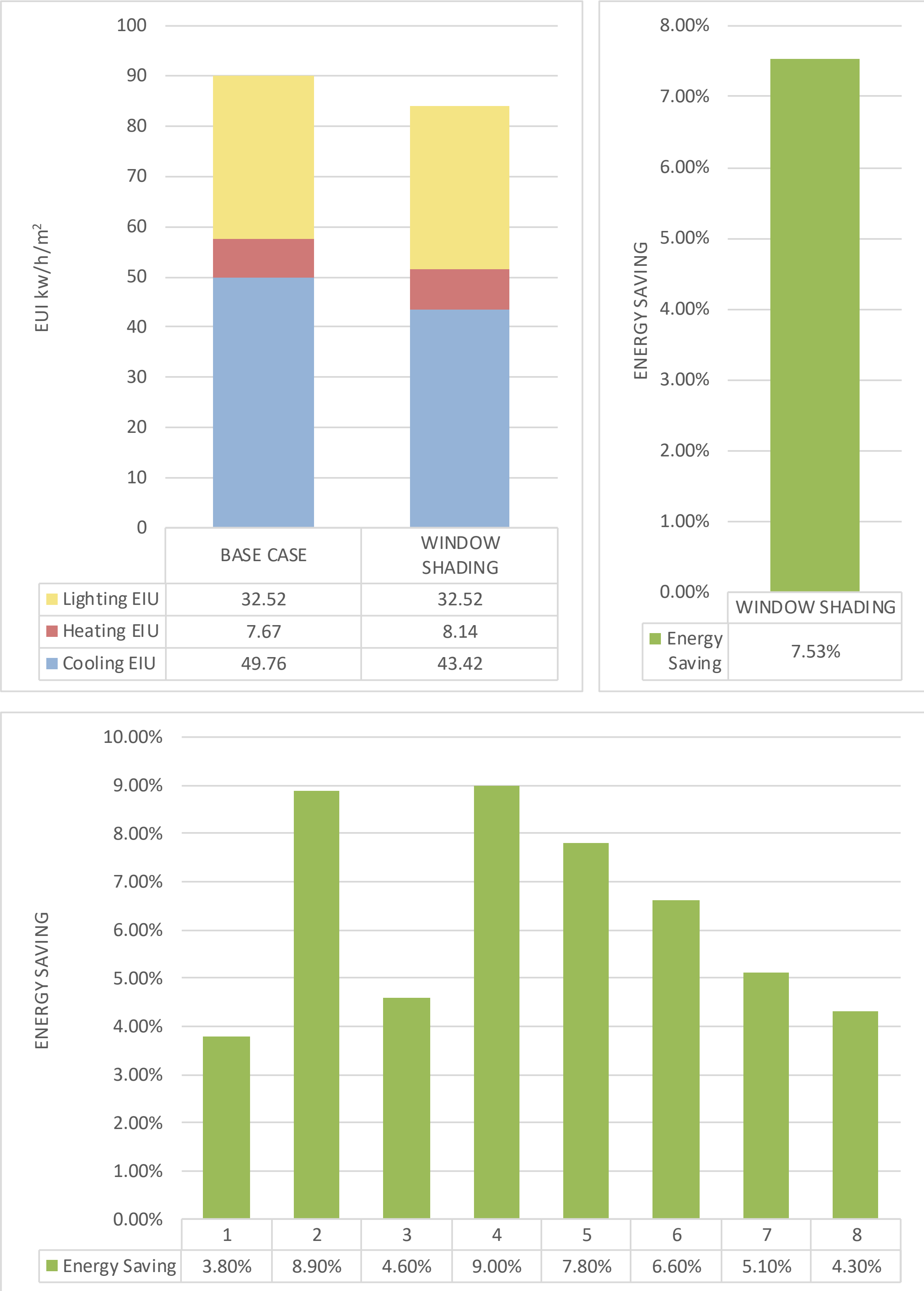


Figure 40. The comparison of Cooling, Heating & Lighting Energy Use Intensity (EUI) and energy savings for the facade Shading Case compared to the Base Case reveals a saving of 7.53%.

5.1.5 Natural Ventilation Case

a) Intervention

The simulation of natural ventilation in two distinct scenarios—exclusive natural ventilation and a hybrid approach combining natural ventilation with mechanical cooling systems—offers valuable insights into the potential of natural ventilation to reduce cooling energy demands while maintaining indoor comfort levels. Delving into the specifics of the natural ventilation configurations, several key parameters were meticulously configured to ensure optimal performance:

- **Outside Air Change Rate:** Set at 5 per hour, indicating the frequency at which fresh outdoor air replaces indoor air within the building. This ensures adequate ventilation to maintain indoor air quality and comfort.
- **Minimum Outside Air Temperature:** Defined at 18°C, ensuring that only air above this threshold is drawn into the building. This helps prevent discomfort due to overly cold outdoor air while still allowing for natural ventilation when outdoor conditions permit.
- **Maximum Outdoor Air Temperature:** Limited to 25°C, preventing the intake of excessively warm outdoor air that could lead to discomfort within the building. This ensures that natural ventilation remains effective in cooling the indoor environment without introducing excessive heat.
- **Delta T (Temperature Difference):** Established at 3°C, ensuring that the outdoor air temperature remains at least 3°C cooler than the indoor air temperature. This temperature difference facilitates effective cooling through natural ventilation, helping to maintain comfortable indoor conditions even during warmer outdoor temperatures.

By configuring these parameters with precision, the simulation aims to evaluate the efficacy of natural ventilation in maintaining optimal indoor comfort levels while minimizing the need for mechanical cooling systems. This approach not only promotes energy efficiency but also underscores the importance of leveraging natural resources to enhance sustainability in building design and operation. It highlights the potential of natural ventilation as a cost-effective and environmentally friendly solution for reducing cooling energy demands and improving indoor air quality in buildings.

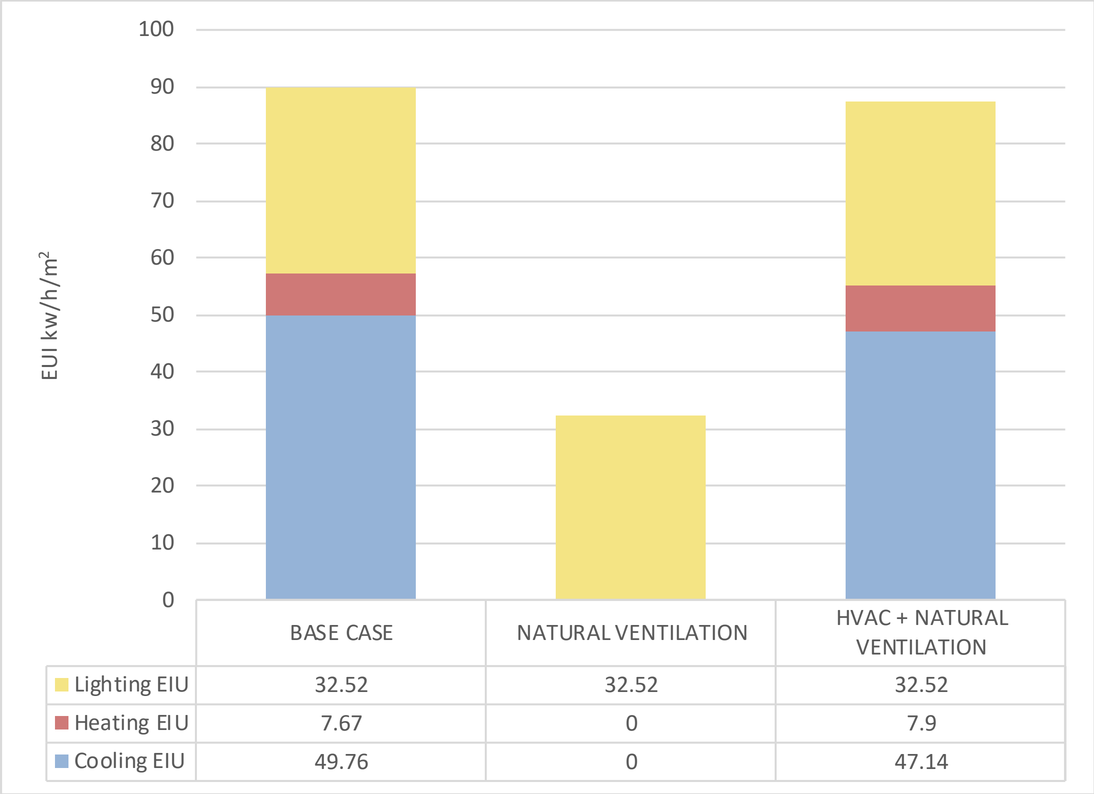
b) Results

In the base case scenario, where the building relied on conventional means for temperature control, temperature fluctuations ranged from 19°C to 28°C. However, when the building was subjected to natural ventilation alone, the temperature span widened, ranging from 18°C to 35°C. Despite achieving a remarkable 63.7% reduction in energy consumption through exclusive reliance on natural ventilation, this approach came at a significant cost to interior thermal comfort. The widened temperature range indicates potential discomfort for occupants, as illustrated in Figure 43. Therefore, while environmentally favorable in terms of energy efficiency, relying solely on natural ventilation proved impractical due to its adverse impact on occupant comfort.

In contrast, the second scenario, which involved a hybrid approach integrating mechanical heating and cooling systems with natural ventilation, yielded more modest yet sustainable outcomes. It achieved a 5.6% decrease in cooling Energy Use Intensity (EUI) and a marginal 2.7% reduction in overall EUI. The key aspect of this approach was maintaining the initial levels of thermal comfort. This hybrid strategy effectively minimized energy consumption while ensuring that occupants' comfort remained uncompromised.

The findings underscore the importance of balancing energy efficiency and occupant comfort in building design and operation. While natural ventilation offers significant potential for energy savings, it must be complemented by mechanical systems to maintain consistent thermal comfort levels, especially in regions with wide temperature variations. This hybrid approach represents a sustainable solution that optimizes energy usage while prioritizing occupant well-being.

Furthermore, this scenario highlights the adaptability and resilience of hybrid systems in responding to varying environmental conditions. By combining the strengths of both natural and mechanical ventilation, buildings can better cope with seasonal changes and extreme weather events. This approach not only enhances energy efficiency but also supports the long-term sustainability and resilience of the built environment. Emphasizing such balanced strategies in future building designs can lead to more holistic and sustainable outcomes, addressing both energy consumption and occupant satisfaction.



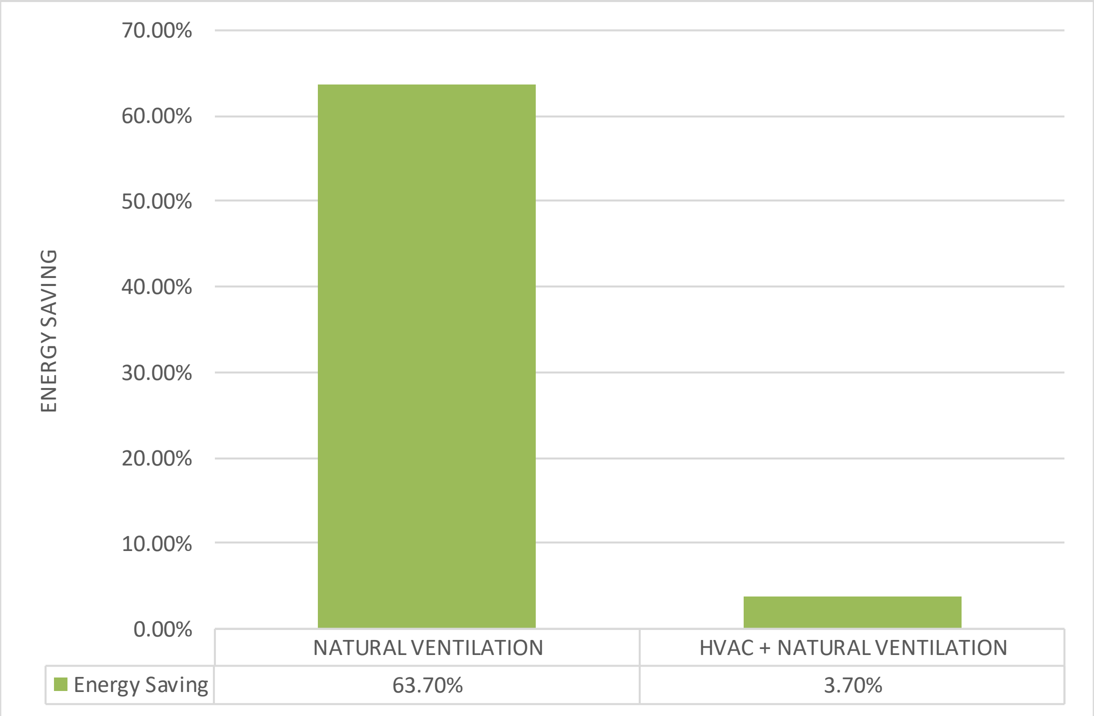


Figure 41. The Cooling, Heating & Lighting Energy Use Intensity (EUI) of the Natural Ventilation Case and Natural Ventilation + HVAC Case, compared to the Base Case, demonstrates energy savings of 63.7% and 3.7%, respectively.

Figure 42. Operative Temperature for the HVAC Base Case, the Natural Ventilation Case and the HVAC + Natural Ventilation Case.

5.1.6 Photovoltaic Panels Case

a) Intervention

In the region of Albania, the vast potential of solar renewable energy resources remains largely untapped. The description of Albania's strategic deployment of solar technology is compelling and highlights the country's commitment to embracing renewable energy solutions for a sustainable future. Let's break down the key points and further emphasize the significance of this initiative:

Abundant Solar Renewable Energy Resources: Acknowledging the untapped potential of solar energy in Albania underscores the country's recognition of its natural resources and the importance of harnessing them for sustainable development.

Proactive Step in Installing PV Panels: By taking proactive measures to install photovoltaic (PV) panels covering a substantial area of 1231 square meters, Albania demonstrates a commitment to leveraging its solar resources for electricity generation.

Impressive Efficiency Rating: The impressive efficiency rating of 20% for the PV panels showcases the high-performance standards of the technology deployed, ensuring optimal energy conversion from sunlight to electricity.

Significant Investment in Renewable Energy Infrastructure: The strategic deployment of solar technology signifies a substantial investment in renewable energy infrastructure, positioning Albania to capitalize on its solar resources and contribute to environmental sustainability and energy independence.

Stimulating Economic Growth and Job Creation: The investment in solar energy infrastructure not only enhances energy security but also stimulates economic growth and creates job opportunities in the renewable energy sector, fostering innovation and skills development.

Enhanced Energy Independence and Resilience: Diversifying the energy mix with renewable sources like solar power enhances Albania's energy independence and resilience to external supply disruptions, strengthening the country's energy security.

Transition towards a Sustainable and Resilient Energy Future: The strategic deployment of solar technology represents a significant milestone in Albania's transition towards a more sustainable and resilient energy future, unlocking its renewable energy potential and paving the way for a cleaner, greener, and more prosperous future for generations to come.

Overall, Albania's commitment to harnessing solar energy reflects a visionary approach to energy planning, positioning the country as a leader in renewable energy adoption and sustainable development. By leveraging its abundant solar resources, Albania is not only reducing its environmental footprint but also fostering economic growth and ensuring energy security for its citizens.

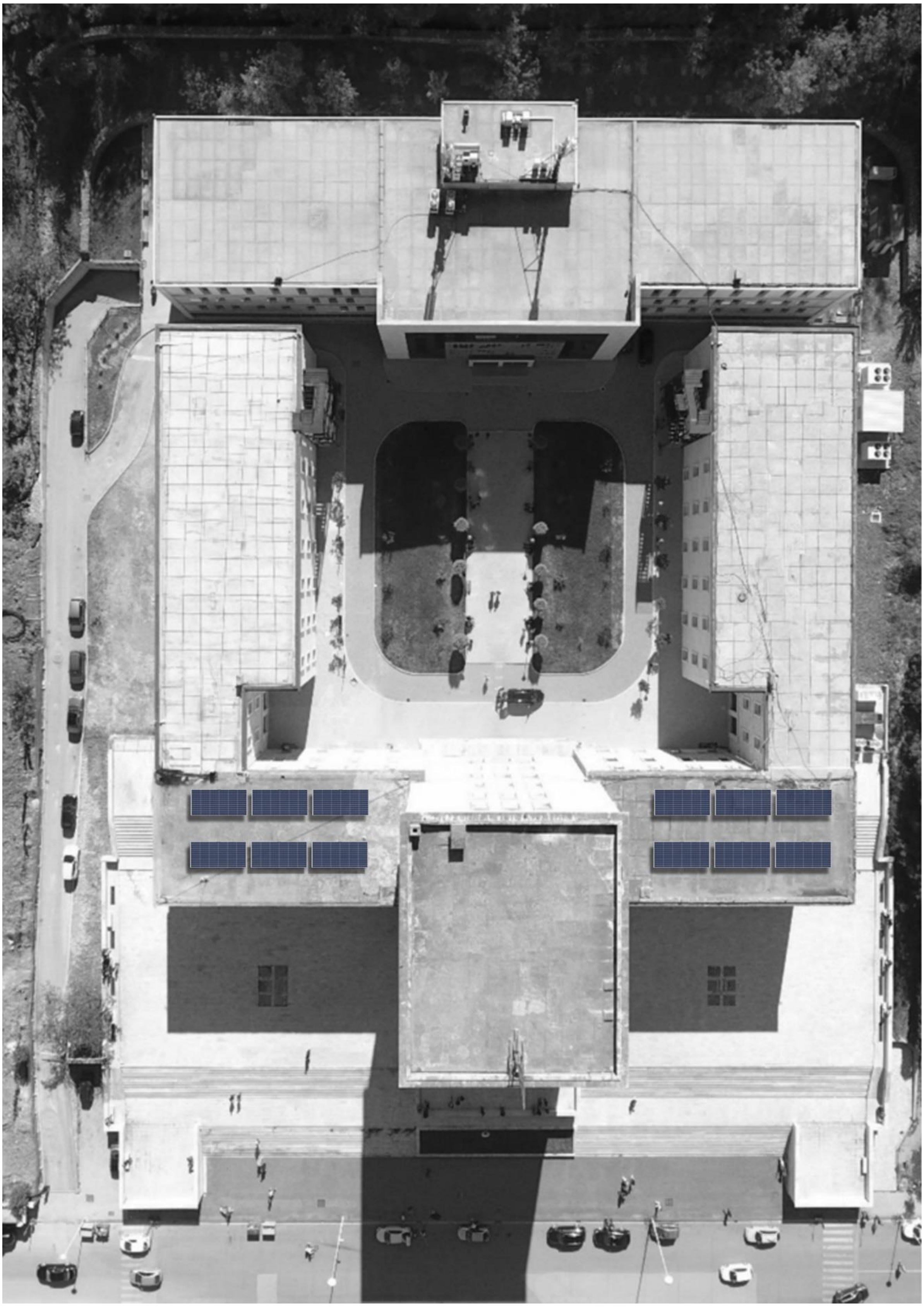


Figure 43. Photovoltaic panels installed on the roof cover a total area of 1231 square meters.

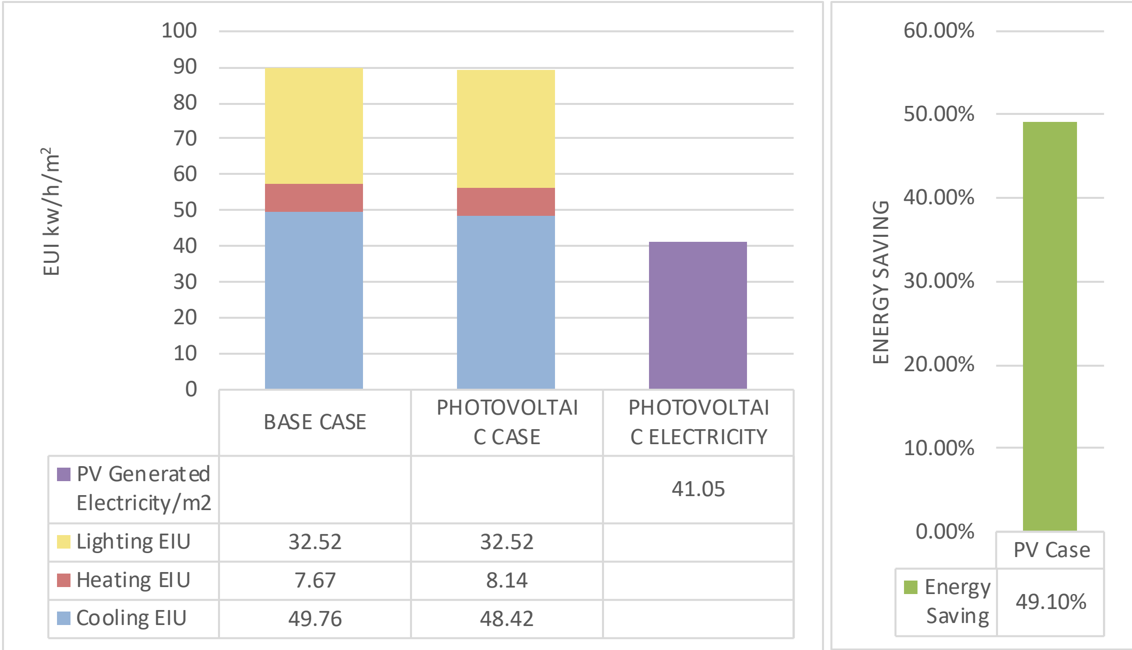


Figure 44. The Cooling, Heating & Lighting Energy Use Intensity (EUI) and energy generation for the built-up area of the PV Generation Case compared to the Base Case.

In analyzing the scenario of PV generation, the energy production for urban areas, including cooling, heating, and lighting Energy Use Intensity (EUI), is compared to a Base Case. The results show a noteworthy 0.8% improvement in energy savings, highlighting the beneficial impact of photovoltaic (PV) generation on overall energy consumption. A key finding is the significant contribution of PV generation to the EUI, with 48.7% specifically allocated to lighting, heating, and cooling systems. This illustrates the crucial role PV generation plays in directly reducing energy demands for these essential building functions. By using solar energy for lighting, heating, and cooling, the building reduces its reliance on traditional energy sources, resulting in both environmental and economic benefits.

Overall, these improvements lead to an impressive 49.1% reduction in energy consumption compared to the Base Case. This considerable decrease highlights the powerful effect of integrating PV generation into a building's energy system. Incorporating renewable energy sources such as solar power not only reduces the building's carbon footprint but also enhances its resilience to energy price fluctuations and supply disruptions.

Additionally, the adoption of PV technology aligns with broader environmental sustainability goals. By harnessing solar energy, buildings can significantly cut greenhouse gas emissions, contributing to global efforts to combat climate change. The reduced dependency on fossil fuels not only mitigates environmental impacts but also promotes energy independence and security.

5.2 MODIFICATION CASES

5.2.1 Comparison of all modification cases

After analyzing the various simulated cases, the Energy Use Intensity (EUI) and corresponding energy savings are summarized as follows:

1. Base Case
2. PV Generation Case
3. Hybrid Approach (Natural Ventilation + Mechanical Systems) Case
4. Double-Glazing Options Case

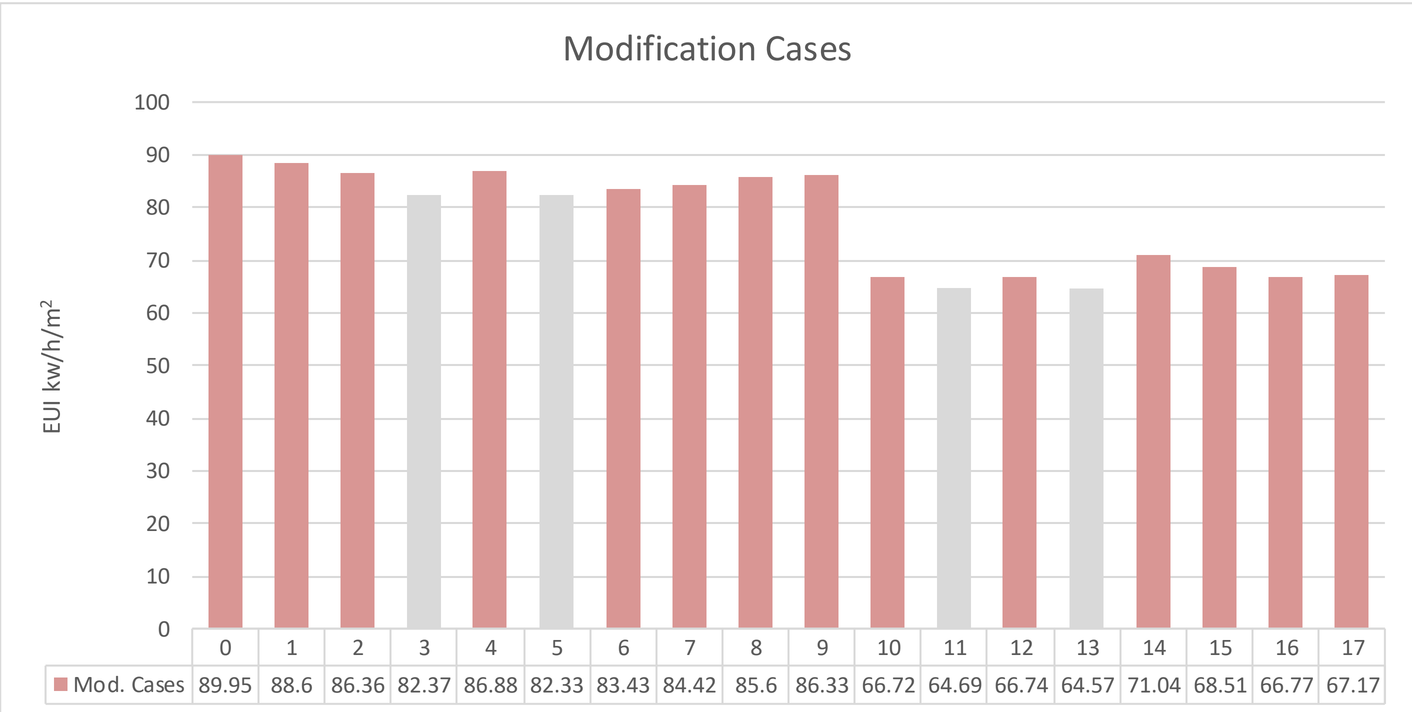


Figure 45. Different modified cases EUI

These representations provide a clear overview of the energy performance and efficiency improvements achieved in each simulated scenario. They serve as valuable insights for decision-making regarding energy-efficient building design and retrofit strategies.

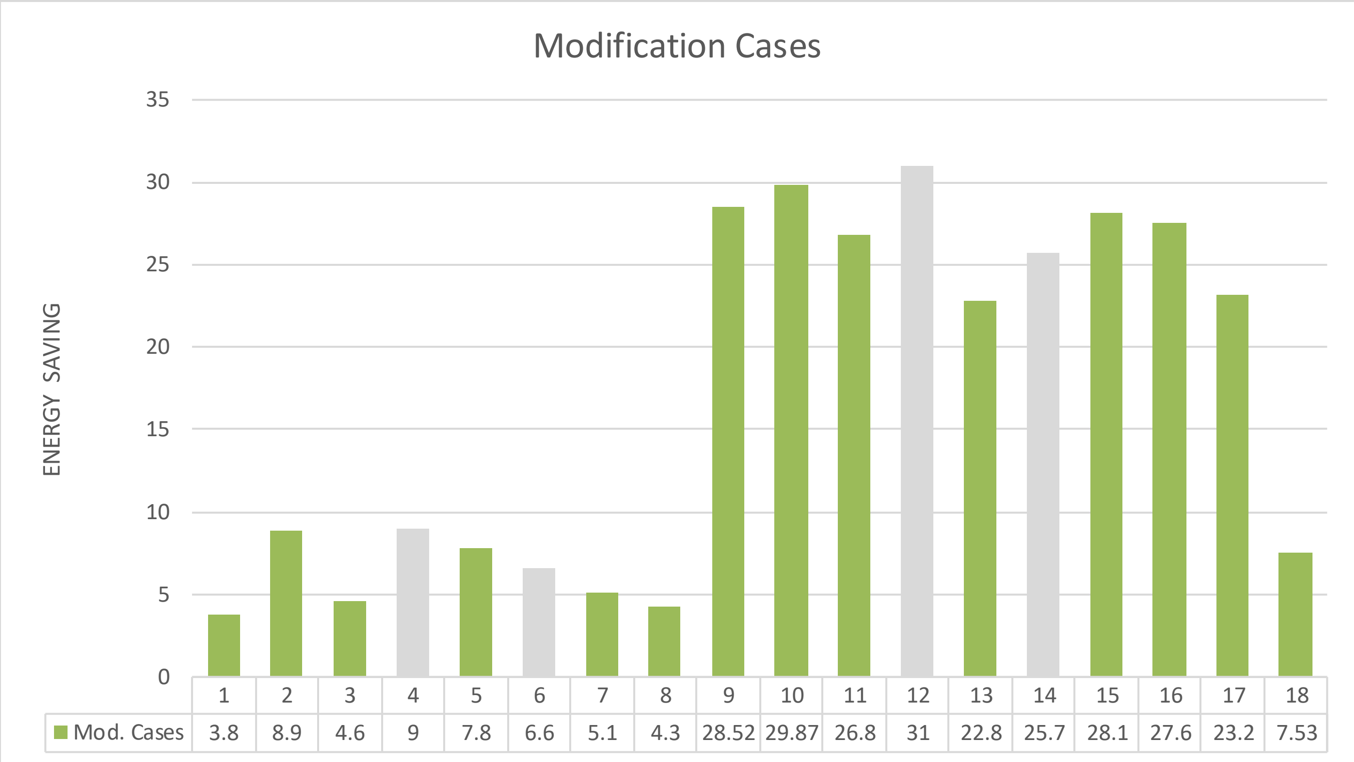


Figure 46. Energy saving percentages

- **Scenarios shown in above graph for Improving Energy Efficiency:**

1. **Base Case**:
    - The starting reference point for comparing all other scenarios.
2. **Wall Insulation**:
    - Adding insulation to the walls to reduce heat transfer and improve energy efficiency.
3. **Clear Double Glass with Air Gap**:
    - Utilizing double-pane clear glass with an air gap to enhance insulation properties and reduce heat loss.
4. **Tinted Double Glass with Air Gap** (Not applicable due to facade preservation):

- Tinted glass reduces solar heat gain but cannot be used due to restrictions on altering exterior appearances.

5. **Clear Double Glass with Argon Gap**:
    - Argon gas between the panes provides better insulation than air, reducing heat transfer further.
6. **Tinted Double Glass with Argon Gap** (Not applicable due to facade preservation):
    - Similar to the above, with enhanced thermal performance, but also restricted by facade preservation.
7. **Clear Double Glass with Internal Louvers Always On**:
    - Internal louvers help control solar heat gain and glare, providing continuous shading.
8. **Clear Double Glass with Internal Louvers Activated at 120 W/m²**:
    - Louvers are activated when solar radiation exceeds 120 W/m², dynamically reducing heat gain.
9. **Clear Double Glass with Internal Louvers Activated at 400 W/m²**:
    - Louvers are activated at a higher threshold, offering a balance between natural light and heat control.
10. **Clear Double Glass with Internal Louvers Activated at 600 W/m²**:
    - Louvers are activated at an even higher threshold, maximizing natural light until solar radiation is very high.
11. **Clear Double Glass with Air Gap + Lighting Control**:
    - Combining improved glazing with lighting control to optimize natural and artificial lighting.
12. **Tinted Double Glass with Air Gap + Lighting Control** (Not applicable due to facade preservation):
    - Integrates both tinted glazing and lighting control, restricted by facade considerations.
13. **Clear Double Glass with Argon Gap + Lighting Control**:
    - Enhances thermal performance with argon gas and optimizes lighting.
14. **Tinted Double Glass with Argon Gap + Lighting Control** (Not applicable due to facade preservation):
    - Combines high-performance glazing and lighting control, but is limited by facade preservation.

15. **Clear Double Glass with Internal Louvers Always On + Lighting Control**:
    - Integrates continuous shading and lighting control for comprehensive energy management.
16. **Clear Double Glass with Internal Louvers Activated at 120 W/m² + Lighting Control**:
    - Dynamically adjusts shading and lighting control based on solar radiation thresholds.
17. **Clear Double Glass with Internal Louvers Activated at 400 W/m² + Lighting Control**:
    - Provides a balance between shading, lighting control, and solar heat gain management.
18. **Clear Double Glass with Internal Louvers Activated at 600 W/m² + Lighting Control**:
    - Maximizes natural light and energy savings with high-threshold louver activation and lighting control.
19. **Window Shading**:
    - External or internal shading solutions to reduce solar heat gain and improve occupant comfort.
20. **Lighting Control**:
    - Systems that adjust lighting based on occupancy and daylight availability to reduce energy use.
21. **Natural Ventilation Only** (Not applicable due to internal thermal comfort):
    - Utilizes natural airflow for cooling and ventilation but is not feasible due to comfort concerns.
22. **Natural Ventilation + HVAC**:
    - Combines natural ventilation with HVAC systems to optimize energy use and maintain comfort.
23. **Photovoltaic Case**:
    - Integration of PV systems to generate renewable energy and offset building energy consumption.

Wall insulation plays a crucial role in reducing heat transfer, which enhances overall energy efficiency. Double glazing options, especially those with argon gaps, improve thermal insulation significantly, with argon providing superior performance.

Internal louvers offer dynamic control of solar heat gain, particularly when combined with advanced lighting control systems. These lighting control systems optimize the use of natural and artificial lighting, further enhancing energy efficiency. Window shading is effective in reducing solar heat gain, and while natural ventilation can be beneficial, it may compromise thermal comfort without HVAC support. Photovoltaic systems generate renewable energy, significantly reducing reliance on traditional energy sources and offering substantial environmental benefits.

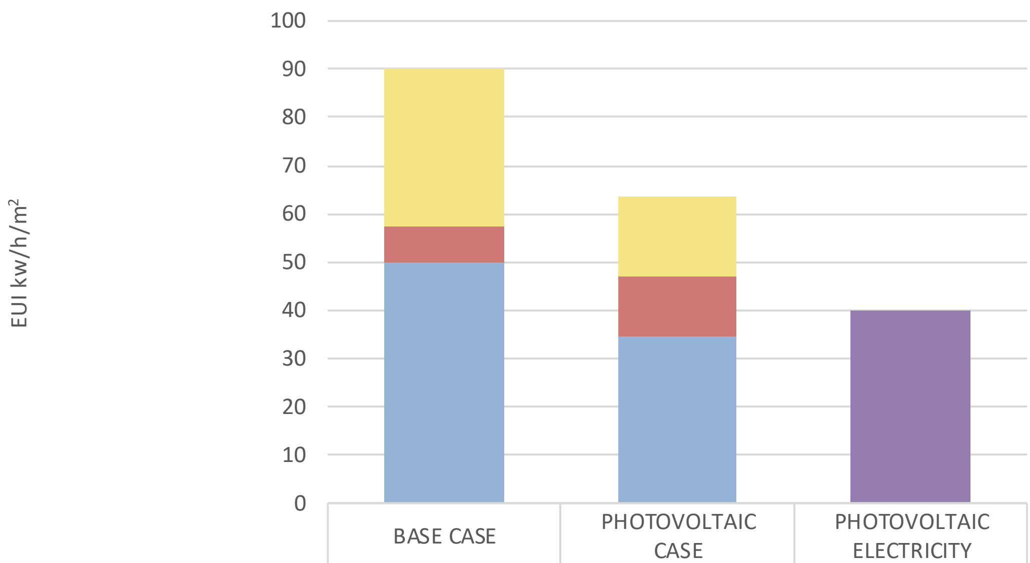
By thoroughly assessing and implementing these strategies, buildings can achieve notable enhancements in energy efficiency, reduced operational costs, and improved sustainability. In this comprehensive scenario, wall insulation was excluded from the considerations since it accounted for only 0.4% of energy savings. Instead, the focus shifted to optimizing more impactful energy-saving measures.

The chosen configuration featured double glazing with internal louvers that activate when solar radiation exceeds 400 W/m^2, providing effective management of solar heat gain. Additionally, atrium shading was incorporated to control internal temperatures, thereby reducing cooling loads. Advanced lighting control systems were integrated to optimize energy use by adjusting illumination based on occupancy and natural light availability. Photovoltaic (PV) panels were also installed to generate renewable energy on-site, decreasing reliance on grid electricity.

To enhance these measures, the heating and cooling systems were paired with natural ventilation, leveraging the building's architectural design to minimize dependence on mechanical systems. This comprehensive approach aimed to balance occupant comfort with sustainability by combining passive design strategies with active technologies.

By integrating these elements, the strategy sought to achieve significant reductions in energy consumption while ensuring occupant comfort and maintaining environmental responsibility. This holistic approach underscores a commitment to optimizing building performance and harnessing renewable energy sources for a sustainable future.

Furthermore, this strategy exemplifies an integrated approach to building design, where every component works together to maximize efficiency and sustainability. The exclusion of minor contributors like wall insulation in favor of more impactful solutions highlights the importance of targeted interventions in achieving substantial energy savings. The incorporation of both passive and active design elements demonstrates a forward-thinking approach to modern building management, ensuring that buildings are not only energy-efficient but also adaptable to future technological advancements and environmental challenges.



	BASE CASE	PHOTOVOLTAIC CASE	PHOTOVOLTAIC ELECTRICITY
PV Generated Electricity/m2			40.13
Lighting EIU	32.52	16.4	
Heating EIU	7.67	12.74	
Cooling EIU	49.76	34.4	

Figure 47. Comparing the Proposed Modifications to the Base Case shows a 32.2% energy saving and 69.8% energy generation of the Cooling, Heating & Lighting EUI.

The analysis of the combined case revealed a significant 33.8% reduction in cooling Energy Use Intensity (EUI), a substantial 52.6% reduction in lighting EUI, but a notable 70.1% increase in heating EUI. Despite the rise in heating EUI, the total energy consumption saw an impressive reduction of 32.2%, with generated energy contributing to 68.8% of the total energy consumed.

The increase in heating EUI was primarily due to the reduced heat gain from internal lighting and decreased solar heat gain because of the implemented shading measures. While these strategies effectively lowered cooling demands and lighting energy use, they inadvertently increased the energy required for heating.

To address this issue, the simulation was rerun with the reintroduction of wall insulation. This adjustment significantly mitigated the increase in heating energy, bringing it down to a manageable 5.4%. As a result, total energy savings improved to an impressive 36.5%, and the share of generated energy rose to 74.7%.

This reevaluation highlights the importance of a comprehensive approach to energy efficiency, considering the interplay between various building components and systems. By optimizing insulation in conjunction with other energy-saving measures such as shading and lighting control, a more balanced and effective strategy can be achieved. This approach not only reduces overall energy consumption but also maximizes the contribution of renewable energy sources like photovoltaic panels.

In summary, the analysis emphasizes the need for a holistic view in energy-efficient building design. By carefully considering the interactions between different elements and making necessary adjustments, it is possible to achieve significant energy savings and enhance the sustainability of buildings.

5.3 Analyses Comparison with previous studies

In this section we will compare our findings with those from previous sustainability projects, like the Villa Antoniadis case study in Alexandria, Egypt [20] . By doing this, we can see how our results stack up and identify the best practices for improving energy efficiency and sustainability in heritage buildings. This comparison will help us understand what works well and what can be improved, providing valuable insights for future projects.

5.3.1 Thermal Insulation Case

The slight improvement in cooling and heating Energy Use Intensity (EUI) compared to the base case can be explained by several factors unique to the building and its environment. Firstly, if the existing walls already have good insulation, adding more during retrofitting might not make a big difference, as the extra insulation might not lead to significant energy savings. Secondly, Tirana's moderate climate means there's less heat gain or loss compared to places with more extreme temperatures. This results in lower heating and cooling needs, limiting the potential for major EUI improvements through retrofitting. Lastly, a high window-to-wall ratio can make the building more susceptible to heat gain or loss through windows. In warmer climates, this increases cooling demands, while in cooler climates, it raises heating needs. So, it's essential to consider the impact of windows on overall energy performance to optimize cooling and heating EUI.

When we compare this to the Villa Antoniadis case study in Alexandria, Egypt, we see different results. Alexandria has a hot steppe climate, where thermal insulation is much more effective in reducing EUI. In such climates, insulation plays a bigger role in lowering energy use, leading to more significant improvements in EUI compared to Tirana's moderate climate.

5.3.2 Lighting Control Case

In our case the results show a 56% improvement in lighting energy consumption. While cooling energy consumption decreased by 9.1%, heating energy consumption increased by 16.8% due to the reduced heat gain from artificial lighting. However, the overall energy use intensity improved by 23.9%.

In the Villa Antoniadis case study, the results showed a 47% improvement in lighting energy consumption. Cooling energy consumption decreased by 8.3%, and heating energy consumption increased by 19.2%. Despite this, the overall energy use intensity for cooling, heating, and lighting improved by 18.2%.

Comparing the two scenarios, we see that both show substantial overall improvements in energy efficiency thanks to lighting control and other energy-saving measures. The first scenario achieved a 23.9% improvement in energy use intensity, while the Villa Antoniadis case study saw an 18.2% improvement. Despite some differences in specific outcomes, the results highlight the significant impact of implementing effective lighting controls and energy-saving strategies in both cases.

5.1.3 Double Glazing Case

The results of Polytechnic University of Tirana demonstrate varying improvements in cooling and heating Energy Use Intensity (EUI), with the highest improvements observed in the tinted glass cases (9%) and internal louvers cases (7.7%). However, these options could impact daylighting levels, potentially increasing lighting energy consumption if lighting controls are in place.

In the Villa Antoniadis the results indicated improvements in cooling and heating Energy Use Intensity (EUI), using tinted glass by 11% and internal louvers by 8.1%.

Comparing the two cases, the difference in energy savings is largely due to the orientation of the buildings and their surrounding environments. In the Villa Antoniadis case, the higher energy savings from using double glazing can be attributed to the way the building is positioned and the presence of surrounding vegetation. These factors enhance the effectiveness of the double glazing, leading to greater energy savings. The unique features of the Villa Antoniadis site help explain why this approach was more successful there compared to other scenarios.

5.1.4 Implementing shading for façade Case

The simulation results show a 14.4% improvement in cooling Energy Use Intensity (EUI) and a 6.5% reduction in heating EUI, thanks to tinted glass and internal louvers. However, this may lead to increased heating needs in winter. Despite this, overall energy consumption for heating and cooling improved by 11.6%, and total EUI for heating, cooling, and lighting improved by 7.4%. This indicates that double glazing and internal lighting controls significantly enhance the building's energy efficiency.

The simulation showed a 17.6% improvement in the building’s cooling energy use, while heating energy use decreased by 8.2% due to reduced heat gain. This might mean using more energy for heating in winter. However, the overall energy consumption for both heating and cooling improved by 12.6%, and when we include lighting, the total energy use improved by 8.7%.

When we compare the two cases, we see that the values for the facade shaders are quite similar. However, the Alexandria case stands out because it has a larger glass surface area and experiences higher temperatures. These differences in climate and building design significantly impact the overall energy performance and the effectiveness of the energy-saving measures.

5.1.5 Natural Ventilation Case

In the base case scenario of Polytechnic University, the building used conventional methods for temperature control, keeping indoor temperatures between 19°C and 28°C. However, when we switched to using only natural ventilation, the temperature range became much wider, going from 18°C to 35°C. This change resulted in an impressive 63.7% reduction in energy consumption, but it significantly impacted indoor comfort.

Compared to the Alexandria case, we see a more significant effect of ventilation on energy consumption due to the climate and temperatures in Tirana, which are lower than those in Alexandria. In Tirana, natural ventilation had a greater impact on reducing energy use because the milder temperatures made it more effective. In contrast, the hotter climate in Alexandria means that ventilation alone isn't as efficient at maintaining comfortable indoor temperatures, leading to less dramatic energy savings. This highlights how local climate conditions play a crucial role in the effectiveness of energy-saving strategies.

5.1.6 Photovoltaic Panels Case

The improvements of Polytechnic University lead to an impressive 49.1% reduction in energy consumption compared to the base case. This significant decrease highlights the powerful effect of integrating PV generation into a building's energy system. Incorporating renewable energy sources, such as solar power, not only reduces the building's carbon footprint but also enhances its resilience to energy price fluctuations and supply disruptions.

In Alexandria, the energy reduction is 40.7%, which is quite close to the reduction we achieved but slightly lower. This is mainly because the higher temperatures in Alexandria lead to higher energy consumption. Despite this difference, both cases show significant energy savings, highlighting how effective renewable energy sources like solar power can be in cutting down overall energy use.

5.4 Thermal Analyses in DesignBuilder

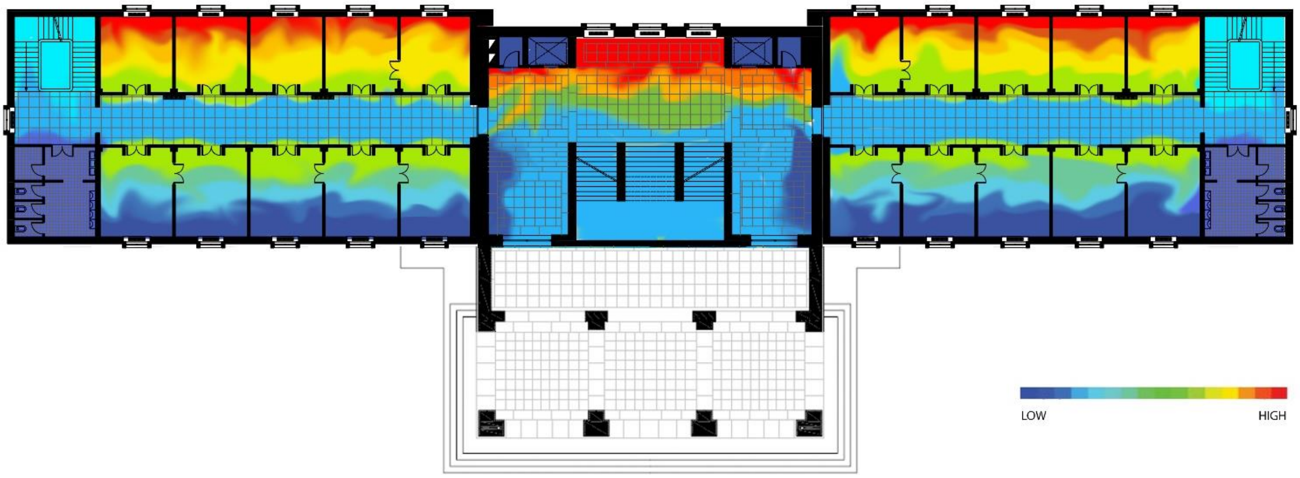


Figure 48. Thermal analysis of the ground floor of the existing building without interventions, worked in DesignBuilder

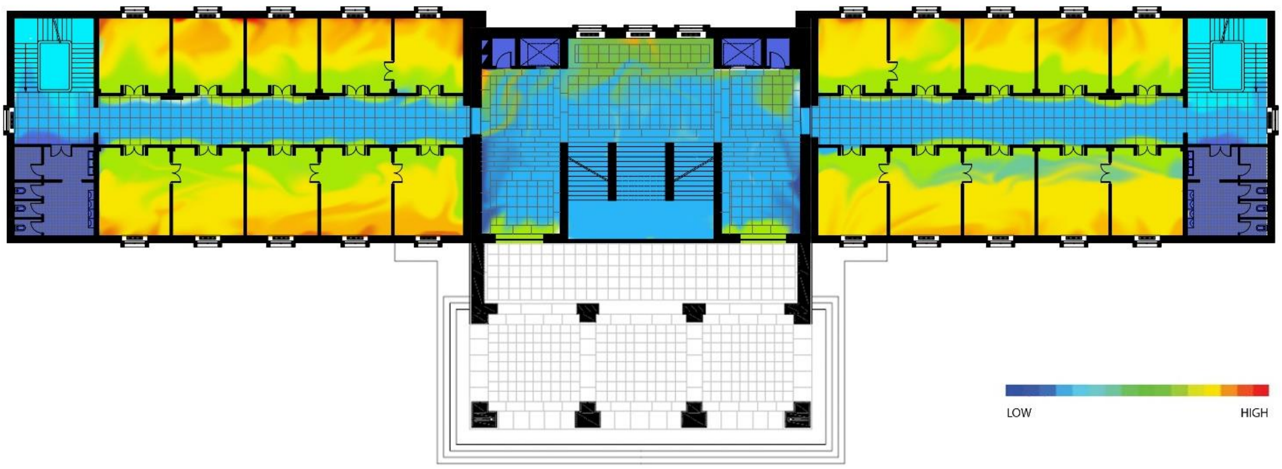


Figure 49. Thermal analysis of the ground floor of the existing building after interventions, worked in DesignBuilder

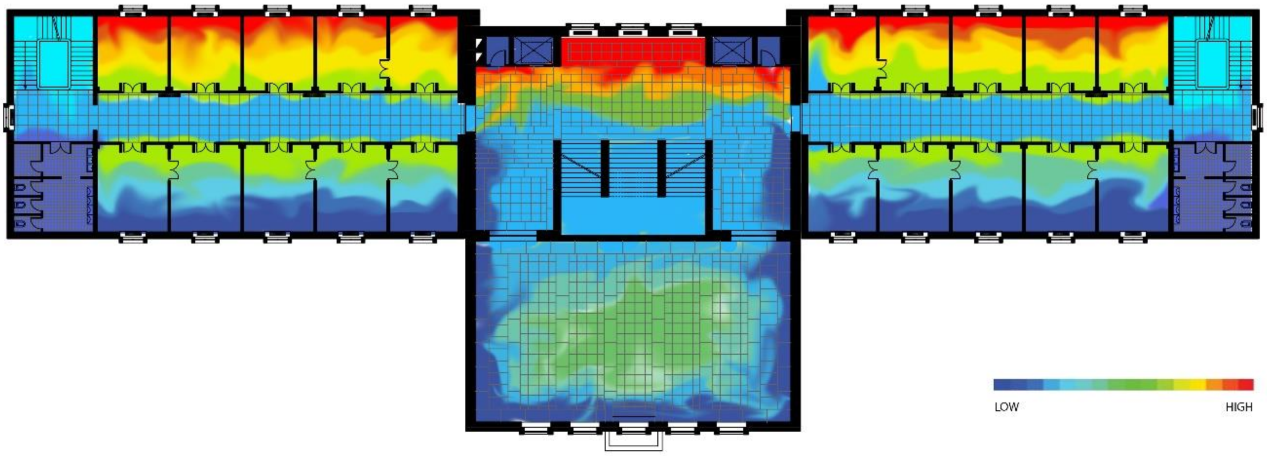


Figure 50. Thermal analysis of the first and second floor of the existing building without interventions, worked in DesignBuilder

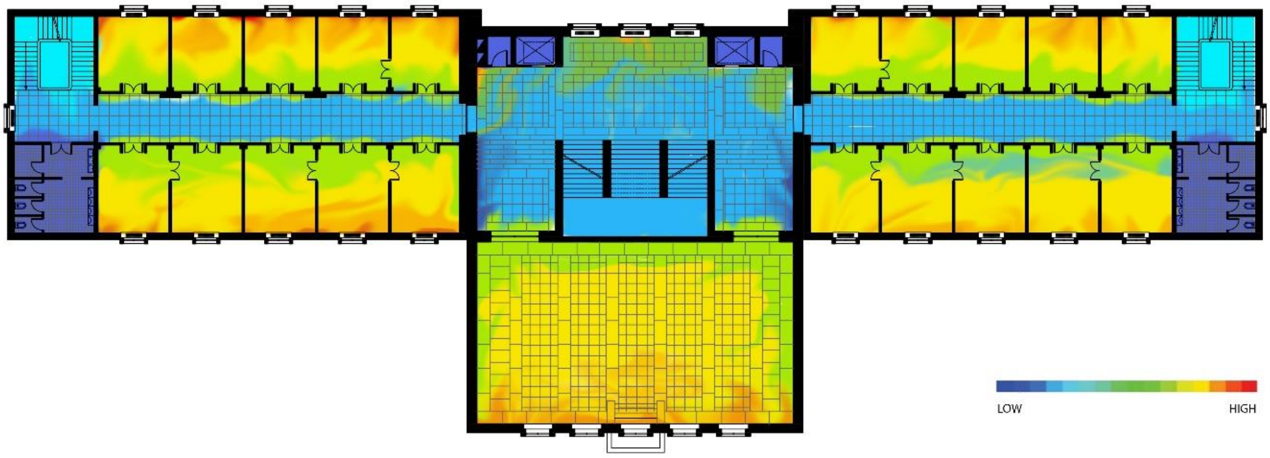


Figure 51. Thermal analysis of the first and second floor of the existing building after interventions, worked in DesignBuilder

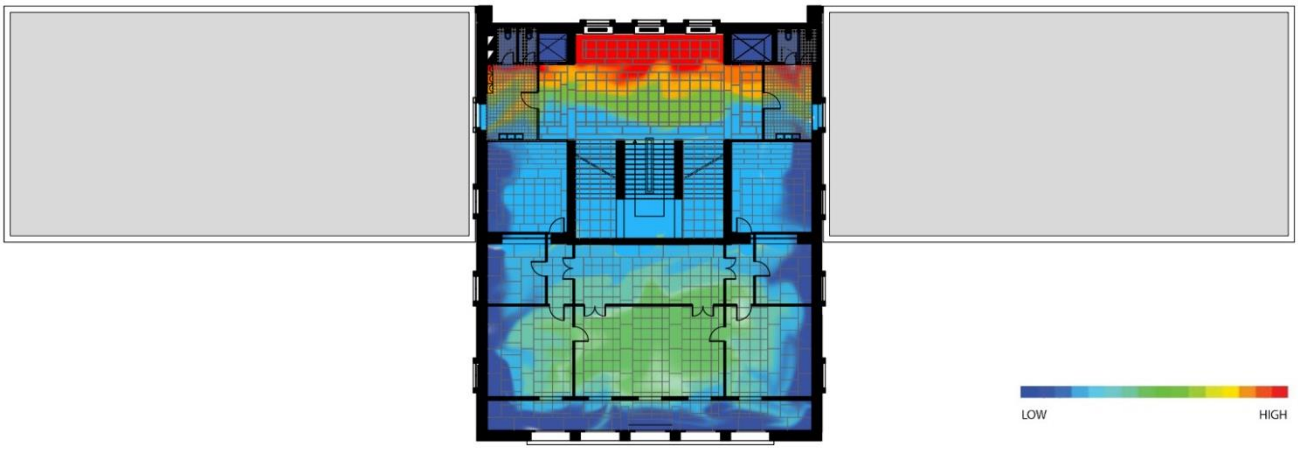


Figure 52. Thermal analysis of the third and fourth floor of the existing building without interventions, worked in DesignBuilder

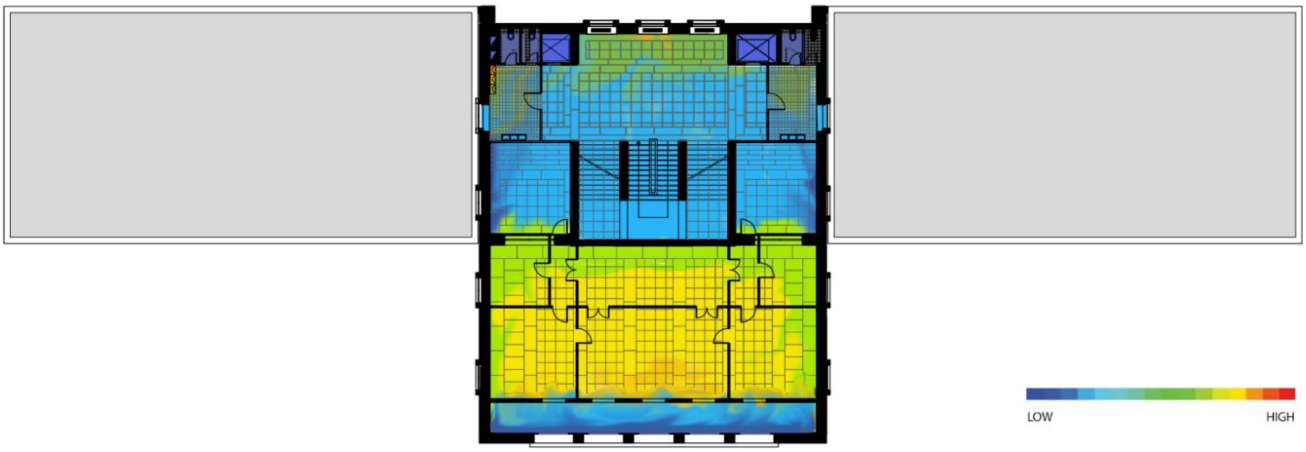


Figure 53. Thermal analysis of the third and fourth floor of the existing building after interventions, worked in DesignBuilder

6. CONCLUSIONS

Sustainability and conservation are closely linked in their mission to protect valuable natural and cultural resources for future generations. Heritage buildings naturally embody sustainability through their construction and use of passive thermal and lighting treatments. Preserving these buildings is crucial for socio-cultural and economic sustainability, as it maintains both their physical integrity and their cultural significance. Enhancing the environmental performance of these structures further boosts their overall sustainability. Embracing a 'reuse' philosophy in conservation efforts maximizes environmental, economic, and socio-cultural benefits.

Given the diverse nature of heritage buildings, finding the right conservation methods requires careful thought and collaboration among various stakeholders. Using building energy simulation software is essential for predicting a structure's behavior and assessing potential energy-saving measures. In places with moderate climates, like Alexandria, passive treatments alone might not be as effective, so active measures such as lighting control and solar energy become important to reduce energy consumption.

Heritage buildings have inherent embodied energy, reflecting the energy used in their construction, which underscores their sustainability by reducing the need for new materials. Features like natural ventilation and daylighting are often integral to these buildings, cutting down on the need for mechanical systems and additional energy consumption.

Preserving heritage buildings maintains their cultural significance and fosters community identity. Economically, conservation can boost local economies through tourism and the revitalization of historic areas. Improving these buildings' environmental performance, such as enhancing insulation or installing energy-efficient windows, can significantly reduce their carbon footprint. The concept of 'reuse' in conservation emphasizes adapting heritage buildings for new uses, which can be more sustainable than demolition and new construction.

Building energy simulation software helps analyze a building's energy performance in detail, identifying the most effective energy-saving measures. These tools can model different scenarios, allowing conservationists to optimize both passive and active interventions tailored to the building's specific climate and structure.

In moderate climates, passive strategies alone might not be enough to achieve significant energy savings. Therefore, active measures like advanced lighting controls and solar energy systems are essential to complement passive techniques and achieve comprehensive energy efficiency. Effective conservation requires collaboration among architects, engineers, historians, and local communities to ensure that interventions respect the building's heritage while enhancing its sustainability. This multidisciplinary approach ensures that all aspects of the building's value are considered, leading to balanced and sustainable outcomes.

In conclusion, aligning sustainability and conservation in heritage building preservation offers a comprehensive approach to protecting cultural heritage while improving environmental performance. Using advanced tools and collaborative strategies ensures that heritage buildings remain vibrant and sustainable assets for future generations.

In our base case, the building's Cooling, Heating, and Lighting Energy Use Intensity (EUI) was 89.95 kWh/m². Comparing this with different scenarios, the Insulation Case showed a slight decrease of 0.43% in EUI. On the other hand, the Lighting Control Case demonstrated significant savings of 24.18% in EUI compared to the base case.

Further analysis revealed various improvements in cooling and heating EUI, with the highest gains seen in the use of tinted glass (9%) and internal louvers (7.7%). However, these measures might affect daylighting levels, potentially increasing lighting energy consumption if lighting controls are implemented.

The Facade Shading Case achieved a 7.53% energy saving in EUI compared to the base case. Meanwhile, the Natural Ventilation Case and the Natural Ventilation + HVAC Case showed substantial energy savings of 63.7% and 3.7%, respectively, when compared to the base case.

Exploring the impact of PV generation in urban areas, we found a notable 0.8% improvement in energy savings over the base case. PV generation contributed significantly to the EUI, with 48.7% of the energy specifically allocated to lighting, heating, and cooling systems.

By thoroughly assessing and implementing these strategies, buildings can achieve significant improvements in energy efficiency, lower operational costs, and enhanced sustainability. In our comprehensive scenario, wall insulation was excluded due to its minimal contribution of 0.4% to energy savings, allowing us to focus on more impactful energy-saving measures.

Analyzing the cost efficiency of the given interventions involves considering various factors. Incorporating thermal insulation reduces heat transfer through walls and roofs, requiring an initial investment in materials and installation but leading to long-term savings on heating and cooling costs. Installing double glazing on exterior openings involves a higher upfront cost compared to single-pane windows but results in improved thermal insulation and reduced HVAC load, lowering energy bills over time.

Implementing internal shading devices, such as awnings or louvers, controls solar heat gain and glare, requiring installation and maintenance costs but reducing cooling demand and enhancing occupant comfort. Employing internal lighting control systems, including occupancy sensors and dimmers, optimizes lighting usage based on occupancy and daylight availability, leading to energy savings despite initial setup costs.

Utilizing natural ventilation reduces reliance on mechanical cooling systems, improving indoor air quality and potentially lowering overall energy consumption with minimal ongoing costs. Installing photovoltaic panels on the roofs involves significant initial investment in equipment and installation but generates renewable electricity, offsetting grid consumption and offering long-term savings on electricity bills.

Each intervention offers potential cost savings over the building's lifespan, depending on factors such as local climate conditions, building usage patterns, and available financial incentives for energy-efficient upgrades. A comprehensive cost-effectiveness analysis would consider lifecycle costs, maintenance expenses, energy savings, and potential financial incentives to determine the most beneficial interventions for enhancing energy efficiency at the Polytechnic University of Tirana.

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[9] R. Renzi, "Regime e rappresentazione," Bloom n. 13, 2012, pp. 73-77, edited by the Ph.D. Program in Planning of the University of Naples.

[10] The Archive of Bosio's Heirs (hereafter A.E.B.), now held by the granddaughter Marie Lou Busi, the relations with the ministry are controversial.

[11] Within the urban plan, many project sketches of the Casa del Fascio have been found. It is conceived as the culminating point of the axis of the Avenue of the Empire.

[12] From the maps in the A.E.B., Tirana appears in 1939 as a city with low-density construction systems spread across the territory.

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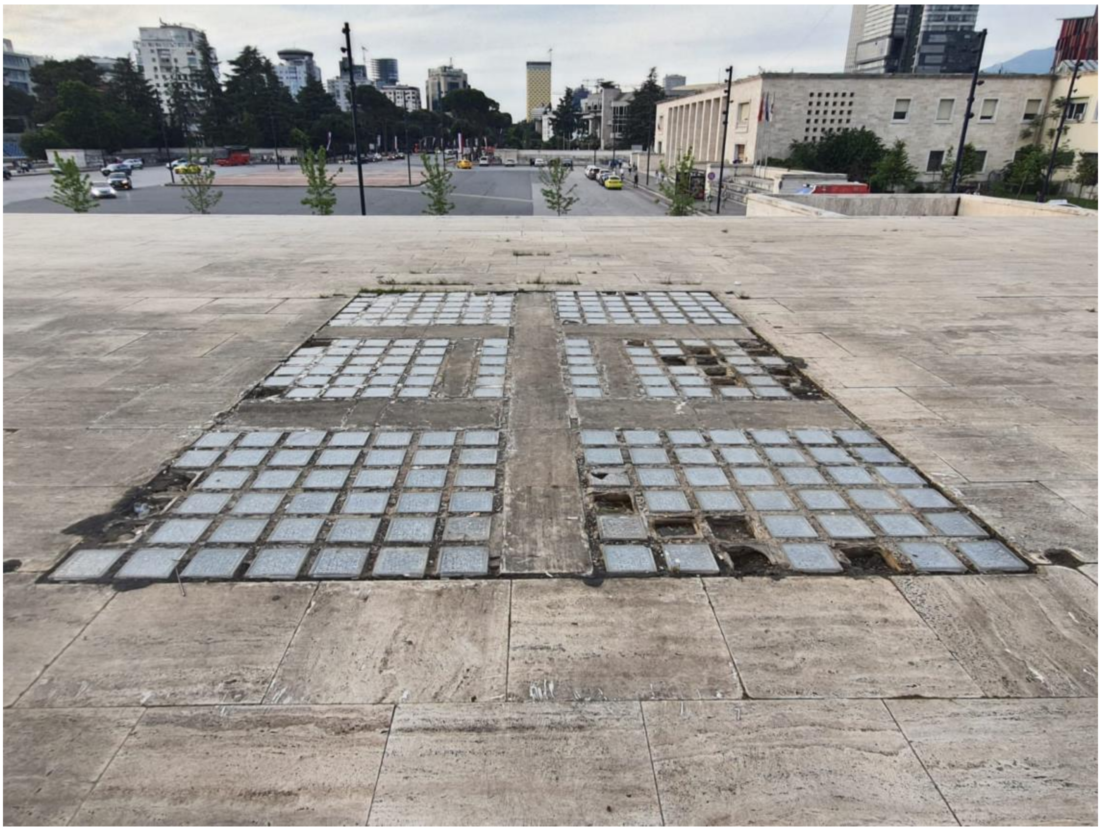
[20] Implementing Sustainability in Retrofitting Heritage Buildings. Case Study: Villa Antoniadis, Alexandria, Egypt Ahmed M. R. Khalil *, Naglaa Y. Hammouda and Khaled F. El-Deeb

APPENDIX

Photographs depicting the current condition of the object.



Records retrieved from the central repository.