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CAPSTONE DESIGN & RESEARCH PROJECT III

SEMELI HOTEL

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CHAPTER 1: INTRODUCTION

1.1. INTRODUCTION TO CAPSTONE DESIGN & RESEARCH PROJECT III

The analysis of the Semeli Hotel, an important architectural element in the center of Nicosia, constitutes a substantial study with multiple aspects. The selection of this building was based on a series of criteria concerning its architectural dynamics, strategic location, and potential for improvement regarding functionality and sustainability.

While the building fulfills its initial purpose to a limited extent, it presents significant opportunities for enhancement, particularly regarding energy efficiency and thermal comfort. The design of the hotel does not fully meet the modern sustainability requirements in terms of thermal performance and the use of natural resources, such as natural light and passive shading. At the same time, the analysis of the existing context highlights considerable opportunities for reducing energy consumption and improving the overall user experience.

The building offers a unique opportunity for redesign and upgrading, and this study aims to evaluate practical solutions that could be applied to other similar projects. This study adopts a multi-dimensional approach that goes beyond simple architectural analysis.

Initially, the topography, land uses, and solar conditions were analyzed in detail through an in-depth site study, followed by the analysis of technical and meteorological data, with particular emphasis on recording thermal conditions and comfort levels within the building.

At a subsequent stage, and based on the questionnaire results, a simulation was conducted using the DesignBuilder software in order to assess how the building's conditions would be affected following the energy upgrade and the modifications to the building envelope. Based on the interventions implemented within the software, feasibility studies were then carried out to evaluate the viability and cost-effectiveness of the proposed investments.

At the same time, particular attention was given to the human experience through data collection via questionnaires. These questionnaires were designed to capture the perceptions of visitors and staff regarding thermal comfort during different seasons of the year.

The results from the analysis of the questionnaires are directly linked to the simulation observations, in order to better understand the relationship between the building's energy characteristics and the quality of the user experience.

At a subsequent stage, and based on the questionnaires, a simulation was conducted using the DesignBuilder software to estimate how the building's condition would be affected after the energy upgrade and the changes made to the building envelope.

In summary, the study aimed to integrate data from different scientific fields to achieve a comprehensive understanding of the Semeli Hotel. This process included identifying issues, proposing solutions, and evaluating the potential for adapting the building to future needs, while maintaining its role as a significant architectural landmark in Nicosia.

1.2. AREA ANALYSIS

The Semeli Hotel, located in the heart of the capital, Nicosia, holds significant architectural and residential value for the city. Relevant areas that impact this analysis include traffic flow, property distribution, flora, geomorphology, and solar maps. The space analysis is expected to be accompanied by documentation, which will include either stereoscopic or illustrated diagrams, as well as an outline of potential limitations that may affect the future development prospects of the area.

Next, the location of the hotel is presented at a scale of 1:2000.



Image 1.2. Location of Semeli Hotel S C A L E 1 : 2 0 0 0

CHAPTER 2: SITE ANALYSIS

2.1. ANALYSIS OF SATELLITE IMAGE

The image below presents a detailed approach to the location of the Semeli Hotel through four thematic sections that highlight the key elements of its spatial and urban positioning:



Diagram 2.1. Analysis of Satellite Image

➤ **RESIDENTIAL AREAS**

The first section emphasizes that the hotel is situated within a residential area. The diagram shows that the hotel is surrounded by residential zones, depicted in dark red. This information is important for understanding the dynamics of the neighborhood, housing density, potential noise pollution, or the need to maintain privacy and tranquility within the hotel premises.

➤ **ACCESS TO THE HOTEL (ACCESS POINTS)**

The second section describes the access points to the hotel, marked by red lines. The main access points are directly connected to the hotel and the surrounding urban fabric. Accessibility is a crucial factor for the functioning of the space, facilitating the flow of visitors and staff.

➤ **MAIN ROADS**

The third section focuses on the main roads close to the hotel. These roads, indicated by red lines, provide direct connections to the surrounding area. The main roads are easily accessible by car, which is particularly important for tourists and business travelers.

➤ **HIGH AND LOW TRAFFIC ROADS (SECONDARY ROADS)**

The fourth section highlights the secondary roads, which identify areas with lower traffic volume. These roads provide quieter connections and are useful for serving the residents of the area and pedestrians. Analyzing this element is also important for designing access for logistics and field support services.

➤ **OVERALL RESULTS**

The images at a 1:2000 scale provide a comprehensive view of the urban development surrounding the hotel. The analysis of built areas, access points, and road networks reveals the significant position of the hotel in a vibrant, complex, and connected urban area. These data are valuable for optimizing the use of space, both in terms of functionality and architecture.

2.2. TRAFFIC DENSITY

The data regarding traffic density in the hotel's area are presented. The data were collected every two hours during the busiest day of the week, with the aim of understanding the noise levels. The findings indicate that one direction of the area experiences higher levels of noise pollution. This makes the application of a double-skin facade in that direction necessary to ensure the building's sound insulation.

The scale of the map is 1:40000, providing a broad overview of the area. Below are the detailed observations:

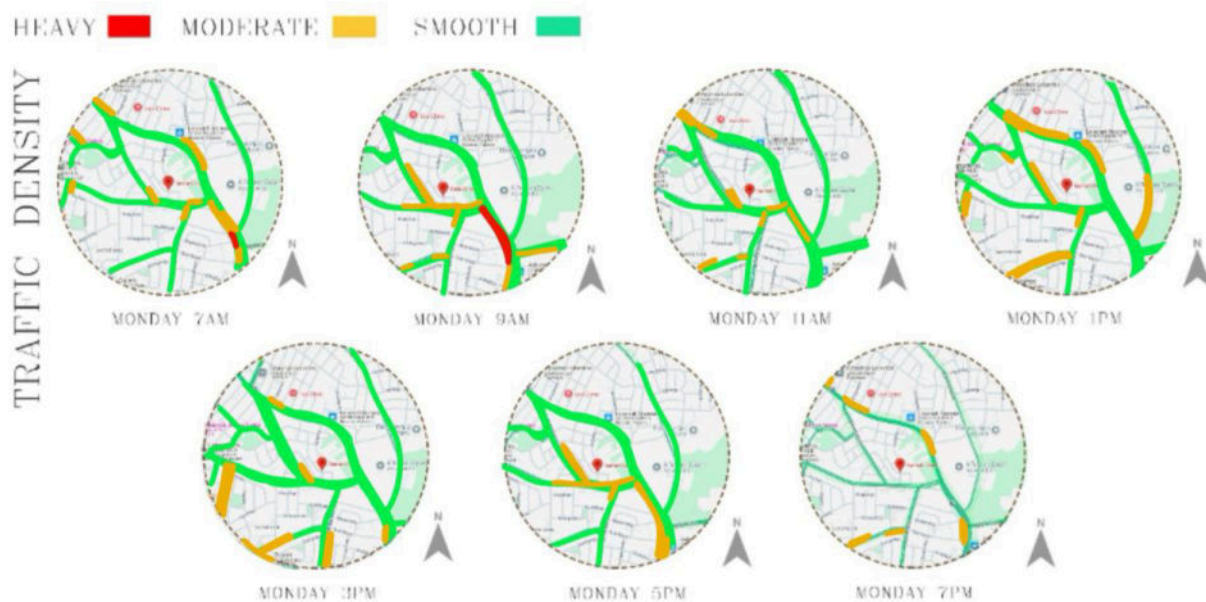


Diagram 2.2. Traffic Density

- **07:00 a.m.** – The traffic is generally smooth (green), with some moderate (yellow) spots on the main roads. Overall, traffic flow is relatively smooth.
- **09:00 a.m.** – A significant increase in traffic, with clear signs of congestion (red). This is the peak time for commuting to work or school.
- **11:00 a.m.** – Traffic decreases, with smoother flow (green) and moderate traffic (yellow) observed.
- **13:00 p.m.** – Traffic is mainly smooth (green), with some moderate (yellow) spots.
- **15:00 p.m.** – Traffic remains smooth (green) and moderate (yellow).
- **17:00 p.m.** – Traffic is smooth (green) with some moderate (yellow) spots. Moderate traffic is observed on the roads in front of the hotel.
- **19:00 p.m.** – Traffic is mainly smooth (green), with some moderate (yellow) spots on the main roads. Traffic flow is relatively smooth.

In summary, moderate traffic is observed on the nearby roads of the hotel, particularly during the hours of 09:00 a.m., 01:00 p.m., and 05:00 p.m. The hour of 09:00 a.m. stands out for the highest traffic density at the traffic lights due to people commuting to their workplaces. Additionally, during these specific hours, increased noise levels are observed in the area.

2.3. USER AREA ANALYSIS

According to the diagram of the analysis of regional users, the majority of users are residents of the surrounding areas, representing a relatively large percentage of activity. Students make up 10%, while 5% are tourists and workers. This distribution highlights the diversity of users and underscores the need for plans that cater to the needs of all groups.



Diagram 2.3. User Area Analysis

2.4. MASTERPLAN

The general plan of the area, as shown in the image, reveals the overall urban layout, providing crucial information about the space and the location of the Semeli Hotel. The area includes main and secondary roads, green spaces, school facilities, and parking infrastructures. The Semeli Hotel is marked in red, highlighting its strategic location in relation to the surrounding roads and facilities.

The scale of the plan (1:2000) offers precise information about distances and the arrangement of elements. It can be observed that the hotel is located in close proximity to the main road, which is depicted in dark yellow (Main Road), facilitating access for both vehicles and pedestrians. Additionally, the proximity of green spaces and school facilities (School Field) enhances the character of the area as a vibrant and multifaceted environment.

The presence of multiple parking areas (Parking) indicates that the area is well-served in terms of infrastructure. However, the fact that the hotel itself does not have private parking space for its staff and guests affects its functionality. In conclusion, the strategic location of the Semeli Hotel combines easy access and connectivity with a diverse urban environment, making it ideal for both leisure and business activities.

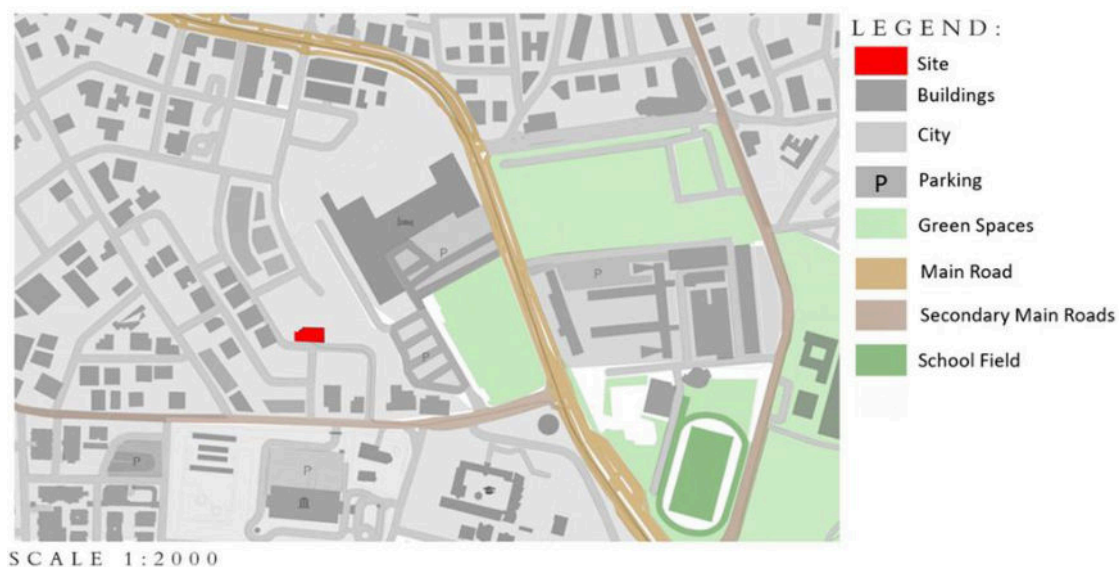


Image 2.4. Masterplan

2.5. CONTOUR LINES

The contour lines indicate that the hotel is located at an elevation of 166-167 meters above sea level. The flat topography facilitates construction and reduces infrastructure costs. The map's detail, with a scale of 1:2000, provides important information regarding the elevation differences.

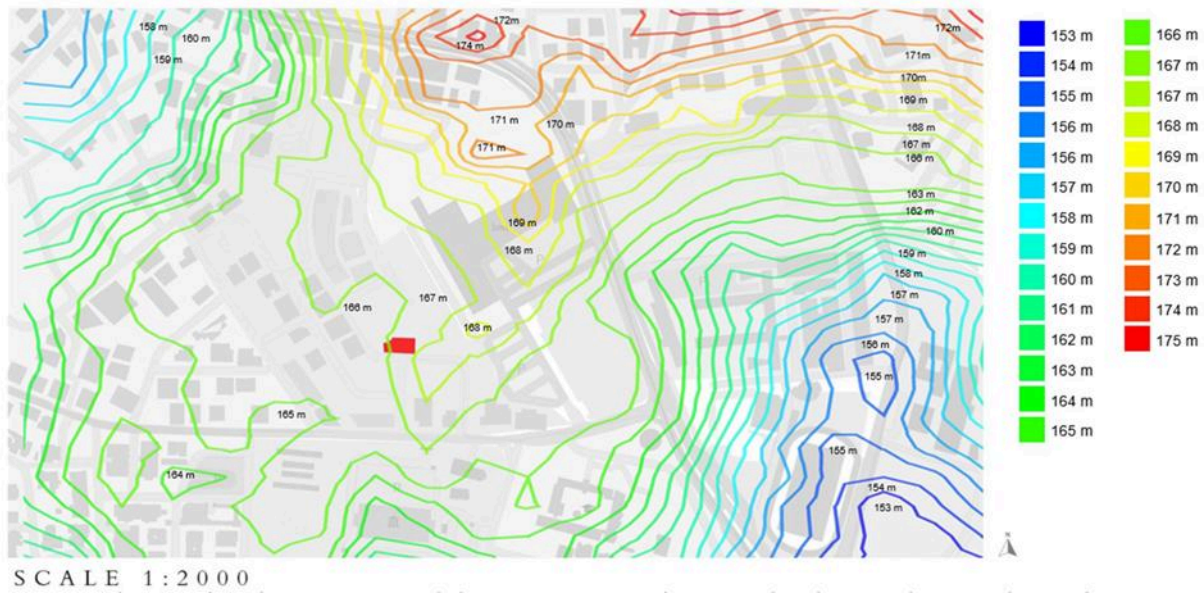


Image 2.5. Contour Lines

2.6. SUNPATH DIAGRAMS

The solar diagrams are presented next: on the left for the summer solstice and on the right for the winter solstice. The sun's paths illustrate the sunrise and sunset, as well as the shading of the hotel during these specific periods. These data are crucial for energy efficiency and natural lighting design. The scale is 1:10000.

➤ SUMMER SOLSTICE

On June 20, 2024 – 14:38, the day of the summer solstice, when summer is at its peak (hence the choice of these two dates), the sun's trajectory shows that the area receives a large amount of solar radiation throughout the day. The shadow is limited, and the main surfaces of the hotel are exposed to intense light. This information is important for optimizing natural lighting inside the hotel and designing outdoor spaces to provide natural shading.

➤ WINTER SOLSTICE

On December 21, 2024 – 14:38, the day of the winter solstice, the sun passes low in the sky, resulting in large shadows. Since natural lighting in the hotel area may be reduced, strategic planning is required to harness solar energy, such as installing solar collectors and using materials with high reflectivity.

➤ CONCLUSIONS FROM THE DIAGRAMS

The solar diagram shows that the design of the hotel must be flexible to adapt to seasonal variations in light and temperature. This information helps in creating energy-efficient and environmentally sustainable designs.

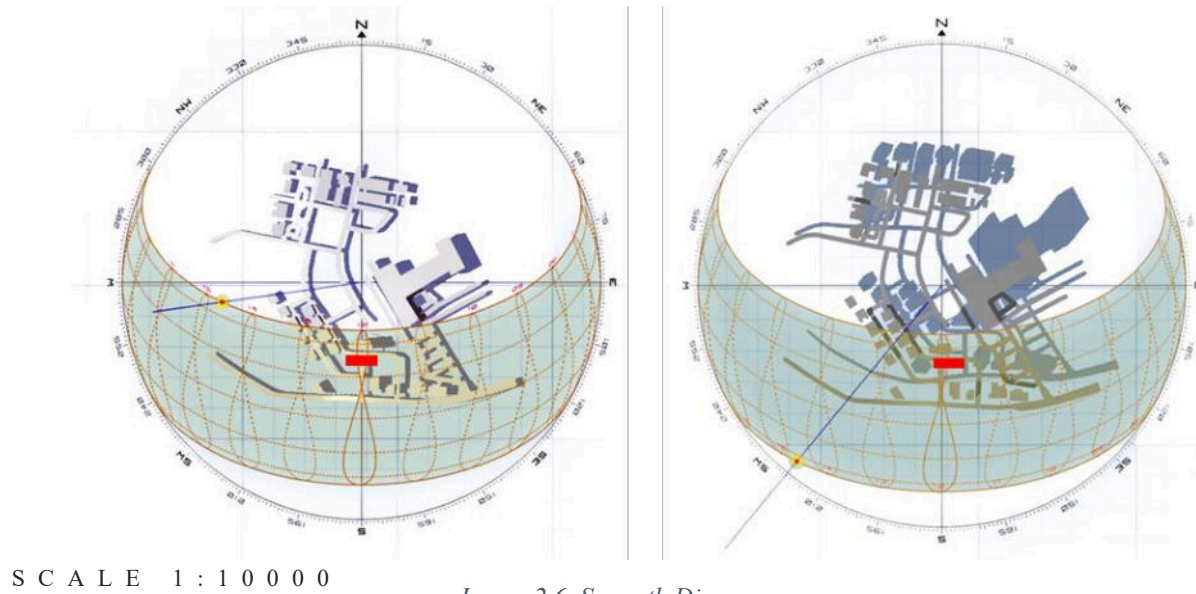


Image 2.6. Sunpath Diagrams

2.7. VEGETATION DIAGRAM

The following diagram shows the vegetation in the area. Observations indicate that there are many shrubs and Cypriot trees, such as olives, cypresses, palm trees, and lemon trees. Most of the trees are located near schools and residential areas. It is important to integrate this vegetation into the design of the area to maintain ecological balance.

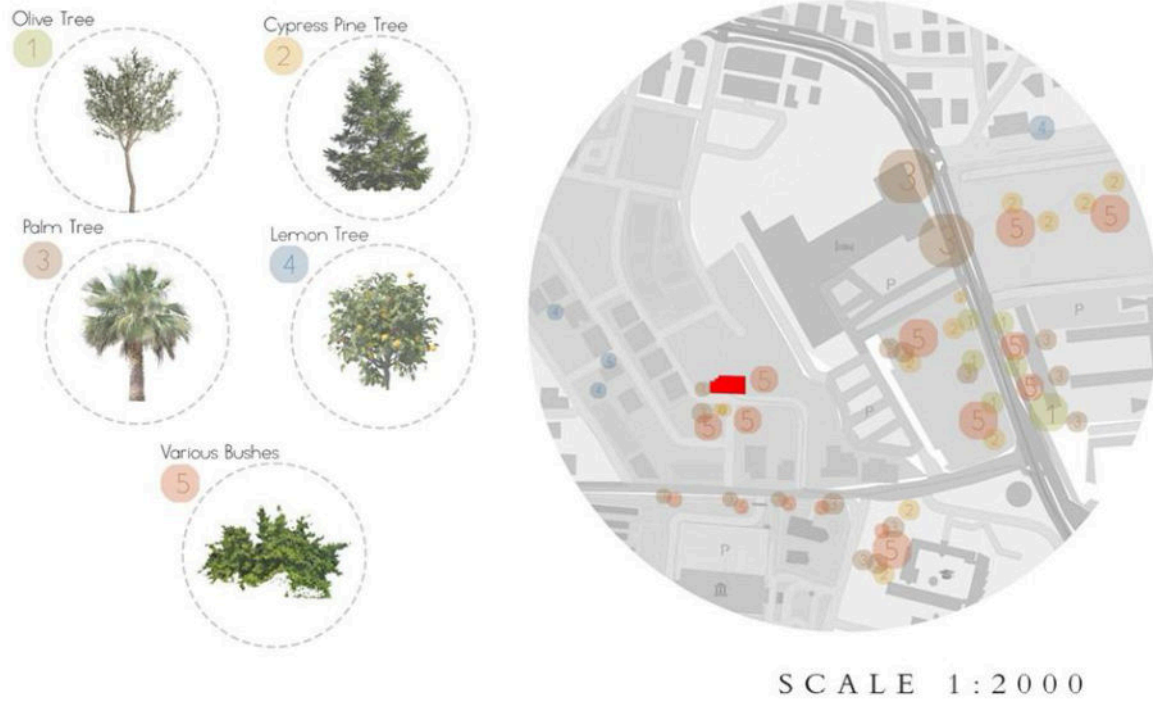


Diagram 2.7. Vegetation Diagram

2.8. BUILDING FLOOR PLANS

After the visit to the hotel and the collection of available data, the floor plans of the ground floor and the other floors of the hotel were redesigned. Each floor presents the distribution of rooms, walls, and common areas. These diagrams are essential for understanding the functioning of the interior of the building. It is also worth mentioning that the boundaries of the plot and the surrounding vegetation are clearly distinguished.

➤ GROUND FLOOR PLAN



Image 2.8a. Ground Floor Plan

➤ **1ST FLOOR PLAN**



Image 2.8b. 1st Floor Plan

➤ **2ND FLOOR PLAN**



Image 2.8c. 2nd Floor Plan

➤ **3RD FLOOR PLAN**

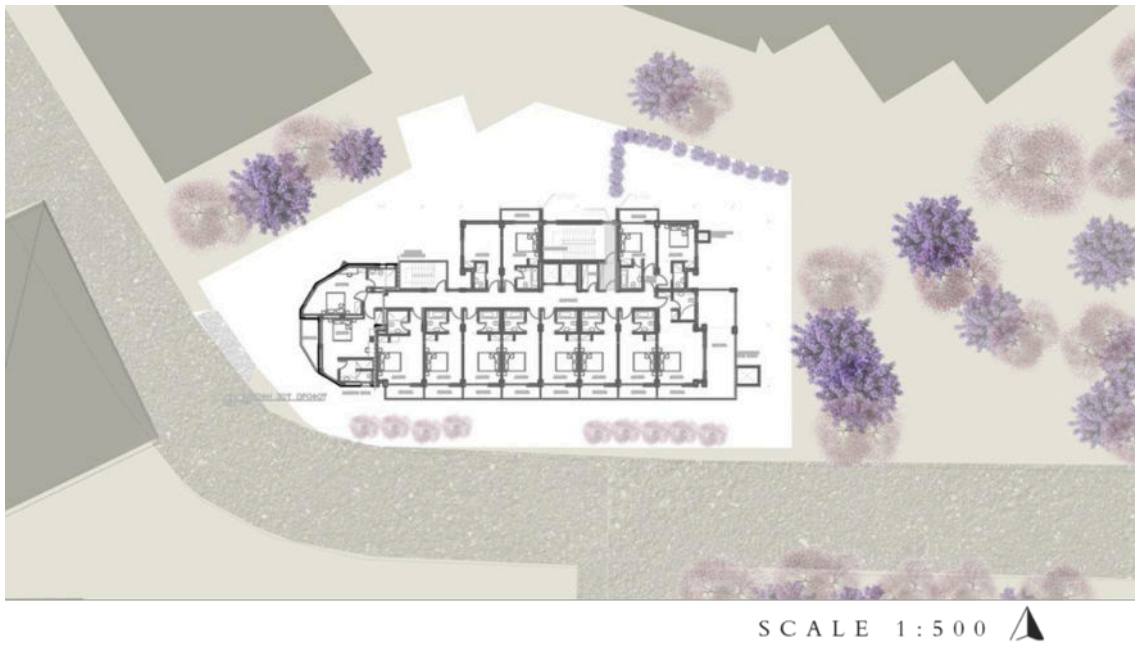


Image 2.8d. 3rd Floor Plan

➤ **4TH FLOOR PLAN**



Image 2.8e. 4th Floor Plan

➤ **5th Floor Plan**



Image 2.8f. 5th Floor Plan

2.9. SOUTHWEST ISOMETRIC VIEW / SIMULATION – RENDER

The south-west isometric diagram illustrates the internal structure of the Semeli Hotel and its relationship with the surrounding buildings, providing valuable insights for potential expansions or renovations. A simulation was then conducted, depicting the hotel during the summer sunrise. The analysis highlights the need for renovation of materials to align with contemporary standards.

This location analysis of the Semeli Hotel offers a detailed understanding of the urban, architectural, and environmental context. The data gathered will enable potential improvements regarding sustainability, functionality, and user-friendliness. Future proposals should be based on these findings to address issues such as noise pollution, energy efficiency, and the preservation of the natural balance.

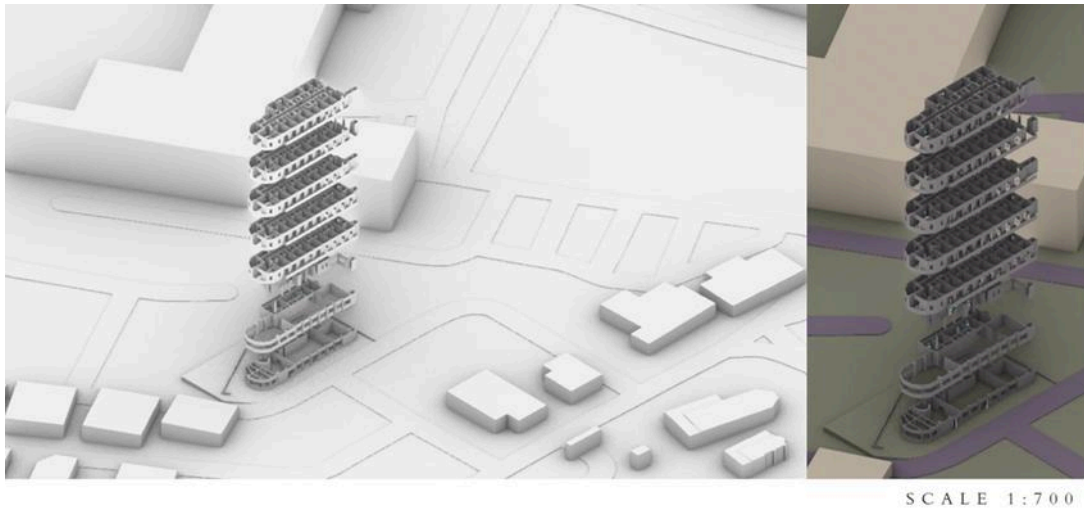


Image 2.9b. Southwest Isometric Diagram



SCALE 1:400 

Image 2.9a. Simulation – Render

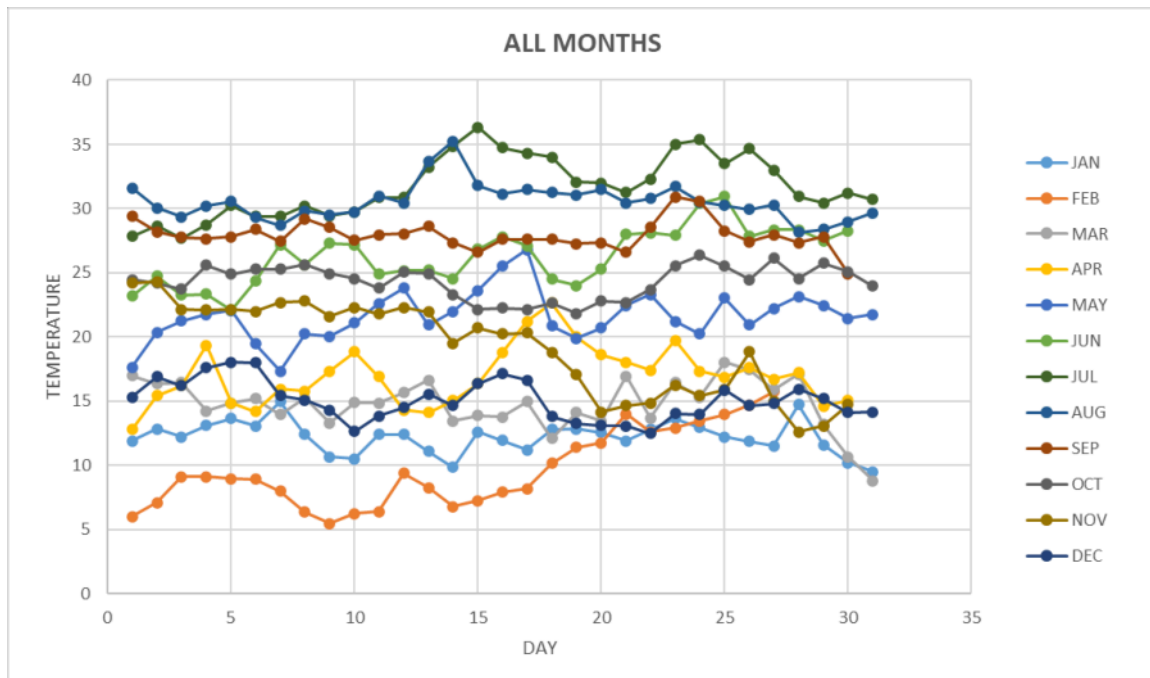
CHAPTER 3: METEOREOLOGICAL CONDITIONS

The meteorological conditions are an important factor as they have significant effects on the building. Therefore, an analysis will be provided for each season individually. Each season affects the building in a unique way, especially due to the lack of thermal insulation.

3.1. TEMPERATURE BY MONTH

In the graph below, lines are depicted for each month from January to December. Most of the lines exhibit relatively stable fluctuations, though there are some increases and decreases.

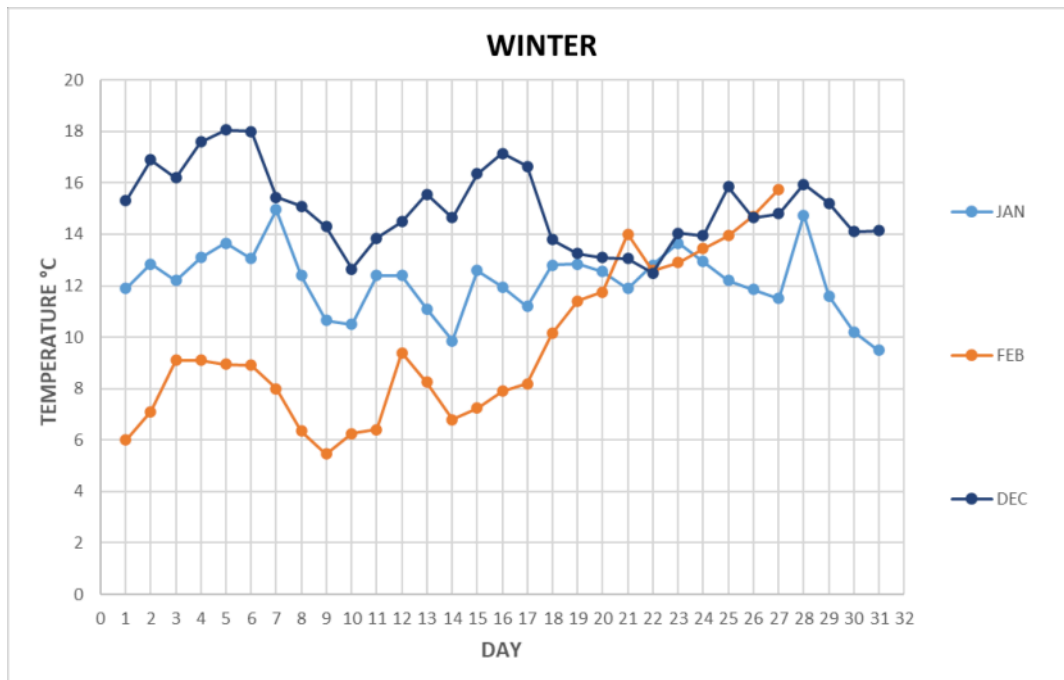
Some months, such as August and January, show lower values of variation compared to the others. January, February, and November appear to have similar fluctuations, but with lower values compared to July or September. Months like June and July display high values.



Graph 3.1. Monthly Temperature

3.2. TEMPERATURE IN WINTER

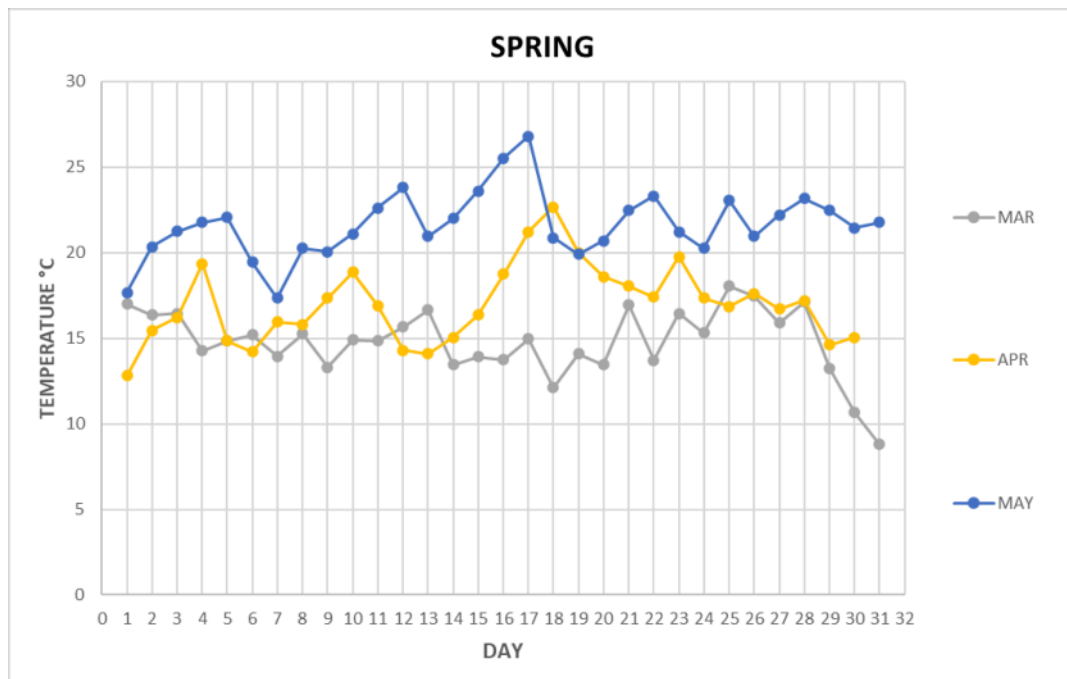
During the winter months, it appears that December starts with higher temperatures and decreases towards the end of the month. January seems to have the most stable temperature, while February experiences the most variation, starting at around 6 degrees and ending with approximately 16 degrees.



Graph 3.2. Temperature in Winter

3.3. TEMPERATURE IN SPRING

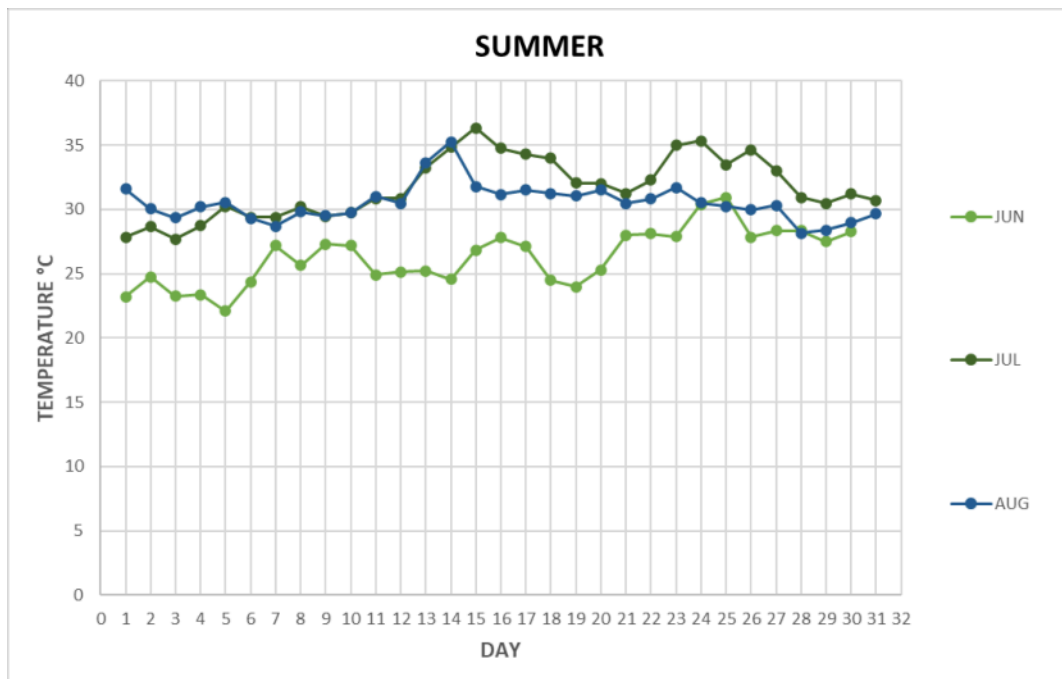
Spring seems to start with lower temperatures, as it follows winter in the month of March. However, the temperature during this month is almost stable, except for the last four days. April shows an upward trend compared to March, while May experiences a larger increase compared to the previous months.



Graph 3.3. Temperature in Spring

3.4. TEMPERATURE IN SUMMER

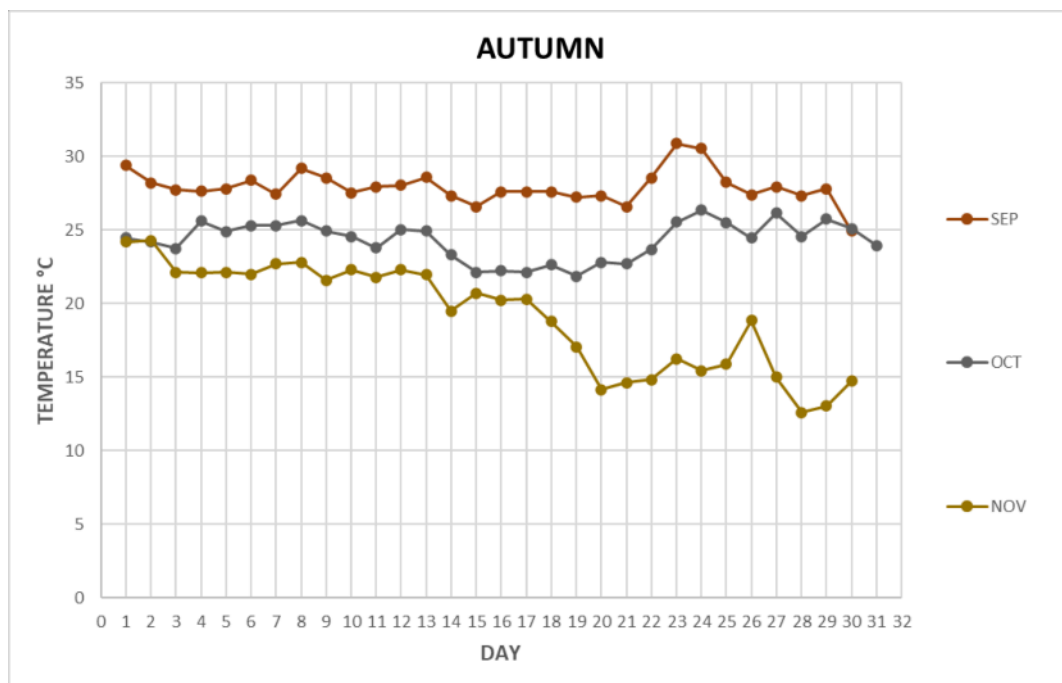
The summer months show the greatest increase in temperature. July and August have the highest temperatures of all months in the year, which is expected as they represent the peak of summer. June also experiences high temperatures, but they are somewhat milder compared to the other two summer months.



Graph 3.4. Temperature in Summer

3.5. TEMPERATURE IN AUTUMN

During the autumn months, we observe greater fluctuations between the months, as September follows summer, while November precedes winter. September has relatively high temperatures, which decrease towards the end of the month. This is followed by October, which shows almost stable temperatures that reflect the drop from September. November starts with temperatures similar to October's, and after mid-month, a gradual decrease begins, leading to temperatures 10 degrees lower than at the start of the month.



Graph 3.5. Temperature in Autumn

CHAPTER 4: ON – SITE MEASUREMENTS

4.1. ON – SITE MEASUREMENTS

The on-site measurements at the Semeli Hotel were conducted to check the air quality in various areas of the hotel, the lighting quality, the measurement of solar radiation passing through the windows, the thermography of the electromechanical equipment, and the measurement of the electrical voltage. These measurements will be compared to the relevant standards to determine if they fall within the specified limits, ensuring proper operating conditions.

The measurements at Semeli Hotel were carried out on November 2, 2024, on a Saturday, specifically at 14:00, at the following points of the hotel:

1. Hotel entrance with windows on the South orientation
2. Reception desk with North orientation, no windows
3. Corridor of the 1st floor with windows on the North orientation
4. Room on the 1st floor with windows on the North orientation
5. Accounting office with windows on the North orientation

Next, the floor plans illustrating the above points are presented. In the following analysis, parameters such as air quality, lighting uniformity, and more will be examined.

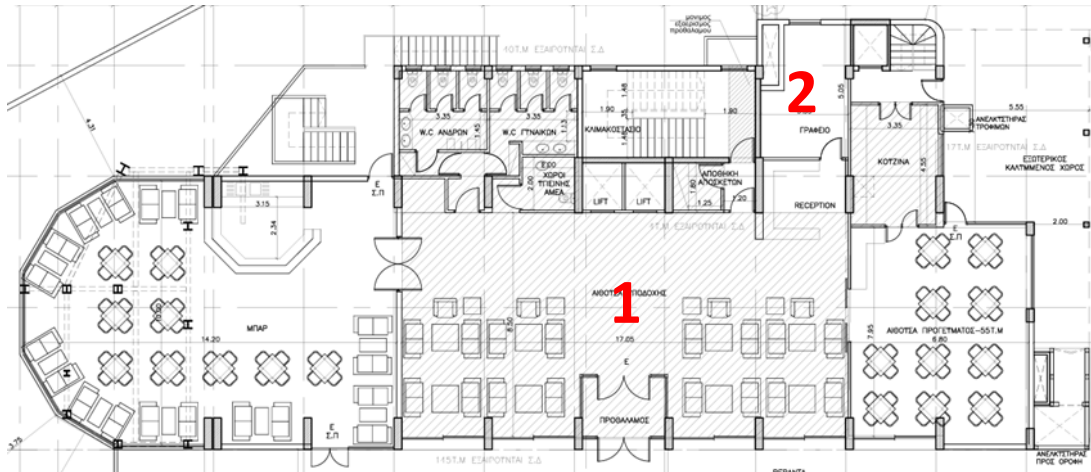


Image 4.1a. Ground Floor Plan

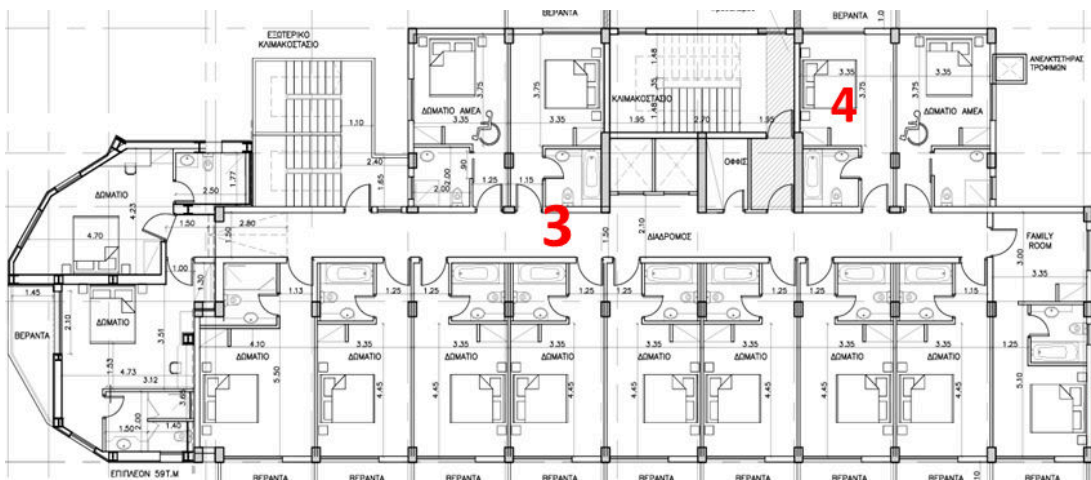


Image 4.1b. 1st Floor Plan

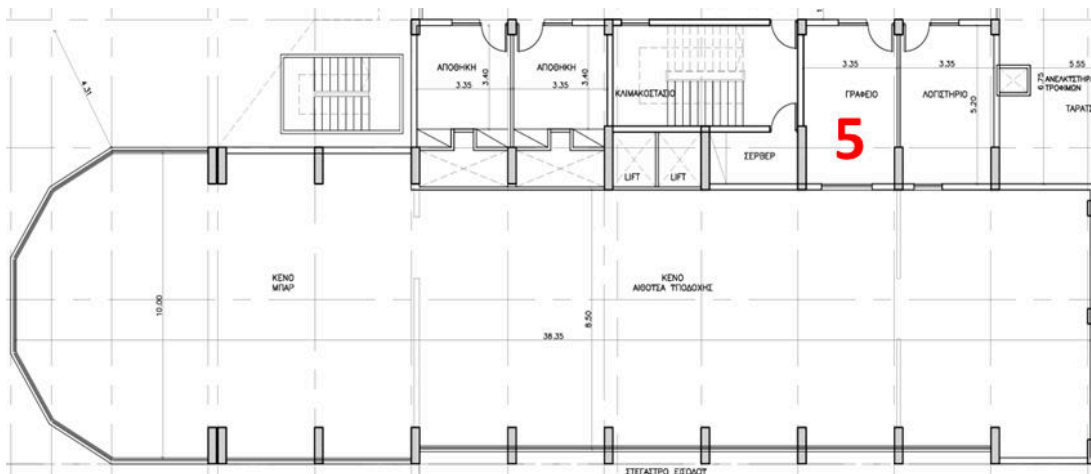


Image 4.1c. Mezzanine Plan

4.1.1. MEASUREMENT INSTRUMENTS

During the on-site measurements, various instruments were used. Initially, for checking temperature, humidity, and carbon dioxide levels (air quality), the CO2/Temp./RH DATA LOGGER was used. To measure the artificial lighting from the lamps, the Mastech MS6612 Digital LUX Meter was employed. For measuring the solar radiation passing through the windows, the TES 1333R Datalogging Solar Power Meter was used. Furthermore, for measuring electrical supply quality (voltage), the Plug-in Power & Energy Monitor 2000MU was used, while for thermography of the electromechanical equipment, the handheld Thermal Camera FLIR E8 was utilized.

These specific instruments, along with their technical specifications, are presented in detail in ANNEX I.

4.1.2. AIR QUALITY MEASUREMENTS

During the on-site measurements, air quality was checked in various zones of the hotel to determine if the relevant parameters met the acceptable limits according to the standard **EN ISO 13790:2008** [1].

Air quality is a crucial factor for the comfort and well-being of both the hotel's employees and guests. Proper air quality control contributes to creating a healthy and comfortable environment, which is essential for the smooth operation of the space.

In the tables below, we observe that the temperature and carbon dioxide levels are within the desired limits according to the standard. On the other hand, the relative humidity does not meet the desired limits, which can be attributed to the lack of thermal insulation in the building. This lack of thermal insulation may affect humidity management, causing instability in its levels.

Proper humidity management is particularly important, as it can affect the health of individuals in the space as well as the condition of the building materials. To ensure better air quality, it is recommended to implement measures to enhance thermal insulation and improve the hotel's air conditioning system.

Below are the results of the aforementioned measurements:

AIR QUALITY IN DIFFERENT AREAS OF THE HOTEL			
AREA	CO₂-PPM	°C	%RH
HOTEL ENTRANCE	513	24.8	50.7
RECEPTION DESK	573	23.7	47.6
1ST FLOOR CORRIDOR	452	24.6	51.9
1ST FLOOR ROOM	480	24.3	53.2
ACCOUNTING OFFICE	449	25.1	50.4

Table 4.1.2a. Air Quality in Different Areas of the Hotel

DESIRED AIR QUALITY, TEMPERATURE & HUMIDITY LIMITS		
CO₂-PPM	°C	%RH
<1000	20 – 26	40% – 50%

Table 4.1.2b. Desired Air Quality, Temperature & Humidity Limits

4.1.3. LIGHTING QUALITY MEASUREMENTS

In addition to air quality, lighting quality was also measured, as it is an important factor for the comfort and performance of employees in the workplace. According to the requirements of the standard **Light and lighting - Lighting of work places - Part 1: Indoor work places, EN 12464-1:2011** [2], adequate lighting in indoor workspaces is crucial for the health and productivity of employees.

Poor lighting quality can cause eye strain, headaches, and reduced productivity, directly impacting the comfort and performance of workers. On the other hand, appropriate lighting helps reduce eye strain, promotes good health, and improves the mood of people in the space. Specifically, the proper lighting intensity in workplaces, such as offices and reception areas, contributes to improving concentration and efficiency.

The table below presents the lighting measurements in various zones of the hotel. At a later stage, the average of the lighting measurements for each zone will be calculated and compared with the standard.

LIGHTING QUALITY MEASUREMENTS IN DIFFERENT ZONES OF THE HOTEL										
AREA	LUX 1	LUX 2	LUX 3	LUX 4	LUX 5	LUX 6	LUX 7	LUX 8	LUX 9	LUX 10
HOTEL ENTRANCE	147.6	100.9	155.9	140.6	175	139	177	169	172	171.8
RECEPTION DESK	136	135	105	142	112	171	88	98	150	83.6
1ST FLOOR CORRIDOR	6.79	12.1	24.5	16.02	61.7	3.26	6.8	14.66	18.17	6.5
1ST FLOOR ROOM	85	75	65	70	65	60	58	62	55	73
ACCOUNTING OFFICE	161.1	154.9	111	174	134	164	93	85	83	113

Table 4.1.3a. Lighting Quality Measurements in Different Zones of the Hotel

AVERAGE LIGHTING QUALITY MEASUREMENTS IN DIFFERENT ZONES OF THE HOTEL				
AREA	MINIMUN LUX	MAXIMUN LUX	AVERAGE LUX (MEASUREMENTS)	TARGET FOR GOOD LIGHTING QUALITY
HOTEL ENTRANCE	100.90	177.00	154.88	300
RECEPTION DESK	83.60	171.00	122.06	300
1ST FLOOR CORRIDOR	3.26	61.70	17.05	100
1ST FLOOR ROOM	55.00	85.00	66.80	300
ACCOUNTING OFFICE	83.00	174.00	127.30	500

Table 4.1.3b. Average Lighting Quality Measurements in Different Zones of the Hotel

We observe that the lighting measurements in certain areas do not meet the standards for good lighting quality. Specifically, the areas of the First Floor Corridor and First Floor Room have lighting levels significantly below the required standard values, with the illuminance level being much lower than the desired threshold of 300 LUX.

On the other hand, areas such as the Hotel Entrance and Reception Office are close to meeting the minimum requirements, but they do not reach the 300 LUX target set for indoor working spaces. The areas that require improvement are those showing lighting levels below the desired values, which could affect the comfort and productivity of employees in these spaces.

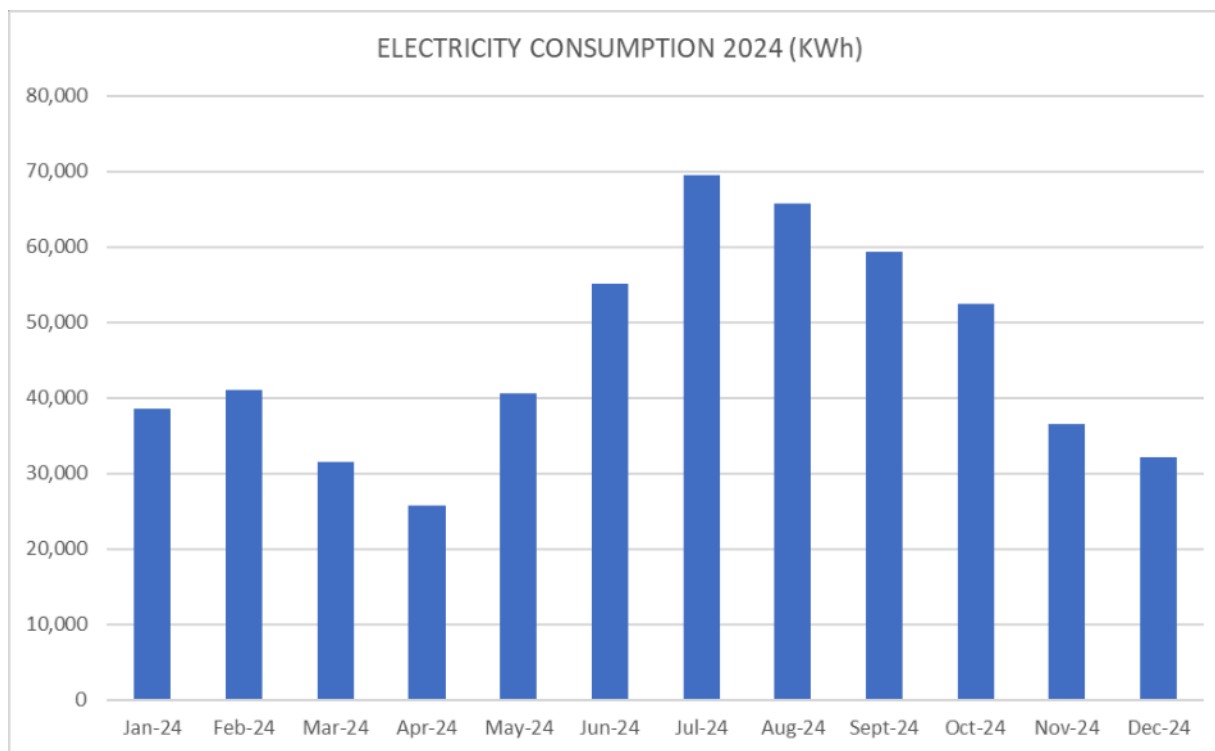
Overall, the lighting in the hotel does not fully meet the objectives of the EN 12464-1:2011 standard and actions are needed to increase the illuminance in certain areas of the building to ensure proper comfort for employees and optimize their performance.

4.2. ANALYSIS OF EAC BILLS

At a later stage, an analysis of the EAC (Electricity Authority of Cyprus) bills was conducted, where the electricity consumption and the related cost per consumption are recorded. This analysis was deemed necessary to establish the baseline both in terms of the quantity of electrical energy in kWh and the cost per kWh (as a comparison will be made later). The following table presents the monthly consumptions, the electricity cost excluding VAT, and the cost per kWh.

EAC BILLS SEMELI HOTEL			
MONTH	ELECTRICAL CONSUMPTION (kWh)	COST EX. VAT (€)	COST PER kWh (€/kWh)
Jan-24	38,515	€10,653	€0.277
Feb-24	41,110	€11,596	€0.282
Mar-24	31,575	€8,404	€0.266
Apr-24	25,743	€6,976	€0.271
May-24	40,585	€10,446	€0.257
Jun-24	55,093	€15,447	€0.280
Jul-24	69,571	€19,029	€0.274
Aug-24	65,714	€18,317	€0.279
Sep-24	59,307	€16,992	€0.287
Oct-24	52,500	€13,924	€0.265
Nov-24	36,439	€9,198	€0.252
Dec-24	32,216	€7,716	€0.240
TOTAL	548,368	€148,697	€0.271

Table 4.2a. Analysis of EAC Bills



Grafic 4.2a. Analysis of EAC Bills

According to the above table and diagram 4.2a, it is observed that during the summer months, electricity consumption increases due to the higher use of air conditioning systems. The total electricity consumption of the hotel for the year 2024 amounted to 548,368 kWh, with a total cost of €148,697, excluding VAT. The cost per kWh, which will be used as a basis for subsequent techno-economic analyses, amounts to €0.271/kWh.

4.3. THERMOGRAPHY

During the on-site visit to the hotel, spot thermographic scans were performed at points deemed potentially problematic in their operation. Additionally, thermographic scans were carried out at locations considered responsible for high electricity consumption.

More specifically, the thermography was conducted to detect malfunctions in the electromechanical equipment. Notably, thermography can prevent any damage or even destruction of the equipment.

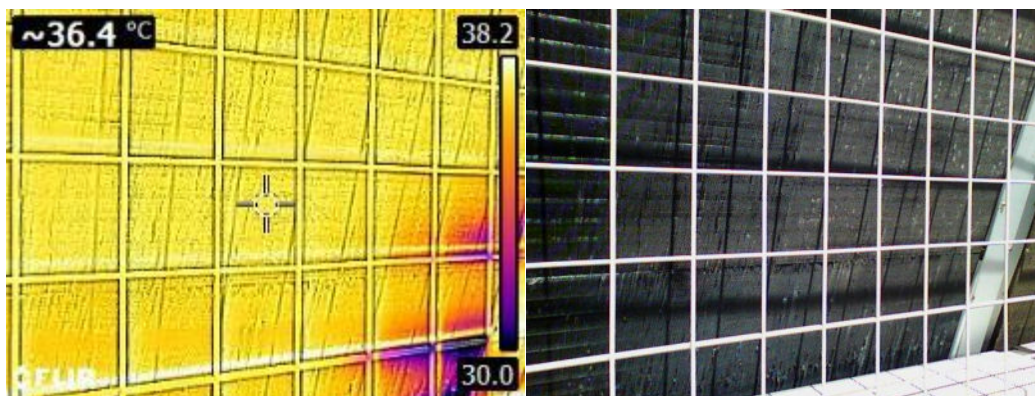
The thermography was carried out at the following points with the help of the thermal camera, the technical specifications of which are provided in Appendix 1:

- a) Thermography of Mechanical Equipment & HVAC
- b) Thermography of Boiler Pumps & Piping
- c) Thermography of Refrigeration Equipment

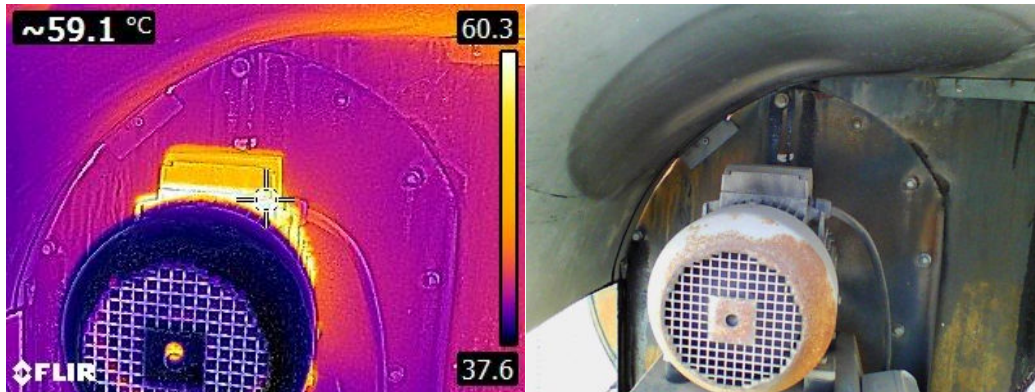
➤ THERMOGRAPHY OF MECHANICAL EQUIPMENT & HVAC

Regarding the thermography of the mechanical equipment and HVAC, it is observed that according to the **SuccessIRies™ 104 standard: Temperature Limits for Electrical & Mechanical Equipment [3]**, the temperatures for all cases are within the permissible limits, as they are below 70°C.

RADIATOR CHILLER



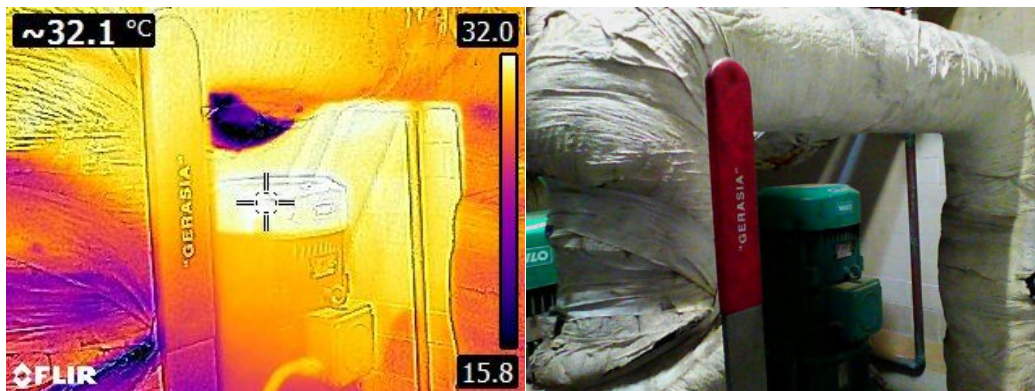
PUMP CHILLER

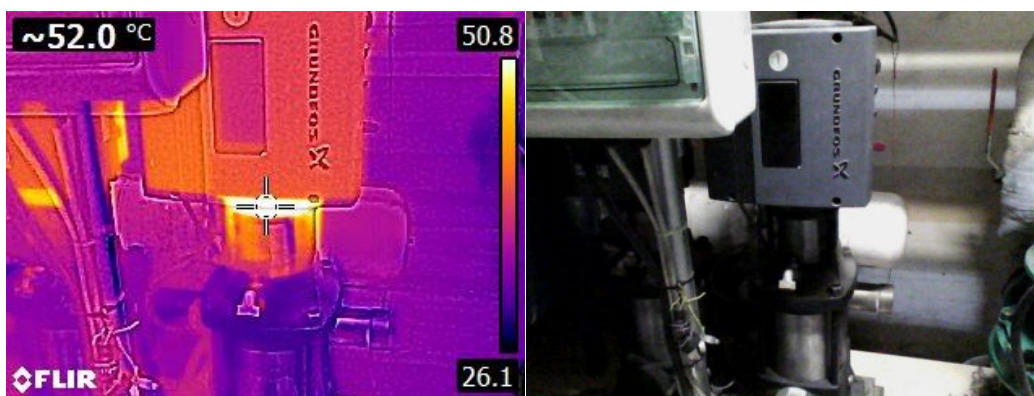
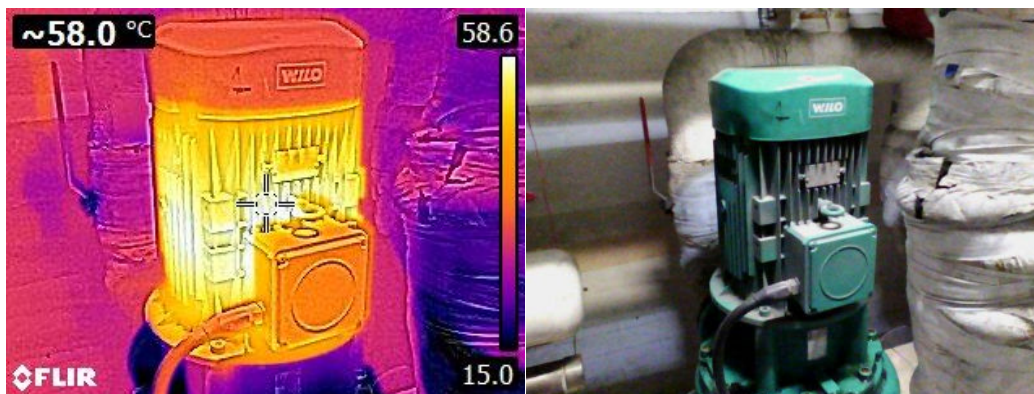


➤ THERMOGRAPHY OF BOILER PUMPS & PIPING

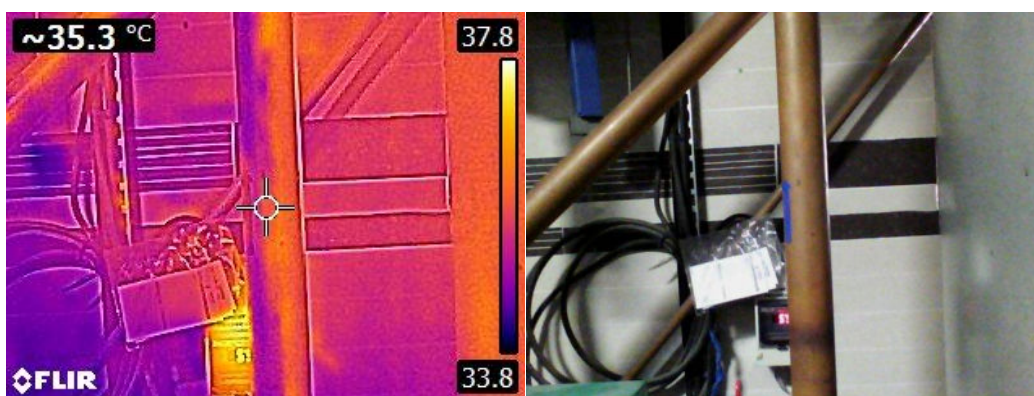
Regarding the thermography of the Boiler Pumps & Piping, it is observed that according to the **SuccessIRies™ 104 standard: Temperature Limits for Electrical & Mechanical Equipment [3]**, the temperatures for all cases are within the permissible limits, as they are below 70°C.

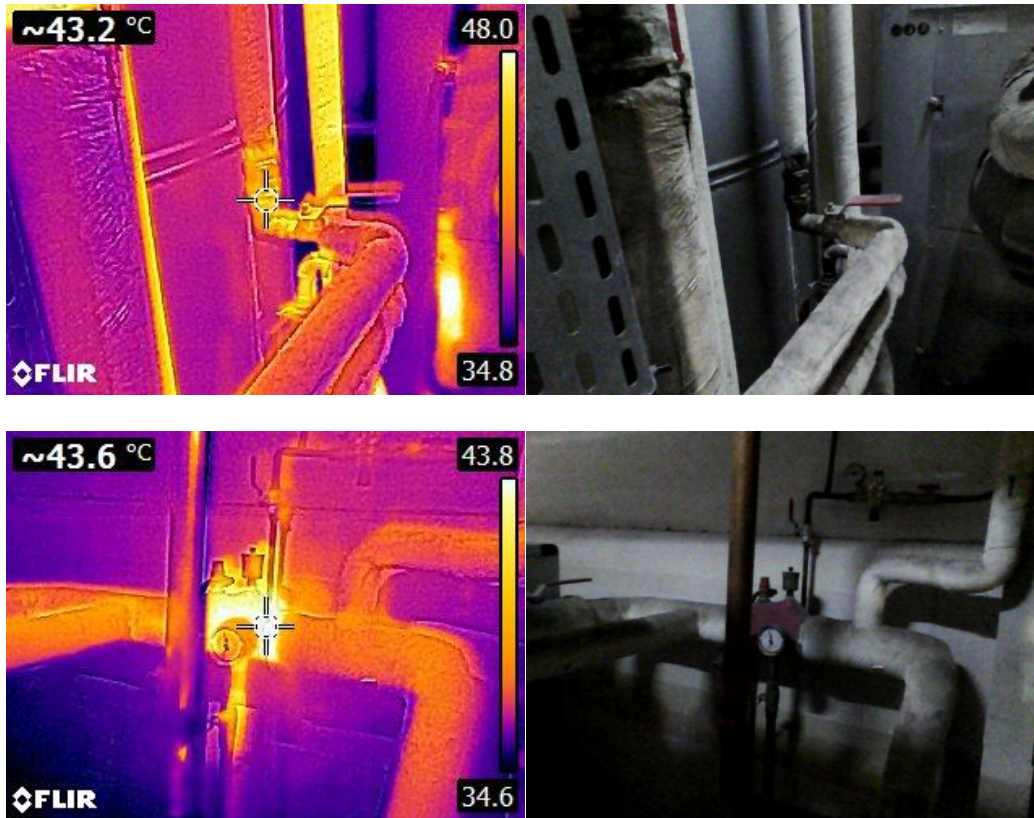
PUMP BOILER





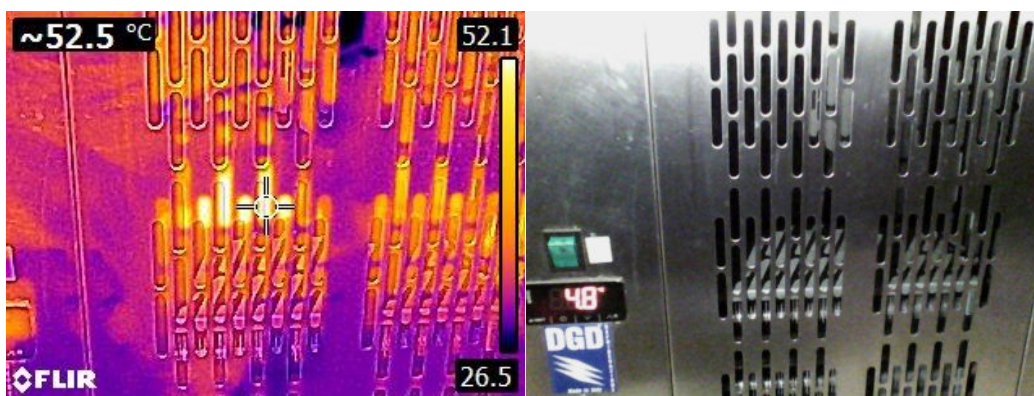
TUBES BOILER

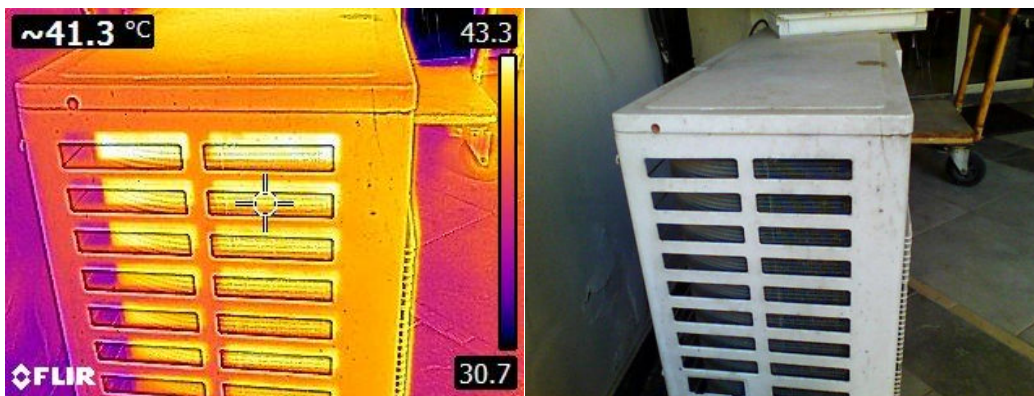
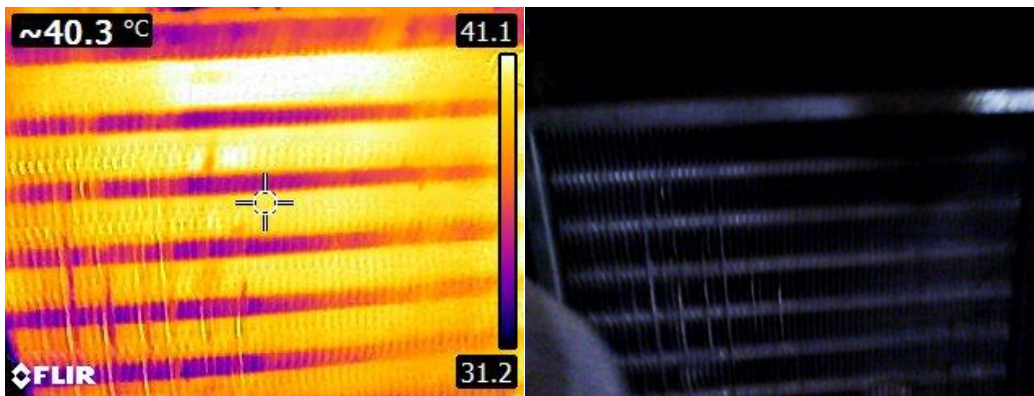
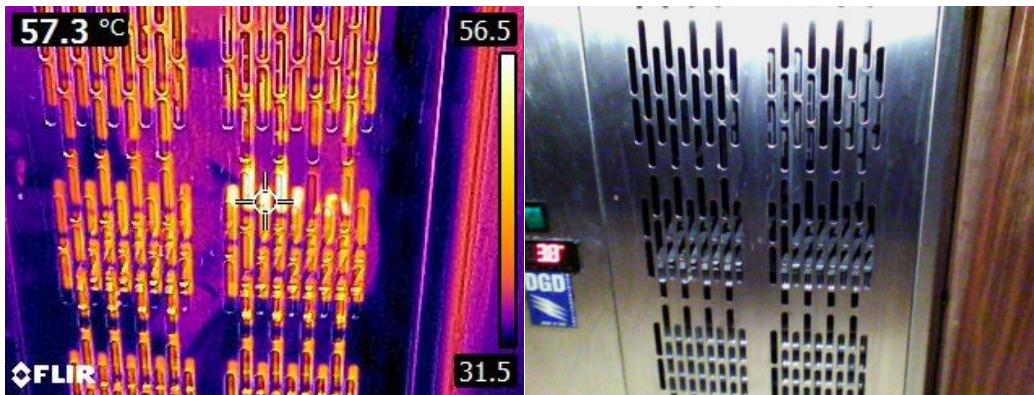
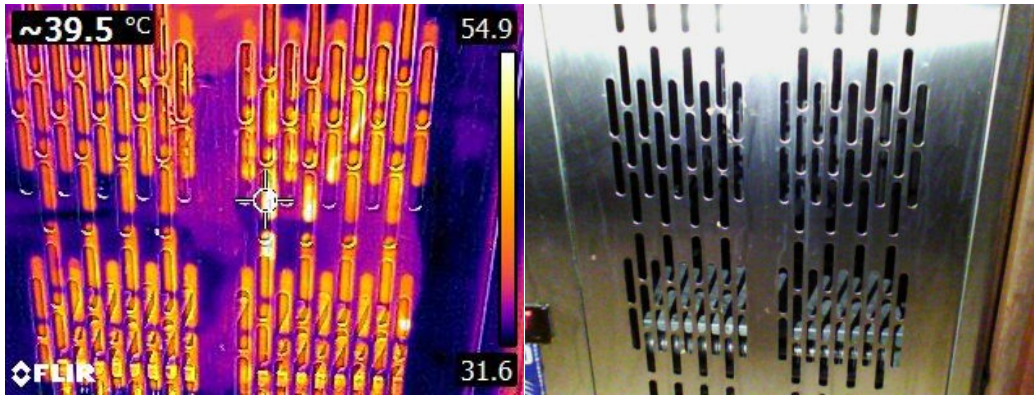


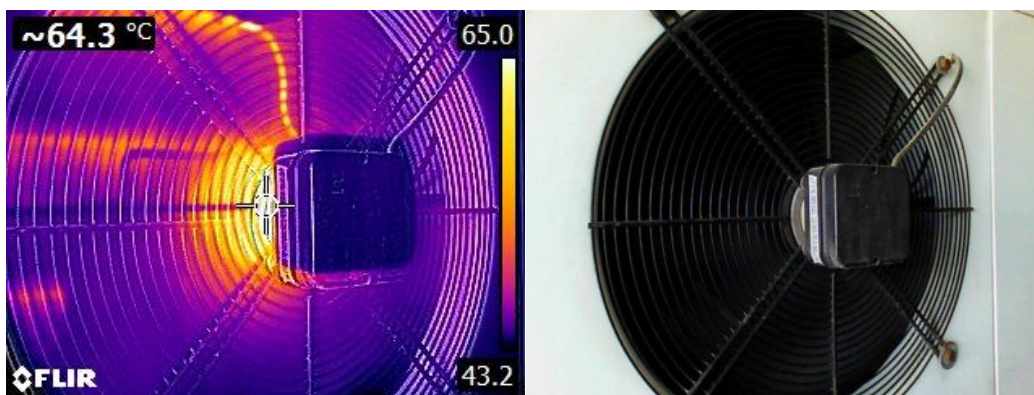
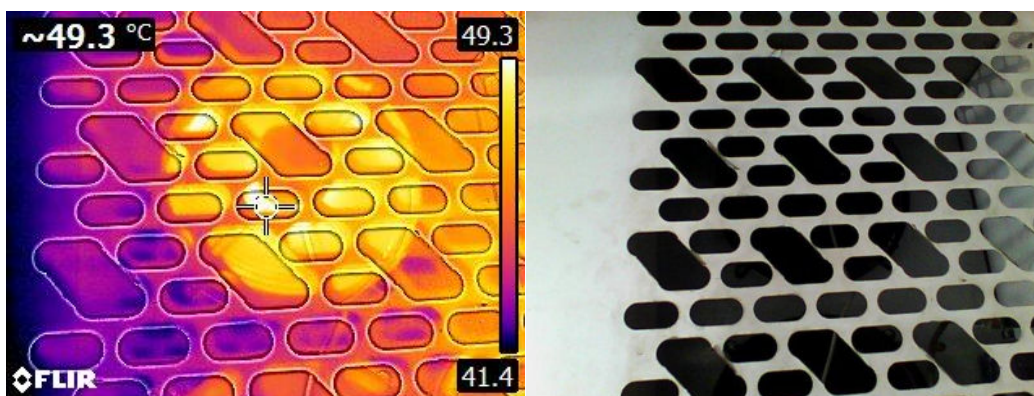
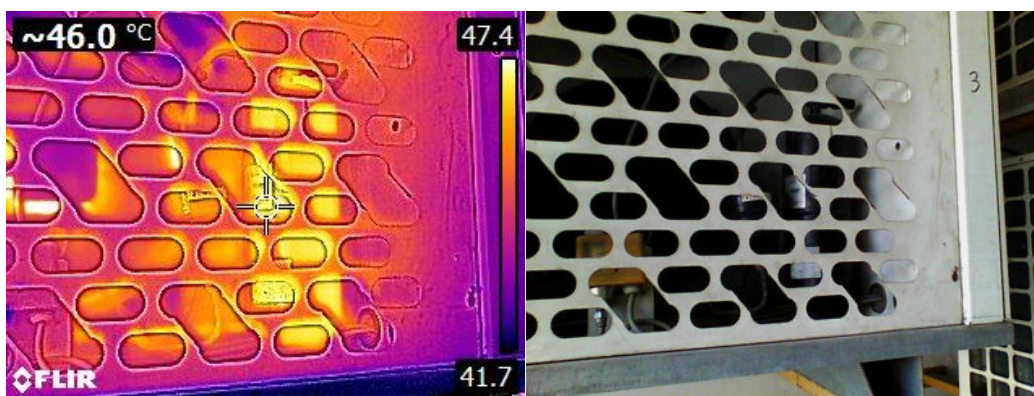
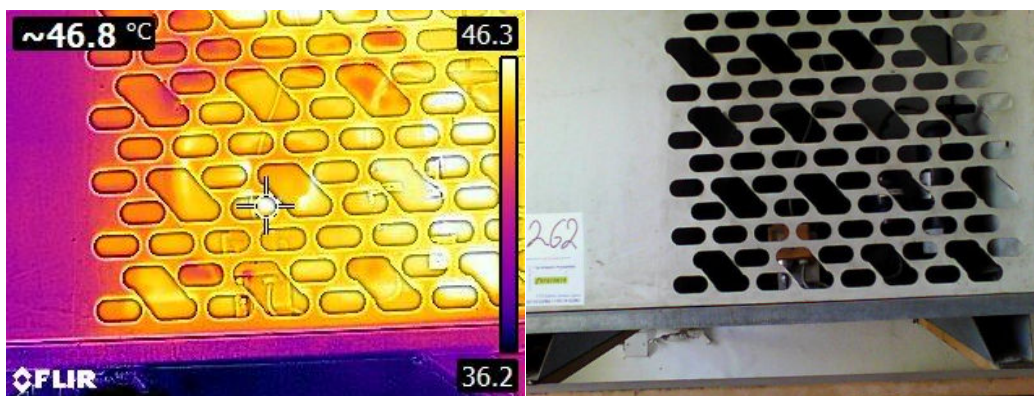


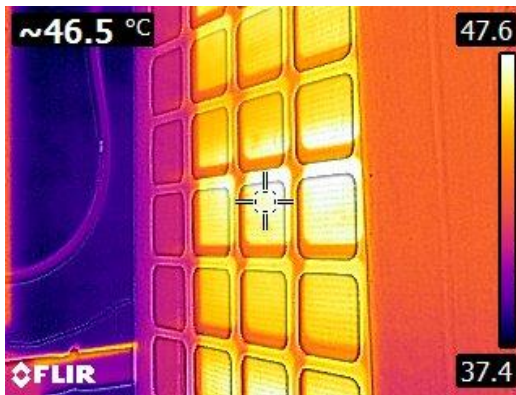
➤ THERMOGRAPHY OF REFRIGERATION EQUIPMENT

Regarding the thermography of the Refrigeration Equipment, it is observed that according to the **SuccessIRies™ 104 standard: Temperature Limits for Electrical & Mechanical Equipment [3]**, the temperatures for all cases are within the permissible limits, as they are below 70°C.









4.4. ELECTROMECHANICAL EQUIPMENT

Semeli Hotel, in order to provide the best service to its guests, uses air conditioning systems for cooling and heating the building. It also has a large number of refrigeration equipment to meet its operational needs. Below is an overview of the electromechanical equipment used in the hotel.

4.4.1 HEATING VENTILATION AIR CONDITIONING SYSTEM – ELECTRICAL ENERGY

The air conditioning system of the hotel (heating and cooling) is provided by 6 chillers, in combination with 16 cassette units, 9 standalone air conditioning units, and 86 built-in cassette units in the common areas of the hotel, such as rooms, kitchens, etc.

The model of these chillers is MGA-F65W/SN, with a heating performance factor (COP) of 3.009 and a cooling performance factor (EER) of 3.286. However, these units are considered quite energy-intensive, as they are relatively old and therefore cannot operate at their maximum efficiency, with empirical data suggesting a potential performance loss of up to 40% (EER = 1.81 and COP = 1.98). It is worth noting that they consume more energy compared to modern units, as indicated by the fact that their heating and cooling performance factors fall below 3.00, whereas modern chillers have significantly higher performance ratings.



Image 4.4.1a. Six Chillers on the Roof of the Building

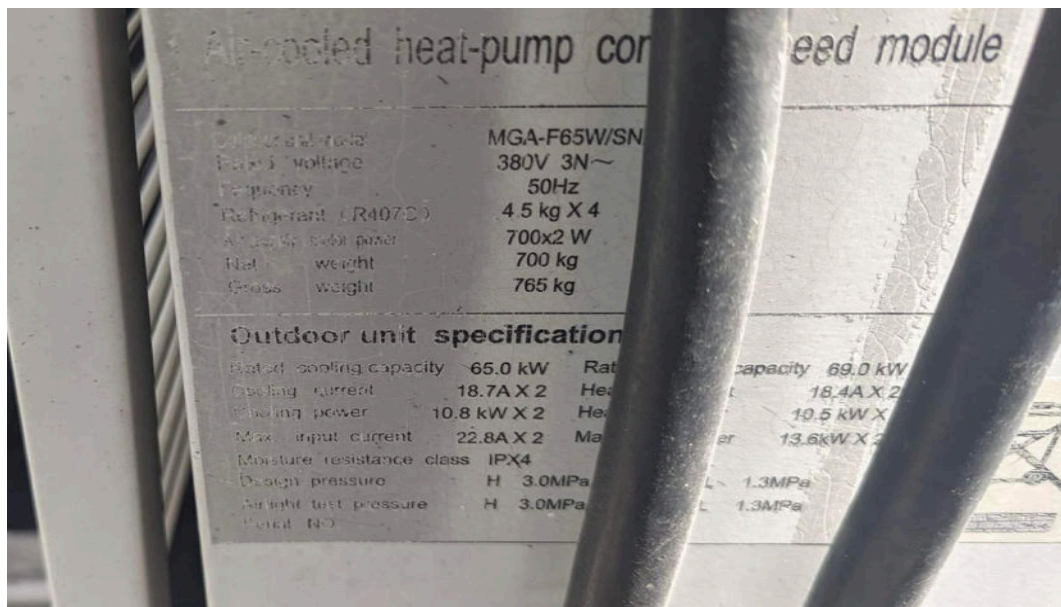


Image 4.4.1b. Technical Specifications of the Chillers



Image 4.4.1c. Cassettes of HVAC



Image 4.4.1d. Split Unit of HVAC

4.4.2 HEATING VENTILATION AIR CONDITIONING SYSTEMS AND DHW WITH BOILERS – THERMAL ENERGY

At Semeli Hotel, heating is also provided with the help of two oil boilers, in addition to the chillers. Notably, the use of the two boilers also produces Domestic Hot Water (DHW). The building has two oil boilers and two BEO30AL burner units, which have an electrical power ranging from 71 to 202 kW.



Image 4.4.2a. Diesel Boiler



Image 4.4.2b. Technical Specification of Burner

4.4.3. LIGHTING

The lighting installed in the hotel consists of LED bulbs, which consume less electrical energy as they are more energy-efficient compared to conventional bulbs. It is also worth noting that LED bulbs have a longer lifespan compared to conventional bulbs.



Image 4.4.3a. Lighting LED

4.4.4. REFRIGARITION EQUIPMENT – COLD ROOM

The storage of products for food preparation and processing in the kitchen, as well as the storage of beverages in the hotel's bar, is done using refrigerators that are relatively old. As a result, there is a high consumption of electrical energy, as these systems are quite energy-intensive.

Additionally, in the kitchen, there are installed cold rooms for storing products that require freezing for preservation. It is worth noting that this equipment is also considered quite energy-consuming, as it is also quite old.



Image 4.4.4a. Refrigeration Equipment



Image 4.4.4b. Refrigeration Equipment



Image 4.4.4c. Compressor Cold Room



Image 4.3.4d. Technical Specification Cold Room

4.4.5. CALCULATION OF HEAT TRANSFER COEFFICIENT (U-value)

The heat transfer coefficient is an important factor for the energy performance of a building, as it determines the heating and cooling needs depending on the conditions. In simpler terms, the heat transfer coefficient defines how warm or cool the interior of the building will remain.

The heat transfer coefficient (U-Value) expresses the rate of heat transfer through a material or a structural surface. It is measured in W/m^2K and indicates how much heat (in Watts) passes through 1 square meter of surface for each degree Kelvin temperature difference between the two sides of the material.

In the existing building, as will be analyzed in a later stage, the heat transfer coefficients of the frames, masonry, roof, and floor are significantly higher than the permissible limits set by Regulation K.Δ.Π. 122/2020. This results in increased heating and cooling demands, as the building fails to maintain a stable and desired interior temperature.

Below are the calculations performed to determine the heat transfer coefficient in each case. At this point, it is worth noting that ideally, the measurements should be taken using a special instrument for measuring the heat transfer coefficient. However, due to the unavailability of this equipment, Excel calculation sheets provided by the Insulation Guide were used.

Calculation of U-value for existing windows:

The hotel's glazing is double, without special protection, and has dimensions 4-16-4 with air in the gap. According to Table 6.12 from the insulation guide, for this configuration, the heat transfer coefficient U_g is $2.7 \text{ W/m}^2\text{K}$.

In Table 6.13 from the insulation guide, the overall heat transfer coefficient of the frames (U-value) is presented, which depends on the values of U_g and U_f . Where $U_g = 2.7 \text{ W/m}^2\text{K}$ and the corresponding value for the frame is $U_f = 7.0 \text{ W/m}^2\text{K}$.

Therefore, the total heat transfer coefficient of the frame is $U\text{-value} = 4.0 \text{ W/m}^2\text{K}$, which is above the desired limit of $2.25 \text{ W/m}^2\text{K}$ (according to regulation K.Δ.Π. 122/2020).

Πίνακας 6.12: Συντελεστές θερμοπερατότητας διπλών και τριπλών υαλοστασίων με διαφορετικούς τύπους αερίων στο διάκενο

Υαλοστάσια			Συντελεστής Θερμοπερατότητας για διαφορετικούς τύπους αερίων στο διάκενο U_g					
Τύπος	Υαλοπίνακας	Συντελεστής εκπομπής θερμικής ακτινοβολίας(ε)	Διαστάσεις mm	Αέρας (Air)	Αργό (Argon)	Κρυπτόν (Krypton)	SF ₆ b	Ξένον (Xenon)
Διπλά Υαλοστάσια	Χωρίς προστασία (συνήθεις υαλοπίνακες)	0.89	4-6-4	3.3	3.0	2.8	3.0	2.6
			4-8-4	3.1	2.9	2.7	3.1	2.6
			4-12-4	2.8	2.7	2.6	3.1	2.6
			4-16-4	2.7	2.6	2.6	3.1	2.6
			4-20-4	2.7	2.6	2.6	3.1	2.6
	Με προστασία στη μία πλευρά	≤0.2	4-6-4	2.7	2.3	1.9	2.3	1.6
			4-8-4	2.4	2.1	1.7	2.4	1.6
			4-12-4	2.0	1.8	1.6	2.4	1.6
			4-16-4	1.8	1.6	1.6	2.5	1.6
			4-20-4	1.8	1.7	1.6	2.5	1.7
	Με προστασία στη μια πλευρά	≤0.15	4-6-4	2.6	2.3	1.8	2.2	1.5
			4-8-4	2.3	2.0	1.6	2.3	1.4
			4-12-4	1.9	1.6	1.5	2.3	1.5
			4-16-4	1.7	1.5	1.5	2.4	1.5
			4-20-4	1.7	1.5	1.5	2.4	1.5
	Με προστασία στη μια πλευρά	≤0.1	4-6-4	2.6	2.2	1.7	2.1	1.4
			4-8-4	2.2	1.9	1.4	2.2	1.3
			4-12-4	1.8	1.5	1.3	2.3	1.3
			4-16-4	1.6	1.4	1.3	2.3	1.4
			4-20-4	1.6	1.4	1.4	2.3	1.4
	Με προστασία στη μια πλευρά	≤0.05	4-6-4	2.5	2.1	1.5	2.0	1.2
			4-8-4	2.1	1.7	1.3	2.1	1.1
			4-12-4	1.7	1.3	1.1	2.1	1.2
			4-16-4	1.4	1.2	1.2	2.2	1.2
			4-20-4	1.5	1.2	1.2	2.2	1.2
Τριπλά Υαλοστάσια	Χωρίς προστασία (συνήθεις υαλοπίνακες)	0.89	4-6-4-6-4	2.3	2.1	1.8	1.9	1.7
			4-8-4-8-4	2.1	1.9	1.7	1.9	1.6
			4-12-4-12-4	1.9	1.8	1.6	2.0	1.6
	Με προστασία σε δύο πλευρές	≤0.2	4-6-4-6-4	1.8	1.5	1.1	1.3	0.9
			4-8-4-8-4	1.5	1.3	1.0	1.3	0.8
			4-12-4-12-4	1.2	1.0	0.8	1.3	0.8
	Με προστασία σε δύο πλευρές	≤0.15	4-6-4-6-4	1.7	1.4	1.1	1.2	0.9
			4-8-4-8-4	1.5	1.2	0.9	1.2	0.8
			4-12-4-12-4	1.2	1.0	0.7	1.3	0.7
	Με προστασία σε δύο πλευρές	≤0.1	4-6-4-6-4	1.7	1.3	1.0	1.1	0.8
			4-8-4-8-4	1.4	1.1	0.8	1.1	0.7
			4-12-4-12-4	1.1	0.9	0.6	1.2	0.6
	Με προστασία σε δύο πλευρές	≤0.05	4-6-4-6-4	1.6	1.2	0.9	1.1	0.7
			4-8-4-8-4	1.3	1.0	0.7	1.1	0.5
			4-12-4-12-4	1.0	0.8	0.5	1.1	0.5

Πίνακας 6.13: Συντελεστές θερμοπερατότητας για κάθετα κουφώματα με ποσοστό εμβαδού πλαισίου ως προς το συνολικό εμβαδόν του κουφώματος 30% για συνηθισμένου τύπου εξαρτήματα διαχωρισμού υαλοπινάκων

Τύπος Υαλοστασίου	U _g W/(m ² .K)	Συντελεστές θερμοπερατότητας για συνηθισμένου τύπου εξαρτήματα διαχωρισμού υαλοπινάκων (spacer bars) U _f W/(m ² .K)													
		0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.6	3.0	3.4	3.8	7.0	
Μονό	5.7	4.2	4.3	4.3	4.4	4.5	4.5	4.6	4.6	4.8	4.9	5.0	5.1	6.1	
	3.3	2.7	2.8	2.8	2.9	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	4.5	
	3.2	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.2	3.3	3.5	3.6	4.4	
	3.1	2.6	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.3	3.4	3.5	4.3	
	3.0	2.5	2.5	2.6	2.7	2.7	2.8	2.8	3.0	3.1	3.2	3.3	3.4	4.2	
	2.9	2.4	2.5	2.5	2.6	2.7	2.7	2.8	2.9	3.0	3.1	3.2	3.4	4.2	
	2.8	2.3	2.4	2.5	2.5	2.6	2.6	2.7	2.8	2.9	3.1	3.2	3.3	4.1	
	2.7	2.3	2.3	2.4	2.5	2.5	2.6	2.6	2.7	2.9	3.0	3.1	3.2	4.0	
	2.6	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.7	2.6	2.9	3.0	3.2	4.0	
	2.5	2.1	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.5	2.8	3.0	3.1	3.9	
	2.4	2.1	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.5	2.8	2.9	3.0	3.8	
	2.3	2.0	2.1	2.1	2.2	2.2	2.3	2.4	2.5	2.4	2.7	2.8	3.0	3.8	
	2.2	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.4	2.3	2.6	2.8	2.9	3.7	
	2.1	1.9	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.3	2.6	2.7	2.8	3.6	
	Διπλό ή Τριπλό	2.0	1.8	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.5	2.6	2.7	2.8	3.6
1.9		1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.3	2.4	2.5	2.5	2.7	3.6	
1.8		1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.4	2.6	2.7	3.5	
1.7		1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.4	2.5	2.6	3.4	
1.6		1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.1	2.2	2.3	2.4	2.5	3.3	
1.5		1.5	1.5	1.6	1.7	1.7	1.8	1.8	2.0	2.1	2.2	2.3	2.5	3.3	
1.4		1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.2	2.3	2.4	3.2	
1.3		1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.8	2.0	2.1	2.2	2.3	3.1	
1.2		1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.3	3.1	
1.1		1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.2	3.0	
1.0		1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.9	
0.9		1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.6	1.7	1.8	1.9	2.0	2.9	
0.8		1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.8	
0.7		0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.7	
0.6	0.9	0.9	1.0	1.0	1.1	1.2	1.2	1.4	1.5	1.6	1.7	1.8	2.7		
0.5	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.8	2.6		

Calculation of the Heat Transfer Coefficient (U-Value) for Masonry, Floor, and Roof

According to the building energy performance regulations (K.D.P. 122/2020), the maximum allowable limit for masonry and roof is 0.4 W/m²K.

If the values exceed the allowable limits, the following negative impacts may occur:

- **Increased energy losses:** A significant amount of heat is lost during winter and heat enters during summer, increasing heating and cooling demands.
- **Higher operational costs:** Due to thermal losses, more energy is required to maintain a comfortable indoor temperature.
- **Reduced comfort:** Indoor spaces are more affected by external weather conditions, resulting in larger temperature fluctuations.
- **Risk of condensation and moisture:** Insufficient thermal insulation can cause cold surfaces where moisture condenses, leading to mold and damage.

Construction description		Floor			
A/A	Name of Material	Material Thickness d (m)	Thermal Conductivity Material λ (W/mK)	Thermal Resistance of Material R (m²K/W)	Typical Design Detail
Starting from the inside					
1	Ceramic/clay tiles	0.020	0.800	0.025	
2	Cement screed	0.050	1.400	0.036	
3	Cast Concrete	0.100	0.380	0.263	
4	Aerated Concrete Slab	0.200	0.160	1.250	
Heat Flow		Downwards		Coefficient of Thermal Conductivity U (W/m²K)	
Rsi (m²K/W)		0.170			
Rse (m²K/W)		0.040			
				0.561	
Notes:					
The requirement of U≤0.4 W/m²K as defined by the relevant decree is not met					

Construction description		External Wall			
A/A	Name of Material	Material Thickness d (m)	Thermal Conductivity Material λ (W/mK)	Thermal Resistance of Material R (m²K/W)	Typical Design Detail
Starting from the inside					
1	Cement plaster	0.025	0.720	0.035	
2	Brick	0.200	0.720	0.278	
3	Cement plaster	0.025	0.720	0.035	
Heat Flow		Horizontally		Coefficient of Thermal Conductivity U (W/m²K) 1.933	
Rsi (m²K/W)		0.130			
Rse (m²K/W)		0.040			
Notes: The requirement of U≤0.4 W/m²K as defined by the relevant decree is not met					

Construction description		Roof			
A/A	Name of Material	Material Thickness d (m)	Thermal Conductivity Material λ (W/mK)	Thermal Resistance of Material R (m²K/W)	Typical Design Detail
Starting from the inside					
1	Cement plaster	0.025	0.720	0.035	
2	Aerated Concrete Slab	0.200	0.160	1.250	
3	Cement screed	0.050	1.400	0.036	
4	Roofing Felt	0.002	0.190	0.011	
Heat Flow		Downwards		Coefficient of Thermal Conductivity U (W/m²K)	
Rsi (m²K/W)		0.100			
Rse (m²K/W)		0.040		0.680	

Notes:

The requirement of $U \leq 0.4 \text{ W/m}^2\text{K}$ as defined by the relevant decree is met

Construction description		Floor slab			
A/A	Name of Material	Material Thickness d (m)	Thermal Conductivity Material λ (W/mK)	Thermal Resistance of Material R (m²K/W)	Typical Design Detail
Starting from the inside					
1	Ceramic/clay tiles	0.020	0.800	0.025	
2	Cement screed	0.050	1.400	0.036	
3	Cast Concrete	0.200	1.400	0.143	
4	Cement plaster	0.025	0.720	0.035	
5	Cement screed	0.050	1.400	0.036	
6	Cast Concrete	0.200	1.400	0.143	
7	Cement plaster	0.025	0.720	0.035	
Heat Flow		Downwards		Coefficient of Thermal Conductivity U (W/m²K)	
Rsi (m²K/W)		0.100			
Rse (m²K/W)		0.040			
Notes:					
The requirement of U≤0.4 W/m²K as defined by the relevant decree is not met					

According to the above results, it is observed that in all cases the heat transfer coefficients exceed the allowable limits. This results in increased use of air conditioning systems, as they operate for longer hours to maintain the desired indoor temperature of the hotel. Their extended operation leads to higher electricity consumption, which in turn causes an increase in operating costs. At the same time, the company's carbon footprint also rises due to the greater emissions released into the atmosphere.

CHAPTER 5: DESIGN BUILDER OF EXISTING

BUILDING

5.1. PURPOSE

The main purpose of using the DesignBuilder software in the study of the Semeli Hotel was the energy simulation and evaluation of the building. Through the program, it was possible to analyze the energy behavior of the hotel, calculate thermal losses and heating/cooling loads, as well as evaluate alternative energy performance scenarios. The software contributed to a better understanding of the impact of building design and HVAC systems on the overall energy consumption of the building, with the aim of optimizing its operation and reducing its environmental footprint.

5.2. BUILDING DESCRIPTION

The building is a hotel unit consisting of 5 floors— a ground floor and 4 floors with guest rooms. It has dimensions of 38 meters in length and 14.6 meters in width, with a total area of 1,965 m². The building is used both as a hotel and for seminar spaces. It includes areas such as a kitchen, dining room, reception area, bar, lounge, offices, seminar rooms, shared restrooms, staircases, and rooms with private bathrooms.

The building is located in Nicosia, the capital of Cyprus, which is characterized by a warm Mediterranean climate with hot summers and mild winters. Its location significantly affects the thermal behavior of the building.

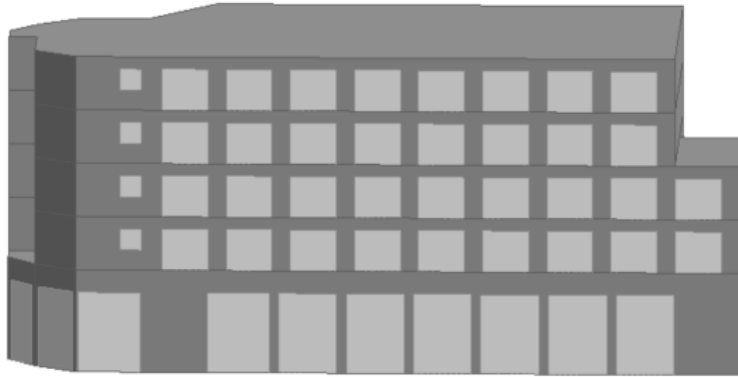


Image 5.2a. Building Façade

5.3. DESIGN BUILDER

DesignBuilder is an advanced building simulation software used for analyzing a building's energy performance, thermal comfort, and lighting. It is based on the EnergyPlus simulation engine and offers a user-friendly interface that allows users to create 3D building models and carry out complex analyses such as thermal/cooling energy consumption, lighting, ventilation, thermal comfort, and more. It is widely used by architects, engineers, and researchers for the design and improvement of buildings' energy efficiency.

5.3.1. BUILDING DESIGN & MODELING

Users can design complex geometric building layouts thanks to a 3D modeling tool. The software provides the ability to import CAD drawings and create zones and surfaces.

5.3.2. CONSTRUCTION AND MATERIALS

The software offers an extensive library of building elements, materials, and systems. The designer can define thermal properties, types of windows and frames, wall materials, insulation,

and more. It also provides predefined construction templates in accordance with national standards.

5.3.3. SPACE USES AND ACTIVITIES

In each building zone, it is possible to define the type of use (offices, school, hotel, residential, etc.), including ventilation standards, comfort conditions, and internal gain profiles (human activity, lighting, equipment).

5.3.4. HVAC SYSTEMS

The software provides capabilities for detailed modeling of cooling, heating, ventilation, and air conditioning systems. The user can choose between simple systems and complex controlled systems, such as heat recovery units, VRV systems, heat pumps, etc.

5.3.5. LIGHTING

The software allows the analysis and adjustment of lighting based on photometric data and the energy consumption from lighting systems.

5.3.6. DAYLIGHT ANALYSIS

Using the Daylight Analysis tool, the software calculates indicators such as the Daylight Factor, which help evaluate the quality of natural lighting in the building.

5.4. THERMAL ZONES

Thermal zones are areas within a building that are assumed to have uniform conditions of temperature, humidity, and ventilation. Each zone may include one or more spaces with similar usage characteristics and comfort requirements.

Zones are used for analyzing the energy performance of the building, as the software calculates the thermal behavior of each zone individually, taking into account factors such as orientation, openings, insulation, HVAC systems, and internal thermal loads (e.g., lighting, appliances, occupancy).

5.5. THERMAL COMFORT CONDITIONS (PMV, PPD)

Thermal comfort refers to the level of satisfaction experienced by occupants in relation to indoor temperature conditions. The key indicators used to assess thermal comfort are PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied).

- **PMV (Predicted Mean Vote):** PMV predicts the average vote of individuals on thermal sensation using a scale from -3 (cold) to +3 (hot). The goal is to keep the PMV close to 0, which indicates neutral thermal comfort. For indoor comfort, the acceptable PMV range is between -0.5 and +0.5.
- **PPD (Predicted Percentage of Dissatisfied):** PPD calculates the percentage of people likely to feel dissatisfied with the thermal conditions. The aim is to maintain PPD below 10%, to ensure the satisfaction of most building occupants.

5.6. BUILDING CREATION IN DESIGNBUILDER

A new file was created in the software, with the location set to Larnaca Airport. This location was chosen because it is the closest available option in the software that provides reliable climatic data, relative to Nicosia, where the building under study is located.

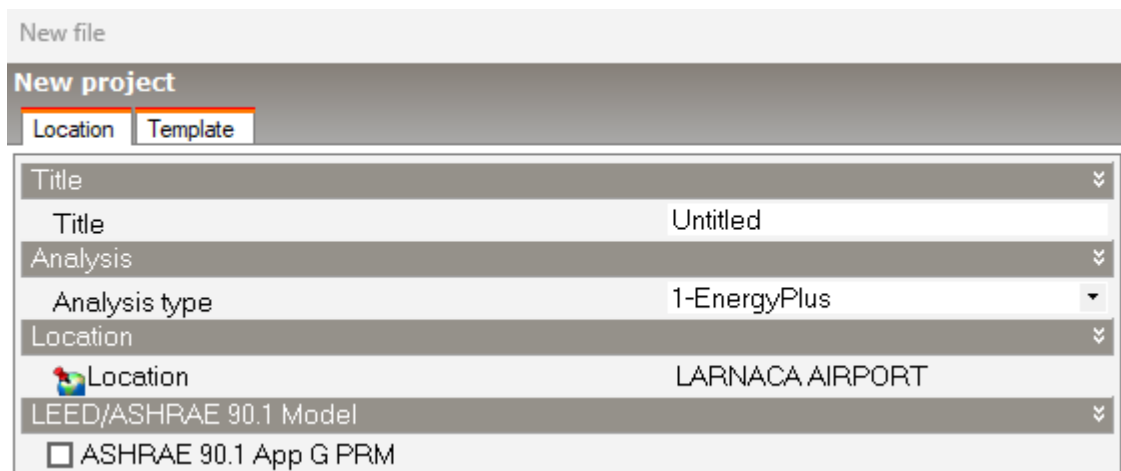


Image 5.6a: Location Selection

The creation of the building's external outline was carried out using the "Add New Block" command from the command bar. The building was designed with external walls measuring 38 meters in length, 14.6 meters in width, and a total height of 16.5 meters. This geometry defines the basic dimensions of the building and the organization of the space.

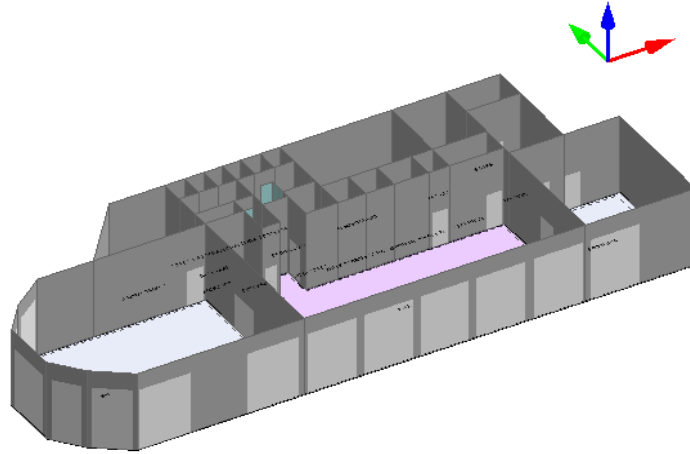


Image 5.6b: 3D visualization of the exterior masonry of a building

5.6.1. EXTERNAL WALL CONSTRUCTION

After completing the creation of the building's external outline, the materials of the external walls were customized. As shown below, the material customization was done using the Construction panel of the software. The external wall consists of three distinct layers, each with different materials and thicknesses. The detailed wall composition includes the following:

1. **External Layer:**
 - Material: Cement/plaster/mortar – cement plaster
 - Thickness: 0.025 m
2. **Second Layer:**
 - Material: Brick
 - Thickness: 0.200 m
3. **Internal Layer:**
 - Material: Cement/plaster/mortar – cement plaster
 - Thickness: 0.025 m

Constructions																																									
Layers	Surface properties Image Calculated Cost Condensation analysis																																								
General																																									
Name	External_wall																																								
Source																																									
Category	Walls																																								
Region	General																																								
Colour																																									
Definition																																									
Definition method	1-Layers																																								
Calculation Settings																																									
Layers																																									
Number of layers	3																																								
Outermost layer																																									
Material	Cement/plaster/mortar - cement plaster																																								
Thickness (m)	0.0250																																								
Bridged?	☐																																								
Layer 2																																									
Material	Brick																																								
Thickness (m)	0.2000																																								
Bridged?	☐																																								
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Bridged?	☐																																								
Cross Section																																									
Outer surface	Inner surface																																								
																																									
<table border="1"> <tbody> <tr> <td colspan="2">Inner surface</td> </tr> <tr> <td>Convective heat transfer coefficient (W/m²-K)</td> <td>2.152</td> </tr> <tr> <td>Radiative heat transfer coefficient (W/m²-K)</td> <td>5.540</td> </tr> <tr> <td>Surface resistance (m²-K/W)</td> <td>0.130</td> </tr> <tr> <td colspan="2">Outer surface</td> </tr> <tr> <td>Convective heat transfer coefficient (W/m²-K)</td> <td>19.870</td> </tr> <tr> <td>Radiative heat transfer coefficient (W/m²-K)</td> <td>5.130</td> </tr> <tr> <td>Surface resistance (m²-K/W)</td> <td>0.040</td> </tr> <tr> <td colspan="2">No Bridging</td> </tr> <tr> <td>U-Value surface to surface (W/m²-K)</td> <td>2.880</td> </tr> <tr> <td>R-Value (m²-K/W)</td> <td>0.517</td> </tr> <tr> <td>U-Value (W/m²-K)</td> <td>1.933</td> </tr> <tr> <td colspan="2">With Bridging (BS EN ISO 6946)</td> </tr> <tr> <td>Thickness (m)</td> <td>0.2500</td> </tr> <tr> <td>Km - Internal heat capacity (KJ/m²-K)</td> <td>157.9200</td> </tr> <tr> <td>Upper resistance limit (m²-K/W)</td> <td>0.517</td> </tr> <tr> <td>Lower resistance limit (m²-K/W)</td> <td>0.517</td> </tr> <tr> <td>U-Value surface to surface (W/m²-K)</td> <td>2.880</td> </tr> <tr> <td>R-Value (m²-K/W)</td> <td>0.517</td> </tr> <tr> <td>U-Value (W/m²-K)</td> <td>1.933</td> </tr> </tbody> </table>		Inner surface		Convective heat transfer coefficient (W/m ² -K)	2.152	Radiative heat transfer coefficient (W/m ² -K)	5.540	Surface resistance (m ² -K/W)	0.130	Outer surface		Convective heat transfer coefficient (W/m ² -K)	19.870	Radiative heat transfer coefficient (W/m ² -K)	5.130	Surface resistance (m ² -K/W)	0.040	No Bridging		U-Value surface to surface (W/m ² -K)	2.880	R-Value (m ² -K/W)	0.517	U-Value (W/m²-K)	1.933	With Bridging (BS EN ISO 6946)		Thickness (m)	0.2500	Km - Internal heat capacity (KJ/m ² -K)	157.9200	Upper resistance limit (m ² -K/W)	0.517	Lower resistance limit (m ² -K/W)	0.517	U-Value surface to surface (W/m ² -K)	2.880	R-Value (m ² -K/W)	0.517	U-Value (W/m²-K)	1.933
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Image 5.6.1a. External wall construction

5.6.2. SEPARATION OF ZONES AND ADDITION OF INTERNAL WALLS

The building consists of various thermal zones corresponding to different spaces. The layout of the building is as follows:

- **Ground floor**

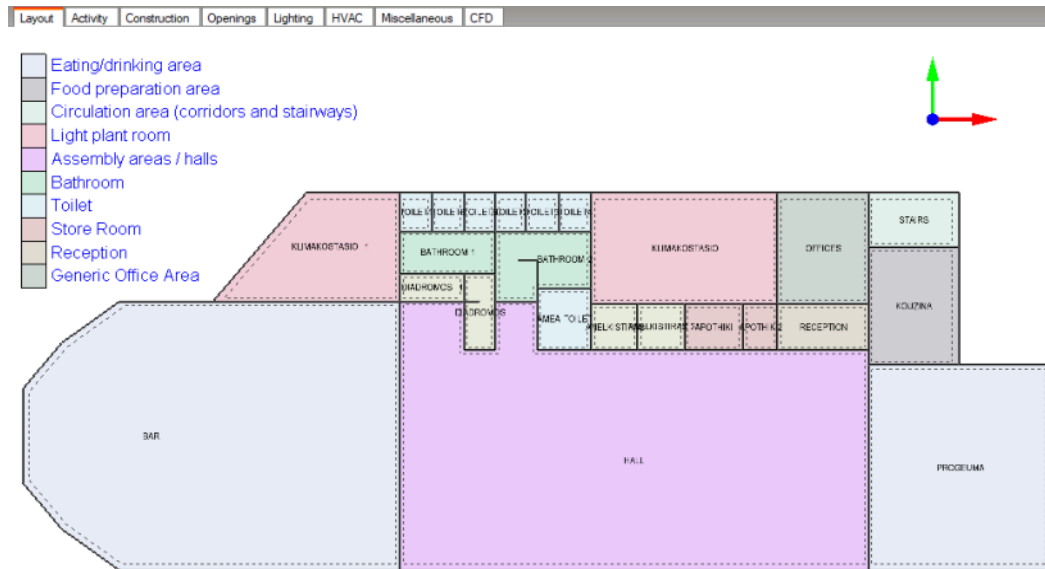


Image 5.6.2a. Zone for ground floor

- **Floors with rooms**

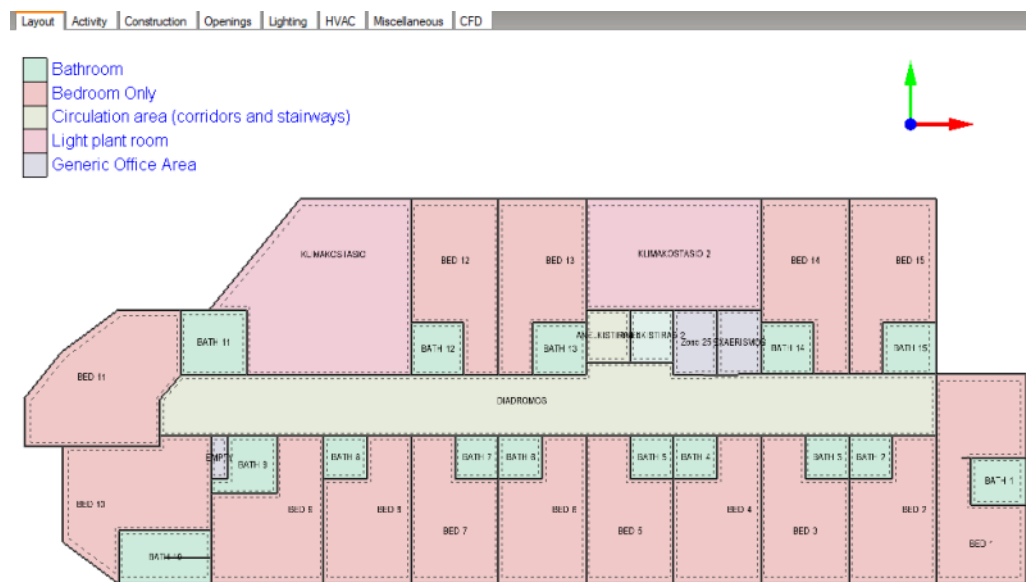


Image 5.6.2b. Zone for ground floor

5.6.3. INTERNAL WALLS

For the internal walls, as mentioned above, we added the wall construction materials using the Construction table of the software. The internal wall consists of three distinct layers, each with different materials and thicknesses. Its detailed composition, as well as the U-value, is shown below:

- **External Layer:**
 - Material: Cement plaster
 - Thickness: 0.025 m
- **Second Layer:**
 - Material: Brick
 - Thickness: 0.200 m
- **Internal Layer:**
 - Material: Cement plaster
 - Thickness: 0.025 m

Constructions

Layers

Surface properties

Image

Calculated

Cost

Condensation analysis

General

Name

in_wall

Source

Category

Partitions

Region

General

Colour

Definition

Definition method

1-Layers

Calculation Settings

Layers

Number of layers

3

Outermost layer

Material

Cement/plaster/mortar - cement plaster

Thickness (m)

0.0250

Bridged?

Layer 2

Material

Brick

Thickness (m)

0.2000

Bridged?

Innermost layer

Material

Cement/plaster/mortar - cement plaster

Thickness (m)

0.0250

Constructions

Layers

Surface properties

Image

Calculated

Cost

Condensation analysis

Cross Section

Outer surface

25.00mm

Cement/plaster/mortar - cement plaster

200.00mm

Brick

25.00mm

Cement/plaster/mortar - cement plaster

Inner surface

Constructions

Layers

Surface properties

Image

Calculated

Cost

Condensation analysis

Inner surface

Convective heat transfer coefficient (W/m2-K)

2.152

Radiative heat transfer coefficient (W/m2-K)

5.540

Surface resistance (m2-K/W)

0.130

Outer surface

Convective heat transfer coefficient (W/m2-K)

2.152

Radiative heat transfer coefficient (W/m2-K)

5.540

Surface resistance (m2-K/W)

0.130

No Bridging

U-Value surface to surface (W/m2-K)

2.880

R-Value (m2-K/W)

0.607

U-Value (W/m2-K)

1.647

With Bridging (BS EN ISO 6946)

Thickness (m)

0.2500

Km - Internal heat capacity (KJ/m2-K)

157.9200

Upper resistance limit (m2-K/W)

0.607

Lower resistance limit (m2-K/W)

0.607

U-Value surface to surface (W/m2-K)

2.880

R-Value (m2-K/W)

0.607

U-Value (W/m2-K)

1.647

Image 5.6.3a. Internal wall construction

5.6.4. ADDITION OF OPENINGS

Using the "Draw Partitions" command of the software, the windows were designed on each floor.

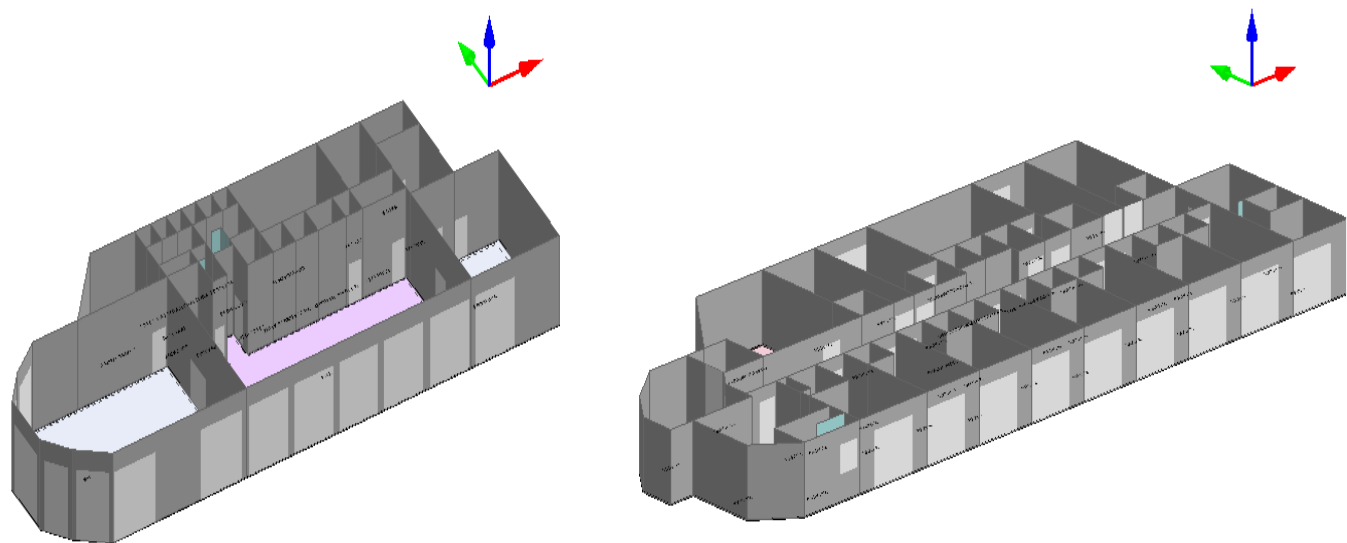


Image 5.6.4a: Representation of openings

Glazing Template	
Template	Single glazing, clear, no shading
External Windows	
Glazing type	Sgl Clr 6mm
Layout	Preferred height 1.5m, 30% glazed

Image 5.6.4b: Window specifications

Calculated Values	
Total solar transmission (SHGC)	0.819
Direct solar transmission	0.775
Visible transmittance	0.881
U-value (ISO 10292/ EN 673) (W/m2-K)	5.718
U-Value (W/m2-K)	5.778

Image 5.6.4c: Thermal transmittance coefficient (U-Value) of the windows

For the building's doors, the material "Woods – oak, beech, ash, walnut, meranti Dry" was used.

Inner surface	
Convective heat transfer coefficient (W/m ² -K)	2,152
Radiative heat transfer coefficient (W/m ² -K)	5,540
Surface resistance (m ² -K/W)	0,130
Outer surface	
Convective heat transfer coefficient (W/m ² -K)	19,460
Radiative heat transfer coefficient (W/m ² -K)	5,540
Surface resistance (m ² -K/W)	0,040
No Bridging	
U-Value surface to surface (W/m ² -K)	5,429
R-Value (m ² -K/W)	0,354
U-Value (W/m²-K)	2,823
With Bridging (BS EN ISO 6946)	
Thickness (m)	0,0350
Km - Internal heat capacity (KJ/m ² -K)	29,2775
Upper resistance limit (m ² -K/W)	0,354
Lower resistance limit (m ² -K/W)	0,354
U-Value surface to surface (W/m ² -K)	5,429
R-Value (m ² -K/W)	0,354
U-Value (W/m²-K)	2,823

Image 5.6.4d: Thermal properties and thermal transmittance coefficient (U-Value) for the interior doors

5.6.5. FLOOR STRUCTURE

For the building's floor, a floor template was created in the “Construction” > GroundFloor section, as shown below. The external layer consists of ceramic floor tiles with a thickness of 0.02 m, while the internal layer is made of reinforced concrete with a thickness of 0.20 m.

Floors	
 Ground floor	GroundFloor
 External floor	Project external floor
 Internal floor	Project internal floor

Image 5.6.5a: Creation of floor template

- **External Layer**
 - Material: Aerated Concrete Slab
 - Thickness: 0.20 m

- **Internal Layer**

- Material: Ceramic/clay tiles – ceramic floor tiles
- Thickness: 0.02 m

Constructions

Layers | Surface properties | Image | Calculated | Cost | Condensation analysis

General

Name GroundFloor

Source

Category Floors (ground)

Region General

Colour

Definition

Definition method 1-Layers

Calculation Settings

Layers

Number of layers 2

Outermost layer

Material Aerated Concrete Slab

Thickness (m) 0.2000

☐ Bridged?

Innermost layer

Material Ceramic/clay tiles - ceramic floor tiles Dr

Thickness (m) 0.0200

☐ Bridged?



Constructions

Layers | Surface properties | Image | Calculated | Cost | Condensation analysis

Inner surface	
Convective heat transfer coefficient (W/m ² -K)	0.342
Radiative heat transfer coefficient (W/m ² -K)	5.540
Surface resistance (m ² -K/W)	0.170
Outer surface	
Convective heat transfer coefficient (W/m ² -K)	19.870
Radiative heat transfer coefficient (W/m ² -K)	5.130
Surface resistance (m ² -K/W)	0.040
No Bridging	
U-Value surface to surface (W/m ² -K)	0.784
R-Value (m ² -K/W)	1.485
U-Value (W/m²-K)	0.673
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.2200
Km - Internal heat capacity (KJ/m ² -K)	62.5000
Upper resistance limit (m ² -K/W)	1.485
Lower resistance limit (m ² -K/W)	1.485
U-Value surface to surface (W/m ² -K)	0.784
R-Value (m ² -K/W)	1.485
U-Value (W/m²-K)	0.673

Image 5.6.5a: Floor structure

5.6.6. ROOF CREATION

The building under analysis does not have a pitched roof; therefore, a flat roof template was created in the “Construction” > Flat Roof section, and the construction materials were added as follows:

- **External Layer:**
 - Material: Roofing Felt
 - Thickness: 0.002 m
- **Second Layer:**
 - Material: Cement/plaster/mortar – cement screed
 - Thickness: 0.05 m
- **Third Layer:**
 - Material: Aerated Concrete Slab
 - Thickness: 0.20 m
- **Internal Layer:**
 - Material: Cement/plaster/mortar – cement plaster
 - Thickness: 0.025 m

Constructions

Layers | Surface properties | Image | Calculated | Cost | Condensation analysis

General

Name: **PlakaPano**

Source:

Category: Roofs

Region: General

Colour:

Definition

Definition method: 1-Layers

Calculation Settings

Layers

Number of layers: 4

Outermost layer

Material: Roofing Felt

Thickness (m): 0.0020

☐ Bridged?

Layer 2

Material: Cement/plaster/mortar - cement screed

Thickness (m): 0.0500

☐ Bridged?

Layer 3

Material: Aerated Concrete Slab

Thickness (m): 0.2000

☐ Bridged?

Innermost layer

Material: Cement/plaster/mortar - cement plaster

Thickness (m): 0.0250

☐ Bridged?



Constructions

Layers | Surface properties | Image | Calculated | Cost | Condensation analysis

Inner surface	
Convective heat transfer coefficient (W/m ² -K)	4.460
Radiative heat transfer coefficient (W/m ² -K)	5.540
Surface resistance (m ² -K/W)	0.100
Outer surface	
Convective heat transfer coefficient (W/m ² -K)	19.870
Radiative heat transfer coefficient (W/m ² -K)	5.130
Surface resistance (m ² -K/W)	0.040
No Bridging	
U-Value surface to surface (W/m ² -K)	0.751
R-Value (m ² -K/W)	1.471
U-Value (W/m²-K)	0.680
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.2770
Km - Internal heat capacity (KJ/m ² -K)	68.4600
Upper resistance limit (m ² -K/W)	1.471
Lower resistance limit (m ² -K/W)	1.471
U-Value surface to surface (W/m ² -K)	0.751
R-Value (m ² -K/W)	1.471
U-Value (W/m²-K)	0.680

Image 5.6.6a: Roof construction

5.6.7. INTERMEDIATE FLOOR CREATION

For the slab between the floors of the building, a roof template was created in the “Construction” > Flat Roof section, and the construction materials were added as follows:

- **External Layer:**
 - Material: Ceramic/clay tiles – ceramic floor tiles
 - Thickness: 0.02 m
- **Second Layer:**
 - Material: Cement/plaster/mortar – cement screed
 - Thickness: 0.05 m
- **Third Layer:**
 - Material: Cast Concrete
 - Thickness: 0.15 m
- **Fourth Layer:**
 - Material: Cement/plaster/mortar – cement plaster
 - Thickness: 0.025 m
- **Fifth Layer:**
 - Material: Cement/plaster/mortar – cement screed
 - Thickness: 0.05 m
- **Sixth Layer:**
 - Material: Cast Concrete

- Thickness: 0.15 m
- **Internal Layer:**
 - Material: Cement/plaster/mortar – cement plaster
 - Thickness: 0.025 m

Constructions

Layers | Surface properties | Image | Calculated | Cost | Condensation analysis

General

Name: **plaka**

Source:

Category: Roofs

Region: General

Colour:

Definition

Calculation Settings

Layers

Number of layers: 7

Outermost layer

Material: Ceramic/clay tiles - ceramic floor tiles Dry(not to scale)

Thickness (m): 0.0200

☐ Bridged?

Layer 2

Material: Cement/plaster/mortar - cement screed

Thickness (m): 0.0500

☐ Bridged?

Layer 3

Material: Cast Concrete (Dense)

Thickness (m): 0.1500

☐ Bridged?

Layer 4

Material: Cement/plaster/mortar - cement plaster

Thickness (m): 0.0250

☐ Bridged?

Layer 5

Material: Cement/plaster/mortar - cement screed

Thickness (m): 0.0500

☐ Bridged?

Layer 6

Material: Cast Concrete (Dense)

Thickness (m): 0.1500

☐ Bridged?

Innermost layer

Material: Cement/plaster/mortar - cement plaster

Thickness (m): 0.0250

Cross Section

Outer surface

20.00mm - Ceramic/clay tiles - ceramic floor tiles Dry(not to scale)

50.00mm - Cement/plaster/mortar - cement screed

150.00mm - Cast Concrete (Dense)

25.00mm - Cement/plaster/mortar - cement plaster(not to scale)

50.00mm - Cement/plaster/mortar - cement screed

150.00mm - Cast Concrete (Dense)

25.00mm - Cement/plaster/mortar - cement plaster(not to scale)

Inner surface

Constructions

Layers | Surface properties | Image | Calculated | Cost | Condensation analysis

Inner surface

Convective heat transfer coefficient (W/m²·K): 4.460

Radiative heat transfer coefficient (W/m²·K): 5.540

Surface resistance (m²·K/W): 0.100

Outer surface

Convective heat transfer coefficient (W/m²·K): 19.870

Radiative heat transfer coefficient (W/m²·K): 5.130

Surface resistance (m²·K/W): 0.040

No Bridging

U-Value surface to surface (W/m²·K): 2.630

R-Value (m²·K/W): 0.520

U-Value (W/m²·K): 1.922

With Bridging (BS EN ISO 6946)

Thickness (m): 0.4700

Km - Internal heat capacity (KJ/m²·K): 169.2600

Upper resistance limit (m²·K/W): 0.520

Lower resistance limit (m²·K/W): 0.520

U-Value surface to surface (W/m²·K): 2.630

R-Value (m²·K/W): 0.520

U-Value (W/m²·K): 1.922

Image 5.6.7a: Intermediate floor construction

5.6.8. LIGHTING

For the lighting template, LED fixtures were used with a Normalized Power Density ranging from 10 W/m² to 100 lux. The Luminaire Type selected is "Surface mount," as the lighting fixtures are surface-mounted. The Radiant Fraction is set to 0.4, which defines the portion of lighting energy converted into radiant heat. The Visible Fraction is set to 0.2, indicating the portion of energy that is visible light. The lighting control system is set to on (enabled). The Control Type is 1-Linear, which corresponds to a basic switch.

- **Min Output Fraction: 0.1**
- **Min Input Power Fraction: 0.1**
- **Maximum Allowable Glare Index: 22**
- **View Angle Relative to Y-Axis: 0°**

Task and display lighting are enabled (on). The Power Density is set to 0.5 W/m², as LEDs are more energy-efficient. In the activity settings, the target illumination is defined as 400 lux.

Section	Property	Value
General Lighting	On	☒
	Normalised power density (W/m ² -100 lux)	10.0000
	Schedule	Office_OpenOff_Light
	Luminaire type	2-Surface mount
	Radiant fraction	0.4
	Visible fraction	0.18
	Convective fraction	0.420
Lighting Control	On	☒
	Working plane height (m)	0.80
	Control type	1-Linear
	Min output fraction	0.100
	Min input power fraction	0.100
	Glare	
	Maximum allowable glare index	22.0
View angle rel. to y-axis (°)	0.0	
Task and Display Lighting	On	☒
	Power density (W/m ²)	0.5
Exterior Lighting	Schedule	Hotel_Circulation_Light
	On	☐
Lighting Summary	Target Illuminance (lux)	400
	Default display lighting density (W/m ²)	0

Image 5.6.8a: Lighting Template

In the living room, which is a large space, an additional smaller lamp was installed to supplement the main lighting. Therefore, a second light fixture was added with a target illuminance of 150 lux.

5.6.9. HVAC SYSTEM

In the HVAC tab, the specifications for each zone were configured individually. In all spaces equipped with cooling/heating systems, the following components were installed:

- Fan Coil Unit
- Air-Cooled Chiller

A custom operation schedule was set for each zone.

- For example, the Hotel_Toilet schedule was applied to bathrooms,
- The Hotel_Bed schedule was used for bedrooms,
- And similar schedules were set for all other rooms of the building.

All units operate using electrical energy.

For domestic hot water (DHW), a centralized system was defined to serve the entire building.

Additionally, in all rooms with windows, natural ventilation was implemented.

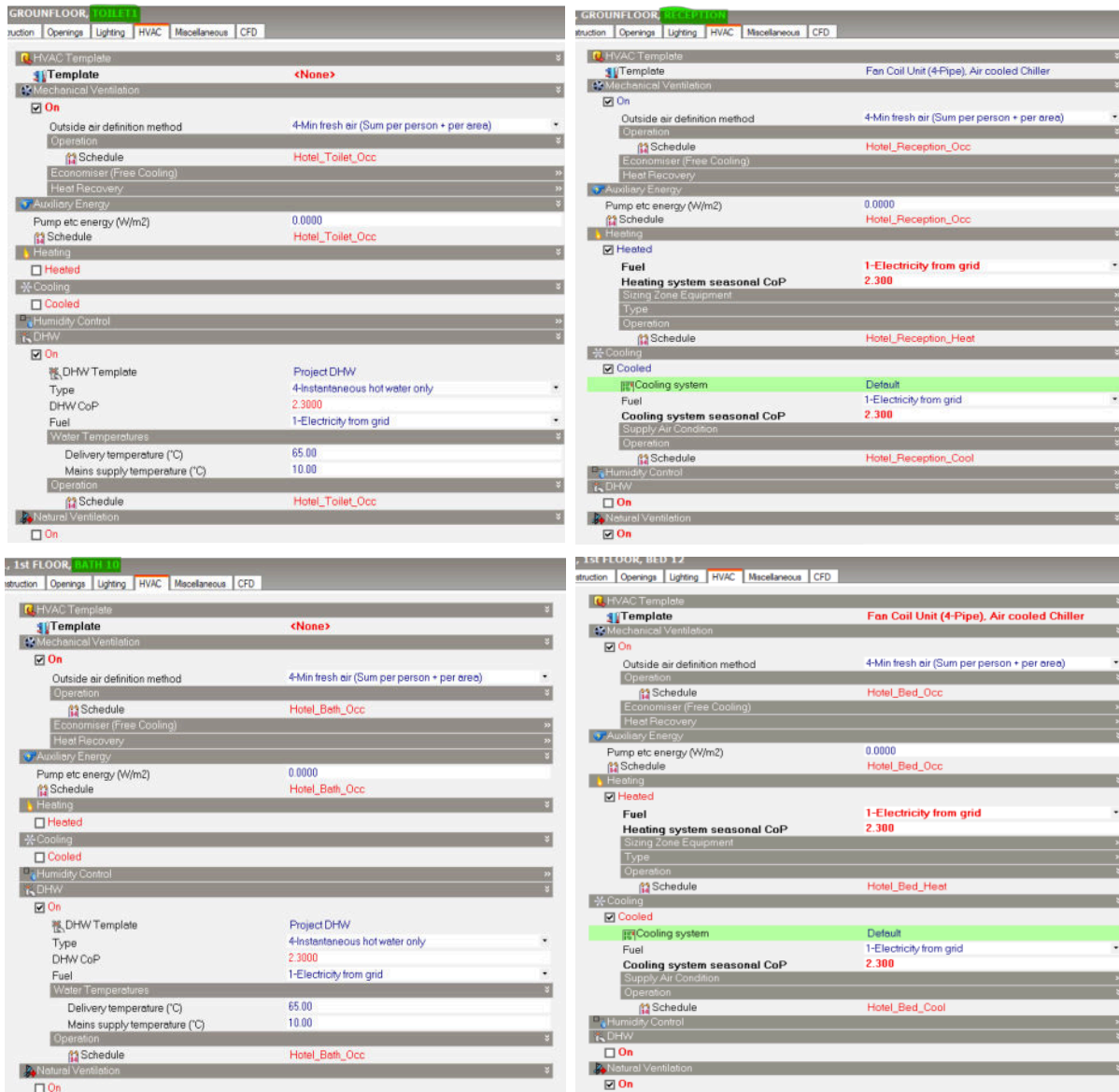


Image 5.6.8a: HVAC specification

5.6.10. FINAL VISUALIZATION OF THE BUILDING

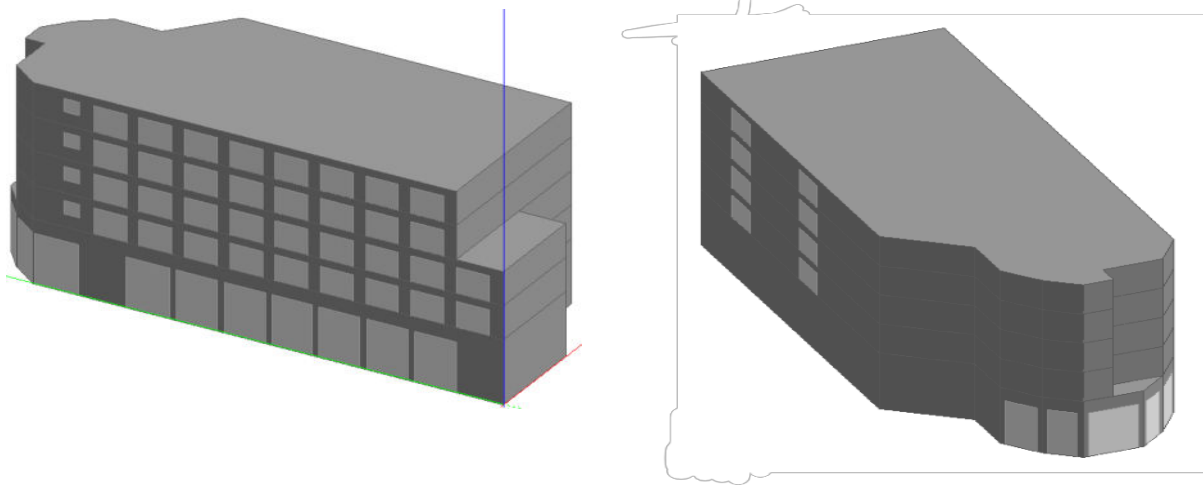


Image 5.6.10a: Building from Design Builder

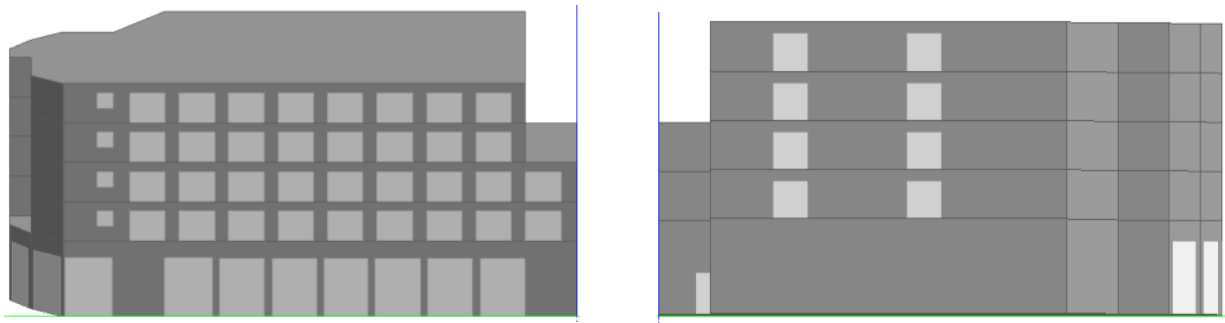


Image 5.6.10b: South and north elevation

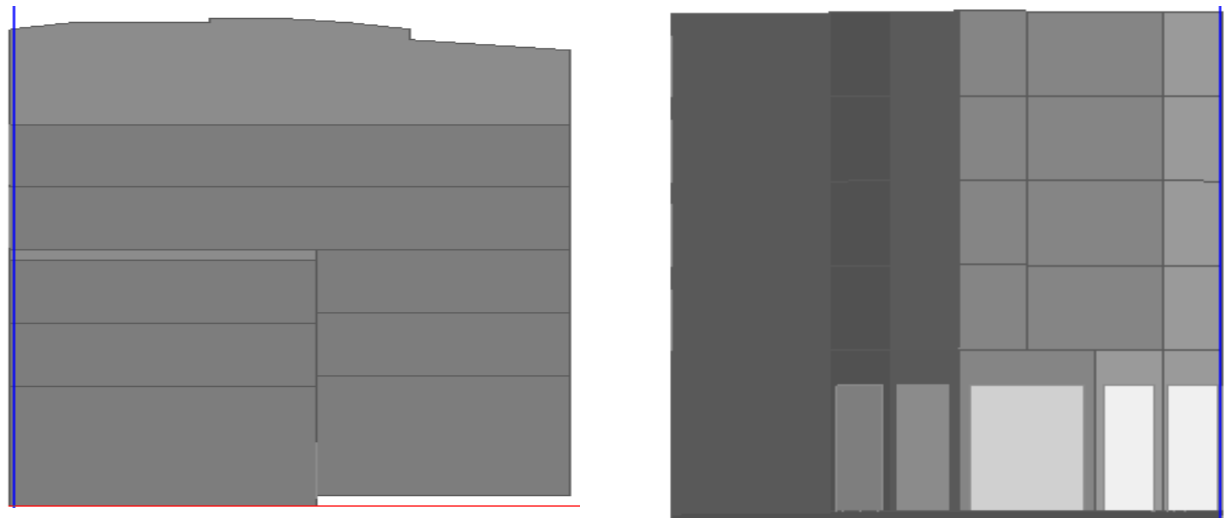


Image 5.6.10c: East and west elevation

5.7. DAYLIGHT SIMULATION

In the DesignBuilder software, we carried out a daylight simulation for the building under study, selecting four representative dates of the year: December 21st, March 21st, June 21st, and September 21st. The simulations were performed at four times of the day, at 09:00, 12:00, 15:00, and 18:00 in order to capture the variation in natural lighting intensity throughout the day and to evaluate the lighting performance in the various spaces of the building, as shown in the corresponding Table 5.7a, with the maximum illuminance values.

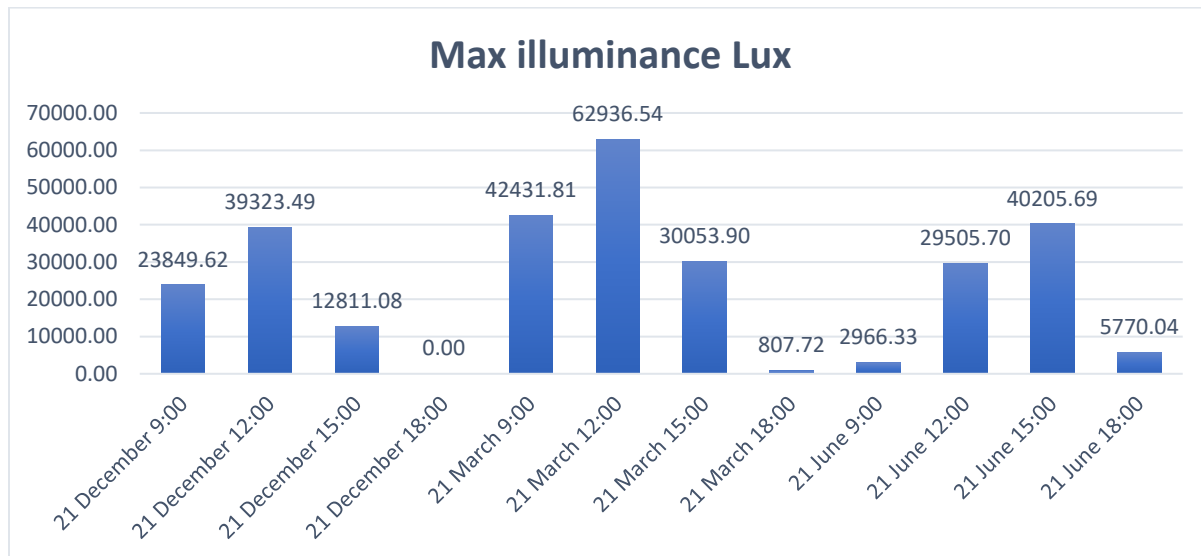
The unit of measurement used was lux, which is the standard unit of illuminance in the International System of Units (SI). For the evaluation of the results, we set acceptable limits for natural lighting intensity between 300 and 3000 lux, in accordance with established specifications for comfort and sufficient lighting conditions in indoor spaces.

The aim of the analysis was to capture the variation in natural illuminance as a function of both time of day and season.

From the data analysis, it is evident that the maximum illuminance generally occurs around midday (12:00), with the highest value recorded on March 21st. In contrast, on December 21st, when the day is shorter, the values remain lower. On the same day, at 18:00, the illuminance drops to zero, indicating that sunset occurs before that time.

NATURAL LIGHTING SIMULATION	
Date/Time	Max illuminance Lux
21 December 9:00	23849,62
21 December 12:00	39323,49
21 December 15:00	12811,08
21 December 18:00	0,00
21 March 9:00	42431,81
21 March 12:00	62936,54
21 March 15:00	30053,90
21 March 18:00	807,72
21 June 9:00	2966,33
21 June 12:00	29505,70
21 June 15:00	40205,69
21 June 18:00	5770,04
21 September 9:00	45921,73
21 September 12:00	63559,86
21 September 15:00	28208,52
21 September 18:00	632,85

Table 5.7a: Max illuminance



Graph 5.7a: Comparison of Maximum Illuminance Values by Month

As shown in the Image 5.7a, the ground floor receives the highest amount of natural light. This phenomenon is attributed to the presence of large glazed surfaces and openings on the façades of the ground floor, which allow sunlight to enter the interior. As a result, the indoor spaces on the ground floor benefit more from natural lighting, a fact reflected in the higher values observed on the illuminance scale.

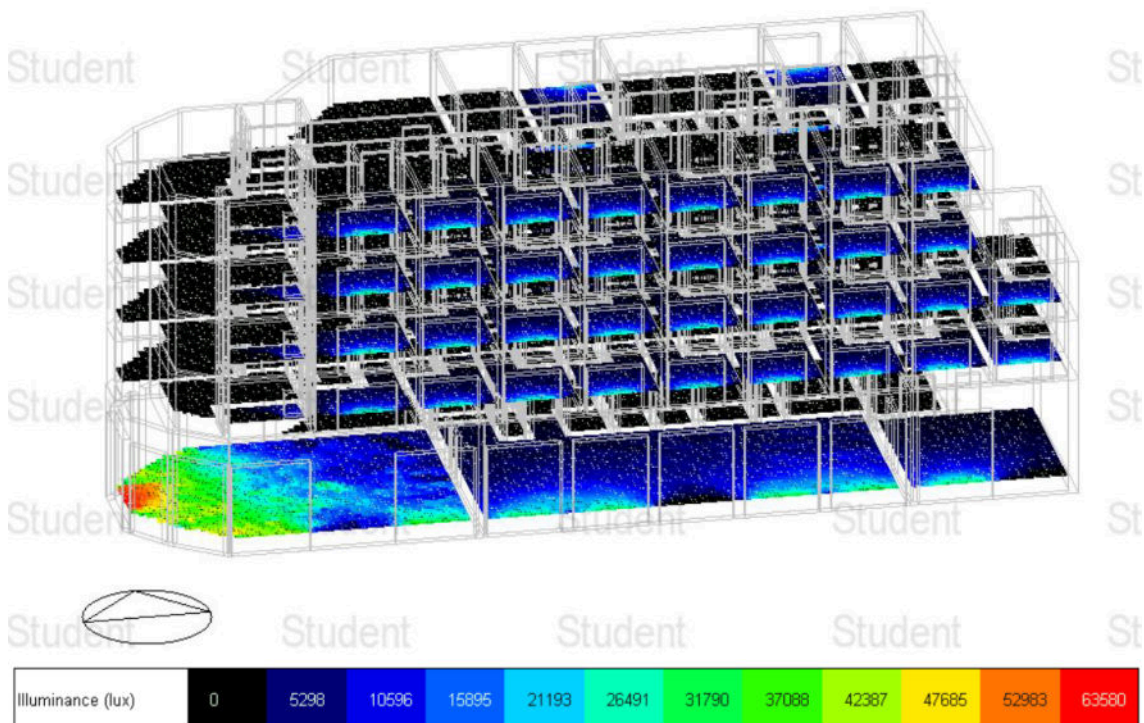


Table 5.7a: Natural Lighting Simulation

5.8. SUN PATH DIAGRAM

In the Image 5.8a, the sun path diagram is shown, illustrating the position of the sun in the sky throughout the day. More specifically, the angular positions of the sun at 09:00, 12:00, 15:00, and 18:00 are depicted, allowing us to analyze the effects of solar radiation and shading on the building. Through the three-dimensional representation, the shadows cast by the building's envelope and architectural elements are clearly visible, directly affecting the distribution of natural light within the interior spaces.

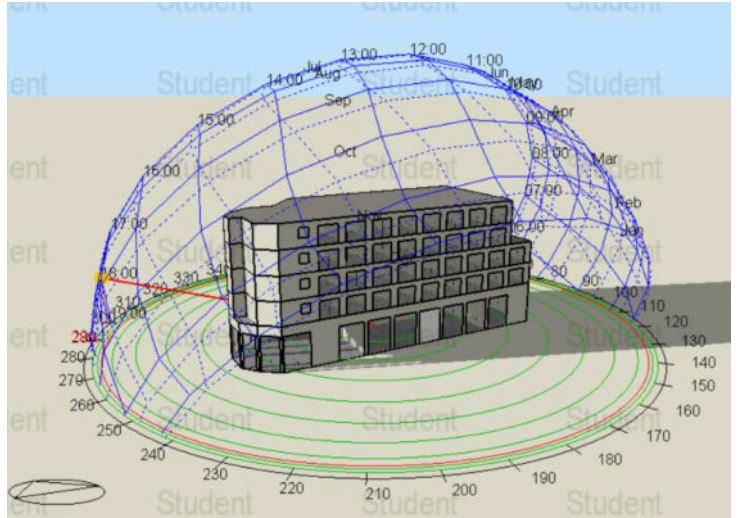
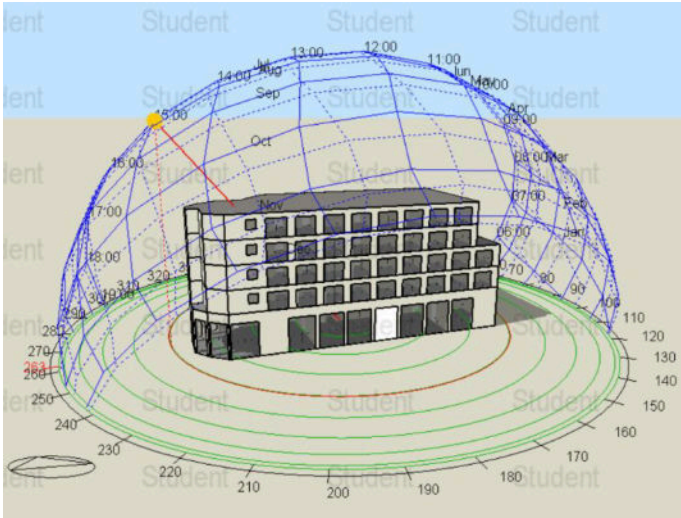
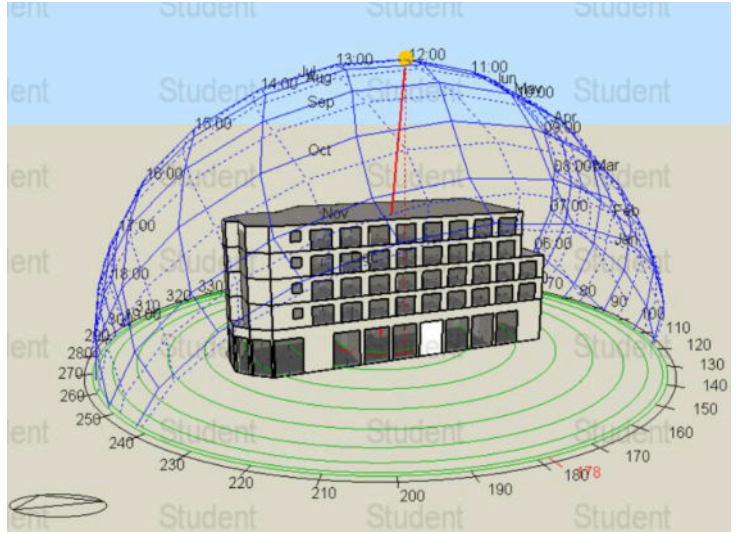
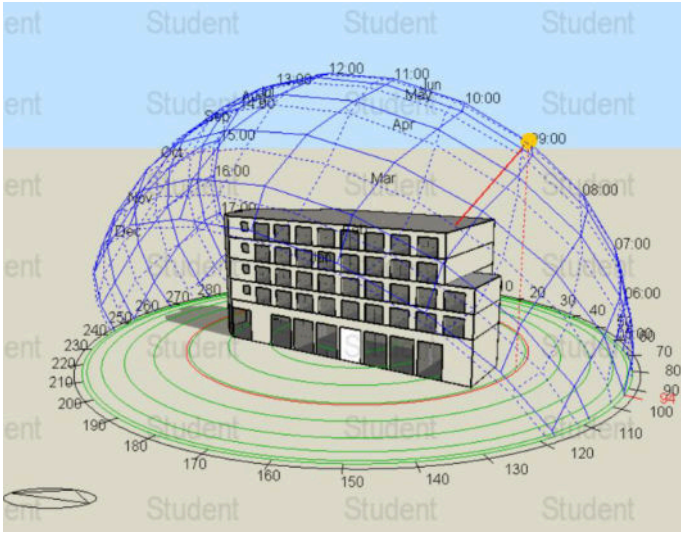


Image 5.8a: Sun Path Diagram

5.9. SIMULATION – DESIGN BUILDER

Below is the diagram showing the temperatures, heating/cooling loads, and ventilation for the entire building throughout the year.

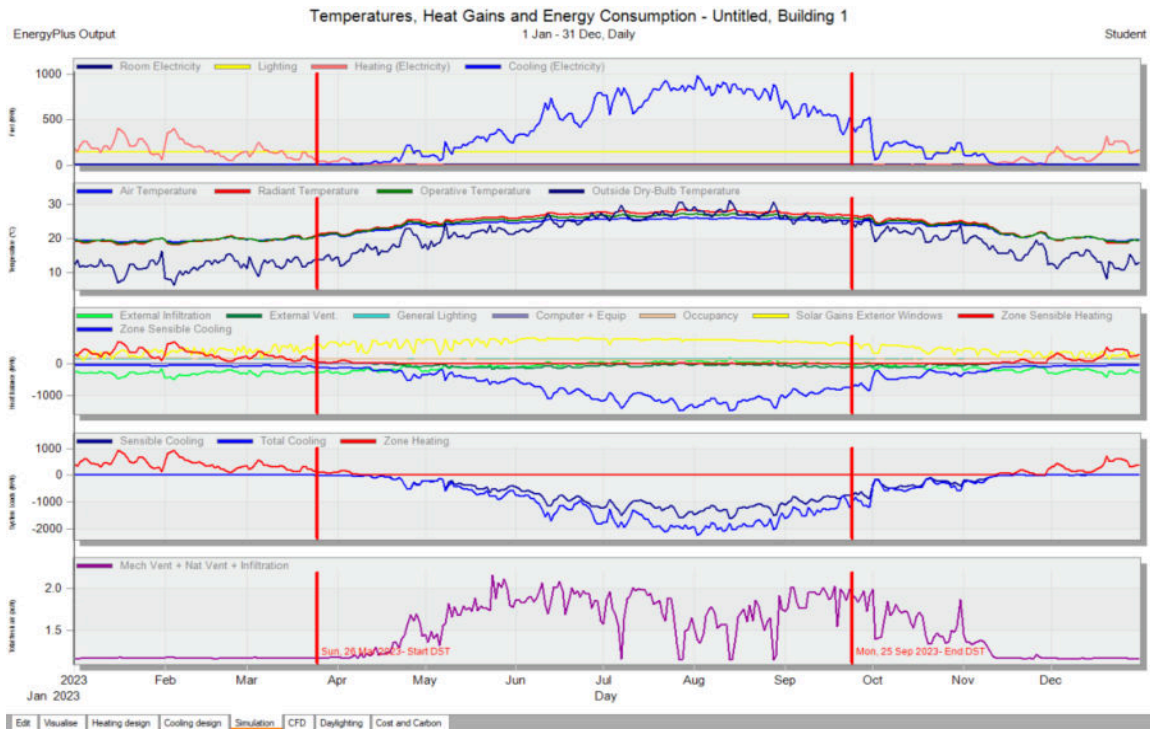


Diagram 5.9a: Diagram Annual analysis of temperatures, thermal loads, and ventilation of the entire building

Explanation of the Simulation Graphs:

- First Graph: Temperature (°C) vs. Time

This graph displays both indoor and outdoor temperatures over time. It includes:

- Air temperature
- Radiant temperature
- Operative (or comfort) temperature
- External temperature

The external temperature shows greater fluctuation, while the internal temperature remains more stable due to the building's construction.

- Second Graph: Thermal Gains & Balance (kWh) vs. Time

This graph shows:

- External air infiltration
- Outdoor ventilation
- Solar gains through windows
- Heating and cooling loads per zone

- Third Graph: Cooling & Heating System (kWh) vs. Time

This graph includes:

- Sensible cooling
- Total cooling
- Zone heating

Noticeable cooling loads occur in spring and summer, while heating loads peak in

autumn and winter. This is mainly due to the lack of insulation and increased thermal and cooling loads associated with it.

- Fourth Graph: Ventilation – Total Fresh Air (air changes per hour, ac/h)

This graph shows:

- Mechanical ventilation
- Natural ventilation
- Air infiltration

There is an increase in natural ventilation during the warmer months.

○

5.10. CONSUMPTION ANALYSIS

Below is the "Site and Source Energy" output from DesignBuilder, which presents the total energy consumption of the building.

Site and Source Energy

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m ²]	Energy Per Conditioned Building Area [kWh/m ²]
Total Site Energy	324507.87	162.18	184.79
Net Site Energy	324507.87	162.18	184.79
Total Source Energy	581012.90	290.37	330.85
Net Source Energy	581012.90	290.37	330.85

Table 5.10a: Building energy consumption

The Total Site Energy amounts to 324,507.87 kWh, representing the energy consumed within the building. The Net Site Energy has the same value, indicating that there is no renewable energy production reducing the final consumption.

Furthermore, the Total Source Energy is 581,012.90 kWh, reflecting the actual energy required to meet the building's energy demands. The Net Source Energy remains the same due to the absence of any renewable energy sources.

Below is the distribution of the building's energy consumption, breaking down the final energy uses. The table includes energy sources such as electricity and natural gas, along with consumption for cooling, heating, and domestic hot water.

End Uses

	Electricity [kWh]	Natural Gas [kWh]	Gasoline [kWh]	Diesel [kWh]	Coal [kWh]	Fuel Oil No 1 [kWh]	Fuel Oil No 2 [kWh]	Propane [kWh]	Other Fuel 1 [kWh]	Other Fuel 2 [kWh]	District Cooling [kWh]	District Heating [kWh]	Water [m3]
Heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	48739.74	0.00
Cooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	221877.65	0.00	0.00
Interior Lighting	52988.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	901.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	53890.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	221877.65	48739.74	0.00

Table 5.10b: Building energy consumption by end use

The main energy source for the building is electricity, with total consumption of 48,739.74 kWh for heating and 221,877.65 kWh for cooling. The electricity consumed by the internal lighting amounts to 52,988.86 kWh. Finally, the domestic hot water consumption is 901.61 kWh.

Next, the electrical energy consumptions derived from the simulation carried out using the DesignBuilder software are presented. The values refer both to the total consumption and to the consumption specifically related to the building's heating and cooling.

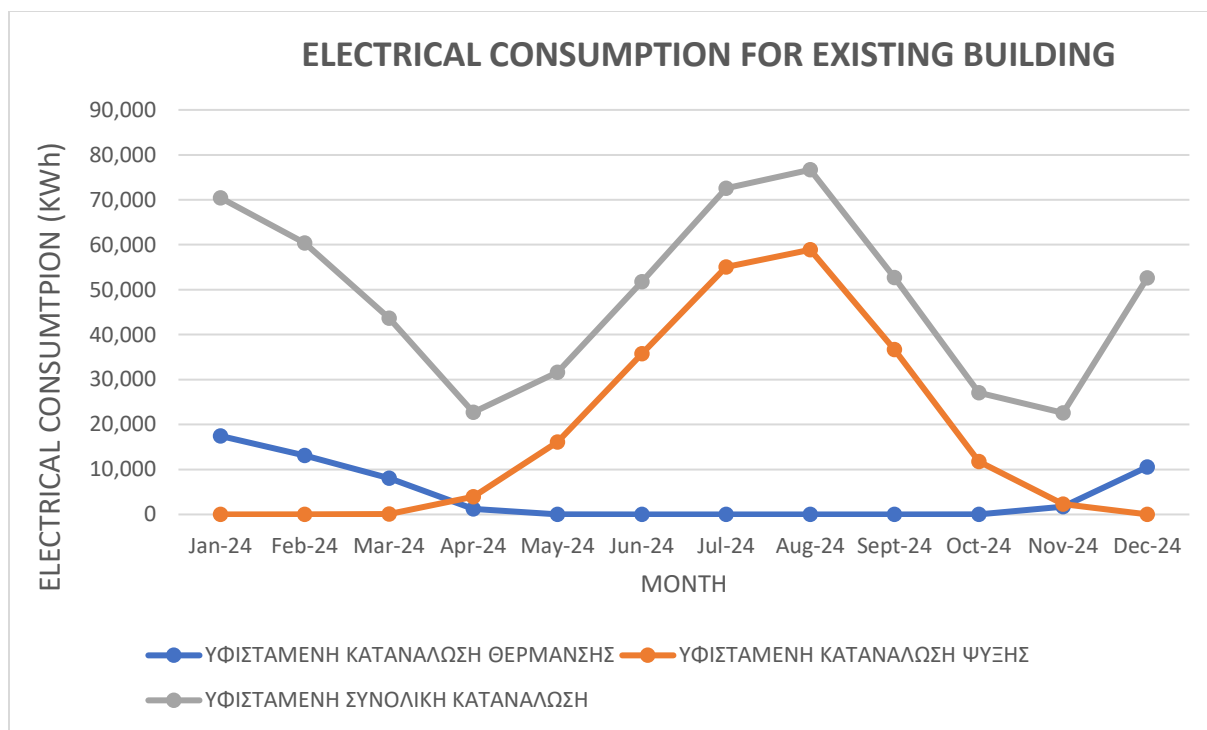
In a subsequent stage, a comparison will be made between the total consumption recorded by the Electricity Authority (AHK) and that obtained from the software simulation, in order to evaluate the accuracy of the simulation.

FROM DESIGN BUILDER				COMPARISON	
MONTH	ELECTRICAL CONSUMPTION FOR HEATING (kWh)	ELECTRICAL CONSUMPTION FOR COOLING (kWh)	TOTAL ELECTRICAL CONSUMPTION (KWh)	TOTAL ELECTRICAL CONSUMPTION FROM EAC (KWh)	COMPARISON OF MONTHLY CONSUMPTION (%)
Jan-24	17,458	4	70,426	38,515	-82.85%
Feb-24	13,091	18	60,417	41,110	-46.96%
Mar-24	8,045	101	43,694	31,575	-38.38%
Apr-24	1,258	3,971	22,734	25,743	11.69%
May-24	25	16,098	31,601	40,585	22.14%
Jun-24	0	35,727	51,759	55,093	6.05%
Jul-24	0	55,061	72,596	69,571	-4.35%
Aug-24	0	58,883	76,677	65,714	-16.68%
Sep-24	0	36,654	52,714	59,307	11.12%
Oct-24	38	11,795	27,082	52,500	48.41%
Nov-24	1,704	2,275	22,601	36,439	37.98%
Dec-24	10,546	49	52,629	32,216	-63.36%
TOTAL	48,740	221,878	581,013	548,368	-5.95%

Table 5.10c: Consumption from Design Builder

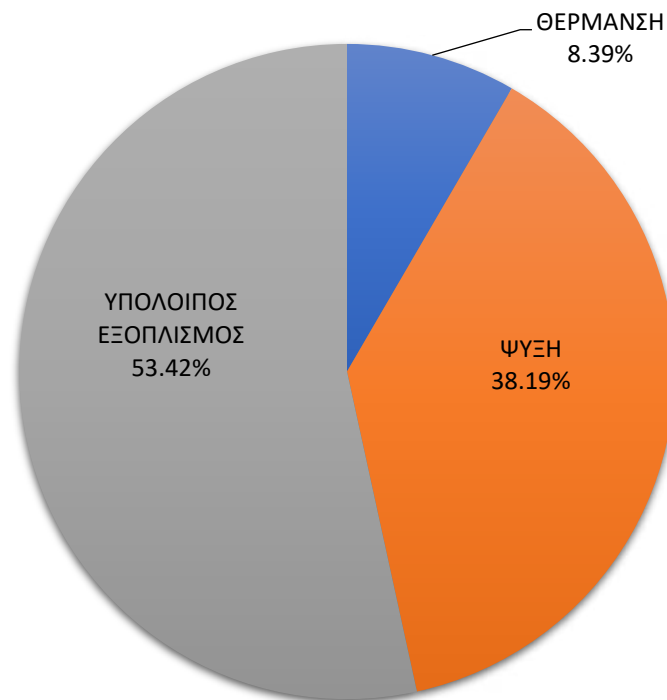
According to the above table, we observe a deviation between the values produced by the software and the actual consumption values recorded by the Electricity Authority (AHK). This deviation is expected, as the program cannot capture with absolute accuracy the real energy consumption of a building.

Next, the graphical representation and the energy balance with the three processes will be presented.



Graph 5.10a: Electrical Consumption for existing building

ENERGY BALANCE ELECTRICAL ENERGY



Graph 5.10b: Energy balance Electrical energy

In winter (December, January, February), the outdoor temperature is low (around 0-12°C), resulting in increased heating use, while cooling and natural ventilation remain low. The low temperatures and reduced solar radiation increase heat losses and heating demands of the building. Natural ventilation is limited to avoid heat loss.

In spring (March, April, May), the temperature rises reaching approximately 16-21°C, reducing the need for heating, while solar gains and ventilation increase. Heating rises due to solar radiation provided by longer days.

In summer (June, July, August), the outdoor temperature reaches its highest points, around 25-40°C, increasing the thermal loads entering the building, with the need for cooling dramatically increasing due to the increased solar gains.

In autumn (September, October, November), the temperature begins to decrease again, with cooling gradually reducing, while heating demand also gradually increases close to November. Ventilation is limited as temperatures drop and windows remain mostly closed.

According to the energy balance, cooling accounts for 38.19% of the total electrical consumption, while heating accounts for 8.39%.

Based on the above data, the following conclusions arise: High electricity consumption during the summer and winter periods is mainly attributed to the use of energy-intensive cooling systems. During the winter, consumption is relatively lower, which is explained by the reduced use of air conditioners for heating.

Factors worsening energy consumption include the absence of insulation in the building envelope and the use of window frames without thermal breaks. Additionally, insufficient maintenance of cooling and heating systems leads to reduced efficiency and, consequently, increased energy consumption.

The lack of shading on openings (windows, balcony doors) intensifies the thermal load during the summer months, increasing the use of cooling systems. Finally, according to the questionnaire findings, users do not make use of natural ventilation, which leads to greater dependence on air conditioning and reflects low energy awareness.

CHAPTER 6: QUESTIONNAIRE

6.1. QUESTIONNAIRE

During the Integrated Design I project, a questionnaire was provided in collaboration with the hotel's management, which was answered by the hotel staff. This questionnaire was based on the thermal comfort experienced by the employees during their work at the building. Based on the results presented below, we evaluated and determined the changes that we will propose.

The questionnaire given to the employees of Semeli Hotel is presented in Appendix II.

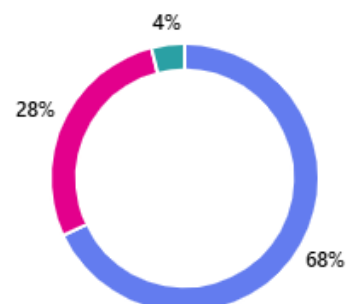
6.2. RESULTS OF THE QUESTIONNAIRE

The results of the questionnaire distributed to the hotel staff are presented below. The questionnaire was completed by 25 participants, and the results include the evaluation of satisfaction with the heating/cooling system and the measures employees take to improve their working environment.

➤ QUESTION 1

1. Φύλο:

● Άνδρας	17
● Γυναίκα	7
● Άλλο	1

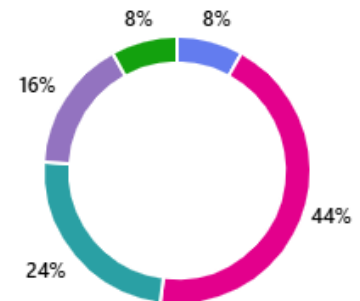


This question concerns the gender of the participants. According to the answers, the majority (68%) stated they are male, while 28% are female. A small percentage, only 4%, selected "Other".

➤ QUESTION 2

2. Ηλικία:

● Κάτω των 20	2
● 20 - 29	11
● 30 - 39	6
● 40 - 49	4
● 50 και άνω	2

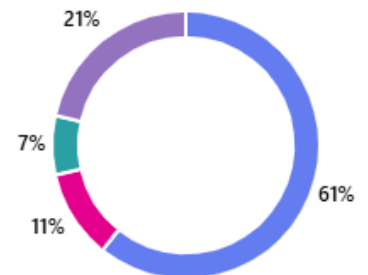


This question examines the age distribution of the participants. The age group of 20-29 years forms the largest category, covering 44% of the responses, which suggests that most of the participants are young adults. The second-largest group is the 30-39 years age group with 24%, indicating the presence of a more mature professional team. The age categories of 40-49 years follow with 16%, while those under 20 years and those 50 and older are tied at 8%, representing the smallest groups. This distribution shows a general prevalence of younger age groups.

➤ **QUESTION 3**

3. Σε ποιον όροφο εργάζεστε;

● Ισόγειο	17
● 1ος Όροφος	3
● 2ος Όροφος	2
● Other	6

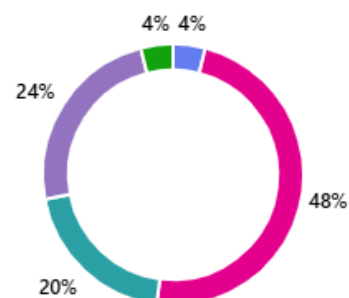


This question concerns the floor where the participants work. The majority, 61%, work on the ground floor, indicating that the ground floor accommodates the largest number of staff. 21% said they work on "Other" floors, a category that includes different spaces like mezzanines or multiple floors. The 1st floor accounts for 11%, while 7% work on the 2nd floor. This distribution shows that work is mostly concentrated on the lower floors.

➤ QUESTION 4

4. Πώς αξιολογείτε τη θερμοκρασία στο χώρο εργασίας σας κατά τους καλοκαιρινούς μήνες;

● Πολύ δυσαρεστημένος/η	1
● Δυσάρεστημένος/η	12
● Ουδέτερος/η	5
● Ικανοποιημένος/η	6
● Πολύ ικανοποιημένος/η	1



This question examines employee satisfaction with the temperature in their workplace during the summer months, a period where climatic conditions demand effective cooling system operation. According to the results, dissatisfaction is widespread, as 48% of participants report being dissatisfied, indicating that the temperature in the space does not meet their needs sufficiently. Issues may relate to weak cooling, uneven distribution of air conditioning, or insufficient system adjustment options, leading to widespread dissatisfaction. 20% of employees report being neutral, which could mean they either do not experience significant discomfort or do not feel particularly satisfied with the current state.

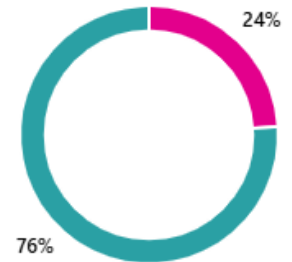
On the other hand, 24% of participants express satisfaction with the temperature, which is a relatively low percentage, emphasizing the need for improvement. The extreme ends of the scale are extremely low, with only 4% reporting being very dissatisfied and 4% very satisfied. This indicates that extreme experiences, either positive or negative, are limited, while the majority are in a neutral or negative situation.

Overall, the results show that temperature in the workplace during the summer months is a significant issue for many employees. The majority of dissatisfied and neutral responses reveal that the existing conditions clearly need improvement.

➤ QUESTION 5

5. Πώς θα θέλατε να είναι η θερμοκρασία στο χώρο εργασίας σας κατά τους καλοκαιρινούς μήνες;

● Ψηλότερη θερμοκρασία (πιο ζεστός ο χώρος)	0
● Χωρίς αλλαγή	6
● Χαμηλότερη θερμοκρασία	19



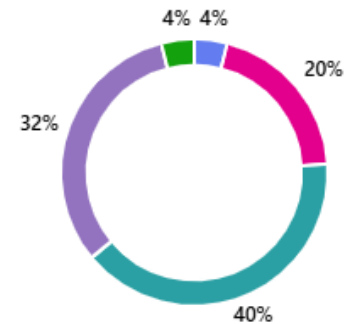
This question concerns employee preferences for temperature in the workplace during the summer months. According to the responses, 76% of participants (19 people) stated that they would prefer a lower temperature, indicating that the workspace is likely quite hot. 24% (6 people) prefer "no change," suggesting they are satisfied with the current state. None of the participants reported preferring a higher temperature.

These results show that for the vast majority of employees, temperature during the summer is a source of discomfort, and there is a need for better cooling management in the workspace to meet the majority's needs.

➤ QUESTION 6

6. Πώς αξιολογείτε τη θερμοκρασία στο χώρο εργασίας σας κατά τους χειμερινούς μήνες;

● Πολύ δυσαρεστημένος/η	1
● Δυσαρεστημένος/η	5
● Ουδέτερος/η	10
● Ικανοποιημένος/η	8
● Πολύ ικανοποιημένος/η	1

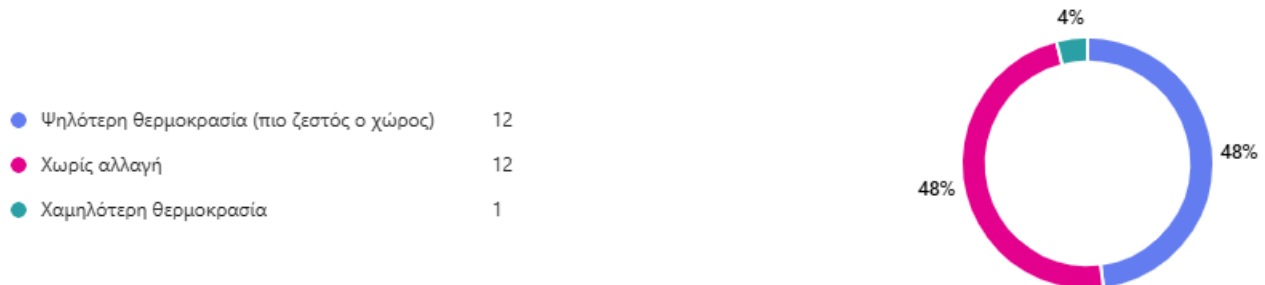


This question evaluates the temperature in the workplace during the winter months. The largest percentage of participants (40%) reported being satisfied, indicating that, generally, heating or temperature regulation is adequate for many. 32% were neutral, showing neither satisfaction nor dissatisfaction, which may reflect small issues or a lack of priority on this matter. A smaller percentage (20%) reported being dissatisfied, while the extreme responses are low, with 4% very dissatisfied and 4% very satisfied.

Overall, the picture is more positive compared to the summer months, but there is still room for improvement to ensure comfort in the workplace during winter.

➤ QUESTION 7

7. Πώς θα θέλατε να είναι η θερμοκρασία στο χώρο εργασίας σας κατά τους χειμερινούς μήνες;



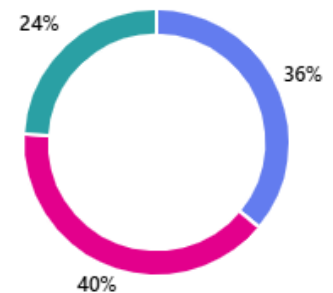
This question concerns employee preferences for temperature in the workplace during the winter months and provides interesting results. Specifically, 48% of participants (12 people) expressed a desire for higher temperatures, indicating that a significant number of employees find the winter temperature insufficient and feel the need for better heating. This preference may relate to personal comfort needs, workspaces in colder areas, or insufficient heating system performance.

Simultaneously, an equal percentage (48%) of employees (12 people) stated that they do not want any change in temperature, indicating they are satisfied with the current situation. This group shows that for many employees, the heating system meets their expectations and provides a suitable working temperature.

➤ QUESTION 8

8. Παρατηρείτε συχνές αλλαγές στη θερμοκρασία του χώρου σας κατά τη διάρκεια της ημέρας;

● Ναι, συχνά	9
● Μερικές φορές	10
● Σπάνια	6
● Ποτέ	0



This question examines how often employees notice changes in the temperature of their workspace during the day. According to the answers, 40% of participants (10 people) report noticing changes "sometimes," while 36% (9 people) say these changes occur "often." A smaller percentage, 24% (6 people), noted that they notice changes "rarely." No participants reported that temperature changes never occur.

These data suggest that temperature instability throughout the day is a common phenomenon for most employees, with only a small portion noticing it rarely. This likely affects comfort and concentration, highlighting the need for a more stable temperature control system.

➤ QUESTION 9

9. Ποιο από τα παρακάτω προκαλεί τη μεγαλύτερη δυσφορία στον χώρο σας (μπορείτε να επιλέξετε πάνω από μία επιλογές);



The results show that the main cause of discomfort in the workplace is the inadequate response of the air conditioning system, reported by 43% of employees. This percentage highlights the central issue that employees face, possibly due to a system that cannot meet the space's needs or is not functioning correctly. The system's inability to maintain a stable and appropriate temperature may negatively affect productivity and employee well-being.

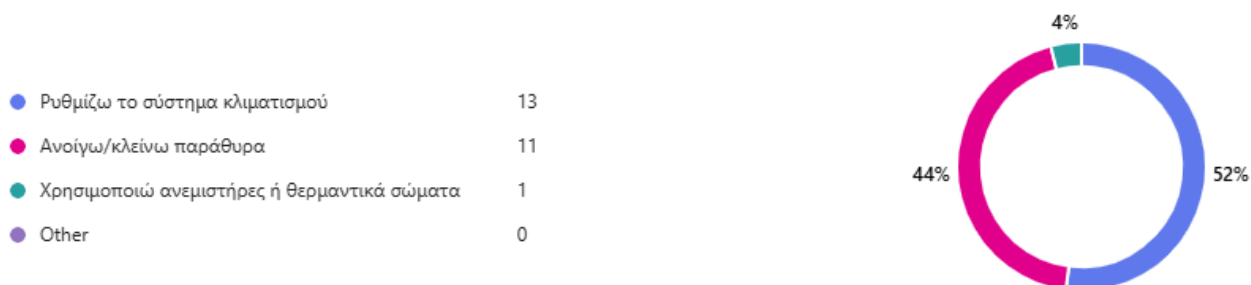
Temperature unevenness, reported by 25% of participants, is also a significant problem. This could indicate temperature differences between different parts of the workspace, resulting in some employees feeling discomfort due to excessive heat or cold. This unevenness often causes complaints, as the needs of all employees are not met in a uniform manner.

Additionally, inadequate ventilation, reported by 29% of employees, exacerbates the situation. The lack of fresh air may cause a feeling of suffocation or create an unpleasant working environment, affecting both physical comfort and concentration.

Only 4% of respondents referred to other factors, suggesting that the three main causes—insufficient air conditioning, temperature unevenness, and inadequate ventilation—are the primary sources of discomfort in the workplace. Overall, the results indicate the need for improvements in the air conditioning system to stabilize temperatures, improve air circulation, and ensure a more uniform environment for employees.

➤ QUESTION 10

10. Ποια μέτρα συνήθως παίρνετε για να βελτιώσετε το περιβάλλον στον χώρο σας;



Question 10 examines the measures that employees take to improve their environment. 52% of participants stated that they adjust the air conditioning system, while 44% prefer to open or close windows. Only a small percentage, 4%, use fans or heaters, and none of the respondents reported taking other actions. The choice of these immediate solutions suggests that employees are trying to counteract potential problems or inefficiencies in the heating/cooling system they have.

➤ QUESTION 11

11. Γενικά, πόσο ικανοποιημένος/η είστε με το σύστημα θέρμανσης/ψύξης του χώρου σας;



This question concerns the general satisfaction of respondents with the heating/cooling system in their workspace. The results show that 36% of participants reported being dissatisfied, while 44% were neutral. A smaller percentage, 16%, reported being satisfied, and only 4% (1 person) stated they were very satisfied.

CHAPTER 7: PROPOSALS – SOLUTIONS FOR THE ENERGY UPGRADE OF THE BUILDING

The energy upgrade of the building constitutes one of the most important steps toward reducing the carbon footprint and achieving the goal of a nearly zero-energy building. For this reason, it was decided to improve the building's energy performance through interventions in the building envelope as well as by replacing energy-intensive equipment with more energy-efficient solutions and low greenhouse gas emission systems.

The existing building is characterized as highly energy-consuming, as the windows are single-glazed and the masonry lacks external insulation. This results in the inability to maintain the desired indoor temperature. Additionally, the absence of insulation leads to increased operation of the cooling units and the boiler, which in turn causes higher consumption of electrical and thermal energy and, simultaneously, increased carbon dioxide emissions into the atmosphere.

It is also worth noting that the low efficiency of the chillers and boilers limits the system's ability to effectively heat or cool the interior space.

This chapter proposes appropriate solutions to improve the building's thermal and cooling performance, aiming to reduce primary energy consumption and carbon dioxide emissions.

7.1 EXTERNAL WALL INSULATION

Initially, the first proposed solution concerns the insulation of the external masonry, which significantly contributes to the improvement of the building's energy performance for both heating and cooling.

For the study, an insulation thickness of 80 mm was selected, deemed sufficient for effectively maintaining the thermal conditions inside the building. It is worth mentioning that tests were also carried out for thicker insulation layers; however, no significant improvements in energy performance were observed that would justify the increased cost. Consequently, the 80 mm thickness was chosen, offering a balance between performance and cost-effectiveness.

It is important to note that external insulation was selected instead of internal insulation. The main reason is to avoid thermal bridges and condensation of water vapor on the inner surface of the walls—phenomena that worsen the energy behavior and structural integrity of the building.

The insulation material used was extruded polystyrene (XPS), chosen for the following advantages:

- High resistance to moisture
- Durability against corrosion
- Ability to withstand mechanical pressure and compression

Moreover, extruded polystyrene demonstrates stable thermal performance over time and high resistance to weather variations, making it suitable for external applications.

Below is a table presenting the new thermal transmittance coefficient (U-value) of the external walls after the addition of insulation.

Construction description		External Wall			
A/A	Name of Material	Material Thickness d (m)	Thermal Conductivity Material λ (W/mK)	Thermal Resistance of Material R (m²K/W)	Typical Design Detail
Starting from the inside					
1	Cement plaster	0.025	0.720	0.035	
2	Brick	0.200	0.720	0.278	
3	Glass Wool	0.080	0.040	2.000	
4	Cement plaster	0.025	0.720	0.035	
Heat Flow		Horizontally		Coefficient of Thermal Conductivity U (W/m²K)	
Rsi (m²K/W)		0.130			
Rse (m²K/W)		0.040			
				0.397	
Notes:					
The requirement of U≤0.4 W/m²K as defined by the relevant decree is met					

7.2 ROOF INSULATION OF THE BUILDING

The second proposed solution concerns the insulation of the roof, which significantly contributes to improving the building's energy performance during both heating and cooling. Roof insulation is one of the most important factors for maintaining the desired indoor temperature.

For the study, an insulation thickness of 80 mm was selected, as it was considered sufficient for effectively maintaining the thermal conditions. It is worth noting that thicker insulation layers were also examined, but no significant differences in energy performance were observed that would justify the increased cost. Therefore, the 80 mm thickness was chosen, ensuring an excellent balance between performance and economic viability.

Extruded polystyrene (XPS) was used as the insulation material for the same reasons mentioned in the previous analysis: high resistance to moisture, corrosion, and mechanical stresses.

Below is a table presenting the new thermal transmittance coefficient (U-value) of the roof after the addition of the insulation.

Construction description		Roof			
A/A	Name of Material	Material Thickness d (m)	Thermal Conductivity Material λ (W/mK)	Thermal Resistance of Material R (m²K/W)	Typical Design Detail
Starting from the inside					
1	Roofing Felt	0.002	0.190	0.011	
2	Cement screed	0.050	1.400	0.036	
3	Aerated Concrete Slab	0.200	0.160	1.250	
4	Glass Wool	0.080	0.040	2.000	
5	Cement plaster	0.025	0.720	0.035	
Heat Flow		Downwards		Coefficient of Thermal Conductivity U (W/m²K)	
Rsi (m²K/W)		0.100			
Rse (m²K/W)		0.040			
				0.288	
Notes:					
The requirement of U≤0.4 W/m²K as defined by the relevant decree is met					

7.3 REPLACEMENT OF WINDOW FRAMES

One of the most significant factors affecting the heating and cooling of the building is the window frames. In the present case, the existing frames, as indicated in the relevant data, are double-glazed with a thermal transmittance coefficient (U-value) of approximately 4 W/m²K.

According to the requirements of the current Building Energy Performance Regulation (B.E.P.R.), these frames are not considered energy efficient. Moreover, they contribute to significant heat losses during the winter period and cooling losses during the summer, which increases energy consumption needed to maintain comfortable indoor conditions.

For the above reasons, it is proposed to replace the old frames with new, more energy-efficient frames, which will feature:

- Low-emissivity (Low-E) glass panes
- Multiple glazing layers (double or triple glazing)
- Frames with thermal breaks
- Improved thermal transmittance coefficient (U-value)

By replacing the window frames, a significant reduction in heat losses and gains is expected, improving the building's energy performance, upgrading the level of thermal comfort, reducing heating and cooling demands, and consequently lowering operational costs.

Below are the characteristics of the new window frames:

Πίνακας 6.12: Συντελεστές θερμοπερατότητας διπλών και τριπλών υαλοστασίων με διαφορετικούς τύπους αερίων στο διάκενο

Υαλοστάσια			Συντελεστής Θερμοπερατότητας για διαφορετικούς τύπους αερίων στο διάκενο ^a U_g					
Τύπος	Υαλοπίνακας	Συντελεστής εκπομπής θερμικής ακτινοβολίας(ε)	Διαστάσεις mm	Αέρας (Air)	Αργό (Argon)	Κρυπτόν (Krypton)	SF ₆ b	Ξένον (Xenon)
Διπλά Υαλοστάσια	Χωρίς προστασία (συνήθεις υαλοπίνακες)	0.89	4-6-4	3.3	3.0	2.8	3.0	2.6
			4-8-4	3.1	2.9	2.7	3.1	2.6
			4-12-4	2.8	2.7	2.6	3.1	2.6
			4-16-4	2.7	2.6	2.6	3.1	2.6
			4-20-4	2.7	2.6	2.6	3.1	2.6
	Με προστασία στη μία πλευρά	≤0.2	4-6-4	2.7	2.3	1.9	2.3	1.6
			4-8-4	2.4	2.1	1.7	2.4	1.6
			4-12-4	2.0	1.8	1.6	2.4	1.6
			4-16-4	1.8	1.6	1.6	2.5	1.6
			4-20-4	1.8	1.7	1.6	2.5	1.7
	Με προστασία στη μία πλευρά	≤0.15	4-6-4	2.6	2.3	1.8	2.2	1.5
			4-8-4	2.3	2.0	1.6	2.3	1.4
			4-12-4	1.9	1.6	1.5	2.3	1.5
			4-16-4	1.7	1.5	1.5	2.4	1.5
			4-20-4	1.7	1.5	1.5	2.4	1.5
	Με προστασία στη μία πλευρά	≤0.1	4-6-4	2.6	2.2	1.7	2.1	1.4
			4-8-4	2.2	1.9	1.4	2.2	1.3
			4-12-4	1.8	1.5	1.3	2.3	1.3
			4-16-4	1.6	1.4	1.3	2.3	1.4
			4-20-4	1.6	1.4	1.4	2.3	1.4
	Με προστασία στη μία πλευρά	≤0.05	4-6-4	2.5	2.1	1.5	2.0	1.2
			4-8-4	2.1	1.7	1.3	2.1	1.1
			4-12-4	1.7	1.3	1.1	2.1	1.2
			4-16-4	1.4	1.2	1.2	2.2	1.2
			4-20-4	1.5	1.2	1.2	2.2	1.2
Τριπλά Υαλοστάσια	Χωρίς προστασία (συνήθεις υαλοπίνακες)	0.89	4-6-4-6-4	2.3	2.1	1.8	1.9	1.7
			4-8-4-8-4	2.1	1.9	1.7	1.9	1.6
			4-12-4-12-4	1.9	1.8	1.6	2.0	1.6
	Με προστασία σε δύο πλευρές	≤0.2	4-6-4-6-4	1.8	1.5	1.1	1.3	0.9
			4-8-4-8-4	1.5	1.3	1.0	1.3	0.8
			4-12-4-12-4	1.2	1.0	0.8	1.3	0.8
	Με προστασία σε δύο πλευρές	≤0.15	4-6-4-6-4	1.7	1.4	1.1	1.2	0.9
			4-8-4-8-4	1.5	1.2	0.9	1.2	0.8
			4-12-4-12-4	1.2	1.0	0.7	1.3	0.7
	Με προστασία σε δύο πλευρές	≤0.1	4-6-4-6-4	1.7	1.3	1.0	1.1	0.8
			4-8-4-8-4	1.4	1.1	0.8	1.1	0.7
			4-12-4-12-4	1.1	0.9	0.6	1.2	0.6
	Με προστασία σε δύο πλευρές	≤0.05	4-6-4-6-4	1.6	1.2	0.9	1.1	0.7
			4-8-4-8-4	1.3	1.0	0.7	1.1	0.5
			4-12-4-12-4	1.0	0.8	0.5	1.1	0.5

Πίνακας 6.13: Συντελεστές θερμοπερατότητας για κάθετα κουφώματα με ποσοστό εμβαδού πλαισίου ως προς το συνολικό εμβαδόν του κουφώματος 30% για συνηθισμένου τύπου εξαρτήματα διαχωρισμού υαλοπινάκων

Τύπος Υαλοστασίου	U_g $W/(m^2.K)$	Συντελεστές θερμοπερατότητας για συνηθισμένου τύπου εξαρτήματα διαχωρισμού υαλοπινάκων (spacer bars) $U_f W/(m^2.K)$												
		0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.6	3.0	3.4	3.8	7.0
Μονό	5.7	4.2	4.3	4.3	4.4	4.5	4.5	4.6	4.6	4.8	4.9	5.0	5.1	6.1
Διπλό ή Τριπλό	3.3	2.7	2.8	2.8	2.9	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	4.5
	3.2	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.2	3.3	3.5	3.6	4.4
	3.1	2.6	2.6	2.7	2.7	2.8	2.9	2.9	3.0	3.1	3.3	3.4	3.5	4.3
	3.0	2.5	2.5	2.6	2.7	2.7	2.8	2.8	3.0	3.1	3.2	3.3	3.4	4.2
	2.9	2.4	2.5	2.5	2.6	2.7	2.7	2.8	2.9	3.0	3.1	3.2	3.4	4.2
	2.8	2.3	2.4	2.5	2.5	2.6	2.6	2.7	2.8	2.9	3.1	3.2	3.3	4.1
	2.7	2.3	2.3	2.4	2.5	2.5	2.6	2.6	2.7	2.9	3.0	3.1	3.2	4.0
	2.6	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.7	2.6	2.9	3.0	3.2	4.0
	2.5	2.1	2.2	2.3	2.3	2.4	2.4	2.5	2.6	2.5	2.8	3.0	3.1	3.9
	2.4	2.1	2.1	2.2	2.2	2.3	2.4	2.4	2.5	2.5	2.8	2.9	3.0	3.8
	2.3	2.0	2.1	2.1	2.2	2.2	2.3	2.4	2.5	2.4	2.7	2.8	3.0	3.8
	2.2	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.4	2.3	2.6	2.8	2.9	3.7
	2.1	1.9	1.9	2.0	2.0	2.1	2.2	2.2	2.3	2.3	2.6	2.7	2.8	3.6
	2.0	1.8	1.9	2.0	2.0	2.1	2.1	2.2	2.3	2.5	2.6	2.7	2.8	3.6
	1.9	1.8	1.8	1.9	1.9	2.0	2.1	2.1	2.3	2.4	2.5	2.5	2.7	3.6
	1.8	1.7	1.8	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.4	2.6	2.7	3.5
	1.7	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.4	2.5	2.6	3.4
	1.6	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.1	2.2	2.3	2.4	2.5	3.3
	1.5	1.5	1.5	1.6	1.7	1.7	1.8	1.8	2.0	2.1	2.2	2.3	2.5	3.3
	1.4	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.2	2.3	2.4	3.2
	1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.7	1.8	2.0	2.1	2.2	2.3	3.1
	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.3	3.1
	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.2	3.0
	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.6	1.8	1.9	2.0	2.1	2.9
	0.9	1.1	1.1	1.2	1.2	1.3	1.4	1.4	1.6	1.7	1.8	1.9	2.0	2.9
	0.8	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.8
	0.7	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.7
	0.6	0.9	0.9	1.0	1.0	1.1	1.2	1.2	1.4	1.5	1.6	1.7	1.8	2.7
	0.5	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.8	2.6

7.4 REPLACEMENT OF AC

The air conditioning units currently used in the hotel are considered highly energy-consuming, as confirmed by their low energy efficiency coefficients — COP (Coefficient of Performance) and EER (Energy Efficiency Ratio).

Therefore, it is proposed to replace them with new, modern air conditioning systems, specifically heat pumps, which are significantly more efficient and less energy-intensive.

According to the conducted study and research, the new heat pump systems to be installed will have:

- Energy Efficiency Ratio (EER) = 3.15 for cooling operation
- Coefficient of Performance (COP) = 3.15 for heating operation

This choice will contribute to a drastic reduction in the hotel's energy consumption while simultaneously improving the thermal comfort level for guests. Additionally, this upgrade will enhance the building's overall energy class and achieve significant reductions in operational costs.



Image 7.4a. Heat Pump

7.5 INSTALLATION OF A 60.32 kWp PV SYSTEM

By installing a photovoltaic system with a capacity of 60.32 kWp using the Net Billing method, the business will be able to save the electrical energy it currently purchases from the Electricity Authority (EAC), significantly reducing its operating costs.

To evaluate the proposed solution, a simulation was conducted using SolarEdge software, which shows the exact layout of the photovoltaic panels on the building's roof. The related visualization is included in the following image.



Image 7.5a. Photovoltaic System of the roof

The installation will include 104 monocrystalline photovoltaic panels, each with a power rating of 580 W, and two inverters for proper management and conversion of the generated energy. Fifty-three panels will be installed at a 26-degree tilt, while the remaining 51 will be positioned at an 11-degree tilt.

The system's performance ratio is 1.751 kWh/kWp, corresponding to a net energy production of 105,620 kWh during the first year of operation.

Considering a performance loss of 2% during the first year and 0.55% for each subsequent year, the estimated average annual energy production over the next 25 years will be approximately 97,553 kWh.

CHAPTER 8: DESIGN BUILDER OF THE

UPGRADED BUILDING

During the building upgrade, insulation was installed on the external walls as well as on the roof. Additionally, the existing frames and glazing were replaced, and oil boilers were installed for heating.

Below are the changes as implemented in the software:

8.1 EXTERNAL WALL INSULATION

MW Glass Wool insulation with a thickness of 8 cm was applied to the external walls.

The upgraded external wall consists of four distinct layers, each made of different materials and thicknesses. The detailed composition of the wall includes:

1. External Layer:

- Material: Cement/plaster/mortar – cement plaster
- Thickness: 0.025 m

2. Second Layer:

- Material: Brick
- Thickness: 0.200 m

3. Third Layer:

- Material: MW Glass Wool insulation
- Thickness: 0.08 m

4. Internal Layer:

- Material: Cement/plaster/mortar – cement plaster
- Thickness: 0.200 m

Edit construction - Wall_new

Constructions

Layers
Surface properties
Image
Calculated
Cost
Condensation analysis

General

Name
External_Wall_new

Source

Category
Walls

Region
General

Colour

Definition

Definition method
1-Layers

Calculation Settings

Layers

Number of layers
4

Outermost layer

Material
Cement/plaster/mortar - cement plaster

Thickness (m)
0.0250

Bridged?

Layer 2

Material
Brick

Thickness (m)
0.2000

Bridged?

Layer 3

Material
MW Glass Wool (rolls)

Thickness (m)
0.0800

Bridged?

Innermost layer

Material
Cement/plaster/mortar - cement plaster

Thickness (m)
0.0250

Bridged?

Constructions

Layers
Surface properties
Image
Calculated
Cost
Condensation analysis

Cross Section

Outer surface

25.00mm
Cement/plaster/mortar - cement plaster

200.00mm
Brick

80.00mm
MW Glass Wool (rolls)

25.00mm
Cement/plaster/mortar - cement plaster

Inner surface

Constructions

Layers
Surface properties
Image
Calculated
Cost
Condensation analysis

Inner surface

Convective heat transfer coefficient (W/m2-K)
2.152

Radiative heat transfer coefficient (W/m2-K)
5.540

Surface resistance (m2-K/W)
0.130

Outer surface

Convective heat transfer coefficient (W/m2-K)
19.870

Radiative heat transfer coefficient (W/m2-K)
5.130

Surface resistance (m2-K/W)
0.040

No Bridging

U-Value surface to surface (W/m2-K)
0.426

R-Value (m2-K/W)
2.517

U-Value (W/m2-K)
0.397

With Bridging (BS EN ISO 6946)

Thickness (m)
0.3300

Km - Internal heat capacity (KJ/m2-K)
37.7160

Upper resistance limit (m2-K/W)
2.517

Lower resistance limit (m2-K/W)
2.517

U-Value surface to surface (W/m2-K)
0.426

R-Value (m2-K/W)
2.517

U-Value (W/m2-K)
0.397

Image 8.1a. External wall construction

8.2 ROOF INSULATION

MW Glass Wool insulation with a thickness of 8 cm was installed on the roof.

The upgraded roof consists of five distinct layers, each made of different materials and thicknesses. The detailed composition of the roof includes:

1. External Layer:

- Material: Roofing Felt
- Thickness: 0.002 m

2. Second Layer:

- Material: Cement/plaster/mortar – cement screed
- Thickness: 0.05 m

3. Third Layer:

- Material: Aerated Concrete Slab
- Thickness: 0.2 m

4. Fourth Layer:

- Material: MW Glass Wool insulation
- Thickness: 0.08 m

5. Internal Layer:

- Material: Cement/plaster/mortar – cement plaster
- Thickness: 0.025 m

Constructions

Layers

Surface properties

Image

Calculated

Cost

Condensation analysis

General

Name

Orofi

Source

Category

Roofs

Region

General

Colour

Definition

Definition method

1-Layers

Calculation Settings

Layers

Number of layers

5

Outermost layer

Material

Roofing Felt

Thickness (m)

0.0020

Bridged?

Layer 2

Material

Cement/plaster/mortar - cement screed

Thickness (m)

0.0500

Bridged?

Layer 3

Material

Aerated Concrete Slab

Thickness (m)

0.2000

Bridged?

Layer 4

Material

MW Glass Wool (rolls)

Thickness (m)

0.0800

Bridged?

Innermost layer

Material

Cement/plaster/mortar - cement plaster

Thickness (m)

0.0250

Bridged?

Constructions

Layers

Surface properties

Image

Calculated

Cost

Condensation analysis

Cross Section

Outer surface

2.00mm - Roofing Felt (not to scale)

50.00mm - Cement/plaster/mortar - cement screed

200.00mm - Aerated Concrete Slab

80.00mm - MW Glass Wool (rolls)

25.00mm - Cement/plaster/mortar - cement plaster

Inner surface

Constructions

Layers

Surface properties

Image

Calculated

Cost

Condensation analysis

Inner surface

Convective heat transfer coefficient (W/m²-K)

4.460

Radiative heat transfer coefficient (W/m²-K)

5.540

Surface resistance (m²-K/W)

0.100

Outer surface

Convective heat transfer coefficient (W/m²-K)

19.870

Radiative heat transfer coefficient (W/m²-K)

5.130

Surface resistance (m²-K/W)

0.040

No Bridging

U-Value surface to surface (W/m²-K)

0.300

R-Value (m²-K/W)

3.471

U-Value (W/m²-K)

0.288

With Bridging (BS EN ISO 6946)

Thickness (m)

0.3570

Km - Internal heat capacity (KJ/m²-K)

37.7160

Upper resistance limit (m²-K/W)

3.471

Lower resistance limit (m²-K/W)

3.471

U-Value surface to surface (W/m²-K)

0.300

R-Value (m²-K/W)

3.471

U-Value (W/m²-K)

0.288

Image 8.2a: Roof construction

8.3 WINDOWS AND FRAMES

Replacement of the existing glazing with double-glazed units of type 4 – 16 – 4, featuring an air gap and reflective coating, but without additional protective layers. Replacement with frames featuring reduced heat losses and improved performance.

Glazing Template

Template

External Windows

Glazing type

Layout

Double glazing, reflective, clear, no shading

4-16-4mm

Preferred height 1.5m, 30% glazed

Glazing

Layers

Calculated

Cost

General

Name

4-16-4mm

Description

Source

EnergyPlus dataset

Category

Double

Region

General

Colour

Definition method

Definition method

1-Material layers

Layers

Number layers

2

Outermost pane

Pane type

Generic Low-E 4mm glass

Flip layer

Window gas 1

Window gas type

AIR 16MM

Innermost pane

Pane type

Generic Low-E 4mm glass

Flip layer

Radiance Daylighting

Glazing

Layers

Calculated

Cost

Calculated Values

Total solar transmission (SHGC)

0.532

Direct solar transmission

0.387

Visible transmittance

0.722

U-value (ISO 10292/ EN 673) (W/m2-K)

1.282

U-Value (W/m2-K)

1.375

Image 8.3a: Window specifications

8.4 SIMULATION – DESIGN BUILDER

Below is the diagram showing the temperatures, heating/cooling loads, and ventilation for the entire building throughout the year, after the building's upgrade.

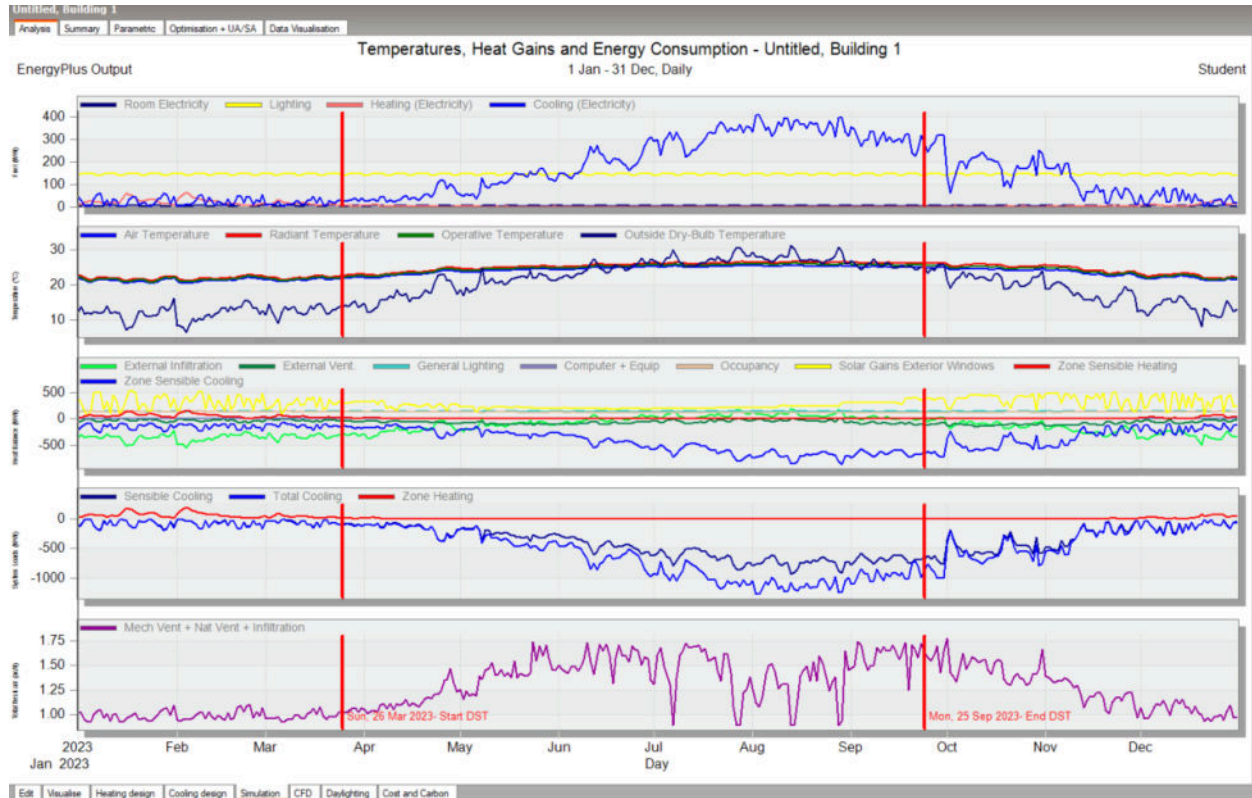


Diagram 8.4a: Diagram Annual analysis of temperatures, thermal loads, and ventilation of the entire building

Next, the consumption table of the upgraded building is presented.

MONTH	ELECTRICAL CONSUMPTION FOR HEATING (kWh)	ELECTRICAL CONSUMPTION FOR COOLING (kWh)	TOTAL ELECTRICAL CONSUMPTION (KWh)
Jan-24	3,763	322	32,472
Feb-24	3,388	498	29,759
Mar-24	1,363	1,071	24,902
Apr-24	235	5,702	25,013
May-24	12	15,357	35,103
Jun-24	0	27,494	47,253
Jul-24	0	39,323	60,273

Aug-24	0	41,528	62,687
Sep-24	0	27,710	47,438
Oct-24	20	11,905	31,443
Nov-24	228	3,875	23,143
Dec-24	1,796	631	25,917
TOTAL	7,352	164,674	372,262

Table 8.4a. Consumption from Design Builder

During winter (December, January, February), the outside temperature is low (around 0–12°C), resulting in heating usage at reduced levels due to the insulation, while cooling and natural ventilation remain at even lower levels. Because of the insulation and the new windows–frames, thermal losses and the building’s heating demands decrease. Natural ventilation is limited to avoid heat loss.

In spring (March, April, May), the temperature rises to about 16–21°C, further reducing heating needs, while solar gains and ventilation increase.

In summer (June, July, August), outside temperatures reach their highest points, around 25–40°C, increasing thermal loads entering the building, with cooling needs rising but remaining much lower thanks to the insulation and the installed windows.

In autumn (September, October, November), the temperature starts to fall again, cooling needs gradually decrease, while heating needs increase but not significantly in November. Ventilation is reduced as temperatures drop and windows remain mostly closed.

8.5 CONSUMPTION ANALYSIS

Below is the "Site and Source Energy" from DesignBuilder, which presents the total energy consumption of the building.

Site and Source Energy

	Total Energy [kWh]	Energy Per Total Building Area [kWh/m2]	Energy Per Conditioned Building Area [kWh/m2]
Total Site Energy	226290.60	115.15	115.28
Net Site Energy	226290.60	115.15	115.28
Total Source Energy	372262.38	189.43	189.64
Net Source Energy	372262.38	189.43	189.64

Table 8.5a: Building energy consumption

The Total Source Energy is 372,262.38 kWh, which represents the actual energy required to meet the building's energy needs. It is evident that due to the changes made to the building, there is a significant decrease in the building's overall energy consumption. Below is the breakdown of the building's energy consumption, analyzing the final energy uses. The table includes energy sources such as electricity, natural gas, as well as consumption for cooling, heating, and domestic hot water.

End Uses

	Electricity [kWh]	Natural Gas [kWh]	Gasoline [kWh]	Diesel [kWh]	Coal [kWh]	Fuel Oil No 1 [kWh]	Fuel Oil No 2 [kWh]	Propane [kWh]	Other Fuel 1 [kWh]	Other Fuel 2 [kWh]	District Cooling [kWh]	District Heating [kWh]	Water [m3]
Heating	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7352.00	0.00
Cooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	164673.85	0.00	0.00
Interior Lighting	52199.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Lighting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interior Equipment	2065.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Exterior Equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fans	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pumps	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Rejection	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Humidification	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heat Recovery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Water Systems	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Refrigeration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Generators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total End Uses	54264.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	164673.85	7352.00	0.00

Note: District heat appears to be the principal heating source based on energy usage.

Table 8.5b: Building energy consumption by end use

The main energy source in the building is electricity. The total consumption for heating is 7,352.00 kWh and for cooling is 164,673.85 kWh. The electrical energy consumed by the interior lighting amounts to 52,199.26 kWh.

CHAPTER 9: COMPARISON EXISTING WITH UPGRADED BUILDING

The following section presents the table and several diagrams that illustrate the results of the energy upgrades to the building, prior to the installation of the photovoltaic system. As observed in the diagrams below, there is a significant reduction in energy consumption for heating and cooling following the implementation of the energy efficiency interventions.

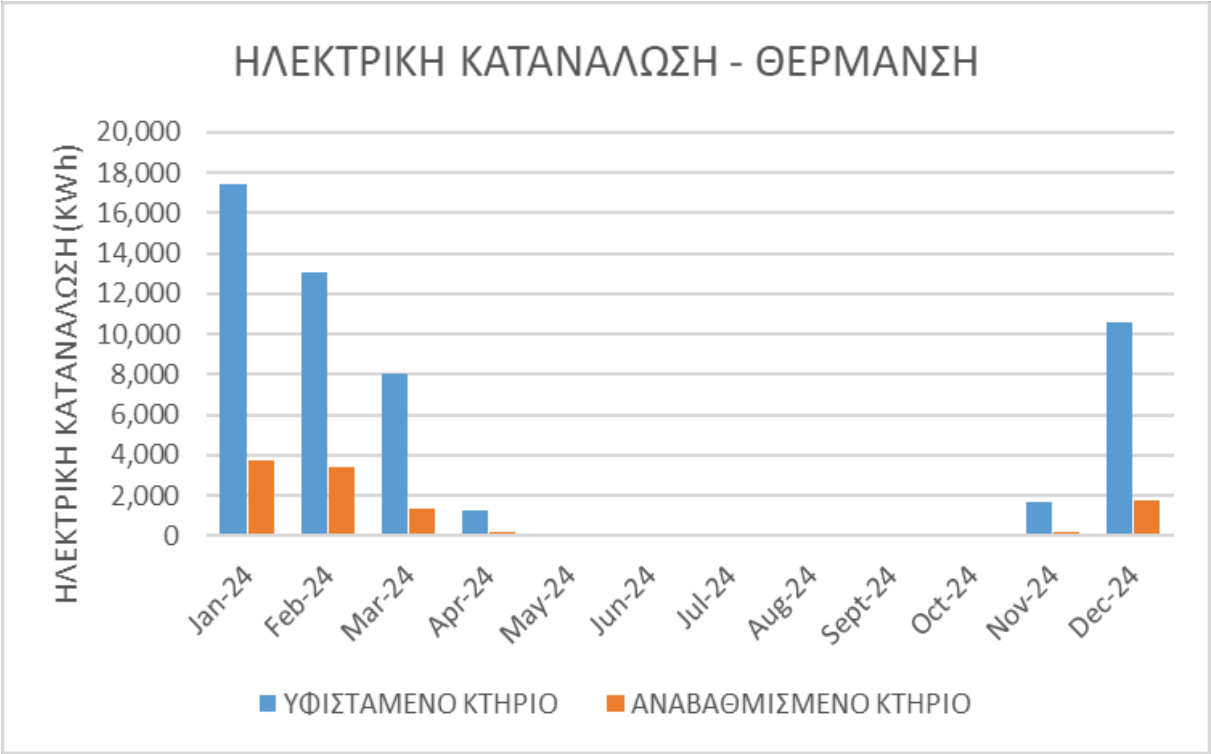
This is due to the fact that the upgrades make the building less energy-intensive, resulting in optimized energy performance. Specifically, the energy savings for heating reach the impressive rate of 84.92%, while for cooling they amount to 25.78%. These figures highlight the particularly positive impact of the interventions in reducing thermal losses and improving indoor temperature management.

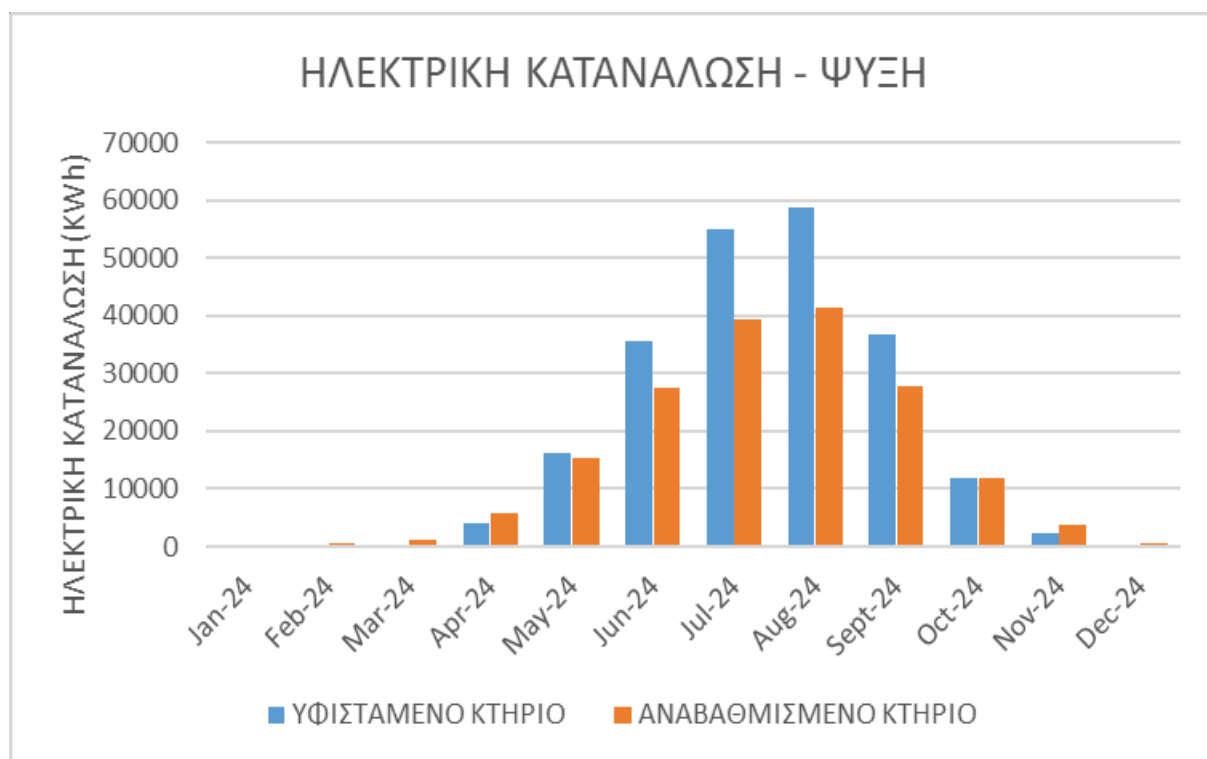
Furthermore, the energy upgrade of the building also leads to a reduction in indoor humidity, which contributes to the improvement of indoor air quality and enhances occupant comfort. This reduction in humidity is mainly attributed to the thermal insulation reinforcement of the building elements, the reduction of thermal bridges, and the use of more efficient window systems.

Overall, these interventions offer multiple benefits, not only in terms of energy savings and reduced operating costs but also in terms of improving living conditions within the building.

ELECTRICAL CONSUMPTION FOR EXISTING BUILDING			ELECTRICAL CONSUMPTION FOR UPGRADED BUILDING		COMPARISON	
MONTH	ELECTRICAL CONSUMPTION FOR HEATING (kWh)	ELECTRICAL CONSUMPTION FOR COOLING (kWh)	ELECTRICAL CONSUMPTION FOR HEATING (kWh)	ELECTRICAL CONSUMPTION FOR COOLING (kWh)	COMPARISON OF HEATING	COMPARISON OF COOLING
Jan-24	17,458	4	3,763	322	78.44%	-7940.75%
Feb-24	13,091	18	3,388	498	74.12%	-2667.94%
Mar-24	8,045	101	1,363	1,071	83.06%	-960.70%
Apr-24	1,258	3,971	235	5,702	81.29%	-43.60%
May-24	25	16,098	12	15,357	51.76%	4.60%
Jun-24	0	35,727	0	27,494	0.00%	23.04%
Jul-24	0	55,061	0	39,323	0.00%	28.58%
Aug-24	0	58,883	0	41,528	0.00%	29.47%
Sep-24	0	36,654	0	27,710	0.00%	24.40%
Oct-24	38	11,795	20	11,905	48.50%	-0.93%
Nov-24	1,704	2,275	228	3,875	86.62%	-70.32%
Dec-24	10,546	49	1,796	631	82.97%	-1188.55%
TOTAL	48,740	221,878	7,352	164,674	84.92%	25.78%

Table 9a. Heating & cooling savings percentages





Graph 9a. Heating & cooling difference for existing and upgrade building

MONTH	ELECTRICAL CONSUMPTION EXISTING BUILDING (kWh)	ELECTRICAL CONSUMPTION UPGRADED BUILDING (kWh)	COMPARISON
Jan-24	70,426	32,472	53.89%
Feb-24	60,417	29,759	50.74%
Mar-24	43,694	24,902	43.01%
Apr-24	22,734	25,013	-10.02%
May-24	31,601	35,103	-11.08%
Jun-24	51,759	47,253	8.71%
Jul-24	72,596	60,273	16.97%
Aug-24	76,677	62,687	18.24%
Sep-24	52,714	47,438	10.01%
Oct-24	27,082	31,443	-16.10%
Nov-24	22,601	23,143	-2.40%
Dec-24	52,629	25,917	50.76%
TOTAL	581,013	372,262	35.93%

Table 9b. Percentages for total consumption

According to the table above, a total energy saving of 35.93% is observed, resulting from the implementation of targeted energy efficiency interventions in the building. This reduction is particularly significant, as it plays a crucial role in lowering operating costs and improving the building's overall energy performance.

More specifically, in terms of heating, energy savings reach 84.92%, indicating a remarkable reduction in thermal losses and improved insulation. This reduction is mainly due to the reinforcement of the building envelope with insulating materials and the upgrade of window systems, which effectively limit thermal bridges and heat losses.

Similarly, in the area of cooling, energy savings amount to 25.78%, which can be attributed to improved shading and better thermal behavior of the external structural elements, as well as to the reduction of overheating during the summer months. As a result, the building maintains more stable and comfortable indoor temperatures, reducing the need for energy-intensive cooling systems.

Overall, the energy savings across all sectors – heating, cooling, and other energy uses – enhance the sustainability and energy autonomy of the building. At the same time, the reduction of carbon dioxide emissions contributes to environmental protection, while the improvement of indoor living conditions enhances the comfort and quality of life for the occupants.

The following table presents the total energy savings for each month after the installation of the photovoltaic (PV) system.

MONTH	ELECTRICAL CONSUMPTION EXISTING BUILDING (kWh)	ELECTRICAL CONSUMPTION UPGRADED BUILDING (kWh)	PVs PRODUCTION (KWh)	FINAL ELECTRICAL CONSUMPTION UPGRADED BUILDING (kWh)	COMPARISON
Jan-24	70,426	27,472	5,100	27,372	61.13%
Feb-24	60,417	24,759	6,800	22,959	62.00%
Mar-24	43,694	19,902	9,000	15,902	63.61%
Apr-24	22,734	20,013	10,100	14,913	34.40%
May-24	31,601	30,103	11,750	23,353	26.10%
Jun-24	51,759	42,253	12,400	34,853	32.66%
Jul-24	72,596	55,273	11,500	48,773	32.82%
Aug-24	76,677	57,687	11,000	51,687	32.59%
Sep-24	52,714	42,438	9,500	37,938	28.03%
Oct-24	27,082	26,443	7,500	23,943	11.59%
Nov-24	22,601	18,143	6,000	17,143	24.15%
Dec-24	52,629	20,917	4,970	20,947	60.20%
TOTAL	581,013	372,262	105,620	266,642	54.11%

Table 9c. SAVINGS PERCENTAGES AFTER THE INSTALLATION OF RENEWABLE ENERGY SOURCES (RES)

The above data present the monthly electrical consumption of the existing and upgraded building, as well as the energy production from photovoltaic (PV) systems, for the year 2024.

The total electrical consumption of the existing building for the year amounts to 581,013 kWh, whereas for the upgraded building it decreases to 372,262 kWh. Additionally, with the installation of the photovoltaic system, 105,620 kWh are produced, resulting in a final net consumption of 266,642 kWh. This translates to a total savings of 54.11%, confirming a significant improvement in energy performance.

The energy upgrade of the building combined with the installation of the photovoltaic system leads to a dramatic reduction in consumption. The greatest savings are observed during the winter and transitional months. Investment in Renewable Energy Sources and energy efficiency interventions proves to be economically and environmentally beneficial.

CHAPTER 10: FEASIBILTIES AND EVALUATIONS OF INVESTMENT PROJECTS

Subsequently, feasibilities studies were carried out in order to assess the viability and profitability of the aforementioned investments. Each investment will be presented individually, followed by a combination of selected investments. Finally, a comprehensive presentation of all the investments combined will be provided.

10.1 Proposal 1 – Replacement of Air Conditioning Systems

The first investment proposal concerns the replacement of existing air conditioning systems with new, high-efficiency units. The aim of this intervention is to significantly reduce electricity consumption and, consequently, the operational costs of the facility. The feasibility analysis demonstrates particularly positive financial outcomes, with a simple payback period of 3.16 years and an internal rate of return (IRR) of 31.07%. Furthermore, the net present value (NPV) of the investment is estimated at €193,963, with a return on investment (ROI) of 374% and a benefit-to-cost ratio (BCR) of 4.74. These indicators confirm the viability and high profitability of the proposed investment.

PROPOSAL 1 – REPLACEMENT OF AIR CONDITIONING SYSTEMS	
ESTIMATED COST (€)	€ 85,000
ELECTRICITY COST FOR 2024 (€/KWH)	€ 0.271
ELECTRICITY SAVINGS (KWH)	99,173 kWh
COST SAVINGS (€)	€ 26,876
SIMPLE PAYBACK PERIOD	3.16
NET PRESENT VALUE (NPV)	€ 193,963
INTERNAL RATE OF RETURN (IRR)	31.07%
RETURN OF INVESTMENT (ROI)	374%
BENEFIT TO COST RATIO (BCR)	4.74

Table 10.1 Replacement of air conditioning systems

10.2 Proposal 2 – Replacement of Window Frames

The second investment proposal involves replacing window frames covering a total area of 546 m², at an estimated cost of €350 per square meter, amounting to a total investment of €191,174. Although the annual electricity savings are calculated at 20,959 kWh, the resulting cost reduction amounts to only €5,680.

This leads to an extremely long payback period of 33.66 years and a negative net present value (NPV) of -€120,388. The IRR, ROI, and BCR indicators cannot be calculated positively, which indicates that this investment is not financially viable under current conditions.

PROPOSAL 2 – REPLACEMENT OF WINDOW FRAMES	
SQUARE METERS OF WALL AREA	546
ESTIMATED COST PER SQUARE METER	€ 350
ESTIMATED COST (€)	€ 191,174
ELECTRICITY COST FOR 2024 (€/KWH)	€ 0.271
ELECTRICITY SAVINGS (KWH)	20,959 kWh
COST SAVINGS (€)	€ 5,680
SIMPLE PAYBACK PERIOD	33.66
NET PRESENT VALUE (NPV)	-€ 120,388
INTERNAL RATE OF RETURN (IRR)	-
RETURN OF INVESTMENT (ROI)	-
BENEFIT TO COST RATIO (BCR)	-

Table 10.2 Replacement of Window Frames

10.3 Proposal 3 – Roof Thermal Insulation Installation

The third investment proposal concerns the installation of thermal insulation on the roof, covering a total area of 450 m². This intervention aims to significantly reduce electricity consumption and, consequently, lower the operational costs of the facility. The feasibility analysis reveals particularly encouraging financial results: the simple payback period is estimated at 2.00 years, while the internal rate of return (IRR) reaches 49.87%. Furthermore, the net present value (NPV) is calculated at €193,963, the return on investment (ROI)

at 898%, and the benefit-to-cost ratio (BCR) at 9.98. These indicators confirm the viability and high economic efficiency of this investment.

PROPOSAL 3 – ROOF THERMAL INSULATION INSTALLATION	
SQUARE METERS OF WALL AREA	450
ESTIMATED COST PER SQUARE METER	€ 100
ESTIMATED COST (€)	€ 45,000
ELECTRICITY COST FOR 2024 (€/KWH)	€ 0.271
ELECTRICITY SAVINGS (KWH)	82,837 kWh
COST SAVINGS (€)	€ 22,449
SIMPLE PAYBACK PERIOD	2.00
NET PRESENT VALUE (NPV)	€ 234,763
INTERNAL RATE OF RETURN (IRR)	49.87%
RETURN OF INVESTMENT (ROI)	898%
BENEFIT TO COST RATIO (BCR)	9.98

Table 10.3 Roof Insulation

10.4 Proposal 4 – External Wall Insulation of Building Envelope

The fourth investment proposal concerns the application of thermal insulation to the building's external walls, aiming to improve the energy efficiency of the building envelope. This intervention is intended to significantly reduce thermal losses, which in turn decreases electricity consumption for heating and cooling and lowers the overall operational costs. The feasibility analysis shows highly positive results: the investment's simple payback period is 3.24 years, the internal rate of return (IRR) reaches 30.77%, and the net present value (NPV) is estimated at €385,578. The return on investment (ROI) stands at 518%, while the benefit-to-cost ratio (BCR) is 6.18. These figures confirm the viability and high profitability of investing in external wall insulation.

PROPOSAL 4 – EXTERNAL WALL INSULATION OF BUILDING ENVELOPE	
SQUARE METERS OF WALL AREA	1,352
ESTIMATED COST PER SQUARE METER	€ 100
ESTIMATED COST (€)	€ 135,186
ELECTRICITY COST FOR 2024 (€/KWH)	€ 0.271
ELECTRICITY SAVINGS (KWH)	154,197 kWh
COST SAVINGS (€)	€ 41,787
SIMPLE PAYBACK PERIOD	3.24
NET PRESENT VALUE (NPV)	€ 385,578
INTERNAL RATE OF RETURN (IRR)	30.77%

RETURN OF INVESTMENT (ROI)	518%
BENEFIT TO COST RATIO (BCR)	6.18

Table 10.4 Thermal Insulation of Building Envelope Walls

10.5 Proposal 5 – Installation of Photovoltaic System

The fifth investment proposal concerns the installation of a photovoltaic system to meet the building's energy needs through the use of solar power. The total investment cost is €60,000, while the annual electricity production is estimated at 97,553 kWh, corresponding to annual savings of €25,637.

The annual maintenance cost of the system is €800, which is deducted from the yearly benefit to calculate the net savings accurately.

The feasibility analysis reveals exceptionally positive results: the net present value (NPV) amounts to €301,325 the internal rate of return (IRR) reaches 42.72%, and the return on investment (ROI) is calculated at 541%. The benefit-to-cost ratio (BCR) stands at 6.41, confirming the viability, profitability, and high level of energy autonomy offered by this investment.

PROPOSAL 5 – INSTALLATION OF PHOTOVOLTAIC SYSTEM	
ESTIMATED COST (€)	€ 60,000
ELECTRICITY COST FOR 2024 (€/KWH)	€ 0.271
MAINTENANCE COST (€)	97,553 kWh
COST SAVINGS (€)	€ 800
ELECTRICITY SAVINGS (KWH)	€ 25,637
SIMPLE PAYBACK PERIOD	2.34
NET PRESENT VALUE (NPV)	€ 301,325
INTERNAL RATE OF RETURN (IRR)	42.72%
RETURN OF INVESTMENT (ROI)	541%
BENEFIT TO COST RATIO (BCR)	6.41

Table 10.5 Installation of Photovoltaic System

10.6 Combination of All Investments

The complete combination of the proposed interventions includes the replacement of air conditioning systems, installation of thermal insulation on the roof and external walls, replacement of window frames, and installation of a photovoltaic system. The total estimated cost amounts to €516,359.

Total annual electricity savings reach 306,304 kWh, which corresponds to cost savings of €99,980, based on the 2024 electricity rate of €0.271/kWh.

The simple payback period for the combined investment package is 5.16 years. The financial indicators confirm the high efficiency of the investment: net present value (NPV) of €521,402, internal rate of return (IRR) of 17.68%, return on investment (ROI) of 190%, and benefit-to-cost ratio (BCR) of 2.90.

These figures clearly demonstrate that the combined investment strategy is both fully viable and highly advantageous from an energy and financial perspective.

PROPOSAL 4 – COMBINATION OF ALL INVESTMENT	
ESTIMATED COST (€)	€ 516,359
ELECTRICITY COST FOR 2024 (€/KWH)	€ 0.271
ELECTRICITY SAVINGS (KWH)	306,304 kWh
COST SAVINGS (€)	€ 99,980
SIMPLE PAYBACK PERIOD	5.16
NET PRESENT VALUE (NPV)	€ 521,402
INTERNAL RATE OF RETURN (IRR)	17.68%
RETURN OF INVESTMENT (ROI)	190%
BENEFIT TO COST RATIO (BCR)	2.90

Table 10.6 Combination of All Investments

CONCLUSIONS AND FUTURE WORK

The overall assessment of the building's current conditions revealed that, although temperature and CO₂ levels remain within acceptable limits, relative humidity exceeds the desirable range. At the same time, the presence of energy-intensive air conditioning systems, the absence of adequate insulation, and outdated window frames contribute to increased energy consumption and reduced efficiency.

The conducted feasibility analyses demonstrate that investments in replacing the air conditioning system, installing thermal insulation on the roof and external walls, replacing window frames, and installing a photovoltaic system are viable and efficient interventions. Notably, the combination of all these measures can achieve up to 54.11% reduction in electricity consumption, significantly improve thermal comfort within the premises, and substantially lower the business's environmental footprint, aligning with sustainable development goals.

The financial indicators of the combined investment confirm its strong performance, with a net present value (NPV) of €521,402, internal rate of return (IRR) at 17.68%, return on investment (ROI) of 190%, and benefit-to-cost ratio (BCR) of 2.90. It should be noted, however, that the isolated replacement of window frames, without complementary measures, is not considered a viable investment according to the detailed results.

Based on the above, we recommend the implementation of the full package of proposed investments, as this approach offers the highest possible energy and financial returns while enhancing the environmental performance of the facility. Additionally, we propose the organization of training sessions and awareness seminars for staff to foster environmental responsibility and ensure the long-term success of the interventions.

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ANNEX

ANNEX I: MEASURING INSTRUMENTS

The measuring instruments used during the on-site measurements are presented below:

➤ Thermal Camera FLIR E8



SPECIFICATIONS

OVERVIEW

Accuracy	±2°C (±3.6°F) or ±2% of reading, for ambient temperature 10°C to 35°C (50°F to 95°F) and object temperature above 0°C (32°F)
Detector Type	Uncooled microbolometer
Field of view (FOV)	45° x 34°
IR Resolution	320 x 240 pixels
List of Contents	•Infrared camera •Hard transport case •Battery (inside camera) •USB cable •Power supply/charger with EU, UK, US and Australian plugs •Printed documentation
Multi Spectral Dynamic Imaging (MSX)	IR image enhanced with visible camera detail
Object Temperature Range	-20°C to 250°C (-4°F to 482°F)
Packaging Size	305 x 165 x 315 mm (15.2 x 6.5 x 12.4 in)
Thermal Sensitivity/NETD	<0.06°C (0.11°F) / <60 mK
FLIR Screen-EST Mode	No
Sampling Average in Screen EST Mode	Recommended temperature range: 30 to 45°C (86 to 113°F) in stable room temperature
Accuracy (Drift) in Screen EST Mode	Accuracy (drift): ±0.3°C (±0.5°F)

➤ **TES 1333R Datalogging Solar Power Meter**



Display	LCD display, 4 digit LCD reading
Range	2000 W/m ² 634 Btu / (ft ² x h)
Resolution	0.1 W/m ² 0.1 Btu / (ft ² x h)
Spectral response	400-1100nm
Accuracy	Typically within ± 10 W/m ² [± 3 Btu / (ft ² x h)] or $\pm 5\%$, whichever is greater in sunlight ; Additional temperature induced error ± 0.38 W/m ² /°C [± 0.12 Btu / (ft ² x h)/°C] from 25°C
Angular accuracy	Cosine corrected <5% for angles < 60°
Drift	< $\pm 2\%$ per year
Calibration	User recalibration available
Over-Input	Display shows "OL"
Sampling Rate	4 times/sec
Manu Data Memory and Read	99 sets
Auto Data Memory	43000 sets (TES-1333R)
Battery	4 pcs size AAA
Battery Life	Approx. 100 hours
Operating Temp and Humidity	0°C to 50°C (32°F to 122°F) below 80%RH
Storage Temp and Humidity	-10°C to 60°C below 70%RH
Weight	Approx. 158g
Dimension	110(L) x 64 (W) x 34(H) mm
Accessories Included	Manual, 4 pcs size AAA, (RS232 Cable, CD software → TES-1333R)

➤ **Mastech MS6612 digital LUX meter**



Light Meter : MS6612

Specifications	Range	Resolution	Accuracy
Measurement Range	0~200000 Lux	0.01 Lux	$\pm(3\%+2)$
	0~20000 FC	0.01 FC	$\pm(3\%+2)$

➤ **Plug-in Power & Energy Monitor 2000MU**



Model 2000M Specifications:

ITEM	RANGE	
RMS voltage	180.0~250.0 Vrms	
RMS current	0.00~15.00 Arms	
Active power	0~3750 Watts	
Apparent power	0~3750 VA	
Line Frequency	47.0~63.0 Hz	
Power Factor	0.00~1.00	
Energy Quantity	0.00~9999 KWH	
KWH Hour	00:00~9999	
Items	Accuracy	
	Max.	Typ.
RMS voltage	1%	0.2%
RMS current	1%	0.3%
Active power	2%	0.5%
Apparent power	2%	0.5%
Line Frequency	2%	±0.1Hz
Power Factor	0.03	0.01
Energy Quantity	2%	0.5%
KWH Hour	30 ppm	
Fuse Rating	0.2A/250V 3x11mm	

➤ **CO2/Temp./RH DATA LOGGER**



Specifications	Range	Resolution	Basic Accuracy
Carbon Dioxide (CO ₂)	0 to 9,999ppm	1ppm	±75ppm+5% of reading
Temperature	14 to 122°F (-10 to 50°C)	0.1°F/°C	±2.0°F/1.0°C
Humidity	10 to 90%RH	0.1%RH	±5%RH (@ 25°C)
Dew Point	-99.22 to 118°F (-72.9 to 47°C)	0.1°F/°C	
Wet Bulb	12.2 to 118.8°F (-11 to 48.2°C)	0.1°F/°C	
Dimensions/Weight	8.3x2.4x1.6" (211x60x40mm)/ 6.4oz (181.4g)		

ANNEX II: QUESTIONNAIRE

Το ερωτηματολόγιο που έχετε μπροστά σας έχει σχεδιαστεί στο πλαίσιο του μαθήματος "Προχωρημένη Εργασία: Ενοποιημένος Σχεδιασμός και Έρευνα" και απευθύνεται στους εργαζομένους του ξενοδοχείου Semeli Hotel. Σκοπός του είναι να εξετάσει τη θερμική άνεση των εργαζομένων στο χώρο εργασίας τους. Η συμβολή σας είναι ιδιαίτερα πολύτιμη για την υλοποίηση της έρευνας.

Το ερωτηματολόγιο είναι ανώνυμο, ενώ κάθε απάντηση θα συμβάλλει στην καλύτερη διερεύνηση του θέματος που μελετάται. Να θυμάστε ότι δεν υπάρχουν σωστές ή λάθος απαντήσεις παρά μόνο οι δικές σας απαντήσεις. Σας ευχαριστούμε εκ των προτέρων για τη συμμετοχή σας!

1. Φύλο:

- ☐ Άνδρας
- ☐ Γυναίκα
- ☐ Άλλο

2. Ηλικία:

- ☐ Κάτω των 20
- ☐ 20 - 29
- ☐ 30 - 39
- ☐ 40 - 49
- ☐ 50 και άνω

3. Σε ποιον όροφο εργάζεστε;

- ☐ Ισόγειο
- ☐ 1ος Όροφος
- ☐ 2ος Όροφος
- ☐ Άλλο: _____

4. Πώς αξιολογείτε τη θερμοκρασία στο χώρο εργασίας σας κατά τους καλοκαιρινούς μήνες;

- ☐ Πολύ δυσαρεστημένος/η
- ☐ Δυσαρεστημένος/η
- ☐ Ουδέτερος/η
- ☐ Ικανοποιημένος/η
- ☐ Πολύ ικανοποιημένος/η

5. Πώς θα θέλατε να είναι η θερμοκρασία στο χώρο εργασίας σας κατά τους καλοκαιρινούς μήνες;

- ☐ Ψηλότερη θερμοκρασία (πιο ζεστός ο χώρος)
- ☐ Χωρίς αλλαγή
- ☐ Χαμηλότερη θερμοκρασία

6. Πώς αξιολογείτε τη θερμοκρασία στο χώρο εργασίας σας κατά τους χειμερινούς μήνες;

- ☐ Πολύ δυσαρεστημένος/η
- ☐ Δυσαρεστημένος/η
- ☐ Ουδέτερος/η
- ☐ Ικανοποιημένος/η
- ☐ Πολύ ικανοποιημένος/η

7. Πώς θα θέλατε να είναι η θερμοκρασία στο χώρο εργασίας σας κατά τους χειμερινούς μήνες;

- ☐ Ψηλότερη θερμοκρασία (πιο ζεστός ο χώρος)
- ☐ Χωρίς αλλαγή
- ☐ Χαμηλότερη θερμοκρασία

8. Παρατηρείτε συχνές αλλαγές στη θερμοκρασία του χώρου σας κατά τη διάρκεια της ημέρας;

- ☐ Ναι, συχνά
- ☐ Μερικές φορές
- ☐ Σπάνια
- ☐ Ποτέ

9. Ποιο από τα παρακάτω προκαλεί τη μεγαλύτερη δυσφορία στον χώρο σας (μπορείτε να επιλέξετε πάνω από μία επιλογές);

- ☐ Το σύστημα κλιματισμού δεν ανταποκρίνεται σωστά
- ☐ Ανομοιόμορφη θερμοκρασία
- ☐ Ανεπαρκής αερισμός
- ☐ Άλλο: _____

10. Ποια μέτρα συνήθως παίρνετε για να βελτιώσετε το περιβάλλον στον χώρο σας;

- ☐ Ρυθμίζω το σύστημα κλιματισμού
- ☐ Ανοίγω/κλείνω παράθυρα
- ☐ Χρησιμοποιώ ανεμιστήρες ή θερμαντικά σώματα
- ☐ Άλλο: _____

11. Γενικά, πόσο ικανοποιημένος/η είστε με το σύστημα θέρμανσης/ψύξης του χώρου σας;

- ☐ Πολύ δυσαρεστημένος/η
- ☐ Δυσαρεστημένος/η
- ☐ Ουδέτερος/η
- ☐ Ικανοποιημένος/η
- ☐ Πολύ ικανοποιημένος/η