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CRES

CENTRE FOR RENEWABLE ENERGY SOURCES
ΚΕΝΤΡΟ ΑΝΑΝΕΩΣΙΜΩΝ ΠΗΓΩΝ ΕΝΕΡΓΕΙΑΣ

GREEN CITY BUILDING

WP Activity 4.3

ENERGY AND ENVIRONMENTAL RATING OF THE MUNICIPAL BUILDING OF SYKIES



19th km Marathonos Avenue
190 09 Pikermi
Tel. +30 210 66 03 300
Fax. +30 210 66 03 301,2,5

CRES – CENTRE FOR RENEWABLE ENERGY SOURCES

**PROJECT: ENERGY AND ENVIRONMENTAL RATING OF THE
MUNICIPAL BUILDING OF SYKIES**

PROJECT Eugenia Lazari, Architect, MA Arch
TEAM: *Director of the Department of Buildings*
 Elpida Polychroni, Mechanical Engineer
 George Polymenopoulos, Mechanical Engineer MSc

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1. INTRODUCTION

The aim of this analysis is to examine the energy and environmental impact of specific interventions in the building shell of a mixed use municipal building of Sykies, Thessaloniki. Simulation analysis has been carried out and a series of recommendations and best practice indicators, according to the proposed interventions, have been concluded.

This study assesses the impact of energy refurbishment in the municipal building of Sykies with variable activities, promoting an effective dissemination plan to building users and governmental policies, encouraging local communities to invest on energy measures.

Energy interventions in the building shell and in the electromechanical installations aim to achieve a significant decrease in energy consumption (for heating, cooling and lighting) and to create optimum conditions in the indoor environment, in terms of thermal and visual comfort. There are several types of energy interventions in existing buildings and in most of the cases they are prioritized according to the cost of investment required and the respective payback period. The type (construction and architectural) and use of the building, the occupancy, the orientation and the microclimatic conditions (climate, topography, surrounding built and non-built environment, etc), are some of the parameters that determine the potential of energy saving in the building.

The municipal building has three uses clearly defined by the independent accesses to the sections with no internal communication.

- The ground floor is occupied by the elderly health, treatment and cultural centre with total area of 150m².
- The first floor is occupied by the ERGANI Centre – Women’s Business and Entrepreneur Centre with total area of 250m².
- The second floor is occupied by a kindergarten with total area of 250m².

1.1 Energy Performance of municipal building in Sykies and Proposed Interventions

The overall energy performance of a building is being influenced and determined by several parameters that correspond either to the use and location of the building in the urban tissue or to its bioclimatic characteristics that have been integrated to its design.

It has been monitored by CRES that the indoor conditions (thermal and visual) of the existing building are very poor and this is mostly due to construction and maintenance defaults. At CRES study, through an extensive monitoring and simulation process, it resulted that the energy which may be saved through different interventions is at least 40%. Furthermore, the improvement in thermal and visual comfort which could be achieved through energy interventions is significant but no easy to evaluate. Energy interventions concern to the building design and construction, and rational operation of energy systems, application of energy management and maintenance schemes, etc. An

important factor that should also be taken into consideration is the environmental, economic and social impact of energy interventions in the building, by decreasing CO₂ and SO₂ emissions.

Several interventions in the building shell have been analyzed in terms of improving the building fabric (replacement of old windows, limit infiltration losses and draughts, etc). Efficient cooling especially of the classrooms (kindergarten) is important due to the high number of users/pupils which results to increased internal gains. Shading of building openings is essential for achieving thermal and visual comfort conditions during warm periods. External shading is most recommended and so are movable shading devices in order to utilize the solar radiation in winter period for space heating and respectively reduce solar gains during summer period. However, for this building construction, shading is not essential due to reduced solar gains considering the relevant glazed areas of SW, SE and NE facades.

Therefore, three scenarios have been addressed to the building, as follows:

- **Base case scenario:** Existing conditions of the building structure and use
- **Scenario 1:** Refurbishment of a) external walls (U-value wall = $0.52 \text{ Wm}^{-2}\text{C}^{-1}$) with internal insulation (U-Value wall = $0.3 \text{ Wm}^{-2}\text{C}^{-1}$), b) Roof (U-Value roof = $2.6 \text{ Wm}^{-2}\text{C}^{-1}$) with internal insulation (U-Value roof = $0.77 \text{ Wm}^{-2}\text{C}^{-1}$)
- **Scenario 2:** Replacement of single-glazed windows (Ground floor: U-Value windows = $5.8 \text{ Wm}^{-2}\text{C}^{-1}$, 1st and 2nd floor: U-Value windows = $3.8 \text{ Wm}^{-2}\text{C}^{-1}$) with double-glazed windows (U-Value windows = $2.4 \text{ Wm}^{-2}\text{C}^{-1}$)
- **Scenario 3:** Replacement of single-glazed windows (Ground floor: U-Value windows = $5.8 \text{ Wm}^{-2}\text{C}^{-1}$, 1st and 2nd floor: U-Value windows = $3.8 \text{ Wm}^{-2}\text{C}^{-1}$) with double-glazed windows (U-Value windows = $2.4 \text{ Wm}^{-2}\text{C}^{-1}$) **and** Refurbishment of a) external walls (U-Value wall = $0.52 \text{ Wm}^{-2}\text{C}^{-1}$) with internal insulation (U-Value wall = $0.3 \text{ Wm}^{-2}\text{C}^{-1}$), b) Roof (U-Value roof = $2.6 \text{ Wm}^{-2}\text{C}^{-1}$) with internal insulation (U-Value roof = $0.77 \text{ Wm}^{-2}\text{C}^{-1}$)

Applying **Scenario 1**, 20% energy saving is achieved for the heating period whilst the energy demand for cooling is increased by 7%, in comparison to the base case scenario. However, the total energy demand for heating and cooling decreases from 137.6 kWh/m^2 to 117.5 kWh/m^2 with total savings of 15%.

Applying **Scenario 2**, 31% energy saving is achieved for the heating period and 18% energy saving is achieved for the cooling period, in comparison to base case scenario. The total energy demand for heating and cooling decreases from 137.6 kWh/m^2 to 98.04 kWh/m^2 with total savings of 29%.

Applying **Scenario 3** which is the combination of Scenario 1 and Scenario 2 refurbishments, 56% energy saving is achieved for the heating period and 6% energy saving is achieved for the cooling period, in comparison to base case scenario. The total energy demand for heating and cooling decreases from 137.6 kWh/m^2 to 74 kWh/m^2 .

The **total energy saving in the case study of municipality building of Sykies**, after the replacement of single-glazed windows with double-glazed and the refurbishment of external walls with additional insulation is concluded to **46%**. The benefits of the

proposed interventions are also to the improvement of the indoor environment by improving the internal conditions (improve the energy performance of the building shell, reduce infiltration losses and draughts through the old windows, and improve lighting conditions, improve thermal and visual conditions, significantly reduce noise entering the classrooms, etc.).

2. CLIMATIC ANALYSIS

The climate in Greece is typical of the Mediterranean climate: mild and rainy winters, relatively warm and dry summers and, generally, extended periods of sunshine throughout most of the year.

For the specific analysis of the municipal building within Thessaloniki area, climatic data from the Hellenic National Meteorological Service, Mikra Station was used.

The characteristics of Mikra Meteorological Station are the following:

- Latitude 40°31'1",
- Longitude 22°58'1" and
- Elevation (Station) 4m.

Based on the recorded data of the Meteorological Station, the following diagrams and figures have been summarized in order to present the climatic characteristics of the area.

Air Temperature The mean yearly air temperature is 15.7oC, with mean minimum temperature of 9.7°C and mean maximum temperature of 20.4°C.

Relative Humidity The mean annual relative humidity is 67%, which is relatively high, ranging from 53.2% to 78%.

Wind The wind speed is moderate – the mean value is approximately 2.86m/sec and the maximum is 3.34m/sec in July. The wind direction is usually North West except for the month August which is South.

Taking into account the mean temperature chart of Sykies for January, February, November and October (Diagram 2.3), the mean hourly temperature range during January is between 1-9°C and the monthly relative humidity 76.1% (Diagram 2.7). Therefore, due to the relatively high values, the space heating is necessary early in the morning and during night.

In the following diagrams the climatic data for the area of Thessaloniki are presented (Mikra Meteorological Station):

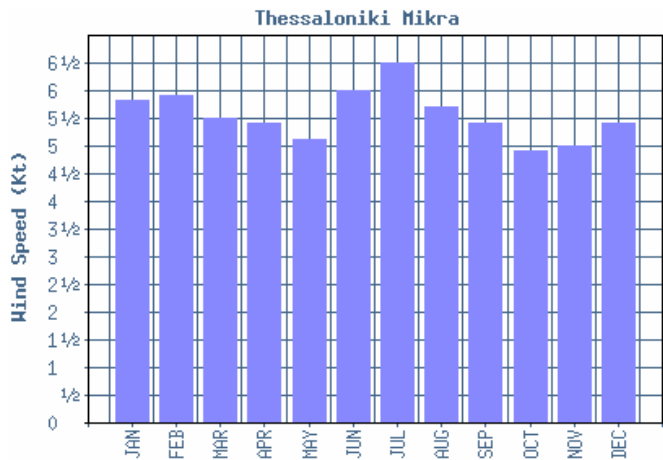


Diagram 2.1. Wind Speed for the area of Thessaloniki

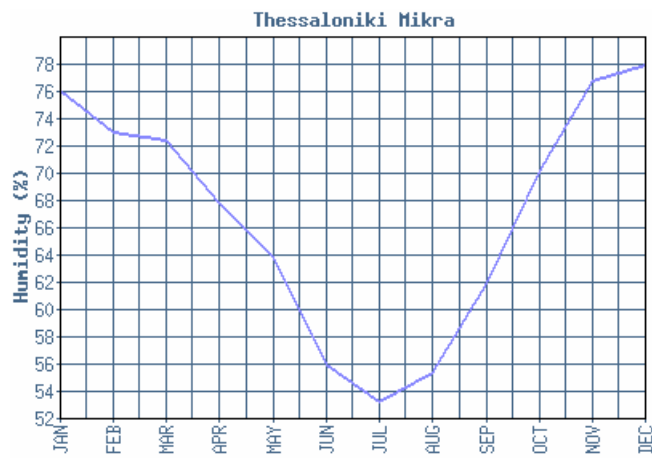


Diagram 2.2. Relative humidity for the area of Thessaloniki

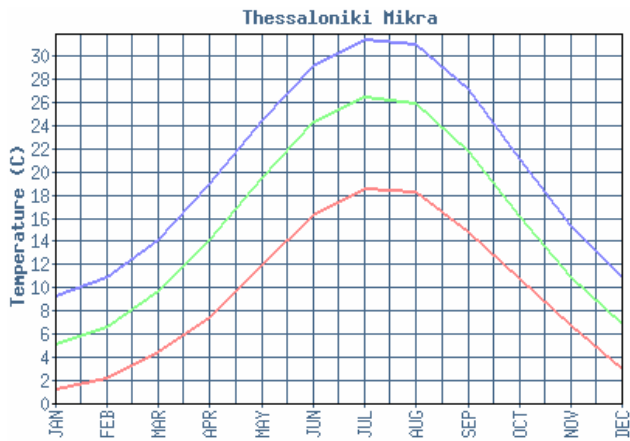


Diagram 2.3. Air Temperature for the area of Thessaloniki

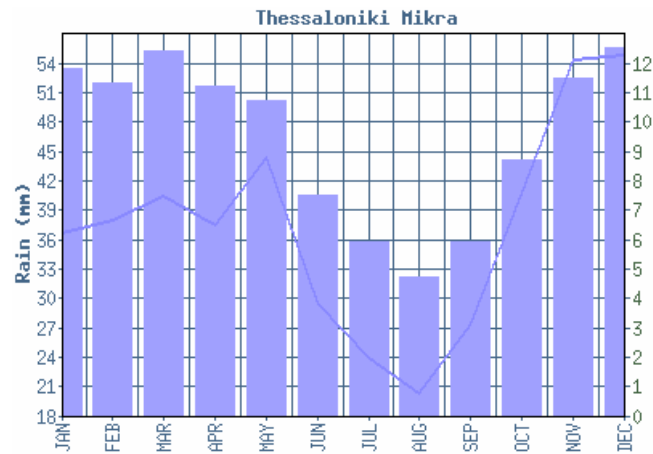


Diagram 2.4. Rainfall for the area of Thessaloniki

1° Semester	JAN	FEB	MAR	APR	MAY	JUN
Monthly Min Temperature	1.3	2.2	4.5	7.5	12.1	16.3
Monthly Average Temperature	5.2	6.7	9.7	14.2	19.6	24.4
Monthly Max Temperature	9.3	10.9	14.2	19.0	24.5	29.2
2° Semester	JUL	AUG	SEP	OCT	NOV	DEC
Monthly Min Temperature	18.6	18.3	14.9	10.8	6.8	3.0
Monthly Average Temperature	26.6	26.0	21.8	16.2	11.0	6.9
Monthly Max Temperature	31.5	31.1	27.2	21.2	15.4	11.0

Diagram 2.5. Average air temperature for the area of Thessaloniki

1° Semester	JAN	FEB	MAR	APR	MAY	JUN
Monthly Average Humidity	76.1	73.0	72.4	67.8	63.8	55.9
2° Semester	JUL	AUG	SEP	OCT	NOV	DEC
Monthly Average Humidity	53.2	55.3	62.0	70.2	76.8	78.0

Diagram 2.7. Average humidity for the of Thessaloniki

1° Semester	JAN	FEB	MAR	APR	MAY	JUN
Monthly Average Rainfall	36.8	38.0	40.6	37.5	44.4	29.6
Total days of Rain	11.8	11.3	12.4	11.2	10.7	7.5
2° Semester	JUL	AUG	SEP	OCT	NOV	DEC
Monthly Average Rainfall	23.9	20.4	27.4	40.8	54.4	54.9
Total days of Rain	5.9	4.7	5.9	8.7	11.5	12.5

Diagram 2.6. Average rainfall for the area of Thessaloniki

1° Semester	JAN	FEB	MAR	APR	MAY	JUN
Monthly Average Wind Direction	NW	NW	NW	NW	NW	NW
Monthly Average Wind Speed	5.8	5.9	5.5	5.4	5.1	6.0
2° Semester	JUL	AUG	SEP	OCT	NOV	DEC
Monthly Average Wind Direction	NW	S	NW	NW	NW	NW
Monthly Average Wind Speed	6.5	5.7	5.4	4.9	5.0	5.4

Diagram 2.7. Average wind speed and direction for the area of Thessaloniki

3. ENERGY AND ENVIRONMENTAL ANALYSIS

3.1 Methodology of Analysis

The impact of the proposed interventions for the municipal building of Sykies have been analyzed and assessed and are presented in the Section 3.3.

The methodology used for the analysis of the building is the following:

- i. Analysis of the environmental and microclimatic conditions of the area
- ii. Simulation analysis of the thermal performance and resulted thermal comfort conditions in the existing building (according to the building form and structure)
- iii. Parametric simulation analysis for the building, using different scenarios for the improvement of the energy performance and internal comfort conditions
- iv. Evaluation of the results from simulation analysis
- v. Environmental assessment of the proposed interventions in the building shell

3.1.1 Simulation programmes description

In the framework of the thermal simulation analysis of the specific building, specialized software has been used for the assessment of the energy and environmental impact of the proposed interventions. The simulation programmes used are described below:

- **TRNSYS** (TRaNsient SYstems Simulation program) is a transient systems simulation program with a modular structure. It recognizes a system description language in which the user specifies the components that constitute the system and the manner in which they are connected. The TRNSYS library includes many of the components commonly found in thermal and electrical energy systems, as well as component routines to handle input of weather data or other time-dependent forcing functions and output of simulation results. The modular nature of TRNSYS gives the program tremendous flexibility, and facilitates the addition to the program of mathematical models not included in the standard TRNSYS library. TRNSYS is well suited to detailed analyses of any system whose behavior is dependent on the passage of time.
- **ASCOT** is an assessment tool for the reduced environmental impact in sustainable building renovation. It is developed in Microsoft Excel. The ASCOT model allows a comparison between a traditional (reference) building renovation and different sustainable concepts for the renovation of the building. This comparison takes into account usage savings during the total lifetime of the building and the frequency of future replacing of building components and systems.

3.2 Input data and assumptions made

At the following, input data and assumptions made in the thermal simulation process are presented:

i. Climatic Data

Hourly climatic data (mean hourly data for each month) from the closest meteorological station of the Hellenic National Meteorological Service have been used (Mikra Meteorological Station). Solar radiation, external air temperature, relative humidity, wind speed and ground temperature are the main climatic data input.

ii. Geometric Data

As geometric data, dimensions and form of each building have been used according to the architectural drawings. For the thermal simulations, different thermal zones have been defined for each building, according to the level (Zone 1: ground floor, Zone 2: 1st floor, Zone 3: 2nd floor).

iii. Thermal and optical characteristics of materials and systems

The thermal and optical characteristics of the materials and systems used were defined according to bibliography and directions given by the municipality of Sykies. For the opaque building components, the following properties have been considered: thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$), density ($Kg \cdot m^{-3}$), specific capacity ($J \cdot Kg^{-1} \cdot K^{-1}$) and thickness of the component. For the transparent building components the following properties have been considered: thickness and properties of the material, overall thermal transmittance coefficient (window and frame) ($W \cdot m^{-2} \cdot C^{-1}$) and shading coefficient.

iv. Building use data

A principle parameter of the analysis is the profile of the specific use, such as the number of operating hours, the number of occupants, the number and type of lighting equipment and other equipment used.

For the present study the following assumption have been made:

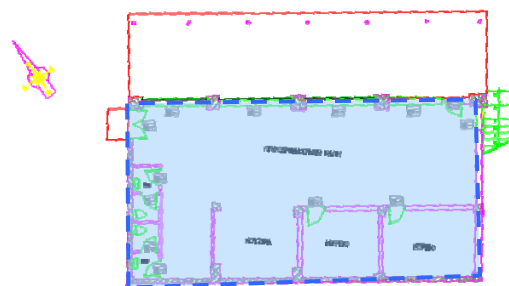
- The operating period of the municipality building is considered for:
 - ♦ Elderly health, treatment and cultural centre (ground floor) from 7:00 to 19:30 – Whole week.
 - ♦ ERGANI centre (first floor) from 8:30 to 20:00 – Monday to Friday.
 - ♦ Kindergarten (second floor) from 7:45 to 16:00 – Monday to Friday. The months July and August have been excluded from the analysis.
- The number of occupants is 10 persons in the ground floor, 13 persons in the first floor and 76 persons in the second floor.
- The set point indoor temperature used for the thermal simulation was assumed as: 22°C for the heating period and 25°C for the cooling period.
- A ventilation rate (fresh air) of 2 ACH (air changes per hour) was considered for the operating hours.

3.3 Case study analysis

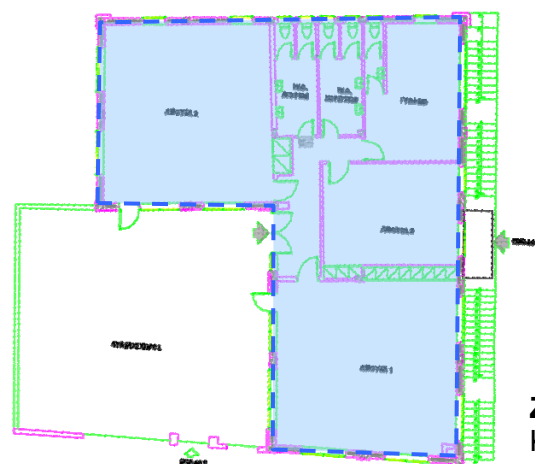
3.3.1 Technical description

The municipal building of Sykies which is located near to the Historical Byzantine City Wall was constructed in 1984 by the Technical Department of Sykies Municipality sited at a very inclined plot with access from three sides, with a view to an open space area. The first level is orthogonal and the next two are L shaped.

For the thermal simulation analysis, the building was divided into three thermal zones. The division is based on the building profile (see section 3.2), and the thermal zones are illustrated below:



Zone 2 – First floor:
ERGANI Centre – Women’s
Business and Entrepreneur Centre



Zone 3 – Second floor:
Kindergarten

3.3.2 Microclimatic analysis

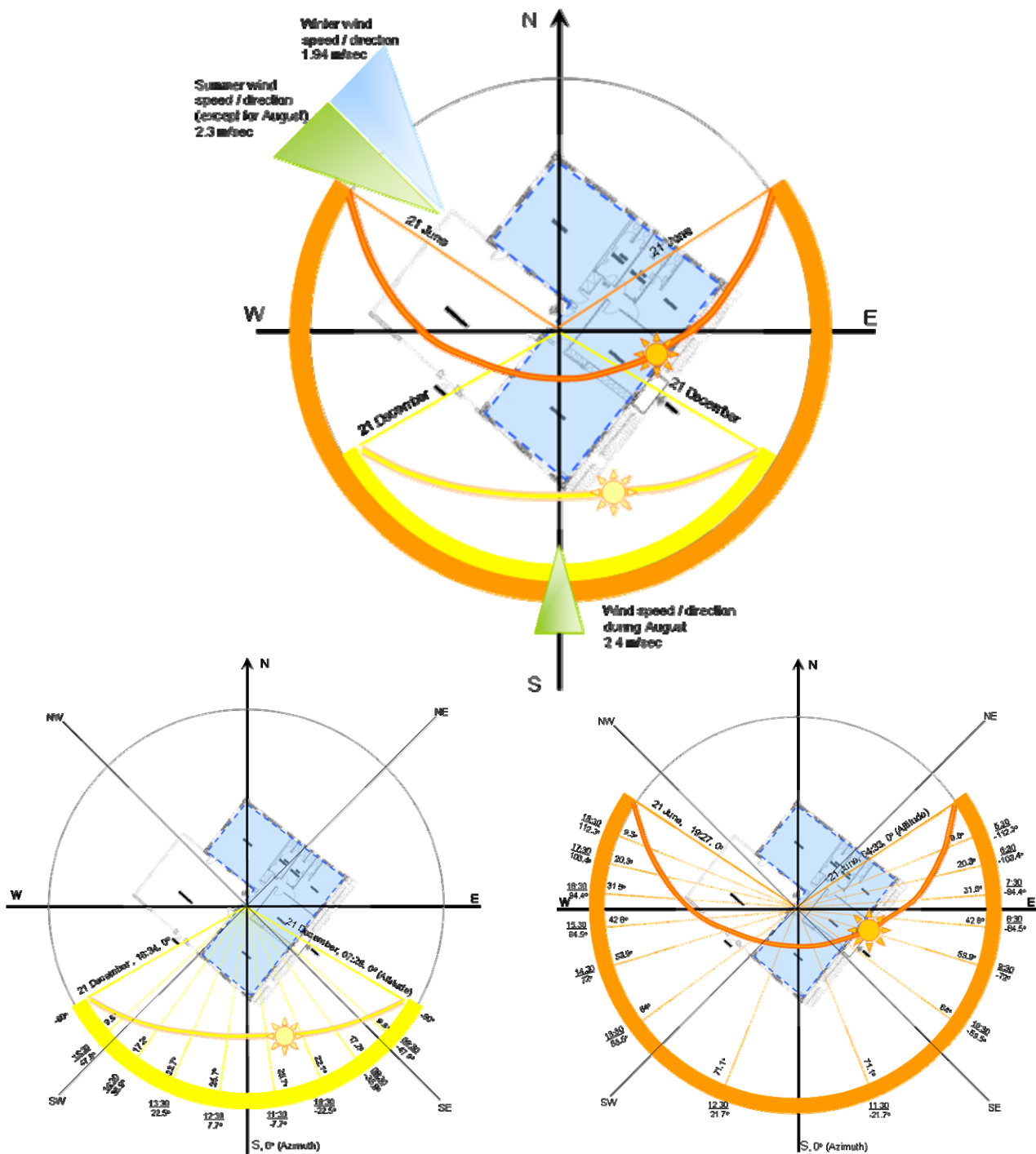


Diagram 3.1: Sunpath diagrams for summer and winter and prevailing wind directions

The main axis of the building is NE-SW, with long facades facing to NE for ground and first floor and the whole second floor. The ground and first floor face the ground at the SW side, and the second floor is exposed to the sun and prevailing winds throughout the year.

3.3.3 Thermal Simulation Analysis

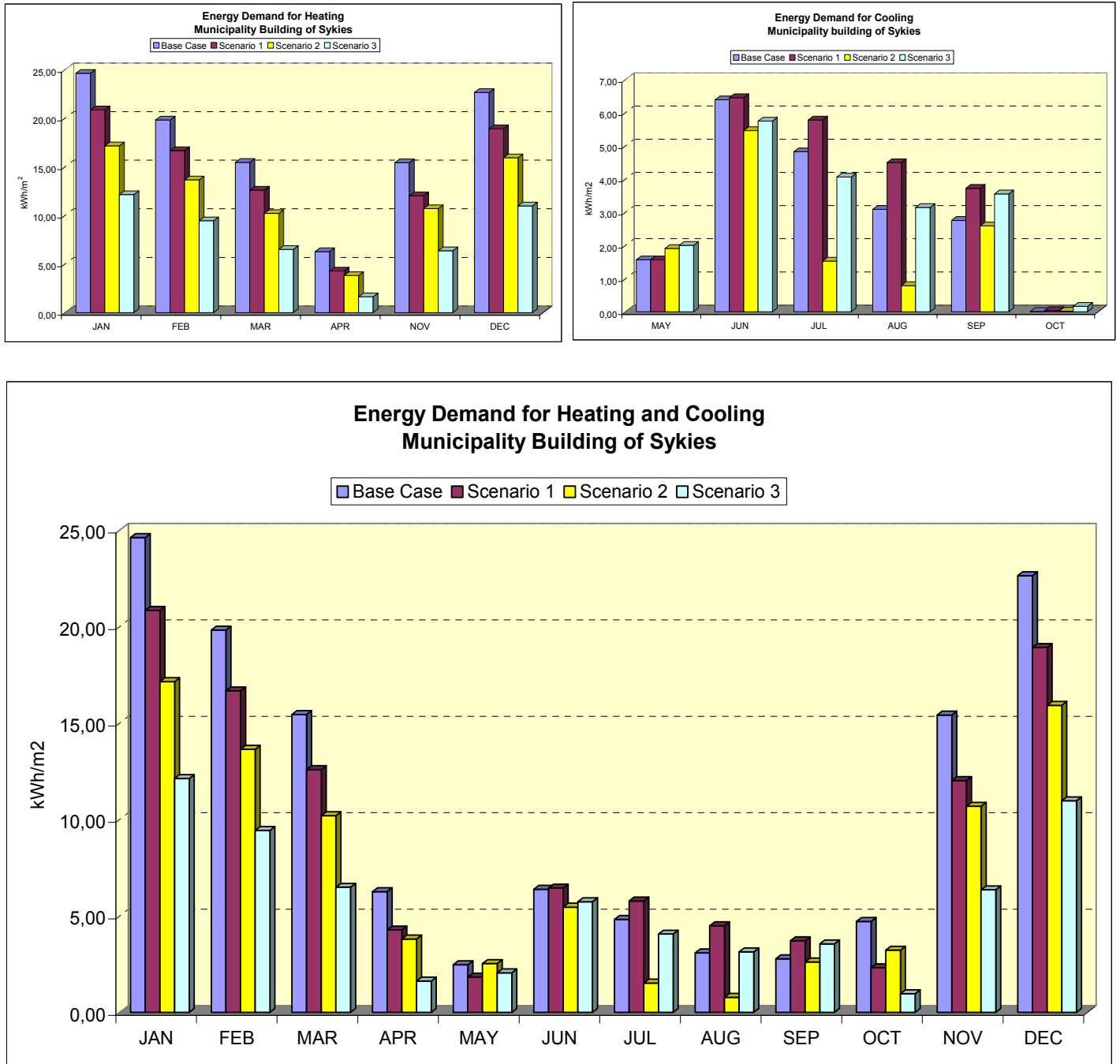


Diagram 3.2: Energy demand (kWh/m²) for Heating and Cooling – Municipal Building of Sykies

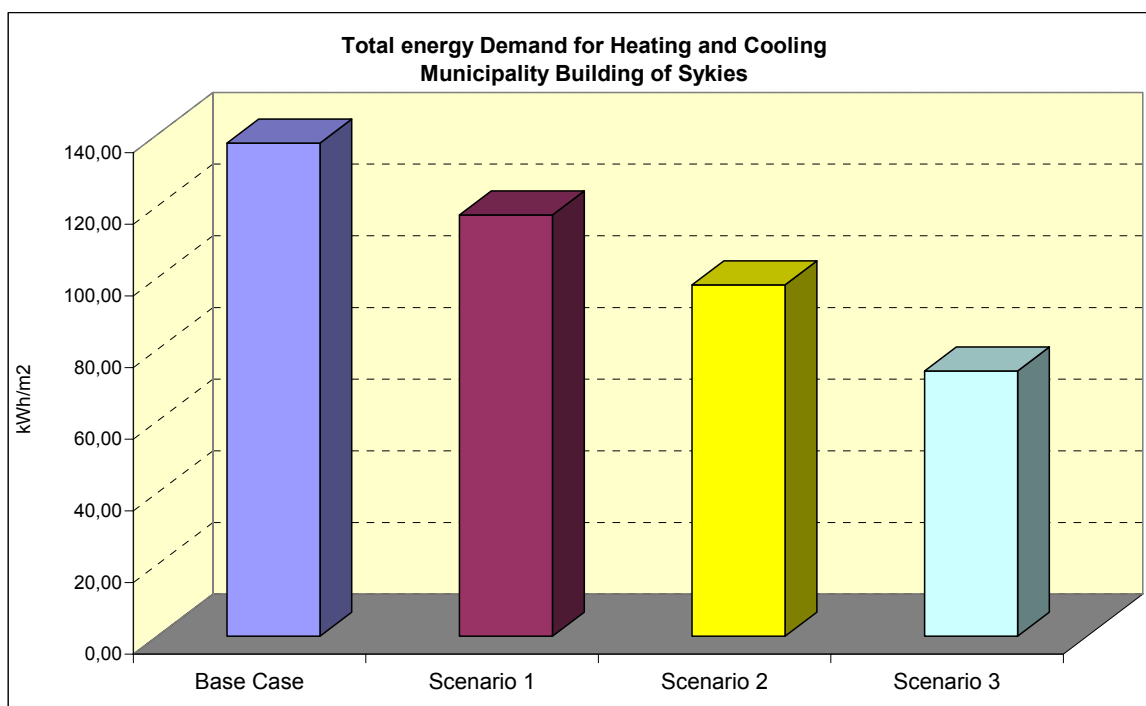


Diagram 3.3: Total energy demand (kWh/m²*year) for Heating and Cooling – Municipal building of Sykies

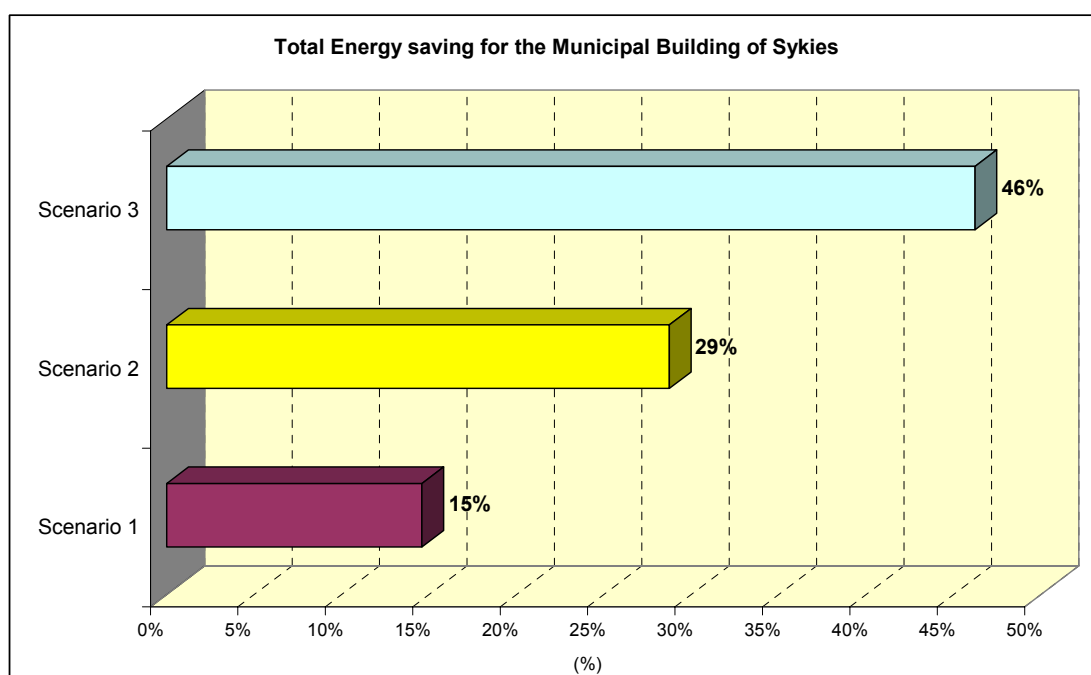


Diagram 3.4: Total energy saving (%) for Heating and Cooling after the application of Scenarios 1, 2 and 3 compared to base case – Municipal building of Sykies

From the analysis above, it can be concluded that the application of Scenario 1 (refurbishment of external walls, roof) results to a significant improvement of the energy performance of the building for heating. The total energy saving for heating is approximately 20%. There is an increase of the total energy demand for cooling

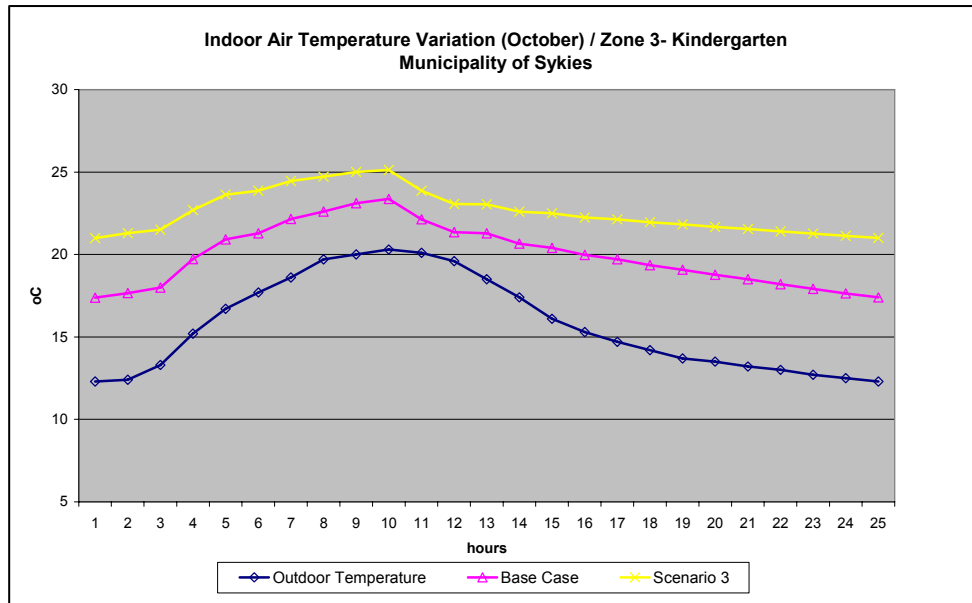
which is approximately 7% while for Scenario 2 (*replacement of windows*) the energy saving for cooling reaches 18% (no infiltration losses) (Diagram 3.3).

From the diagram 3.2 it is noted that the energy demand by applying Scenario 1 is reduced especially for the cold winter months (January, February and December) in comparison to the rest winter period. Respectively, the energy demand is reduced further for the aforementioned months (Jan, Feb, Dec) by the replacement of windows (Scenario 2). This is due to the reduced infiltration losses of the windows. Furthermore, infiltration losses affect also the energy demand for cooling in high outdoor temperatures (June) in comparison to rest of the summer. It is noted that during July and August the kindergarten is closed resulting into reduced energy demand for cooling. Comparing Scenario 1 and Scenario 2 it can be seen that the windows' replacement affect more the energy demand for cooling than that of the better insulation.

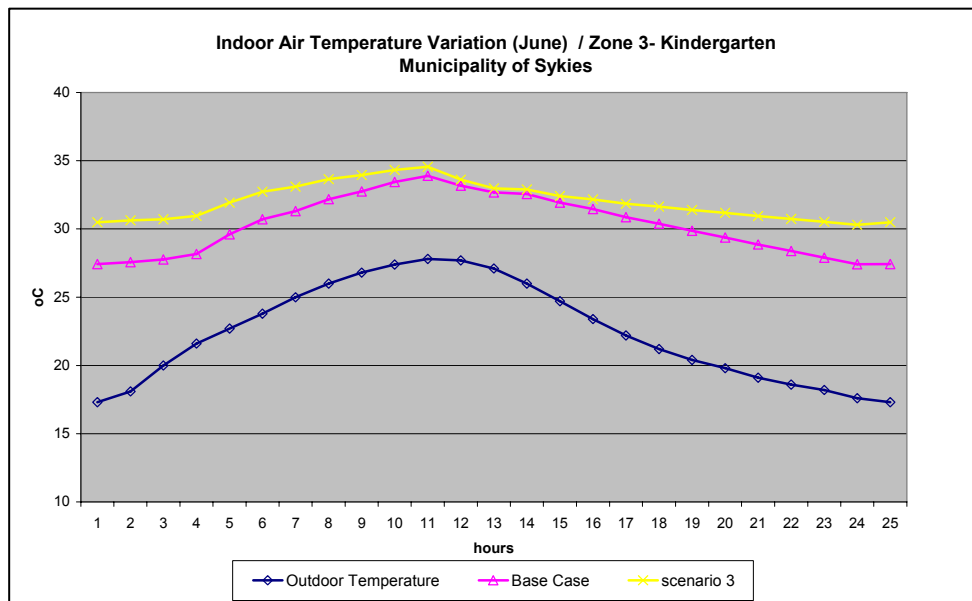
Therefore, by applying the combined Scenario 3, a significant energy saving is achieved in annual basis for heating and cooling. The energy savings for heating and cooling is 56% and 6% respectively. The savings achieved are greater during the winter than that of summer. This is due to a number of reasons: a) the ground and first floor at the southwest are adjacent to the ground, b) during July and August the kindergarten which is exposed to all orientations is closed and c) the opaque refurbishment (Scenario 1) yield to increased cooling loads during summer period.

An efficient energy management system in combination with interventions in the lighting system (artificial and natural) will result to an additional energy saving in the building throughout the year.

3.3.4 Indoor Air Temperature Variation



(a)

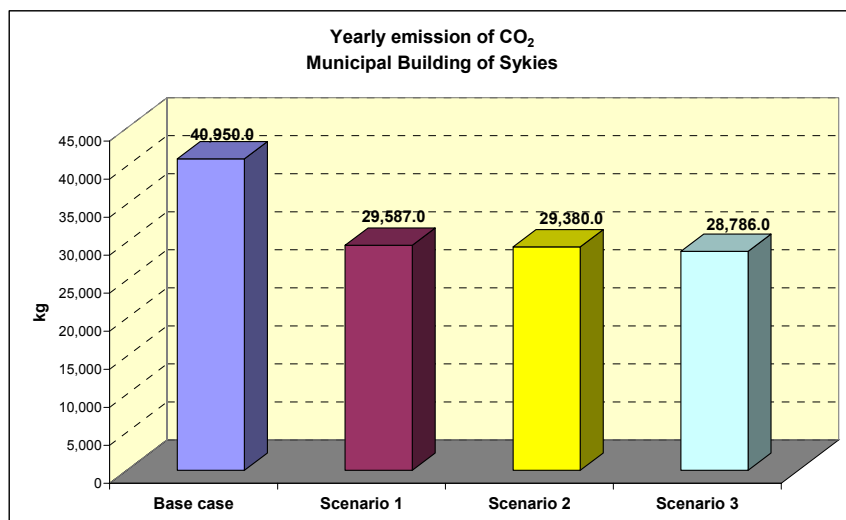


(b)

Diagram 3.5: Indoor air temperature variation for typical winter (a) and summer (b) day (second floor)

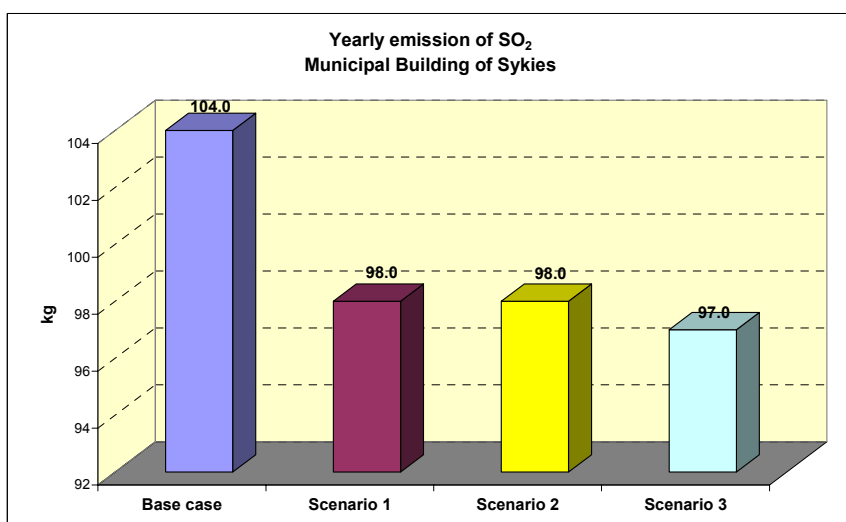
Diagram 3.5 presents the temperature variation in the second floor (kindergarten) for a representative winter and summer day for October and June respectively. It can be concluded that after the replacement of single-glazed windows with double-glazed and the refurbishment of the opaque building elements (Scenario 3), the indoor temperature increases by $\sim 2.5^{\circ}\text{C}$ in winter period and negligibly to $\sim 1^{\circ}\text{C}$ in summer period (no infiltration losses).

3.3.5 Environmental Assessment

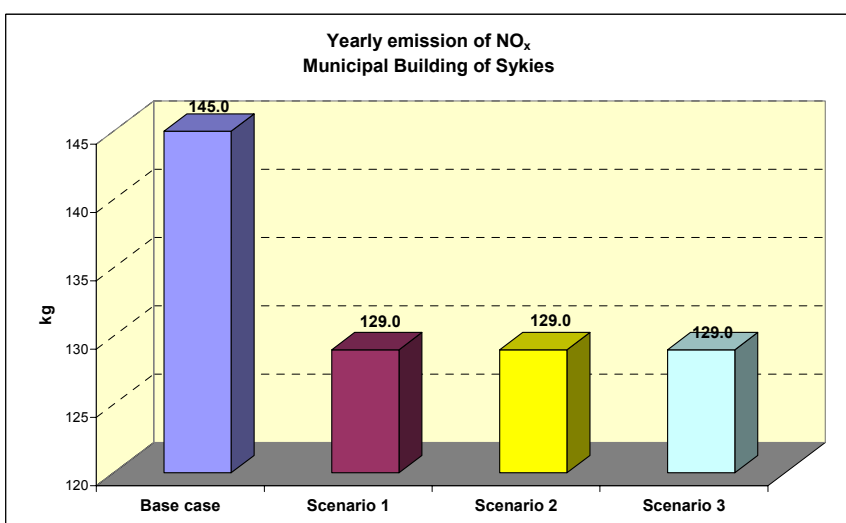


From the analysis of the ASCOT tool, it can be concluded the following regarding the environmental impact:

- Reduction of CO₂ emissions
 - Scenario 1: 11,363.0 kg per year
 - Scenario 2: 11,570.0 kg per year
 - Scenario 3: 12,164.0 kg per year



- Reduction of SO₂ emissions
 - Scenario 1: 6.0 kg per year
 - Scenario 2: 6.0 kg per year
 - Scenario 3: 7.0 kg per year



- Reduction of NO_x emissions
 - Scenario 1: 16.0 kg per year
 - Scenario 2: 16.0 kg per year
 - Scenario 3: 16.0 kg per year

Diagram 3.6: Yearly emissions of air pollutants – Municipal Building of Sykies