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# Costing energy efficiency improvements in buildings Case study: Braşov, Romania

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**Abstract**
One of the methods of buildings' energetic streamline consists of reducing the thermal energy needs (i.e. the building heating/cooling demand) at the level of building. In this regard, this study provides the opportunity of performing a comparative analysis between the values of energy demand for space heating/cooling, based on a case study in which for a building have been modified, at a time, the insulation material of exterior walls, the thermopane windows and the roof insulation. To evaluate the energy consumption in buildings, it is proposed an advanced hourly calculation method using simulations with TRNSYS program, in order to obtain values as close to reality of the energy demand for their space heating and cooling. It is envisaged that the use of building performance simulation programs allow the modelling and computer simulation of building performance in order to obtain a solution that to approximate to a large extent an actual case. Also it should be noted that the estimation and the analysis of the building energy behaviour – still from the design phase or prior to its rehabilitation – is more efficient and economical than solving problems in the use phase of the building.


**Keywords:** Building performance; Indoor thermal comfort; Low-energy buildings; Space heating/cooling demand; TRNSYS.

## 1. Introduction
Globally, about 40% of the total energy consumption is represented by the thermal energy demand of buildings. In addition, the construction sector is growing, which will lead to the increase of energy consumption [1, 2]. The residential buildings and the trade ones (offices, commercial areas, hotels, restaurants, schools, hospitals, gyms, indoor swimming pools) are the largest final consumers of energy, particularly for heating, lighting, home appliances and equipment [1].
At present, the care for global energy depletion makes from the increasing of building energy efficiency a necessary economical standard; so besides the aesthetic factors underlying the construction of a building, it needs to be also designed from the point of view of energy efficiency.
A major objective of low energy buildings is to minimize the amount of external energy purchased – providing indoor thermal comfort of occupants – regardless of the season and outdoor climatic conditions [3]. Low energy buildings usually use a high level of insulation and energy efficient windows to reduce heating and cooling demand, and obtaining of high energy efficiency.
The energy efficiency increase of buildings consists of a set of methods and techniques that consider both the buildings as a whole, as well as that centres of energy exchange with the environment.

Increasing the energy performance of a building can be achieved by different methods such as:
- at the building level by creating the indoor comfort conditions, respectively a good insulation of walls and the use of windows with a high degree of thermal protection;
- increasing the performance of heating systems;
- increasing the performance of air conditioning systems and those concerning the electrical installations.

This paper aims to analyze some of the most effective methods to improve the energy performance of a building at construction level, namely:
- the thermal insulation of exterior walls, a method by which, once with the building envelopment it is also provided an increase of their lifetime;
- the use of thermopane windows, preferably modern windows with triple-pane insulation glass (glazed windows with double effect), that to assure the maintaining of heat indoor during the winter, but also to prevent its excessive influx during summer;
- the thermal insulation of roofs with lightweight materials that do not load the building but ensure its higher lifetime.

The objective of the study is to quantify by energy simulation, which are the values of the energy demand for space heating and cooling, thus highlighting the differences between the energy performances of a building in various embodiments; in this regard it will be achieved a comparative analysis of energy demand values obtained by the use of three different types of insulation materials, by replacing windows and by replacing the roof insulation. The exemplification will be performed by a case study for a multi-zone building located in urban area of Braşov.

## 2. Materials and methods used

### *2.1 Possibilities to increase the energy efficiency of building*

The best solution and the one with the best efficiency of heat gain and of heat carrier saving is the insulation of whole building, both of the roof as well as of the basement, by which large amounts of heat are lost.
The highest losses of a building are found in the field of thermal energy. For this reason, there are required a number of additional measures that take into account the following aspects:
- the building thermal envelope must ensure the comfortable indoor climate with low energy consumption, regardless of the season (both in warm seasons as well in the cold ones) [4-6];
- the windows must have a coefficient of thermal loss as low as possible and the highest solar gain, for saving more energy;
- the proper insulation of the roof especially for buildings with a few floors.

For a detailed study of the energetic behaviour of buildings, the constructive properties and also the materials for walls, ceilings, floors, windows and roof must be known.

#### *2.1.1 Exterior walls insulation*

As first method of rehabilitation of a building, the exterior walls insulation is considered. It is envisaged that the thickness and quality of envelope have a significant influence on the amount of energy that is lost due to excessive transfer between the inside and the outside thereof.
The insulation defects have as effects the heat losses during the winter (these causing the condensation on inside walls) and the excessive power consumption of air-conditioning equipments in the summer.
One of the easiest methods to maintain the indoor thermal comfort of a building consists of the thermal insulation that will reduce the costs for thermal energy [4].
The most commonly used insulation materials are the expanded polystyrene (EPS) and extruded polystyrene (XPS).
To determine the most effective choice of polystyrene type, the following aspects must be considered:
- Expanded polystyrene (according to EN 13163 [7])
  - ✓ it can be used successfully in buildings located in areas with high humidity; the fungi, bacteria or mould do not affect it.
  - ✓ the vapour permeability of the material, if it is mounted on the outside, does not favour the "lock" of moisture between the polystyrene plate and the wall, thus the mould does not appears.
  - ✓ in the last years, while the price for the most construction materials has fluctuated much, the cost of expanded polystyrene remained constant.

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- Extruded Polystyrene (in accordance with EN 13164[8])
  - ✓ it does not allow the vapour crossing, the humidity remains between the wall and the insulation material and thus the condensation occurs;
  - ✓ reliability and high resistance to the destructive effects of nature;
  - ✓ high resistance to heat transfer when the temperature drops;
  - ✓ higher strength compared to of expanded polystyrene to chemical agents such as acids, alkalis, alcohol and alcohol-based dyes, salt water, cement, asphalt etc.;
  - ✓ an extruded polystyrene plate exposed to sunlight, even if it changes its colour, it will not change significantly its thermal insulation values.

Regardless of the used polystyrene type, its thickness influences the heat loss. The recommended minimum thickness for insulation of facades is by 10cm; the thickness increase of polystyrene makes that the investment to be more profitable in the long term [9].

Still the polystyrene – that does not allow the air crossing from the outside to the inside to save energy – can represent a significant disadvantage; in a hermetically sealed building, energy is saved, but over time the construction is not protected due to the mould occurrence and condensation.

In a building must exist transfer between the air from the inside – that has already been used – and the air from the outside, but the polystyrene has not the property of being a good air conductive that to let building "to breathe".

In these situations, there can be used new alternative materials, more efficient and even cheaper. In this category are included, facade systems that includes insulation made of polyurethane.

- Polyurethane thermal insulation (in accordance with EN 13165 [10])
  - ✓ its heat transfer coefficient has a value of about 0.020 W/mK, compared to expanded polystyrene that has a value of about 0.036 W/mK; (these values for both materials may vary depending on the density of the material and the manufacturer);
  - ✓ it is resistant to damages caused by chemical substances; expanded polystyrene is sensitive to petroleum-based solvents such as gasoline, several insect sprays and ordinary adhesives;
  - ✓ it has fireproof properties, it does not burn and does not sustain combustion;
  - ✓ it can be applied without interruption, eliminating the thermal bridges between the panels, on the entire surface of building, regardless its size and form;
  - ✓ the properties of polyurethane foam in terms of soundproofing are far superior to those of expanded polystyrene;
  - ✓ it has waterproofing properties that makes it from this point of view to be preferable compared to polystyrene that can absorb and retain water, which can lead to increasing of the structure weight on what this was mounted (in these situations, the detachment of insulation material may result).

#### *2.1.2 New modern windows with triple-pane insulation glass (low-E)*

The exterior windows are part of the building envelope so that in a rehabilitation process the characteristics of windows are important.

The energy efficient glazed windows reduce the thermal energy consumption.

In the field of high quality windows, currently there were developed a number of modern technologies that allow reducing costs for space heating. The current trend in this field is directed to windows with triple-pane insulation glass [11]; these windows have double effect, respectively of maintaining the heat indoors in winter but do not allow excessive influx from outside in summer.

#### *2.1.3 Roof insulation*

The thermal protection improvement of the roof represents an effective measure that can be applied to existing buildings, in view of the rehabilitation and their thermal energy modernization.

The proper insulation of roof prevents heat loss, respectively energy, that occur at the roof level; therefore its efficient thermal insulation is essential to ensure indoor thermal comfort of the building.

Providing an additional insulation layer for this construction element does not require major investments, it is relatively simple to perform, and the investment recovery time is reduced.

A substantial increase in the thermal resistance of the roof is much more effective and appropriate if the number of floors is more reduced.

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*2.2 Computational methods*

The energy performance simulation of building proposed to study was performed using transient analysis software, TRNSYS (TRansient System Simulation) [12]. This software is dynamic simulation program that benefits by a modular structure that makes possible its supplement with mathematical models.

The energy simulation was performed using the weather data recorded by a local weather station (Braşov urban area) by implementing them in TRNSYS subroutines; it was considered the fact that to achieve an energy calculation as accurately is important to have accurate weather data (solar radiation data, ambient temperature, relative humidity, wind speed and direction).

Implementing the building model consisted of the following steps:

- the defining of thermal zones and their characteristics;
- the detailed specification of envelope elements for building, the optical properties of windows, the working programme of the equipment;
- defining of the orientation for building and for glazed surfaces;
- the specification of infiltration due to leaks and the type of air conditioning;
- the specification of heating and cooling regimes (temperatures during the day and the night, supplied heating power);
- specifying the internal gains distributed in the three components (persons, artificial lighting, electrical devices);
- the detailed description of shading type.

## 3. Results and discussions

*3.1 Case study*

Energy calculation is applied for an office building of Transilvania University of Braşov; the building has two floors with a built area of 260m$^2$. The North and South oriented exterior walls of the second floor are formed mostly from windows (Figure 1).

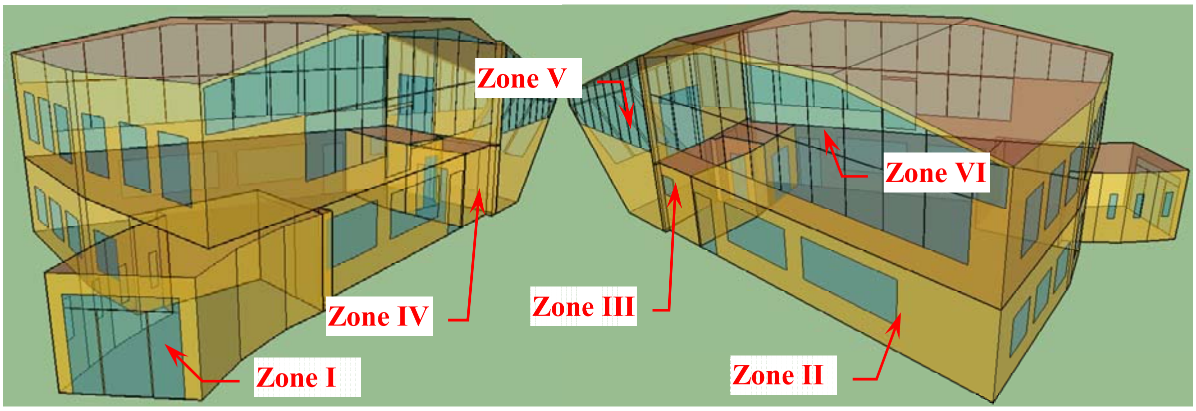



Figure 1. Sample of figure for the international journal of energy and environment

To define in detail the characteristics and the thermal behaviour of proposed building this was divided into 6 thermal zones (Zone I: Entrance Hall, Zone II: Office (First Floor), Zone III: Bathroom, Zone IV: Small Lobby, Zone V: Staircase; Zone VI: Second Floor), for each zone being possible to define a different thermal regime.

The two offices are located each on one floor having each 10 occupants.

The occupants schedule was considered from 8.00 until 20.00 during the weekdays, from Monday to Friday.

The control strategy for electronics apparatus from offices (PC, laptop, printer, and photocopier) was defined according to the same schedule.

The artificial lighting scenario is the same as that for occupants activity, lighting being available from 8.00 to 20.00, during the days from Monday to Friday.

For setting of the heating requirements, the air temperature of the zone was set to 21°C during workday and for the periods of night, Saturday and Sunday, the air temperature was set to 19°C.

Regarding the cooling control, for the set-point temperature above which the cooling is active, it was considered a constant value of 25°C.

The air flow from outside into the building zones was specified by defining the type of infiltrations [12, 13]. The air change rate of the infiltration was considered as having a value of 0.5 1/h for the following thermal zones: Entrance Hall, Bathroom, Small Lobby, First Floor, respectively 0.3 1/h for the Second Floor and Staircase (it is considered that airing takes place only during work schedule).
TRNSYS simulations were performed for specific climatic conditions of Braşov urban area (Romania); thus the meteorological database implemented in TRNSYS subroutines contains the data monitored using a local Weather Station (Delta T) placed near the building subjected to analysis.
The geographic coordinates of Braşov are 23.1° East longitude and 45.5° North latitude, this area being characterized by a climate profile of continental temperate type.
The proposed simulations were performed for the same configuration of building, during the same time period, but this being affected by a series of successive modifications. Therefore, the simulated model is a transformation of an existing reference building into a low energy building.
Thus, Table 1 shows the building variants for which the simulations were made respectively using three types of insulation materials (and different thicknesses) for exterior walls, different types of windows (double-pane insulation glass (low-E) and triple-pane insulation glass (low-E)) and two different types of thermal insulation of the roof.

Table 1. Building variants for which the energy simulations were carried out

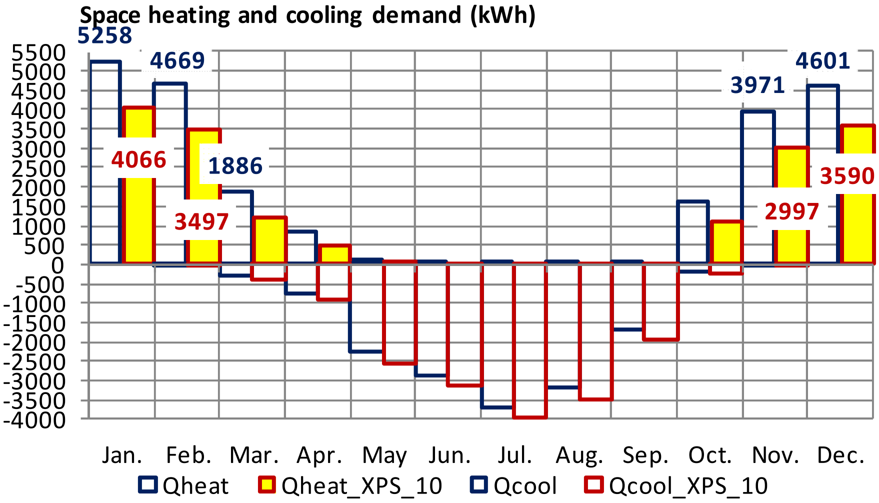
| Variant | Characteristics | Energy demand for space heating (kWh/m$^2$ / year) |
|---|---|---|
| Reference building $v_0$ | - building without insulation of the exterior walls; u-value for exterior walls, 0.908 W/(m$^2$K);<br>- exterior windows with a standard spacer and a standard double pane low-e glazing (u=1.27 W/(m$^2$K); g=0.591);<br>- roof insulated with mineral wool of 15cm (according to EN 13162 [14]), u-value for roof, 0.299 W/(m$^2$K); [12] | 87.87 |
| $v_1$ | - reference building + extruded polystyrene insulation (XPS), 10 cm thickness, u-value for exterior walls, 0.247 W/(m$^2$K); | 65.09 |
| $v_2$ | - reference building + expanded polystyrene insulation (EPS), 10 cm thickness, u-value for exterior walls, 0.278 W/(m$^2$K); | 66.29 |
| $v_3$ | - reference building + expanded polystyrene insulation (EPS), 20 cm thickness, u-value for exterior walls, 0.164 W/(m$^2$K); | 62.23 |
| $v_4$ | - reference building + polyurethane insulation, 10cm thickness, u-value for exterior walls, 0.213 W/(m$^2$K); | 63.98 |
| $v_5$ | - reference building + polyurethane insulation, 15cm thickness, u-value for exterior walls, 0.154 W/(m$^2$K); | 61.79 |
| $v_6$ | - reference building + polyurethane insulation, 15cm thickness, u-value for exterior walls, 0.154 W/(m$^2$K);<br>- new exterior windows with triple-pane low-e glazing (u=0.4 W/(m$^2$K); g=0.408); | 48.42 |
| $v_7$ | - reference building + polyurethane insulation, 15cm thickness, u-value for exterior walls, 0.154 W/(m$^2$K);<br>- new exterior windows with triple-pane low-e glazing (u=0.4 W/(m$^2$K); g=0.408);<br>- new roof (polyurethane insulation of 20cm), u-value for roof, 0.132 W/(m$^2$K); | 42.79 |

### *3.2 Energetic simulation of building - Space heating demand*

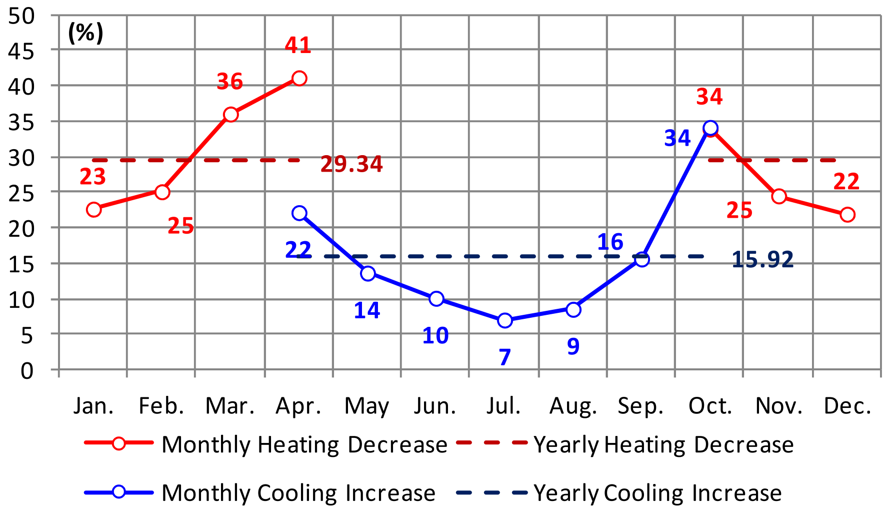
#### *3.2.1 The exterior walls insulation*

The correct insulation of a building leads to reducing of energy consumption for heating space, in the same time ensuring a constant temperature indoor and improving also its sustainability.
Considering the building without thermal insulation of exterior walls and with their thermal insulation with extruded polystyrene of 10cm ($v_1$ versus $v_0$, Figure 2) it can be noticed a considerable decrease of

heating demand (annually this decrease is about 30%) and an increasing of cooling demand (annually with about16%).




(a)




(b)

Figure 2. Exterior walls insulation ($v_0$ versus $v_1$): (a) Monthly demand of space heating and cooling; (b) Monthly percentage differences between variants

However it should be taken into account that in order to ensure a certain degree of indoor thermal comfort, there are needed both the avoidance of condensation on the inside surfaces of the walls as well the discomfort avoidance; the lower the difference between the indoor air temperature and the inside surface temperature of the wall is, the lower the discomfort of cold radiation is.

Considering this aspect in Figure 3 is represented the monthly variation of the differences between indoor air temperature and the inside surface temperature of the North wall for the Second Floor.

The exterior walls insulation with extruded polystyrene leads to a significant decrease of the difference between the indoor air temperature and the North wall temperature, during the months, January to March and October to December (a monthly average of 1.8°C); however, during the months of April to September there is an increase of this difference, respectively the inside surface temperature of wall is higher than indoor air temperature (an average increase of 0.9°C).

A thermal insulation material is characterized by the thermal conductivity that measures the ability of a material to transmit thermal energy; therefore, the lower this coefficient is the better insulation is obtained.

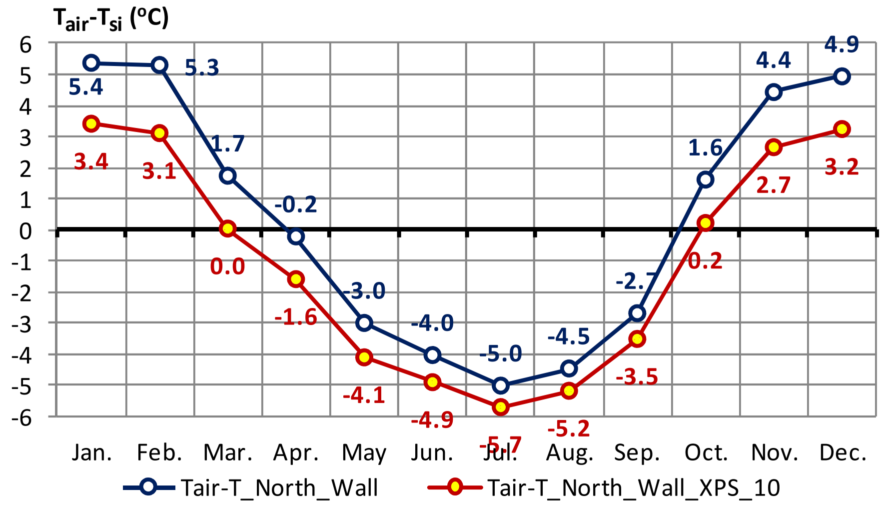



Figure 3. Differences between the monthly averages of indoor air temperature and monthly averages of inside surface temperature of the North wall (Second Floor)

The comparison of different insulation materials is achieved based on their thermal conductivity values, but there are not available concrete comparative analyzes in terms of energy demand for space heating / cooling. Although it can be said that: the polyurethane foam is better in terms of thermal conductivity, with 20.7% compared to extruded polystyrene and with 41.5% compared to expanded polystyrene (Table 2, [4]), these percentages do not reflect themselves in a similarly manner on the differences between thermal demands for building heating / cooling.
Therefore at the insulation material selection is recommended the comparative analysis of thermal demand for space heating / cooling, the values obtained for different types and thicknesses of insulation materials. In this way it can also takes account of factors such as the complete structure of the building and climatic conditions of the geographical area.
Thus for the considered building, the energy simulations were achieved for three types of insulation materials (all of 10cm thick), Figure 4.

Table 2. Insulation materials used in the building energy simulation [12]

| Insulation | Thermal conductivity (W/mK) | Density (kg/m$^3$) |
|---|---|---|
| Extruded Polystyrene Average Density (XPS) | 0.032 | 35 |
| Expanded Polystyrene Average Density (EPS) | 0.0375 | 25 |
| Polyurethane Average Density | 0.0265 | 40 |

The carried analysis led to the conclusion that the polyurethane foam provides the best insulation during the cold period but its use leads to an increased demand for the space cooling. The expanded polystyrene (EPS) provides the worst insulation during the cold period and the extruded polystyrene (XPS) leads to the lowest values of the space cooling demand.
However, among the annual obtained values (both for heating and cooling demand) small differences were recorded; thus,

- the percentage increase of heating demand compared to polyurethane foam,
  - when using the expanded polystyrene is 3.6% and,
  - when using the extruded polystyrene 1.73%,
- the percentage increase of cooling demand compared to extruded polystyrene,
  - when using the expanded polystyrene is 1.78%, and,
  - when using polyurethane foam of 3.0%.

One of the factors that make the difference between a good insulation and an inefficient one is the thickness of insulation material. In this respect Figure 5 shows the influence of insulation material thickness, respectively for expanded polystyrene (10cm and 20cm thick) and polyurethane foam (10cm and 15cm).

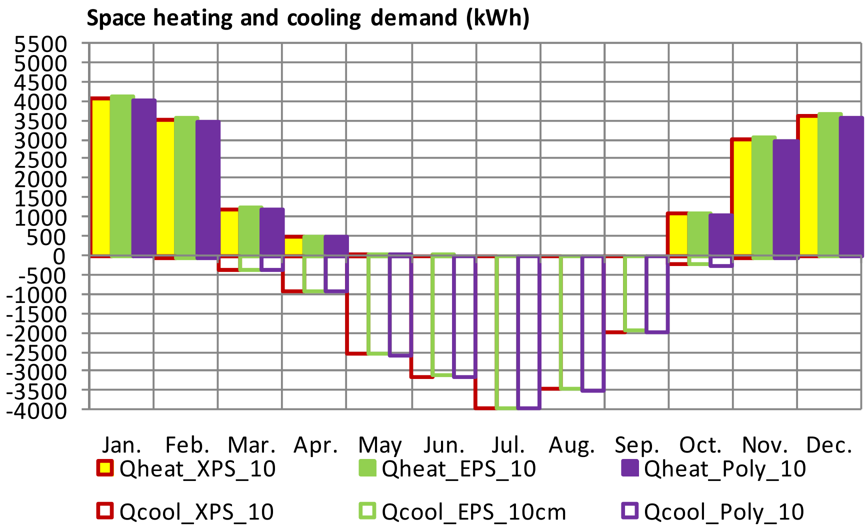
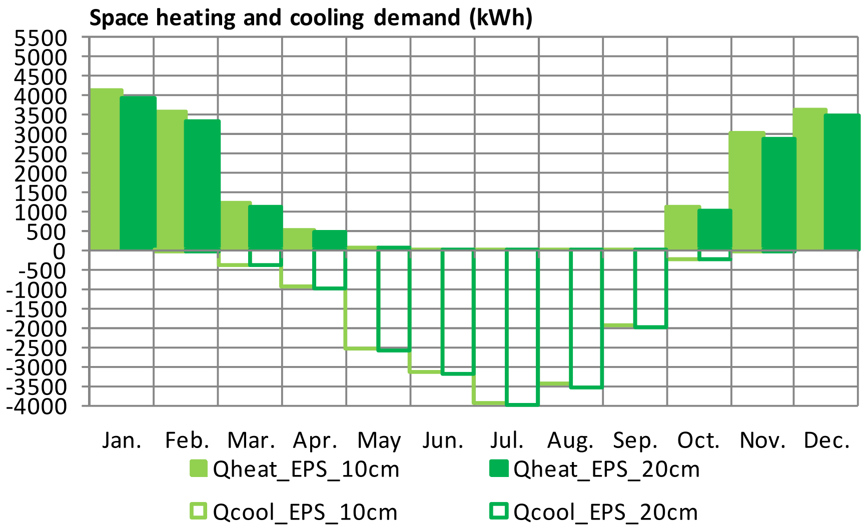
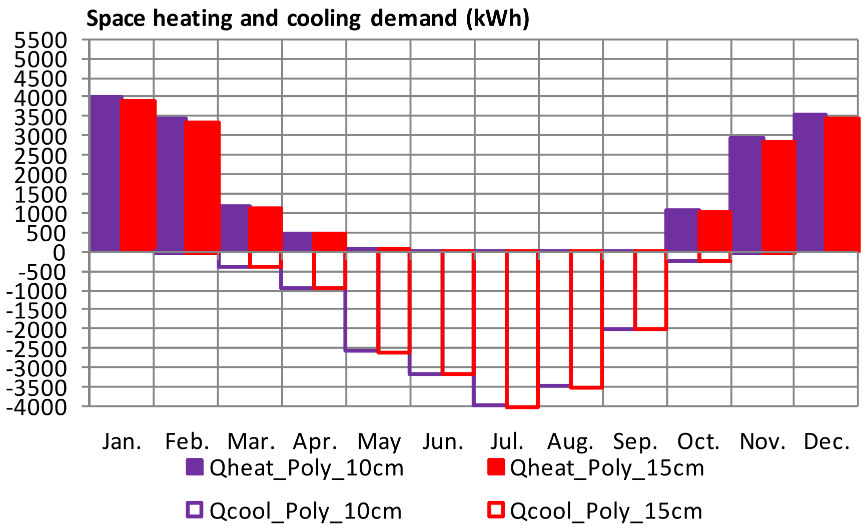



Figure 4. Insulation of exterior walls with different insulation materials with thickness of 10cm (the comparison of variants $v_1$, $v_2$, $v_4$)




(a)




(b)

Figure 5. Insulation of exterior walls using different thicknesses of insulation material ($v_2$ versus $v_3$ and $v_4$ versus $v_5$): (a) expanded polystyrene; (b) polyurethane foam

In the case of expanded polystyrene use, doubling the thickness of the insulation layer leads to a decrease in the space heating demand with 6.1%, but to an increase in the cooling demand with 2.1% (Figure 5,(a)). However it is noted that an increasing of the polyurethane foam layer from 10cm to 15cm leads to a decrease of space heating demand with 3.4% and to a ***decrease*** of cooling demand with 1.3% (Figure 5,(b)).
In view of the above conclusion, for the building being analyzed it is recommended the use of polyurethane foam with 15cm thick as insulation material (the following simulations were made for variants of the building for what the thermal insulation of exterior walls was made with polyurethane foam of 15cm).

*3.2.2 New modern windows with triple-pane insulation glass (low-E)*
The thermal losses for windows are characterized by the value of heat transfer coefficient U; this value is inversely proportional to the thermal resistance, a low value for U leading to a better energy efficiency of the window [11, 13].
As a measure for the possible solar heat gain, the glazing g-value must be as high as possible.
Although the reference building variant is provided with double-pane insulation glass (low-E) for exterior windows (u=1.27 W/(m$^2$K); g=0.591) their change with triple-pane insulation glass windows (u=0.4 W/(m$^2$K); g=0.408) has positive effects both on the heating /cooling demand as well on the indoor thermal comfort (Figures 6 and 7).

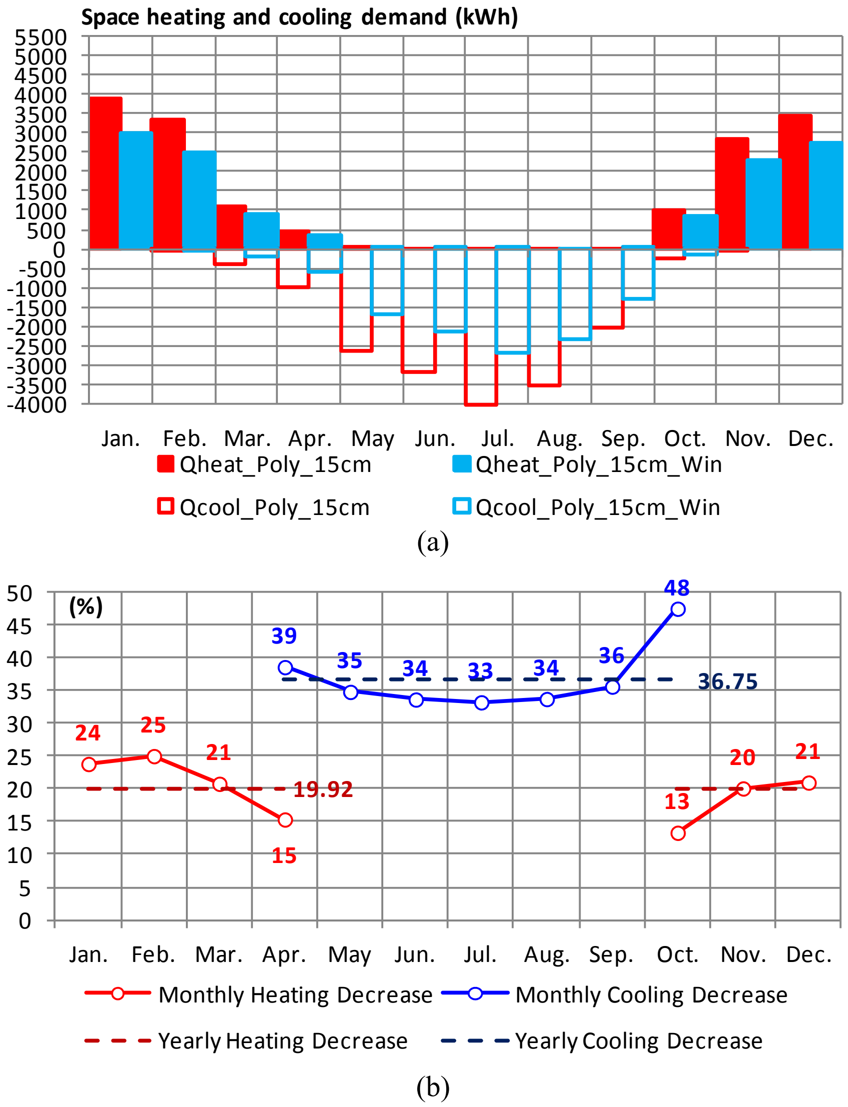



Figure 6. The replacement of the double-pane insulation glass windows by triple-pane insulation glass windows ($v_5$ versus $v_6$): (a) monthly demand for space heating and cooling; (b) monthly percentage differences between variants

Thus, the use of modern windows leads to a decrease of the annual value of energy demand for space heating with about 20%; the decrease for annual space cooling demand is about 37%.
The analysis of monthly temperature differences between the indoor air temperature and the inside surface temperature of the North wall for the Second Floor is presented in Figure 7,(a).

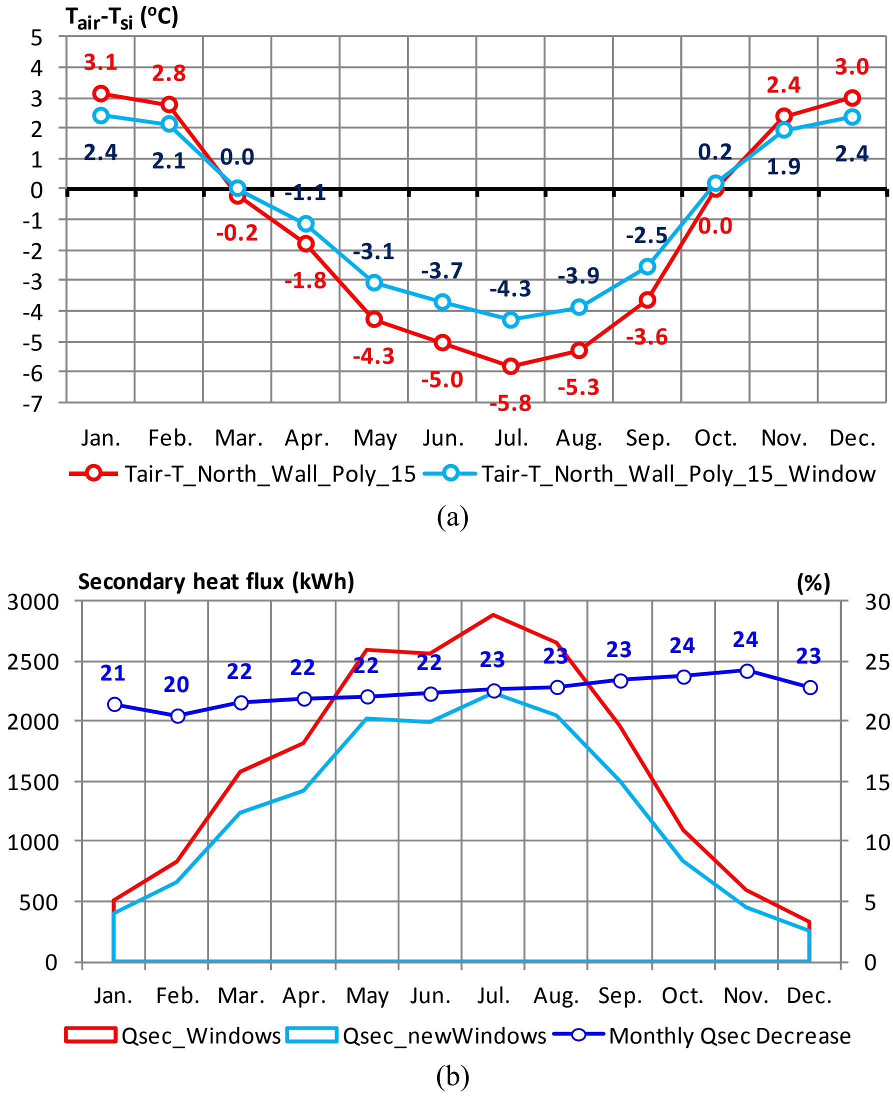



Figure 7. The use of triple-pane insulation glass windows ($T_{air}$ – air temperature; $T_{si}$ - inside surface temperature): (a) $T_{air}$-$T_{si}$ – the North wall of the Second Floor; (b) secondary heat flux of all windows

It is noted that changing the windows has a positive influence on indoor comfort both in the cold periods January to March and October to December as well during the warm period April to October. Thus for the two cold periods mentioned above it is recorded a decrease of temperature difference on average with 0.4°C, a significant decrease of the temperature difference being obtained during the warm period, respectively of 1.2°C.
This fact is due to the decrease of secondary heat flux that is transmitted through the windows throughout the year (Figure 7,(b)); as it can be seen, the use of triple-pane insulation glass windows leads to a decrease of the monthly values of the secondary heat flux with 20-24%.

*3.2.3 The roof insulation*
For the thermal insulation of the roof, this paper proposes to replace the existent insulation of mineral wool with the polyurethane foam.
Considering the building (provided with exterior walls insulated with polyurethane foam of 15cm and triple-pane insulation glass windows) the replacement of roof insulation with polyurethane foam of 15cm

thickness, leads to a decrease in the annual demand of space heating with about 11%, but to an increase in cooling demand of about 7% (Figure 8).

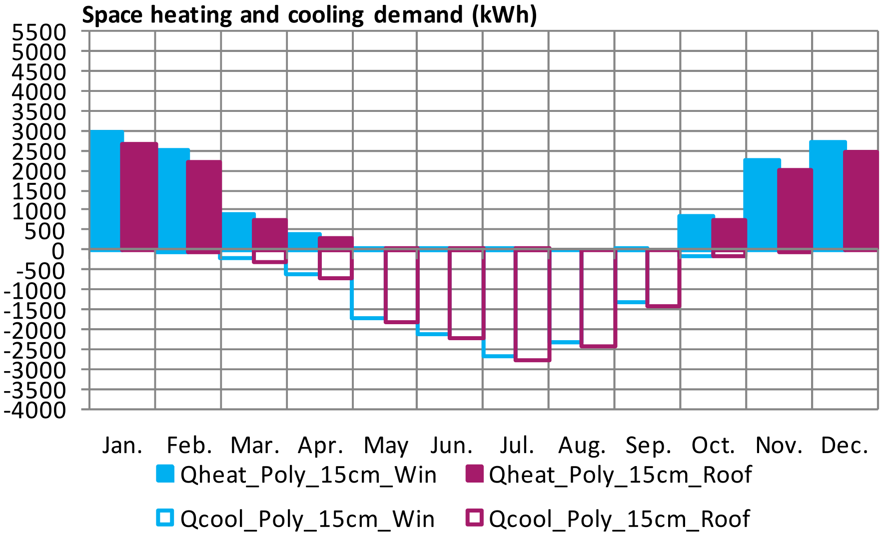


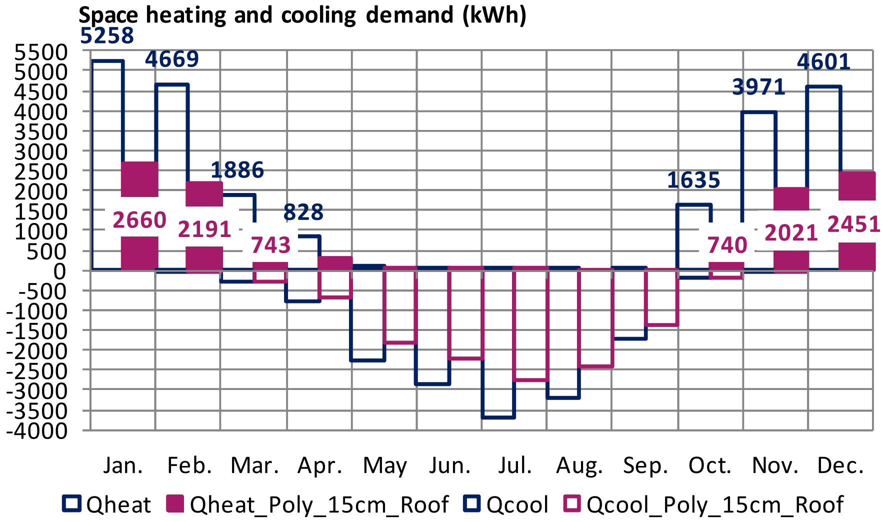

Figure 8. Monthly values of heating and cooling demand at the replacement of the roof insulation ($v_6$ versus $v_7$)

The last stage of the study proposes a comparative analysis between the building reference variant ($v_0$) and the latest variant proposed ($v_7$).
From the comparative analysis of results obtained following the energy simulations (Figures 9 and 10 and Table 3) it can be said that the rehabilitation of the entire building can lead to:

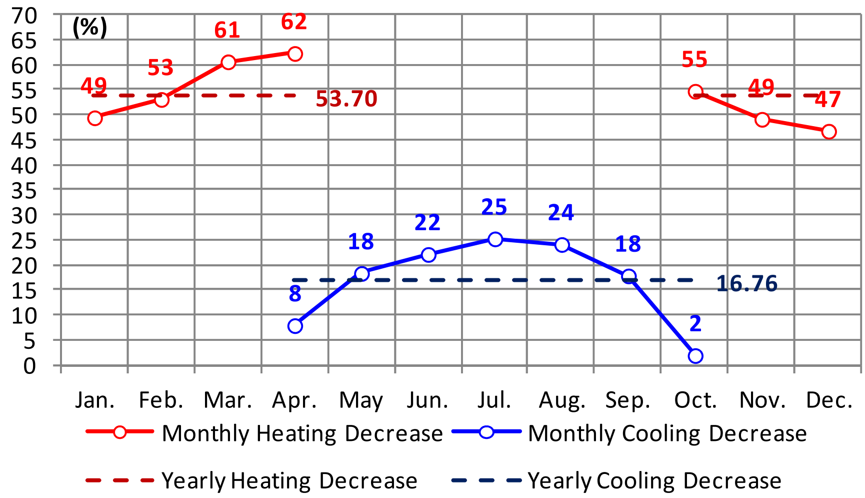
- the decrease of space heating demand with about 53% compared to the reference variant;
- the decrease of space cooling demand with about 17% compared to the reference variant;
- the temperature difference between indoor air temperature and North wall surface temperature for the Second Floor, decreases on average with about 2.6°C during the cold periods: January to March, October to December, and with about 0.3°C during period of May to September.

Table 3. The annual values of the space heating / cooling demand

| Variant | Yearly Qheat [kWh] | Yearly Qcool [kWh] | Yearly decrease of heating demand (%) compared to $v_0$ | Yearly increase of cooling demand (%) compared to $v_0$ |
|---|---|---|---|---|
| $v_0$ | 22847 | 14663 | - | - |
| $v_1$ | 16923 | 16295 | 25.93 | 11.13 |
| $v_2$ | 17235 | 16587 | 24.56 | 13.12 |
| $v_3$ | 16181 | 16940 | 29.18 | 15.53 |
| $v_4$ | 16634 | 16785 | 27.19 | 14.47 |
| $v_5$ | 16066 | 16570 | 29.68 | 13.01 |
| $v_6$ | 12589 | 11060 | 44.90 | -24.57 |
| $v_7$ | 11127 | 11851 | 51.30 | -19.18 |




(a)




(b)

Figure 9. The reference variant versus the final one (v0 versus v7): (a) monthly demand of space heating / cooling; (b) monthly percentage differences between variants

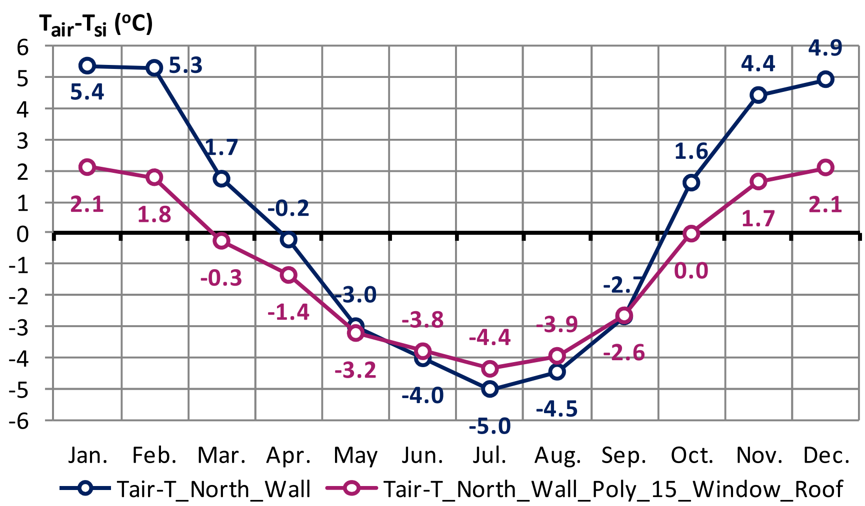



Figure 10. Differences between the monthly averages of indoor air temperature and the monthly averages of the North wall temperature (Second Floor)

## 4. Conclusions

For Braşov area, the energy demand for building heating in cold season represents an important share in energy consumption. Thus, as early as the construction phase of a building there can be considered a series of methods to reduce the energy demand for heating. To highlight the advantages of such methods, this paper proposed the energy analysis of an office building and the comparative study of the influence of various factors, such: the insulation material type of the exterior walls, the type of thermopane windows and the thermal insulation type of the roof. Following the achieved study, the following conclusions can be formulated:

- The climatic conditions of area have a significant influence both on the indoor comfort as well on the energy consumption in buildings. In view of this aspect, the energy demand simulation was performed using weather data recorded by a local weather station (data specific to Braşov area), data that were then implemented for simulations with TRNSYS software.
- The building envelope must be analyzed for its features of heat transmission, for its ability to control heat gain and losses considering the use of different insulation materials.
- A good insulation of exterior walls leads to a decrease in heating demands, through a good preservation of indoor temperature. Also, an increase in indoor thermal comfort is recorded due to eliminating the effect of "cold wall" on exterior walls (the difference between the wall surface temperature and indoor air temperature decreases). In addition, the risk of condensation is reduced and sudden temperature changes are prevented.
- High efficiency windows (which include multiple layers of insulation and low emissivity coatings) lead to energy savings by reducing the energy losses during the cold period, but also to maintaining of some reduced temperatures and reduced cooling demands during the warm period.
- The roof thermal insulation leads to a decrease of heating energy demand (for the considered case study the annual reduction of heating demand for the Second Floor is of 20%).

Finally it must be mentioned the important role of computer simulation in the design based on energy performance of buildings, in order to obtain some results based on which the final solution will decided. Using libraries of building materials, windows, weather data and standards for determining the buildings performance, through computer simulations there can be evaluated the parameters that ensure the energy efficiency of a building (calculation of building loads and of energy consumption; evaluation of thermal comfort conditions, thermal behaviour, etc.).

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