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ANALYSIS OF ENERGY SAVING MEASURES FOR AN EXISTING RESIDENTIAL BUILDING

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- The most common measures taken in order to increase energy efficiency and thereby reduce emissions of greenhouse gases are: insulation of a building, replacement of dilapidated windows and doors and installation of measuring and regulating devices (heat meters and thermostatic valves).

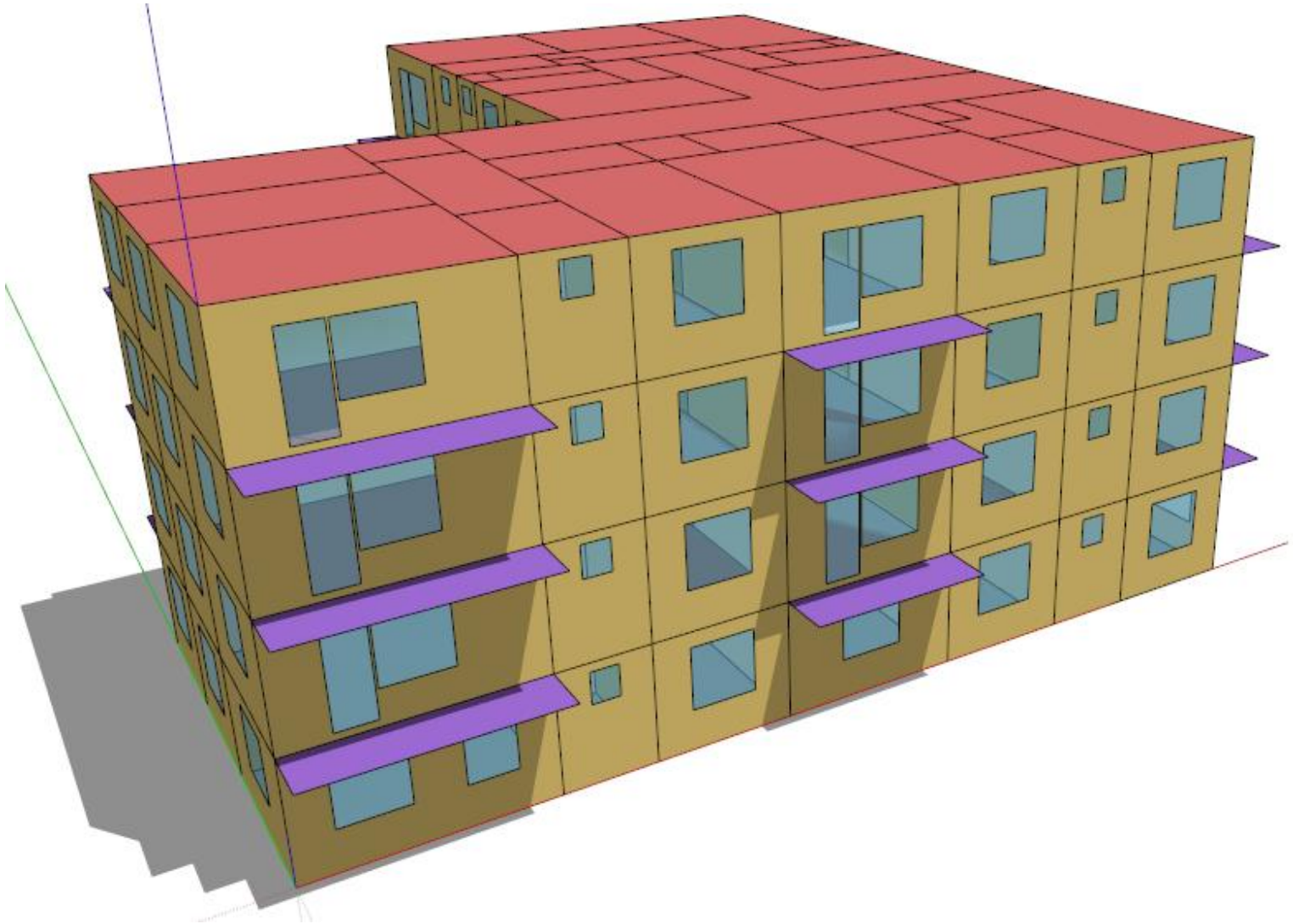
- The objective of this paper is reffered to the analysis of energy saving measures for an existing residential building. Analysis was performed comparing the building with existing constructions and building with implemented energy saving measures that are related to: **replacement of windows and doors**, **change of the roof construction**, **change of the ground floor and ceiling constructions**, **change of the interior walls between different users** and **change of the interior walls toward unheated space**.

- This paper is a part of investigation that is related to the analysis of heating consumption in heated apartments during the reduction of air temperature or unheating of adjacent apartments of an residential building.

Description of the residential building

The total area of the analyzed residential building is 1504 m^2 and useful heating area 1247.68 m^2.

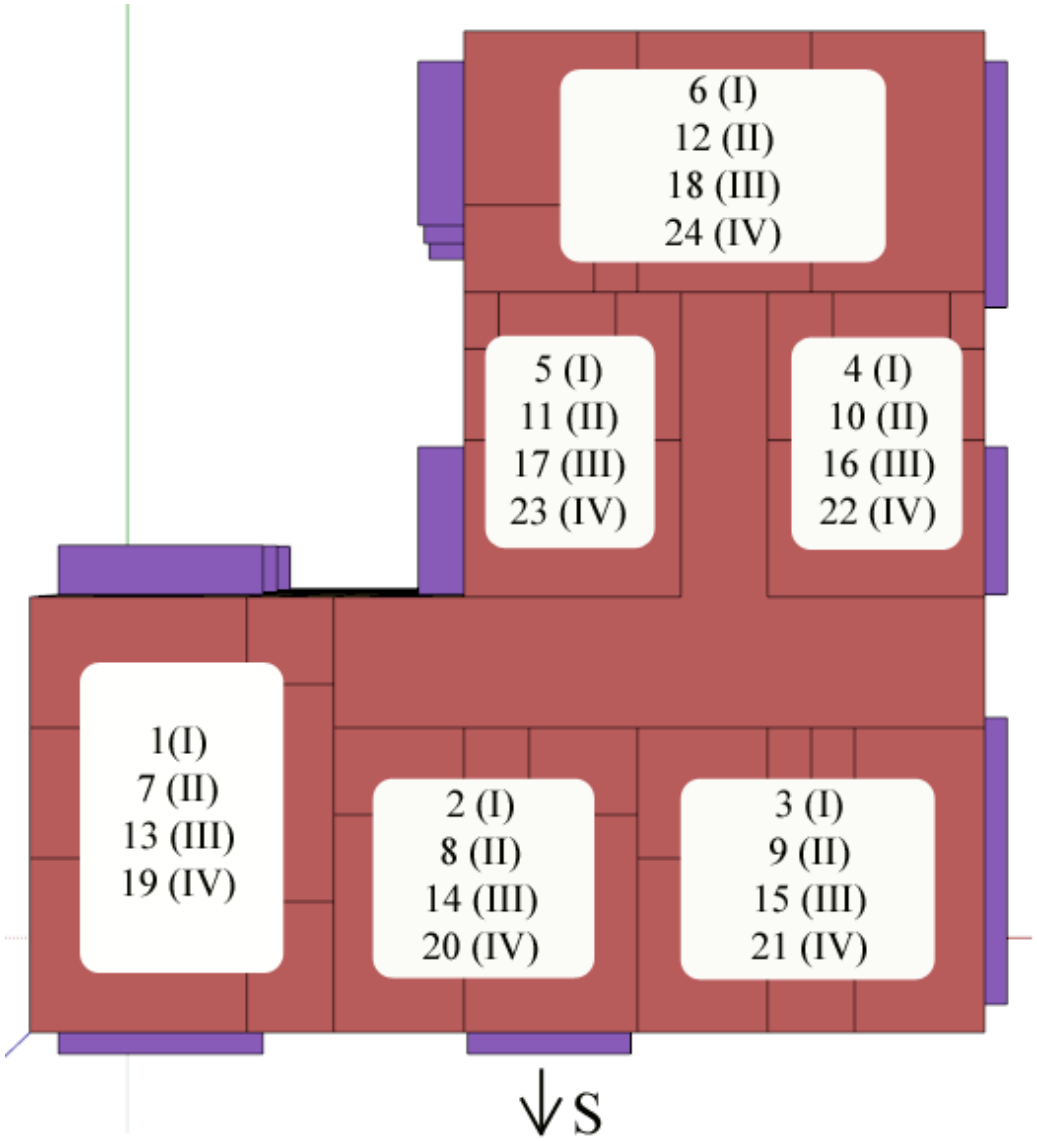
The building has a total of 24 apartments distributed on 4 levels.



Isometric view of the analyzed residential building

Description of the residential building

Distribution of apartments per levels of the analyzed residential building



Only construction of the exterior wall meets the Regulations on energy efficiency of buildings. The layers added to the building constructions are bolded as well as new obtained values for *U* - coefficient.

Table 1 *The characteristics of the building constructions*

Construction	Layer	*U* [W/m^{2}K]
Window and balcony door	Glass (0.3 cm), Air (1.3 cm), Glass (0.3 cm); **Glass (0.6 cm), Xenon (1.6 cm), Glass (0.6 cm), Xenon (1.6 cm), Glass (0.6 cm)**	2.72; **1.5**
Exterior door	Wood (3.5 cm); **Wood (2 cm), Cellulose fibers (2 cm), Wood (2 cm)**	4; **1.27**
Exterior wall	Brick (12 cm), Expanded polystyrene foam (15 cm), Air (2 cm), Clay block (25 cm), Lime mortar (2.5 cm)	0.22
Interior wall	Lime mortar (2.5 cm), Brick (12 cm), Lime mortar (2.5 cm)	2.17
Interior wall between different users	Lime mortar (2.5 cm), **Expanded polystyrene foam (1.5 cm),** Brick (12 cm), **Expanded polystyrene foam (1.5 cm),** Lime mortar (2.5 cm)	2.17; **0.81**
Interior wall toward unheated space	Lime mortar (2.5 cm), Brick (12 cm), **Expanded polystyrene foam (6 cm),** Lime mortar (2.5 cm)	2.17; **0.51**
Roof	Gravel (5 cm), Waterproofing (0.5 cm; **1.5 cm**), **Mineral wool (12 cm)**, Cotton (5 cm), Vapor barrier (0.5 cm), Lightweight concrete 1 (5 cm), Lightweight concrete 2 (4 cm), Lightweight concrete 3 (16 cm), Lime mortar (2.5 cm);	0.51; **0.19**
Floor with tiles	Stone (25 cm), Gravel (5 cm), Lightweight concrete 2 (4 cm), Waterproofing (0.8 cm), Lightweight concrete 2 (4 cm), **Expanded polystyrene foam (8 cm), Waterproofing (1 cm),** Ceramic tile (1.5 cm)	1.68; **0.38**
Floor with hardwood	Stone (25 cm), Gravel (5 cm), Lightweight concrete 2 (4 cm), Waterproofing (0.8 cm), Lightweight concrete 2 (4 cm), **Expanded polystyrene foam (8 cm), Waterproofing (1 cm),** Hardwood (2 cm)	1.46; **0.37**
Interior ceiling (with tiles)	Lime mortar (2.5 cm), Lightweight concrete 3 (16 cm), Lightweight concrete 2 (4 cm), **Expanded polystyrene foam (3 cm), Waterproofing (1 cm),** Ceramic tile (1.5 cm)	2.06; **0.76**
Interior ceiling (with hardwood)	Lime mortar (2.5 cm), Lightweight concrete 3 (16 cm), Lightweight concrete 2 (4 cm), **Expanded polystyrene foam (3 cm), Waterproofing (1 cm),** Hardwood (2 cm)	1.77; **0.71**

Description of the residential building

The most apartments consists of: living room, bedroom, kitchen and bathroom.

Use of lighting, electric equipment and occupancy in the building is defined by the schedules within the software EnergyPlus.

Total number of people that accommodates each appartment is 4.

During the interval of 8 to 16 h there is no presence of people.

Total power of lighting and electric equipment is approximately the same for every appartment.

Description of the residential building

The building is heated by hot water from the heating system that consists of a boiler on natural gas, convective baseboard heaters and variable flow pump. The water convective baseboard heaters are put in each of the heated rooms.

The heating system operates each day of the heating season from 15th of October to 15th of April. During the day, they operates from 7:00 am to 9:00 pm, if the room temperature is below 20˚C (22˚C), from 9:00 pm to 12:00 pm if the room temperature is below 18˚C and from 12:00 pm to 7:00 am if the room temperature is below 15˚C.

Air temperatures in the heated rooms are set to 20 ˚C for living room, bedroom and kitchen and 22 ˚C for bathroom.

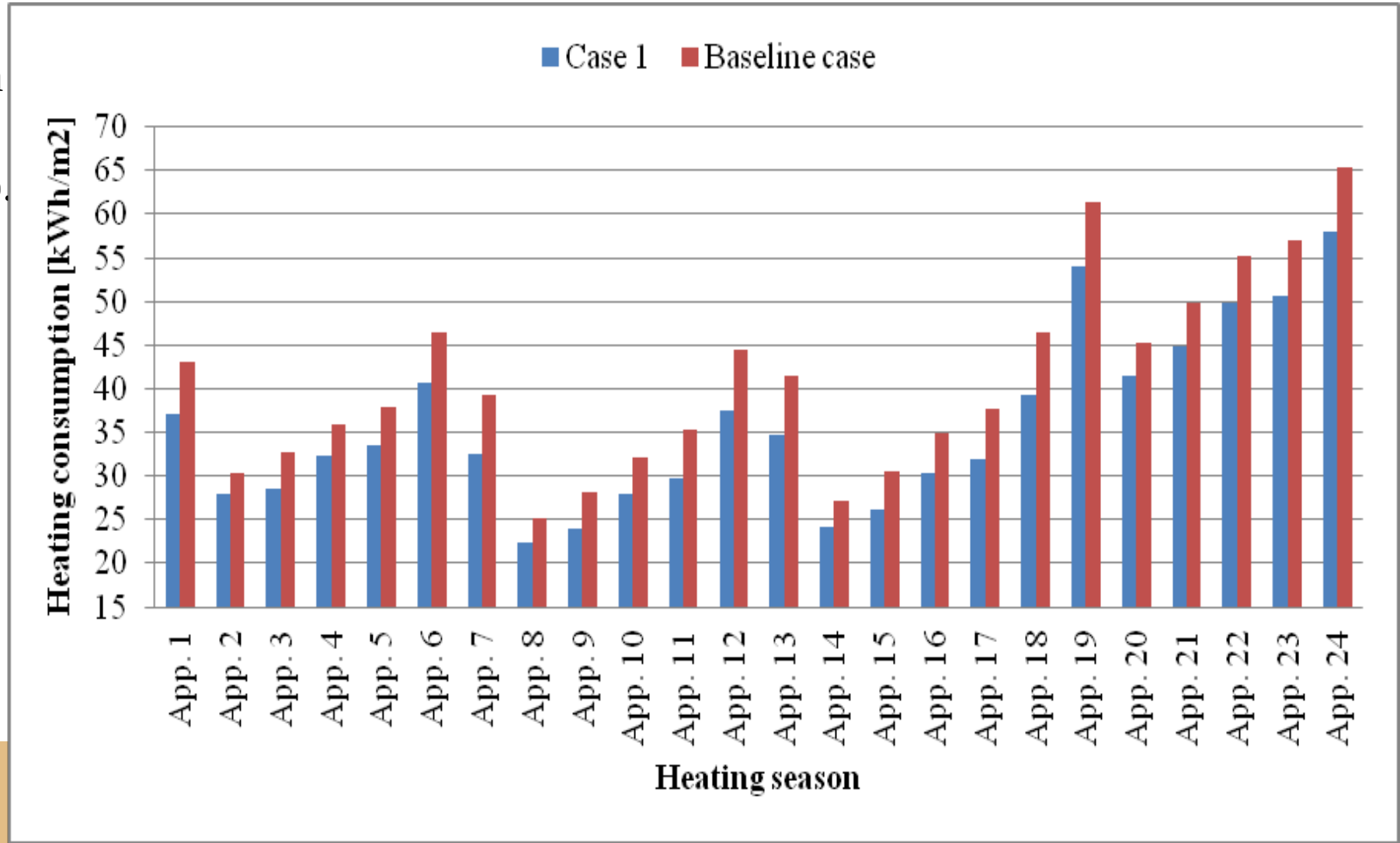
Results and discussion

This paper is related to the analysis of implementation of energy saving measures in an existing residential building. Six measures was proposed and analyzed: replacement of windows and doors (**case 1**), change of the roof construction (**case 2**), change of the ground floor and ceiling constructions (**case 3**), change of the interior walls between different users (**case 4**) and change of the interior walls toward unheated space (**case 5**). **Case 6** is related to the situation when all previously mentioned measures would be implemented.

To simulate energy behavior of the analysed building, software EnergyPlus (version 7.1.0) was used.

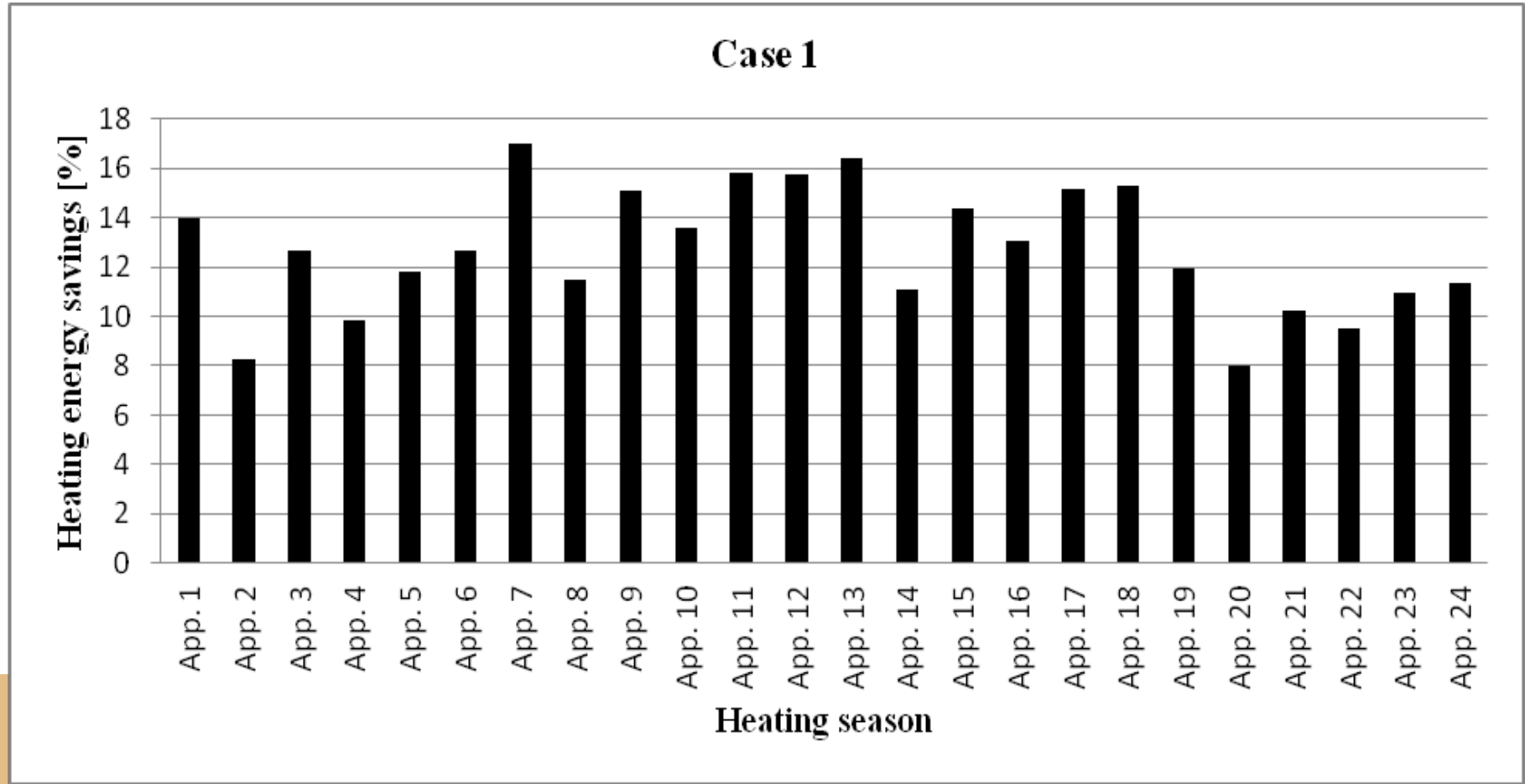
Results and discussion - Case 1 - Replacement of windows and doors

It can be concluded that first six appartments, on the ground floor (first level), have identical change of heating consumption as appartments on the upper levels. The largest appartments have the highest heating consumption in the building (1, 6, 7, 12, 13, 18, 19, 24). On the other side, the appartments with the lowest heating consumption are 2, 8, 14 and 20.



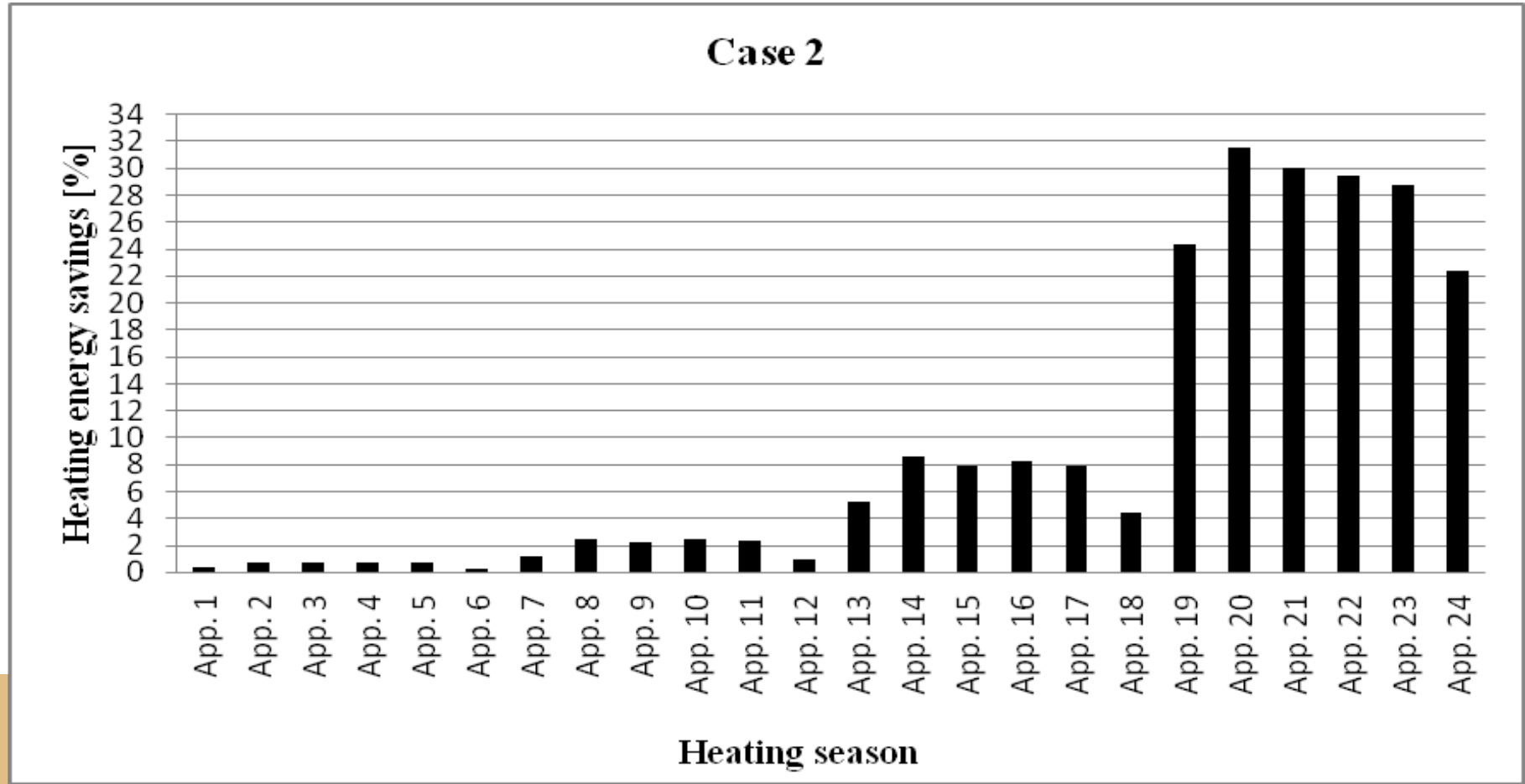
Results and discussion - Case 1 - Replacement of windows and doors

By replacing the balcony doors and windows (***U* = 1.5 W/m²K**) and exterior door (***U* = 1.27 W/m²K**) it can be saved 8 to 17% of heating energy. The average heating consumption of the building for this case would decrease form 40.97 to 35.81 kWh/m^2 and average percentage savings of heating energy would be **12.71%**.



Results and discussion - Case 2 - Change of the roof construction

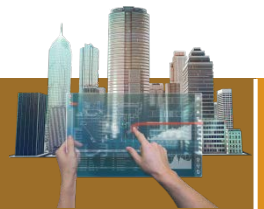
Change of the roof construction is reffered to the addition of the hydro insulation (**waterproofing (1.5 cm)**) and thermal insulation (**mineral wool (12 cm)**). By adding this layers the *U* - coefficient changed form value of 0.51 to 0.19 W/m^{2}K. The average percentage savings of heating energy for this case would be **9.35%**.



Results and discussion - Case 3 - Change of the ground floor and ceiling constructions

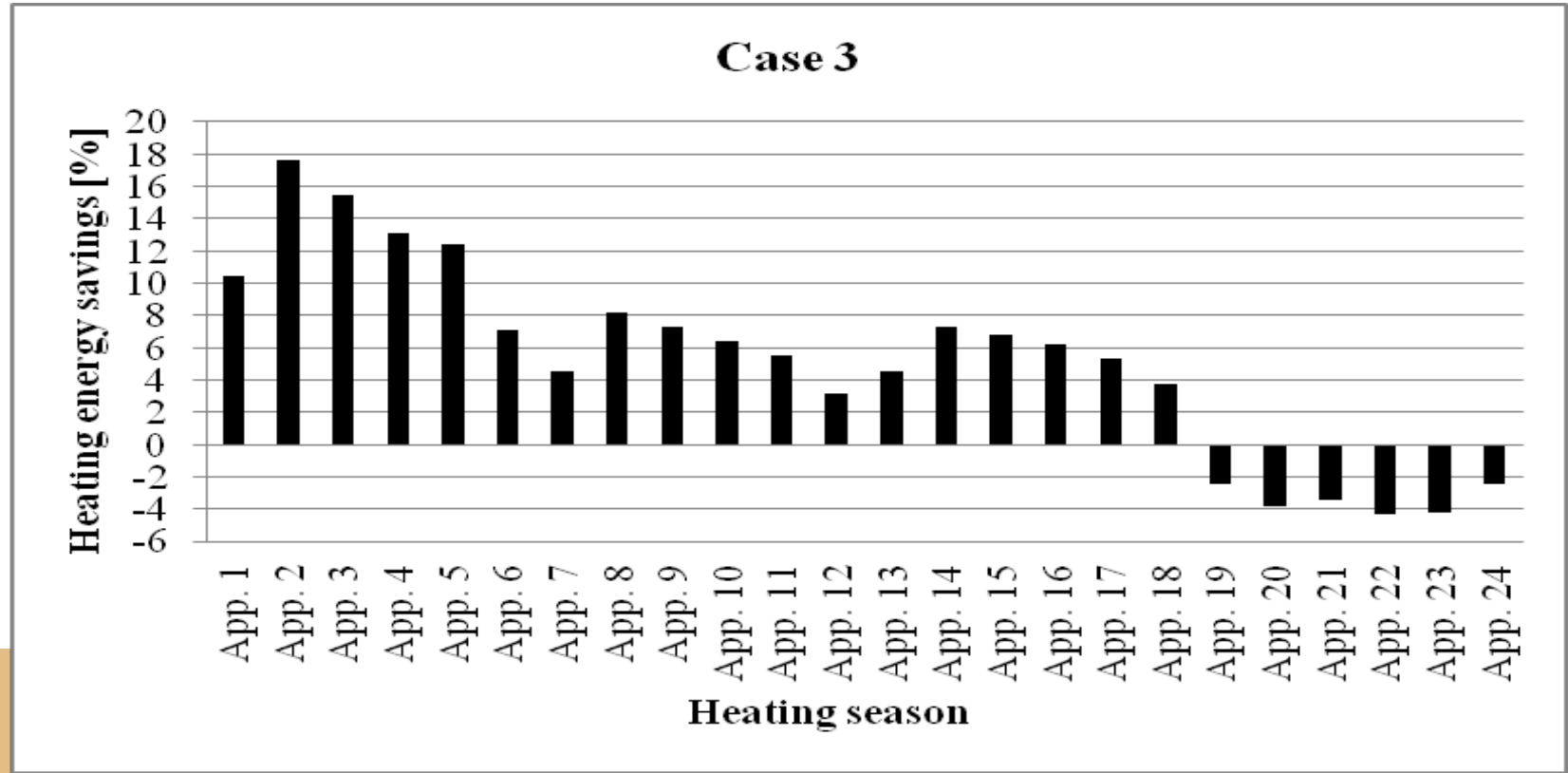
There are **two types** of floor and ceiling constructions. One includes **hardwood layer** and the other one **layer of tiles**. Hardwood is placed in hallways, living room and bedrooms while the layer of tiles is mounted in kitchens and bathrooms.

By adding the thermal insulation (**expanded polystyrene foam (8 cm)**) and hydro insulation (**waterproofing (1 cm)**) the *U*-coefficient change its value from 1.46 to 0.37 W/m^{2}K **for floor** with hardwood and 1.68 to 0.38 W/m^{2}K for floor with tiles. The **ceiling construction** is changed by adding the same insulation layers but with different thickness: **expanded polystyrene foam (3 cm)** and **waterproofing (1 cm)**. The value of *U*-coefficient drops from 1.77 to 0.71 W/m^{2}K for ceiling with hardwood and 2.06 to 0.76 for ceiling with tiles.



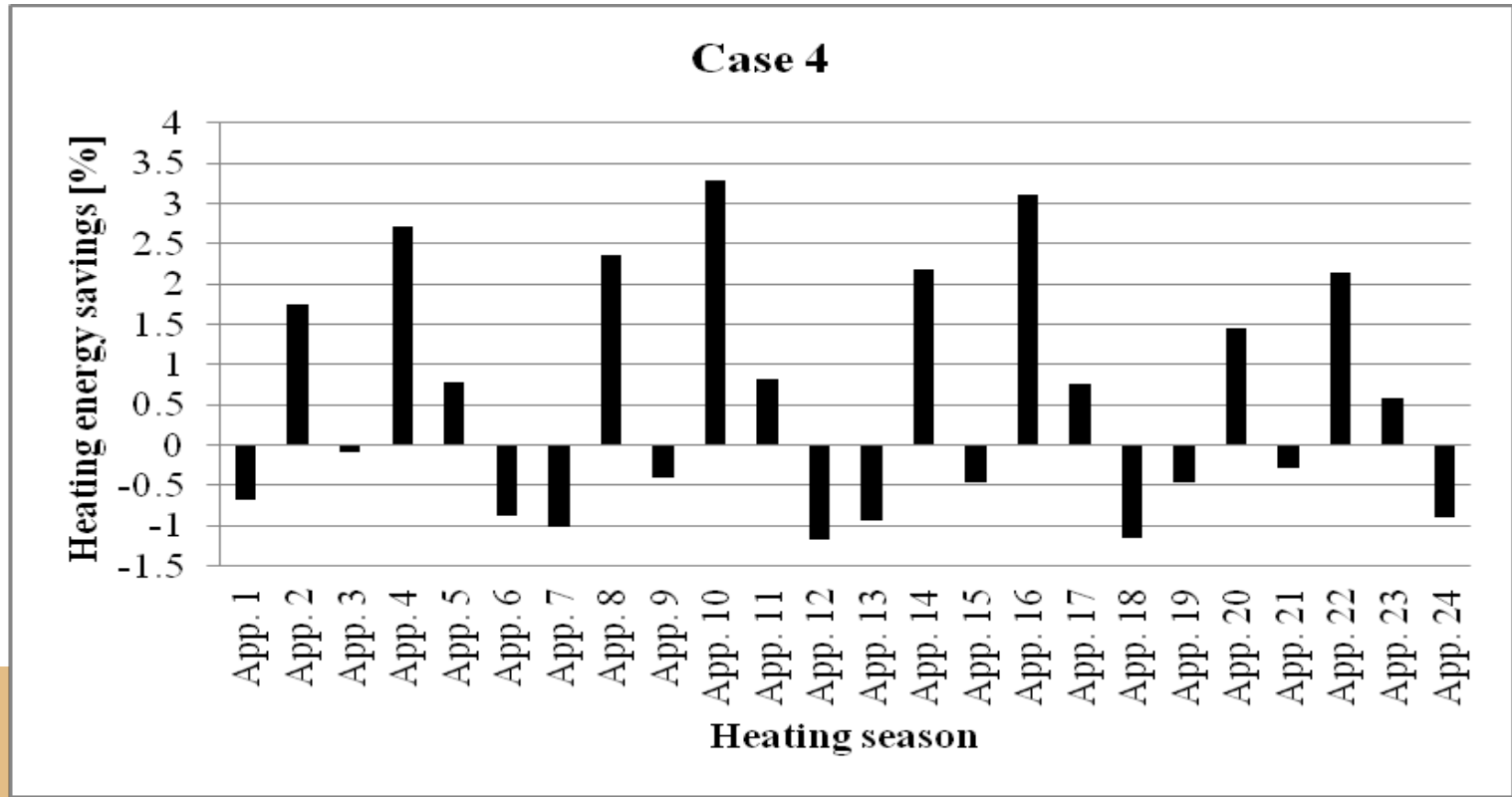
Results and discussion - Case 3 - Change of the ground floor and ceiling constructions

Because of the slower cooling of appartments on this level and lower heat transfer rate through the ceiling constructions the decrease of heating consumption would be achieved on the second and third level, too. On the other side, in appartments of the highest level the increase of heating consumption would occur (-3.42%), as a consequence of its position in the building (last level) and decrease of *U* - coefficient of ceiling construction. The average percentage savings of heating energy for this case and building would be **5.2%**.



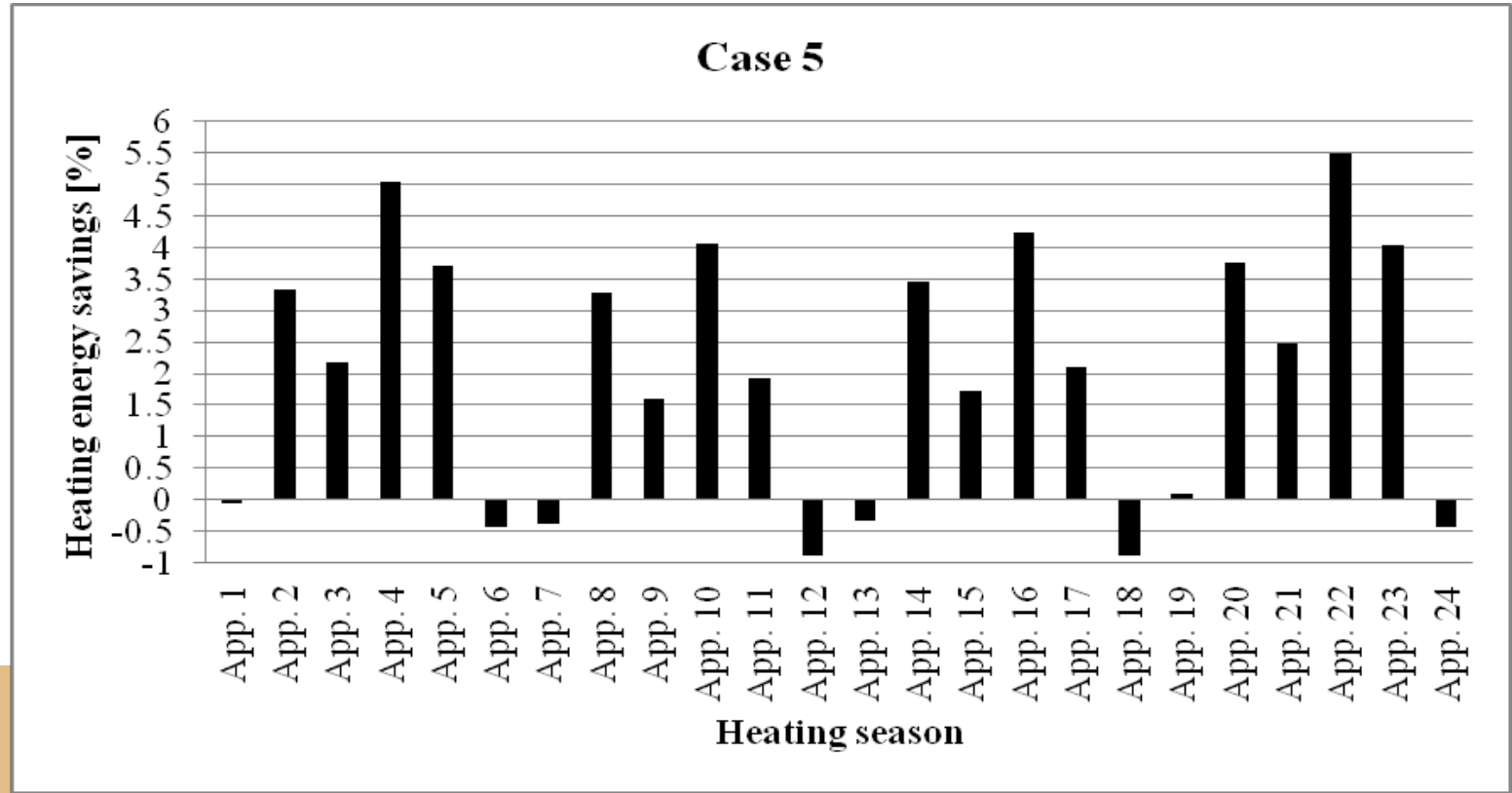
Results and discussion - Case 4 - Change of the interior walls between different users

The term interior wall between different users is reffered to all walls that separate two different users (tenants) or appartments. The *U* - coefficient for these walls is changed from value 2.17 to 0.81 by adding two layers of thermal insulation (**expanded polystyrene foam**) with thickness **of 1.5 cm**. Also, in this case it can be noticed that heating consumption in some appartments decrease and in some appartments increase. The average percentage savings of heating energy for this case 4 would be **0.56%**.



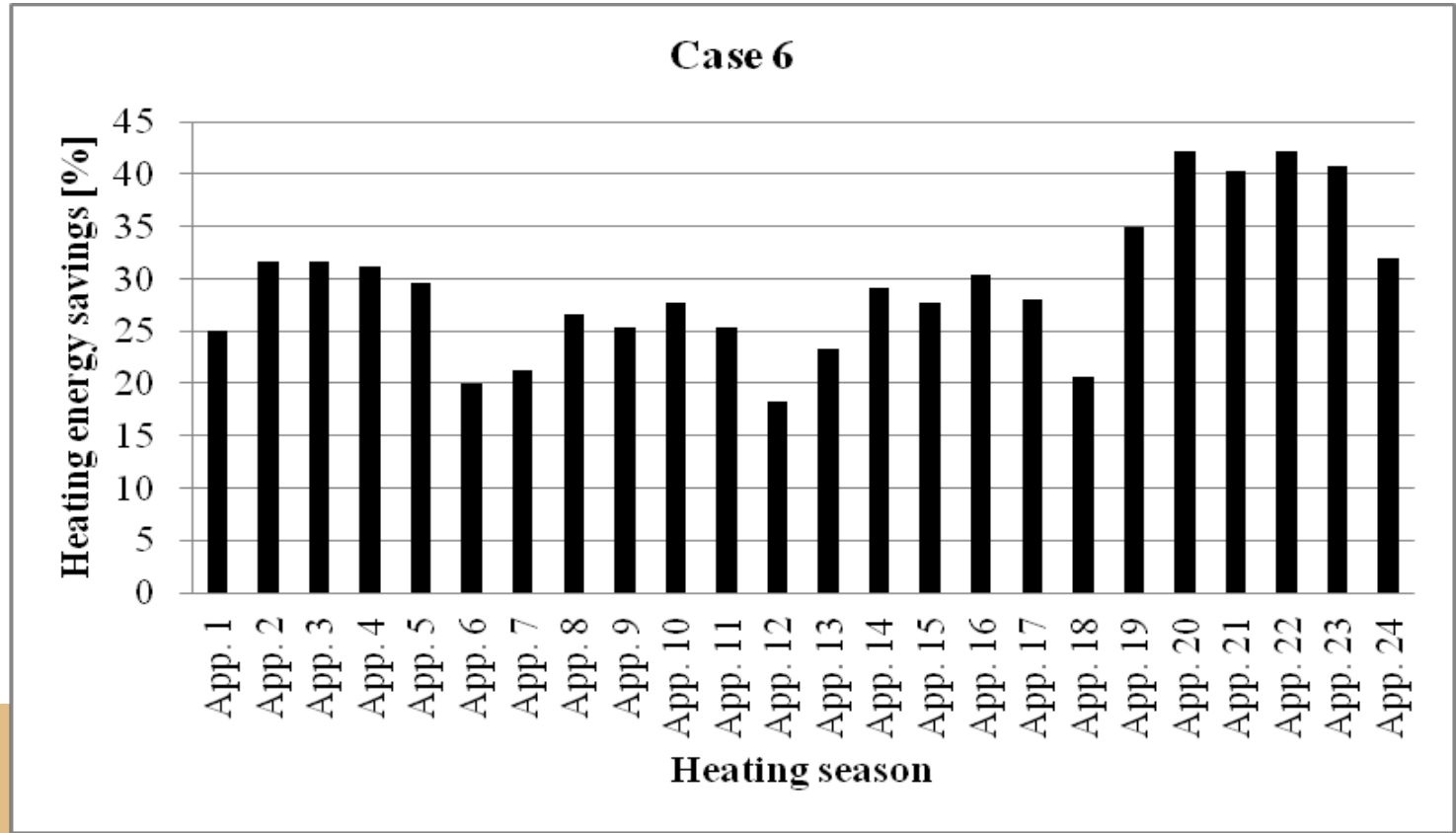
Results and discussion - Case 5 - Change of the interior walls toward unheated space

Unheated spaces of the analyzed building are related to the pantries (storage rooms) and building hallways. The Regulations on energy efficiency of buildings indicates that the maximum value of *U* - coefficient (for an existing building) has to be 0.55 W/m^{2}K. In order to achieve value of *U* - coefficient that is less than value of 0.55 W/m^{2}K the interior wall has to be insulated with **6 cm of expanded polystyrene foam**. The average percentage savings of heating energy for this case 5 would be **2.04%**.



Results and discussion - Case 6 - Implementation of all previously mentioned measures

Case 6 includes a situation when all building constructions would have a value of *U* - coefficient that meets the Regulations on energy efficiency of buildings. In other words, this case represents possible implementation of all previously mentioned measures. In relation to that, the average heating consumption of the building would be 28.67 kWh/m^2 and the average percentage savings of heating energy would be **29.37%**.



Conclusions

In this paper the analysis of implementation of different energy saving measures in an existing residential building was conducted. Six proposed measures was analyzed: replacement of windows and doors (case 1); change of the roof construction (case 2); change of the ground floor and ceiling constructions (case 3); change of the interior walls between different users (case 4); change of the interior walls toward unheated space (case 5) and implementation of all previously mentioned measures (case 6). The simulation results indicate that the average savings of heating energy of analyzed biulding are, respectively: **12.71% (case 1); 9.35% (case 2); 5.2% (case 3); 0.56% (case 4); 2.04% (case 5) and 29.37% (case 6)**. For reconstruction of all building constructions in order to achieve the value of U - coefficient that meets the Regulations on energy efficiency of buildings, a large investments are needed. In terms of investments **the best solution is related to the change of the roof construction**.

This paper is a part of investigation that is related to the analysis of heating consumption in heated apartments during the reduction of air temperature or unheating of adjacent apartments of an residential building.

THANK YOU FOR YOUR ATTENTION