Computational algorithm for estimation of heat energy saving in conventional and new designed flats

Aleksandar Dedinec[1], Aleksandra Kanevce[2]

[1]Research Center for Energy, Informatics and Material, Macedonian Academy of Sciences and Arts, Skopje, Macedonia

[2]Faculty of Computer Science and Engineering, University St. Cyril and Methodius, Skopje, Macedonia

Abstract

This study investigates whether it should be allowed in a building designed and connected to usedistrict heating, certain apartments to quit the service without payment of the fee that would cover the loss of heat energy. In order to answer this question a mathematical model is developed in this paper and a numerical solution is implemented in MATLAB. Four different cases are analyzed which includebuildings constructed more than fifteen years ago and buildings constructed following the latest European directives, and additionally we analyze whether the neighboring apartments use or don't use district heating. The results show thatup to 74% of the heat transfer is through the neighboring apartments.

Furthermore, the results show the difference in the prices of using electricity for heating and the district heating (Toplifikacija-Skopje). In all four cases the price of electricity is higher for about 24% than the price of district heating.

Keywords: heating energy, energy savings, insulation

1. INTRODUCTION

Energy is a fundamental part of modern life.Starting from the lights that illuminate our homes to the engines that drive our cars, everything that we consider to be necessary in order to have a better life depends on energy.From the other hand the energy demand is continually growing. The two main reasons for this is the introduction of more and more devices that use electricity and the population growth [1]. This leads to higher waste of resource and higher greenhouse emissions. Therefore, one of the main goals of the energy policies is to reduce the usage of energy.

In Macedonia, the domestic energy consumption makes up to 30% of the total final energy and 48% of the total electric energy consumption in 2010 [2]. A special case of domestic electricity consumption is the electricity used for heating. The energy consumed for heating of a specific object depends on few factors, among which is the insulation of the object. Lately, more importance was given to this factor because they impose certain standards that must be met for energy efficiency. On the other hand we are witnessing a growing initiative for isolation of existing facilities. Furthermore,in Macedonia, a program and action plan for energy efficiency were adopted, as well as a program for energy efficiency in public buildings [3], [4] and [5]. All these actions motivate citizens to begin isolating their existing facilities, and buying new oneswith built-in insulation.

Similarly, this motivates researcher to explore different aspects of heat energy savings. In [6] energy savings of a conventional Spanish house are examined using simple passive strategies. The thermal performance and embodied energy analysis of a passive vault roof mud-house in India is explored in [7]. The study in [1] seeks for the economically most profitable combination of insulation for a Flemish citizen. Electrical savings by use of wood pallet stoves and solar heating systems in electrically heated single-family houses is researched in [8].

In this paper, we analyze two cases: buildings constructed more than fifteen years ago and buildings constructed following the latest European directives. Moreover, we analyze the impact of the cancellation of certain flat from the district heating depending on the type of building insulations. In fact, we examine to what extent the one who uses the district heating pays for the losses to the neighboring apartments. In such cases, techno-economic analysis of the impact of additional insulation is performed and the difference between the cost of heating using district heating and electricity.

This paper is organized as follows. Section 2 describes the mathematical model and Section 3 the numerical solution. Different case studies are presented in Section 4. In Section 5 the obtained results are shown and analyzed. Section 6 concludes the paper.

2. MATHEMATICAL MODEL

In this paper, a mathematical model is used for calculation of the heat transfer rate in a certain object under different types of insulation.

For each type of material *i* the heat resistance can be calculated according to the following equation:

$$R_i[\frac{1}{W/m^2K}] = \frac{\delta_i[m]}{\lambda_i[W/mK]}$$

where δ_i represents the thickness of the material *i* and λ_i represents the heat transmission coefficient, which has characteristic value for each type of material.

Because the walls of an object consist of more types of materials the total heat resistance should be calculated using the sum of the separate resistances for each material. The overall equation for the total heat resistance is defined by the following equation:

$$R[\frac{1}{W/m^2K}] = \frac{1}{\alpha_1[W/m^2K]} + \frac{1}{\alpha_2[W/m^2K]} + \sum R_i\,[\frac{1}{W/m^2K}]$$

where $\alpha_1[W/m^2K]$ and $\alpha_2[W/m^2K]$ represent the heat transfer coefficient. α_1 refers to the external side of the object and α_2 refers to the internal side of the object. This coefficient is a quantitative characteristic of convective heat transfer between a fluid medium (a fluid) and the surface (wall) flowed over by the fluid [9].

The heat transmission coefficient U for a certain material is calculated according to:

$$U[W/m^2K] = \frac{1}{R_i[W/m^2K]}$$

The thermal conductivity*k* for more than one type of material is defined by:

$$k[W/m^2K] = \frac{1}{R[\frac{1}{W/m^2K}]}$$

Using the heat transmission coefficient *k*, the heat flux*q* can be calculated according to the following equation:

$$q[W/m^2] = k[W/m^2K] * (T_{inside}[K] - T_{outside}[lK])$$

where T_{inside} is the temperature inside of an object and $T_{outside}$ is the temperature outside of the object.

The total heat transfer rate is then calculated by the equation:

$$Q[kW] = q[kW/m^2] * A[m] * B[m]$$

where $A[m]$ and $B[m]$ are the width and length of the analyzed surface.

The final useful energy consumption for an average month can be calculated by multiplying the heat transfer rate by the average number of hours in a month, which is presented by the following equation:

$$E[kWh] = Q[kW] * 30 * 24[h]$$

2.1 Heat energy cost using district heating

Because one of the goals of this paper is to analyze the heat energy consumption in building that use district heating, in this section the calculation of the cost of the heat energy is presented.

The total cost of the heat energy distributed by Toplifikacija AD Skopje, Macedonia is calculated by the equation:

$$cost[den] = \left(F\left[\frac{den}{kW}\right] * C1[kW] * U * \frac{MD[days]}{HP[days]} + P\left[\frac{den}{kWh}\right] * E[kWh]\right) * VAT$$

whereF=665.2 [den/kW] is a fix cost,C1=41 [kW] is engaged power,Uc= 8.589 [%] is participation in fix costs, P=3.3755 is theprice of heat energy per kWh [den/kWh], E[kWh] isenergy consumption,HP[days] is heating period, MD[days] represents days in a month and VAT =18 [%] is the value added tax. The heating season starts on 15th of October and ends on 16th of April or the heating period lastsfor 184 days.

2.2 Heat energy cost usingelectricity

The comparison between the prices of heating an object using district heating and electricity in Macedonia is also examined in this paper. The cost for the heat energy using electricity is calculated by:

$$cost = P * E * C * VAT$$

whereP=3.35[den/kWh] is the medium tariff, E[kWh] isenergy consumption and C=33 [%] is the engaged power and VAT =18 [%] is the value added tax.

3. NUMERICAL SOLUTION

The numerical solution of the mathematical model is implemented in MATLAB. We have developed a graphical user interface application by which we can easily calculate different case studies. Figure1presents the layout of the program.

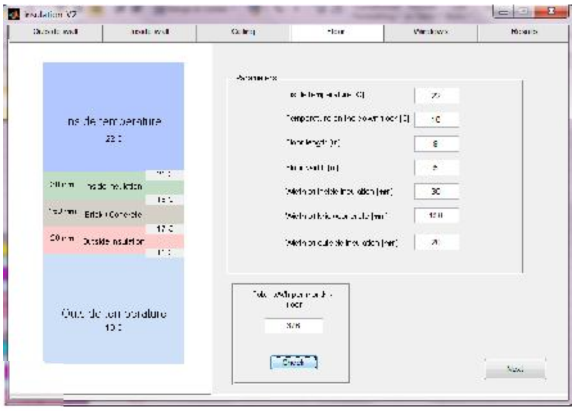

Figure1. Graphical user interface of the application for heating energy savings

4. CASE STUDIES

We have considered an ordinary isolated building with five floors, each consisting of two flats. The analyzed flat is 55m^2, and is located on the third floor. This means that it has three neighboring flats: one on the same floor, one on the upper floor and one on the lower floor.

Using these characteristics of the flat, we have analyzed the total heat transfer rate for four specific cases. The first two cases refer to newly constructed buildings that follow the latest European directives. The parameters concerning these two cases are presented in Table1. Parameters for newly constructed flat. The third and the fourth case refer to an older building, constructed more than fifteen years ago, having insulation with parameters shown in Table2.

Table1. Parameters for newly constructed flat

	Outside wall	Inside wall	Ceiling	Floor	Windows
Area [m^2]	55	32	55	55	8,1
Brick/concrete [mm]	200	250	150	150	
Inside isolation [mm]	0	0	20	30	
Outside isolation [mm]	50	0	30	20	

Table2. Parameters for older flat

	Outside wall	Inside wall	Ceiling	Floor	Windows
Area [m^2]	55	32	55	55	8,1
Brick/concrete [mm]	250	250	150	150	
Inside isolation [mm]	0	0	20	30	
Outside isolation [mm]	0	0	30	20	

The first analyzed case assumes that the neighboring flats are not used, i.e. they are excluded from the district heating. The second case considers that no unique flat can be excluded from the district heating, so all neighboring flats have approximately the same temperature as the analyzed one. The third and the forth case refer to the same situations, but considering an older flat. These four cases are summarized inTable3.

Table3. Four case studies analyzed in the paper

	new/old flat	neighbours connected to DH
Case 1	new	no
Case 2	new	yes
Case 3	old	no
Case 4	old	yes

In the simulations the average inside temperature is 22^0C, and the average outside temperature in the heating season in Macedonia is 5.19^0C [10].

The windows used in the new flats are PVC with double insulated glazing with filling from Argon and one selective layer. Average U value of these type of windows is 1.4 W/m^{2}K [11], and in the older flats coupled wood windows are used, with U value of 2.35 W/m^{2}K[11].

The values for the heat transfer coefficients $\alpha_1$and α_2 are 15 W/m^2K and 50 W/m^2Krespectively [12]. The values for the heat transmission coefficient λ_i, for each type of material are given in Table4.

Table4. Values for the heat transmission coefficient λ

material	λ
wood	0,1
brick	0,8
concrite	1,5
polystyrene	0,04

5. RESULTS

The results show the total useful energy per month needed to heat the objects in the four analyzed cases (Figure2). It is obvious that the useful energy spent in an older flat is up to 242% more than in a new flat. An interesting result is the difference between useful energy used in the cases when the neighboring flats use district heating (Case 2 and Case 4) and when there is no heating in the neighboring flats (Case 1 and Case 3). For new buildings, there is about 280% more energy spent if the neighbors do not use heating. The difference is smaller for the case of an older flat, and is about 83%.

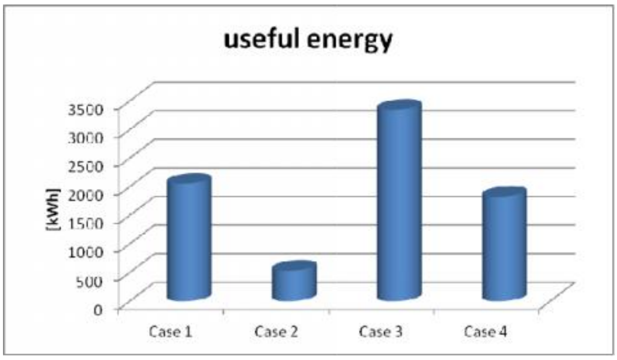

Figure2. Total useful energy per month for each analyzed case

Figure3 illustrates the heat transfer rate for each part of the analyzed flat (floor, ceiling, inside wall, outside wall and windows) for the first case, i.e. newly constructed building and no heating in the neighboring flats. It can be noticed that the biggest part of the heat energy is transferred through the inside wall - 31%, floor – 22% and ceiling - 21%. This is because the neighbors don't use heating and although they maybe don't live there, heat energy is transferred in their flats. It is obvious in Figure4 that if the neighbors use district heating the three parts in which most of the heat energy was transferred are now minimized to nearly 0%.

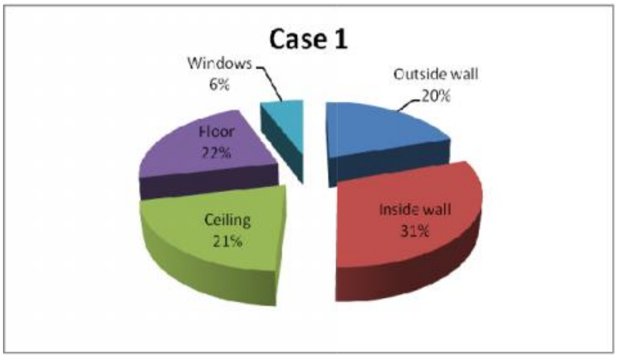

Figure3. Heat transfer rate for each part of the analyzed flat for Case 1

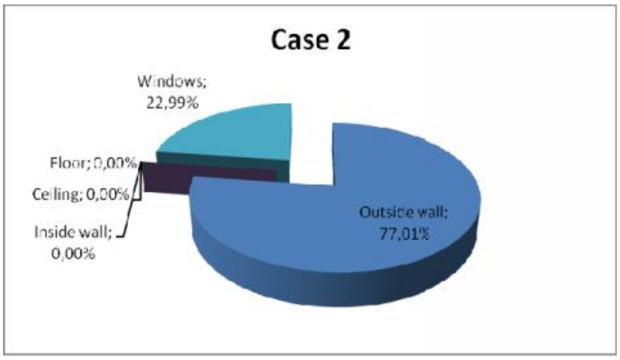

Figure4. Heat transfer rate for each part of the analyzed flat for Case 2

If we analyze an older flat and the neighbors don't use heating, the situation is a little bit different (Figure5). Most of the heat energy is transferred through the outside wall – 43%, followed by inside wall – 19%, floor – 14% and ceiling 13%. The reason for this is that there is no insulation on the outside wall and outside temperature is lower than in the neighboring flats, which, in turn is a result of the heat transfer through the inside wall.

In the fourth case (Figure6) – an old building and the neighbors use district heating, almost the whole heat energy is transferred through the outside wall – 90%, and the rest is transferred through the windows – 10%.

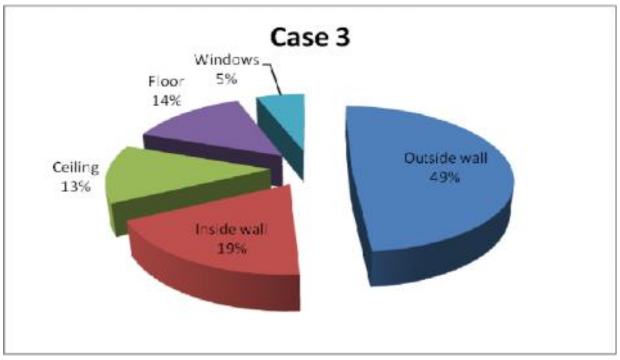

Figure5. Heat transfer rate for each part of the analyzed flat for Case 3

Figure7 depicts the difference in the prices per year that the owner of the flat pays in the four analyzed cases between district heating (AD Toplifikacija-Skopje) and heating using electricity. It is clear that the smallest price is paid in the case of a new flat with corresponding insulation and new windows and that the neighbors use district heating too. Another conclusion is that the owner pays smaller amount of money if district heating is used than if electricity for heating is used. In all four cases the price of electricity is higher for about 24% than the price of district heating.

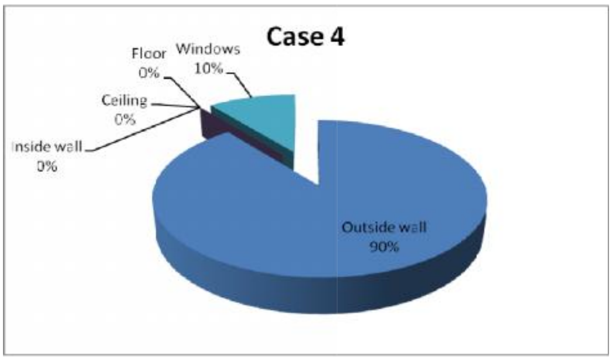

Figure6. Heat transfer rate for each part of the analyzed flat for Case 4

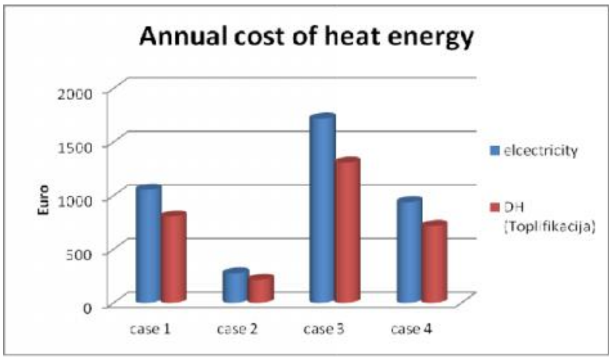

Figure7. Annual cost of heat energy in the four analyzed cases

6. CONCLUSION

The conclusion of this paper is that for maximizing the heat energy savings it should not be allowed individual apartment to cancel the central heating in a building which is designed and connected to district heating. However, even if it is allowed particular apartment to be excluded from the district heating, the owner should pay fee which corresponds to the loss of heat energy through the neighboring apartments.

Another measure for heat energy savings is insulation of the old buildings and replacement of the old windows with new ones. Additionally, analyzes showed that it is not useful and profitable to replace the district heating with heating that uses electricity in Skopje, Macedonia.

REFERENCES

[1] Audenaert, A., Boeck, LD. and Roelants, K. "*Economic analysis of the profitability of energy-saving architectural measures for the achievement of the EPB-standard*", Energy, Vol. 35, pp 2965-2971, 2010.

[2] State Statistical Office Republic of Macedonia. "*Energy balances, 2010*", No. 6.1.11.93, November 2011.

[3] Ministry of Economy, Republic of Macedonia.*"Strategy for Improvement of the Energy Efficiency in the Republic of Macedonia until 2020"*,Official Gazette no. 63/2006, 36/2007 and 106/2008, Skopje, September 2010.

[4] Ministry of Economy, Republic of Macedonia. *"First Energy Efficiency Action Plan of the Republic of Macedonia by 2018"*, adopted: April 2011, [Online]: http://www.ea.gov.mk/projects/unece/docs/legislation/First_EEAP_Macedonia_EN.pdf

[5] Национална програма за енергетска ефикасност во јавните згради во Република Македонија 2012-2018, Прелиминарна нацрт програма, *ТИМЕЛ, ENSI, E3 International*, 2011, [Online]: http://economy.gov.mk/ministerstvo/sektori_vo_ministerstvo/sektor_za_energetika/3093.html

[6] Ruiz, MC. and Romero, E. "*Energy savings in the conventional design of a Spanish house using thermal simulation*", Energy and Buildings, Vol. 43, pp 3226-3235, 2011.

[7] Chel, A. and Tiwari, GN. "*Thermal pperformance and embodied energy analysis of a passive house – Case study of vault roof mud-house in India*", Applied Energy, Vol. 86, pp 1956-1969, 2009.

[8] Person, T., Nordlander, S. and Ronnelid, M. "*Electrical savings by use of wood pellet stoves and solar heating systems in electrically heated single-family house*", Energy and Buildings, Vol. 37, pp 920-929, 2005.

[9] Thermopedia. "*Heat transfer coefficient"*, February 2011, [Online]: http://www.thermopedia.com/content/841/.

[10] AD Toplifikacija- Skopje. *"Annual report 2009"*, [Online]: http://www.toplif.com.mk/Tekstovi/AR2009.pdf

[11] UNDP. *"Energy Efficiency in Public Buildings in Macedonia – Feasibility Study"*, August 2011, [Online]: http://europeandcis.undp.org/uploads/public1/files/UNDP%20FYROM%20Feasibility%20Study%20-%20Kalinka%2017%2008.pdf

[12] Kasebalfa, K., El-Hariry, G. *"Electronics Cooling - Part A: Introduction to Electronics Cooling"*, [Online]: http://www.pathways.cu.edu.eg/ec/Text-PDF/Part%20A-3.pdf