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CALCULATING THE THERMAL EFFICIENCY OF A HOTEL UNIT IN THE BRASOV AREA

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Abstract: *The paper analyzes energy efficiency at a hotel unit in the Brasov area. For this analysis a hotel unit with a capacity of 15 rooms in which 35 people can be accommodated was chosen. This hotel unit has a ground floor, two floors and an attic and is located in the Brasov area. In this energy analysis, heat losses through the thermal bridges related to the building elements the construction were determined, such as exterior walls, windows, flooring, roof over the attic. Also, energy consumption per square meter of useful area was directly and indirectly heated yearly compared to a reference building.*

Key words: *Hotel unit, heat loss, energy efficiency.*

1. Introduction

Energy efficiency means increasing the hotel's energy performance to the current requirements, normalized by applying heat insulating materials to the exterior walls, the floor above the ground and on the terraces, as well as by upgrading heating and hot water heating, replacing windows and doors with other more energy efficient

Energy modernization measures aim at improving the thermal comfort and reducing the energy consumption of the building. Improving the thermal comfort by energy efficiency at hotel units implies reducing the performance criteria associated with this requirement, at least with normative values. The main performance criteria that define the thermal behavior in operation are:

Thermal comfort: ambient temperature during winter and summer, speed of room airflow, Relative air humidity.

Air aggressiveness, the oscillation amplitude of indoor air temperature and radiant temperatures in the vertical and horizontal plane; The difference between the indoor air temperature and the internal surface temperature of the element delimiting the rooms; The risk of condensation on the surface and structure of the building envelope elements, values given in the design rules.

Economy: reduction of operating expenses; Heat losses through heat transmission and air exchange, reflected in the global thermal insulation coefficient

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or in specific or annual energy consumption; Energy consumption for cooling during the hot season of the year.

Environment protection: Energy consumption, therefore burning of fossil fuels is accompanied by the emission of harmful gases in the form of oxides of carbon, sulphate and nitrogen, powders and unburned hydrocarbons;

Reducing energy consumption in the buildings sector will allow for a reduction in emissions of harmful gases.

2. Material and Methods

In this paper we determine the consumption of energy per square meter of useful area heated directly and indirectly per year compared to a reference building. The analyzed hotel unit has 15 rooms in which 30 people are accommodated; the location is in the Brasov area. This hotel unit has ground floor height, 2 floors and attic. Built surface of the building: 175.59 mp, built volume 1252.83 mp, Useful area 390.31mp.

The average thermal resistance corrected on the building envelope. R_M^1 [m²k/w].

$$R_{M,}^1 = \frac{\sum A_{mj}}{\sum \frac{A_{mj} \times \tau_{mj}}{R_{mj}}}; \quad [m^2k/w]. \tag{1}$$

where:

A_{mj} is the area of the building envelope;

τ_{mj} - factor of external temperature correction;

R_{mj} - average thermal resistance on the whole building.

Table 1 presents the thermal resistances by type of elements of the analyzed building.

Table 1

The thermal resistances by type of elements of the analyzed building

Elements	Area of the building [m^2]	Thermal resistance [m²k/w]	Factor
Exterior walls:	$P_E = 340$	$R_{p,E}^1 = 0{,}580$	$\tau_{PE} = 1{,}00$
Plan over the attic:	$P_{P,P} = 142{,}59$	$R_{p,p}^1 = 0{,}522$	$\tau_{PP} = 0{,}90$
Floor on the ground:	$P_{P,S} = 142{,}59$	$R_{p,S}^1 = 2{,}02$	$\tau_{PS} = 0{,}50$
Glazed areas:	$P_V = 73{,}38$	$R_V^1 = 0{,}430$	$\tau_{PV} = 1{,}00$

$$R_M^1 = \frac{340 + 142{,}59 + 142{,}59 + 73{,}38}{\frac{340}{0{,}580}\times 1{,}00 + \frac{142{,}59}{0{,}522}\times 0{,}9 + \frac{142{,}59}{2{,}02}\times 0{,}5 + \frac{73{,}38}{0{,}43}\times 1{,}00} = 0{,}672\, m^2K/W$$

The global heat loss coefficient G_{ef}:

$$G_{ef} = G_{1ef} + G_{2ef} \quad [W/m^3K] \qquad (2)$$

where:

G_{1ef} is the overall coefficient of thermal isolation;

G_{2ef} - correction coefficient.

Estimated heat consumption for heating $Q_{înc}^{year}$:

$$Q_{înc}^{year} = \frac{24}{1000} \times G_{ef} \times C_{ef} \times N_{12}^{\theta i} - (Q_1 + Q_s) \qquad (3)$$

where:

G_{ef} is the global heat loss coefficient;

C_{ef} - correction coefficient;

$N_{12}^{\theta i}$ - the annual number of calculation days corresponding to the place where the building is located;

$N_{12}^{\theta i}$ = 4030 k days according to C107/2005;

Q_1 - the useful heat input from the building;

Q_s- the useful heat input from solar radiation.

Calculation values:

$G_{ef} = 1{,}479$ [W/m^{3}K];

$V_{înc}$ = 1126,46 m^3;

$A_{uînc} = 390{,}31$ m^2;

$C_{ef} = 0{,}942$ - thermal power station without thermostat.

$$Q_s = 0{,}40 \times \sum I_{Gj} \times g_i \times \frac{A_{Fij}}{V} \qquad (4)$$

where:

$\sum I_{Gj}$ is global solar radiation according to the cardinal orientation;

g_i – the degree of penetration of energy through the windows of the exterior carpentry;

A_{Fij} - the area of the exterior carpentry with clear windows and arranged according to the cardinal orientation;

V - the indoor or indoor heated room volume of the hotel unit;

$I_{Gs} = 420$ KWh/m^{2}year;

$A_{FS} = 4{,}32 m^2$;

$I_{GN} = 100$ KWh/m^{2}year;

$A_{FN} = 19{,}68 m^2$;

$I_{GE} = 210$ KWh/m^{2}year;

$A_{Fs} = 4{,}32 m^2$;

$I_{GV} = 210$ KWh/m^{2}year;

$A_{FV} = 32{,}82 m^2$;

$g_i = 0{,}75$ thermal insulating glass.

$$Q_s = 0{,}40 \times [\frac{420 \times 0{,}75 \times 4{,}32 + 100 \times 0{,}75 \times 19{,}68 + 210 \times 0{,}75 \times (19{,}56 + 32{,}82)}{1126{,}46}] = 3{,}93 \left[kWh/m^2 \, year\right]$$

$$Q_{\hat{i}nc}^{year} = \frac{24}{1000} \times G_{ef} \times C_{ef} \times N_{12}^{\theta i} - (Q_1 + Q_s) \text{ [KWh/ m}^3\text{ year]}$$
$$Q_{\hat{i}nc}^{year} = \frac{24}{1000} \times G_{ef} \times C_{ef} \times N_{12}^{\theta i} - (Q_1 + Q_s) \text{ [KWh/m}^3\text{year]} \quad (5)$$

$$q_{\hat{i}nc}^{year} = \frac{Q_{\hat{i}nc}^{year} \times V_{\hat{I}nc}}{A_{u\hat{I}nc}} \text{ [KWh/ m}^2\text{ year]} \quad (6)$$

where:

$V_{\hat{I}nc}$ is the heated volume of the hotel unit analyzed;

$A_{u\hat{I}nc}$ – the useful area of the hotel unit;

$$q_{\hat{I}nc}^{year} = \frac{123{,}53 \times 1126{,}46}{390{,}31} = 356{,}51 \text{ [KWh/m}^3\text{year]}$$

Energy consumption for heating $q_{E\hat{I}nc}^{year}$

The hotel unit is equipped with central heating with its own AMIC 2 boiler with efficiency η =0,82;

$$q_{E\hat{I}nc}^{an} = \frac{q_{\hat{I}nc}^{an}}{\eta} \text{ [KWh/m}^2\text{year]}$$
$$q_{E\hat{I}nc}^{an} = \frac{356{,}51}{0{,}82} = 434{,}77 \text{ KWh/m}^2\text{year]} \quad (7)$$

According to Methodology Mc 001 / 3-2006 for $q_{E\hat{I}nc}^{year}$ = 434,77 KWh/m^{2}year the building falls under F with the limits 343 - 500 KWh/m^{2}year.

Energy consumption for heating:

For methane gas with Pe = 10 KWh/m^{2}year, it results:

$$Q_{comb.} = \frac{q_{E\hat{I}nc}^{an} \times A_{uinc}}{P_e} \; [m^3 / year]$$
$$Q_{comb.} = \frac{434{,}77 \times 390{,}31}{10} = 16969 \text{ m}^3\text{/year} \quad (8)$$

Emissions of CO2 Ico2 Kg/m^2 year

ICO2=0,19 Kg CO_2/KWh

ICO2=0,19x434,77=82,60 Kg/m^{2}year

Diagnosis of the building

Characteristics of the reference building Consists in comparing the analyzed hotel unit energy analyzed with a reference building.

The reference building has: the same geometric features as the hotel unit analyzed energetically: - corrected thermal resistances are those normalized in Mc 001/1-2006; - the number of air shifts is n=0,5 h^{-1}; - heating system: the existing central equipped with a thermostatic control system and yield η = 0.82; n = 0,5 h^{-1}; $A_{uînc}$ = 390.31 m^2; A_{anv} = 844.15 m^2; $V_{înc}$ = 1126.46 m^3; g_i = 0.75.;

Table 2 shows the thermal resistances of the reference building.

Calculation of the thermal building performance of the reference building.

Corrected thermal resistance of the building envelope $R_M^{1(R)}$:

$$R_M^{1(R)} = \frac{\sum A_{mj}}{\sum \frac{A_{mj} \quad \tau_{mj}}{R_{mj}^{1}}} \; [m^2K/W] \quad (9)$$

where:

A_{mj} ie the area of the building envelope;

τ_{mj} - factor of external temperature correction;

R_{mj} - average thermal resistance on the whole building.

Table 2

The thermal resistances of the reference building

Elements	Area of the building [m^2]	Thermal resistance [m^{2}K/W]	Factor
Exterior walls:	$P_E = 340$	$R_{p,E}^{1(R)} = 1{,}40$	$\tau_{PE} = 1{,}00$
Plan over the attic:	$P_{P,P} = 142{,}59$	$R_{p,P}^{1(R)} = 3{,}00$	$\tau_{PP} = 0{,}90$
Floor on the ground:	$P_{P,S} = 142{,}59$	$R_{p,S}^{1(R)} = 3{,}00$	$\tau_{PS} = 0{,}50$
Glazed areas:	$P_V = 73{,}38$	$R_{p,V}^{1(R)} = 0{,}40$	$\tau_{PV} = 1{,}00$

$$R_M^{1(R)} = \frac{844{,}15}{\frac{340}{1{,}40} \times 1{,}00 + \frac{142{,}59}{3{,}00} \times 0{,}9 + \frac{142{,}59}{3{,}00} \times 0{,}5 + \frac{76{,}38}{0{,}40} \times 1{,}00} = 1{,}687 \; [m^2K/W]$$

The global heat loss coefficient G_{ef}^{R} [m^2K/W]:

$$G_{ef}^{R} = \frac{A}{R_M^{1(R)} \times V_{înc}} + 0{,}34 \times n = \frac{844{,}15}{1{,}687 \times 1126{,}46} + 0{,}34 \times 0{,}5 = 0{,}61 \; [W/m^3K]$$

Annual heat consumption needed to heat the reference building $Q_{înc}^{an(R)}$:

$$Q_{înc}^{year(R)} = \frac{24}{1000} \times G_{ef} \times C_{ef} \times N_{12}^{\theta i} - (Q_{i}^{(R)} + Q_{S}^{(R)}) \quad [\text{KWh/ m}^3 \text{ year}] \qquad (10)$$

characteristic values:

$G_{ef}^{R} = 0{,}61$ [W/m^{3}K];

$V_{înc}$ = 1126,46 m^3;

$N_{12}^{\theta i} = 4030$ k days;

C_{ef} = 0,878;

$Q_{i}^{R} = 7$ [kW/m^3 *year*];

$Q_{s}^{R} = 3{,}93$ KW/m^{3}year.

$$Q_{înc}^{year(R)} = \frac{24}{1000} \times 0{,}61 \times 0{,}878 \times 4030 - (7 + 3{,}93) = 40{,}02 \ [\text{kWh/m}^3 \text{ year}]$$

$$q_{înc}^{year(R)} = \frac{Q_{înc}^{year} \times V_{înc}}{A_{uînc}} = \frac{40{,}02 \times 1126{,}46}{390{,}31} = 115{,}50 \quad [\text{KWh/ m}^3 \text{ year}] \qquad (11)$$

The global heat loss coefficient G_{ef}^{R} [W/m^{3}K]:

$$G_{ef}^{R} = \frac{A}{R_{M}^{1(R)} \times V_{înc}} + 0{,}34 \times n$$

$$G_{ef}^{R} = \frac{844{,}15}{1{,}68 \times 1126} + 0{,}34 \times 0{,}5 = 0{,}61 \quad [\text{W/m}^3\text{K}] \qquad (12)$$

Energy consumption for heating: for yield η = 0.82.

$$Q_{E,inc}^{year(R)} = \frac{Q_{înc}^{year(R)}}{\eta} \text{ [KWh/m}^3\text{year]} \quad (11) \qquad Q_{E,inc}^{year(R)} = \frac{40{,}02}{0{,}82} = 48{,}80 \quad \text{[KWh/m}^3\text{year]}$$

$$q_{E,inc}^{year(R)} = \frac{q_{înc}^{year(R)}}{\eta} \text{ [KWh/m}^3\text{year]} \quad (12)$$

$$q_{E,inc}^{year(R)} = \frac{115{,}50}{0{,}82} = 140{,}85 \text{ [KWh/m}^3\text{year]}$$

The necessary fuel for heating the building reference.

$$Q_{comb}^{year(R)} = \frac{Q_{Einc}^{an(R)} \times V_{inc}}{P_{Ecomb}} \quad \text{[m}^3\text{N/year]} \tag{13}$$

$$Q_{comb}^{year(R)} = \frac{48{,}8 \times 1126{,}4}{10} = 5496{,}8 \quad \text{[m}^3\text{N/year]}$$

Emission of pollutants

When burning one cubic meter of methane gas 1,9Kg CO_2/year is removed:

$$Q_{CO2} = 5496{,}8 \times 1{,}9 = 10443 \text{ KgCO}_2\text{/year}$$

Average emission index CO2 reported to:

$A_{uînc}$, $A_{uînc}$ = 390,31 m^2;
I_{co2}=10443:390,31=26,75 KgCO_2/m^{2}year

Fit reference consumption in the rating grid:

$$q_{E,inc}^{an(R)} = 140{,}85 \text{ KWh/m}^3 \text{ year}$$

In Table 3 the comparative data in the analyzed hotel unit and a reference building that has the same dimensions as the analyzed building but has other thermal resistances of its constituent are presented.

The reference building according to the data from the calculations has a lower degree of loss of cloud compared to the analyzed building.

Table 3

The comparative data in the analyzed hotel unit and a reference building that has the same dimensions as the analyzed building

Buildings analyzed	R_M^1 [m^{2}K/W]	G_{ef} [W/m^3]	$q_{înc}^{year}$	$q_{Eînc}^{year}$	Grid framing	I_{CO2} [kg/m^{2}year]
The analyzed hotel	0,678	1,479	356,51	434,7	F	82,60
Reference building	1,68	0,61	115,50	140,8	C	26,75

3. Conclusions

As a result of the analysis at the hotel unit, it was found that it recorded large losses regarding energy consumption through its building elements that make up the construction. The hotel unit analyzed is in the F grid at the energy consumption required for heating, according to the Mc 006/2006 methodology. Energy efficiency can reduce energy consumption and hence reduce heat loss through building elements of the construction. Energy efficiency is important in the context of reducing greenhouse gas emissions and global warming. At the hotel units in the Brasov area due to the climatic conditions we have a large number of days a year in which we have to warm the hotel unit so the heating costs per year are much higher compared to other regions of the country.

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