THE SOCIAL AND ENVIRONMENTAL IMPACT OF INCREASING ENERGY EFFICIENCY OF BUILDINGS IN ROMANIA (STUDY CASE)

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The present paper presents the results obtained on the social and environmental impact of the thermal rehabilitation of residential multifamily buildings through programs financed by the local authorities as well as reasons why similar buildings obtain different values of energy savings. The conclusions show how much energy savings can be achieved if a proper energy management system is installed and how a thermal rehabilitation of residential buildings should be viewed to obtain the main goal: maximum reduction of energy invoices while keeping the indoor comfort standard. The paper also presents the impact on the environment and on the return of investment relative to the life cycle of the technical solutions chosen for the thermal rehabilitation process. The analysis is performed on two similar residential buildings thermally rehabilitated in the year2011.

Keywords: thermal rehabilitation, energy efficiency, CO_2 emissions.

1. Introduction

Starting with the year 2002, the issue of the energy efficiency increase in buildings was brought to fore in the European Union with the publication of the first directive, Directive 2002/91/CE.

This directive was republished in 2010 (Directive 2010/31/EU also known as recast EPBD) and is complemented by the Directive 2012/27/UE on energy efficiency [1][2].

The social impact of energy efficiency increase is very important considering, in first place, the ratio between the energy bill for heating and the family monthly income, and in the second place to reduce the CO_2 emissions related to energy-inefficient buildings.

In this context it is necessary to have a detailed analysis with respect to the results of the implementation measures taken to increase energy efficiency in Romania, especially for the thermal housing rehabilitation program implemented by the local authorities for old block of apartments where the rate of finding families with difficult social status is high.

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In Romania several programs were initiated for thermal rehabilitation of multifamily residential buildings built before 1990, with full or partial funding from local authorities to date (end of 2012) resulting in the thermal rehabilitation of 3% of the estimated 3,18 million apartments.

In order to determine if the maximum of energy savings is achieved through thermal rehabilitation, a detailed analysis is performed on two multifamily buildings (apartment buildings) located in Bucharest. The buildings were built in 1984 and were thermally rehabilitated in 2011 trough the national program on increasing energy efficiency in residential buildings.

The comparison was made between the energy consumption of each building in the same heating season (T1 to T2 in the heating season 2011-2012 and T1 to T2 in the heating season 2012-2013). External conditions were the same for each building per season. Buildings have the same role, are executed after the same project, have the same number of apartments, and similar areas and were thermally rehabilitated by the same company using the same process and materials. A number of 126 people live in building T1 while in building T2 live 135 people.

2. The buildings

The first building is a middle section, hereinafter referred to as T1, having exposed the main facades in direct contact with the outside air, the other two being the common wall side facades with neighboring buildings. The orientation of the main facade is on NE.

The second building, hereinafter referred to as T2, is an end section having exposed the main facades and a secondary façade in direct contact with the outside air. The two buildings are shown in fig. 1:

Fig. 1 Buildings T1 and T2

The specific and calculated features of each building were determined according with the methodology [3,4].

The results would indicate the hypothesis that the building T2 requires more energy than the building T1, having a slightly larger building envelope where heat losses occur, and therefore energy consumption for heating should be:

$$Q_{inc}^{T1} < Q_{inc}^{T2} \quad (1)$$

where:
Q_{inc}^{T1} - energy consumption for heating building T1;
Q_{inc}^{T2} - energy consumption for heating building T2.

The energy necessary for heating the buildings is supplied by the Regia Autonomă de Distribu□ie a Energiei Termice (R.A.D.E.T.) using a local substation. There have been no thermal rehabilitation interventions on the building's interior installations, both buildings using the same method for heat distribution.

As a result, the thermal rehabilitation of these buildings is intended to reduce the energy consumption for heating by at least 40%, according to preliminary energy audit conclusions. The expanded polystyrene thickness used to increase the thermal resistance of the walls is 100 mm. A study made on for a building located in the same climatic area suggests the optimal insulation thickness should be greater than 200 mm [8]. The insulation thickness used for "POLITEHNICA" Passive House is 300 mm and a study suggests that the return of the investment is 10 years [9]..

The behavior of the buildings has been determined from invoices for the heating season of 2011-2012 (before thermal rehabilitation) and the heating season 2012-2013 (after thermal rehabilitation). The billing meters are located in the basement of each building, on the primary energy ducts. No method of regulating the heat flow in the rooms was used in building T1, the temperature/flow of the heating agent was made entirely in the local substation. In the case when the interior temperature was higher than the comfort temperature, natural ventilation was used to lower the room temperature. The natural ventilation was conducted by the not recommended method of opening the windows, thus exchanging the higher temperature interior air with the lower temperature exterior air. The allocation of energy costs for each apartment of building T1 is done in relation with the useful area of the apartment.

Building T2 uses thermostatic valves on all the heat radiators to regulate the heat flow and thus maintaining the comfort temperature thus reducing the natural ventilation rate. The thermostatic valves are used in together with billing meters installed on each radiator. The allocation of energy costs for the apartments of building T2 is made using the measurements of each radiator meter.

2. Analysis of the results

The outside average heating season temperatures for Bucharest are shown in table 1 [6]:

Table 1

Outside average heating season temperatures

Season	Heating season 2011-2012	Heating season 2012-2013	S.R. 4839-97
Average temperature	5,14	5,72	4,26

The energy consumption for heating the two buildings, in the heating season 2011-2012 before thermal rehabilitation is shown in table 2:

Table 2

Energy consumption for heating before thermal rehabilitation

Heating season 2011-2012	$Q_{inc.1}^{T1}$	$Q_{inc.1}^{T2}$
	kWh	kWh
October	19.269	11600
November	58489	26925
December	81009	36349
January	68781	49239
February	68169	47279
Mars	42409	52859
April	4219	31709
Total	**342348**	**255963**

The energy consumption for heating the two buildings, in the heating season 2012-2013 after thermal rehabilitation is shown in table 3:

Table 3

Energy consumption for heating after thermal rehabilitation

Heating season 2012-2013	$Q_{inc.2}^{T1}$	$Q_{inc.2}^{T2}$
	kWh	kWh
October	0	0
November	32959	19825
December	61379	22249
January	64909	35329
February	54149	37249
Mars	37039	28239
April	10499	19849
Total	**260937**	**162743**

The results obtained for the heating season 2011-2012, for the two buildings T1 and T2, before thermal rehabilitation, are shown in fig. 2:

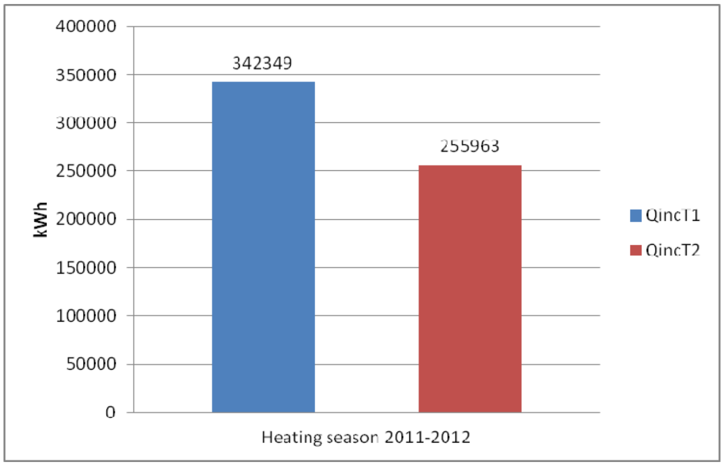

Fig. 2. Energy consumption in the heating season before thermal rehabilitation

The results shown in fig. 2 contradict the hypothesis presented in relation (1), the measured energy consumption in the heating season for building T2, , being lower by 25% than .

This behavior is caused by the management of the comfort temperature in the two buildings, namely by the management of the energy consumption in order balance the heat losses. However, the high difference between the two values presented in fig. 2 suggests an extreme usage of the thermostatic valves installed on the radiators (even at the point of permanently shutting down the heating in particular areas). This caused a drastic decrease of energy consumption and a decrease of the interior temperature under the comfort values. Also the variable interior temperatures in many unheated areas of the T2 building caused the heating transfer between different apartments and an uneven distribution of the total energy bill. Frequent use of these equipments can cause hydraulic imbalance and can deteriorate the distribution pipes.

After the thermal rehabilitation of the envelope for the two buildings, the energy consumptions decreased relative to the previous heating season.

The compared results are shown in fig. 3:

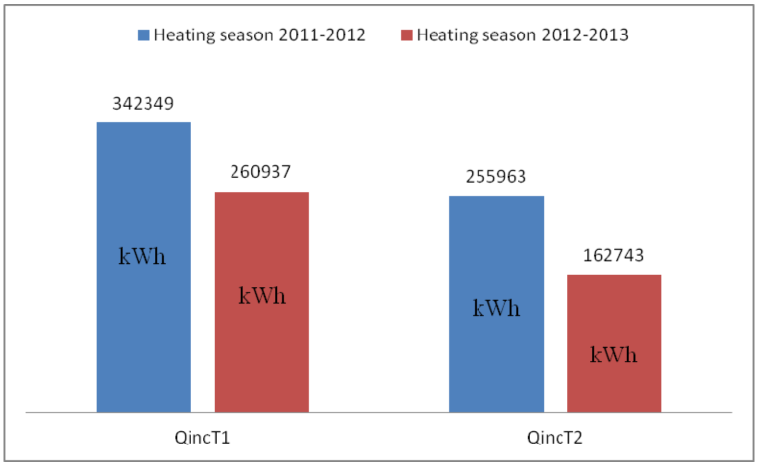

Fig. 3. Comparative chart for energy consumption in the heating season

Through the thermal rehabilitation process, building T1 achieved 81,4 MWh of energy savings and building T2 achieved 93,2 MWh energy savings, slightly higher due to more exterior surface building envelope exposed to exterior temperature. The energy reduction achieved by the building T2 is higher than the energy reduction of building T2 mostly due to lower energy consumption measured before thermal rehabilitation.

As it is shown in fig. 3, the energy economy achieved by each build is:

$$E_{T1} = 23,78\% \qquad (2)$$

for the T1 building, and:

$$E_{T2} = 36,42\% \qquad (3)$$

for the T2 building.

The maximum potential of increasing the energy efficiency for building T1, in this case, can be estimated using the following equation:

$$E_{T1}^{c} = 100 - \frac{Q_{inc.1}^{T1}}{Q_{inc.2}^{T2}} \cdot 100 \qquad (4)$$

where:

E_{T1}^{c} - the maximum potential of increasing the energy efficiency for the building T1;

$Q_{inc.1}^{T1}$ - energy consumption for the heating season before thermal rehabilitation of the building T1;

$Q_{inc.2}^{T2}$ - energy consumption for the heating season after thermal rehabilitation of the building T2.

The result is:

$$E_{T1}^{c} = 52,46\% \quad (5)$$

The results presented so far suggest a different impact of the thermal rehabilitation process on the energy invoices for every building.

The result shown in relation (5) shows the maximum energy savings potential that can be achieved using thermostatic valves in combination with cost allocators and users behavior. As already stated, this technical solution for regulating the heat flow creates areas with abnormal temperatures which produce heat transfer between the wall of different apartments and an uneven distribution of the total energy bill. In these conditions the indoor temperature of building T1 may fall under the comfort level in some areas. A normalization of the space averaged indoor temperature to match comfort values would decrease the the energy savings level shown in relation (5) in range of 40% to 50%.

In Bucharest, the heating cost for the analyzed heating seasons was subsidized according to the Decision of the General Council of Bucharest (HCGMB) nr.141/2011. The cost is reduced from 328 lei/Gcal (production cost, VAT included) to 169,88 lei/Gcal (consumption cost, VAT included), which represents a reduction of 48% of the heating invoices [4]. However, the high level of fuel poverty in Romania still makes the thermal rehabilitation process to have a powerful social impact by additionally reducing the energy costs per apartment, especially in the heating season, reducing the CO_2 emissions associated with the district heating.

Following the savings achieved trough decreasing consumption, the subsidized cost from the local budget decreases and the money saved can be redirected to investments in other social sectors. Taking into consideration all the aspects above, we calculate the economies achieved by the two buildings and their distribution. The results are shown in tables 4.a and 4.b:

Table 4.a

The analysis of real cost savings

Building	Invoice for heating season 2011-2012			Invoice for heating season 2012-2013		
	Paid by the owners association	Subsidized by the local budget	Total	Paid by the owners association	Subsidized by the local budget	Total
	lei	lei	lei	lei	lei	lei
T1	50016	46554	96570	38122	35483	73605
T2	37395	34807	72202	23776	22130	45907

Invoice reduction is very important in the context of the elimination, in the future, of the subsidies for heating provided by the local authorities.

Table 4.b

The analysis of real cost savings

Building	Achieved cost economy		
	Owners association	Local budget	Total
	lei	lei	lei
E_{T1}	11894	11070	22964
E_{T2}	13619	12676	26295

The social impact of eliminating theses subsidizes on the cost of energy for heating the two buildings is shown in table 5:

Table 5

Eliminating the subsidizes hypothesis

Building	Heating invoice, heating season 2011-2012			Heating invoice, heating season 2012-2013	
	Paid by the owners association	Subsidized by the local budget	Total	Paid by the owners association	
	lei	lei	lei	lei	%
T1	50016	46554	96570	73605	47,16
T2	37395	34807	72202	45907	22,76
$T1_{optimal}$	50016	46554	96570	45907	-8,22

From the results presented in table 5 it is concluded that, by the assumption of the achieved energy savings and the elimination of subsidies, the heating bill supported by the association of owners for each building will rise above the invoice paid during the period when the building was not thermally rehabilitated.

For the building T1 the raise can reach 47,16 % while for the building T2 can be up to 23%. By simulating an optimal consumption of energy, after thermal rehabilitation, for building T1 a reduction of 8% can be achieved, in comparison to the initial, non rehabilitated situation.

The environmental aspect of increasing energy efficiency through thermal rehabilitation is the achieved reduction of CO_2 emissions.

Results are shown in table 6 [7]:

Table 6

The impact of increasing energy efficiency on CO_2 emissions

-	Building		U.M	Notation
	T1	T2		
Energy savings after thermal rehabilitation	81411	93219	kWh/year	E_{T1}, E_{T2}
Specific emissions for district heating	0,24		kgCO_2/kWh	$e_{specific}^{CO_2}$
Achieved emission reduction	20	22	tone CO_2/year	$R_{T1}^{CO_2}, R_{T2}^{CO_2}$

By simulating a potential of energy saving for building T1 calculated with the equation (4), the potential of CO_2 emission reduction for building T1 is:

$$R_{T1_{optim}}^{CO_2} = e_{specific}^{CO_2} \cdot (Q_{inc.1}^{T1} - Q_{inc.2}^{T2})/1000 \tag{6}$$

resulting:

$$R_{T1_{optim}}^{CO_2} = 43{,}11\ (t\ CO_2/an\ ) \tag{7}$$

The return of investment (ROI) for the thermal rehabilitation of each building can be estimated by using the values from Annex no. 2.4 of Government Decision no. 363/2010, indicative SCOST-04/MDRT published in October 2012 and the exchange rate 1 Euro = 4,45 lei.

The return of investment (ROI) is calculated as the ratio between the initial investment and the cost of annual energy savings achieved. The ROI for T1 in optimal potential is also determined. The results are shown in table 7:

Table 7

Return of investment analysis

Building	Estimated investment	Achieved cost reduction	ROI	Life cycle of the thermal rehabilitation measures	**Observații**
	euro	euro	years	years	
T1	137232	5160	27	20	ROI exceeds the life cycle of the technical solutions.
T2	154388	5909	26	20	ROI exceeds the life cycle of the technical solutions.
$T1_{optimal}$	161200	15210	11	15	Initial investment value increases

Through the analysis of the investment required for thermal rehabilitation of the building T1 to achieve optimal energy savings, $T1_{optimal}$, an additional investment is required to implement the missing energy management solutions: fixing/restoration of the interior installations which distribute the heating agent to the apartments, thermal and hydraulic compensation of the interior installation, reduction of the radiators surface/elements in order to adjust the power output to match the new energy demand etc.

Additional investment required, added to the initial investment in thermal rehabilitation, is 7 Euro/m^2.

Life-cycle of the whole rehabilitation process drops to 15 years, according to the life-cycle of the new installation modifications.

4. Conclusions

In Romania, for the blocks of apartments built in the period 1950-1990 and heated through the district heating system, there are two ways of allocating the share of cost to a specific apartment:

- a share system proportional with the heated surface of the apartment;
- by using metering systems installed on each radiator.

The scope of the national program of increasing the energy efficiency in buildings trough thermal rehabilitation is, mainly, to reduce heating invoice by 40%.

The regulation of the necessary heat flow in each apartment must be achieved using thermostatic valves installed on each radiator. However, the excessive use of these equipments can cause indoor temperatures below the comfort threshold in some areas, heat transfer between apartments through interior walls and thus an uneven distribution of the total energy bill. The incorrect use of the thermostatic valves is a phenomenon which appears whenever these equipments are seen as directly related to the method of calculating the energy bill and not to the thermal comfort [10].

The case study reveals that, although the same solutions were used in the thermal rehabilitation process for the building T1 and T2, a regulation system for energy management was not installed on building T1. Thus a share system proportional with the heated surface of each apartment is used to allocate the energy cost for each apartment. The regulation of the temperature/flow of the heating agent was made in the local substation. This caused an overheating of the useful area of building T1 and an excessive ventilation by opening windows which increased the energy consumption. Noteworthy, old radiators usually have un-functional/deteriorated valves and cannot be shut down.

Building T2 uses metering systems installed on each radiator to calculate energy costs and a regulating system using thermostatic valves.

After analyzing the architectural characteristics of the two buildings, the conclusion is that the energy consumption of the T2 building should be higher than the energy consumption of the T1 building. This theoretical hypothesis was contradicted by the actual measured values of the energy consumption for heating.

Conclusions of the study case:

1. Taking into consideration that the only major difference between T1 and T2 buildings are the method of managing the regulation of the comfort temperature and the allocation of the heating costs method, it may be concluded that the difference between the achieved energy savings of the building T1 (23,78%) and achieved energy savings of the building T2 (36,42%) is the result of the energy management used by each building.

2. Modifying the energy management for the building T1 should maximize the energy efficiency, resulting in the increase of energy savings up to 52,46%. This would imply installing thermostatic vales and cost allocators on each radiator. Under these conditions the indoor temperature of building T1 can be situated under the comfort level in some areas and create areas with abnormal temperatures which produce heat transfer between the wall of different apartments and an uneven/unfair distribution of the total energy bill. The readings of the cost allocators do correspond to the real heat transfer from the radiator, but cannot distinguish between heat loss from the apartment where they are installed to the exterior/stair case or to neighbors. Therefore, other solutions to regulate the supplied heat flow should be implemented to make the cost allocation fairer and to motivate users to save energy by a proper behavior. These solutions, however, should not exclude users' direct interventions, but should keep it in reasonable limits (for example, radiators cannot be completely shut down). The technical solutions can be: modifying the radiant area of each radiator to meet the new energy demand, installing heating substations to personalize the heating curve for each building, installing thermostatic valves without cost allocators, along with the know-how on regulating the indoor temperature to avoid extreme interior conditions. These solutions can ensure an indoor comfort temperature and a potential of energy savings situated between 40% and 50%. More studies are needed to evaluate the technical, economical and social impact of each solution.

3. Achieving the maximum potential of energy saving, in this case for building T1, while maintaining the indoor thermal comfort, has an important social impact on the reduction of the energy invoice. This impact manifests on two levels: at the consumer level and at the local budget level through the reduction of subsidizing. The reduction of the energy invoice for heating the building T1 can increase from existing 23,78% to over 50%, relative to energy consumption before thermal rehabilitation.

4. From the overall social point of view, implementing the energy management solutions for the building T1 can double the current CO_2 emissions reduction.

5. A simulation of cancelation of the subsidize scheme was made for this study case, to determine the impact on energy invoices for the thermally

rehabilitated buildings. The results suggest an increase of energy invoice for the building T1 with 47,16% and for the building T2 with 22,76%. The increase is relative to the energy invoice before thermal rehabilitation. If the maximum potential of energy saving is achieved by building T1, the simulation suggests a decrease with 8% of the energy invoice relative to the costs before the thermal rehabilitation

REFERENCES

[1] *** Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast).
[2] *** Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.
[3] *** Metodologie de calcul al performanței energetice a clădirilor (Methodology for calculating the energy performance of buildings). Monitorul Oficial al României, Partea I, nr. 126 bis/21.02.2007, Anexa nr. 1.
[4] *** Hotărârea Guvernului nr.1061 din 30.10.2012 pentru modificarea anexei nr. 2.4 la Hotărârea Guvernului nr. 363/2010 privind aprobarea standardelor de cost pentru obiective de investiții finanțate din fonduri publice (the Government Decision no. 363/2010 regarding cost standardization for investments from public budget), Monitorul Oficial nr. 765 din 14 noiembrie 2012.
[5] *** Hotărâre a Consiliului General al Municipiului Bucureşti privind aprobarea prețului local de facturare a energiei termice furnizate populației practicat de R.A.D.E.T. Bucureşti (The Decision of the General Council of Bucharest Municipality regarding the approval of the local price of heat supplied to the population practiced by R.A.D.E.T.), HCGMB no. 141/ 2011.
[6] http://www.meteoromania.ro/anm/?lang=ro_ro, Administratia Nationala de Meteorologie website.
[7] *** Metodologie de calcul al performanței energetice a clădirilor partea I – Anvelopa clădirii - Indicativ Mc 001/1–2006(Methodology for calculating the energy performance of buildings part I - Building envelope), Monitorul Oficial al României, Partea I, nr. 126 bis/21.02.2007, Tabelul 1.13., pag. 53.
[8] *M. Stroe, A. Leca, P. Blaga*, The transient regime behaviour of the brick-polystyrene wall insulating system in winter conditions, Energy Development Frontier, July 2013, vol. 2, ed. 3, Pag. 80-88.
[9] *T. Baracu*, Contributions to the numerical modeling of the buildings, Phd. Thesis, University Politehnica of Bucharest, 2013.
[10] *E.C. Mladin,* Tehnica Auditului Energetic pentru Cladiri. O abordare inginerească, ed. MatrixRom, 2001.