Calculated and measured energy use before and after thermal renovation for Romanian apartment buildings

The objective of the article is to analyse the energy use for space heating and production the domestic hot water (DHW) before and after the thermal refurbishment of five blocks of flats in Timisoara, Romania which have been included in the multi-annual National Program, financed in 2009, to increase of the energy performance of blocks of flats. In addition we estimate the factors that lead to the differences between the calculated and measured energy use, and recommend some energy saving measures for the future.

Silviana Brata
"Politehnica" University of
Timisoara, Romania,
silviana.brata@gmail.com

Ioan Silviu Dobos
REHVA vice-president; Dosetimpex,
Timisoara, Romania,
ioansilviu@dosetimpex.ro

Ioan Bistran
Dosetimpex,
Timisoara, Romania,
ioan.bistran@gmail.com

Sorin Brata
student,
"Politehnica" University of
Timisoara, Romania,
sorin.brata@gmail.com

Regulatory background

The Directives 2002/91/CE and 2010/31/EU regarding the energy performance of buildings, recommended that each energy performance of buildings should be determined independently nationally based on a methodology that includes the thermal insulation of buildings, and the modernization of the building installations. [1] [2] [6]

As a result of EPBD 2002 directive Romania enforced the 372/2005 law that regarded the increase in building energy performance. The law covers the general framework for the energy performance of buildings including calculation methodology. In 2006, the Mc001/2006 methodology for determining the energy performance of buildings was elaborated and approved.

The National Program for Thermal Refurbishment initiated by the Ministry of Development, Public Works and Buildings for increasing the energetic performance of residential buildings is based on the Government Emergency Ordinance OUG 174/2002, and OUG 18/2009 and the applicable methodology Norms. This program was initiated out of the need to reduce the energy consumption of buildings while maintaining and assuring a degree of indoor comfort. If the energy consumption is reduced, the heating costs of buildings and the greenhouse gas emissions will be reduced, thus also improving the urban aspect of cities in a noticeable way.

Thermal refurbishment measures and financing

The thermal refurbishment measures have been taken, with regards to the all the quality requirements and the mandatory norms afferent to law no.10/1995 for multi-story buildings and their installations, built after a standard type during 1950 and 1985, in heavily populated urban areas, which are connected to the central district heating network. For reducing the energy use, the following measures have been taken:

- Thermal insulation of the exterior walls;
- Thermal insulation of the basement floors;
- Thermal insulation of the terrace-type roofs;
- Sealing/replacing the exterior walls and windows;
- Thermal insulation of the pipes from the technical rooms and replacing it where heavy losses have registered;

	Case 1	Case 2	Case 3	Case 4	Case 5
Before refurbishment					
Net heated area, [m^2]	4.843	5.303	3.135	2.712	2.325
Net heated volume, [m^3]	13.252	14.501	8.465	7.458	6.207
After refurbishment					

Figure 1. Case buildings before and after renovation.

- Thermal energy metering;
- Installing heating cost allocator and thermostatic radiator valves for the heating units;
- Measuring individual domestic hot water consumption.

At that time, the financing for the technical documentation and for the refurbishment works had been made as follows: 34% from the state budget, 33% from the local budgets and 33% from the reparation funds of the House Tenants' and Flat Owners' Association.

Heating energy use of blocks of flats

Five blocks of flats in chosen to the study (**Figure 1**) were built during 1970 – 1977, and had exterior walls of large prefabricated panels made out of reinforced concrete with three-layer panels with

- Interior resistance layer;
- Thermal insulating layer;
- Exterior layer for protection of the thermal insulation.

An exception from this pattern is the block of flats Case 4, built in 1965, with brick walls.

The exterior windows are partial double windows with simple glass and partially insulating glass windows. The air change rates were estimated to be (0.7 - 0.8) h^{-1}. The interior two pipe hot water radiator heating units are supplied from energy thought the centralized municipal thermal energy station.

During the first phase of the process, the energy use was calculated for the following climatic data scenarios:

- The energy simulation before the thermal refurbishment:
  - conventional year
  - year 2007;
- The energy simulation after the thermal refurbishment:
  - conventional year
  - year 2010;

Table 1. Monthly average of outdoor temperatures, in °C.

	Annual Average	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Conventional year	10.6	–1.6	1.2	5.8	11.2	16.3	19.4	21.1	20.4	16.5	11	5.6	0.8
2007	12.4	4.4	5.5	8.6	12.7	18.3	22.4	24.2	23	14.8	10.7	4.2	0
2010	11	–1	–1	6	12	16	20	23	22.2	16.4	9.4	9.1	0

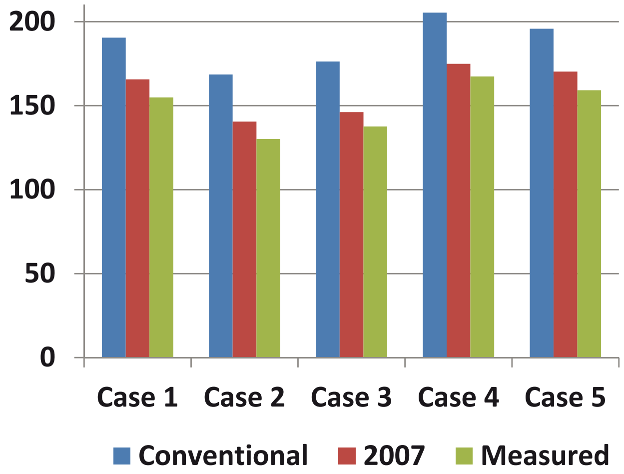

Figure 2. Calculated energy use before thermal refurbishment using conventional or 2007 weather data and measured energy use, in kWh/m²a.

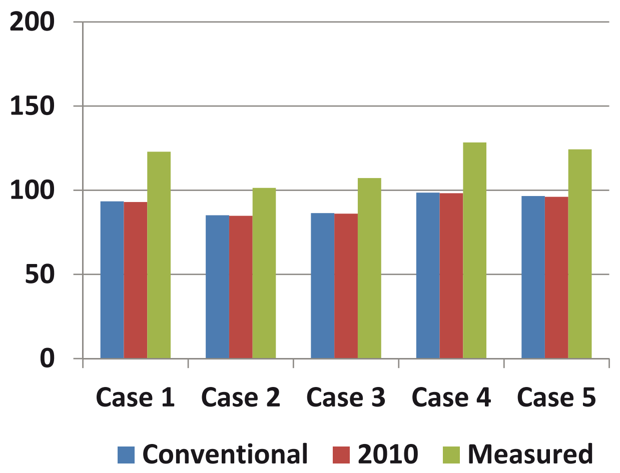

Figure 3. Calculated energy use after thermal refurbishment using conventional or 2010 weather data and measured energy use, in kWh/m²a.

In the second phase of the process the calculated energy use [3][4][5] were compared with the consumption registered on the invoices, based on the thermal energy meter readings. The energy demand was determined at the boundary of the building.

Taking into consideration the two calculus hypotheses, we have the following energy use distribution:

- before the thermal refurbishment (**Figure 2**):
  - conventional year: (168.6 – 205.4) kWh/m²a, most belonging to the energy class D (House 2 belonging to the energy class C);
  - year 2007: (140.5 – 174.9) kWh/m²a
  - measured values: (130.2 – 167.4) kWh/m²a
- after thermal refurbishment, **Figure 3**:
  - conventional year: (85.1 – 98.6) kWh/m²a, belonging to the energy class B;
  - year 2007: (84.8 – 98.2) kWh/m²a, belonging to the energy class B;
  - measured values: (101.4 – 128.4) kWh/m²a, belonging to the energy classes B and C;

The study showed that through the thermal refurbishment of buildings there was an estimated reduction of energy use of 50%. In reality the consumption was lowered with approximately (20 – 25)%.

Energy use for DHW

The energy use for preparing DHW is determined according to the net surface and the average number for occupying the block of flats in the Timis County, from which Timisoara is part of. **Figures 4 and 5** synthesize the energy use before and after the thermal refurbishment in all the five cases taken into consideration:

- before the thermal refurbishment, **Figure 4**:
  - conventional year: (61.9 – 97.2) kWh/m²a, belonging to the energy classes D and E;
  - measured values: (38.1 – 55.8) kWh/m²a, belonging to the energy class C;
- after the thermal refurbishment, **Figure 5**:
  - conventional year: (50.4 – 7.2) kWh/m²a, belonging to the energy classes C and D;
  - measured values: (31.8 – 46.8) kWh/m²a, belonging to the energy classes B and C;

Besides the reduction of the energy use for production of DHW, determined by the refurbishment measures, the reduction of DHW can also be motivated by the increase of the hot water costs with 62.6%, during 2010 – 2011 compared to 2007 – 2008.

Conclusions

The causes for the differences between the measured and calculated consumption are estimated as follows:

- for the heating installation:
  - incorrect estimation value of the thermal resistance;
  - actual indoor temperatures can be higher than the conventional ones; Energy demand depends strongly on indoor temperature shown in **Table 2.**
- air change rates can be higher than the conventional (estimated) air change rates. Energy demand depend strongly on air change rate as shown in **Table 3**.
- not using heating cost allocators.

Table 2. Effect of indoor temperature on heating energy demand (Case 1).

Temperature, °C	20	22	23.3
Energy demand, kWh/m^2a	93.4	110.2	122.2

Table 3. Effect of air change rate on heating energy demand (Case 1).

Air change rate, h^{-1}	0.7	0.9	1.1
Energy demand, kWh/m^2a	93.4	108.0	123.2

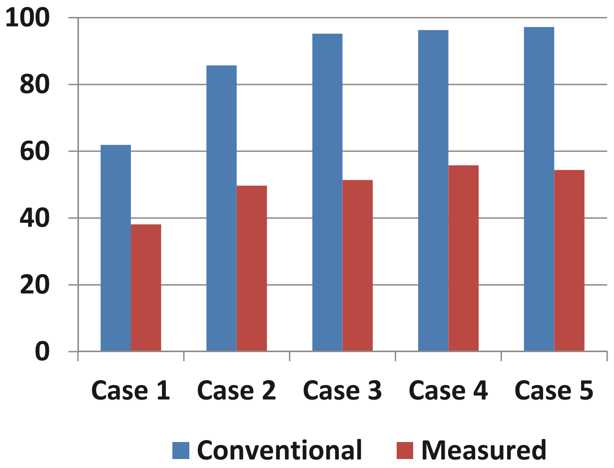

Figure 4. Calculated (conventional year) and measured use of energy for DHW before the refurbishment.

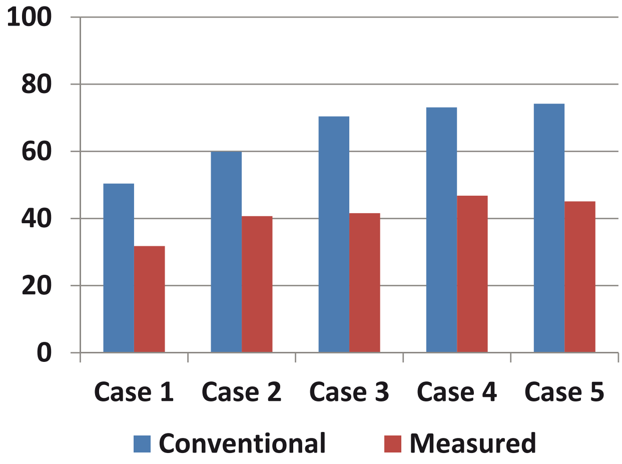

Figure 5. Calculated (conventional year) and measured use of energy for DHW after the refurbishment.

- for the domestic hot water installation:
  - the conventional (estimated) number of people may be different than the real one;
  - the temperature values for the DHW preparation and supply and the temperature of the cold water that enters the DHW installation may be different than the values from the conventional calculus;
  - the calculation of the heat losses from supplying the consumer with DHW, presents differences in the proposed volume calculation methods of the DHW, corresponding to the losses of water, which is calculated according to the following:
    - specific DHW losses
    - dimensioning factors
    - table values

By analysing all the case study results, the following recommendations for reducing costs are proposed:

- a better understanding on behalf of the owners and tenants of the way how the building functions,
- installing heating cost allocators onto each heating unit;
- periodic analysing the energy bills;
- quantifying the energy cost reduction potential with up to 50% from the initial situation (at the moment the reduction being up to 20 – 25%);
- reducing the indoor temperature and the number of air change rates to the point of indoor comfort;
- energy consultancy.

References

[1] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings. http://www.energy.eu/directives/2010-31-EU.pdf

[2] Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002, on the energy performance of buildings
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:001:0065:0071:EN:PDF

[3] Metodologia de calcul al performanţei energetice a clădirilor MC 001/2006:
Partea I – „Anvelopa clădirii”, indicativ Mc 001/1 – 2006;
Partea a II – a – „Performanța energetică a instalațiilor aferente clădirii;
Partea a III –a – „Auditul şi certificatul de performanţă a clădirii”.

[4] Program de calcul al performanţei energetice a clădirilor Doset-PEC.

[5] Implementarea Metodologiei Mc001/2006 în practică. - Conf. Dr. Ing. Silviana BRATA, Universitatea "Politehnica", Timişoara; Dr. Ing. Ioan Silviu DOBOŞI, Dosetimpex SRL Timişoara; Prof. Ioan BISTRAN, Dosetimpex SRL Timişoara (Revista Instalatorul Nr. 4 - 2012).

[6] Zoltan Magyar – „Buildings in the key role in the EU Energy Efficiency Action Plan", The Rehva European HVAC Journal, Volume:48, Issue:3, May 2011, pag. 86-88.