

PAPER • OPEN ACCESS

Indoor Air Quality and Energy Audit and in an Apartment Building in Slovakia

To cite this article: Imrich Sanka and Dusan Petras 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **471** 062022

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the **collection** - download the first chapter of every title for free.

Indoor Air Quality and Energy Audit and in an Apartment Building in Slovakia

Imrich Sanka ¹, Dusan Petras ¹

¹ Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Department of Building Services, Radlinského 11, 810 05 Bratislava, Slovakia

imrich.sanka@gmail.com

Abstract. This article investigates the impact of energy renovation on the indoor environmental quality of apartment building during heating season. The study was performed in one residential building before and after its renovation. Energy auditing and classification of the selected building into energy classes were carried out. Additionally, evaluation of indoor air quality was performed using objective measurements and subjective survey. Thermal environment and concentration of CO₂ was measured in bedrooms. Higher concentrations of CO₂ were observed in the residential building after its renovation. The concentrations of CO₂, in some cases exceeded the recommended maximum limits, especially after implementing of energy saving measures on the building. The average air exchange rate was visible higher before renovation of the building. The current study indicates that large-scale of renovations may reduce the quality of the indoor environment in many apartments, especially in the winter season.

1. Introduction

From the year 2021, all the newly built buildings will have to comply the most stricter building energy criteria so far in Slovakia. It means that the houses will have to fit into energy class A0 according to the global indicator. Simplistically the primary energy consumption of the buildings mentioned above need to be lower than 54 kWh/(m².a) regarding to family houses, 32 kWh/(m².a) regarding to apartment buildings and 60 kWh/(m².a) regarding to office buildings. These buildings are called as nearly zero energy buildings (nZEB). These requirements can be achieved by perfect application and increased thickness of thermal insulation systems on to building envelope (for example 350 mm of mineral wool to the roof, 200 mm of EPS polystyrene to the external walls and 150 mm of XPS polystyrene to the floor). Of course the terms for the transparent constructions are as much strict as for the thermal insulation requirements mentioned above. The windows and doors must have heat transfer coefficient lower than 0,6 W/(m².K). In this case the architect has to design top quality windows with triple glazing. These energy saving measures are reducing the U value and are minimizing the heat losses of the building.

2. Energy Evaluation

However, the good architects, civil engineers and designers know that these design measures are not enough to achieve the required energy class so active parts must be also designed for nearly zero energy buildings. These active parts can be high quality devices of environmental technology (HVAC-R systems).



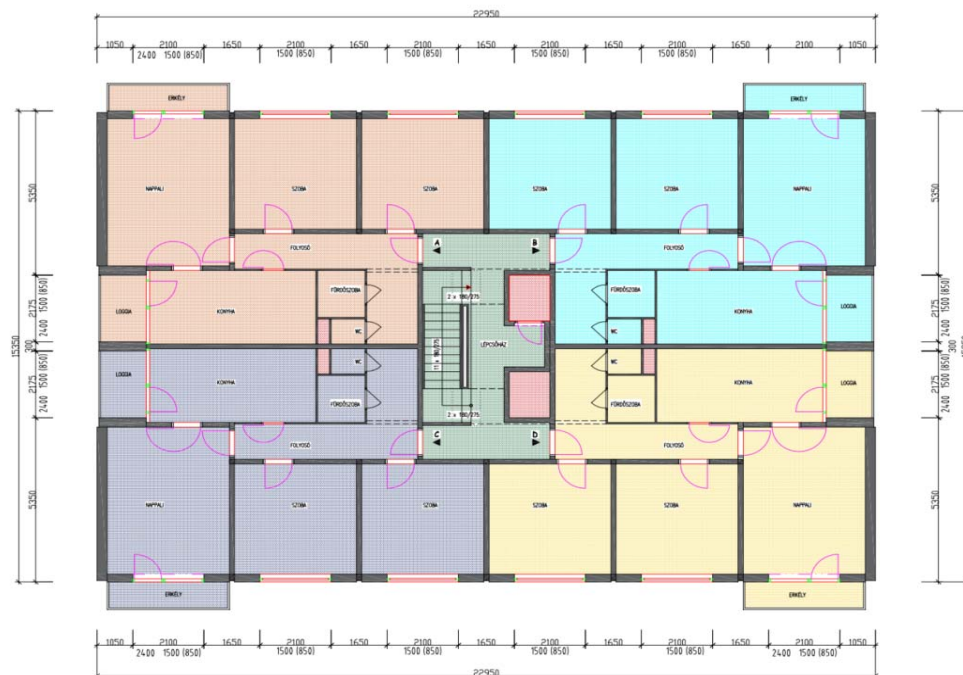


Figure 1. Floor plan of the investigated building

2.1 Energy audit

The residential building investigated is located in Šamorín, Slovakia. It was built in 1964 from lightweight concrete panels. The building was naturally ventilated. Exhaust ventilation was only used in sanitary rooms, such as the bathrooms and toilets. Renovation of the building was carried out in 2015 and included the following measures: insulation of the building envelope using polyethylene, insulation of the roof using mineral wool and hydraulic balancing of the heating system. New plastic frame windows had already been installed in recent over the last years in most of the apartments in the building [1].

Table 1. Heat transfer coefficients of the structures

Structure	Heat transfer coefficient Non renovated building	Heat transfer coefficient Renovated building	Area	Average heat transfer coefficient Non renovated building	Average heat transfer coefficient Renovated building	Improvement of the heat transfer coefficient (%)
	U_i [W/(m ² K)]	U_i [W/(m ² K)]		U_i [W/(m ² K)]	U_i [W/(m ² K)]	
External wall 1	1.6	0.37	1766.85	1.49	0.35	76.50%
External wall 2	1.59	0.36				
External wall 3	0.49	0.23				
External wall 4	0.44	0.23				
Wall of the machine room	1.69	0.38	328.77	1.23	0.23	81.30%
Flat roof	0.8	0.22				
Flat roof of the machine room	1.93	0.27	338.77	0.88	0.34	61.40%
Ceiling above the basement	0.88	0.33	569.43	1.56	1.3	16.70%
Transparent structures	1.56	1.3	3013.82	1.439	0.544	

The heat demand was calculated for the non-renovated and renovated condition. The highest energy-saving is provided by the thermal insulation of the external walls. This can be explained with the large heat exchange surface of the walls. On the Figure 2. is clearly indicated the heat demand for the structures for square meter and the solar and heat gains for both types of residential building. The figure shows that the heat demand for the insulated part of the building significantly decreased and for the calculated air exchange rate (AER) and gains remained the same.

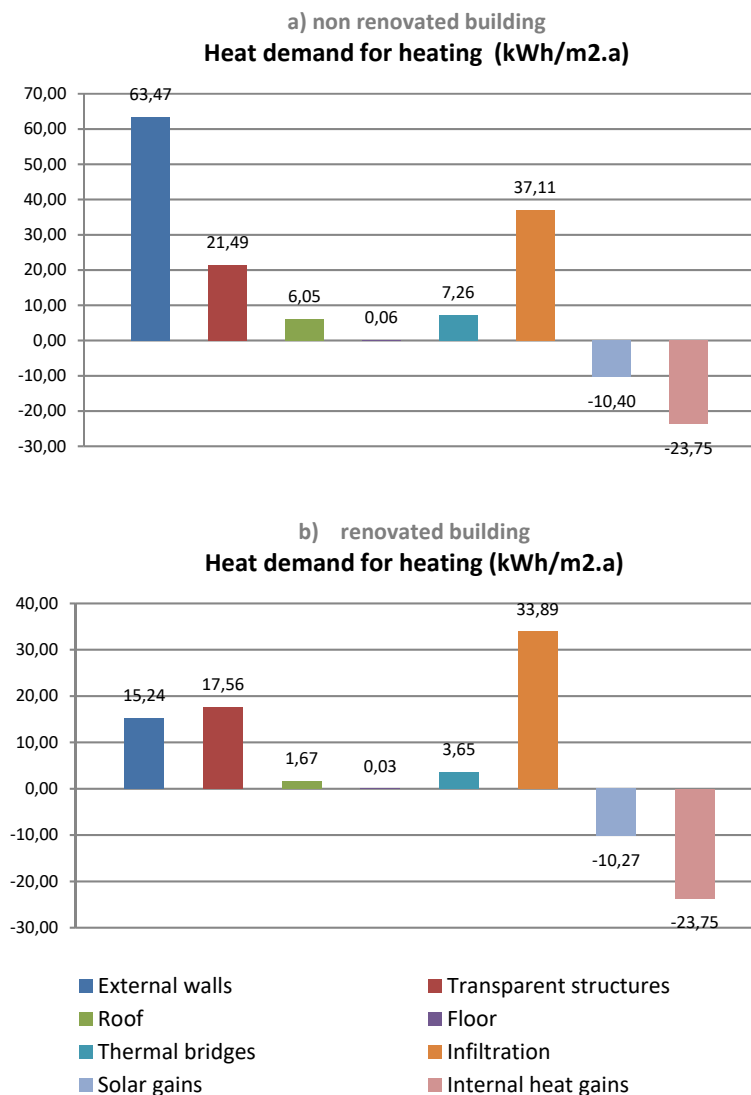


Figure 2. Heat demand of the structures (a- non renovated, b- renovated)

2.2 Results

The renovated and non-renovated residential building were classified into energy classes by the valid Slovak legislation: Decree of the Ministry of Transport, Construction and Regional Development No:300/2012.

The energy-saving measures mentioned above decreased the energy consumption by 55%. In accordance to our law on energy efficiency of buildings, the original dwelling belonged to the „E“ category (159 kWh/m²a), after refurbishment to the „B“ category (74 kWh/m²a).

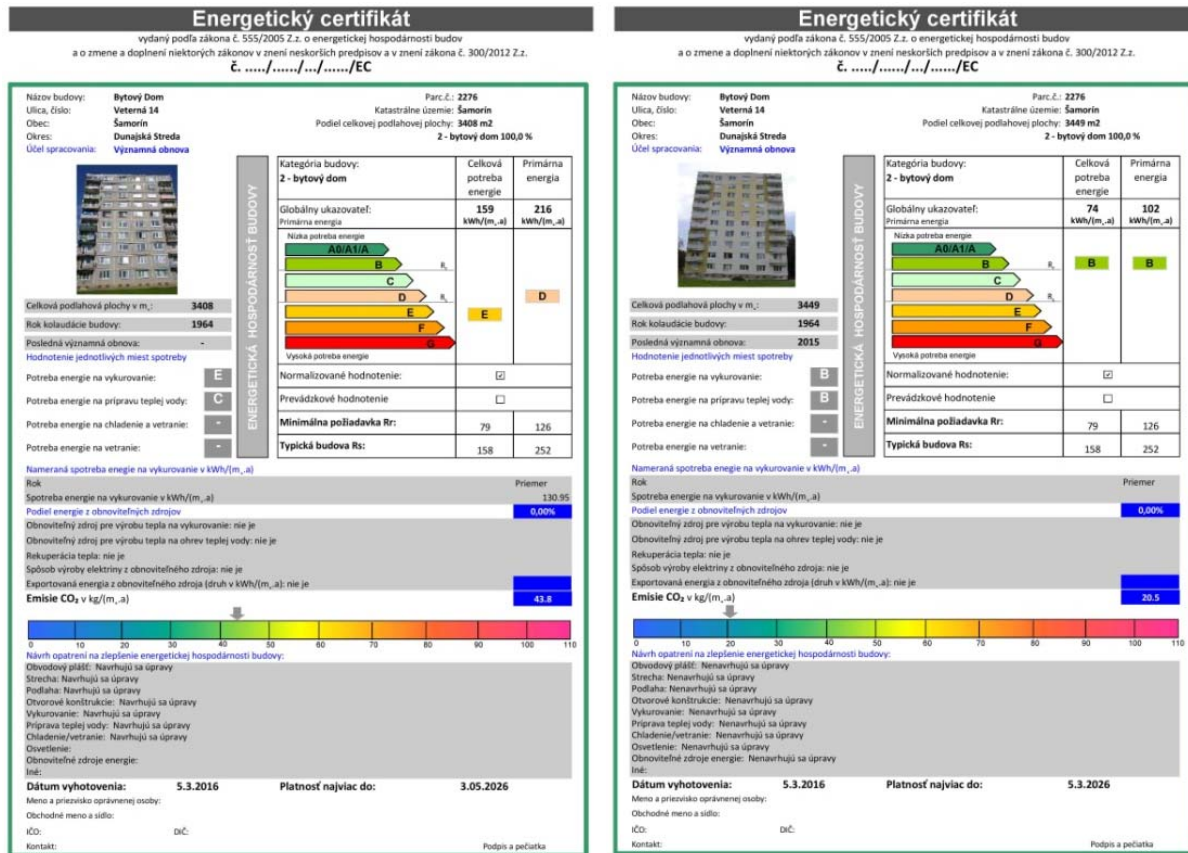


Figure 3: Energy Certificate of the building (non-renovated-left, renovated-right)

3. Environmental evaluation and results

Majority of the people are spending more than 80% of their times in indoor environment but its quality is rarely considered in nearly zero energy building.

Many studies have shown that well insulated buildings are very tight and the air exchange rate is very low, but authors of these studies often evaluated renovated buildings from the 20th century.

3.1 Methods

The first round of the measurements was performed in January 2015 when the building was still in its original condition, and the second round was performed in January 2016 after energy saving-measures had been implemented. Twenty apartments were selected across the residential building; they were equally distributed on the lower, middle and highest storeys of the building. The same apartments were investigated in both winter seasons over a period of eight days [2]. The temperature, relative humidity and CO₂ concentration, were measured in the bedrooms of the apartments. HOBO U12-012 data loggers and CARBOCAP CO₂ monitors (Figure 4) were used for recording the temperature and CO₂ concentration data.



Figure 4: Hobo data logger and Carbocap CO₂ monitor

Each unit was placed at a sufficient distance from the windows and beds to minimize the effect of the incoming fresh air or the effect of the sleeping occupants. The space between the furniture and the rooms corners was avoided. The CO₂ concentration was used to calculate the air exchange rate over eight nights in each bedroom. The occupants CO₂ emission rate was determined from their weight and height as set out in questionnaires [2].

3.2 Results

In Effect of energy renovation on indoor air quality in multifamily residential buildings in Slovakia [4-5] is shown increased concentration of harmful substances (CO₂, formaldehyde, VOC) and this can be attributed to the tightness of the building, low air exchange rate. In this case the situation is very similar.

The CO₂ concentrations before and after the renovation of the building are shown in Figure 5. Most of the CO₂ concentration data points were within the acceptable limit (green line) before the renovation (blue line), while significantly higher concentrations were measured after the renovation (red line). Table 2 present the descriptive statistics of the day and night-time CO₂ concentrations before and after the renovation of the residential building. The grand average was 1205 ppm and the median was 1190 ppm before the renovation.

After implementing the energy-saving measures, the CO₂ concentration visibly increased. The mean was 1570 ppm and the median was 1510 ppm. A higher number of the apartments exceeded 1500 ppm and upper concentrations during both the day and night-time after the renovation than before the renovation.

The lower CO₂ concentration before the renovation resulted in higher AERs in the apartments (average 0.61 h⁻¹). After the renovation, the mean air exchange rate (0.44 h⁻¹) dropped below the recommended minimum (0.5 h⁻¹) (Table 3).

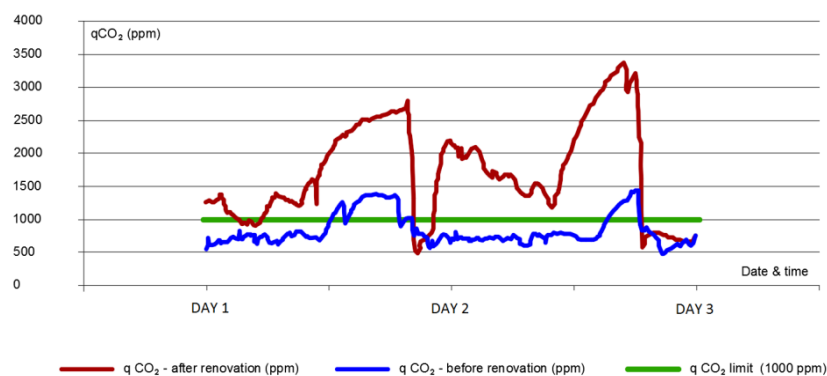


Figure 5: Example of CO₂ concentration in one selected apartment during two days out of the whole measurement period before and after renovation, [6]

Table 2: Day- and night-time CO₂ concentration before and after renovation

a) Before renovation (N=20)

Time period	CO ₂ (ppm)			
	Average	Minimum	Maximum	Median
Day	1040	595	1550	1030
Night	1400	740	2665	1300
Whole period	1205	660	2050	1190

b) After renovation (N=20)

Time period	CO ₂ (ppm)			
	Average	Minimum	Maximum	Median
Day	1320	790	2210	1265
Night	1925	865	3575	1825
Whole period	1570	870	2770	1510

Table 3: AER before and after renovation, [6]

AER	Average	Minimum	Maximum	Median
Before renovation (N=20)	0.61	0.32	1.15	0.59
After renovation (N=20)	0.44	0.21	0.76	0.45

4. Discussion

Indoor air quality is a dominant contributor to total personal exposure because most people spend a majority of their time indoors [1]. The findings presented in this measurement campaign further support the conclusions of previous studies in Slovakia [2] that deterioration of indoor air quality follows energy renovations. In this study the implementation of the energy-saving measures was not combined with measures to improve the indoor environmental quality, which explains the lower AERs and higher CO₂ concentrations in the renovated buildings in the winter season.

5. Conclusion

A key goal of the implementation of an energy renovation strategy is to achieve the improved energy efficiency of buildings. However, the effect of these programs has not been systematically assessed. The effects on indoor air quality and well-being of the occupants is often ignored. There is an urgent need to assess the impact of the currently applied building renovation practices on the residential indoor air quality on a nationwide scale.

The big question is: how it will be from the year 2021, when all the requirements will be stricter than ever?

Acknowledgment(s)

This work was supported by the Slovak Research and Development Agency under the Contract No. DS-2016-0030, by the Ministry of Education, Science, Research and Sport under VEGA Grant 1/0807/17 and by VEGA Grant 1/0847/18.

References

- [1] Földvály V., Bekö G., Petráš D. (2014) Impact of energy renovation on indoor air quality in multifamily dwellings in Slovakia. Proceedings of Indoor Air 2014, Hong Kong, Paper No. HP0143. Arash Rasooli, Laure Itard, Carlos Infante Ferreira, "Rapid, transient, in-situ determination of wall's thermal transmittance," in *Rehva Journal*, vol. 5, 2016, pp16-20.
- [2] Földvály V., Bekö G., Petráš D. (2015) Seasonal variation in indoor environmental quality in non-renovated and renovated multifamily dwellings in Slovakia. Proceedings of Healthy Buildings Europe 2015, Eindhoven, Paper ID 242.
- [3] Földvály V. (2016) Assessment of indoor environmental quality in residential buildings before

- and after renovation. Doctoral thesis. Bratislava, Slovakia.
- [4] Sánka I., Földváry V., Petráš D. (2016) Experimentálne meranie CO₂ a intenzity výmeny vzduchu v bytovom dome. (Experimental measurements of CO₂ concentration and air exchange rate in a multifamily building) TZB-Haustechnik, Vol 25, pp. 46-49.
 - [5] Sánka I., Földváry V., Petráš D. (2017) Evaluation of Indoor Environment Parameters in a Dwelling before and after renovation. Magyar épületgépészet Vol, 65, pp. 29-33.
 - [6] Sánka I., Földváry V., Petráš D. (2017) Experimentálne meranie toxických látok vo vnútornom vzduchu pred a po obnove bytového domu. (Experimental measurements of toxic substances in a residential building before and after renovation) TZB-Haustechnik, Vol 26. 2/2017, pp. 32-35