Indoor Climate After Energy Renovation of Family house



ANNA PREDAJNIANSKA
Ing., Department of Building Services, Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Bratislava, Slovakia
predajnianska.anna@gmail.com

EVA ŠVARCOVÁ
Ing., Department of Building Services, Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Bratislava, Slovakia

DUŠAN PETRÁŠ
Prof. Ing., PhD, Department of Building Services, Slovak University of Technology in Bratislava, Faculty of Civil Engineering, Bratislava, Slovakia

The model renovation of typical family houses in Slovakia can help everyone who want to indulge in modern 21st century living with a healthy indoor environment even in an older house. This project is not only a source of inspiration. In addition to proven tips and practical advice from experts, it will also provide complete instructions for the reconstruction of a family home with an emphasis on healthy living.

Keywords: energy, renovation; family house; indoor climate, energy evaluation

The results of an international study entitled Healthy Home Barometer 2017 showed that every sixth Slovak is not satisfied with their housing. Slovaks are troubled by insufficient light conditions or excessive humidity causing mold. Up to 21% of Slovak households are not economically able to heat their house or apartment to a comfortable temperature. The speed of the renovation process in Slovakia is also insufficient. According to available statistics, there are more than 950 000 family houses in Slovakia, of which only 35% have been renovated. The renovation project of typical family houses has them ambition to change this unfavorable statistic. The model renovation for healthy living is intended to inspire Slovaks how they can renovate their house in a financially optimal way. At the end of the entire process, they will receive modern and healthy housing that takes into account parameters in three fundamental categories – quality of housing, impact on the environment and operating costs.

Family House Renovation

Family houses built between 1950s and 1970s had a typical square floor plan and material composition. At present, many of them are inhabited, but they do not meet today´s strict thermal technical requirements. Exterior walls were built without thermal insulation. The interior and exterior finishing of the walls, ceilings, and floors are in unsatisfactory conditions. Single or double windows with simple glazing were used in these houses. The ceilings were made of wooden beams. In many cases, the roof system is degraded by time, especially due to weather conditions.

The project documentation of these house was drawn by hand, as no drawing software was uses at that time (Predajnianska et al. 2021, 2022; Švarcová et al 2021). The original state of family house is showed in the **Figure 1.** Renovation of building structures is very important. However, it is not the only parameter that improves the energy efficiency of the building. A large share in the energy efficiency of building also plays building services. The new heat source in the renovated family house is a gas condensing boiler, which represents an excellent price-quality ratio. For domestic hot water preparation was used storage heat system with volume of 120 ℓ. Heating in the building is provided by radiators. Renovated family house is showed in the **Figure 2**.

Energy Evaluation

At the beginning of the project, several reconstruction variants were created for the family house. Each variant included different thicknesses of thermal insulation, or different heat sources. A detailed description of the various renovations will not be given. However, an energy evaluation was created for the various renovations which is given in **Table 1** and **Figure 3**. The aim of the energy evaluation is to compare the energy needed for the family house in different variants and after the renovation. As a part of the energy evaluation, the building is classified into classes based on the energy need for heating, energy need for domestic hot water preparation, energy need for ventilation or forced air extraction, total needed energy, primary energy and emission CO_2. The renovations were designed in such a way that it was possible to create a passive building that corresponds to class A1 in the classification system. The most demanding renovation was designed in such a way that it was possible to create a nearly zero energy building, which corresponds to class A0 in the classification system. The criteria to specific total energy use for different types and global indicator classification of buildings are defined in Regulation No. 364/2010 (Decree No. 625; Standard STN EN 15603/NA: 2012).

The results of the energy evaluation are summarized also in the following graph, in which it is possible to compare the individual energy needs within the various variants of the reconstruction of a family house. The graph clearly shows the huge difference between the energy required for a family house in its original state and the energy need for a family house after any proposed renovation.

Figure 1. Original state of family house in Šaľa. [Authors]

Figure 2. Renovated family house in Šaľa. [Authors]

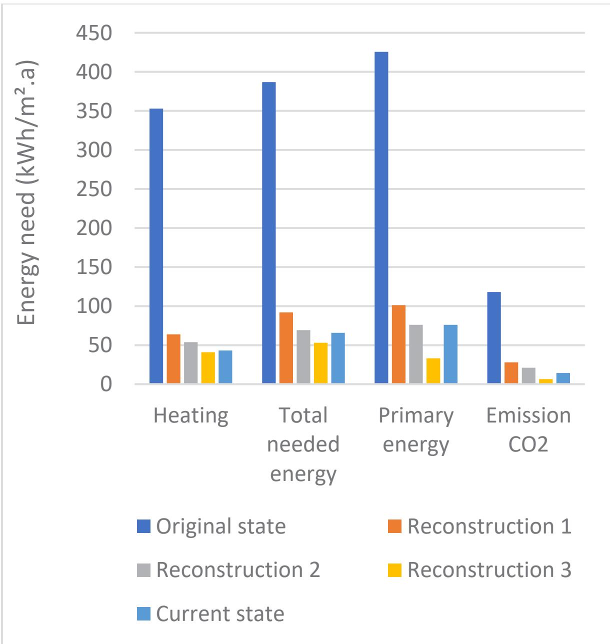

Figure 3. Energy needed based on energy evaluation. [Authors]

Indoor Climate Measurements

The model renovation for healthy living is intended to inspire Slovaks how they can renovate their house in a financially optimal way. The main criteria of the renovation project is the house that provides comfortable and healthy living which is affordable and repeatable. At the end of the entire process of the reconstruction of the family house, there is an increase on the living space to 115 m², an increase in energy savings of up to 80%, but above all a healthy living full of daylight and fresh air. Renovated family house has been occupied by a young family of four since September 2019. At the beginning of 2022, the stage of gathering experience with operation, monitoring and measuring key parameters began. These current measurements are ensured by the Department of Building Services at the Slovak University of Technology in Bratislava. With the consent of the family, measuring devices are currently installed in the family house, which record the interior temperature, CO_2 concentration and air humidity in every room. The measuring devices placed in the family house are COMET U3430. The data-logger measures and records the values in its internal memory. **Figure 4** shows the floor plan of the first floor, where an entrance hall, a bathroom, a kitchen a living room and a children's playroom are located.

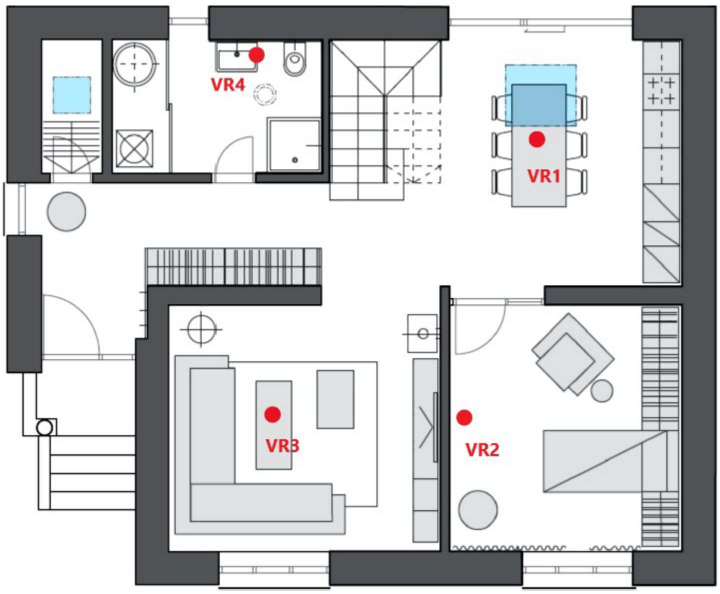

Figure 4. Measuring device's location in first floor. [Authors]

Table 1. *Energy evaluation of different types of renovation. [Authors]*

Variant	Energy need for heating	Energy need for DHW preparation	Energy need for ventilation	Total needed energy	Primary energy	Emission CO_2
	kWh/(m².a)	kWh/(m².a)	kWh/(m².a)	kWh/(m².a)	kWh/(m².a)	kg/(m².a)
Original state	353,0	34,0	0	387,0	425,7	117,92
	G (>258)	C (25-36)	Not evaluated	G (>258)	D (325-432)	-
Renovation 1	63,9	28,1	0	92,0	101,2	28,03
	B (43-86)	C (25-36)	Not evaluated	B (55-110)	A1 (55-108)	-
Renovation 2	53,7	15,4	0	69,1	76,01	21,05
	B (43-86)	B (13-24)	Not evaluated	B (55-110)	A1 (55-108)	-
Renovation 3	40,8	12,2	0	53,0	33,17	6,37
	A (<42)	A (<13)	Not evaluated	A (<54)	A0 (<54)	-
Current state	40,5	11,4	0	51,9	29,29	18,36
	A (<42)	A (<12)	Not evaluated	A (<54)	A0 (<54)	-

In addition to the corridor, there is a datalogger in each room, which records the mentioned values. The ideal location of datalogger is in the middle of the room, but this is not possible in all cases. The location of the dataloggers is adapted to the location of the furniture in the interior. It was also more than necessary to take into account the fact that the house is inhabited by a young family with children and the dataloggers should not disturb the comfort of residents.

On the second floor there is a bathroom, parent´s bedroom and children´s room. In these rooms, the comfort of the residents and the placement of furniture in the rooms were also taken into account. The location of the dataloggers is shown in **Figure 5**.

Results of Indoor Climate Measurements

The aim of the experimental measurements is to record the temperature, humidity and CO_2 concentration in the interior of a renovated family house and evaluate them. Measurement started in February 2022 and will run for two years. The values are recorded in the internal memory of the dataloggers COMET U3430. The recording interval is once per four hours. For the ongoing evaluation of the data, the measured quantities were taken from the memory of the dataloggers in the interval from February 2, 2022 to July 28, 2022. A two-week period from March 7, 2022 to March 21, 2022 was selected for the ongoing evaluation of the measured data. **Figure 6** shows the progress of air temperatures in each measured room. The indoor air

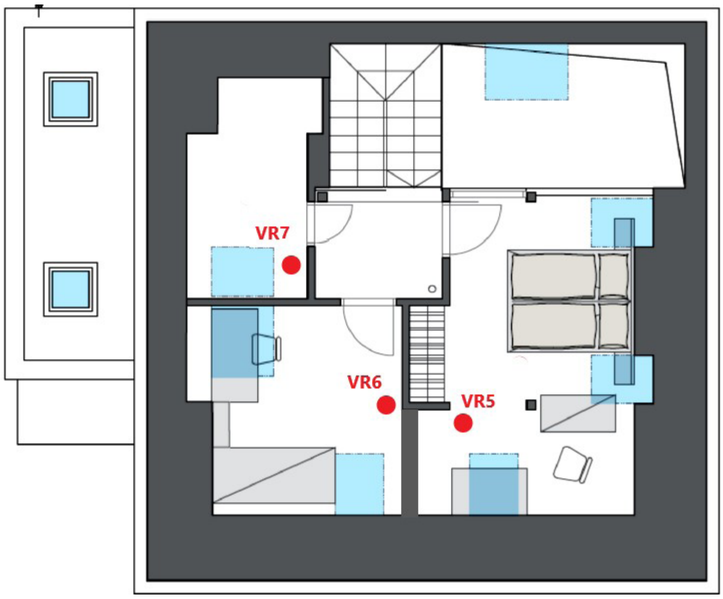

Figure 5. Measuring devices location in first floor. [Author]

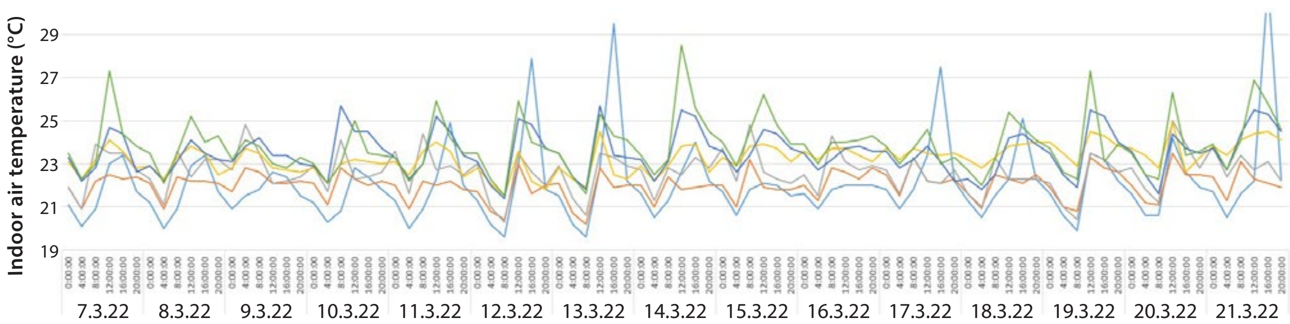

Figure 6. Indoor air temperature in each measured room. [Authors]

temperature ranged from 19 to 30°C. The drop in temperature to a lower value corresponds to the time when the room was naturally ventilated.

This corresponds also to the concentration of CO_2 at the given time, which is shown in **Figure 7**. It is clear that the object was regularly naturally ventilated, which corresponds to a regular decrease in CO_2 concentration. The last **Figure 8** shows the progress of air humidity in the interior of each measured room.

The following **Table 2** summarizes the minimum, average and maximum temperature, CO_2 concentration and air humidity in each room.

The datalogger VR2 in the children´s playroom did not work after two days from the start of the measurement. Therefore, data on temperature, humidity and CO_2 concentration in this room are unknown. After talking with the owners of the family house, information was found that this room is used very rarely.

Table 2. *Summary average temperature, CO_2 concentration and humidity [Author]*

Room	Device	Temperature (°C)			CO_2 concentration (ppm)			Humidity (%)		
		Min	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max
Kitchen	VR1	19,6	22,1	31,4	475	746	1113	12,8	34,8	46,8
Playroom	VR2	-	-	-	-	-	-	-	-	-
Livingroom	VR3	20,2	22,0	23,5	488	810	1399	26,8	34,8	43,9
Bathroom 1NP	VR4	20,3	22,6	25,0	494	706	1035	24,1	35,2	41,2
Bedroom	VR5	21,5	23,2	24,9	500	1141	1955	18,2	34,5	41,3
Children bedroom	VR6	21,4	23,5	25,7	445	869	1272	14,9	31,5	37,5
Bathroom 2NP	VR7	21,5	23,8	28,5	457	729	1162	20,3	31,5	43,8

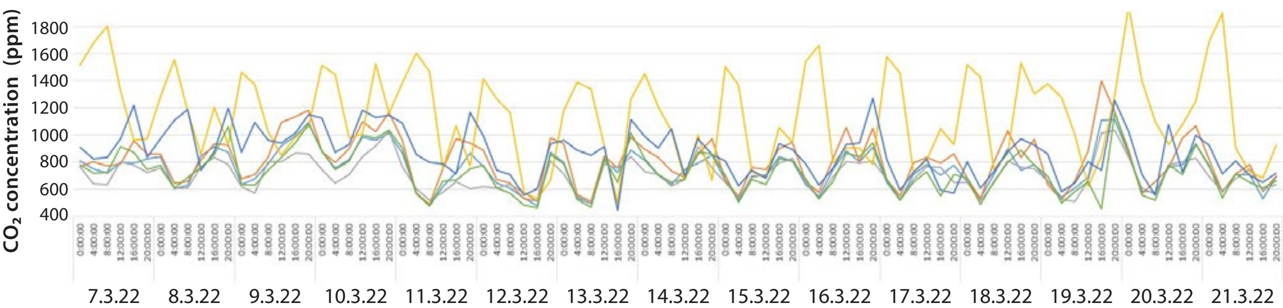

Figure 7. CO_2 concentration in each measured room. [Authors]

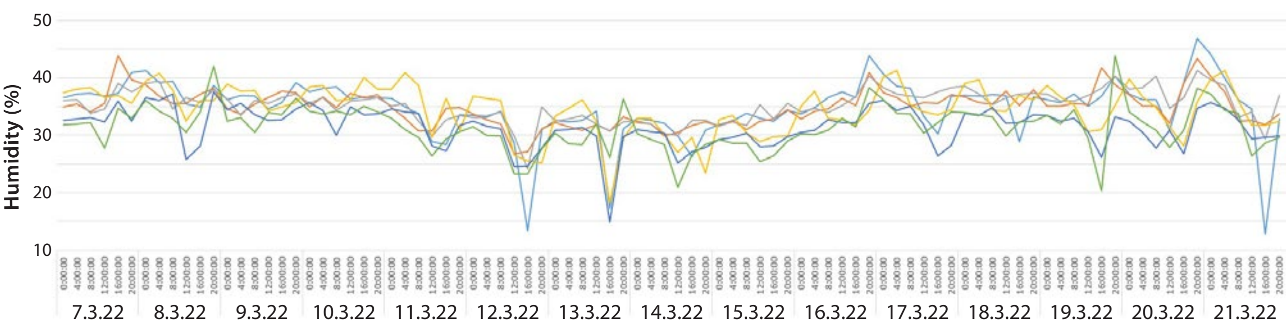

Figure 8. Humidity in each measured room. [Authors]

Conclusion

The original family house was in a desolate state and uninhabited for many years. Therefore, in such a case like this one, is not possible speak about a satisfactory indoor climate. Renovation of a family house should ensure satisfactory conditions for living in terms of indoor climate. Not only the renovation of building structures and technical equipment, but also the operation of the building has a great impact on the comfort in the building. Therefore, it is more than important that even the owners of the family home care about its quality. This is mainly connected with the ventilation of the building. In cooperation with Department of Building Services at Slovak University of Technology in Bratislava, measurements of the indoor climate of building are carried out. The interim results showed that thanks to the renovation of the building, the required indoor climate for the residents is ensured in terms of temperature, air humidity and CO_2 concentration.

You can find a square family house in almost every Slovak village. Most often in original condition. The owners are attracted by reconstruction, but they don´t know where to start. The RenovActive model renovation will help everyone who wants to indulge in modern 21st century living with healthy indoor environment even in an older house. Owners of typical square family houses, such as the one in Šaľa, can find the complete instruction on how to renovate the house and transform it into healthy and modern living. ■

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