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Indoor environmental quality evaluation in NZEB

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Abstract. The European Commission in 2010 accepted Energy Performance of Buildings Directive (EPBD) and the 2012 Energy Efficiency Directive (EED) are the main energy conservation legislative instruments for to reduce the energy consumption of new built and renovated buildings in Europe. The national regulation based on EPBD states that after the year 2016 only so called ultra-low energy buildings can be built. The next tightening in energy saving will come after 2021 (for commercial buildings after 2019), when only nearly zero energy buildings (NZEB) would be allowed to build. It means that these buildings must fulfil A0 category requirements by energy labelling.

But what about the indoor environmental quality in objects like this? This article shows results of indoor environmental quality measurement in NZEB building. Indoor air temperature, relative humidity, carbon dioxide concentration and air exchange rate had been measured. Except these parameters energy consumption from the grid and from the photovoltaic panel had been evaluated.

1 Intorduction

Most of the residential buildings in Slovakia that were built in the 20th century do not satisfy the current requirements for energy efficiency presented in the national building code. [1]

Nationwide remedial measures have been taken to improve the energy efficiency of these buildings and reduce their energy use [2].
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. provides 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.

The 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).

Installing a heat pump is an obvious solution, but there are several systems for heat sources. some of them are not so efficient at the other systems. For example, ground source heat pump (GSHP) and water source heat pump (WSHP) are more efficient than the air source heat pump (ASHP) systems. Except of these there are hybrid and reversible systems for heating and cooling.

However, since the impact of application these standards on indoor air quality is rarely considered, they often compromise indoor air quality due to the decreased ventilation and infiltration rate.

Indoor environmental quality (IEQ) refers to all aspects of the indoor environment that affect the health and well-being of occupants. This must include not only air

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quality but also light, thermal, acoustic, vibration, and other aspects of the indoor environment. With respect to the indoor environment, a healthy building is one that does not adversely affect the occupants. Some authors suggest that it should even enhance the occupants' productivity and sense of well-being to be considered healthy. Thus, it is not only the absence of harmful environmental characteristics but also the presence of beneficial ones that defines a healthy building. Thus, designers should begin by avoiding harmful elements and attempt to incorporate supportive, beneficial ones

The aim of the study was to evaluate the indoor environmental quality in a nearly zero energy building.

2 Building description

The investigated single-family house (Figure 1.) is located in Unterrabnitz, Austria. It was built in 2016 from modern materials with good thermal insulation parameters.
Three permanent occupants lived in the house, when the measurements were carried out.

Fig. 1. The evaluated single-family house

Mechanical ventilation system with heat recovery is installed in the building (Figure 2.) A ground source reversible heat pump had been used as a heat source, which is connected to the heating (floor heating) and cooling (ceiling cooling) system. There are installed Photovoltaic panel as well to cover the electricity use. (Figure 2.)

Fig. 2. Technical room of the building with the heat pump, storage tank and the mechanical ventilation system

3 Methodology

Two rounds of measurements had been completed. The first round of the indoor air quality and thermal environment measuremets was performed in ummer 2017 when the building was set up to cool the indoor environment. The second round had been performed in January and February 2018 in winter season.

Four rooms had been selected across the building, where measuring devices were installed:

- Vestibule
- Workroom
- Hall
- Bedroom

The same rooms were investigated in both winter and summer seasons over a period of 14 days where temperature, relative humidity and CO_2 concentration, were measured with the following devices.

- Vaisala carbocap GMP252 CO2 concentration sensor
- Vaisala GMD20 and GMW21/22 CO2 concentration sensor
- Vaisala HUMICAP HMP110 combined humidity and temperature sensor

Wireless sensor had been set up to see the real time data. This system saved the measured values every minute in all the evaluated rooms.
Except full time measurements three time periods were defined for the analysis:

- Full time measurements
- Work time
- Free time
- Night time

The data evaluation was carried out according to standards EN 15 251 and EN 7730 (the evaluation categories can be observed in Tab. 1).

Fig. 3. Measuring tree with the devices CO2, and thermal comfort connected to the wireless network

Categories I. and II. can be accepted according to the thermal environment standard, when the indoor air temperature is between 20-24 °C, while the relative humidity should be between 30 and 70 %.
In case of the indoor air quality the category I, II, and III can be acceptable. category IV can be not acceptable because of there is CO2 concertation higher than the limit, 1000 ppm

Table 1: Categories of evaluation.

	Temperature (°C)	**CO2 concentration (ppm)**
I.	**21-23**	**<600**
II.	**20-24 (except cat. I)**	**600-800**
III.	19-25 (except cat. I. and II.)	**800-1000**
IV.	<19 - >25	>1000

4 Results

In this section the indoor air quality analysis and the thermal environment evaluation results are presented room by room only from winter measurements.

4.1 Vestibule

The CO_2 concentrations did not exceed the limit value (Figure 4 and table 2). The thermal environment evaluation figure shows the occupants time distribution percentage in the evaluated room. In This case the residents spent their time only in cat. I and II.

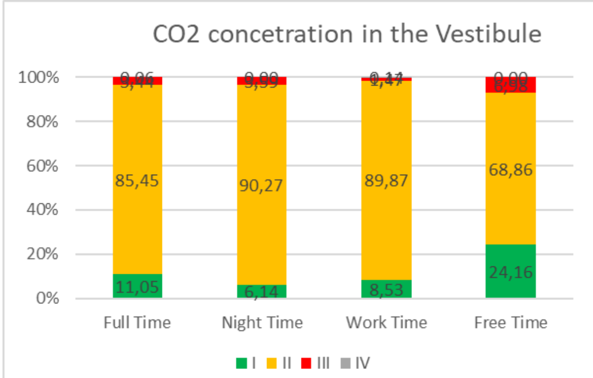

Fig. 4. CO2 concertation in Vestibule

Table 2: Vestibule table data – full time

Full time	Vestibule		
	CO2 (vent on)	T	RH
	(ppm)	(°C)	(%)
AVERAGE	**488,1**	**20,9**	**45,2**
MEDIAN	488,9	20,9	45,1
MIN	415,7	19,8	40,4
MAX	564,0	21,7	48,0

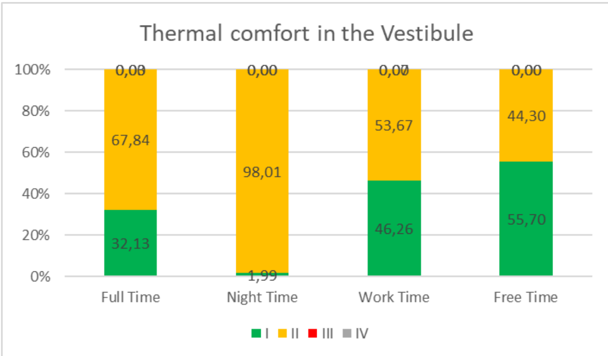

Fig. 5. Thermal comfort in Vestibule

4.2 Workroom

The CO_2 concentrations did not exceed the limit value in workroom either – category I and II (Figure 6 and table 3). The thermal environment evaluation figure shows the occupants majority of their time spent only in cat. I and II.

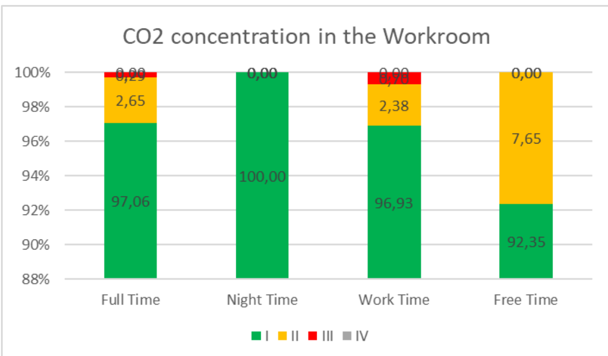

Fig. 6. CO2 concertation in Workroom

Table 3: Workroom table data – full time

Full time	Workroom		
	CO2 (vent on)	T	RH
	(ppm)	(°C)	(%)
AVERAGE	429,5	22,1	34,0
MEDIAN	420,6	21,5	33,9
MIN	334,3	20,4	27,5
MAX	717,2	30,7	44,3

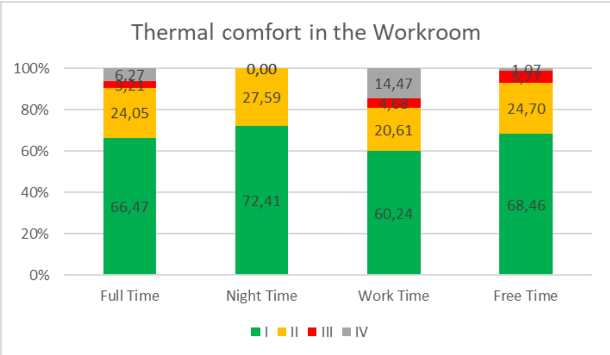

Fig. 7. Thermal comfort in the Workroom

4.3 Hall

The CO_2 concentrations did not exceed the limit value in hall either – category II. (Figure 9 and table 4). The thermal environment evaluation figure shows the occupants mainly spent their time in category I.

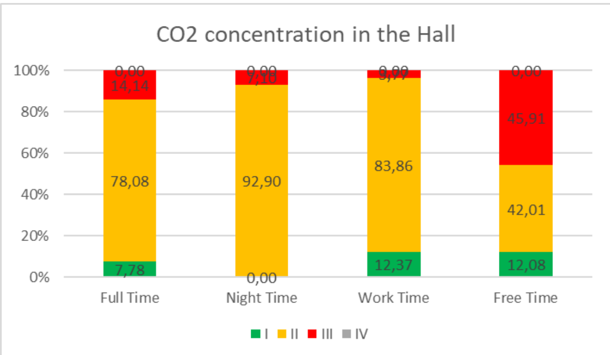

Fig. 8. CO2 concertation in Hall

Table 4: Hall table data – full time

Full time	Hall		
	CO2 (vent on)	T	RH
	(ppm)	(°C)	(%)
AVERAGE	**587,8**	**22,6**	**42,8**
MEDIAN	581,6	22,0	43,2
MIN	403,6	21,1	30,9
MAX	928,7	32,6	50,9

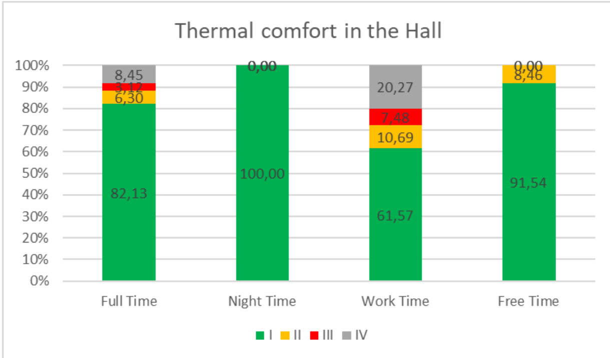

Fig. 9. Thermal comfort in the Hall

4.4 Bedroom

The CO_2 concentrations did not exceed the limit value in bedroom during night time. The maximum measured value was 819 ppm. The average in night time was 520. During the full time measurements some peeks were find, but the maxim value did not exceed 1300 ppm (Figure 10 and Table 5 and 6). The thermal environment evaluation figure shows the occupants mainly spent their time in category II during full time and night time measurements, only 11% of the time was spent in cat. III during night time (Figure 11).

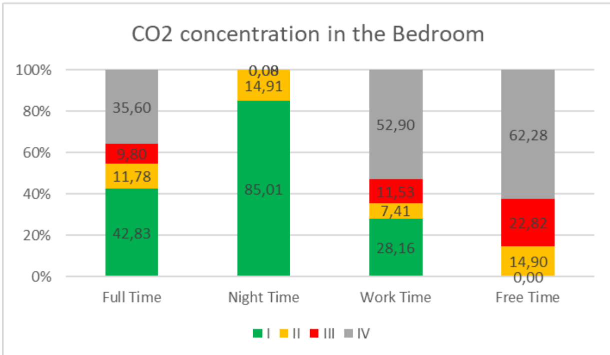

Fig. 10. CO2 concertation in Bedroom

Table 5: Bedroom table data – full time

Full time	Bedroom		
	CO2 (vent on)	T	RH
	(ppm)	(°C)	(%)
AVERAGE	**795,1**	**20,4**	**43,5**
MEDIAN	692,2	20,5	43,7
MIN	427,8	19,3	36,7
MAX	**1292,3**	21,7	49,6

Table 6: Bedroom table data – night time

Night time	Bedroom		
	CO2 (vent on)	T	RH
	(ppm)	(°C)	(%)
AVERAGE	**520,0**	**20,6**	**41,7**
MEDIAN	496,2	20,7	41,9
MIN	437,5	19,3	36,7
MAX	819,6	21,7	47,0

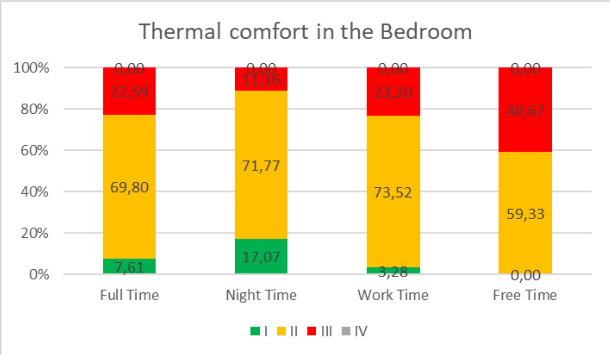

Fig. 11. Thermal comfort in the Bedroom

5 Discussion

Summarized results of indoor environment quality in the single-family house with three occupants, evaluated in four rooms in winter season showed the following.

Thermal comfort in the evaluated rooms in full time measurements mainly ranged between categories I and II. In the bedroom some peeks had been measured during daytime. There the category distribution was: 8% cat. I, 70% cat. II, 22% cat. III– for full time measurements. The average temperature was 20,4 °C for bedroom in winter season, which is acceptable.

The indoor air quality for the evaluated rooms is the following: Vestibule 11% cat. I, 85% cat. II and 4% cat. III. In the workroom the occupants can spend 97% of their time in cat. I and 3% in cat. II. In the hall the percentage distribution is 8% cat. I, 78% cat. II and 14% cat. III. In the Bedroom for full time the results showed 42% cat I, 10% cat. II, 12% cat. III and 36% cat. IV, while the average is 795 ppm. In night time the results are 85% cat. I and 15% cat. II with average 520 ppm. This amplitude during daytime can be explained with the air flow regulation of the mechanical ventilation system, which can be easily set to provide higher air flow when its needed.

6 Conclusion

Indoor air quality is a dominant contributor to total personal exposure because most people spend a majority of their time indoors [7]. The findings presented in this measurement campaign further support the conclusions of previous studies [2][3][4] that mechanical ventilation helps set up a healthier and more comfortable indoor environment.
The study showed that to the building (full time measurements) provided fresh air (average CO2 concertation below 600ppm) and thermal comfort parameters shows 22,5°C in the whole building
Lots of studies have also attributed this phenomenon that the new built buildings are very tight. This can cause indoor environment quality problems, which primary lead to sick building syndrome. Mechanical ventilation system and modern environmental technology can insure the proper indoor environmental quality. The validation of the results on a larger sample size is warranted. The study is ongoing, and additional results will be available in the near future.

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