Nearly Zero Energy Buildings as a Standard of 21st Century – Velux RenovActive

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Abstract. Most residential buildings in Slovakia, built in the 20th century, do not meet current requirements for energy efficiency. Therefore, nationwide remedial measures have been taken to improve the energy efficiency of these buildings and reduce their energy consumption. That is why Velux has created a RenovActive project to make this possible. The goal of renovations is to ensure today´s strict conditions for the energy consumption of buildings and thus achieve nearly zero energy buildings. In this article, we focused on the reconstruction of an old family house, which was built in 1960. The family house has been uninhabited for decades and was in a desolated state. We created three different options of reconstruction for the family house, each with different materials and technical equipment. Part of the article is also a comparison of the need for energy in each variant of reconstruction. We also processed a comparison of investment costs required for individual variants. The article also describes the current state of the family house. Currently, the house is inhabited by a young family and measurements of the basic quantities of internal well-being take place in the house. The aim of this project was to turn an old family house into a nearly zero energy building and ensure the required internal well-being at the level of 21st century.

Keywords. Family house, RenovActive, energy evaluation, nearly zero energy building.
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1. Introduction

The recast the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) was approved by the Parliament and the Council at the end of 2009 and contains number of changes. An important one is that as of 31 December 2020, all new buildings in the EU will have to consume "nearly zero" energy and the energy should to a significant extent be covered from renewable sources [2]. Kurnitski et al. (2011) outlined this general definition of a nearly zero energy building (nZEB): „A nZEB is typically a grid connected building with very high energy performance. nZEB balances its primary energy use so that the primary energy feed-in to the grid or other energy network equals to the primary energy delivered to nZEB from energy networks. Annual balance of 0 kWh/(m2.a) primary energy use typically leads to the situation where significant amount of the on-site energy generation will be exchanged with the grid." Before the nearly zero energy building type was defined in the EPBD, several commercial low energy building types had been defined in Europe. Some of them were so successful that they had been fully or partially implemented into national legislations. The overview of the low energy building types and their state of definition per 1 January 2010 is shown in Table 1.1. One particularly successful low-energy building type is a so-called Passive house, characterized by an extremely low specific energy demand. The passive house can be defined as a building, for which thermal comfort can be achieved solely by post-heating or post-cooling of the fresh air mass, which is required to achieve sufficient indoor air quality conditions – without the need for additional recirculation of air [1].

One of the prerequisites so that the building can be qualified as a nearly zero energy building is very low energy consumption for heating. This should be achieved by an excellent level of thermal insulation and an excellent air tightness to decrease heat losses by transmission and infiltration, resulting in a very low energy need for heating. To evaluate the whole heating system, and not only the level of thermal insulation of the building envelope, heat losses and auxiliary energy for the technical systems need to be added to the energy need for heating. The resulting energy performance indicator is called the energy use. If the calculation methodology follows the rules of energy certification as defined in the Regulation 364/2012 Coll., the heating system can be classified in one of the energy efficiencies classes A to G.

The same classification system applies for the energy use for domestic hot water (DHW). The total energy use for a building presents the sum of all energy uses for the respective building technical system. For apartment buildings, only space heating and DHW are considered, for other buildings also lighting and if applicable ventilation and cooling must be included. The criteria on the specific total energy use for different types of buildings as defined in Regulation 364/2012 Coll. are shown in Tab. 1. The total energy use is calculated by a simple summation of the energy need and energy losses of the heat emission and distribution systems [1].

Tab. 1 – Energy classes to classify the total energy use [1, 10].

Energy performance classes	Family houses	Apartment houses	Office buildings
A	≤54	≤40	≤58
B	55-110	41-79	59-115
C	111-165	80-119	116-166
D	166-200	120-158	167-218
E	221-275	159-198	219-272
F	276-330	199-237	273-327
G	>330	>237	>327

The generation efficiency and renewable sources are considered in the delivered energy, which is defined as the energy content, expressed per energy carrier, supplied to the building through the system boundary, to satisfy the uses considered (heating, cooling, ventilation, DHW, lighting, appliances etc.) or to produce electricity [11].

This delivered energy is a necessary input to calculate the primary energy, which is the global indicator and presents the energy that has not been subject to any conversion or transformation process. The primary energy is calculated using primary energy factors, which are given at the national level and vary for different energy carriers. The scales of primary energy classes are shown in Tab. 2 [1].

Primary energy presents the global indicator that serves for the overall classification of the building. Until the end of 2015, the minimum requirement on the overall energy performance of new buildings, as expressed by the global indicator, was the upper boundary of the energy class B.

The minimum requirement on energy performance (global indicator) of new buildings built after 31 December 2015 was the upper boundary of the energy class A1. After 31 December 2018, new public buildings, and after 31 December 2020 also all other new buildings must fulfil the requirement of class A0 for the global indicator. Energy class A0 represents the nearly zero energy level of the building energy performance [1].

Tab. 2 – Energy classes to classify the primary energy [1, 10].

Energy performance classes	Family houses	Apartment houses	Office buildings	
A0	≤54	≤32	≤60	
A1	55-108	33-63	61-120	
B	109-216	64-126	121-240	
C	161-324	127-189	241-360	
D	325-432	190-252	361-480	
E	433-540	253-315	481-600	
F	541-648	316-378	601-720	
G		>648	>378	>720

2. Typical family houses in Slovakia

There are more than 900,000 family houses in Slovakia. About 100,000 of them were built in the 1950s to 1970s. These family houses have a typical square floor plan, almost identical layout, and material design of internal and external structures. From the point of view of the rising standards and requirements for thermal insulation and energy performance requirements of buildings, these family houses are not in satisfactory and needs reconstruction [2, 3, 4, 5, 6, 7, 8]. Some typical houses are shown in Fig. 1.

Fig. 1 – Sample of the family house in Slovakia built in the 1950s and 1970s [2, 3, 4].

Family houses built between 1950 and 1970 had a typical square floor plan and material composition. At present, many of them are inhabited, but they do not meet today´s thermal-technical requirements. 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 floor is degraded by time, especially due to weather conditions. The project documentation of these family houses was drawn by hand, as no drawing software was used at that time. A sample project documentation can be seen on Fig. 2.

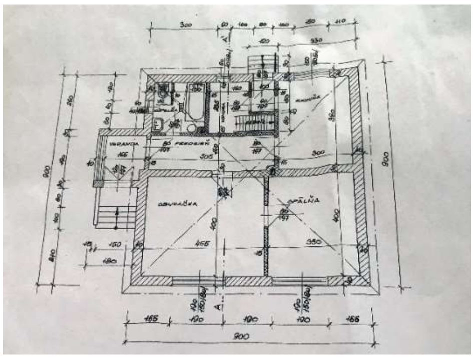

Fig. 2 – Layout of the family houses in Slovakia built in the 1950s to 1970s [2, 3, 4].

These family houses do not meet the energy efficiency requirements of buildings, which are currently very strict. According to the regulations, buildings with almost zero energy demand are required. Therefore, it is necessary to renovate unsuitable family houses. In this article, we will introduce an exemplary reconstruction of a family house, which applies to most of the family houses built between 1950 to 1970.

3. Renovation of a representative family house

The biggest disadvantage of the old family houses is that they were not thermally insulated due to the requirements at the time. The first step in reconstruction is to ensure building modifications in the form of a change in layout, changes in the material design of walls and ceilings. Due to the thermal-technical requirements valid today, thermal insulation of external constructions is required. The original simple windows, which have only minimal insulation ability, need to be replaced by modern window. We are talking here about plastic, plastic-aluminium or wooden windows, which have good thermal insulation properties and are secured with insulating glass. Tab. 3 shows two possibilities of renovation of family houses. The first renovation met energy performance requirements that complied with the values valid after 2016. With this reconstruction, it would be possible to achieve an ultra-low-energy building. The second renovation meet energy performance requirements that have been in force after 2020. With these requirements it is possible to ensure nearly zero energy building. Of course, there are many other ways of renovations. It is important to maintain the thickness of the thermal insulation so that the building meets today´s building conditions with almost zero energy consumption. This step precedes a satisfactory energy evaluation of the building. Heating system, DHW preparation system and other building environment technology positively contribute to achieving a satisfactory energy evaluation of the building.

Tab. 3 – Summary of renovations details [9].

	Renovation 1	Renovation 2
Thermal-technical evaluation regarding values valid after year	2016	2020
Windows, doors	Plastic-aluminium or wooden windows with insulating glass	Plastic-aluminium or wooden windows with insulating glass
Thermal insulation of external walls	160 mm	180-250 mm
Thermal insulation of the roof	320 mm	380-400 mm
Thermal insulation of the floor	120 mm	120 mm
Heating system	Gas condensing boiler, floor heating, control based on climate	Heat pump air-air, photovoltaic panels, and solar collectors on the rooftop
Domestic hot water preparation system	Storage heating system of DWH	Storage heating system of DHW
Ventilation	Natural	Natural, Hybrid
Heat recuperation from exhaust air	No	Yes
Fireplace	Yes	Yes

4. Energy evaluation of buildings

As part of the energy evaluation, the building is classified based on energy demand for heating, DHW, mechanical ventilation and cooling, also based on total energy demand, primary energy, and CO2 emissions. The result of the energy evaluation of previous renovations are summarized in Table 4. The table also shows the energy evaluation of the original condition of the house before renovation. Within the total energy demand, the building falls into class G which represents circa 387 kWh/(m2.a). The primary energy classifies the building into class D which represents almost 426 kWh/(m2.a).

Tab. 4 – Results of energy evaluation of two levels of house reconstruction [9].

	Original state	Renovation 1	Renovation 2
Space heating (kWh/m².a)	353,0 G(>258)	53,7 B(43-86)	40,8 G(<42)
DWH preparation (kWh/m².a)	34,0 C(25-36)	15,4 B(13-24)	12,2 A(< 13)
Total energy demand (kWh/m².a)	387,9 G(>258)	69,1 B(55-110)	53,0 A(< 54)
Primary energy (kWh/m².a)	425,7 D(325-432)	76,0 A1(55-108)	33,2 A0(< 54)
Emission CO_2 (kg/m².a)	117,9	21,1	6,4

It is clear from the results of the energy evaluation that the renovation has a positive effect on the energy intensity of the house. For comparison, we see that the primary energy indicator improves sharply. The first renovation shifts the house to the energy class A1, which is an ultra-low-energy building. With the second renovation, it is possible to attain energy class A0, which is a nearly zero energy building.

5. State of family house before and after renovation

Before the renovation of the family house, an architectural competition was launched, in which several architectural studios participated. In the second round of the competition, the architects presented their studies, and the commission unanimously determined Architectonic Studio Ddak as a winner of architectural competition. The design of the reconstruction preserves the current expression of the family house, but nevertheless the reconstruction improves the quality of life in the house in an economical and feasible way. The architecture of the family house is very fine and clean lines predominate. Neutral colours for exteriors and interiors were chosen. State of the house in exterior before and after renovation are showed in Fig. 3 and Fig. 4.

Fig. 3 – State of the house before renovation [2, 3, 4].

Fig. 4 – State of the house after renovation [2, 3, 4].

A wooden terrace was built in the garden of the family house. Part of the terrace is in interior and is made as a wooden building. The second part of the terrace is exterior with a pleasant sitting area. The family house is an ideal home for a family.

Fig. 5 – View of the family house from the garden before renovation [2, 3, 4].

View of the family house from the garden before and after renovation can be seen in Fig. 5 and Fig. 6.

Fig. 6 – View of the family house from the garden after renovation [2, 3, 4].

A significant renovation also took place in the interior of the family house. The degraded truss was removed and a new one was built. This creates a residential attic and two children´s rooms and a bathroom.

In the residential attic, wooden columns have been preserved, which are part of the truss, which elegantly fits into the architecture of the house. The old degraded wooden truss and new children room created in residential attic can be seen in Fig. 7 and Fig. 8.

Fig. 7 – The old degraded wooden truss before renovation of the house [2, 3, 4].

Construction work on the project was completed in July 2019. To the family moved into the house in September 2019. Over the next years, key parameters will be measured in cooperation with the Department of Building Services of the Slovak University of technology in Bratislava to verify the functionality of the renovated house. The unfavourable pandemic situation currently does not allow us to install measuring devices in the family house and record the necessary key values needed to assess the indoor climate of the renovated space.

Fig. 8 – Children´s room in new residential attic [2, 3, 4].

6. Conclusion

A large part of houses and other buildings in Slovakia was built between the 1950s and 1970s. These buildings do not meet today´s strict criteria, either of the energy efficiency of buildings or the quality of the indoor environment. By increasing the energy efficiency, it is possible to ensure that less energy is needed to provide the service.

Increasing energy efficiency not only allows individuals and organizations to reduce capital and operating costs and can also reduce fuel consumption. It can reduce greenhouse gasses emissions and thus preventing climate change. Almost two-thirds of countries still do not have any energy regulations in place. This contribution showed the possibility of obtaining a building with an ultra-low-energy or ever nearly zero energy demand for a 50-year-old building. This was achieved through modern thermal insulation, space heating, DHW, and ventilation technologies [9]. This home managed to breathe a second life. We will also pay attention to the urgent need to renovate other houses in Slovakia by creating healthy and energy-efficient and affordable homes that bring a healthy indoor environment to their users.

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Data Statement

The results of the energy assessment o the buildings were created by the authors who are part of the RenovActive project. The output data is published with the consent of Velux, which covers the project.

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