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Section: Energy for Buildings

# Nearly Zero Energy Building (nZEB) in Latvia

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**Abstract**

The main question studied during this study was what does it takes conversion of conventional building built according minimum energy efficiency requirement by existing building code to nearly zero energy building (nZEB). The aim of this study is to work out technical requirements to reach nZEB level in Latvia and test them in real building project.
Real energy consumption data and indoor climate conditions have been analysed to understand building energy performance after construction. At the moment no official low energy building guidelines exist how to reach very low energy standard in Latvia climate conditions. This study also helps to identify challenges and future development needed for building components to reach nZEB level.

**Keywords:** Nearly Zero Energy building; energy modelling; energy and indoor climate monitoring.

## 1. Introduction

Building regulations have been developed setting requirements for nearly zero energy building definition as European Parliament set targets that all new buildings in EU must be nearly zero energy by 2020 [1]. There are different definitions what has bee understood by term nZEB. In general and now most widely used definition of nZEB is given by Energy Performance of Buildings Directive (Directive 2002/91/EC,EPBD) and nZEB is defined as building that has a very high energy performance and that energy required should be covered to a very significant extent by renewable energy sources. In many cases net zero energy building term is used. Word "Net" is used what appoints a balance between taken energy from the energy grids and supplied back over a period of time indicating the idea of energy-efficient systems and insulation materials of building to lower heating and electricity demand combined with renewable energy systems like solar thermal and photovoltaic (PV) systems for space heating and covering hot water productions [2], [3], [4]. Acquisitions from each option depend on characteristics of building and conditions, however currently on-site options are accepted in most cases because of possibility to cover energy consumption of building by a significant part of renewable energy [5], [6]. The most common renewable on-site technologies for reaching net zero energy goal are photovoltaic (PV) and solar thermal panels in combination with other technologies like ground source heat pumps [5], [6], [7]. However dependency only on on-site solar energy in the northern Europe deals with obstructions like mismatching between the energy production and consumption [8], [9] and the restricted area of roof and façade [9]. Abundance of local energy variables like biomass in Finland serves as a solution, where it can be used for micro and small-scale biomass-based combined heat and power (CHP) systems and can even reduce dependency on on-site solar energy [10]. In Denmark considering the dense city areas, weather conditions and a large number of wind turbine co-ops, the solution for optimal energy could become off-site renewable energy supply options [5]. In addition analysing current price levels for renewables like PV installation it is considered that investment in energy efficiency is more cost-effective than investment in renewable technologies [11]. It is harder to reach Net ZEB level by renovation than by transposing efficient technologies in new buildings however some examples like multi-family social house building in Montreuil (France, built in 1969) which has been renovated in 2001 fulfils the passive house standard [12]. Innovative technologies can help to improve energy efficiency like improvement of insulation, implementing phase change materials, establishment of innovative shading devices, use of advanced sensors, zone heating and cooling and monitoring systems in order to improve energy performance level [7]. Different techniques reduce energy from economy perspective and optimize cost performance of ZEBs (around 20 $kWh/m^2a$ in Denmark) [5]. Even when elaborating building design to accomplish net-zero energy level in technical effectiveness it is not verified that it can also gain effectiveness of economic resources. [2], [13], [14].

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Current Latvian building codes LBN 002-01 set minimum requirements for U-values of building components and building airtightness. There are no clear guidelines what U-values and what technologies should be used in Latvia to achieve nZEB level. The aim of this study was to find out what does it takes to redesign conventional building built according minimum energy efficiency requirement by existing building code to nZEB level. The requirements for building envelope and ventilation were defined by help of energy modelling. After that single-family house has been designed, build and achieved results measured.

## 2. Climate data

Climatic data play a significant role in building energy consumption therefor good understanding of climate conditions is very important. Latvian climate is characterized by cold climate with very mild summer temperatures. The yearly average temperature is typically around +6 °C. Usually heating season is 211 days long with average temperature +0,4 °C and minimum design temperature – 21 °C. The software Meteonorm and Latvian building code LBN 003-01 was used to generate climate date for energy calculation. In the Figure 1 monthly average values of the outside temperature and solar irradiation on the horizontal as well as on the four main sky directions – north, east, south and west are showed.

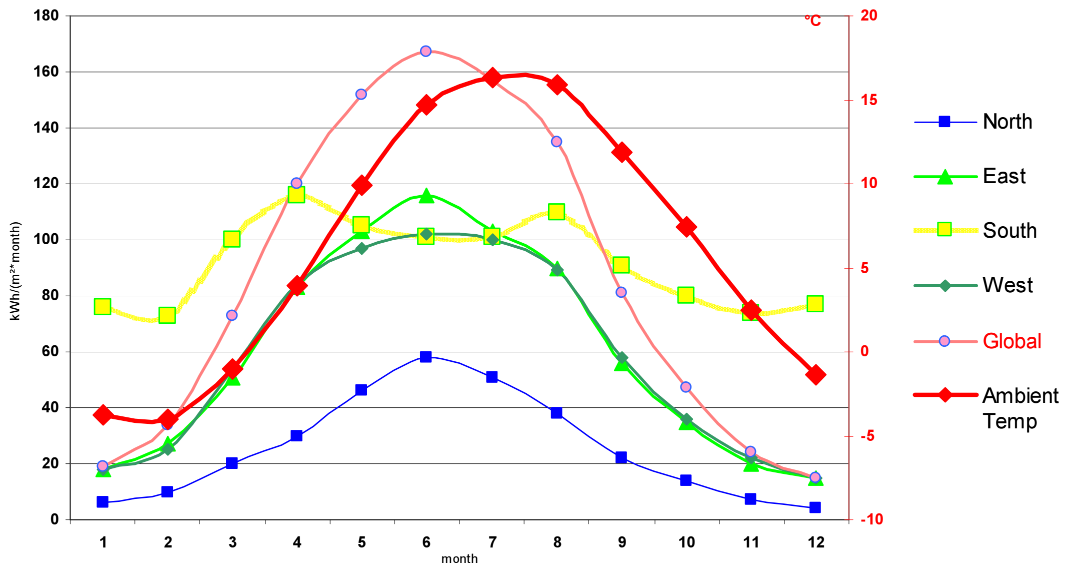



Fig. 1. Climate date

Intensity of the annual available solar irradiation is between 900 and 1000 kWh/m$^2$, which is comparable with other north European cities, like Stockholm (<1000 kWh/m$^2$), Oslo (<900 kWh/m$^2$) and similar to Copenhagen.

## 3. Design and calculations

In the beginning building was designed according to the requirements Latvian legislation in terms of energy efficiency. The main characteristic of the building:

- Building Type: Two storey single family house
- Location: Latvia, Gipka
- Architect: Ervīns Krauklis, "Krauklis Grende" Ltd
- Heated floor area : 191 m²
- Renewable energy used : PV panels
- Ventilation: "Paul" Thermos 300 recuperation system
- Heating and hot water: "Vaillant" heat pump

The building was redesigned to reach very low energy performance level by using PHPP (Passive house planning package) energy calculation programme. Building design followed the main design principles of the very low energy building [15]:

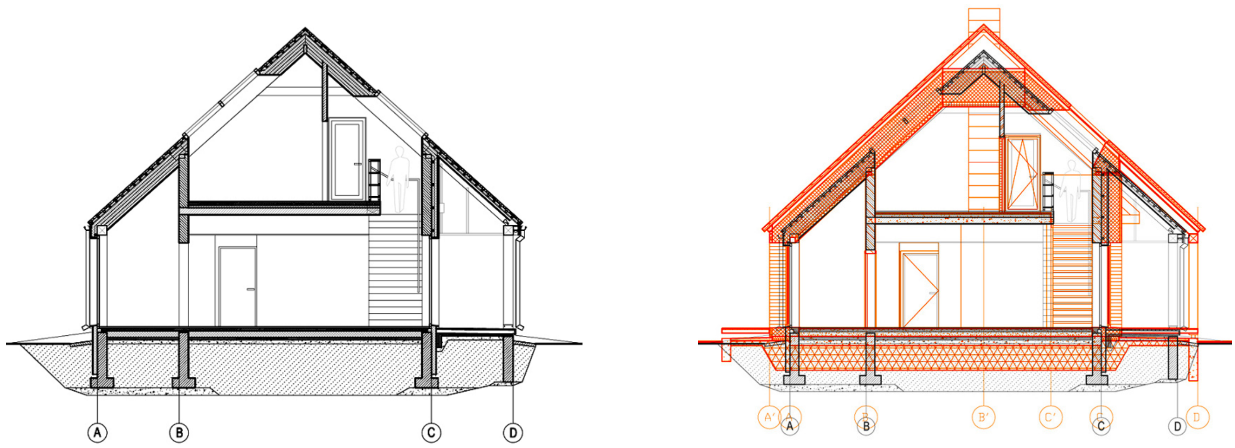
- Minimise losses and consumption;
- Optimise gains;
- Substitute the remaining energy need with environmental friendly energies.

The changes needed and difference between minimum requirements of existing building code LBN 02-01 and nZEB are summarized in Table 1.

Table 1. Building elements

| Building elements | Conventional building | defined nZEB values |
|---|---|---|
| Roof U value, $W/(m^2K)$ | 0.194 | 0.05 |
| Walls U value, $W/(m^2K)$ | 0.291 | 0.06 |
| Ground floor U value, $W/(m^2K)$ | 0.242 | 0.1 |
| Windows U value, $W/(m^2K)$ | 1.745 | 0.8 |
| Ventilation | Natural ventilation 0.3 $h^{-1}$ | 0.3 $h^{-1}$<br>Effective Heat Recovery Efficiency 85% |
| Infiltration $n_{50}$, $h^{-1}$ | 0.93 | 0.43 |

During building redesign process many important solutions for walls, foundation, and roof structures had been found. Elements were carefully redesigned, insulation thickness was optimized, mitigation and minimising of thermal bridging were done. The redesigned building to achieve nZEB performance level shown in Figure 2.



a) building according Latvian building code

b) Redesigned building to achieved nZEB level

Fig. 2. Building cross-section

Two different energy calculation programmes were used for energy calculation to define changes needed:

- PHPP 2007 (passive house planning package);
- TRNSYS 16 simulation program (Transient System Simulation Tool);

With help of PHPP and TRNSYS calculation tools building energy consumption was calculated to optimize building envelope insulation thickness and to define technical requirements what should be fulfilled to reach nZEB level. It was not possible to change building orientation, building shape and building aesthetics. Connection details were designed to eliminate thermal bridges and to assure building airtightness. Construction was made to minimize thermal bridges. According PHPP 2007 calculation space heat consumption for conventional building is 127 $kWh/(m^2a)$ and for building redesigned according passive house concept 33 $kWh/(m^2a)$ with means 75% of savings of heat each year. The real energy consumption has been evaluated during first heating season.

## 4. Measurements and monitoring

To understand real building performance the work for this study includes energy and the indoor climate data monitoring. Monitoring consisting of the following long term measurements:

- Indoor air temperature in all rooms of the building;
- Outdoor air temperature;
- Relative air moisture in the living room and bedroom;
- Level of $CO_2$ in the bedroom;
- Start up and shut down of ventilation equipment’s antifreeze circulation pump;
- Heat consumption for heating and hot water.

Blower door test was carried out for the construction (see Fig. 3) to clarify important elements like building air tightness and thermal bridges.

a) Blower door test during construction

b) Blower door test after construction works

Fig. 3. Blower door test during and after construction works

First Blower door test shown very good results $n_{50} = 0.43\ h^{-1}$ with were used for space heat calculation. After all works during the heating season second blower door test where conducted and with showed worse results $n_{50} = 0.81\ h^{-1}$. The results are summarized in Figure 4

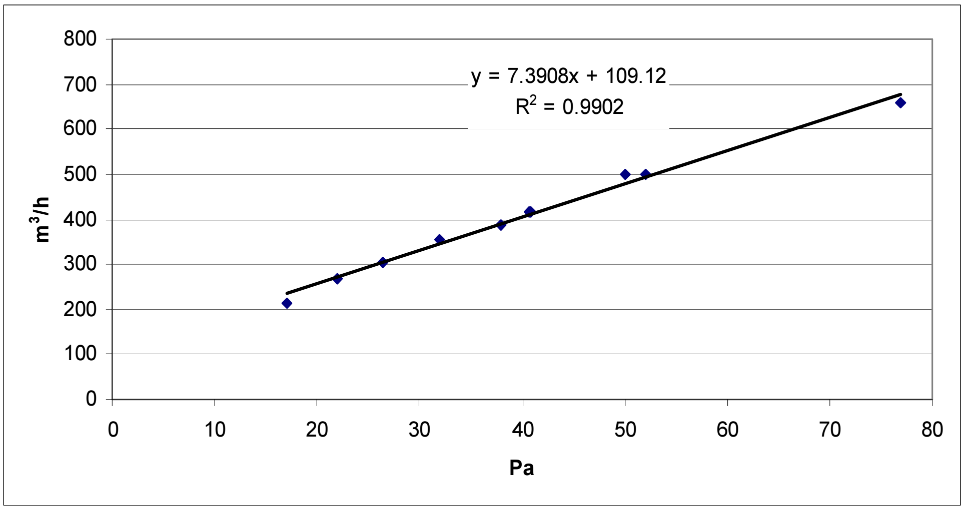



Fig. 4. Blower door test results

During Blower door test fan is used to blow air in or out of the house. Figure 4 shows pressure difference between inside and outside and y axes shows flow through the Blower Door fan. Blower Door test has been used to measured airtightness of a building. According to the existing Latvia building code 002-01 for the airtightness calculation the results obtained at 50 Pa are used. Pressure as 50 Pa is chosen to minimize stack-induced airflow and wind-driven airflow effects.
The results where calculated according Eqn (1).

$$n_{50} = \frac{V'}{V_N} = \frac{499}{619} = 0.81,\ h^{-1}, \tag{1}$$

where,
$V_N$ – building volume;
V' – fan output ($m^3$/h).

Consumed heat energy was measured with help of heat energy meter. Since the amount of used energy for heating depends from outdoor and indoor temperatures, these temperatures were monitored during heating season. For measurements HOBO loggers where used see Figure 5.

a) Temperature logger

b) $CO_2$ and relative humidity logger

Fig. 5. Temperature and $CO_2$ measurements

For the measured energy consumption data to be comparable with calculated data, they were adjusted, assuming that climate conditions are uniform and the indoor temperature t = +20 °C. Adjusted energy consumption data are shown in Figure 6 on a monthly basis.

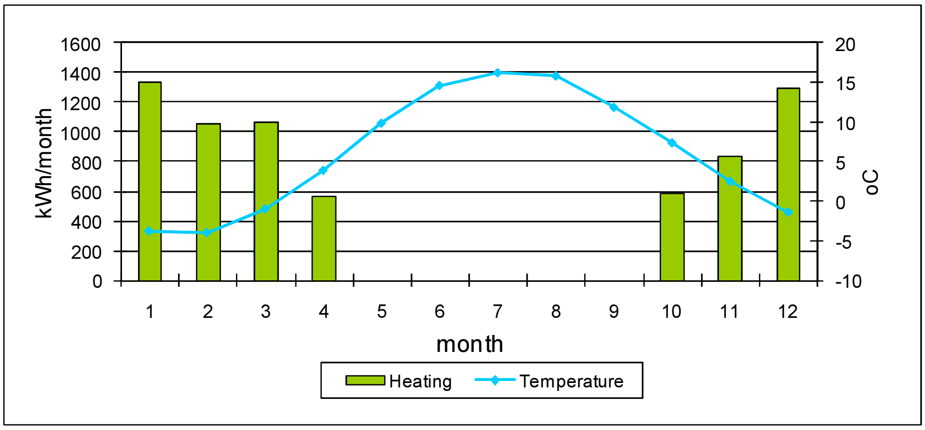



Fig. 6. Adjusted energy consumption data per month

The total energy consumption for the building in 2010 was 6719 kWh, or 35 kWh/m$^2$ a. In Figure 7, calculation results of the model are compared with measured data and data from the dynamic model.

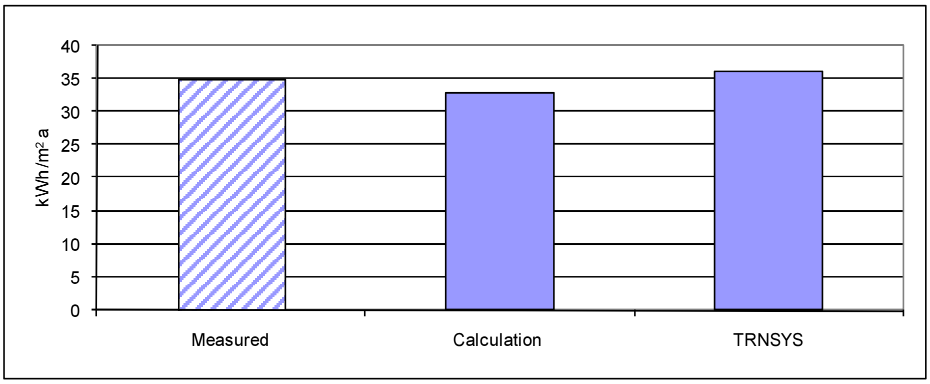



Fig. 7. Comparison of energy consumption – measurements versus calculations

As is shown in the Figure 7, the calculated energy consumption accurately represents energy consumption in the building. Weather normalization of energy consumption data have been done to compere them with calculated data during design phase.

## 5. Results from monitoring and conclusions

First real nZEB have been build according passive house design principles in Latvia. Work conducted for this study includes measurements of energy consumption data and of comfort decision criteria from Latvia's first nZEB. Measurements proved that it is possible to build a private house (heating area 191 m$^2$) in Latvia whose energy consumption for heating does not exceed 35 kWh/($m^2$ a). According to the passive house design principles heating should be provided only with ventilation what limits the heating peak load to 10 W/$m^2$. From experience gained during design and construction of the one of the first nZEB in Latvia it seems very hard to meet required peak load (<10 W/$m^2$) in case of small single family houses with reasonable effort and costs, based on an internal heat gains 2,1 W/$m^2$. We see that to achieved nZEB performance level better windows should be developed and used in cold climates. Some problems have been detected with roof windows and windows where PV cells are mounted.

The following technical indicative properties could be used for Latvian climate to reach nZEB performance level:
- walls, roof, coverings <0.08 W/($m^2$×K);
- windows <0.65 W/($m^2$×K);
- mechanical ventilation with heat recovery >85%;
- building air tightness $n_{50}$ <0.4 $h^{-1}$;
- maximum utilization of solar energy in a passive manner;
- maximum compactness.

To develop cost effective nZEB in Latvia future research and development are needed:
- Airtight and well insulated doors;
- User friendly low temperature heating systems;
- Low costs widows and window installation systems;
- Low costs and user friendly indoor climate and energy consumption monitoring system;
- Sealing and airtightness products;
- Low costs high efficiency recuperation and ventilation systems with simple control;
- Inexpensive automatic external shading systems.

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