Design and implementation of nZEB buildings in Poland. Building certification.

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Abstract. The article will discuss the design and construction aspects of nearly zero-energy buildings (nZEB) in Poland. It is the newest building standard introduced by the Directive on the energy performance of buildings 2010/31 / EU. The directive made the implementation of nZEB buildings compulsory in European countries. The article will present analyzes of the energy performance of nZEB buildings, in accordance with Polish legal requirements, and discuss the possibility of achieving this standard in terms of economic efficiency. An important issue is also the certification of newly designed buildings, allowing the promotion of buildings with more restrictive parameters than the minimum energy efficiency requirements specified for nZEB buildings. In the article, the authors will present the developed methodology for certifying buildings in Poland, based on the requirements related to energy efficiency, and on in situ testing of buildings. The article will also present examples of building certification in Poland.

1. Introduction
In January 2021, the standard of building nearly zero-energy buildings (nZEB) came into force in the European Union. The requirement to build this type of buildings is an implementation of the guidelines of the Directive on energy performance 2010/31 / EU [1]. Designing and implementing nZEB buildings is a very big challenge for all participants of the investment process, including manufacturers and suppliers of construction products and technologies, as well as for building designers and contractors. The directions of the climate and energy policy, preventing the degradation of the natural environment, supporting the protection of natural resources and biodiversity, are one of the most important challenges resulting from the provisions adopted by the Member States of the European Union. During international meetings [2][3][4] representatives of countries submit further declarations of reducing energy consumption in the economy, increasing energy production from renewable energy sources or striving to be zero-emission in sectors of the economy. The decisions taken are the result of the depletion of natural energy resources and the deterioration of the quality of the natural environment. One of the sectors of the economy with the highest energy consumption rates is construction. in the Communication entitled "European Green Deal" [5] it is responsible for around 40% of total energy consumption in the Union. This sector is developing very dynamically, which leads to a further increase in energy consumption and environmental pollution. Actions taken so far and further guidelines also translate into the implementation of the provisions of the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Lower energy consumption and the use of energy from renewable sources also have a positive impact on increasing the security of energy supplies, economic development and, above all, on our health and safety. Another important aspect is to ensure the quality of the environment in which we live [6][7]. The main documents in the field of improving the energy
efficiency of buildings are the Directive on the energy performance of buildings 2002/91 / EC[8], 2010/31/UE [1] and 2018/844/UE [9].

A breakthrough for the construction industry was the obligation of EU countries to introduce a new energy standard for buildings. The national legislation introduces the concept of a nearly zero-energy building (nZEB) which, according to the directive, means a building with very high energy performance. The nearly zero or very low amount of energy required should come to a very high degree from renewable energy, including renewable energy produced on site or nearby” [1]. Pursuant to Art. 4 and 5 of the directive [1] and a delegated act issued on its basis [10] minimum requirements for the energy performance of buildings must be defined by each member state at a level that is optimal in terms of the total cost of the building, ranging from investment costs, running and energy costs to disposal costs (Figure 1).

![Figure 1. The idea of setting minimum requirements for the energy performance of buildings at the optimal level from the point of view of the total cost of the building; based on [10]](image)

In the 2018 amendment to the Energy Performance Directive [9] further goals for the construction industry have been adopted, which include:
- integration of long-term building renovation strategies;
- stimulating the use of ICT and intelligent technologies to ensure the efficient use of buildings;
- simplification of regulations when they did not bring the expected results.

energy-efficient conduct.

The revision of the Energy Performance of Buildings Directive also aims to provide financial incentives to combat energy poverty through building renovation [11].

2. Implementation of Directive 2010/31 / EU to Polish legislation

The implementation of the provisions of Directive 2010/31 / EU on the energy performance of buildings, the Directive, in terms of determining a new energy standard for buildings, defined above as nZEB, was carried out by amending the regulation on technical conditions to be met by buildings and their location in the section on energy efficiency of buildings and thermal protection (Technical Conditions). The requirements for energy efficiency have been formulated in the form of an obligation to meet the condition of not exceeding the permissible value of the EP index, which determines the annual computational demand for non-renewable primary energy and, at the same time, ensuring the required thermal insulation of individual building envelopes as well as wires and components in installations.

Figure 2 shows the tightening energy efficiency regulations for buildings from 2014 up to the nZEB minimum requirements in 2021 for the non-renewable primary energy (EP) index for heating, ventilation
and domestic hot water. The red dots indicate how much EP requirements have changed between 2014 and 2021 in Poland.

![Figure 2. Partial values of the EP index for the needs of heating, ventilation and preparation of domestic hot water; based on [11][12]](image)

In order to meet the requirements of nZEB buildings, it is necessary to increase the energy from renewable sources to supply the building with heat, cold and electricity. Figure 3 and 4 shows the development of heat pumps and PV panels on the Polish technology market. Figure 3 shows the development of the heat pump market in 2010-2019 by type of heat pump, while Figure 4 shows the increase in electricity production from PV micro-installations in 2010-2019.

![Figure 3. Growth of the heat pump market in Poland in 2010-2019. PORT PC source; based on [13]](image)
Figure 4. Annual energy production from PV micro-installations; based on [14]

3. Certification of newly designed buildings

3.1 Energy efficiency of buildings.
Meeting the minimum requirements for the energy efficiency of buildings, set out in the Polish document [13] is not enough. Buildings with even better energy performance should be promoted. Additionally, the Polish requirements only specify the level of minimum requirements for primary energy (EP) and for heat transfer coefficients through partitions. It is equally important to ensure low energy consumed by the building, determined by the parameters of Usable Energy (EK) or Final Energy (EK). Final energy is heat and auxiliary energy that must be supplied to the boundary of the heating system (building) with a given efficiency in order to meet the demand for heat useful for space heating and ventilation and necessary for living, hygienic and household needs. The value of the final energy is characterized, among others, by the quality of thermal protection of rooms, thermal insulation, tightness of the entire external housing and the technical condition of the installations supplying the building with heat and cold. The value of the final energy [kWh / (m2year)] was determined in accordance with the methodology included in the regulation [16], as EK index - denoting the annual final energy demand per unit area of rooms with regulated air temperature in a building or a dwelling, expressed in kWh / (m2year). The EK index was determined according to the formula (1).

\[
EK = \frac{QK}{Af}
\]  
(1)

where:

\(QK\) - annual demand for final energy supplied to the building or part of the building for technical systems [kWh / year],

\(Af\) - area of rooms with regulated air temperature (heated or cooled area) [m2].

Polish regulations [11] do not provide minimum requirements for the EK indicator. This indicator relates directly to the energy efficiency of buildings.

3.2. The quality of construction of buildings
An important aspect of assessing the energy efficiency of a building is also the quality of workmanship. Even the best-designed building may, due to faulty construction, be a building with poor energy
efficiency parameters. Here, the only way to check the building standard are the so-called "in situ" tests, ie tests during the use of an already completed building. The tests "in situ" confirming correctness or performance include the following tests:

- thermovision examination, allowing the detection of thermal bridges. Thermal imaging is based on the registration of infrared radiation emitted by building partitions. The test registers places of increased heat flux flow (thermal bridges). The test is performed in accordance with ISO 18436-7 [17].

- building envelope tightness test for air permeability, allowing for checking and detection of imperfect places in the building envelope, through which there is uncontrolled heat leakage from the building. In order to improve the quality of the results obtained by the leak test, this test is often combined with a thermal imaging test. The building envelope tightness test is performed in accordance with the EN 9970 standard. Polish legislation does not impose any obligation to perform tightness tests on buildings - they are only a recommendation. For suggestions on tightness, see [13]. For buildings with gravity ventilation, the value of the index n50 ≤ 3 [1 / h] at the level of n50 ≤ 3 [1 / h], and for buildings with gravity ventilation at the level of n50 ≤ 1.5 [1 / h]. Passive buildings should have a coefficient value of n50 ≤ 0.6 [1 / h]. The n50 index means the number of air changes in a given cubic capacity of the building at a pressure difference of 50 [Pa].

- tests of the actual heat transfer coefficient U, thanks to which we can assess the thermal insulation of the partition.

3.3. Comfort of use of buildings
In addition to energy efficiency, nZEB buildings should be characterized by high comfort of use and the quality of the internal environment. Providing adequate thermal comfort in NZEB buildings is one of the most important elements in the design and implementation of buildings [15] [16][17].

Many factors influence the comfort parameters of buildings. The criteria for the comfort of building use can be presented in Figure 5.

![Comfort criteria](image)

**Figure 5.** The Criteria Considered in Designing nZEB

3.3.1. Thermal comfort. The methodology for determining thermal comfort is based on the standard [18] The measurement methodology is based on the standard [19]. The device for measuring thermal comfort shown in Figure 6.
3.3.2. Comfort of using the rooms. Lighting comfort. The lighting comfort test methodology defined by the minimum illuminance values is given in the PN-EN 12464-1 standard [20]. The minimum illuminance values given in the standard are operational illuminance values and meet the needs of lighting comfort and visual performance.

3.3.3. Comfort of using the rooms. Vibration comfort. In many cases where buildings are located near highways, railways or in areas at risk of earthquakes, vibration comfort is an important aspect.

Vibration records obtained from monitoring were used for human perception evaluation according to RMS procedure available in [21].

3.3.4. Comfort of using the rooms. Acoustic comfort. Measurement process consisted of obtaining sound level in room. Procedure based on literature is also acceptable for requirements check in polish standard [22] and European standard [23].

4. Certification of newly designed buildings

The first Polish certificate of energy-efficient buildings, which promotes buildings with parameters better than the minimum requirements contained in Polish regulations, defining the nZEB building, is the certificate developed by the Małopolska Center for Energy-efficient Construction, a unit of the Cracow University of Technology together with partners: Małopolska Laboratory of Energy-Saving Construction, National Energy Conservation Agency and Polish Academy of Sciences (Institute of Mineral and Energy Economy). Scientists and experts took into account the regional climatic conditions and defined guidelines that should be met by such a building in order to be considered energy-efficient, healthy and environmentally friendly.

The MCBE PK certificate is the first Polish certificate of energy-efficient buildings that meet the assumptions of the Polish definition of buildings with almost zero energy demand. The MCBE certificate is based on the following assumptions: the building must be energy-efficient - it will bring financial benefits for the Investor through lower operating costs, it must be well implemented, without errors, therefore MCBE experts will participate with the Investor during the construction process, providing their advice, the building must have good microclimate and good indoor air quality, i.e. to be a healthy and comfortable place where we spend most of our lives, and finally to be friendly to the external environment, thus contributing to the protection of nature [24].
Companies and investors in Poland, by designing and building buildings that will obtain the MCBE Certificate, have a chance to be not only leaders of European trends in the field of energy-saving construction, but also ambassadors of improving the quality of life [17] [25] [26] [27].

The MCBE certificate, apart from the Primary Energy assessment, is also based on the Utility Energy assessment of the building. This allows the actual energy needs of the building under assessment to be assessed. An important element of the certification of buildings in accordance with the MCBE Certificate are "in situ" tests that allow to realistically determine the energy efficiency of a building and comfort of use. Among the “in situ” tests defined in the building assessment are the building performance tests: thermovision, tightness testing of the building envelope and testing of the actual heat transfer coefficient of partitions. The tests confirming the comfort of using buildings include tests of thermal comfort, tests of the concentration of airborne organic compounds. Acoustic, lighting and vibration comfort tests can also be carried out as additional tests.

5. Examples of buildings certified by the MCBE Certificate

Figure 7 shows the first building of the Małopolska Laboratory of Energy Efficient Building certified with the MCBE Certificate.

Other the best examples of MCBE certified buildings are:
- Central Sports Center in Zakopane. A + class.
- Sports hall in Tarnów. A + class.
- Building on the water. A + class.

6. Results and discussions

As a result of the work of scientists from the Krakow University of Technology, the National Energy Conservation Agency and the Polish Academy of Sciences, a multi-criteria building assessment system was created based on the principles of sustainable development, energy conservation and user comfort. There are also other LEED or Bream assessment systems on the international certificate market. However, the MCBE Certificate is simple and quick to assess the buildings. The interest in the construction market in the MCBE Certificate confirms its effectiveness.
7. Conclusions
Both new and thermo-modernized buildings should be designed not only to reduce energy, but also to ensure comfort and health for the user. It is also important that the building minimizes the impact on the environment in which we live. Building certification is very helpful in achieving these goals.

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