Marek Grymin
Łódź University of Technology, Faculty of Civil Engineering, Architecture and Environmental Engineering
al. Politechniki 6, 90-924 Łódź, m.grymin@gtarch.pl

PERSPECTIVES FOR DEVELOPMENT OF ENERGY EFFICIENT CIVIL ENGINEERING

Abstract
The aim of this paper is to introduce energy-saving civil engineering, to demonstrate the need for energy conservation, and to radically change the principles of building. The paper then shows the importance of the principle of sustainable development and acquaints the reader with the objectives of the European Union and its basic documents concerning measures to improve energy and climate protection standards in buildings. This paper presents the research programs and standards for the certification of buildings and housing estates inscribed in the principle of energy efficient civil engineering and sustainable development. Examples of low-energy buildings from Germany and Austria are shown, with an emphasis on the principles of designing passive buildings. A vision of the future of architecture and civil engineering is presented using examples of innovative buildings and settlement structures designed based on energy saving and energy management.

Key words
energy-efficient civil engineering, sustainable development, low-energy buildings, energy certification

Introduction
Living Planet Report WWF is one of the most important publications on the state of nature and the influence of civilization on it. It represents the ecological state of the planet and the greatest dangers associated with the deterioration of the natural environment and the impact of human activity on the state of nature on Earth. The basic conclusion of the report is that man consumes more natural resources than Earth can provide. This leads to living with an "eco mortgage", using the resources that should remain for future generations. The main producers of waste and energy are cities [1], where 80% of the population in Europe now lives and a significant proportion of the populations of North America and Asia. In the past half century, there has been an unprecedented growth of great agglomerations, and trends for the coming years predict their further growth [2].

The basis of the concept of sustainable development is included in many documents, such as the Brundtland report, the Agenda 21 materials, the Earth Summit documents, and the Kyoto Protocol. The foundations for the concept of sustainable development were formulated during the works of the Commission for Environment and Development established in 1987 at the UN [3]. Based on the conclusions from the Commission meetings, its chairman, Gro Harlem Brundtland, presented the report "Our Common Future", also called the Brundtland Report. It drew attention to the need to leave some of the resources to future generations. This report led to the convocation in 1992 in Rio de Janeiro of the so-called Earth Summit. Agenda 21, which was developed during the summit, contained many important elements, including the necessary role of science, industry, technology and business in the support of sustainable development [4]. The Agenda also includes a note on urban planning aspects. Earth Summits also took place in Johannesburg (2002) and in Copenhagen (2009). For the European Union, the 2007 adoption of the Territorial Agenda of the European Union became an important document, assuming the reinforcement of ecological structures. The Kyoto Protocol in 1997 played an extremely important role in the reduction of the energy consumption of the economy. It included a commitment for the states ratifying it to reduce greenhouse gases to 5% by 2012. It is obvious that it must also result in reducing energy consumption in the construction industry as well. It was introduced, albeit to a limited extent, only in 2005.

Key Documents concerning sustainable development and low-energy construction
The principles and practices of promoting low-energy construction in EU Member States are set out in EU documents. The first of them was created in 2002 [5] and referred to the energy characteristics of buildings [6]. In 2008, the European Parliament adopted a very important package of climatic laws, referred to as the "3x20 Package", resulting from the commitments signed in Brussels in September 2007. These documents identify three very important elements of the Member States' ecological policy [7]. First, they call for a 20% reduction in energy consumption, such as that from existing and newly designed buildings. Second, they call for a 20% increase in energy consumption from renewable sources. Third, they highlight the need for 20% less CO_2 emissions by 2020.

This has led to the introduction of new legislation that tightens the policy on energy efficiency in buildings. In May 2010, the European Union Parliament and the Council adopted the amended Directive "Energy Performance of Buildings" [8]. In addition to other changes, it introduced the notion of a building with almost zero energy consumption. This standard should be disseminated until 2020 [9].

Sustainable development in the provisions of the Constitution of the Republic of Poland and its acts

The principle of sustainable development has a constitutional record in Poland: "The Republic of Poland protects the independence and inviolability of its territory… it preserves the national heritage and ensures environmental protection, guided by the principle of sustainable development".

This principle has also been recorded in other documents such as the the Spatial Planning Act [10], in which "Art. 1. 1. The Act specifies the principles of spatial planning policy shaping by territorial self-government units and government administration bodies, and the scope and manner of dealing with land use issues for specific purposes and establishing the principles of their arrangement and development, assuming spatial order and sustainable development as the basis of these activities. "

The Environmental Law Act [11] states in "Art.1.2. In planning and spatial planning, particular consideration is given to:

1) requirements for spatial order, including urban planning and architecture;
2) architectural and landscape values;
3) environmental protection requirements, including water management and protection of agricultural and forest lands. "

Tradition/history based on the example of the Lemko homestead

Many of the solutions used in today's low-energy construction have their roots in history. An example of a rational building project that attempts to minimize energy losses and maximize solar energy gains is the Lemko homestead (grażda). The living area is surrounded from the east, west and north through by utility rooms, all windows face the south, and the far-reaching ventilation hood limits the overheating of the interior of the chambers during the summer [12].

Norma – The norm; Max wartość współczynnika przenikania ciepła – Max. Value of the heat penetration coefficient; Dla ścian zewnętrznych – For external walls; Dla stropodachu – For the flat roof; Dla poddasza – For the attic; Dla okien – for the windows; Obecnie – At present; Dla różnych stref klimatycznych – For different climate zones

Overview of the energy standards in force in the second half of the 20th century

Over the past half a century, the value of the permissible U factor has been changed several times. The data is presented in the table below.

Table 1. Value of the permissible U factor

NORMA	MAX WARTOŚĆ WSPÓŁCZYNNIKA PRZENIKANIA CIEPŁA U [W/m²K]			
	DLA ŚCIAN ZEWNĘTRZNYCH	DLA STROPODACHU	DLA PODDASZA	DLA OKIEN*
PN-57	1,16	0,87	1,16	-
PN-64	1,16	0,87	1,05	-
PN-74	1,16	0,70	0,94	-
PN-82	0,75	0,45	0,40	2,0-2,6
PN-91	0,55-0,70	0,30	0,30	2,0-2,6
Obecnie	0,30-0,50	0,30	0,30	2,0-2,6
*dla różnych stref klimatycznych				

Source: taken from: [13]

In a noticeable way, it affected the energy consumption indicators.

Table 2. Indicative annual energy consumption indicator

Budynki budowane w latach – Buildings built in the years; do 1967 – up to 1967; po 2009 – after 2009; Orientacyjny wskaźnik zużycia energii cieplnej – Orientational indicator of heat energy consumption; Bez zmian – No change

Budynki budowane w latach	Orientacyjny wskaźnik zużycia energii cieplnej (kWh/m^2 • rok)
do 1967	240–350
1967–1985	240–280
1986–1992	160–200
1993–1997	120–160
1998–2008	90–120
po 2009	Bez zmian

Source: taken from: [14]

The beginnings of energy efficient construction

The term of energy-efficient or low-energy home started to appear in the 1970s during the first oil crises. At that time, the search for alternative sources of energy began. Special attention was paid to the possibility of using solar energy in civil engineering. The first passive house, created based on this revised approach to energy consumption, was built in 1990 in Darmstadt, Germany [15].

The issue of buildings' *Life Cycle* (LCA)

By analyzing the issues of low-energy construction in the context of the principle of sustainable development, one cannot overlook the issues of the full life cycle of a building. It starts at the design stage and goes on in the initial stages of construction, when the materials necessary for its realization are obtained, through the construction process itself, and the subsequent operation of the building, and the demolition and recycling of the remaining construction waste [16].

Green construction

In the context of the sustainable development principle and life cycle of the building, it is worthwhile to get acquainted with other programs and certifications included in the sustainable development program. A whole range of research programs were launched in the 1990s [17]. Apart from the problems of energy efficiency, sustainable development issues were of great importance [18].

Certification of buildings included in the principles of sustainable development (i.a. LEED, BREAM, DGNB)

LEED is the world's most widely recognized certification system. In the certification processes, the most important parameters for sustainability examined are energy savings, rational water consumption, CO2 emissions, improvements to the indoor environment, and subsequent management of resources. The full life cycle of the building is also taken into consideration. This standard was developed by the US Green Building Council. LEED is a universal certification system that is applicable to almost all types of buildings [19].

BREEAM is a building quality assessment system developed in the UK based on a wide range of different criteria. It considers many features of the building, including the quality of the internal environment, energy efficiency, transport accessibility, the materials used and the construction method used, the course of the construction, operation of the building, water management and waste management. The BREEAM certificate is awarded by BRE (Building Research Establishment Global). To achieve a high level of certification, it is desirable for the project team to collaborate with the BREEAM certification team as early as the building concept stage.

DGNB, or Deutsches Gutesiegel Nachhaltiges Beuen, has been under development since 2008 by the German Association for Sustainable Development and the Federal Ministry of Transport. This certification system also includes all relevant elements that address the issues of sustainable development and energy efficiency in civil engineering. The final result of certification is influenced by six criteria: ecology, economics, socio-cultural aspects, function, applied technical and technological solutions, localization factors.

The typology and definitions of energy saving buildings [20]

Energy-efficient building

In Poland, an energy-efficient building is assumed to have a seasonal demand for energy for heating and ventilation purposes that does not exceed kWh/m^2 per year**.** This is the so-called 7-liter building (7l heating oil/m^2 of heated space per year). A low energy building has a seasonal demand for energy for heating and ventilation purposes that does not exceed 30 kWh/m^2 per year. This corresponds to the so-called 3-liter building (3l heating oil/m^2 of heated space per year).

Near zero energy building (nZEB)
"Nearly zero energy building" means a building with a very high energy performance, specified in accordance with Annex 1 to the Directive. Nearly zero or very low energy requirements should mainly come from renewable energy sources, including renewable energy produced locally or in close vicinity *Article 2, item 2 of Directive 2010/31/EU.* It is assumed that it is a building in which the demand for primary energy is Ep = 0 kWh/m^2 per year [21].

Zero energy building
This building is considered to be self-sufficient in terms of energy [22].

Passive building
Aaccording to W. Feist's definition from 1988, a passive building has extremely low interior heating energy demand (15kWh/m2/year), where thermal comfort is ensured by a passive heat source and heating of the air ventilating the building [23].

According to the Passivhaus Institut Darmstadt [24], the five main principles for passive housing are very good heat insulation, windows that let more energy in rather than out of the interior, a structure without cold bridges, tight coating of the building, and daily ventilation with effective heat recovery.

Certification programs for housing complexes and cities
As is the case for individual buildings, since 2009, housing complex groups can also be certified. The certificate awarded in such a multi-criterion evaluation process is a sign of quality and usually has a significant impact on the positive image of the housing complex. The most commonly used housing complex certification systems are LEED for Neighborhood Development Rating System and BREEAM COMMUNITIES.

Passive construction - the standards and history in selected countries (Germany, Austria)
The first pioneering passive house construction took place in Germany. The first four-room passive building was erected in 1991 in Darmstadt, in the district of Kranichstein, according to the architectural concept, which was authored by three architects: prof. H. Bott, K. Rider, H. Westermeyer. This project was created under the supervision of Dr. W. Feist. That moment marked a change in the approach to the energy efficiency of buildings. Initially it covered the designs of simple single-family houses, with more and more individualized architectural forms over time (e.g. the wooden rowhouse in Darmstadt, built in 2003 by G. Zielke). Gradually, other types of buildings were included, such as the schoolhouse in Frankturt, Architekten 4a, 2004 and multi-family buildings (e.g. the passivization of the block in Freiburg, 2009). Passive construction developed especially dynamically in Austria. The first building was erected in Vorarlberg in 1996. In 2002, there were already over 100 passive houses, in 2007 over 1000, and in 2011 over 10,000. At the same time, multi-family housing was developing. By 2011, more than 21,000 flats conforming to passive house standards were built in the country. In 2011, the construction of the passive Eurogate housing estate in Vienna also started. Apart from residential buildings, many schools, kindergartens, office buildings and cultural centers are being built there in this standard. This standard predominates in public construction.

The correctness of passive house designs is ensured by the methodology developed by the Passive Building Institute in Darmstadt and assumes design data is related to energy efficiency, obtaining energy and energy requirements, and their verification. This package also allows for energy assessment and certification of buildings.

"The Passive-On Project for selected European countries"
The program was aimed at promoting passive houses in selected European countries, especially in temperate and warm climate countries. It allowed to formulate design guidelines for the design of passive objects. A demonstrative version of the house design package is included in the program's web site. It allows for tracing the factors

that are important for improving their energy standard. Below, with a brief commentary, the most important elements of determining a passive house standard are presented [25].

- building spatial figure: striving for maximum compactness;
- orientation: optimal - south;
- shade: impact of neighboring buildings, high greenery, terrain shape;
- buffer zones: intermediate spaces, ensuring a reduction in heat loss;
- thermal mass: materials with high heat capacity allow for temperature regulation;
- passive cooling: the use of night/day temperature differences and the use of soil temperature;
- partition insulation: minimizes heat loss; [26]
- tightness: hitherto often overlooked element - essential for achieving a high energy standard and avoiding condensation;
- thermal bridges: an underestimated element, in addition to the heat losses, they result in the formation of mold and the risk of destruction of structural components;
- efficiency of household appliances: they significantly influence the energy intensity of buildings;
- window frame woodwork: proper parameters, use of positive radiation and proper installation significantly affect the heat balance of the building;
- surface color: a rarely appreciated element, affecting energy absorption.

A diagnosis concerning the energy consumption of civil engineering in the EU and in Poland

Forecasts indicate an inevitable increase in energy consumption in Poland. Civil engineering has a significant share in this, amounting to over 40%. It is therefore important to quickly and significantly reduce the energy consumption of buildings. In the 1990s, the energy intensity of buildings in Poland was over 50% higher than the EU average. Fortunately, a gradual improvement of this situation has been observed for a few years now. It is made possible by the introduction of new, energy-efficient technologies and thermo-modernization of old resources [27]. According to current requirements:

Table 3. Current energy use requirements in selected EU countries

POLAND	**90-120 kWh/m2 x year**
GERMANY	50-100 kWh/m2 x year
DENMARK	35-65 kWh/m2 x year

Source: the author's own study.

EU objectives for improving the energy standards of buildings

The purpose of Directive 2010/31/EU is [8] to improve the energy performance of buildings, to increase the use of RES energy while paying attention to the economic justification of the investment, and to fulfill the obligations under the 3x20 package.

The objectives of the European Union are to reduce energy consumption by 20% in comparison with the forecasts by the year 2020, and to renovate public sector buildings annually to reach the minimum energy efficiency standard. There is also a call to energy distributors and providers to save 1.5% energy annually.

According to the assumptions of the European Union, until the end of 2020, all newly designed buildings should be buildings with almost zero energy consumption. By the end of 2018, new buildings occupied by public authorities and owned by them should be almost zero energy consumption buildings. Selected examples of low energy, zero energy and energy plus buildings. In this energy situation, the future for the construction industry of the European Union is likely to involve more energy plus houses subordinate to the idea of sustainable construction.

Sample structures include the following buildings:

- Effizienzhaus-Plus, Berlin 2012;
- "Plus-Energy-House" prototype, 2010 in Frankfurt am Main;
- The plus energy building - The Heliotrope in Freiburg 1994, Rolf Disch - the first in the world. Another 2 - in Offenburg and Hipoltstein;
- The Heliodome building, Cosswiller in Alsace;

- IAAC Endesa Pavilion solar house in Barcelona;
- The Art Center in Apeldoorn, the Netherlands. Rau Architecture's;
- Villa in Finland, Ville Hara, Anu Puustinen;
- North Beach Residence, Sean Airhart and Ben Benschneider;
- The experimental passive house designed in the 90s. In the vicinity of Warsaw;
- Peark River Tower, Guangzhou; China;
- Gwanggyo City Center, South Korea;
- Sky Village Sky Tower, Copenhagen;
- Dubai Dynamic Tower;
- Editt Tower, Singapore;
- Tornado-Haus;
- Eco-city of the future, San Francisco;
- Masdar - self-sufficient city of the future, Abu Dhabi.

Bibliography

[1] M. J. Chmielewski, Teoria urbanistyki w projektowaniu i planowaniu miast, Warszawa, 2001.

[2] Living Planet Report 2012, Gland, Switzerland: WWW Internetional, 2012.

[3] M. Jarzemska, A. Węglarz and M. Wielomska, Zrównoważone miasto-zrównoważona energia, Warszawa, 2010.

[4] M. Stangel, "Zrównoważona urbanistyka," *Architektura,* no. 4, 2010.

[5] D. 2002/91/EC.

[6] A. Panek, "Polskie i unijne normy a istniejące systemy oceny ekologicznej budynków," *Architektura,* no. 4, 2010.

[7] "Rezolucja Parlamentu Europejskiego z dnia 31 stycznia 2008r. w sprawie planu działań na rzecz racjonalizacji zużycia energii," [Online]. Available: http://eur-lex.europa.eu.

[8] D. n. 2010/31/UE.

[9] Nearly Zero Energy Buildings in Europe. Perspective and Paths to 2020. A Brainstorming Workshop, Brussels, 2010.

[10] D. U. z. 2. p. 647.

[11] *Dz. U. z 2008 nr 25 poz. 150.*

[12] W. Witkowski, Architektura drewniana huculszczyzny - budowle świeckie, Łódź, 2003.

[13] R. Pilch, *Aktualne przepisy i normy regulujące warunki techniczne i ekonomiczne projektowania budynków energooszczędnych,* Poznań, 2011.

[14] T. Żuchowski, "Budynki zeroenergetyczne - potrzeba czy konieczność," *Arkadia,* no. 1, 1 2011.

[15] J. Pogorzelski, Dom energooszczędny, Poznań: Ardo-Studio, 2012.

[16] "Projekt ASIEPI," [Online]. Available: http: //www.buildup.eu/pl/publications/8756.

[17] E. Heiduk, Zrównoważone, inteligentne i finansowo wydajne budownictwo, Poznań: PIBP, 2010.

[18] S. Draeger, "Zrównoważony rozwój – podstawowe certyfikaty," *Architektura,* no. 4, 2010.

[19] P. Bartkiewicz, "EU Green Building- założenia Programu i implementacje w Polsce," *Energia i Budynek,* no. 7, 2010.

[20] A. Panek, M. Robakiewicz, R. Nowak, P. Cembala and T. Trusewicz, Dom energooszczędny, Warszawa: Oficyna Wydawnicza Sadyba, 2011.

[21] "Dyrektywa Parlamentu Europejskiego i Rady 2010/31/UE z dnia 19 maja 2010r. w sprawie charakterystyki energetycznej budynków," [Online]. Available: http://eur-lex.europa.eu.

[22] M. Idczak, "Idczak M, Ogólna koncepcja budynku pasywnego," 2012. [Online]. Available: http://www.ibp.com.pl/biblioteka/budownictwo-pasywne.aspx.

[23] W. Feist, R. Pfluger, B. Kaufman, J. Schnieders and O. Kah, Pakiet do projektowania budynków pasywnych, Gdańsk: PIBP, 2006.

[24] W. Feist, Podstawy budownictwa pasywnego, Gdańsk: PIBP, 2012.

[25] "The Passive–On Project,Efficiency Research Group of Politecnico di Milano," [Online]. Available: http://www.passive-on.org/en.

[26] G. Haese and M. Żukowski, "Analiza wpływu standard izolacji termicznej budynku na zużycie energii," *Energia i Budynek,* no. 11, 2008.

[27] T. Niedziółka, "Bezpieczeństwo energetyczne Polski," *Doradca Energetyczny,* no. 10, 2009.