Energy-efficient Construction in Poland as a Chance for Sustainable Development

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Abstract. One of the basic challenges of the contemporary world is to limit energy consumption. This results from the economic and ecological reasons. Minimization of energy consumption is one of the elements of implementation of the concept of sustainable development in the construction sector, which consists in the economical use of energy resources and environmental protection in order to maintain these resources for the generations to come. The paper presents the idea of energy-efficient construction and key objectives and areas of activities in this field. The energy consumption in the construction sector in Poland was discussed with the emphasis on various types of buildings, their character, purpose and time of use. The increasing requirements of the European Union and the obligations adopted by Poland set new objectives for activities aimed at the improvement of energy efficiency of buildings.

1. Introduction
One of the basic challenges of the contemporary world is to limit energy consumption. This results from the economic and ecological reasons. The higher energy consumption, the higher emission of pollutants to the atmosphere.

Therefore, the energy demand should be reduced through rationalization of the consumption. An important element of this programme should be limitation of energy consumption in buildings. According to the forecast presented in the Green Paper „Towards a European Strategy for the security of energy supply” [1], while maintaining the energy efficiency at the current level, i.e. without implementation of the savings program, ca. 70% of energy and energy resources would have to be imported from outside the EU.

New opportunities are offered by technological advances in civil engineering, manifested in development and implementation of not only new solution for the design but also more energy-efficient systems used in buildings. The depleting resources of conventional energy resources and the necessity for greater care for the status of natural environment require the savings in energy consumption in the housing sector. It was the seventies of the 20th century when the research was started and modern initiatives were implemented, with their goal being radical cut-off in energy consumption in buildings. These activities lead to the development of a new energy-efficient construction which is characterized by reduced energy consumption and the use of renewable sources of energy to meet the energy demands of the building [2,3,4].

Minimization of energy consumption is also one of the elements of implementation of the concept of sustainable development in the construction sector, which consists in the economical use of energy resources and environmental protection in order to maintain these resources for the generations to come.
2. Sustainable building

The basis for the concept of sustainable development is several documents, of which the most important are the Brundtland Report, Agenda 21 materials, documents of the earth summits and the Kyoto protocol. The first definitions concerning the sustainable development were used during the works of the UN Commission on Environment and Development established in 1987. Based on the conclusions from the commission, the president of the commission Gro Harlem Brundtland, presented the report Our Common Future, also known as the Brundtland Report. The report emphasized leaving a part of natural resources to the generations to come. The report led to the Rio de Janeiro Earth Summit held in 1992. The Agenda 21 developed during the summit contained a series of significant elements, among which the provisions concerned the role of science, industry, technology and business in initiatives towards sustainable development. A very negative effect on the environment is from energy waste excessive energy consumption in the economy, which was emphasized by the Kyoto Protocol (1997). Other world summits in Johannesburg (2002) and Copenhagen (2009) became the foundations for the actions in the European Union in various areas, including the construction sector. Sustainable building and common use of renewable energy in the European Union and, consequently, in Poland, were considered the two of six lead markets, susceptible to innovations and with huge developmental potential. Implementation of new technologies and solutions in the construction sector was found as very important since they can substantially affect the three domains defined as priorities for sustainable development [3,5]:

- environment: construction and use of buildings cause 35% of final energy consumption in the EU, emissions of 42% of greenhouse gases to the atmosphere and substantial consumption of such raw materials as water or aggregate (sand, gravel etc.). Environmental threats are also caused by the waste after demolishing of building structure,
- society: average citizen of a developed country spends around 80% of their life indoors. This leads to a natural need for creation of adequate environment and the comfort of using the houses, flats and offices, which have a substantial effect on the quality of human life,
- economy: the construction sector in the European Union generates around 10% of GDP and employs 7% of the labour force [3, 5].

Mutual relations and synergy of the triads of domains being at the core of the contemporary understanding of sustainable development i.e. the environment, society and economy are illustrated in Figure 1.

![Figure 1. Illustration of mutual relations of sustainable development](image-url)
These interpretations indicate that the development of construction, which consists in implementation of innovative technologies and modern solutions that combine beneficial economic effects with care for health and comfort of the users while reducing the negative effect of buildings on natural environment and climate, is a necessary component to drive the economy, both European and global, into sustainable development.

For this reason, it is extremely important from the standpoint of environmental protection to develop and implement new and effective technologies and products with good utility parameters that limit the demand for renewable energy and primary resources. They should increase the contribution of energy from renewable sources to total consumption and allow for utilization of recycled materials, which, apart from environmental benefits, leads to measurable financial savings. Sustainable development is also important for quality of users' life. Innovative solutions in building determine the comfort of use of flats and offices. They can, through formation of internal environment, positively affect health status of people staying in these spaces. Another problem is opportunities for adjustment of buildings to the needs of older adults or disabled people using modern, environmentally-friendly technologies and products.

3. Energy in civil engineering

The costs in building industry largely depend on the level of energy consumption and the costs of energy generation. Therefore, one of the main tasks at individual stages of implementation of building investments is to reduce energy consumption and to seek and use cheaper and environmentally friendly sources [2,6].

Energy consumed in buildings includes:

- embodied energy, which means the energy accumulated in the building when it was being built in the form of the energy consumed for production of materials, transport, construction processes and the energy necessary for maintenance works.
- operational energy, i.e. the energy consumed during normal use of the building for heating purposes, air-conditioning, lighting and the energy consumed for preparation of meals,
- processed energy, which is the energy needed when pulling down the building and for waste management.

![Figure 2. Structure of energy consumption in technical lifecycle of a building](image)

Figure 2, which illustrates a structure of energy consumption balance within a lifecycle of a building, shows dominant importance of the energy connected with operation of the building, which constitutes 83.9% of the total energy. The embodied energy, which includes manufacturing of materials, transport,
building and repair works, accounts for 15.7%. The last position, which means 0.4% of the energy balance in a building, is the energy connected with utilization at the end of its lifecycle [5].
As mentioned before, the construction sector in the European Union is responsible for the substantial contribution to the total energy consumption. Therefore, the problems of energy efficiency of buildings should be approached as priorities. The effects obtained in this sector in terms of energy efficiency can be the most pronounced and have an effect on the whole energy balance.

4. Characteristics of Energy-Saving Civil Engineering
Contemporary buildings must be characterized by low energy consumption. This aspect is of particular importance due to the idea of observance of the energy, whose conventional resources are being irreversibly depleted, world prices are rising and modern renewable resources of energy are still a merely alternative, relatively expensive and capital-intensive. Making investment decision requires extended knowledge. What should be determined first is to reply to the question of what is more profitable and if higher investment costs can be incurred and thus the heating costs reduced, with consideration of the standards and long-term tendencies.

While considering energy-saving civil engineering, one should focus on those technologies which are characterized by reduced extraction of fossil fuels (i.e. non-renewable sources of energy) and focused the use of renewable sources of energy for satisfying of energy demands for a particular building. Energy saving is a standard for modern civil engineering and relates to all types of the buildings, i.e. houses, public utility buildings, office blocks or workplaces.
In energy-saving civil-engineering, a great importance is attached to reduction of energy consumption during utilization of a particular building. In modern residential civil engineering in the European Union countries, at the latitude similar to Poland, index of energy consumption necessary for heating of the rooms amounts to over 40% of the total energy demand. Since recently, this index maintained at the level of 60-70% [2,7]. Changes in the structure of energy consumption in residential buildings in the countries with the latitude similar to Poland are illustrated in Figure 3.

![Figure 3. Changes in the structure of energy consumption in residential buildings](image)

Except for the tendencies in the structure of energy demand for buildings, the tendency for indexes of energy consumption during its use is also important. In order to determine energy standard of the building, an ‘E index’ is used, also called seasonal demand for heat. This index expresses the amount of heat necessary for sufficient heating of all the building’s rooms and facilities throughout the year, relating to the floor surface area or the volume, if necessary. The index is expressed in kW/(m2 year).
One can assume that the term ‘energy-saving house’ denotes a residential house or service-providing facilities with energy consumption lower than normative value being in force in a particular country. Energy-saving civil engineering sparks appearance of new buildings with energy consumption lower than current standards and norms. Such buildings are what we refer to as low-energy buildings. Buildings without conventional heating and cooling with minimal demand for external energy are called passing buildings. Some buildings are already designed and built with no conventional energy used, not only for heating purposes, but also for other needs, including electricity, which are commonly called self-sufficient buildings [5]. Classification of energy-saving buildings, grouped according to the criterion for energy consumption for heating in Poland are presented in Figure 4. Under Polish conditions, the energy-efficient building is understood to mean the building with the index of seasonal demand for energy for heating purposes and ventilation $E$ at the level lower than 70 kWh/m$^2$ per year.

5. Reduction in Energy Consumption in Buildings

Methods of reduction in energy consumption in energy-saving buildings of new generation consist in: [2,8,9]:

- reduction in consumption of conventional energy,
- use of energy from renewable sources with active and passive systems,
- use of heat recovery systems,
- implementation of unconventional methods of acquisition and conversion of energy.

Realization of the methods above requires the use of solutions including [2,8,9]:

- heat insulation of newest generation,
- windows with low heat transfer coefficient,
- efficient ventilation with heat recovery,
- heating systems with heat pumps,
- passive solar systems (use of shape and layout of buildings to trap, store and distribute solar radiation heat),
- storage of waste energy,
- active solar systems,
- illumination with daylight,
- photovoltaic cells, wind turbines.

Figure 4. Classification of the buildings according to energy consumption criteria
Figure 5 presents key features and type of initiatives connected with reduction in energy demands in typical residential building for Polish conditions. The equipment that supplies electricity and heat from renewable sources that can be installed were also illustrated schematically.

In specific types of autonomous buildings which are independent from the external sources of heat and electricity, the buildings use the energy present in the environment, with the energy converted for the internal needs and its excess stored and recovered repeatedly. The autonomy can be achieved through [2,5,7]:

- selection of localization and deployment of the building, its shape and structure and used materials so that the requirements of proper heat/cold management in the building are met (in terms of reduction of heat loss to the environment during winter season, reduction of excessive impact of irradiation during summer season and use of external environment for natural air-conditioning and ventilation),
- selection of localization and deployment of the building, its shape and structure, including the layout of the rooms and facilities in consideration of illumination with daylight and its integration with artificial light,
- use of energy contained in the environment for heating, mainly energy of solar radiation in active systems,
- use of energy contained in the environment to produce electricity (application of photovoltaic systems, wind turbines, fuel cells),
- adaptation of structural and material solutions in the building to use waste energy, including heat recovery from ventilation systems, sewage, use of waste materials, also including water recovered from internal sewage treatment plants, rain water, biomass (biogas) for production of energy,
- automated control of operation of systems and installation of the buildings, with an option of individual intervention of the user,
- short and long-term storage of energy.
6. Conclusions

According to the idea of sustainable development, economic growth in each country and region should not adversely affect natural environment. Formation of the environment by human should consist in creation of conditions conducive to equal use of the environment and improvement in life standards. It is the human race’s right to have access to energy while the diversity of its acquisition creates opportunities of choice, depending on local conditionings.

The resources of conventional energy resources are being depleted, which, in line with the necessity to focus on the state of natural environment, forced implementation of savings in energy consumption to residential building sector. As early as in the seventies of past century, the investigations were initiated, which translated into implementation of innovative projects, whose aim was to radically reduce energy consumption in the buildings. As a result of these initiatives, a type of civil engineering, commonly termed ‘energy-saving civil engineering’ is now dynamically developing, which is characterized by reduced energy consumption and use of renewable resources to meet building’s energy demands.

Poland meets the commitments that result from being the member of the European Union and has to implement many initiatives aimed at improvement in energy efficiency in the economy. Similar to Europe, around 40% of primary energy in Poland is consumed in buildings which is the consumption greater than the industry and transport. In the broadly understood construction sectors, the substantial opportunities for energy efficiency remain to be economically viable. The increasing costs of purchase of energy sources and higher EU requirements concerning the initiatives to prevent climate change lead consequentially to the use of modern means for improving energy efficiency in buildings.

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