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Comparative life cycle assessment of passive and traditional residential buildings' use with a special focus on energy-related aspects

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ABSTRACT

This article presents the results of the research project financed by the Polish Ministry of Science and Higher Education (N N309 078138) and coordinated by the Wood Technology Institute in Poznan. A key point of this project was LCA study performed for four detached single-family dwellings with a particular emphasis on the use stage. The life-cycle assessment involved various types of activity made within a hundred years of use and related to: operation (energy and water consumption), replacements and repairs, renovations and maintenance, land occupation, waste transport and waste management. Two of the four analyzed buildings met passive house standards and their energy demands in the use stage were several times lower than those of their conventional counterparts. The aim of the studies was to demonstrate whether lower nominal energy consumption is sufficient to get the best results of the environmental impact of passive buildings, or whether a type of energy used to cover the demand also plays an important role.

1. Introduction

Sustainable construction is a response to the growing awareness of the negative impact of buildings on the environment as well as the health and lives of people [1]. In practice, different terms (ecological, green, energy-efficient) are used to describe the environmentally friendly construction. The sources of the concept can be found in a report of the World Commission on Environment and Development and the birth of the idea of sustainable development. According to it, sustainable construction is one that meets the needs of the present without compromising the ability of future generations to meet their own needs [2]. Sustainable construction has strong legislative justification that provides a backdrop to undertake such initiatives. Pursuant to the EU Directive 2002/91/EC, from January 2009, all real estate buildings newly put into use or marketed in Poland have to undergo Energy Performance Certification. In accordance with Directive 2010/31/EU, the EU Member States were obliged to change their national regulations on the energy performance of buildings by July 2012 to reduce energy consumption in the building sector by 20%. In addition, each constructed building will have to meet certain standards for minimum energy performance after July 2013 [1]. In the longer term, in accordance with Directive 2010/31/EU, all new buildings will have to have a near-zero energy consumption after January 2021 (public buildings after 2018). The construction, as highly energy intensive sector, is strongly related to national energy system. In Poland the most strategic document in this area is *Energy Policy of Poland until 2030* [3] and especially Appendix 2 [4]. The following targets for Polish energy system are assumed to achieve in coming fifteen years: an improvement of energetic effectiveness, an increase of security of fuel and energy supplies, a diversification of the structure of electrical energy production, including the introduction of nuclear energy, a development of use of renewable energy sources (including biofuels), a development of competitive markets of fuels and energy and a limitation of power energy effects upon the environment. A regulation of the Minister of Environment as of 20 December 2005 relating to emission standards for fuel combustion installations [5] and respective EU provisions [6–8] are also important documents from energy consuming long life buildings' point of view.

Due to the significant environmental impact of the construction sector, different measures are taken to make environmental assessment of construction activity. Due to the very long operation periods, versatility, high structural complexity and material comprehensiveness, buildings are a complex and unique objects of ecological studies. Life cycle assessment (LCA) [9,10] is one of the tools for the environmental assessment of solutions in the construction industry. LCA studies can be conducted for residential

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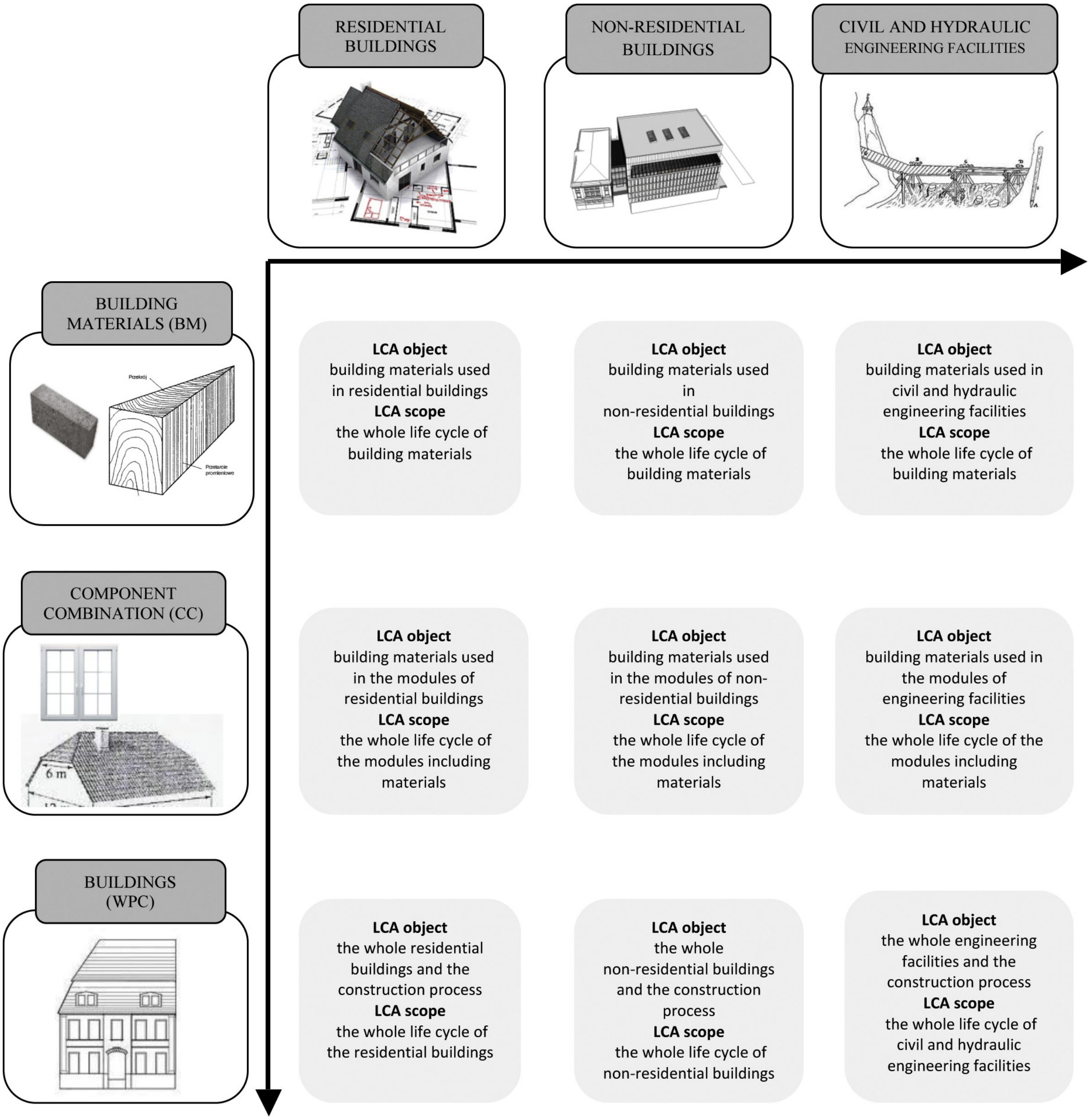

Fig. 1. LCA studies in the construction industry – objects and scopes.

Source: [26].

or non-residential buildings [11–16] as well as civil and hydraulic engineering facilities, although these are less common [17–20]. As for the LCA scope, the literature [19,21–25] suggests analysing: Building Materials (BM), Component Combination (CC) and The Whole Process of the Construction (WPC). As a result, the LCA scope may be varied and refer to different buildings (Fig. 1).

Full-scope LCA provides a full picture of environmental impacts and their sources, taking into account the whole life cycle of buildings. With this type of research, it is possible to define key issues such as: building materials and the related manufacturing technology, the use of a building, or perhaps issues related to waste management, transport or construction processes. Most studies have shown that the main environmental problem lies in the use stage energy consumption of buildings as energy-consuming facilities with a life cycle of at least decades. Thus, the tightening of legislation on building energy performance standards has profound environmental reasons. Sustainable construction is a response to changes taking place in legislation and awareness. A particular example of sustainable building is passive construction, called super energy-saving because of the extremely low heat demand of the buildings (air heating in the ventilation system is often sufficient as the only heat source) [27]. The heat demand of passive buildings can be several times lower than that of their conventional counterparts. However, getting energy levels characteristic for passive buildings (annual heat demand of a building cannot exceed 15 kWh/m^2 per year) is possible by increasing the consumption of building materials, especially insulation. Therefore, improvement is achieved in one life cycle stage, but at the cost of a deterioration in the others, because an increased use of building materials is not only related to a higher impact of their production, but also increased transport activity (both in the transport of new materials and waste) and the need for more waste management. LCAs of buildings can demonstrate whether such measures are environmentally “profitable” and whether the benefits of improved energy performance outweigh the negative impacts occurring in the other stages.