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PhD Dissertation

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Title: Architectural optimisation of single-family residential buildings in terms of their environmental impact using Life Cycle Assessment (LCA)

## Abstract

The existence of buildings (producing construction materials, construction, use, conservation, and demolition) involves the significant use of energy and natural resources, and as a consequence, a negative effect of the entire building sector on the natural environment (European Commission, b.r.; Bayer, Gamble, Gentry, *et al.*, 2010; Antink, Garrigan, Bonetti, *et al.*, 2014). The consumption of energy occurs primarily during the building's use - energy is used for heating, preparing domestic hot water, as well as powering the appliances and lighting inside the building.

Commonly applied measures of improving the energy efficiency of buildings focus on, before everything else, the use of effective thermal insulation in exterior partitions (most often by increasing the thickness of the insulation), using windows with better parameters, or additional appliances (e.g. mechanical ventilation with heat recovery). These measures are usually linked with an increase in embodied energy and a higher use of resources, as well as, increased greenhouse gas and other harmful substances emissions (Bayer, Gamble, Gentry, *et al.*, 2010).

Designing a low-energy and ecological building requires performing simulations and analyses, which include the building's entire life cycle (that is from resources acquisition, transport, production and assembly of materials, use, renovation, and demolition). One of the methods of evaluating the effect of products and processes on the environment over the course of the entire existence cycle is Life Cycle Assessment (LCA).

Methods of performing an environmental assessment of a building during its entire existence cycle are usually complicated and labour-intensive processes. There is a lack of commonly available databases containing all of the popular construction products available on the Polish market together with their influence on the natural environment.

The topic of this doctoral dissertation are: proprietary research concerning the application of the LCA method in designing low-energy buildings, comparison of the available construction product databases, an attempt at creating a proprietary database, as well as developing a quick method for the ecological analysis of buildings. The information collected was used to calculate CO<sub>2</sub> emissions and embodied energy for a couple of variants of single family residential buildings. The results and energy performance simulations of the buildings use served as the basis for analysis concerning optimizing the architectural form of single family residential buildings.

Analysis of the research results is finalized with a summary and conclusions describing how architectural measures concerning building design can affect the achievement of positive pro-environmental effects.

For the purpose of this dissertation, low-energy buildings (pol. *budynki niskoenergochłonne*) means energy efficient buildings which have a relatively lower embodied energy over their whole life cycle (the sum of the embodied energy related to the construction products used and the final energy for space heating) compared to the reference buildings.

**Keywords:** low-energy buildings, LCA, life cycle assessment, green architecture, ecological design, embodied energy, carbon footprint

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