Innovation of University education by using available online LCA methods and their role in construction sector

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Abstract. Currently, active education at universities is increasingly preferred. The introduction of innovative approaches to teaching is reflected in the increased number of practical lectures mainly. The use of new methods has also been applied to the subject of "LCA Building Materials", which is aimed at assessing the environmental impacts of building materials. Regarding the production of building materials and their use, the process of construction and operation of the building, as well as its disposal, the use of environmental assessment methods seems to be very desirable and perspective in regard to negative impacts on the environment and public health. This idea formed the basis for an active approach to teaching. During the lectures, theoretical knowledge is continuously supplemented by an illustrative example of calculating the environmental impacts of a selected family house. Through the available online LCA methods students evaluate their projects in parallel with the teacher, as if they were dealing with a real contract. Main goals of the project are to improve students' skills, to broaden their knowledge, to look at the issues comprehensively (construction industry, environmental protection, climate change etc.), and to apply knowledge to practice.

1. Introduction

One of the main aims of each society is to raise educational standards. High priority of universities is to support the students’ competitiveness and their ability to meet market requirements. New approach called “Life Cycle Thinking” has become a central pillar in environmental policies and sustainable business decision-making. The environmental assessment ensures that the environmental impacts are considered before decisions are made.

Currently, one of the most used methods is Life Cycle Assessment (LCA). LCA method is very popular and perspective. Instead of separate fragments of environmental impacts LCA method considers the entire product’s or service’s life cycle. In the building industry LCA helps to reduce negative environmental impact of buildings, and to improve the future of public health.

LCA method has been developed according to ISO 14040 and ISO 14044 series standards, which describe the general principles and requirements to undertake LCA. Life Cycle Assessment is carried out in four distinct phases including goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation.

Nowadays, it can be used in various fields of building assessment [1]. Many authors monitor the environmental impacts of the production of building materials [2, 3]. González and Navarro [4] present that the building materials with low impacts can reduce CO₂ emissions up to 30%. Negative impacts can also be reduced by using renewable or recycled materials as potential secondary raw
materials in building materials manufacturing [5 - 8]. Study of Turner and Collins proves, that alternative cements based on fly ash and ground granulated blast furnace slag can reduce CO$_2$ emissions by 13–22% [9]. The alternative material options have been studied by Caruso et al. [10]. Valencia and Gómez-Soberón [11] analyse suitable composition of interior partition walls with regard to their environmental impact. Environmental performance of the residential buildings was the topic of many researches. Evangelista et al. quantifies the environmental performance of residential buildings through the complete Life Cycle Assessment [12]. Carbon emissions and energy demand were monitored in his paper, but also in many other works [13, 14]. In general, the results of LCA research papers are different and have proven that optimal design does not exist. There for precise environmental analysis of each project is necessary [15]. Well-considered choice of materials for the construction of buildings should be based on scientific analysis [16].

Practical example of LCA study is given in this paper. It is focused on environmental impact of selected residential house regarding the material composition of each construction. LCA indicators: primary energy consumption (PEN$_{RT}$), global warming potential (GWP), acidification potential (AP), as well as environmental (ΔOI3) and disposal (El$_{KON}$) indicators were used to evaluate the environmental performance.

2. Material and methods
The exemplary study of the masonry family house (Figure 1) with common building materials was selected for determination of its environmental impacts.

![Figure 1. Assessed family house.](image)

The family house is a single-storey building, set in a flat ground and it is without basement. The family house consists of one housing unit with facilities and garage on the first floor. The roof of the building is hipped with a 15° slope with external rainwater drainage on the ground. Floor level (± 0.000) is distant approximately 300 mm from the landscape terrain. The main entrance to the building is from the north. The ground plan of the building is compact, polygonal. It is designed for 3-5 persons. Other technical specifications of assessed family house are presented in Table 1.

The foundation strips are 600 mm wide, made of C 12/15 concrete. Insulation against increased ground moisture is designed to penetrate the substrate, which is melted to the underlying concrete.

The external and internal load-bearing structures are the new brickwork structures made of POROTHERM bricks in the thickness of 300 and 380 mm. The internal partition structures are made of YTONG aerated concrete blocks in 150 mm thick cementitious adhesive. The post columns are designed with monolithic reinforced concrete.

The building is insulated with contact insulation system with NOBASIL mineral wool thermal insulation (minimum thickness of 70 mm), in skirting part of extruded polystyrene XPS (minimum thickness of 50 mm).
Ceilings represent the supporting elements and beams - the reinforcing steel-concrete monolithic rim, non-bearing beams YTONG, above the door openings in the non-loadbearing partitions. Reinforced concrete parts are designed as monolithic, concrete C 16/20 - XC1. The ceiling structure above the first floor is designed as non-load-bearing and it is formed by a suspended plasterboard ceiling RIGIPS. In the ceiling construction thermal insulation is designed mineral wool (minimum thickness of 160 + 60 mm) sealed with a vapor barrier from below.

The basic load-bearing part of the roof is a standing stool, made up of beams, posts, middle binding crafter, on which wooden rafters are placed. The roof slope is 15°. The roofing is designed with heavy concrete, type BRAMAC, including accessories.

| Parameter                  | Family house |
|---------------------------|--------------|
| Number of rooms           | 5            |
| Useful area [m²]          | 112.1        |
| Built-up area [m²]        | 175.25       |
| Living area [m²]          | 82.3         |
| Garage area [m²]          | 27.75        |
| Terrace area [m²]         | 31.92        |
| Accessories [m²]          | 29.8         |
| Total built-up volume [m³]| 701.0        |

Assessment was carried out in four LCA phases including goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation. The functional unit established in all assessed scenarios was 1 m² of the gross floor area. The study period of 100 years was considered for the wall constructions, and 25 years for both exterior and interior plasters. According to EN 15804 standard the evaluation was performed within the „cradle to gate” boundaries using the eco2soft. Baubook eco2soft is a tool that allows the calculation of ecological figures for buildings, including HVAC (Heating, Ventilation, and Air Conditioning). Based on the existing component calculator, it displays global warming potential (GWP), acidification potential (AP) and primary energy content (PENRT) of all building elements. It also features the calculation of environmental indicator ΔOI3, as required for the energy pass of municipal buildings. In addition, the disposal indicator (EI) of a building that is the area-weighted mean value of the disposal indices of the constructions, can be also calculated.

Inventory analysis focused on all environmental inputs and outputs associated with a selected product was processed through the Ecoinvent database.

3. Results and discussion
All calculated environmental indicators mentioned above are given in Table 2.

| Environmental indicator | Family house |
|-------------------------|--------------|
| OI3                     | 592          |
| PENRT [MJ]              | 8104         |
| GWP [kg CO₂ equ.]       | 539          |
| AP [kg SO₂ equ.]        | 1.74         |
| EI                      | 0.67         |
The results presented in Table 2 show that the environmental profile of the assessed family house is slightly above the common average. However, in order to achieve better environmental impact values, it is necessary to use alternative built-in materials or structural elements.

To find more optimal solution for a construction by using variations of original project (usually two more variants) is common practice in LCA method. By using the parameters obtained in the evaluation of the original variant, it is possible to propose individual improvements of each structure.

In this case it is a comparison of two external walls prepared using different thermal insulation systems (XPS, mineral wool).

Figure 2 shows the results of assessed external wall insulated with XPS. Indicator OI3 is on the scale in class “B”, EIKON reached value 0.78 points/m², and the values of the other environmental indicators are as follow: primary energy (PENRT) 1531 MJ/m²; GWP 93.9 kg CO₂/m², and AP 0.293 kg SO₂/m².

This information can be used as input data for other calculated variations in order to reduce negative environmental impact of each unit and the whole family house, ultimately.

![Figure 2](image2)

**Figure 2.** Results of assessed external wall insulated with XPS

(1- CR lime cement finish plaster: d = 0.20cm, λ = 1.050 W/m.K.; 2 - POROTHERM 30 N+F: d = 30.00cm, λ = 0.205 W/m.K.; 3 – XPS: d = 5.00cm, λ = 0.036 W/m.K.; 4 - silicate plaster: d = 1.50cm, λ = 0.800 W/m.K.).

For comparison, Figure 3 shows alternative external wall insulated with mineral wool.

![Figure 3](image3)

**Figure 3.** Results of assessed external wall insulated with mineral wool

(1- CR lime cement finish plaster: d = 0.20cm, λ = 1.050 W/m.K.; 2 - POROTHERM 30 N+F: d = 30.00cm, λ = 0.205 W/m.K.; 3 – mineral wool: d = 7.00cm, λ = 0.044 W/m.K.; 4 - silicate plaster: d = 1.50cm, λ = 0.800 W/m.K.).

Calculated values are significantly reduced in all evaluated indicators. The biggest benefit was marked at EI and PENRT indicator. Regarding recyclability and energy intensity the use of mineral wool is preferred.
Based on these results it is necessary to realize that increased attention should be paid to the environment while choosing the building materials. Slight change in the material composition of the structure can reduce the environmental burden while ensuring the required functional and thermal insulation parameters. The comprehensiveness of LCA evaluation can help in the decision-making process regarding the suitable selection of materials. Another preferred option is the selection of materials based on the EPD (Environmental Product Declarations) certificate, which guarantees a reduced negative impact on the environment.

4. Conclusion
The process of buildings construction consists of a few complex phases (design, construction, operation, maintenance of buildings). Usually, it requires enormous amount of raw materials, and energy and water resources. Moreover, it produces large quantities of waste that causes environmental pollution. Sustainable construction (green buildings) is the only answer for healthier environment. It requires more efficient use of resource in construction, reconstruction, operation and maintenance. Life Cycle Assessment and subsequent smart choice of building materials appear to be a starting point for building sustainability.

The achievement of a "cleaner" future with preservation of today’s comfort is the main goal for coming generations. Therefore, the innovation of university education from passive to active is necessary. Primary is the introducing to practical subjects with modern online access to education. Subsequently, responsible and active preparation of students at universities is highly positively perceived from the perspective of their future job as well as very desirable by employers. In addition, the LCA experience is a very important parameter for the future of construction in connection with our environment.

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