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Comparison of carbon footprint of individual structures in a family house

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Abstract

Construction sector contributes significantly to the production of greenhouse gases (GHG) and thus to climate change. One way to mitigate the climate change is by choosing materials in structures that have lesser impact on global warming due to lower greenhouse gas emissions.

This study aims at quantification of the environmental performance of a selected residential house with a special regard to its contribution to climate change. Based on a more accurate calculation, the family house was divided into individual parts according to the materials´ function and location in the structure in the following way: foundation materials, materials of vertical structures, materials of horizontal structures, materials of the roof, surface materials and insulating materials.

The evaluation was based on Life Cycle Assessment (LCA) methodology within the "cradle to gate" boundaries using the IPCC GWP100 method. The total contribution of the materials of the selected house to climate change was 125 ×10³ kg CO_2 eq. The calculated values of global warming potentials (GWP) ranged from 3 775.3 kg CO_2 eq to 62 212 kg CO_2 eq per individual structures. The results showed that the lowest global warming potential values were calculated for horizontal construction materials and the highest values were recorded for materials of vertical structures.

This article is focused on the identification and assessment of the environmental impacts deriving from a residential house with a special regard to climate change using the LCA approach. The environmental impacts were allocated based on the function of materials in the building thus per individual structures.

Materials and methods

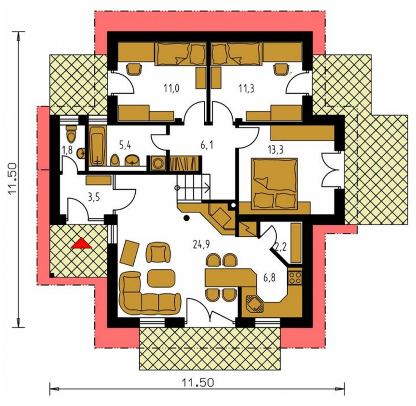


Figure 1: A scheme of the analysed masonry family house.

Specification of the family house

The proposed masonry family house is one - storey building (Figure 1), without a basement or attic, and was designed for living in a family of 4-5 members. The house has 4 rooms, i.e. a bedroom, a living room, two separate rooms, a kitchen with a pantry which is accessible from the living room with a small dining area, and a bathroom. The usable area of the family house is 91.10 m² and the built-up area is 111.5 m².

Life Cycle Assessment

Environmental analysis of the family house was performed to calculate the environmental burdens of the family house and to compare the individual structures using SimaPro software within the system boundaries cradle-to-gate. That means that only the product phase (A1-A3, according to EN 15804) of construction materials was considered in calculation. The declared unit was stated to 1 building. The environmental impacts were consequently allocated based on the function of materials in the building thus per individual structures. The lifespan of the house was assumed to be 50 years, which is in line with most published case studies. Maintenance was evaluated according to the service life of various components and materials. The service life of plasters was assumed to be 25 years, therefore in the calculations the impact values were counted as twice the unit value.

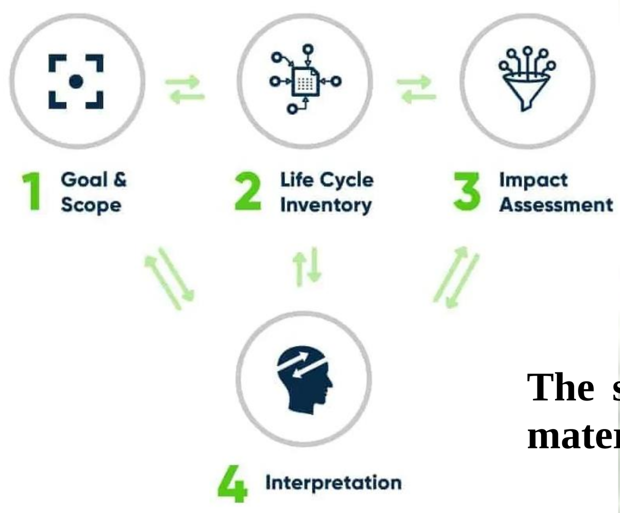


Figure 2: Life cycle assessment phases

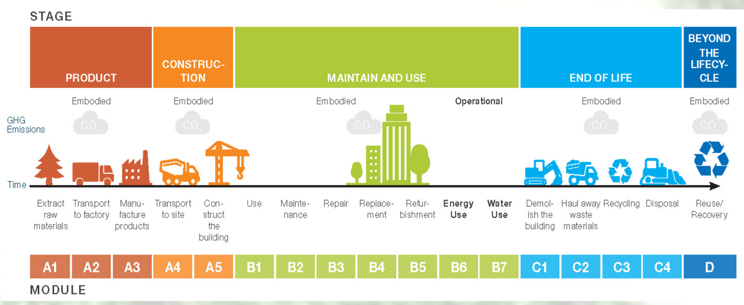


Figure 3: System boundaries in LCA

Cradle-to-gate data for construction materials were collected from the Ecoinvent database. The cradle-to-gate data included typical manufacturing process of particular material considering the average global or European values. The following materials were considered in the individual structures:

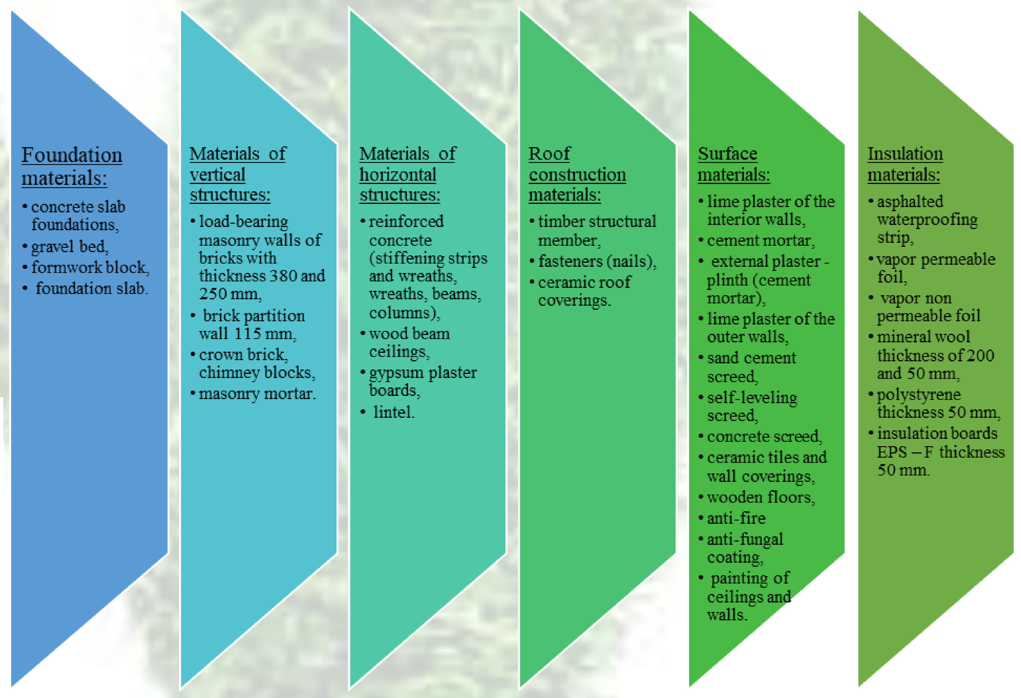


Figure 4: Materials divided into individual structures

The software SimaPro, version 9.4.3, was used to estimate the climate change contribution of the construction materials of the house. The global warming potentials (GWPs) were calculated using IPCC GWP100 method.

Results and discussion

The total contribution of the materials of the selected house to climate change was 125 ×10³ kg CO_2 eq. Converted to 1 kg of materials, this amounts to 0.46 kg CO_2 eq per mass unit of construction materials. To compare the environmental burden of the individual structures, the calculated environmental impacts (GWPs) are presented in Table 1 and compared in percentage each to other in Figure 2.

Table 1. The GWPs calculated per individual structures

Structure/Material	Unit [kg CO_2 eq]
Foundation materials	12 831.92
Materials of vertical structures	62 211.87
Materials of horizontal structures	3 775.34
Surface materials	27 646.86
Insulation materials	12 387.45
Roof construction materials	6 250.62

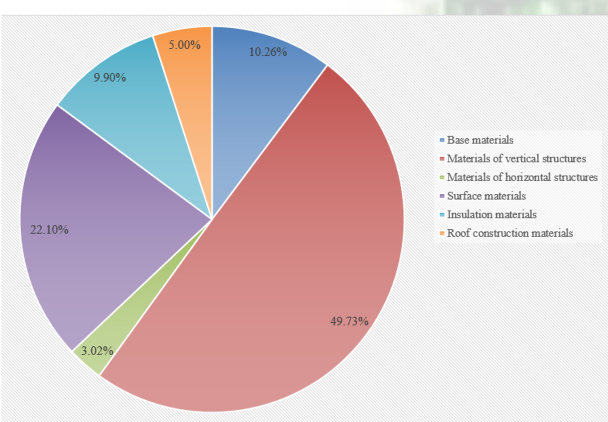


Figure 5. Percentage values of GWP..

Table 2. Minimum and maximum values of GWPs of materials in individual structures.

Structure	GWP [kg CO_2 eq]		Structure member	Percentage share on the total GWP of the structure [%]
Foundation materials	Min	6.56	Gravel bed	0.051
	Max	11 877	Concrete slab foundations	92.56
Materials of vertical structures	Min	198.19	Crown brick	0.31
	Max	45 481	Brick 380 mm	73.11
Materials of horizontal structures	Min	361.44	Timber structural member	32.10
	Max	1 422	Reinforced concrete	37.66
Surface materials	Min	24.16	External plaster (cement mortar)	0.087
	Max	10 520.62	Lime plaster of the outer walls	38.05
Insulation materials	Min	45.24	Vapor non permeable foil	0.36
	Max	7 103.2	Mineral wool (thickness of 50 mm)	87.34
Roof construction materials	Min	73.32	Fasteners (nails)	1.18
	Max	4 876	Roof coverings	78.01

As presented, the materials of vertical structures reached the highest contribution of GWPs to the total environmental impacts of the analysed building. The individual members or materials built-in the vertical structures in terms of their sharing on the vertical structures GWP are analysed and compared in Figure 3.

As it can be seen, when evaluating the GWP 100 potentials, impacts from materials of vertical constructions accounted almost 50 % of the total GWP values, followed by surface materials (22.10 %), foundation materials (10.26 %), insulation materials (9.90 %) and approximately 5 % is represented by materials of roof construction. The lowest percentage (3%) was identified for materials of horizontal structures. The particular members of the structure responsible for the minimum or maximum GWP values in the structures are presented in Table 2.

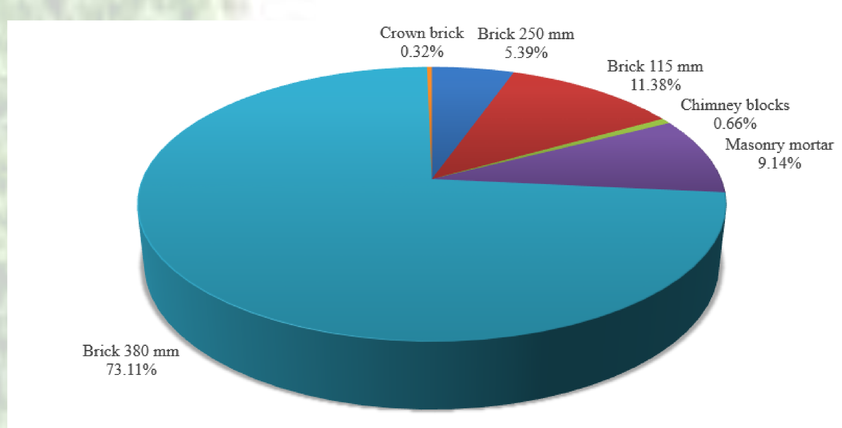
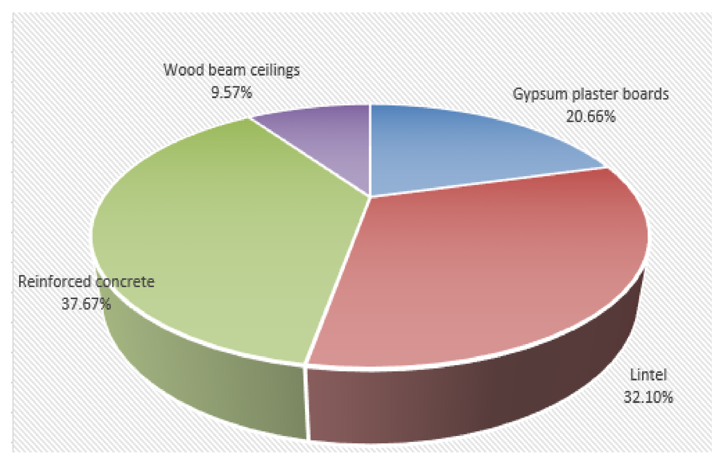


Figure 6: The GWP percentage share of the members and materials in the vertical structures.

In contrast, the horizontal structure achieved the lowest values of GWPs. Figure 4 presents the percentage share of the individual components forming the horizontal structure. The highest value, approximately 38 % were identified for reinforced concrete, following by lintel with 32 %, gypsum plaster boards nearly 21 % and the lowest values (9.57 %) can be assigned to wood beam ceiling.



Fihure 7: The GWP percentage share of the members and materials in the horizontal structures.

Almost two - thirds of the overall GWP identified in vertical structure was represented by environmental impacts of the brick with thickness of 380 mm. This type of bricks was used as load-bearing masonry. Lower percentage share on the overall vertical structure´s GWP can be seen for 115 mm thick brick and masonry mortar. The lowest GWP values were linked to the chimney block and crown brick.

Conclusion

In this paper, the results of the LCA analysis of a masonry family house, using SimaPro software, were presented. The LCA analysis was used to find the building structures and structure members with the most significant environmental impacts.

The case study revealed that vertical structures were responsible for the highest contribution of materials to climate change up to 50% whereas the horizontal structures have demonstrated the lowest environmental impacts represented by the GWPs (3%). The study found that masonry (bricks), concrete, mineral wool and ceramics are the construction materials representing the highest environmental loads.

These results point to the need to recycle or reuse the construction materials not only to save natural resources but also to reduce the production of greenhouse gases from the production of the materials.

Aknowledgment

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