Key Engineering Materials
ISSN: 1662-9795, Vol. 688, pp 204-209
doi:10.4028/www.scientific.net/KEM.688.204

Submitted: 2015-07-20
Accepted: 2015-10-13
Online: 2016-04-26

An Environmental Impact of a Wooden and Brick House by the LCA Method

Jozef Mitterpach[1, a *], Jozef Štefko[2,b]

[1]TU in Zvolen, KEI FEE, Department of Environmental engineering, T. G. Masaryka 24, 96053, Zvolen, Slovakia

[2]TU in Zvolen, KDS FWST, Department of Wooden Constructions, T. G. Masaryka 24, 96053, Zvolen, Slovakia

[a*]jozef.mitterpach@gmail.com, [b]stefko@tuzvo.sk

Keywords: LCA, building, wood, construction, environmental impact

Abstract. The main objective of this paper thesis is to determine the environmental impact of two houses made of two alternative materials - a wooden and a brick house - using a Life Cycle Assessment (LCA). By comparing the material composition of their design to determine the environmental impacts of global warming, human health, consumption of resources and ecosystem quality. An overall comparison showed that the materials for the construction of a wooden house have less negative impact on the environment than materials for the construction of a brick house. Using the GWP method, results show that the materials for the construction of a brick house leave twice the carbon footprint in the environment than materials for a wooden house. This resultant state is mainly due to the use of natural materials in the wooden house (wood, fibre insulation), unlike the materials used in the brick house (ceramic masonry, insulation from stone wool) and so on.

Introduction

The method of settlement and way of life in mountain pastures formed the base of a special, initially wooden, architecture with straw and, later, shingle roofs in the Podpoľanie area – Slovakia. This type of rustic architecture in this area included the Central Slovakia wooden log house, see Fig. 1a. These are mainly around Poľana, Vepor, Zvolenská Panva, Slovenské Rudohorie, Javorie and the northern slopes of Krupinská Vrchovina. This basic wooden construction is barely visible almost throughout the area since the stone and log walls have been plastered with clay and whitened with lime. Simple finishing of walls can only be found in mountain pastures where just the gaps between the wooden logs were filled with clay and the wooden house was then whitened with lime. The entire area was dominated by a truss construction, and a saddle construction was only rarely used. Fire resistant material - stone - gradually started to be used when, by the 19th Century, stone as a solid, non-combustible material, started to prevail in villages on the northern slopes of Krupinská Vrchovina and in the south western part of Zvolenská Panva. However, wood as a basic building material was used in the mountain pastures under Poľana until the 1930s. Settlements in these areas were built in an L or U shape [1].

The theme of permanently sustainable construction, which is currently defined in the Agenda 21 basic document for sustainable construction, represents a complex issue with a large number of parameters in various fields of the building industry [2]. Optimisation of building design in terms of environmental parameters is a wide, multi-criteria issue [3].

Life Cycle Assessment (LCA) methods were used to evaluate the protection process of various products for a fairly long time. The application of this method in the building sector has only been seen for the last 10-13 years [4]. Since the LCA method has a complex and systematic approach to environmental evaluation, interest lies in including the LCA method into the building decision-making process for selecting and favouring ecological products, as well as for assessing and optimising building processes [5].

Goal and scope

The main aim of this paper is to assess the environmental impact of building a house using two alternative material bases - a brick house and a wooden house - using the life cycle assessment (LCA) method. To determine the environmental impact for the final points of a life cycle assessment in terms of global warming, human health, consumption of resources and ecosystem quality.

Material and method

Characteristics of a brick house and a wooden house

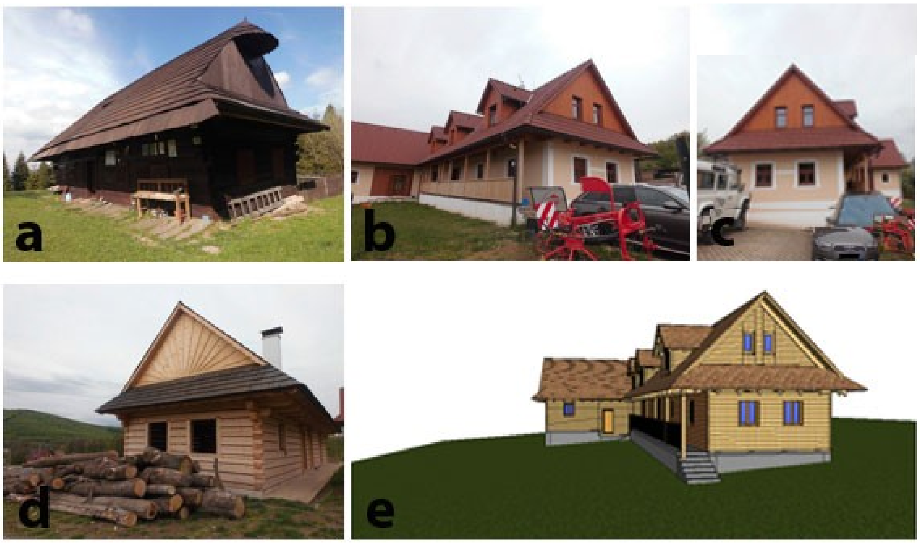

Fig. 1 Model house: a-historical architecture (present), b,c- brick house, d- wooden house (unfinished), e- 3D design for a wooden house and a brick house by "a"

The brick house (Fig. 1b, c, e) is single storey without a basement. The construction lies on a strip foundation. The house has two chimney stacks. The construction of the circumference is made of ceramic masonry insulated with a thermal insulation composite system covered with a silicon coating. Internal partitions on the ground floor are made of ceramic masonry coated with plaster. The ceiling load-bearing construction consists of ceiling beams placed along the whole width of the house and protruding to the exterior. The ceiling beams hold the ceiling decking made of tiles, which holds the attic flooring. Internal partitions in the attic are made of a frame sandwich walls coated with chipboard and plaster boards which are covered with a layer of plaster. The house has a saddle roof with an incline of 42°. Joists and wall beams are placed on the ceiling beams into which they are anchored. Double sided stud ties are fixed to the truss by studs. Stone wool thermal insulation is placed between the trusses. There are three dormers on the roof, situated on the southern side. The northern side contains three roof windows. The roof covering is made of concrete tiles.

The wooden construction of a wooden house (Fig. 1d, e) is a constructional copy of the brick house, apart from the used materials and their construction principles. For example, the brick house, like the wooden house, is built on strip foundations with a higher strength class of the concrete. The circumference walls are a double-walled wooden construction. The double-wall is formed of two wooden profiles. There are cork chippings between the two, acting as thermal insulation. The internal partitions are made of a frame sandwich construction with wood-fibre insulation. The walls are covered with chipboard with mounted clay panels and coated with clay. The ceiling construction is identical to the construction in the "brick house" apart from acoustic insulation which is wood-fibre. The construction of the external walls below the gable is made of frame sandwich construction. Fibre insulation is designed to act as thermal insulation. A wooden, ventilated façade is created at the exterior. The interior coating is made of woodchip boards on which clay panels are mounted. A layer of clay coating is added to the panels. Internal partitions in the attic are of the same construction as the partitions on the ground floor. The shape and construction of the roof is identical to the roof of the brick house. There are only two differences which are the use of different thermal insulation (wood-fibre insulation) and roof covering, which in this case is wooden shingle.

Life Cycle Assessment methodology

The LCA methodological framework is described in STN EN ISO 14040. Environmental management. Life cycle assessment. The principles and structure (ISO 14040:2006) [6] and STN EN ISO 14044:2006. Environmental management. Life cycle assessment. Requirements and instructions (ISO 14044: 2006) [7]. The SimaPro database tool was selected for a life cycle assessment of houses [8]. The level of environmental impact upon selected categories of impact: human health, consumption of resources and ecosystem quality, was determined using the ReCiPe assessment method. The main aim of the ReCiPe is to transform all inputs and outputs into a limited number of environmental output indicators. In this paper, we evaluated two constructions at the 2nd level in 3 end points - Human Health, Ecosystem Quality and Resources. The impacts of the material composition of the wooden house and brick house upon global warming are expressed and assessed using the IPCC 2013 GWP 100a method [8].

The designed houses are assessed based on the input material composition which was divided into the main construction units, into: Foundations (Table 1), Ground Floor (Table 2), Attic (Table 3, Roof (Table 4).

Table 1 Materials for the foundations of the wooden house and brick house

	Material	mm	m^3	kg	Material	mm	m^3	kg
Const. unit	wooden house				brick house			
Foundations	Concrete C16/20	-	47.85	110055	Concrete C20/25	-	47.85	110055

Table 2 Materials for the ground floor of the wooden house and brick house

	Material	mm	m^3	kg	Material	mm	m^3	kg
Const. unit	wooden house				brick house			
Ground floor	oak parquet floors	-	4.66	3168.00	oak parquet floors	-	4.66	-
	ceramic tiles	7	0.39	784.00	ceramic tiles	7	0.39	784.00
	PE sheet	0.2	-	70.79	PE sheet	0.2	0.00	70.79
	concrete screed	50	9.31	-	concrete screed	50	9.31	-
	fibreboard	80	14.90	3427.69	exp. polystyrene	80	14.90	447.00
	waterproofing	4	-	1279.00	waterproofing	4	0.00	1279.00
	reinforced concrete C16/20	-	33.66	-	reinforced concrete C20/25	-	33.66	-
	prism. softwood	92	17.52	8234.40	silikone plaster	-	17.52	513.00
	cork insulation	-	37.71	1897.09	reinforcing mesh. *m^2	190*	-	-
	prism. softwood	44	8.09	3802.30	construkcion adhesive	-	-	1501.00
	clay plaster	5	1.99	3781.00	rock mineral wool	60	11.40	1368.00
	clay layer	30	1.49	3427.00	brick	440	83.60	62700.00
	oriented strand board	15	1.49	1847.60	masonry mortar	-	0.59	-
	fibre insulation	80	6.63	995.10	gypsum plaster	20		3610.00
	oriented strand board	15	1.49	1847.20	gypsum plaster	20	0.27	253.65
	clay layer	30	1.49	3427.50	brick	250	3.34	2503.13
	clay plaster	5	1.99	3781.15	gypsum plaster	20	0.27	253.65
	sawn. timber. softwood	-	2.83	1107.40	masonry mortar	-	0.02	-

Table 3 Materials for the attic of the wooden house and brick house

	Material	mm	m^3	kg	Material	mm	m^3	kg
Const. unit	wooden house				brick house			
Attic	wooden siding	25	1.38	828.00	silikone plaster	-	0.28	149.85
	protection foil	0.15	-	-	reinforcing mesh. *[m^2]	-	-	56.00*
	fibre insulation	100	5.22	768.00	construkcion adhesive	-	-	437.80
	fibre insulation	100	4.60	704.25	rock mineral wool	60	3.33	399.60
	oriented strand board	18	0.93	576.60	brick	440	24.42	18315.00
	fibre insulation	50	2.33	349.20	gypsum plaster	20	1.11	1050.70
	clay layer	30	0.76	874.00	masonry mortar	-	0.17	-
	clay plaster	5	1.01	959.50	gypsum plaster	20	0.19	180.50
	clay plaster	5	3.12	2965.00	gypsum plaster	20	2.94	2793.00
	clay layer	30	2.34	2692.00	gypsun fibre board	15	2.20	2530.00
	oriented strand board	15	2.34	1451.60	oriented strand board	15	2.20	1364.00
	fibre insulation	80	10.50	1575.15	rock mineral wool	80	10.00	800.00
	oriented strand board	15	2.34	1450.00	oriented strand board	15	2.20	1364.00
	clay layer	30	2.34	2690.00	gypsun fibre board	15	2.20	2530.00
	clay plaster	5	3.12	2963.00	gypsum plaster	20	2.94	2793.00
	clay layer	30	0.74	1081.00	gypsun fibre board	15	0.74	851.00
	oriented strand board	15	0.79	489.80	oriented strand board	15	0.79	489.80
	fibre insulation	80	4.00	599.40	rock mineral wool	80	4.00	599.40
	oriented strand board	15	0.89	551.80	oriented strand board	15	0.89	551.80
	clay layer	30	0.94	851.00	gypsun fibre board	15	0.94	1081.00
	clay plaster	15	1.28	1216.00	gypsum plaster	20	1.28	1216.00
	sawn. timber. softwood	-	3.96	1367.00	sawn. timber. softwood		3.96	1367.00
	oak floors	-	2.46	1670.00	oak floors	DB	2.46	1670.00
	fibreboard washer	20	0.33	81.75	fibreboard washer	20	0.33	81.75
	ceramic tiles	0.7	0.06	116.00	ceramic tiles	0.7	0.06	116.00
	PE sheet	0.2	-	1.60	PE sheet	0.2	-	1.60
	oriented strand board	15	2.46	1523.34	oriented strand board	15	2.46	1523.34
	fibre insulation	50	8.19	1884.16	fibre insulation	50	8.19	1884.16
	wooden decking. softwood	-	4.10	1925.15	wooden decking. softwood	-	4.10	8279.43
	sawn timber. softwood	-	8.61	4045.70	sawn timber. softwood	-	8.61	4045.70
	wooden siding. softwood	-	4.64	2179.80	wooden siding. softwood	-	4.64	2179.80
	sawn timber. softwood	-	0.27	128.78	sawn timber. softwood	-	0.27	128.78

Table 4 Materials for the roof of the wooden house and brick house

	Material	m^2	m^3	kg	Material	mm	m^3	kg
Const. unit	wooden house				brick house			
Roof	sawn timber. boards	-	3.64	1277.00	sawn timber. boards	SM/JD	3.64	1277.00
	sawn timber. skeleton	-	15.90	5566.00	sawn timber. skeleton	SM/JD	15.90	5566.00
	wood shingle. softwood	444.119	-		concrete roofing tiles	-	-	19097.12
	fibre insulation	-	74.50	11175.00	rock mineral wool	200mm	74.50	5960.00

Results

The data necessary for the life cycle assessment using the ReCiPe method for a wooden house and brick house (Fig. 2), required by the SimaPro program, was taken from Tables 1-4. The life cycle assessment for selected groups of environment impact of the wooden house shows that the greatest negative impact of the wooden house is upon ecosystem quality, 7.4 kPt, then upon consumption of resources, 1.97 kPt and finally upon human health, 1.55 kPt. The life cycle assessment of the brick house upon selected groups of environmental impact shows that the greatest negative impact was upon ecosystem quality, 5.35 kPt, then upon consumption of resources, 4.15 kPt and finally upon human health, 3.05 kPt. kPt (Kilo point) is a standard eco-indicator normalized unit [8].

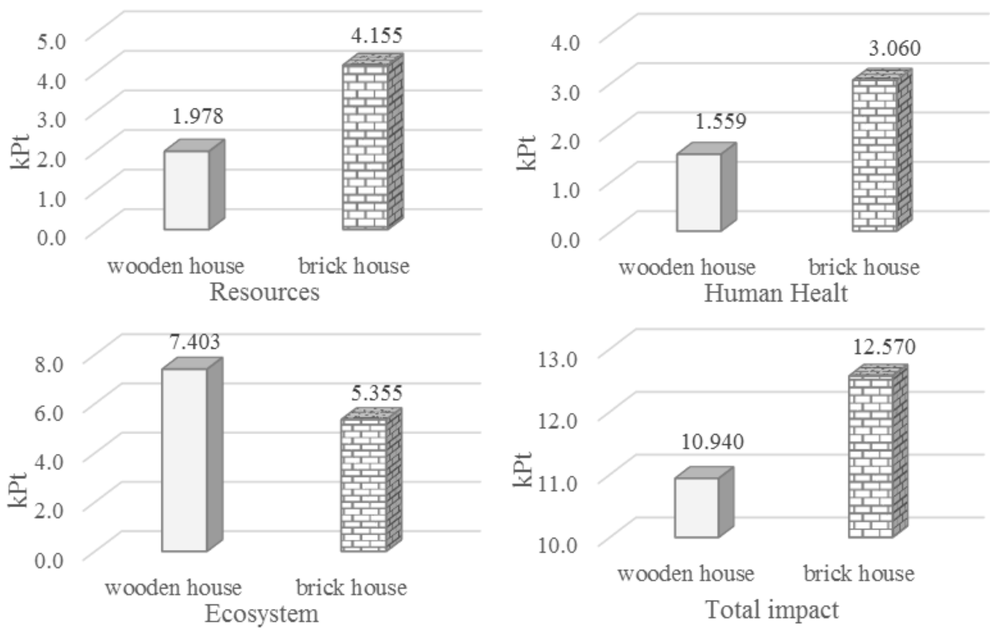

Fig. 2 Comparison of the life cycle assessment of the wooden house and brick house, ReCiPe

From a comparison of the negative impacts in the groups of impact (Fig. 2), it follows on that the brick house negatively influences (4.155 kPt) the assessed final impact, Resources, by than twice the negative impact of the wooden house (1.978 kPt). This is a result of the materials used in the wooden house, from renewable resources (wood, wood-fibre insulation, clay coating). A comparison of the negative impact upon human health shows that the overall negative impact of the brick house (3.060 kPt) upon human health is approximately double the negative impact of the wooden house (1.559 kPt). This result is mainly caused by the use of ceramic bricks in the circumference walls, concrete roofing and the selected insulation. A comparison of the negative impact upon ecosystem quality shows that the wooden house influences ecosystem quality (7.403 kPt) more than the brick house (5.355 kPt). This result is mainly due to the use of wooden raw materials in the construction of the wooden house and the negative impact mainly due to the mining of wood raw materials as the main material. A comparison of total negative impact using the ReCiPe method shows that the total negative impact upon the environment by the wooden house (10.937 kPt) is less than the negative impact of the brick house (12.569kPt).

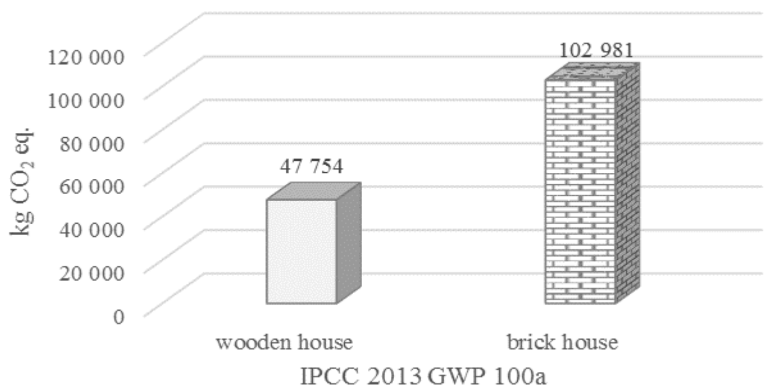

Fig. 3 Life cycle assessment of a wooden and brick house, IPCC 2013 GWP 100a

Comparison IPCC 2013 GWP 100a (Fig. 3) shows that the wooden house leaves a carbon footprint in the environment with a value of 47454.11 kg CO_2eq, which is less than half that of the brick house construction which leaves a carbon footprint of 102981.49 kg CO_2eq.

Conclusion

The main aim of this paper was to evaluate the environmental impact of building a house using two alternative materials: a brick house and a wooden house. An overall comparison using ReCiPe showed that the materials for building a wooden house have a less negative environment impact than materials for building a brick house. Using the GWP method, the results showed that the materials used for building a brick house leave double the carbon footprint in the environment than the materials used for building a wooden house. Assessment using the ReCiPe method showed that the use of wood has the greatest negative impact upon the selected final impact, Ecosystem Quality. This is caused by the unsuitable method of management and mining wood as a renewable material resource, which was included in the assessment. The results of the work further show that building wooden houses when using suitable materials is friendlier in terms of the consumption of resources and has less impact upon human health. The results of the analysis [9] point to the fact that it is possible to reduce the environmental impacts by up to 61.0 % in particular structures. A more significant decrease in the creation of greenhouse gases can be achieved by using suitable materials [10], as well as improving ecosystem quality, e.g. by planting suitable plants in the countryside.

Acknowledgements

This research was supported by VEGA 1/0213/15.

References

[1] S. Švehlák, et al., in Slovak language: Podpoľanie tradície a súčasnosť, Bratislava: Obzor, 1979, p. 193.

[2] Agenda 21, Agenda 21, Agenda 21 on Sustainable Construction, CIB Report Publication 237, Rotterdam, 1999.

[3] S. Solomon, D. Qin, M. Manning, Y. Chen, M. Marquis, K.B. Averyt, M. Tignor, H.L. Miller (Eds.), Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change, Cambridge University Press, NY, USA, 2007.

[4] M. Buyle, J. Braet, A. Audenaert, Life cycle assessment in the construction sector: a review, Renewable & Sustainable Energy Reviews, 26 (2013), pp. 379–388.

[5] F. Asdrubali, C. Baldassarri, V. Fthenakis, Life cycle analysis in the construction sector: guiding the optimization of conventional Italian buildings, Energy and Buildings, 64 (2013), pp. 73–89.

[6] ISO 14040:2006, Environmental management. Life cycle assessment - Principles and framework (ISO 14040:2006)

[7] ISO 14044:2006, Environmental management. Life cycle assessment - Requirements and guidelines (ISO 14044:2006)

[8] Pré Consultant 2015, http://www.pre.nl/simapro/

[9] A. Eštoková, M. Porhinčák, Environmental analysis of two building material alternatives in structures with the aim of sustainable construction, Clean Technologies and Environmental Policy, 17, 1 (2015), pp. 75-83.

[10] M. Ondová, A. Eštoková, Analysis of the environmental impact of concrete-framed family house using LCA method, Ciencia E Tecnica Vitivinicola, 29, 7 (2014), pp. 267-376.