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LIFE CYCLE IMPACT ASSESSMENT OF CONSTRUCTION MATERIALS OF A WOOD-BASED BUILDING IN AN ENVIRONMENTAL CONTEXT

Jozef Mitterpach – Rozália Ilečková – Jozef Štefko

ABSTRACT

The paper is aimed at Life Cycle Impact Assessment (LCIA) of the designed wood-based reference prototype building designed at the Department of Wooden Constructions. The main objective is to identify the environmental impacts of the compositions and elements in the construction using the LCIA EDIP 2003 methodology, taking into account the thermal and technical complexity of the Reference Prototype Building (RPB). The RPB was also assessed in terms of current energy efficiency requirements as well as nearly zero-energy buildings requirements. This example also shows the possibilities of optimization of the construction design focusing on lowering environmental impacts and energy demands. The design lays the emphasis on the potential of wood-based materials in sustainable buildings.

Keywords: LCA, LCIA, timber building, ultra-low and nearly-zero building, sustainable buildings.

INTRODUCTION

As the population of the world increases, the pressure on natural resources is rising rapidly and the environmental burden is escalating dramatically. Life Cycle Assessment (LCA) method presents a model considering the net environmental impact based on the selection of materials that naturally support long-term management of energy sources (KOČÍ 2010, KOČÍ 2012). Life Cycle Impact Assessment (LCIA) is an important part of modern building construction process.

It is necessary to address the environmental requirements of building construction and its operation, but also to describe the life cycle of buildings starting from raw material extraction through materials production to their transport to a construction site, using of buildings (also e.g. indoor environmental quality) and demolition and eventual recycling of building materials (ESTOKOVA, ONDOVA 2015, VILČEKOVÁ et al. 2017).

Building regulations and standards aim at almost zero-energy consumption. Based on the European Parliament and Council Directive No. 2010/31/EU on the energy performance of buildings, all buildings built after 2020 should have almost zero-energy consumption. However, many regulations referring to almost zero-energy consumption focus only on operating energy and ignore the energy stored in the materials.

COLE *et al.* (2010) developed a method for integrating total energy into the annual consumption analysis, thereby creating a simplified model for total energy (LC-ZEB) - the Life Cycle of a Zero Energy Building. A lot of countries have introduced ZEB (Zero Energy Building) as their further target in the field of construction. Amongst a number of strategies to reduce energy consumption in buildings, zero buildings have the potential to reduce the energy they use significantly while increasing the share of renewable resources (MARSZAL *et al.* 2011).

The main energy consumption in a building is considered to be the energy for operation (heating, cooling, lighting, etc.). The amount of consumption can be regulated by technical innovations, control regulators and evaluations of a wide range of evaluation methods. With the rising buildings, materials for their production is being increased, but at the same time we try to reduce the consumption of operating energy. Energy contained in building materials is an important part of the building's energy lifecycle (HERNANDEZ, KENNY 2011).

It is proven that there is a linear dependence between operating and total energy This also applies to different climatic regions. This means that low energy buildings are more efficient than conventional buildings, even if their total energy is slightly higher. The demand to reduce operating energy seems to be the most important aspect of designing low-energy buildings (ADALBERTH *et al.* 2001).

The main objective of the study is to identify the environmental impacts of construction materials of a wooden Reference Prototype Building (RPB) using the LCIA method and presentation of the life cycle assessment principles for designing wood-based buildings for civil construction in terms of sustainable development in building industry.

MATERIALS AND METHODS

The reference prototype building is the designed wood-based building that serves as a research and educational center as well as a reference demonstration object with the use of technology for ultra-low energy buildings with an intelligent management system (Figure 1).

The building is a two-storey structure with a countertop roof, standing on a flat terrain without basement. The ground plan is rectangular with a total area of 19.2 × 29.8 m and a 572.16 m^2 built-up area. Table 1 includes the heated floor area and the volume of building. The supporting structure consists of wooden (OSB + spruce column) box beams 400 × 80mm together with straw bale insulation with a bulk density ρ = 90 kg/m^3. The structures of each construction are shown in Figure 2. The Foundations are on reinforced concrete feet. The floor above the terrain is formed by a beam construction with a double beam 150x300 mm in the 2000 mm module. Above this construction, the construction of peripheral wall is also created with straw bale insulation (400 mm thick) and additional mineral insulation (50 mm thick). The construction of windows is designed to be made of A+ triple glazed windows. The heating is designed to be hot-water underfloor heating provided by a central low-energy gas boiler with a hot water storage tank.

Fig. 1 Wood-based reference prototype building (RPB).

Layout of the peripheral wall layers from the inside out:

- CLT board, PU lacquer finish
- Box beams 400x80
- Straw insulation 400 mm
- DHF fiberboard 15 mm
- Facade diffusion foil
- Grate 70 x 60 mm
- Wooden facade cladding 25 mm

Floor layers layout from the inside out:

- Ceramic paving
- Flex glue 8 mm
- OSB III board 22 mm
- Grate + mineral wool insulation 50 mm
- Box beams 400x80
- Straw insulation 400 mm
- Diffusion foil
- DHF fiberboard 15 mm

Roof layers layout from the outside in:

- Folded sheet metal roofing
- OSB III paneling 22 mm
- Grate 60 x 50 mm
- Box beams 400x80
- Straw insulation 400 mm
- OSB III board 15 mm
- Grate + mineral wool insulation 70 mm
- Cetris Basic Board

Fig. 2 Composition of peripheral walls, floors, roof in the reference prototype building.

Tab. 1 Characteristic of the reference prototype building.

Built-up area	19.2 × 29.8 m	572.16 m^2
Heated floor area	1st floor	272.46 m^2
	2nd floor	256.26 m^2
	Together	528.72 m^2
Heated volume	1st floor	817.38 m^3
	2nd floor	861.67 m^3
	Together	1679.05 m^3
Lighting of the reference prototype building	114 × LED Tube 16 W	4377.6 kWh
	38 × LED bulb 8 W	2188.8 kWh
	Lighting area	544.4 m^2
	Together	6566.4 kWh
Energy balance of the reference prototype building	Thermal losses in the structure	24382.66 kWh/year
	Solar gains in the construction	3428.91 kWh/year
	Energy needed for heating	21.59 kWh/(m^2.year)
	Electricity needed for lighting	12.05 kWh /m^2 .year
	The need for energy to produce hot water	8.60 kWh/(m^2.year)
	The need for primary energy together	45.28 kWh/(m^2.year)

RESULTS AND DISCUSSION

LCA of the reference prototype building

The assessment was carried out at the whole unit of reference prototype building. (Table 1). The system boundaries from the cradle to the use of the building were chosen, without taking into account the transportation of the used materials and without preparatory and realization works. The materials necessary for the construction of the building were analyzed (Table 2).

Life cycle inventory (LCI) quantifies inputs and outputs within the system boundaries with respect to the selected functional unit. All wood-based building construction elements were included in LCI. The building was divided into the following main construction units: Foundations, Peripheral walls, Inner walls 1st floor, Inner walls 2nd floor, Flooring 1st floor, Flooring 2nd floor, Roof, Windows and doors and Energy.

Tab. 2 List of construction units of the reference prototype building, OSB - Oriented Strand Board, GLT - Glued Laminated Timber, DFP - Diffusion Fiber Plate, PU – Polyurethane.

Construction Unit	Subtitle	Width [mm]	Length [mm]	Height [mm]	Pieces	Volume piece [m³]	Total volume [m³]	Density [kg/m³]	Total weight [kg]
Foundations	Concrete C 20/25	500	1000	1000	48	0.5	24	2250	54000
		500	500	500	48	0.125	6	2250	13500
	Rolled steel 4mm thick	1250	800	4	48	0.004	0.192	7850	1507.2
	Solid wood SM C24	150	32200	300	6	1.449	8.694	420	3651.48
	Solid wood SM C24	150	18000	300	8	0.81	6.48	420	2721.6
Flooring - 1st floor	DHF fiberboard	17500	29600	15	1	7.77	7.77	600.00	4 662.0
	Box beam Spruce short	90	35860	60	8	0.19	1.55	420.00	650.64
	Box beam OSB short	400	35860	10	8	0.14	1.15	550.00	631.14
	Box beam Spruce long	90	64388	60	6	0.35	2.09	420.00	876.19

	Box beam OSB long	400	64388	10	6	0.26	1.55	550.00	849.92
	Straw insulation	23900	11400	400	1	108.98	108.98	90.00	9 808.56
	Grate Spruce	50	32200	50	6	0.08	0.48	420.00	202.86
	Grate Spruce	50	18000	50	8	0.05	0.36	420.00	151.20
	Isover DOMO insulation	32200	18000	50	1	28.98	28.98	120.00	3 477.60
	Flex glue	32200	18000	8	1	4.64	4.64	1 600.00	7 418.88
	Ceramic paving	32200	18000	12	1	6.96	6.96	2 000.00	13 910.40
	Exterior stairs	300	4800	40	6	0.06	0.35	420.00	145.15
Flooring - 2nd floor	CLT board	32200	18000	180	1	104.33	104.33	470.00	49 034.16
	Epoxy resin	32200	18000	2	1	1.16	1.16	1 750.00	2 028.60
	Ceramic paving	5300	5400	12	1	0.34	0.34	2 000.00	686.88
	Paving BK	10300	10500	20	1	2.16	2.16	380.00	821.94
Peripheral walls - 1st floor	Facade cladding SMC	35000	3500	25	1	3.06	3.06	550.00	1 684.38
	Grate Spruce	280000	70	60	1	1.18	1.18	420.00	493.92
	DHF fiberboard	3500	35000	15	1	1.84	1.84	600.00	1 102.50
	Box beam Spruce	90	7000	60	68	0.04	2.57	420.00	1 079.57
	Box beam OSB	400	7000	10	68	0.03	1.90	420.00	799.68
	Straw insulation	35000	3500	400	1	49.00	49.00	90.00	4 410.00
	CLT board	35000	3500	100	1	12.25	12.25	470.00	5 757.50
	PU lacquer	35000	3500	0.5	1	0.06	0.06	950.00	58.19
Inner walls - 1st floor	CLT board	41200	3500	100	1	14.42	14.42	470.00	6 777.40
	Glazed walls	9800	3500	10	1	0.34	0.34	2 600.00	891.80
	GLT columns	200	4100	200	48	0.16	7.87	420.00	3 306.24
Ceiling beams	GLT	150	22700	300	1	1.02	1.02	420.00	429.03
	GLT	150	17900	300	1	0.81	0.81	420.00	338.31
	GLT	150	18350	300	3	0.83	2.48	420.00	1 040.45
	GLT	150	10900	300	1	0.49	0.49	420.00	206.01
	GLT	150	5200	300	1	0.23	0.23	420.00	98.28
Inner walls - 2nd floor	CLT board	35100	3510	100	1	12.32	12.32	470.00	5 790.45
	Glazed walls	1700	2500	10	8	0.04	0.34	2 600.00	884.00
	Glazed walls	2300	2500	10	1	0.06	0.06	2 600.00	149.50
	Glazed walls	9800	3880	10	1	0.38	0.38	2 600.00	988.62
	GLT columns	200	3510	200	48	0.14	6.74	420.00	2 830.46
Roof	Roof beams GLT	300	29600	150	12	1.33	15.98	420.00	6 713.28
	Cement board CETRIS BASIC	23900	11500	15	1	4.12	4.12	1 300.00	5 359.58
	Grate Spruce	70	32200	60	1	0.14	0.14	420.00	56.80
	Grate Spruce	70	18000	60	1	0.08	0.08	420.00	31.75
	Isover plus	23900	11500	70	1	19.24	19.24	130.00	2 501.14
	OSB III board	23900	11500	15	1	4.12	4.12	550.00	2 267.51
	Box beam Spruce	90	19400	60	50	0.10	5.24	420.00	2 199.96
	Box beam OSB	400	19400	10	50	0.08	3.88	550.00	2 134.00
	Straw insulation	23900	11500	400	1	109.94	109.94	90.00	9 894.60
	DHF fiberboard	30900	19326	15	1	8.96	8.96	600.00	5 374.56
	Grate Spruce	60	19326	60	50	0.07	3.48	420.00	1 461.05
	OSB III board	23900	19326	22	1	10.16	10.16	550.00	5 588.89
	Folded sheet metal roofing	23900	19326	0.7	1	0.32	0.32	7 140.00	2 308.53

Thermal and technical characteristics

When assessing the thermal and technical characteristics of horizontal and vertical envelope structures using the FRAGMENT 4.0 program, the normative boundary conditions of the indoor and outdoor climate according to the national technical standard STN 73540 - Thermal Protection of Buildings and Components, and the particular temperature ranges were considered in all calculations. Passive ventilation with heat recovery with a normative air exchange rate of 0.5/h was considered for the calculation of the specific heat demand. The floor area is only related to the heated part of the building calculated from the outer dimensions. The designed building complies with the standardized specific heat demand according to the above mentioned national standard. It complies with the assumption that the reference prototype building would achieve maximal specific heat demand $Q_{N,EP}$ less than 40.7 kWh/(m^2·year).

According to thermal and technical characteristics of the reference prototype building by Fragment 4.0, peripheral walls construction has a interior surface temperature of 19.46°C The heat transfer coefficient U is equal to 0.12 W/(m^2·K). Diffusion resistance R_D reaches 0.16×10^{-9} m/s. Thermal resistance R of the structure is 8.256 m^2·K/W. The peripheral walls construction does not cause condensation of water vapor.

The floor construction has an interior surface temperature of 19.33°C. The heat transfer coefficient U equals 0.11 W/(m^2·K). Diffusion resistance R_D reaches 2.39×10^{-9} m/s. Thermal resistance R is 8.776 m^2·K/W. Condensation of vapor is not evaluated in the floor structure.

Tab. 3 Heat loss of the analyzed wood-based building by FRAGMENT 4.0 program.

No.	Fragment	Heat Transfer Coefficient U [W/(m^{2}K)]	Area [m^2]	Reduction factor B_i	$U_i.A_i.B_{xi}$ [W/K]	Resulting heat loss [kWh/year]
1	Wall 1st floor	0.12	204.35	1	24.25	1991.89
2	Wall 2nd floor	0.12	203.22	1	24.12	1980.88
3	Roof attic	0.13	256.26	1	32.25	2648.66
4	Floor over terrain	0.18	272.46	1	49.04	4027.79
5	Windows, ext.doors	0.55	47.55	1	26.15	2147.85
6	Entrance door	1.20	12.46	1	14.95	1227.98

The roof structure surface temperature reaches 19.51 °C. The heat transfer coefficient U is equal to 0.11 W/(m^2·K). Diffusion resistance R_D is 0.16×10^{-9} m/s. Thermal resistance R of the structure is 9.183m^2.K/W. Annual amount of condensed water vapor in the roof construction is up to 0.0043 kg/(m^2.year) that falls into the permitted range of less than 3,1268 kg/(m^2·year) of evaporated water vapor.

All three structures mentioned above (peripheral walls, floor over the terrain, roof) meet the recommended target value of the heat transfer coefficient U to be less than 0.15 W/(m^2·K). Moreover, all these constructions meet all the criteria involved in national technical standard STN 73540 - Thermal Protection of Buildings and Components. According to the specific heat demand method, annual heat loss Q_L of the reference prototype building reaches 24382.66 kWh/year. The solar gains of the building were 3428.91 kWh/year. Annual heat consumption for heating Qh is 10771.71 kWh/year that is equivalent to specific value of 19.77 kWh/m^2 per year. Specific energy needed for heating $Q_{h,r}$ represents 21.29 kWh/(m^2.year). Primary energy Q_p achieved 45.28 kWh/(m^2·year), placing the reference prototype building in the “A1” energy class according to Ministerial Decree of the Ministry of Transport, Construction and Regional Development of the Slovak Republic No. 364/2012 Coll. on the energy performance of buildings with the defined primary energy of 35 to 68 kWh/(m^2·year).

LCIA of the reference prototype building by EDIP2003 method

Assessment of the reference prototype building by EDIP2003 method (Figure 3) shows that the largest negative impact on the environment in the wood-based building construction are Windows and doors unit with a total area of 121.15 m^2, which represents 20% of the impact. The Inner walls 2nd floor unit is the next most negative component of the building, with a total area of 267.401 m^2 representing 18% of the impact due to the use of glass fillings of 82 m^2, Flooring 2nd floor unit accounts for 14% of the impact, Roof unit represents about 13% of the impact, Flooring 1st floor unit stands for 11%, Peripheral walls unit corresponds to 10%, Inner walls 1st floor takes 9% and, eventually, the smallest negative impact on the environment refer to Foundations unit with the total volume of 30 m^3. Further reducing of the negative impact of Foundations is possible e.g. by using green and waste materials instead of cement materials (DAOUI *et al.* 2015, SAFI *et al.* 2017).

Tab. 4 LCIA of the reference prototype building by EDIP 2003 method, Midpoint, characterization.

Impact category	Unit	Construction together	Foundations	Flooring 1st floor	Peripheral walls
Global warming 100a	kg CO_2 eq	2.06E+05	1.33E+04	2.02E+04	1.93E+04
Ozone depletion	kg CFC11 eq	1.52E-02	9.35E-04	1.59E-03	1.72E-03
Ozone formation (Vegetation)	m^2.ppm.h	1.64E+06	9.47E+04	1.21E+05	1.45E+05
Ozone formation (Human)	person.ppm.h	1.14E+02	6.59E+00	8.51E+00	1.01E+01
Acidification	m^2	2.30E+04	9.20E+02	2.12E+03	2.26E+03
Terrestrial eutrophication	m^2	2.26E+04	1.10E+03	1.71E+03	1.74E+03
Aquatic eutrophication EP(N)	kg N	3.83E+02	1.64E+01	2.97E+01	5.30E+01
Aquatic eutrophication EP(P)	kg P	4.45E+01	2.12E+00	4.77E+00	4.85E+00
Human toxicity air	person	1.55E+10	5.56E+08	5.08E+09	9.07E+08
Human toxicity water	m^3	7.28E+06	2.65E+05	5.37E+05	6.25E+05
Human toxicity soil	m^3	9.98E+04	8.00E+03	1.80E+04	5.62E+03
Ecotoxicity water chronic	m^3	2.82E+08	1.07E+07	2.78E+07	2.96E+07
Ecotoxicity water acute	m^3	5.35E+07	2.03E+06	7.35E+06	5.85E+06
Ecotoxicity soil chronic	m^3	1.08E+07	6.03E+04	3.86E+06	1.91E+06
Hazardous waste	kg	1.87E+02	4.94E-01	1.34E+02	1.02E+00
Slags/ashes	kg	1.99E+03	6.95E+01	1.66E+02	2.68E+02
Bulk waste	kg	3.83E+04	3.13E+03	4.43E+03	4,10E+03
Radioactive waste	kg	7,48E+00	5,12E-01	6,73E-01	9,65E-01
Resources (all)	PR2004	2,46E+02	2,12E+00	3,55E+01	1,25E+01

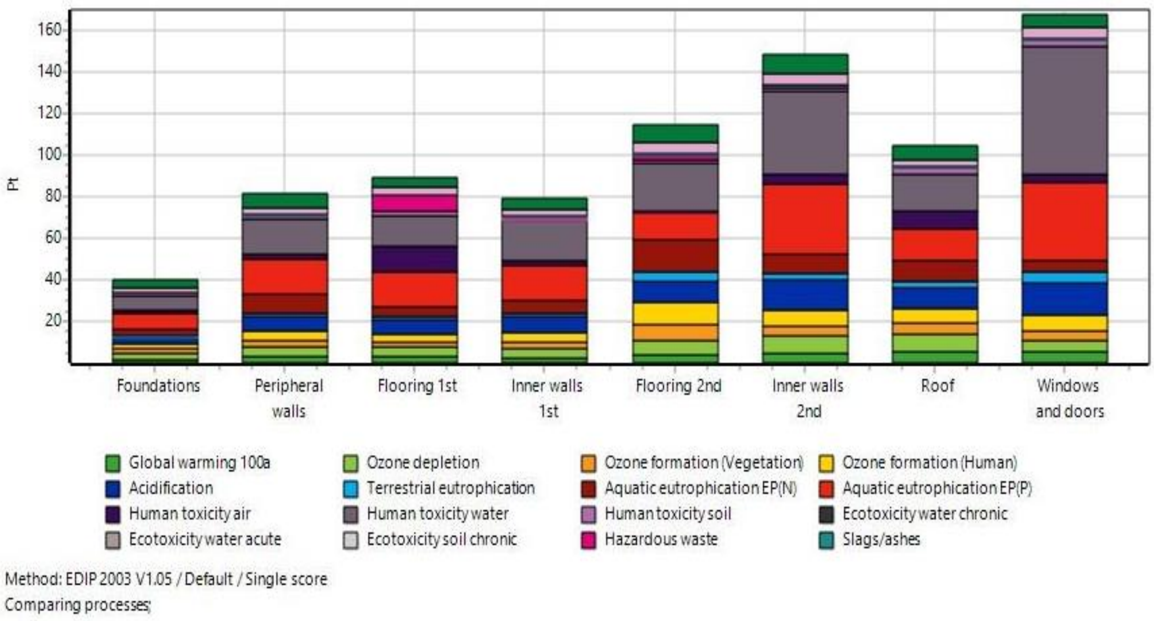

Fig. 3 LCIA of the reference prototype building by EDIP 2003 method, Midpoint, score Pt.

Tab. 5 LCIA of REFERENCE PROTOTYPE BUILDING by EDIP 2003 method, Midpoint, characterization.

Impact category	Unit	Inner walls 1st floor	Flooring 2nd floor	Inner walls 2nd floor	Roof	Windows and doors
Global warming 100a	kg CO_2 eq	1.73E+04	2.98E+04	3.31E+04	3.61E+04	3.71E+04
Ozone depletion	kg CFC11 eq	1.51E-03	2.11E-03	2.62E-03	2.90E-03	1.77E-03
Ozone formation (Vegetation)	m^2.ppm.h	1.49E+05	3.73E+05	2.55E+05	2.47E+05	2.51E+05
Ozone formation (Human)	person.ppm.h	1.04E+01	2.57E+01	1.79E+01	1.71E+01	1.80E+01
Acidification	m^2	2.30E+03	3.20E+03	4.49E+03	3.02E+03	4.70E+03
Terrestrial eutrophication	m^2	1.76E+03	4.46E+03	2.92E+03	3.27E+03	5.62E+03
Aquatic eutrophication EP(N)	kg N	3.94E+01	9.38E+01	5.89E+01	5.93E+01	3.28E+01
Aquatic eutrophication EP(P)	kg P	4.77E+00	3.58E+00	9.44E+00	4.43E+00	1.06E+01
Human toxicity air	person	1.04E+09	5.93E+08	2.13E+09	3.50E+09	1.71E+09
Human toxicity water	m^3	6.95E+05	8.37E+05	1.43E+06	6.61E+05	2.23E+06
Human toxicity soil	m^3	6.23E+03	9.58E+03	1.01E+04	2.02E+04	2.20E+04
Ecotoxicity water chronic	m^3	3.19E+07	3.24E+07	6.04E+07	3.13E+07	5.79E+07
Ecotoxicity water acute	m^3	6.68E+06	4.44E+06	1.37E+07	4.38E+06	9.09E+06
Ecotoxicity soil chronic	m^3	1.97E+05	3.90E+05	3.02E+05	4.05E+06	5.69E+04
Hazardous waste	kg	1.07E+00	4.58E+01	2.17E+00	6.07E-01	1.27E+00
Slags/ashes	kg	2.69E+02	2.26E+02	5.01E+02	2.18E+02	2.74E+02
Bulk waste	kg	3.72E+03	6.23E+03	6.47E+03	3.99E+03	6.25E+03
Radioactive waste	kg	8.29E-01	1.26E+00	1.38E+00	9.61E-01	9.10E-01
Resources (all)	PR2004	1.55E+01	5.60E+00	3.37E+01	1.65E+01	1.25E+02

HÄFLIGER *et al.* (2017) in their study evaluated an uninhabited wooden building with a built-up area of 517 m^2. The study was processed by CML-IA method. The global warming value in the Häfliger study was 7.3 kg CO_2eq/m^2. In the reference prototype building, this value is higher - 10.2 kg CO_2eq/m^2. This may be due to a different structure of the construction elements. The annual energy consumption for heating reaches 30 kWh/m^2 per year. The reference prototype building annually consumes only 21.59 kWh/m^2. HERNANDEZ *et al.* (2011) considers operating energy as the main energy consumption in the building, used for heating, cooling, lighting, etc.

ESTOKOVA *et al.* (2017) evaluated a masonry house in terms of primary energy. The environmental impact assessment acknowledges that the foundations have the greatest negative impact on the brickwork, and in the case of a wooden house the greatest negative impact is held by windows (ESTOKOVA *et al.* 2017, ONDOVA *and* ESTOKOVA 2016, ESTOKOVA *and* ONDOVA 2015).

On one hand, there is a trend to build more and therefore to use more materials and energy in building industry. On the other hand, there is an effort to reduce operating energy of buildings. ERHORN *et al. (*2014) in their study compared operating energy and CO_2 emissions. He found out that the percentages of energy consumed in the building: electricity / heating / hot water accounted fort 41:40:18. The remaining percentage is due to the loss of energy by distribution. Many consumptions can be controlled by technical innovations and regulatory systems.

The amount of produced CO_2 emissions was 10.4 kg/m^2 per year. In reference prototype building this ratio is 33:47:19. The remaining percentage is also due to the loss of energy by distribution. ROBERTSON (2007) in his work compared a wood-based construction with its equivalent of a silicate construction by the CLM-IA method. The acidification potential in the Robertson wooden building represented 1.346 km^{2}eq. In wood-based reference prototype building, this value is equal to 2.338 km^{2}eq. Depletion of the ozone layer occurs when trichlorofluoromethane eq. (CFC-11 eq.) equals 0.019 kg. In the wood-based reference prototype building, the value is more favorable, only 0.016 kg of CFC-11 eq.

The most negative environmental impact is represented by Windows with a total area of 121.15m^2 that affect the ecosystem the most, namely water eutrophication and human water toxicity, the index of which is a potentially harmful chemical released into the environment. Eutrophication refers to excessive amounts of organic and inorganic substances contained in water, resulting in ecosystem disruption and biodiversity depletion due to low oxygen content and increased toxin content. From the midpoint categories the glass elements have the greatest impact for water eutrophication EP(P) and water toxicity.

CONCLUSIONS

When assessing the thermal and technical characteristics of horizontal and vertical packaging structures using the FRAGMENT 4.0 program, all the calculations considered normative boundary conditions of the indoor and outdoor climate for the indoor environment and the respective temperature ranges. Primary energy Q_p equals to 45.28 kWh/(m^2.year). According to Ministerial Decree No. 364/2012 Coll. on the energy performance of buildings, the analyzed wood-based building falls under “A1” energy class of primary energy classes with the defined primary energy of 35 to 68 kWh/(m^2.year) and meets the energy efficiency of the building ($Q_{N,EP}$ > 40.7 kWh/(m^2.year)).

The environmental assessment of the reference prototype building was performed by SIMAPro 8.0 program and evaluated by EDIP2003 method. The building was divided into construction units: Foundations, Peripheral Walls, Flooring 1st floor, Flooring 2nd floor and Operating Energy. LCIA showed that Windows with the total area of 121.15 m^2 have the most adverse effect, with an impact of 19.6%. The Inner walls are 267.401 m^2, which represents 17.4% impact due to the use of glass fillings of 82m^2 and their production demands.

The results shows that the analyzed wood-based reference prototype building causes relatively small environmental damage due to the use of more environmentally friendly materials, less demanding for raw materials, processing, production and transport.

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AUTHORS'ADDRESS

Ing. Jozef Mitterpach, PhD.
Technical University in Zvolen
T. G. Masaryka 24
960 53 Zvolen
Slovakia
jozef.mitterpach@gmail.com

Ing. Rozália Ilečková
prof. Ing. Jozef Štefko, CSc.
Technical University in Zvolen
T. G. Masaryka 24
960 53 Zvolen
Slovakia
r.ileckova@gmail.com
stefko@tuzvo.sk