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Variants of determining the construction production carbon footprint

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Professional paper

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Variants of determining the construction production carbon footprint

The aim of the paper is to quantify the construction production carbon footprint per m3 of the built-up volume of the building. In order to determine the carbon footprint, 5 typical detached houses were selected. The individual buildings have the same material-construction characteristics; however, they differ in the size of the built-up volume, i.e. also in the built-up area. The LCA software was used to quantify the carbon footprint during the production phase of the model houses project. A budget indicator per m^3 of the built-up volume was determined based on these calculations.

Key words:

budget indicator, built-up volume, carbon footprint, construction production, life cycle

Stručni rad

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Varijante određivanja ugljičnog otiska građevinske proizvodnje

Cilj ovog rada jest odrediti ugljični otisak gradnje po kubnom metru izgrađenog volumena zgrade. Za određivanje ugljičnog otiska odabrano je pet tipskih samostojećih kuća. One imaju ista materijalna svojstva, no razlikuju se po volumenu i izgrađenoj površini. Za određivanje ugljičnog otiska tijekom gradnje samostojećih kuća primijenjen je računalni program LCA (engl. *Life Cyle Assesment* - LCA). Na temelju tih izračuna određen je indikator proračuna po kubnom metru izgrađenog volumena građevine.

Ključne riječi:

indikator proračuna, izgrađeni volumen, ugljični otisak, gradnja, uporabni vijek

1. Introduction

Recently, men have stopped behaving in harmony with nature and have started to transform it in a very significant way. The intensive exploitation of natural resources disturbs the Earth's balance, leading to many environmental problems at the global level. The air, water and soil are being burdened by emissions of pollutants having a negative impact on both the environment and human health as a result of construction production.

Climate change represents the most important environmental as well as political and economic issues of the 21st century [1-3]. The Paris Agreement which aims to reduce greenhouse gas emissions so that the temperature increase does not exceed 1.5 °C and thus keep global warming at an acceptable level, was adopted at the Paris Climate Conference United Nations Summit in 2015 [4, 5]. The Agreement included all major emitters of greenhouse gases and it replaced the Kyoto Protocol in 2016 [6-8].

The UN Environment Programme (UNEP) develops an annual Emissions Gap Report, which aims to achieve agreed goals at the lowest possible cost. Emissions from all greenhouse gases are expected to be reduced and 42 $GtCO_{2e}$ (Global total CO_2 emissions) should not be exceeded in 2030 [9]. The latest assessment shows that the EU is well on track to exceed the current target, mainly thanks to the progress in the use of renewable energy sources across Europe [10]. The transition to a climate-neutral economy will only be possible if everyone contributes to it. The key to achieving climate neutrality is to reduce energy supplies [11, 12].

The construction industry consumes approximately 40 % of the world's annual energy consumption [13]. It is energy consumption that contributes significantly to the global warming of the Earth [14]. As a result, the first passive houses began to be built in Germany in the 1990s to reduce this consumption, where architects were able to reduce operating energy consumption ten times compared to low-energy houses [15-17]. Currently, it is necessary to promote architecture that, in addition to meeting the needs, addresses the issue of protection and prevention of negative impacts on nature within the whole process from the construction, through the use to the demolition of the building and its subsequent recycling [18]. The term sustainable architecture means preserving the environment for future generations. It does not deal just with saving energy, using healthy materials from renewable sources [19, 20], but addresses all contexts such as the protection of cultural values, managing the development of large settlements to work well and efficiently and does not leave a large ecological footprint [21].

The amount of the human activity impact on the environment (especially on climate change) is referred to as the carbon footprint [22]. It is a measure of the amount of greenhouse gas emissions arising from certain activities or products [23]. Results are given in CO_2 equivalents [24]. The amount of carbon footprint can be determined at national, city, individual, company or product levels. The most important greenhouse gas is clearly carbon dioxide, which chemical formula is CO_2 and it is released during burning fossil fuels, such as crude oil, natural gas, coal, etc [25, 26].

Currently, the construction industry makes an effort to mitigate its negative impact on the environment [27]. The construction industry is one of the largest global consumers of natural resources [23]. It significantly contributes to the production of greenhouse gases both from the construction itself, the subsequent building operation and finally its liquidation [28]. Therefore, the assessment of buildings and their environmental certification has been introduced.

There are many possibilities and ways to reduce CO_2 emissions during the building life cycle, i.e. from the implementation phase, through the operational phase to the liquidation phase [29]. Construction work represents a complex of a large number of products and works with a long service life, where the operational phase forms a major part of the building life cycle. The design itself can take into account the bound emissions of materials and their service life [30, 31].

The aim of the research described in this article is to determine the carbon footprint per production unit of the budget indicator, mainly in the phase of production of building materials and in the implementation phase of the building. The calculation of the carbon footprint mainly takes into account the impact of the life cycle of the material used for the construction.

2. Methodology

Global warming refers to the phenomenon of a long-term increase in the average surface temperature of the Earth, which leads to further climate change such as ice melting, sea levels rising, precipitation changes, more frequent extreme weather conditions such as drought, floods and others [32, 33]. Global warming is caused by increasing concentrations of greenhouse gases in the atmosphere, which amplify the greenhouse effect [34, 35].

The global warming potential indicates how much heat the greenhouse gas traps in the atmosphere [36]. It is calculated in carbon dioxide equivalents and is determined in units of kg CO_2 eq. CO_{2e} emissions (GWP - Global Warming Potential) and includes emissions of substances [37, 38]. The equivalent means that these are not only carbon dioxide emissions, but also other greenhouse gas emissions (methane, nitrous oxide, sulphur hexafluoride, freons and halons) [39]. Their production is perceived as a carbon footprint [40]. The carbon footprint is thus a measure of the human activity impact on the environment and it is an indirect indicator of the consumption of energy, products and services [41, 42].

Various specialized software and inventory data databases are used to calculate and model product life cycles [43]. The professional One Click LCA software, developed by the Bionova company, was used in this research. One Click LCA software provides various data sources from around the world [44]. For the purposes of the calculations, the vast majority of the data was taken from the Cenia and Ökobau.dat databases, thanks to the largest available coverage of materials commonly used in Central Europe. This LCA software covers the life cycle stages from the cradle to the grave. It distinguishes product phases, construction process, use phase, operational energy and end of the life cycle phase [45]. The LCA system was chosen to calculate the carbon footprint, while the software itself provides further assessments, such as the BREAMM Mat or the CML Life Cycle Cost [46].

The One Click LCA software used allows data to be displayed according to the items, groups and subgroups of materials that contribute most to a certain impact category. It allows assessing both the share of individual materials or structural elements and the overall environmental impact of the project. The software provides various environmental impact indicators: Global Warming Potential (kg CO_2 e), Acidification Potential (kg SO_2 e), Eutrophication Potential (kg PO_4 e), Ozone Depletion Potential (kg CFC-11e), Photochemical Ozone Creation Potential (kg Ethene), total Primary Energy use (MJ), Abiotic Depletion Potential (kg Sb e), and others. Although all the listed impact indicators are essential for the life cycle assessment, this article takes into account especially the carbon footprint of buildings, i.e. the Global Warming Potential, which is given in units of kg CO_2 or t CO_2 [41].

The purpose of the research described in the article was to determine the average amount of the carbon footprint per unit of the budget indicator [47]. The determination of the carbon footprint per unit of production of the budget indicator may be related to the unit of the built-up volume or the built-up area of individual buildings. The Czech national classification: the Uniform Classification of Buildings and Construction Work of a Production Nature (JKSO) was therefore chosen to determine the amount of the carbon footprint [48, 49]. This classification classifies buildings according to their technical properties and material characteristics in contrast to the International Classification of Types of Construction (CC) which classifies construction production according to the way of use [50].

3. Results and discussion

One Click LCA software divides the cycle into several phases, see Figure 1, according to the LEED methodology, which defines the stages of the life cycle (A1-A3, A4, B1-B5 and C1-C4), i.e. "Cradle to Grave". The "Cradle to Grave" model, therefore, covers processes from raw material extraction through material production, transport, inbuilding, maintenance during its lifetime to disposal. The software determines potential loads also beyond the system; however, it does not include these benefits and loads in the calculation results.

The One Click LCA building life cycle assessment tool includes all the above-mentioned processes and impacts in the calculations. In order to determine the carbon footprint per unit of production of the budget indicator, it is necessary to determine the first two phases, i.e. the product phase (A1-A3) and the construction phase (A4-A5), as these two phases are the most accurate for the purpose of this research. The consumption of energy and water, which has the greatest impact on global warming, depends, for example, on the type of heating of the building, so these phases are not accurate enough for evaluating the total carbon footprint.

An item budget, technical report and building design are required to determine the amount of material to create the carbon footprint of the building. Five sample detached houses were selected to determine the carbon footprint and the impact of construction production on the environment. All these sample houses were detached, without a basement, based on concrete foundation strips, the load-bearing system was made of brick, with a timber roof framework and tile roof covering. These houses were selected to correspond to the JKSO classification in the chapter Houses for a living - single-family houses; isolated; masonry of bricks or blocks; new building - 803 61 11.

First, it was necessary to assign the individual materials to determine the carbon footprint. Either the exact product from the manufacturer was looked up or the closest match was found. If necessary, it is possible to use general data in case a suitable product cannot be found, therefore a product with similar quality can be used instead. These general materials can be found mainly in the German database Öekobau.dat. However, each material has its own service life, which is needed to calculate the impacts resulting from its replacement and disposal in category B4-B5.

A default initial service life that is automatically applied to each material can be set In One Click LCA program. If necessary, this value can be set manually in the settings, however, this option was not used in the research. The same applies to the transport distance of the material. The transport mode and the distance from the building material manufacturer to the construction site are used for each material in the assessed building. Distances are automatically

Table 1. Life cycle phases, according [9]

A1-A3	A4-A5	B1-B7	C1-C4	D
Product phase	**Implement action phase**	**Operation phase**	**End of the life cycle phase**	**Benefits and burdens outside the system**
A1 – Extraction of materials A2 – Transport A3 – Production	A4 – Transport to the construction site A5 – Inbuilding	B1 – Use B2 – Maintenance B3 – Repair B4 – Exchange B5 – Renovation B6 – Energy consumptione (operation) B7 – Water consumptione (operation)	C1 – Demolition C2 – Transport C3 – Waste processing C4 – Waste disposal	Reuse / renovation / recycling

Table 2. Characteristics of individual sample houses [Authors´ own work]

House No.	Built-up volume [m^3]	Built-up area [m^2]	Floor area [m^2]	Energy consumption [MWh/year]	Water consumption [m^3/year]
House 1	457.60	102.06	78.66	12.40	144.00
House 2	899.82	196.78	147.94	17.80	144.00
House 3	591.53	121.37	95.54	13.30	144.00
House 4	523.53	81.88	120.85	11.80	144.00
House 5	604.77	129.36	101.41	13.70	144.00

defined using a compensation factor. As the assessed buildings are located in the Czech Republic, a local compensation factor that adjusts the impacts of material production to the conditions of the selected country was chosen. Therefore, by default, the software determines the localization of the material, which remains the same for all other objects to avoid confusion.

The annual energy consumption of each house was determined based on the energy performance certificate of the building. The source of electricity was determined as Electricity, Czech Republic according to the programme of the Bionova EN15804 standard. The Global Warming Potential was 0.59 kg CO_2 e/kWh.

Furthermore, Table 1 shows the values of annual energy consumption in MWh/year for individual assessed houses. This data was taken from energy certificates, which were provided together with the project documentation of the buildings.

Annual water consumption was considered the same for all types of houses. A model of the family of 4 living in the house was considered. Average water consumption per year according to Decree No. 120/2011 Coll. is 35 m^3 per inhabitant of the house, 1 m^3 is added for the consumption associated with the cleaning of the house surroundings. The annual water consumption per capita is 36 m^3, for a family of 4, it was 144 m^3 per year.

One Click LCA software makes it possible to add impacts related to the building site operation using project-specific data or use average impacts by climate zone. For the purpose of this research, the construction site scenario corresponding to the averages of our climate zone – temperate continental climate, was used. A suitable climatic zone and built-up area of the building in m^2 were selected. The averages include the average electricity, fuel consumption and waste production impacts on individual climatic zones. The expected average construction waste production for the temperate continental climate zone was 5 kg/m^2, the expected electricity consumption was 37 kWh/m^2 and the expected total use of diesel oil was 4.5 l/m^2. The Global Warming Potential (A1-A3) was 30.34 kg CO_2 e/m^2 [29].

The calculation period defines the lifespan of the building with all impacts calculated for this period. The program allows values between 0 and 80 years. Even though the lifespan of a brick house is approximately 100 years, the lifespan in the research was set at 50 years. It thus fell within the permitted values of the program. Product and construction phases, which are not affected by the service life of the entire building, were also required for the purpose of the research.

It was necessary to determine carbon footprint in kg of CO_2 and built-up volume, or built-up area for individual buildings. The share of the carbon footprint and the built-up volume or built-up area determined a new indicator, in units of measure kg CO_2/m^3, or CO_2/m^2. This indicator could help to determine in advance the carbon footprint of a building, i.e. how construction production affects the environment.

The indicator, set per production unit, can be used for the purpose of quick and easy determining the approximate amount of the carbon footprint. The basic principle is to determine the number of technical units, e.g. per m^3 of built-up volume or m^2 of built-up area.

Sample detached houses were selected in order to determine the carbon footprint per unit of measure. Individual buildings differ in built-up volume, i.e. also in the built-up area. However, no extreme values that would have to be ruled out due to skewing of the results, appeared.

The following tables and figures quantify the environmental impacts during the entire life cycle of each evaluated detached house. The largest share of the carbon footprint is borne by energy consumption, followed by construction materials. However, only the first two phases are used to calculate the carbon footprint per unit of production of the budget indicator. The product phase, which includes the extraction of raw materials, transport and the actual production of materials, and the construction phase, which includes transport to the construction site and their inbuilt. The research aimed to determine the carbon footprint per the production unit of the budget indicator.

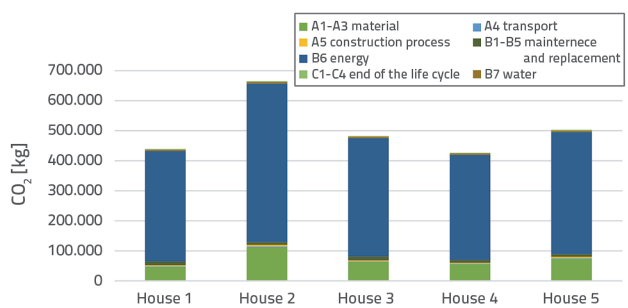

Figure 1. Assessment of the life cycle in kg CO_2 [Authors´ own work]

Table 3. A list of the imported materials for the House No.3 [Authors´ own work] [rad autora]

	Class	Ifcmaterial	Quantity	Unit	Thickness [mm]	Comment
1	foundation	concrete, cast	17 799	m^3		Concrete C 20/25 X0 XC2 aggregate fraction 0/22 (base slab)
2	foundation	lumber	17 968	m^2		Foundation slab formwork
3	foundation	reinforcement	413	kg		Welded Kari nets 150x150 D 5 mm
4	foundation	concrete, cast	26 548	m^3		Foundation strips and footings made of concrete, clas. C12/15 fraction 0/22
5	foundation	masonry, blocks ZTB	31.6	m^2	300	Lost formwork concrete split slab for masonry 300 mm thick
6	foundation	concrete, cast	8 557	m^3		Concrete C 16/20 X0, XC1 aggregate fraction 0/22
7	foundation	reinforcement	468	kg		Ribbed steel bar BSt 500S
8	internal wall	masonry, ground bricks	46.65	m^2	250	Ground brickwork, 250 mm thick
9	external wall	masonry, ground bricks	100.28	m^2	440	Ground brick thermal insulation masonry, thickness 440 mm
10	external wall	Masonry, ground bricks	9.88	m^2	380	Ground brick thermal insulation masonry, thickness 380 mm
11	external wall	mortar	654	kg		Dry mortar mix
12	external wall	lintel, ceramic	1.211875	m^3		High ceramic overlay
13	external wall	polystyrene EPS	8.88	m^2	80	EPS thermal insulation between lintels
14	external wall	concrete, cast	281	m^3		Reinforced concrete lintel cc. C 20/25 X0XC2
15	external wall	reinforcement	236	kg		Lintel reinforcement, profile steel
16	external wall	wooden planks	53	m^3		Lintel formwork
17	internal wall	masonry, ground bricks	38.85	m^2	115	Partition made of ground bricks, 115 mm thick
18	internal wall	masonry, aerated concrete blocks	3.96	m^2	150	Lintel made of aerated concrete blocks, thickness 150
19	horizontal structures	concrete, cast	3.57	m^3		Reinforcing strips and coping blocks made of reinforced concrete cc. C 16/20
20	horizontal structures	reinforcement	513.13	kg		Reinforcement of reinforcing strips and coping blocks with BSt 500S reinforcing steel
21	slab	Ceramic ceiling insert	105 751	m^2	190	Ceramic ceiling insert
22	slab	concrete, cast	9 688	m^3		Concrete C20/25
23	slab	reinforcement	681	kg		Welded Kari nets 150x150 D 5 mm
24	slab	anhydrite	95.6	m^2	60	Self-levelling anhydrite screed C20
25	slab	PE foil	95.6	m^2		Separation layer made of PE foil
26	slab	PE tape	9.6	m^2		PE foam expansion tape 80 mm wide
27	external wall	polystyrene, XPS	49 613	m^2	60	Contact insulation board 60 mm thick
28	finish	cement spraying	1139.3	kg		Cement spray, dry plaster mixture
29	finish	fibreglass fabric	155	m^2		Cover outer walls with fibreglass mesh, fibreglass fabric for ETICS 162 g/m^2
30	finish	screed, cement	651	kg		Dry adhesive and screedl cement mix
31	finish	plaster, external, thermal insulation	1515.125	kg		Thermal insulating plaster, dry plaster thermal insulating compound
32	finish	plaster, external, silicon silicate	346	kg		Silicone-silicate thin-film paste plaster
33	foundation	coating, penetrating	19	kg		Acrylic primer coating compound
34	foundation	coating, penetrating	46	kg		Ground moisture insulation, asphalt penetrating varnish
35	foundation	asphalt strip	182.62	m^2		Soil damp proofing, asphalt strip, fusible modified SBS 4 mm thick with glass fabric liner, mineral sprinkling

Table 3. A list of the imported materials for the House No.3 [Authors´ own work] - continuation

Class		Ifcmaterial	Quantity	Unit	Thickness [mm]	Comment
36	roof	coating, penetrating	34	kg		Soil damp proofing, asphalt penetrating varnish
37	roof	asphalt strip	130 548	m²		Soil damp proofing, asphalt strip 4 mm thick fusion modified SBS with glass fabric liner, mineral sprinkling
38	finish	glass fibre cloth	27.5	m²		Coating of internal walls with glass fibre mesh, glass fibre fabric for ETICS 162 g/m²
39	finish	screed, cement	115.5	kg		Dry adhesive and trowel cement mix
40	finish	plaster, internal, lime cement	6075	kg		Lime-cement plaster interior stucco fine
41	roof	polystyrene, mineral	234.6	m²	140	Insulation mineral universal insulation, thickness 140
42	slab	polystyrene, EPS	97 512	m²	70	Thermal insulation EPS grey
43	foundation	polystyrene, XPS	21	m²	40	XPS thermal insulation, thickness 40 mm
44	roof	construction timber, prism	6 642	m³		Kce of roof trusses
45	roof	lumber, spruce	3.52	m³		Roof formwork, coniferous spruce timber, thickness 18-32 mm
46	roof	lumber, spruce	1 596	m³		Battening, lumber batten
47	roof	decking, spruce	33.11	m²		Decking boards
48	roof	fungicide impregnator	19.2	kg		Impregnation against wood-boring insects
49	roof	Fasteners	73.32	kg		Roof truss fasteners, formwork, lathing
50	other	Sheet metal, Pz	4.44	m²	0.6	Sheathing, sills made of Pz rš up to 400 mm
51	other	sheet metal, Pz	9.9	m²	0.6	Eaves trough, width 330 mm
52	other	sheet metal, Pz	4.7728	m²	0.6	Oval drain
53	roof	embossed roof tile	168.86	m²		Ceramic tile with groove
54	roof	PES/PR foil	184	m²		Safety waterproofing foil
55	horizontal finish	Penetrating coating	126.6	kg		Floor coating penetrating
56	horizontal finish	cement adhesive	101.28	kg		Flexible cement adhesive
57	horizontal finish	floor tiles, ceramic	24 776	m²	8	Floor, ceramic tiles smooth
58	horizontal finish	screed, waterproofing	16.2	kg		Insulation under tiles, waterproofing screed
59	horizontal finish	floor, floating laminate	78 225	m2	8	floor, floating laminate, thickness 8 mm
60	horizontal finish	PE underlay	74.5	v		PE foam insulation pad with vapour barrier
61	vertical finish	coating penetrating	270	kg		Wall penetration
62	vertical finish	screed, waterproofing	15.53	kg		Insulation under the tiling with screed
63	vertical finish	grout	24	kg		Flexible cementitious grout
64	vertical finish	wall tiles ceramic	44	m²	8	Ceramic tiling
65	vertical finish	wall tiles, brick	50	m²	14	Brick tiles
66	finish	painting, abrasion-resistant	100.1	kg		Painting compound

Figure 1 graphically shows the carbon footprint of the individual buildings needed for the determination analysis of a budget indicator. It can be clearly seen that the energy consumption for all buildings and its origin has the greatest influence on the carbon footprint creation. Therefore, only the first phases (A1-A5) of the entire life cycle of the building are taken into account to determine the budget indicator, see Figure 2. It graphically shows the phases that were selected to determine the carbon footprint per production unit (construction material, transport and its inbuilt).

All building materials that were used to build the house were budgeted out. Table 3 shows a list of the imported materials for the House No.3. Similarly, lists of imported materials were prepared for the other assessed houses.

Table 4. Assessment of the life cycle phases A1-A5 in kg CO_2 [Authors´ own work]

House No.	Material [kg CO_2]	Transport [kg CO_2]	Construction process [kg CO_2]	Total [kg CO_2]
House 1	47 372.73	1 510.52	3 096.85	51 980.10
House 2	110 868.99	3 427.22	5 970.99	120 267.20
House 3	62 664.58	2 154.83	3 682.79	68 502.20
House 4	56 279.63	1 597.08	2 484.52	60 361.23
House 5	74 433.87	1 963.13	3 925.23	80 322.23

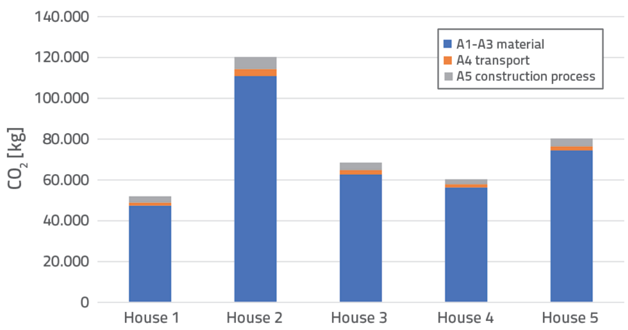

Figure 2. Assessment of the life cycle phases A1-A5 in kg CO_2 [Authors´ own work]

It can be seen from Figure 2 above and the Table 4 that House No. 2 reaches the largest carbon footprint, 120.3 tons of CO_2. It is the largest building in terms of the built-up volume or the built-up area. This is related to the largest amount of the built-in material. Focusing on the resulting Table 5, this size of the building does not have a significant impact on the determination of the result, therefore this object could also be included in the calculation.

Construction materials seem not to have the most significant impact on the carbon footprint creation as can be seen in Table 3 above and Figure 3. Their inbuilt follows, while the lowest carbon creation has their transport. As mentioned above, the largest producer of the carbon footprint is House No. 2 with 120.27 tons of CO_2. In contrast, the lowest producer is House No. 1 with 51.98 t CO_2.

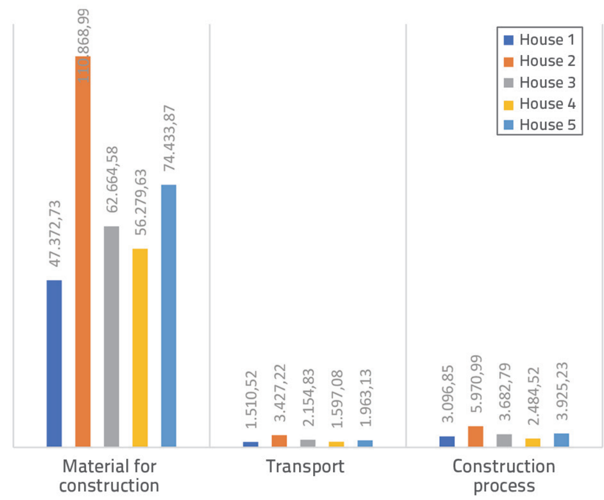

Figure 3. Carbon footprint of individual buildings in phases A1-A5 in kg CO_2 [Authors´ own work]

The Table 5 shows the determination of the carbon footprint per unit of production of the budget indicator. The built-up volume and the built-up area of individual buildings are calculated as well as their carbon footprint of phases A1-A5 of building life cycles and

Table 5. Weighted arithmetic average per built-up volume/ built-up area [Authors´ own work]

House No.	House 1	House 2	House 3	House 4	House 5
Carbon footprint [kg CO_2]	51.980.10	120.267.20	68.502.20	60.361.23	80.322.23
Built-up volume [m^3]	457.60	899.82	591.53	523.53	604.77
Indicator - carbon footprint/built-up volume [kg CO_2/m^3]	113.59	133.66	115.81	115.30	132.81
Weighted arithmetic average [kg CO_2/m^3]	**122.25**				
Difference from the average	8.66	-11.41	6.44	6.88	-10.57
Built-up area [m^2]	102.06	196.78	121.37	81.88	129.36
Indicator - carbon footprint/built-up volume [kg CO_2/m^3]	509.31	611.18	564.41	737.19	620.92
Weighted arithmetic average [kg CO_2/m^3]	**608.60**				
Difference from the average	99.29	-2.58	44.19	128.59	12.32

the production indicators were determined. The determination of the carbon footprint per unit of production of the budget indicator can be related to the unit of the built-up volume or the built-up area of individual buildings. The authors of the article assume that it is more accurate to determine the carbon footprint per m^3 of the built-up volume. This can be proven in Table 4, where the weighted arithmetic average of the built-up volume of 122.25 kg CO_2/m^3, the weighted arithmetic average of the built-up area of 608.60 kg CO_2/m^2 and the carbon footprint of individual houses were determined. The row of the table "Difference from the average" gives evidence that the determination of the carbon footprint per production unit of the built-up space of buildings is more accurate.

The carbon footprint has been currently quite high, so there is a tendency to reduce it. One of the possible recommendations to reduce the carbon footprint at the product phase is mainly to use local materials and raw materials so as to reduce the transportation distance of raw materials for the material production. Another option to reduce the carbon footprint at the construction phase is to use materials that have a lower carbon footprint in the production while maintaining the same, if not better, technical and physical properties [51]. Secondly, to increase the application of circular economy principles. Thirdly, to motivate manufacturers to change or adapt technological processes in the material production.

4. Conclusion

The aim of the research described in the article was to determine the carbon footprint of construction production per the production unit of the budget indicator and to compare buildings of different production technology. There has been a strong emphasis on the environment in recent years while the construction industry has made a significant contribution to global warming. Therefore, this research focuses on the possible facilitation of the carbon footprint of buildings determination.

The environmental impacts of the building operation are mainly influenced by their energy intensity e.g. efficiency. The greater the building energy consumption, the greater the environmental impacts. It is possible to reduce the energy intensity of buildings by making the heating sources greener using the Czech national subsidy New Green Savings Programme. Households can obtain subsidies for the replacement of a boiler, e.g. for a heat pump, a biomass boiler or a gas condensing boiler. Furthermore, the programme supports the construction of new buildings with very low energy intensity.

Five detached houses of the same production technology were selected for the purposes of the research described in the article, their built-up volume was calculated and the carbon footprint was determined using the One Click LCA software. Subsequently, the amount of the carbon footprint per 1 m^3 of the built-up volume (122.25 kg CO_2/m^3) was determined using the weighted arithmetic average. The quantification of the carbon footprint took place during the production phase of the building, thus, in the phase which involves the extraction of raw materials, their transport and production, and in the construction phase, which includes transport to the construction site and subsequent inbuilding of the material.

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