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Life Cycle Assessment (LCA) for clay masonry units-case study: Environmental product declaration (EPD) for clay blocks-production plant of clay blocks in Republic of Serbia

***Summary**: Life Cycle Assessment (LCA) analyses all phases of the life cycle of a construction product, takes into account the different impacts of these phases on the environment, evaluates, analyses and interprets the results. In life cycle assessment, the Environmental Product Declaration (EPD) is a standardized way of quantifying the impact of a product or system on the environment. This study evaluates the environmental impact of 1 tone of clay blocks produced in production plant in Republic of Serbia and grouped by use of Product Category Rules (PCR). The aim of this study is to determine the life cycle stages of the clay blocks that affect significantly to environment. LCA analysis for clay blocks has been conducted with the One Click LCA software, developed by One Click LCA Ltd, Finland. All processes have been modelled based on the inventory data given in the Ecoinvent database (v3.6). Based on the LCIA results in this study, product stage (modules A1-A3) contributes the most to the environmental impact. Taken as a whole, energy processes and raw material consumption dominate most impact categories.*

***Key words:** LCA, EPD, PCR, clay bricks*

Ocena životnog ciklusa (LCA) za elemente za zidanje od gline-studija slučaja: Deklaracija proizvoda za životnu sredinu (EPD) za blokove od gline-fabrika za proizvodnju blokova od gline u Republici Srbiji

***Rezime:** Procena životnog ciklusa (LCA) analizira sve faze životnog ciklusa građevinskog proizvoda, uzima u obzir različite uticaje ovih faza na životnu sredinu, ocenjuje, analizira i tumači rezultate. U proceni životnog ciklusa, Deklaracija proizvoda za životnu sredinu (EPD) je standardizovani način kvantifikacije uticaja proizvoda ili sistema na životnu sredinu. Ova studija procenjuje uticaj na životnu sredinu 1 tone blokova od gline proizvedenih u fabrici u Republici Srbiji grupisanih primenom Pravila o kategoriji proizvoda (PCR). Cilj ove studije je da se utvrde faze životnog ciklusa blokova gline koji značajno utiču na životnu sredinu. LCA analiza za glinene blokove je sprovedena pomoću One Click LCA softvera, koji je razvio Bionova Ltd, Finska. Svi procesi su modelovani na osnovu podataka inventara datih u bazi podataka Ecoinvent (v3.6). Na osnovu rezultata LCIA u ovoj studiji, faza proizvoda (moduli A1-A3) najviše doprinosi uticaju na životnu sredinu. Gledano u celini, energetski procesi i potrošnja sirovina dominiraju u većini kategorija uticaja.*

***Ključne reči:** LCA, EPD, PCR, clay bricks*

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1. INTRODUCTION

The building industry uses great quantities of raw materials that also involve high energy consumption. The production of clay masonry units is energy intensive, leading to carbon dioxide increased emissions. Life Cycle Assessment (LCA) is a method for quantifying, evaluating, comparing and improving products and services from the aspect of their potential negative impact on the environment and thus helps to identify opportunities to reduce them [12].

The main objective of the impact assessment is to identify and establish links between the life cycle of products and services and potential environmental impacts. Standards ISO 14040 and 14044 provide principles, frameworks, requirements and instructions for the implementation of the life cycle assessment procedure [5,6].

Life cycle impact assessment (LCIA) provides assessment of potential negative impacts during the life cycle based on input and output material and energy flows of the observed product system. The impacts of resource consumption and generated emissions are grouped and quantified through a certain number of impact categories that can then be weighted by importance. The aim of this study is to determine the life cycle stages of the clay blocks produced in production plant in Republic of Serbia that affect significantly to environment.

The Environmental Product Declaration (EPD) is created and verified in accordance with the international standard ISO 14025 [2]. The European standard EN 15804 contains the basic rules of product categorization for all types of construction products and services. The aim of this standard is to ensure that all Environmental Product Declarations (EPDs) relating to construction products, services and complete processes in construction are verified, determined and presented in a uniform manner [3].

When creating the EPD, it is necessary to establish product categorization rules (PCR - Product Category Rules). PCR is a group of rules, requirements and instructions on the basis of which the Environmental Product Declaration (EPD) is formed [12]. PCR for clay construction products is based on the European horizontal harmonized standard EN 15804 which was developed in CEN/TC 350 "Sustainability of construction works".

In accordance with the requirements of the standard EN 15804, each EPD needs to cover all life stages of the product (module A-D), aswell as informations about the product, reference service life (RSL), declared unit, functional unit, system boundary, allocation, period under review, all input and output flows, and environmental impact categories assessment with results interpretation and recommendations [1,3].

2. MATERIALS AND METHODS

Life cycle impact assessment (LCIA) provides assessment of potential negative impacts during the life cycle based on input and output material and energy flows of the observed product system. The impacts of resource consumption and generated emissions are grouped and quantified through a certain number of impact categories that can then be weighted by importance.

In this study, EPD for clay blocks is based on a cradle-to-grave LCA (module A1-D). All relevant processes during the life cycle of the product have been accounted for and

no life cycle stages have been omitted, in which significant environmental impacts are taking place.

Product stage (A1-A3) includes the supply of all raw materials and energy, transport to the production site, material processing to the final product, packaging and waste processing up to the "end-of-waste" state or until the final disposal.

Construction process stage (A4-A5) includes the provision of all materials, products and energy, as well as waste processing up to the end-of-waste state or disposal of final residues during the construction stage. These information modules also include all impacts and aspects related to any losses during this construction process stage. The loss is set equal to 3% in mass according to the PCR for clay construction products [9,11].

Use stage (B1-B7) include provision and transport of all materials, products, as well as energy and water provisions, waste processing up to the end-of-waste state or disposal of final residues during this part of the use stage. According to the PCR for clay construction products, these modules do not have relevant environmental impacts and therefore can be neglected [11].

In general, clay products have a long lifespan. They do not need maintenance, replacement or surface treatment. The longer a product lasts, the less impact it will have on the environment as defined in module B of EN 15804 [4].

End-of-life stage (C1-C4+D) includes de-construction, demolition, transport to waste processing, waste processing for reuse, recovery and/or recycling and disposal. C1 can be ignored according to the PCR, whereas the rest of the modules are included using national scenarios for the end-of-life (EOL) stage. In C4 30% of the clay masonry units are landfilled according the European EOL scenario for clay products [9,11].

The LCA analysis for clay blocks in this study has been conducted with the One Click LCA software service, which has been developed by One Click LCA Ltd, Finland [10]. All processes have been modelled based on the inventory data given in the Ecoinvent database (v3.6) [7].

All known inputs and outputs were considered. Data relating to raw material usage, energy consumption, water consumption and transport of the products, materials and waste were obtained from the production plant of clay blocks in Republic of Serbia and refer to 2021. In case of insufficient input data, the maximum cut-off of input flows for a module is 5% for energy use and mass, while it is maximum 1% for unit processes according to the PCR for clay construction products.

For the product stage (modules A1-A3), the total consumption of energy and water for the production of 1 tone of clay blocks has been provided by the production plant. The provided values of energy and water consumption for the 1 tone of clay blocks have been obtained by proportionally distributging the total consumption of energy and water based on the overall quantity of the produced clay blocks [8].

All relevant processes during the life cycle of the clay blocks have been accounted for and no life cycle stages have been omitted, in which significant environmental impacts are taking place. The use stage (B1-B7) is assessed not to be relevant because the clay blocks are inert, chemically stable and therefore do not emit pollutants or substances that are harmful to the environment and human health during the use stage. The declared unit was 1 tone of clay blocks.

3. RESULTS AND DISCUSSION

The life cycle impact assessment results (LCIA) of clay blocks are presented in three different categories: environmental impacts, resource use and waste generation.

Table 1 represents environmental impact results of 1 tone of clay blocks for entire life cycle (EPD type: cradle to grave). The LCA environmental impact categories taken in this study are: global warming potential (GWP), ozone depletion potential (ODP), acidification of soil and water (AP), eutrophication potential (EP), photochemical ozone creation potential (POCP), abiotic depletion potential for non-fossil resources (ADPE), abiotic depletion potential for fossil resources (ADPF).

Result show that consumption of raw materials in the production stage (A1) has a significant impact in terms of the possibility of depletion of abiotic non-fossil resources (ADPE) as well as the possibility of global warming (GWP).

Observing the use of energy in the production stage (A1-A3), there is a significant impact in terms of ozone depletion potential (ODP), abiotic depletion potential for fossil resources (ADPF), acidification of soil and water (AP) and the possibility of eutrophication (EP).

The packaging materials in the production stage (A3) have a significant impact in terms of photochemical ozone creation potential (POCP), global warming potential (GWP), acidification of soil and water (AP), eutrophication potential (EP) and abiotic depletion potential for fossil resources (ADPF).

Module A3 (manufacturing) have significant environmental impact for the folowing categories: ODP (66,86%), ADPF (52,95%), EP (32,12%) and AP (30,93%). Module A3 (packaging materials) have significant environmental impact for the folowing categories: POCP (77,06%),GWP (67,78%), AP (61,17%), EP (59,81%), ADPF (43,78%) and ADPE (42,61%).

Resource use per 1 tone of clay blocks are shown in table 2 and waste categories and output flows are shown in table 3.

Global warming potential (GWP) of 1 tone of clay blocks in all life cycle stages is given on the figure 1. The most significant impact on the environment in terms of GWP is manufacturing (A3) with 52% and transport to the building site with 29,9%. Afterwards, with less impact is waste transportation (C2) with 9,5% and raw material extraction and processing with 4%.

Figure 2 shows individual impacts categories for all life cycle stages for 1 tone of clay blocks. According to the results, manufacturing stage (module A3), transport to the building site (module A4) and raw material extraction and processing (module A1) have significant impacts on the environment.

Parameter	Unit	A1-A3	A4	A5	B1-C1	C2	C3	C4	D
GWP	[kg CO_2-eq.]	1,263E2	6,702E1	3,045E−1	-	1,067E1	7,582E0	1,551E0	−1,055E1
ODP	[kg CFC11-eq.]	2,771E−5	1,127E−5	8,896E−8	-	1,893E−6	1,489E-6	5,155E−7	−1,16E-6
AP	[kg SO_2-eq.]	6,307E-1	2,08E−1	1,063E−3	-	2,222E−2	3,654E-2	6,251E−3	-4,763E-2
EP	[kg $(PO_4)^3$-eq.]	2.376E−1	4,898E−2	2,077E−4	-	4,878E−3	6,452E-3	1,21E−3	-1,878E-2
POCP	[kg Ethene-eq.]	5,16E−2	9,14E−3	7,673E−5	-	1,452E−3	1,414E-3	4,584E−4	-3,102E-3
ADPE	[kg Sb-eq.]	3,595E−3	2,336E−3	4,303E−6	-	3,857E−4	9,351E-5	1,444E−5	−7,398E-4
ADPF	[MJ]	3,66E3	9,8E2	7,588E0	-	1,601E2	1,312E2	4,416E1	-1,547E2
Caption	GWP=Global warming potential; ODP=Ozone depletion potential; AP=Acidification of soil and water; EP=Eutrophication potential; POCP= Photochemical ozone creation potential; ADPE=Abiotic depletion potential for non-fossil resources; ADPF= Abiotic depletion potential for fossil resources;								

Table 1. Environmental impacts results of 1 tone of clay blocks [8]

Parameter	Unit	A1-A3	A4	A5	B1-C1	C2	C3	C4	D
PERE	[MJ]	1,536E3	1,272E1	6,884E-2	-	2,722E0	1,984E0	3,571E-1	-9,163E0
PERM	[MJ]	5,64E3	0	0	-	0	0	0	0
PERT	[MJ]	7,176E3	1,272E1	6,884E−2	-	2,722E0	1,984E0	3,571E−1	-9,163E0
PENRE	[MJ]	3,66E3	9,8E2	7,588E0	-	1,601E2	1,312E2	4,416E1	-1,547E2
PENRM	[MJ]	0	0	0	-	0	0	0	0
PENRT	[MJ]	3,66E3	9,8E2	7,588E0	-	1,601E2	1,312E2	4,416E1	-1,547E2
SM	[kg]	7,503E-2	0	0	-	0	0	0	0
RSF	[MJ]	0	0	0	-	0	0	0	0
NRSF	[MJ]	0	0	0	-	0	0	0	0
FW	[m^3]	7,453E-1	1,725E−1	7,154E−3	-	2,783E−2	6,574E-2	4,832E−2	−8,436E-1
Caption	PERE = Use of renewable primary energy excluding renewable primary energy resources used as raw materials; PERM = Use of renewable primary energy resources used as raw materials; PERT = Total use of renewable primary energy resources; PENRE = Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials; PENRM = Use of non- renewable primary energy resources used as raw materials; PENRT = Total use of non-renewable primary energy resources; SM = Use of secondary material; RSF = Use of renewable secondary fuels; NRSF = Use of non-renewable secondary fuels; FW = Use of net fresh water								

Table 2. Resource use per 1 tone of clay blocks [8]

Parameter	Unit	A1-A3	A4	A5	B1-C1	C2	C3	C4	D
HWD	[kg]	8,617E0	1,474E0	7,182E−3	-	1,885E−1	0	4,12E−2	−6,756E−1
NHWD	[kg]	2,68E2	6,715E1	4,318E1	-	1,046E1	0	3E2	−2,834E1
RWD	[kg]	1,537E-2	6,362E−3	5,05E−5	-	1,085E−3	0	2,922E−4	−7,863E−4
CRU	[kg]	0	0	0	-	0	-	0	0
MFR	[kg]	0	0	0	-	0	-	0	0
MER	[kg]	0	0	0	-	0	0	0	0
EEE	[MJ]	0	0	0	-	0	0	0	0
EET	[MJ]	0	0	0	-	0	0	0	0
Caption	HWD = Hazardous waste disposed; NHWD = Non-hazardous waste disposed; RWD = Radioactive waste disposed; CRU = Components for re-use; MFR = Materials for recycling; MER = Materials for energy recovery; EEE = Exported electrical energy; EET = Exported thermal energy								

Table 3. Waste categories and output flows per 1 tone of clay blocks [8]

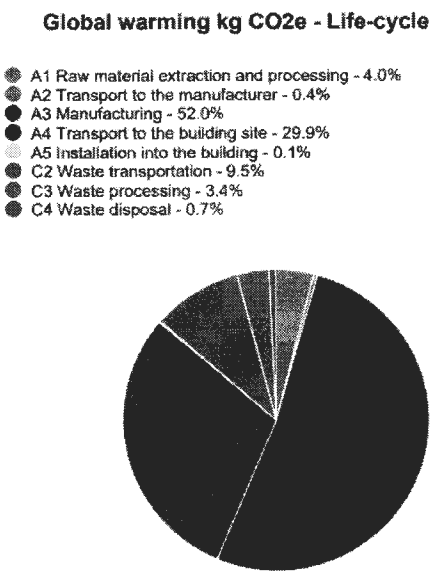

Figure 1. Global warming potential (GWP) of 1 tone of clay blocks in all life cycle stages [8]

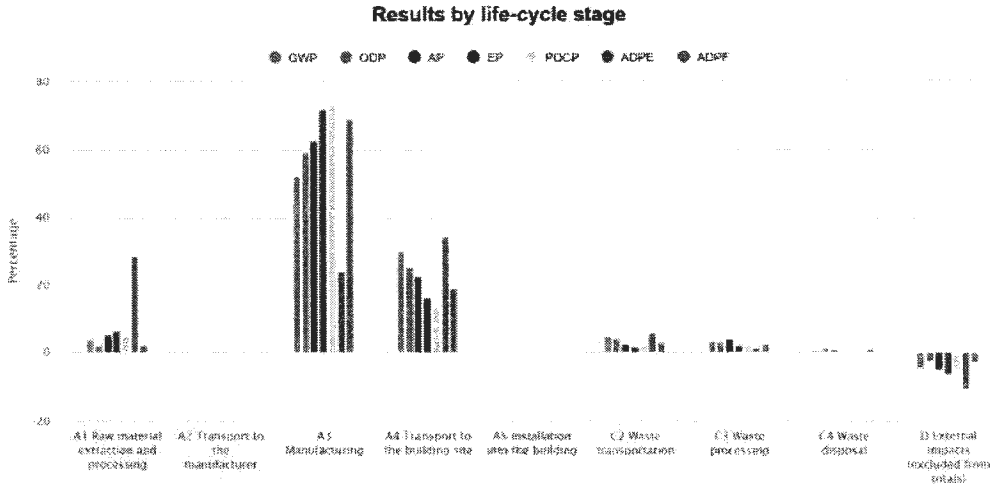

Figure 2. Environmental impact results for the life cycle stages of 1 tone of clay blocks [8]

4. CONCLUSION

The importance and value of LCA methodology, lies in the identification of the impact causes, which are closely linked to the information on processes and supplies, in order to identify where the actions should be focused depending on the impact and its magnitude.

The life cycle impact assessment results (LCIA) of clay blocks in this study shows that product stage (modules A1-A3) contributes the most to the environmental impact. Generally, most of the impact categories are dominated by energy processes and raw material consumption.

Manufacturing stage (module A3), transport to the building site (module A4) and raw material extraction and processing (module A1) have significant impacts on the environment. As well, manufacturing (A3) and transport to the building site (A4) have significantly impact on the environment for global warming potential (GWP).

Also, result of this study shows that transport to the manufacturer (A2) has the least impact on the environment for the categories: global warming potential (GWP), abiotic depletion potential for non-fossil resource (ADPE) and ozone depletion potential (ODP).

The favorable impact on the environment is reflected in the fact that clay blocks have a long service life. Another environmental benefit is at the end-of-life stage (module D) due to reusing of clay blocks. After the demolition and deconstruction stage (C1), crushed clay blocks are used as fillings in road construction or in the production of concrete aggregates (reuse rate of 70%).

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5. REFERENCES

[1] Drpić, A., Spasojević-Šantić, A., Radojević, Z. (2021). Environmental product declaration (EPD) for clay roof tiles-case study: Production plant of clay roof tiles in Republic of Serbia, International Conference on Resource Sustainability, icRS 2021, University College Dublin, Ireland.

[2] EN ISO 14025:2010 (2010). Environmental labels and declarations - Type III environmental declarations - Principles and procedures.

[3] EN 15804:2012+A1:2013 (2013). Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products.

[4] EN 15804:2019+A2 (2019). Sustainability of construction works - Environmental Product Declarations - Core rules for the product category of construction products.

[5] EN ISO 14040:2006/ A1:2020 (2020). Environmental management - Life cycle assessment - Principles and framework – Amendment 1 (ISO 14040:2006/Amd 1:2020).

[6] EN ISO 14044:2006/A2:2020 (2020). Environmental management - Life cycle assessment - Requirements and guidelines - Amendment 2 (ISO 14044:2006/Amd 2:2020).

[7] Ecoinvent database-Ecoinvent database, version 3.6, Developed by Ecoinvent Association, Switzerland, all information available at: https://www.ecoinvent.org/

[8] Environmental Product Declatation according to ISO 14025 and EN 15804 for clay masonry units-product group-clay blocks and clay facade bricks (2022). EPD-IMS-2022-01-EN, Institute for testing materials-IMS Institute, Republic of Serbia.
[9] International guidance document on TBE PCR for clay construction products (2020). Guidance document for developing PCR for clay construction products.
[10] One Click LCA software,developed by One Click LCA Ltd, Finland, all information available at: https://www.oneclicklca.com/
[11] Product Category Rules (PCR) for Construction products and Construction services, PCR 2012:01-SUB-PCR Bricks, blocks, tiles, flagstone of clay and siliceous earths (construction product), version 2.31., The International EPD® System, date: 18.09.2020.
[12] Spasojević-Šantić, T., Radojević, Z. (2019). Analiza postupka ocenjivanja životnog ciklusa opekarskih proizvoda, IZGRADNJA 73 (2019) 3-4, UDK:666.71:005.41, Pregledni rad, str. 197-201.