

Environmental Product Declaration (EPD) For Clay Roof Tiles-Case Study: Production Plant of Clay Roof Tiles in Republic of Serbia

Aleksandar Drpić^{1,*}, Tea Spasojević-Šantić², Zagorka Radojević³

¹Institute for testing materials-IMS Institute, Bulevar vojvode Mišića43, 11000 Belgrade, Republic of Serbia

² Institute for testing materials-IMS Institute, Bulevar vojvode Mišića43, 11000 Belgrade, Republic of Serbia,

tea.spasojevic@institutims.rs

³Institute for testing materials-IMS Institute, Bulevar vojvode Mišića43, 11000 Belgrade, Republic of Serbia, zagorka.radojevic@institutims.rs

Email corresponding author: aleksandar.drpic@institutims.rs

Abstract. 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 roof tiles, produced in production plant in Serbia, defined and grouped by use of Product Category Rules (PCR). The purpose of this study is to determine: (1) life cycle stages of the product which have the major impact on the environment expressed as environmental impact categories; (2) the processes of clay roof tile production which have the most important effects on the environment also expressed as environmental impact categories. The LCA analysis has been conducted with the One Click LCA software, developed by Bionova Ltd, Finland. All processes have been modelled based on the inventory data given in the Ecoinvent database (v3.6). According to the results in this study and observed from the aspect of the product life cycle, the production process has the major impact on the environment, and from the aspect of the resources used, the major impact on the environment has the consumption of energy and the use of raw materials.

Keywords: LCA, EPD, PCR, roof tiles.

1. Introduction

In Europe, the building sector consumes 40% of the total energy and raw materials, emits 36% of the total greenhouse gas emissions (GHG) and produces 15% of the total industrial waste. This sector consumes more raw materials than any other industrial sector and it also involves high energy consumption [1]. [2] concluded that the most commonly used construction materials are steel, cement and ceramic materials and are also the major energy consumers among construction materials. Those conclusions showing us that is important to establish a more efficient construction industry from environmental aspect, but also from the aspect of energy efficiency. Building products like clay roof tiles generates environmental impacts during its entire life cycle stages, such as consumption of resources, water, energy, waste, transport of raw materials, vehicle used for transportation, packaging



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materials, etc. [3]. Growing awareness of the environmental performance of construction products and buildings brings about the need for a suitable method to assess their environmental performance and to provide proper assistance for applying this information for further use in the field of building certification [4]. Environmental Product Declarations (EPDs) belong to the type III environmental declarations. Environmental product declarations (EPD) for construction products are based on reliable and verifiable LCA informations. The EPD contains verified and precise information about the environmental impact of products and the potential for improvement based on the scientifically proven facts [5]. Two important mechanisms for EPD development are: Product category rules (PCR) and Life Cycle Assessment (LCA). Life Cycle Assessment (LCA) is a recognized approach to assess the environmental impacts of life cycle of the product or a service starting from the extraction of raw materials until the end-of-life (recycling, reusing and landfilling) [6,7], helping with the identification of environmental impact of the product and determination of influences for unit process from the environmental performance aspect. LCA is a tool to assess and quantify the potential environmental impacts by collecting and characterizing the inputs (product, material or energy flow that enters a unit process) and outputs (product, material or energy flow that leaves a unit process) in different processes of the product's life cycle. [3]. It has also been used as a tool for decision-making when it's necessary to determine environmental performance of products and the environmental comparison of different building elements [8]. This approach is named cradle-to-grave LCA. LCA results can be used to prioritize and make strategic planning decisions regarding the design or redesign of products or processes [3]. The objective of this study is to provide the European manufacturers of clay construction products, i.e. clay bricks, blocks, pavers and roof tiles, guidance for the development of Environmental Product Declarations (EPDs) for clay construction products based on a LCA approach (EPD from cradle to grave) [3]. Life Cycle Assessment (LCA) includes product stage (A1-A3), construction process stage (A4-A5), use stage (B1-B7), end of life stage (C1-C4+D). For this purpose, LCA results can provide information that serves as a basis for implementing strategies to reduce pollution, preserving resources, and reduce waste within a company, industry, or government sector. [9]. The methodology used to develop the EPD is based on standards EN ISO 14025[10], ISO 21930 [11] and EN 15804 [5]. In accordance with the requirements of the standard EN 15804 [5], each EPD needs to cover all life cycle stages of the product (module A-D), as well 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. A comparison or an evaluation of EPD data is only possible if all the data sets to be compared were created according to EN 15804 and the building context, respectively the product-specific characteristics of performance, are considered [5].

2. Material and methods

For the purposes of this study, the CML methodology is used. CML is the methodology of the Institute of Environmental Sciences Faculty of Science University of Leiden, Netherlands [5]. The main purpose is to group environmental impact categories and expressed them as emissions into the environment. The environmental impact categories are following:

- global warming potential (GWP),
- ozone depletion potential (ODP),
- acidification potential (AP),
- eutrophication potential (EP),
- formation of ozone of lower atmosphere (POCP)
- abiotic depletion potential (ADP-elements) for non-fossil resources (ADPE),
- abiotic depletion potential (ADP-fossil fuels) for fossil resources (ADPF).

The LCA analysis has been conducted with One Click LCA software developed by Bionova Ltd, Finland [12]. All inputs and outputs are taken from Ecoinvent database (v3.6) [13]. According to the PCR for clay construction products, 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 [3]. The

functional unit was 1 t of clay roof tile ready to be used for a period of 50 years. The declared unit was 1 t of clay roof tile. The system boundary includes: raw material extraction and processing (A1), transport to the manufacturer (A2), manufacturing (A3), transport to the building site (A4), installation into the building (A5), waste transportation (C2), waste processing (C3) waste disposal (C4) and external impacts (excluded from totals) (D). The input and output flows for production of 1t of clay roof tiles were considered in this study: the mass of raw materials (clay), transportation vehicle, truck engine type, distances to a different locations, wooden pallets, thermofoil, water consumption, energy consumption for natural gas and electricity, hazardous and non-hazardous waste. These input and output flows are provided from production plant in Republic of Serbia and refer to 2019. The production stage of clay roof tiles includes the following processes: clay extraction, primary processing of clay, clay preparation and shaping, drying, firing, quality management control, packaging and shipping. Clay roof tiles are produced by molding (extruding and / or pressing), drying and firing of clay mass without addition of additives. In the production of clay roof tiles, only natural resources are used. Clay is exploited from a clay pit located near the plant and water is added to clay to achieve the required moisture content, and additionally, electricity and natural gas are used as energy resources. The red color of the tile is achieved during firing at high temperatures (over 1020°) and it is resistant to UV radiation. Clay roof tiles produced in this plant have a properly defined microstructure that provides excellent mechanical properties and exceptional resistance to high and low temperatures. This study does not exclude any hazardous materials or substances.

3. Results and discussion

The results of product life cycle assessment are presented in three different categories: environmental impacts, resource use and waste generation.

Table 1 represents environmental impact assessment results obtained in the One Click LCA software for clay roof tiles production in production plant in Republic of Serbia for entire life cycle (EPD type: cradle-to-grave).

Observing the energy use in the production stage (module A1-A3), there is a significant impact for the following categories: abiotic depletion potential for fossil resources (ADPF), ozone depletion potential (ODP), acidification potential (AP), and global warming potential (GWP). Consumption of raw materials in the production stage (A1) has a significant impact for the following categories: abiotic depletion potential for non-fossil resources (ADPE) and eutrophication potential (EP).

Transport to the manufacturer (A2) has the lowest impact on the environment for the following categories: global warming potential (GWP), abiotic depletion potential for fossil resources (ADPF), ozone depletion potential (ODP) and acidification potential (AP). Also, waste disposal (C4) has low impact on the environment for the following categories: global warming potential (GWP), ozone depletion potential (ODP) and acidification potential (AP).

Resource use per 1 tone of clay roof tiles are shown in the table 2 and waste categories and output flows per 1 tone of clay roof tiles are shown in table 3. There is an environmental benefit at the end-of-life stage (module D) due to reusing of clay roof tiles (reuse rate of 90%) after the deconstruction stage (C1) for another application-as fillings in roads construction.

Table 1. Environmental impact results of 1 tone of clay roof tiles [14].

Parameter	Unit	A1	A2	A3	A4	A5	B1-C1	C2	C3	C4	D
GWP	[kg CO ₂ -eq.]	1,084E1	3,096E0	1,482E2	6,668E1	2,15E-2	-	4,267E1	9,748E0	5,168E-1	-1,356E1
ODP	[kg CFC11-eq.]	1,154E-6	5,514E-7	3,291E-5	1,125E-5	7,149E-9	-	7,572E-6	1,914E-6	1,718E-7	-1,491E-6
AP	[kg SO ₂ -eq.]	5,822E-2	6,474E-3	1,129E0	1,577E-1	8,668E-5	-	8,886E-2	4,697E-2	2,084E-3	-6,124E-2
EP	[kg (PO ₄) ³⁻ -eq.]	2,266E-2	1,422E-3	9,432E-2	3,591E-2	1,677E-5	-	1,951E-2	8,295E-3	4,032E-4	-2,414E-2

POCP	[kg Ethene-eq.]	4,034E-3	3,845E-4	4,897E-2	8,336E-3	6,356E-6	-	5,807E-3	1,818E-3	1,528E-4	-3,989E-3
ADPE	[kg Sb-eq.]	2,328E-3	1,125E-4	3,114E-4	2,336E-3	2,002E-7	-	1,543E-3	1,202E-4	4,812E-6	-9,512E-4
ADPF	[MJ]	1,455E2	4,609E1	5,1E3	9,917E2	6,099E-1	-	6,329E2	1,704E2	1,466E1	-2,022E2
Caption	GWP=Global warming potential; ODP=Ozone depletion potential; AP=Acidification potential; EP=Eutrophication potential; POCP= Formation of ozone of lower atmosphere; ADPE=Abiotic depletion potential for non-fossil resources; ADPF= Abiotic depletion potential for fossil resources										

Table 2. Resource use per 1 tone of clay roof tiles [14].

Parameter	Unit	A1-A3	A4	A5	B1-C1	C2	C3	C4	D	
PERE	[MJ]	6,312E2	1,271E1	4,952E-3	-	1,089E1	2,551E0	1,19E-1	-1,178E1	
PERM	[MJ]	0	0	0	-	0	0	0	0	
PERT	[MJ]	6,312E2	1,271E1	4,952E-3	-	1,089E1	2,551E0	1,19E-1	-1,178E1	
PENRE	[MJ]	5,323E3	1,006E3	6,163E-1	-	6,485E2	1,734E2	1,481E1	-2,304E2	
PENRM	[MJ]	0	0	0	-	0	0	0	0	
PENRT	[MJ]	5,323E3	1,006E3	6,163E-1	-	6,485E2	1,734E2	1,481E1	-2,304E2	
SM	[kg]	1,4E0	4,677E-1	1,66E-4	-	3,144E-1	7,904E-2	3,991E-3	-2,309E-1	
RSF	[MJ]	0	0	0	-	0	0	0	0	
NRSF	[MJ]	0	0	0	-	0	0	0	0	
FW	[m ³]	5,16E-1	1,724E-1	6,7E-4	-	1,113E-1	8,453E-2	1,611E-2	-1,085E0	
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 3. Waste categories and output flows per 1 tone of clay roof tiles [14].

Parameter	Unit	A1-A3	A4	A5	B1-C1	C2	C3	C4	D	
HWD	[kg]	2,925E0	1,473E0	5,732E-4	-	7,539E-1	2,631E-1	1,378E-2	-8,687E-1	
NHWD	[kg]	6,383E1	6,714E1	4,173E0	-	4,184E1	4,022E2	1,003E2	-3,644E1	
RWD	[kg]	1,215E-2	6,351E-3	4,052E-6	-	4,341E-3	1,089E-3	9,74E-5	-1,011E-3	
CRU	[kg]	0	0	0	-	0	-	0	0	
MFR	[kg]	0	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									

It was also considered which inputs and outputs have significant impact on the environment for all impact categories. According to the table 4, for GWP (global warming potential), most contributing inputs and/or outputs are: energy for electricity (36,08%), transported mass (34,19%). For ODP (ozone depletion potential), most contributing inputs and/or outputs are: transported mass (30,27%), energy for electricity (29,29%), energy for natural gas (21,55%). For AP (acidification potential), most contributing input and/or output is energy for electricity (61,37%). For EP (eutrophication potential), most contributing inputs and/or outputs are: energy for electricity (33,69%), transported mass (27,79%). For POCP (formation of ozone of lower atmosphere), most contributing input and/or output is energy for electricity (48,8%). For ADPE (abiotic depletion potential for non-fossil resources), most contributing inputs and/or outputs are: transported mass (47,44%), operation with clay (28,68%). For ADPF (abiotic depletion potential for fossil resources), most contributing inputs and/or outputs are: energy for natural

gas (44,69%), transported mass (21,31%).

Table 4. Most contributing environmental impact categories for 1 tone of clay roof tiles [14].

Impact category	Energy for electricity	Transported mass	Energy for natural gas	Operation with clay	Waste from clay roof tiles	Wooden pallets
GWP (%)	36,08	34,19	6,38	3,78	3,0	-
ODP (%)	29,29	30,27	21,55	2,23	-	-
AP (%)	61,37	15,84	7,27	3,88	2,98	-
EP (%)	33,69	27,79	4,82	11,54	-	5,85
POCP (%)	48,8	19,04	10,48	5,59	-	4,42
ADPE (%)	1,4	47,44	-	28,68	1,45	1,54
ADPF (%)	18,2	21,31	44,69	2,16	2,2	-

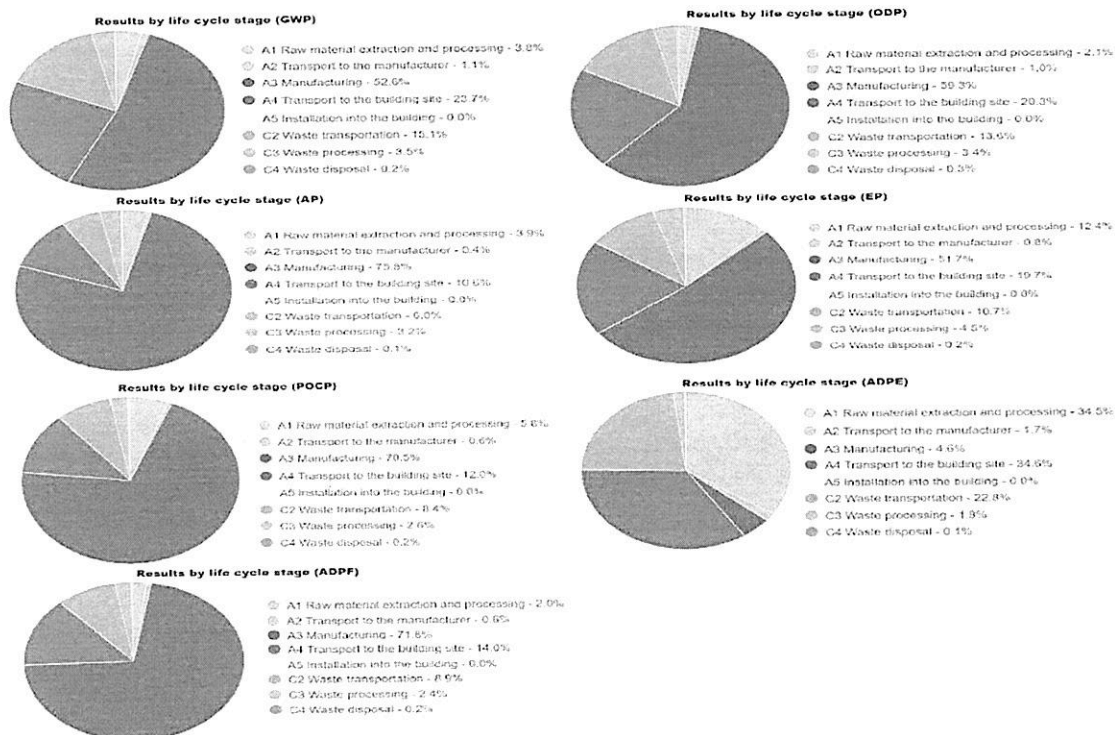


Figure 1. show results by life cycle stages for environmental impact categories for 1 tone of clay roof tiles [14].

Figure 2 shows the individual impacts for all life cycle stages for 1 tone of clay roof tiles. According to the figure 1, manufacturing stage (module A3), transport to the building site (module A4), waste transportation (module C2) and raw material extraction and processing (module A1), respectively, have significant impacts on the environment. Modul A3 (manufacturing) have significant environmental impact for the following categories: AP (71,53%), ADPF (65,94%), and POCP (65,02%). Modul A4 (transport to the building site) have significant environmental impact for the following categories: ADPE (28,15%), GWP (20,55%), and ODP (17,82%). Modul C2 (waste transportation) have significant environmental impact for the following categories: ADPE (18,59%), GWP (13,15%), and ODP (12%). Modul A1 (raw material extraction and processing) have significant environmental impact for the following categories: ADPE (28,05%), EP (11,22%), and POCP (5,36%). Regarding the lowest environmental impact, it was noticed that following modules, C3 (waste processing), A2 (transport to the manufacturer), C4 (waste disposal) and A5 (installation into the building), respectively, with their

individual values for all 7 impact categories do not exceed 5%.

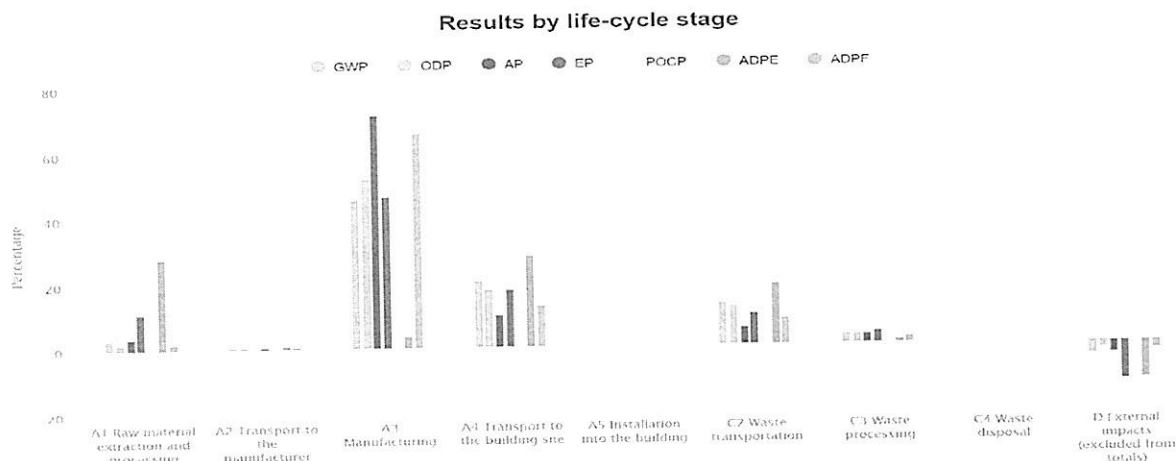


Figure 2. Environmental impact results for the life cycle stages of 1 tone of clay roof tiles [14].

4. Conclusions

Environmental Product Declarations (EPD) for construction products provides important information about products and their use. „Green products” and „cleaner production process” are priority nowadays, and EPD is used to obtain all the necessary information about construction products which have an impact on the environment during their entire life cycle.

Based on the EPD, it is possible to determine which production processes save resources and energy, and which are more financially payable, as well as which are "eco-friendly" in order to reduce the impacts on the environment and human health. The most significant inputs and/or outputs on the environment according to the LCA results are: energy for electricity, the mass of tiles that are transported to the location, energy for natural gas, operation with clay. It is concluded that due to high energy consumption during the roof tile production, as well as due to the transportation of the finished products to long distances, the primary energy and global warming potentials increase. Reducing the temperature during firing process, minimizing transportation of raw materials, controlling emitters during primary processing in order to reduce emissions of hazardous substances into the atmosphere, are some measures that must be implemented according to Serbian law in order to reduce environmental impacts. However, according to the results, there is an environmental benefit at the end-of-life stage due to reusing of clay roof tiles after the deconstruction stage for another application, as fillings in roads construction. This reduces the overall impact on the environment. In the nearest future, when manufacturers want to put any eco-label on their product, they will be obligated to publish EPD for that product on ECO platform.

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