Environment product declaration in ceramic materials as sustainability tool

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Abstract. The ceramic industry is a traditional sector in Portugal, with a typology of products adapted to the diverse habitat requirements. This paper presents the methodology and results obtain in the development of an environmental product declaration (EPD) in the ceramic sector, namely ceramic brick and roof tiles, based on a definition of scope, the required data, collection procedures, data treatment and interpretation. The methodology to develop the EPD takes into account the ISO 14025, ISO 21930, prEN 15978 and the International EPD System ®. The environmental profile was based on the Life Cycle Assessment (LCA) (cradle to gate). The impact categories selected for this study were: global warming (GWP100), ozone layer depletion (ODP), photochemical oxidation, acidification and eutrophication. The results of LCA provide also the EPD data and information to consumers about the environmental quality of products.

1 Introduction

Building materials represent an important research field in the context of sustainability of construction works. Nowadays it is important to know the environmental behaviour of building materials that play an important role on the environmental responsible architecture and design of a building. The concept of the sustainability assessment of buildings includes the environ-mental, social and economic performance of building.

Strategies for sustainable building are based, among other variables, in the selection of sustainable materials, i.e., with the lowest possible impact on the environment throughout its life cycle. According to the EU construction product 302/2011[1], the environmental aspects are one of the essential requirements in construction products.

On the other hand, the Integrated Product Policy (IPP) [2] establishes a new paradigm of growth and improved quality of life through wealth creation and competitiveness on the basis of products with lower environmental impact. This represents a new and promising green market for companies that are trying to understand and satisfy the environmental expectations of their customers, including the ceramic industry, a sector that contributes to building materials.

In Europe, ceramic bricks and roof tiles are produced in large quantities special as building materials [3].

The ceramic industry is a traditional sector in Portugal that produces a typology of products adapted to building works. Given the geological characteristics of Portugal, namely a soil rich in quantity and quality of raw materials, such as clays and fluxes, the industrial ceramic activity was developed with many valences and products, like bricks, covering materials, flooring tiles, sanitary ware, ornamental and porcelain ware [2].

The ceramic industry, like many other sectors, generates over its life cycle, a series of environmental impacts [3, 4, 5, 6, 7] from the extraction of resources until the final disposal of ceramic wastes.

The impacts in the production phase are related to consumption of natural resources, synthetic materials, energy and water; emissions to air resulting from the thermal processes (drying and firing) and cold processes (processes before extrusion); emissions of industrial and domes-tic effluents; production of waste and noise.

The aim of this study is to describe a methodology for developing a type III label that can be used by ceramic manufactures, namely “Sector Environmental Product Declaration” (EPD). The type III EPDs present quantified environmental information about the life cycle of products based on independently verified Life Cycle Assessment (LCA) studies. The studies must be made under specific agreed guidelines for each product category, known as Product Category Rules (PCR).

This study is based on a “cradle to gate” LCA on ceramic bricks and roof tiles produced in Portugal, following the ISO14025, ISO21930, prEN 15978, ISO14040 and ISO14044. The methodology starts with the definition of aim, data requirements, data collection procedures, and sample selection criteria. The impacts were then assessed through LCA.

The communication tools of environmental performance such as EPDs are essential in the calculation and demonstration to others of the environmental aspects and impacts associated with the ceramic product throughout its life cycle. The identified performance can induce an improvement of environmental aspects of other similar products or services from other suppliers. The EPDs are intended to provide information for planning and assessing the sustainability of buildings.

2 Methodology

The methodology used for the preparation of environmental statements of the ceramic product was the development and implementation of ISO 14025 and ISO 21930, starting with the development of the PCR, which define criteria, requirements and guidelines for the identification of specific product categories and define the parameters for preparing and developing an EDP. The PCR includes, among others, the definition of product group, functional unit, system boundaries, exclusion criteria, allocation rules (if necessary), information on the use phase, units, calculation procedures, requirements for data quality and parameters to declare in the EDP, materials and chemicals to declare, and other relevant environmental information.

The LCA methodology was applied to examine the environmental impacts associated to the brick and roof tiles production chain from “cradle to gate”. The methodology takes into account the standards ISO14040, ISO 14044, ISO 21930 and prEN15978, as well as the EPD ® system (www.environdec.com). Calculations were performed using the “SimaPro” software and back-ground data were taken from the “Ecoinvent” database [9].

The LCA methodology comprises four major stages: goal and scope definition, inventory analysis, impact assessment and interpretation of results. The goal and scope definition should include the specification of the goal, the functional unit, system boundaries, allocation procedures, assumptions and limitations, among others. In the inventory analysis, a flow model of the technical system is constructed using data on inputs and outputs of resources, energy and emissions to air and water for all activities within the system boundaries. In the impact assessment, the inventory data are processed in terms of their environmental impact. This phase includes the following mandatory elements: selection of impact categories and corresponding category indicators and models, classification and characterisation. In the interpretation phase, the findings from the inventory analysis and the impact assessment are combined together in order to reach conclusions and make recommendations.

The survey data were collected from more that 15 Portuguese manufacturers of ceramic brick and roof tiles.

2.1 Development of the PCR

The PCR ensures that the EPDs are developed, verified and presented in a harmonised way. Therefore, common and harmonised calculation rules have been developed in this study and were used for the development of the LCA of ceramic bricks and a LCA for ceramic roof tiles.

The methodology used in this study has been based on the document “General Programme Instructions for Environmental Product Declarations, EPD” namely the document PCR 2004:01 from the EPD system, with the adaptation for the ceramic brick and roof tiles sector.

The rules for the PCR developed for the ceramic brick and roof tiles include [10, 11]:

a) definition of the parameters to be declared and how they are compiled and reported,

b) description of the stages of product life cycle considered in the EPD and what processes should be included in the phases of the life cycle,

c) rules for the preparation of scenarios (if necessary),

d) rules for calculating the data of life cycle inventory and Impact Assessment that supports a EPD, including the specification of data quality applied,

e) rules for calculating and reporting the pre-defined environmental information that are not covered by an LCA of a product, process of construction and construction services, if neces-sary,

f) definition of the conditions under which ceramic brick and roof tiles products can be com-pared based on information provided by EPD.

2.2 Development of the LCA

2.2.1 Goal definition

The aim of this work was to identify and assess the environmental impacts associated with the ceramic brick and roof tiles production chain from “cradle to gate” (including the extraction of the raw materials, production of materials and its transport, and ceramic material production).

2.2.2 Functional unit and system boundaries

The functional unit, defined in the ISO 14040 as the "quantified performance of a product system for use as a reference unit”, constitutes the reference flow to which all other flows in the LCA are related. Al-though the functional unit used was 1 m2 of ceramic material ready to be sold, it was used a reference unit of 1 ton.

The system boundary includes the extraction of raw materials, acquisition of processed materials and its transport and the ceramic material production. A cut-off rule was established in order to decide which materials associated to these phases should be excluded from the boundaries.

The phases corresponding to consumer use and final disposal of the product were also excluded, as well as transport and final disposal of industrial waste. The construction and maintenance phases of the factories and remaining infrastructure, production of manufacturing equipment, personal activities were also excluded.

The production phase includes the following phases: storage of raw materials, raw materials preparation, extrusion, drying, decoration (only for roof tile), firing, sorting, packaging and storage.

2.2.3 Quality of the data

The quality of the data is a very important in LCA studies as the reliability of the results depends on the type of data employed.

Data for the ceramic material production process from each selected factory refer to the year 2008 (January to December) and were collected by the Technological Center of Ceramic and Glass (CTCV) from industrial companies located in the center of Portugal. These data were measured directly in the factories and the average of the measures was calculated for each inventory parameter.

Data from the database “Ecoinvent” [9] were used for the remaining processes included in the boundaries.

2.2.4 Inventory analysis

The parameters used to describe the environmental burdens of the processes comprise inputs and out-puts. The inputs normally include materials/products (e.g. chemical substances and preparations), fuels, resources (used as raw material or energy) and electricity. The outputs include materials/products, energy, air emissions, wastewater emissions and waste.

The “Ecoinvent” database was used to obtain data for the production of fuels (natural gas and diesel) and production of packaging materials (LDPE and pallets), steel, lubricating oil, acetylene and oxygen. The generation of electricity corresponds to the mix used in the Portuguese electricity grid for the year 2007 and was also taken from “Ecoinvent” [9].

Tables 1 and 2 present respectively the inputs and the outputs for the production stage of ceramic material (brick and roof tile).

Tab.1: Primary LCI data in terms of inputs (data for the reference unit: 1 kg of brick and 1kg of roof tiles)

Inputs	Brick	Roof tile	Unit
Clays	1.22	1,28	kg
Sand	0	0,11	
Water (well)	9.55E-05	1,64E-04	m3
Domestic water	2.25E-06	4.00E-6	m3
Electricity	6.20E-02	1.07E-01	kWh
Natural gas	1.10E-03	3.10E-03	MJ
Diesel	2.14E-02	8.49E-02	MJ
Lubricating oils	2.92E-06	1.07E-04	kg
Packing film	1.14E-04	1.95E-04	kg
EUR pallet	1.61E-05	7.18E-04	p
Steel castings	9.55E-06	3.06E-05	kg

Tab.2: Primary LCI data in terms of outputs (data for the reference unit: 1 kg of brick and 1kg of roof tiles)

Inputs	Brick	Roof tile	Unit
CO	5.71E-04	6.00E-05	kg
CO2	6.50E-02	1.98E-01	kg
NO	4.35E-05	2.27E-04	kg
SO2	3.56E-05	2.74E-05	kg
F	7.67E-07	1.80E-04	kg
As	1.55E-08	1.55E-08	kg
Cd	7.51E-09	7.50E-09	kg
Cr	2.55E-08	2.50E-08	kg
Cu	4.21E-10	1.11E-09	kg
Hg	3.75E-09	3.75E-09	kg
Ni	3.60E-08	1.40E-04	kg
Pb	7.50E-08	2.25E-07	kg
Zn	1.44E-08	3.80E-08	kg
HCl	7.49E-07	8.50E-05	kg
PM10	1.93E-05	1.16E-04	kg
NMVOC	1.97E-05	1.20E-05	kg
CQO	5.31E-09	6.39E-09	kg
SST	1.81E-08	2.19E-08	kg
Oils	1.38E-09	1.66E-09	kg
Total waste	7.50E-02	5.35E-02	kg

2.2.5 Life cycle impact assessment

The impact categories selected for this study were: global warming, ozone layer depletion, photochemical oxidation, acidification and eutrophication, according to the developed Portuguese PCR for ceramic [10, 11], and ISO 21930. The characterisation factors used in this study are those suggested by the CML method (Leiden University).

3 Results

3.1 Life cycle impact assessment

Table 3 shows the absolute impact assessment results obtained for the ceramic brick and roof tiles produced in the brick and roof tile product throughout their life cycles (from “cradle to gate”).

Tab.3: Environmental impact results (data for the reference unit: 1 kg of brick and 1kg of roof tiles)

Impact category	Brick	Roof tile	Unit
Global warming (GWP100)	1.41E-01	2.98E-01	kg CO2 eq
Ozone layer depletion (ODP)	1.67E-08	3.16E-08	kg CFC-11 eq
Photochemical oxidation	7.50E-05	8.79E-05	kg C2H4
Acidification	5.44E-04	8.61E-03	kg SO2 eq
Eutrophication	7.24E-05	8.10E-05	kg PO4--- eq

3.2 Life cycle impact assessment

The firing process during the brick and roof tile production stage has got the higher consumption of fuel (natural gas) and therefore is the largest contributor in the category of global warming. The stages of atomization and drying are also relevant although to a lesser extent.

Roof tiles have a higher firing temperature requirement and, therefore they consume more resources and emit amore greenhouse gas emissions.

The stages of non-mineral resource extraction, acquisition of materials and transportation of raw materials and auxiliary materials (from inside of Portugal) contribute less significantly to the global warming.

In the category of ozone layer depletion, the transport of materials and the storage of the product seem to be major contributors, despite the weak expression of this impact category.

In the category of photochemical oxidation the process of atomization, drying and firing of ceramic materials, are the main contributors, mainly associated with burning natural gas which emit nitrogen ox-ides (NOx), sulfur oxides (SOx) (less significative), carbon monoxide (CO) and volatile organic com-pounds (VOCs). SOx emissions also arise from the production of electrical energy used in the equipments during the production phase of the tile as well as in the processing of auxiliary materials. Roof tiles have the greatest values, associated with the higher temperatures in firing stage.

Acidification is mainly associated with the emission of NOx and SOx during the stages of atomization, drying and firing of the ceramic tiles, as well as during the combustion of fuels used in the transports along the life cycle of the ceramic product. The extraction phase and processing of raw materials contribute to a less significant impact for this category.

The SO2 emission is very low for all materials studied, as show in Table 2 and Table 3, since the fuel used in the ceramic manufacturing operations is natural gas.

Eutrophication is mainly associated with the NOx emitted in the firing process, and to a lesser extent in the atomization and drying processes. The combustion associated with transport along the life cycle of the ceramic tile is less relevant.

4 Conclusions

The EPD can act as an important tool for voluntary reporting of environmental impacts, demonstrating for the end customer the product's environmental performance, and thus can constitute itself a key differentiator and enabler of improvements in order to decrease environmental impacts of the product.

To develop the EPD, previous works was done in developing a PCR, rules for the product category, which are essential to allow different manufacturers to compare the EPDs.

The methodology selected to evaluate and quantify the environmental impacts was based on a "cradle to gate " LCA, according to the international standards, including ISO 21930 and ISO 14025.

Most of the environmental impacts of this LCA are associated with the firing stage of the ceramic material, since it requires greater use of energy (compared to others processes) and hence a greater emission of pollutants into the atmosphere. Thus, the firing process presents a greater potential for reducing the environmental impact for the impact categories usually selected in EDPs. Measures such as reducing the firing temperature of the ceramic material, adding fluxes or other additives is a possibility for reducing the environmental impact.

The building construction industry will be, in the next future, focused on the EPDs (ISO 14025, ISO 21930, prEN 15978) for the different materials used in building.

5 References

The relevant references must be given at the end of the paper, in the order of citation in the main text. They should be chronologically referred in the text by Arabic numerals enclosed in square brackets, e.g. [1], [1,2], [1-3].
Please use the paragraph template "Reference" for the Reference List.

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