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The carbon footprint and energy consumption of a commercially produced earthenware ceramic piece

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Abstract

The product carbon footprint quantifies the greenhouse gas (GHG) emissions during the life cycle of a product, from the extraction of raw materials, through the production, use and recycling, to the disposal of the used product.

In this study, the carbon footprint of an ornamental earthenware ceramic piece has been estimated following the PAS 2050:2011 methodology, and the energy and GHG hotspots have been identified.

The carbon footprint and the total energy consumption of the selected ceramic piece is 1.22 kg CO_2e per piece and 8.19 kWh, respectively.

The manufacture represents almost 90% of the carbon footprint of the piece.

The energy hotspots are natural gas production, biscuit firing and condensing boiler. Some measures to reduce the consumption of natural gas and electricity have been applied, such as the implementation of a gas pressure control system in the kilns and the mill lighting system optimization, respectively.

Keywords: Carbon; Product carbon footprint; Firing; Slip casting

1. Introduction

The issues related with energy requirements, greenhouse gas (GHG) emissions and sustainable development have become a major concern for many companies and business councils, as they are increasingly being incorporated into governmental policies.

The Brundtland report, published in 1987 by the World Commission on Environment and Development (WCED), defined sustainable development as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.[1] The sustainable development considers three main components: environment, economy and society. These pillars should be equally developed in order to achieve a sustainable development. They are related with each other so as to reduce the exploitation and use of natural resources, the consumption of energy and fuels and to decrease the emissions, maintaining the economic competitiveness and social cohesion.

The energy mix in the European ceramic industry is typically 80% of natural gas and 20% of electricity.[2] In 2003, the average specific energy consumption of the European ornamental earthenware sector was 45.18 GJ/t, whereas the brick sector presented the lowest average specific energy consumption (2.31 GJ/t).[3]

Between 2003 and 2007, the ornamental earthenware sector has been strongly affected by either the economic downturn and by the strong competition from the new emerging markets.[4] Therefore, to ensure the competiveness this sector highlights the need of reduction of the energy consumption across the life cycle of the product, and the quantification and reduction of the GHG emissions.

The ornamental earthenware ceramic manufacturing is typically a multifunctional system because several pieces with different dimensions and geometries are produced in the same mill, at the same time, involving multiple firing cycles for the same ceramic piece. Therefore, to estimate the energy

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consumption and the CO_2 emissions, per piece, in the manufacture stage, an allocation procedure is needed. Different allocation methods based on mass, volume, energy content or market price criteria may be used for solving multifunctionality.[5,6] The choice of the most appropriate method depends, among others, on the available data and the characteristics of the multifunctional system.[6] Therefore, to estimate the energy consumption and the CO_2 emissions, per piece, an allocation hybrid approach has been applied, based on the mass, volume or number of pieces, depending on the type of energy and stage of manufacturing.[7]

Although there are some published studies that quantify energy requirements and emissions for ceramic products,[8–12] none of them deals with ornamental earthenware ceramic pieces. Furthermore, the application of allocation procedures is not commonly referred in those studies.

The product carbon footprint quantifies the GHG emissions over the whole life cycle of a product, from the extraction of raw materials, through the manufacture, use and recycling, to the disposal of the used product (cradle-to-grave approach).[13] The product carbon footprint enables the:

- communication, by labelling, to customers and consumers of the quantified GHG emissions;[14]
- identification of hotspots, i.e. main unit processes where peak energy consumption and/or GHG emissions occur;
- establishment of opportunities measures to reduce the GHG emissions;
- establishment of opportunities measures to promote the energy efficiency and the economic sustainability of the mill; and
- establishment of an opportunity for product differentiation and/or market penetration.

These GHG emissions are converted to their carbon dioxide equivalent (CO_2e) on the basis of their per unit radiative forcing using 100-year global warming potentials defined by the Intergovernmental Panel on Climate Change (IPCC).[15]

Several methodologies are being developed and tested in order to establish an international standard for the product carbon footprint quantification.

In 2011, the second version of PAS 2050 – Specification for the assessment of the life cycle greenhouse gas emissions of goods and services was published by the British Standard Institution (BSI).[16]

In 2008, two parallel initiatives have been launched, both with the aim of to draw up an international standard for measuring the product carbon footprint. One initiative consists on the ISO standards 14067-1 (Carbon footprint of products – part 1: quantification) and ISO 14067-2 (Carbon footprint of products – part 2: communication).[17,18] The first drafts of these standards have been released in 2010 by the ISO Technical Committee for Environmental Management (TC 207) and the final versions are expected for 2012. The other initiative is the product accounting and reporting standard developed by the GHG Protocol of the World Resource Institute and World Business Council on Sustainable Development.[19] The second draft of this standard has been released in 2010 and a final version has been published in October 2011.

In this study, the carbon footprint of an ornamental earthenware ceramic piece (a cubic vessel), has been estimated following the PAS 2050:2011 methodology. This analysis enables the identification of hotspots and proposes improvement measures to reduce the energy consumption and the inherent GHG emissions, promoting thereby the energy efficiency of the mill under study.

2. Methodology

2.1. Aim of the study

This study intends to quantify the carbon footprint of an ornamental earthenware ceramic piece, produced and consumed in Portugal, following the PAS 2050:2011 methodology, and using the GaBi 4.3 life cycle software system. The piece is a cubic vessel with a mass of 0.417 kg and the dimensions of 10 cm × 10 cm × 10 cm.

Further, this study seeks to identify the hotspots across the life cycle of the ceramic piece and to propose measures to reduce the energy consumption and the GHG emissions, promoting, thereby, the energy efficiency of the mill under study.

2.2. Cradle-to-grave system boundary

Fig. 1 shows the detailed process map of the ornamental earthenware ceramic piece life cycle, which illustrates all materials and unit processes belonging to the identified system boundary. This process map provides a graphical reference to conduct both data collection and quantification of the carbon footprint of the ceramic piece. The system boundary identifies the life cycle stages of the piece that should be included in the study of the carbon footprint.

According to PAS 2050:2011 methodology, when the supplementary requirements (e.g. Product Category Rule as outlined in ISO 14025:2006,[20] product rules, product carbon footprint rules or sector-specific standards) specifying a system boundary have been developed for the product under study, they should be used. As the analysed earthenware piece is not covered by any supplementary requirement, the system boundary has been defined by considering the following stages:

- raw and ancillary materials – includes cradle-to-gate GHG emissions (from the raw materials extraction through production stage until the gate of the company) for the production of the raw materials – white and black clays, calcite, kaolin, silica sand and sodium silicate – consumed in the manufacture of the ceramic piece, namely in the proportioning and mixing unit process. This stage also includes cradle-to-gate GHG emissions for the production of the gypsum plaster needed to produce the piece mould, cradle-to-gate GHG emissions associated with the production of cartonboard used to pack the ceramic piece, cradle-to-gate GHG emissions from the production of the diesel necessary to the transport of the raw