POTENTIAL REDUCTION OF CERAMIC TILE CARBON FOOTPRINT BY USING GREEN HYDROGEN

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INTRODUCTION

The CO_2 emissions reduction targets set for the industrial sectors, including the ceramic sector, are unattainable with current ceramics production technologies.

One of the possible options being considered for decarbonising this industrial sector is the use of hydrogen as fuel to obtain the heat required, by direct combustion, in the drying and firing processes.

Hydrogen can be obtained from several sources. However, from an environmental viewpoint, its production only makes sense if the energy needed to obtain it comes from renewable energy sources. Such hydrogen is designated Green Hydrogen.

The great advantage of this process is that hydrogen combustion does not generate CO_2 emissions, so that current direct fuel-related emissions would therefore be completely suppressed. However, in practice, the obtainment of hydrogen, even if green hydrogen is involved, generates emissions in other stages of its life cycle. In fact, many studies consider the Life Cycle Assessment (hereafter LCA) methodology to be the most appropriate, for the scientific basis to assist in the decision-making processes in the development of really effective environmental policies and strategies (Tan and Culaba, 2002).

LCA is a standardised methodology, widely used and accepted in analysing the interactions of a technological system with the environment (Guinée et al., 2002; Klöpffer et al., 2009; Tan and Culaba, 2002), and it consists of quantifying the environmental impacts of a product, service, or system throughout its life cycle based on the quantification of the material and energy inputs and outputs and the interpretation of the results for drawing conclusions and obtaining recommendations (ISO 14040-44 (2006)).

OBJECTIVES

This study seeks to quantify the potential improvements entailed in using green hydrogen in ceramic tile manufacture in terms of CO_2 equivalent emissions, with a life cycle perspective.

METHODOLOGY

The study consists of an environmental life cycle assessment (LCA) in which different energy scenarios are envisaged, in which progressive replacement of natural gas with green hydrogen, from 5% to 100% in the ceramic tile drying and firing processes, without modifying the energy demand of these processes, is analysed.

Specifically, a replacement of 5% was analysed as the legal limit in gas pipelines; 20% to avoid variations in the Wobbe index and changes in the burners or in the rest of the combustion system; and 50% and 100% as extreme scenarios.

For this, a sector Life Cycle Assessment of ceramic tiles made in Spain in 2018 was taken as a basis. That LCA was verified by an independent third party for communication by means of Environmental Product Declarations [ASCER, 2019], updated to 2020, and with the electric mix to 2030 in accordance with the forecasts by the Integrated National Energy and Climate Plan (PNIEC) 2021–2030 (MITERD–IDEA, 2021).

The environmental data on green hydrogen were drawn from the GaBi database (SpheraSolutions, 2021a). This process assumes green hydrogen to be obtained by electrolysis of water with a purity of 99.995%, using electricity from renewable energy sources; specifically, the mix and the proportionality of the renewable electric power generation technologies in 2020 were maintained, increasing their contribution to the generated total to 100%.

The LCA follows standard ISO 14040-44:2006 and EN 15804:2012+A1:2013, supported by GaBi v10 software (SpheraSolutions 2021a) and its databases (SpheraSolutions 2021b).

The scope applied in this LCA is gate to gate, i.e. it considers the operations present in a full-cycle tile manufacturing company, comprising spray-dried granule preparation and ceramic tile manufacture, considering primary energy obtainment and consumption, water consumption, packaging materials, and air emissions, as well as waste generation and management.

The declared unit to which the calculations are referred is 1 m^2 ceramic tile made in Spain in 2020.

The environmental assessment was applied in detail to Global Warming Potential, reference indicator for the Carbon Footprint. However, other environmental impact category were also assessed to determine any possible burden shiftings and to identify the repercussions in other dimensions of the environment. In any event, the impact categories and characterisation factors used are those recommended by standard EN 15804:2012+A1:2013 included in the CML-IA method, after the October 2012 revision. The characterisation factors can be consulted in Annex C of said standard.

Parameters of environmental impact category	Abbreviation	Unit(*)
Global warming potential	GWP	kg CO_2 equivalent
Ozone Layer Depletion Potential	ODP	kg CFC 11 equivalent
Acidification potential of soil and water resources	AP	kg SO_2 equivalent,
Eutrophication potential	EP	kg PO_4^{3-} equivalent
Photochemical ozone creation potential	POCP	kg ethane equivalent
Abiotic depletion potential for non-fossil resources (elements)	ADPE	kg Sb equivalents
Abiotic depletion potential for fossil resources	ADPF	MJ, net calorific value

*Expressed per functional unit

Table 1 *Environmental impact categories*

RESULTS

The results of the ceramic tile LCA with different degrees of green hydrogen implementation in the drying and firing stages are set out below. The scope applied in this LCA considers the operations that occur in a full-cycle tile manufacturing company, i.e. preparation of spray-dried granules and ceramic tile manufacture.

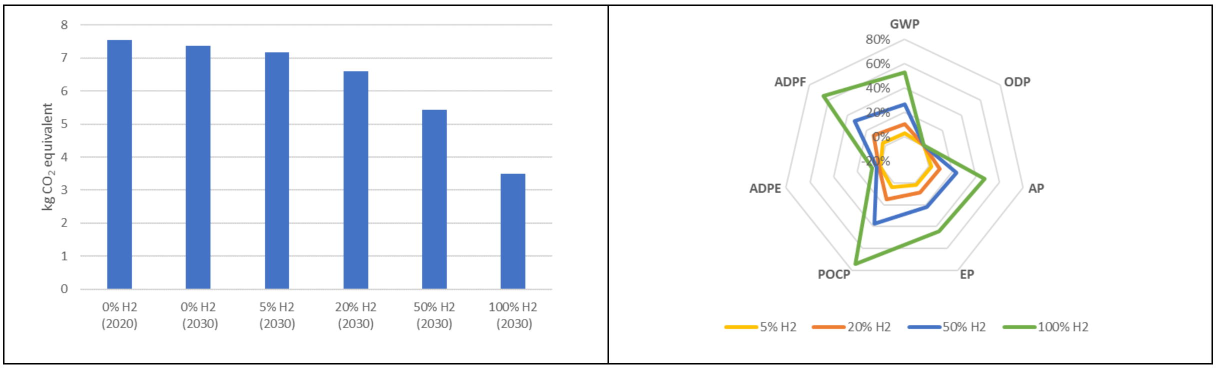

Figure 1 *Results of the Carbon Footprint (left) and relative contribution of each impact category (right)*

A 5% replacement of natural gas with green hydrogen accounted for a 4% reduction in carbon footprint (kg CO_2 equivalents) with respect to the base scenario (LCA of ceramic tiles made in Spain in 2020), it being possible to achieve a maximum reduction of 54% carbon footprint if the replacement were made at 100%.

The global warming potential (carbon footprint) (GWP), the abiotic depletion potential for fossil resources (ADPF), and the photochemical ozone creation potential (POCP) were the most sensitive environmental indicators, i.e. the ones that exhibited the greatest improvements when natural gas was replaced with green hydrogen. However, the ozone layer depletion potential (ODP) and the abiotic depletion potential for non-fossil resources (elements) (ADPE) exhibited practically no variations. On the other hand, none of the studied impact categories were adversely affected by the incorporation of green hydrogen.

It may be noted that the perspective of the present study was the product life cycle, as only considering direct emissions could lead to limited interpretations or undesired consequences, such as possible cessions of environmental impacts among industrial sectors or load transfer between regions, possibly leading to production delocalisation.

CONCLUSIONS

The LCA methodology and carbon footprint were shown to be an appropriate tool for identifying the overall environmental impacts of the use of this technology and for addressing development of environmental policies and strategies on a sector and on an individual scale.

The carbon footprint could be reduced by up to 13% in relation to the current situation with a replacement of 20% natural gas to avoid modifications in the burners and in the combustion systems.

No negative consequences were observed in any of the studied environmental impact categories.

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