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Critical analysis of the Life Cycle Assessment of the Italian cement industry

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ABSTRACT

The interest for environmentally related issues in the construction industry has grown faster in recent years, demonstrating the neccesity to promote both a more responsible use of non-renewable resources and a better use of renewable resources. As a consequence, there is an increasing number of environmental documents and institutional acts on this topic that demonstrate the need for greener approaches in the area of construction engineering. The objective of this study is to evaluate the environmental impact of the Italian gray cement and clinker industry, after distinguishing between the upstream and the core phases of these processes. The study considered clinker and cement generated during 2014 in eleven Italian plants that produced materials complying with the European standard EN 197-1 "Cement - Part 1: Composition, specifications and conformity criteria for common cements". The environmental assessment was conducted through a Life Cycle Analysis (LCA) of these industrial processes, following the standard EN 15804 "Sustainability of construction works, environmental product declarations, core rules for the product category of construction products" and the Product Category Rules (PCR) 2010:09 version 2.1 "Cement". The results permitted to construct the first sector Environmental Product Declaration (EPD) related to cement production published until now by the International EPD System. The analysis of the results demonstrated that among the different phases involved in the production process of these materials (i.e. extraction and production of raw materials and fuels, transportation and core production process), the core phase is responsible for most of the greenhouse emissions (i.e. more than 85% of the total process for clinker, and more than 79% of the total process for cement), and the acidification and eutrophization potential (i.e. 43% and 62% of the total process for clincker, and 33% and 55% of the total process for cement). It was also found that the cement production is mainly responsible for the following environmental impact categories: the overall electrical consumption required as part of these industrial processes (116 kWh/Mg), the output flows of components for re-use and materials for recycling (0.21 and 0.17 kg/Mg, respectively), and the biogenic CO_2 emissions (16 kg/Mg). The results highlight the environmental benefits of applying Best Available Techniques (BAT) for this industry, as reported in the European Reference document for the "Production of Cement, Lime and Magnesium Oxide".

1. Introduction

In recent years, the concern for the preservation of the environment and the interest in environmental-related construction issues have grown faster, becoming a main criterion for the development of socioeconomic policies (Miccoli et al., 2014a, 2014b). Most of these efforts have focused on reducing the emissions of greenhouse gases, especially carbon dioxide (CO_2), which are responsible for trapping heat in the atmosphere. According to the World Meteorological Organization's Annual Greenhouse Gas Bulletin (2016), the concentration of carbon dioxide in the atmosphere reached in 2015 the symbolic and significant milestone of 400 parts per million for the first time in history. In 2009, the International Energy Agency and the World Business Council for Sustainable Development (2009) specifically investigated the environmental impact of the cement industry, since this material – which is used as binder in the construction of hydraulic concrete – is the second most used substance around the world after water, and its production is associated with high amounts of CO_2

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emissions, as demonstrated by several published studies (e.g. Cao et al., 2016; Stafford et al., 2016a; Feiz et al., 2015). In fact, it is estimated that this industry is responsible for generating approximately 5% of the current global man-made CO_2 emissions (Summerbell et al., 2016).

To produce cement, several materials including limestone, clay and other clay-like materials are heated in rotary kilns at 1400 °C to form a solid substance called clinker. Clinker is then combined with gypsum and other constituents to produce cement (Alunno Rossetti, 2007).

There are various types of cement kilns currently used in Italy, including the following:

- Lepol kiln, which uses a semi-dry process (i.e. in a nodulizing pan, 11–14% of water is added to the dry raw materials, also known as "raw meal", before its burning);
- preheater with cyclones, which uses a dry process (i.e. the raw mix powder is heated by the kiln exhaust gas before the initiation of burning processes in the kiln);
- precalciner heater, which uses a dry process (i.e. the homogenized raw meal is introduced into the top of the preheater tower and it passes downwards through a series of cyclones to the precalciner vessel at 850 °C, where extra fuel is burned; at the end of the precalcination phase, the feed is burnt in the kiln).

The type of kiln significatively affects the heat input requirement and the NO_x (i.e. nitric oxide and nitrogen dioxide) emissions rate (Mikulčić et al., 2016). Among the three types of kilns, the precalciner heater is considered the most efficient system, because it facilitates the use of secondary fuels, as tired-derived fuels (TDF) (Stafford et al., 2016b). Besides, this heater reduces the quantities of non-renewable fuels needed for the kiln operation and the quantity of iron added to the raw meal. Moreover, it also reduces the consumption of urea or ammonia required for decreasing the amount of NO_x emissions, avoiding the risk of ammonia slip resulting from the Selective Non-Cathalytic Reduction (SNC). It should be noted, though, that the use of this type of kiln does not significately affects the amount of CO_2 emissions.

The production of cement releases greenhouse gas emissions both chemically and physically: while the heating of limestone chemically releases CO_2, the burning of fossil fuels required to heat the kiln indirectly results in physically produced CO_2 (Bebi, 2007).

Chemical-emissions that derive from raw materials calcination follow the equation:

$$CaCO_3 + heat \rightarrow CaO + CO_2(g) \quad (1)$$

where $CaCO_3$ is calcium carbonate, CaO is calcium oxide, and $CO_2(g)$ is carbon dioxide.

While these emissions are not reducible, physical-emissions can be cut down through the use of alternative fuels and/or by adopting energy-saving technologies. For example, the use of alternative fuels like biomass or waste materials could have an immediate impact on the carbon profile of the cement industry (e.g. Supino et al., 2016). However, it is important to stress that even though political and research authorities consider carbon dioxide emission as the main, and often the only, environmental impact category to be assessed, a proper environmental evaluation of industrial related processes requires a broader and more inclusive approach (Seidel, 2016).

The standard EN 15804 "Sustainability of construction works, environmental product declarations, core rules for the product category of construction products" (EN, 2013) provides guidelines to elaborate an unbiased set of data useful to examine and improve the environmental performance of a building material. For conducting a Life Cycle Assessment (LCA) of cement (i.e. a technique for assessing the potential environmental aspects associated with a product) (ISO, 2006a), some pre-specified minimum requirements are stated by the Product Category Rules (PCR) 2010:09 version 2.1 "Cement" (The International EPD® System, 2014). Indeed, the cited documents can be used to prepare the Environmental Product Declaration (EPD) of this material, in what it is known as a *type III* label (ISO, 2006b). A type III label is a document that quantifies the environmental impact of a product based on its LCA, which is verified by a qualified third party.

Within this context, the Italian cement industry representative body (AITEC) promoted the generation of the LCA of this material, and the development of the sector Environmental Product Declaration (EPD) of the average Italian Cement. The importance of conducting such assessment is the fact that the Italian cement industry is the second European cement producer with over 21 million of Mg generated in 2014, which represents more than 13% of the total production of the 28 European Union (EU) countries (AITEC, 2015). Moreover, the EU cement industry, which "only" represents 3.14% of the global cement production (China accounts for 51.3%), is a world leader when it comes to innovation, research and development.

In general, the results obtained from a LCA of the cement industry could be efficiently used to evaluate the environmental impact of concrete materials (Moretti, 2014), to compare the impact of different building materials (Moretti et al., 2013, 2016, 2017) and/or to assess specific environmental performances of projects constructed with such materials (Loprencipe and Cantisani, 2015; Loprencipe et al., 2015; Miccoli et al., 2014c). Moreover, they could be used to pursue further research efforts (e.g. environmental impact of building and civil constructions, etc.) and to perform comparison studies with other industries. The methodology to accomplish this goal consists on using the LCA formulas for cement, after considering both the Life Cycle Inventory analysis (LCI) and the Life Cycle Impact Assessment (LCIA) of the material (ISO, 1998, 2006c,b). Studies of this nature should also consider a "from cradle to gate" boundary approach, including upstream and downstream processes, as specified in The International EPD® system (2015).

The objective of this work is to assess and evaluate the Italian gray clinker and cement produced during 2014 using a statistical approach and LCA procedures. To accomplish this goal, a total of 11 plants among those associated to AITEC were considered as a representative panel data set. Also, 29 different impact categories, which are recommended by the standard EN 15804 and by other European guidelines (de Baan et al., 2013; Benini et al., 2014), were included in the analysis. The study considered 10 different formulas of clinker and 45 cement formulas defined in the European standard EN 197-1 (EN, 2000).

The interpretation of the LCA results, which followed existing methodological recommendations (ISO, 2000), allowed comparing the environmental impact of the materials, and identifying the strengths and weaknesses of the processes evaluated. This, in turn, is useful for improving and updating the technology used as part of these industrial processes and boost competitiveness. In this regard, it is important to mention that the Italian sector has conducted significant investments to minimize the environmental effects of these industrial production processes in recent years, at the time that has promoted the generation of innovative cements with a lower overall environmental impact. Therefore, the information obtained from this study could be efficiently used to further support these on-going efforts. The results from this work also provide statistical information useful to analyse the Italian industry (AITEC, 2016a), in the light of the Best Available Techniques established by the European Integrated Pollution Prevention and Control Bureau (European Commission, 2013). Finally, the results