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ATTI

XI Convegno della Rete Italiana LCA

Resource Efficiency e Sustainable Development Goals: il ruolo del Life Cycle Thinking

Siena
22 – 23 giugno 2017

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UNIVERSITÀ DI SIENA 1240

ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Rete Italiana LCA

Life Cycle datasets of the Italian stone production chain

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Abstract

The ornamental stone production chain deeply changed in the '70s and in the following decades, when the mechanization of processes increased the production and the safety of workers. Nevertheless, the new techniques are also responsible of not negligible environmental impacts. This paper is focused on the currently most diffused techniques of extraction, cutting and polishing of the Italian stone sector (gneiss and marble). The study follows a Life Cycle Thinking approach and aims to make available detailed Life Cycle datasets on specific techniques of stone production. To this aim, primary data were collected in Italian quarries and transformation plants. The realization of the dataset related to the bridge cutting technique is presented. Some results on environmental impacts associated to this particular stone cutting technology show the most relevant flows in relation to different impact categories.

1. Introduction

Ornamental stones, such as marble and granite, are construction materials with a long tradition and play a big role in the economy of countries that have availability of this resource (such as Italy, Spain, Brazil, etc.). The extraction techniques deeply changed in the XX century, when the mechanization of many processes increased both the production and the safety of workers. Nevertheless, these technical developments also led to some environmental and social problems, which are nowadays quite debated. This paper aims to focus, in particular, on the environmental aspects related to this sector.

Since stone is a non-renewable material formed in the geological past, its use should be careful and responsible. Some properties of stone material can be exploited in this sense: its lifetime is usually longer than other construction materials (Prikryl, 2015) and also after it can be reused in the same structure, recovered for the use in other buildings, or crushed to produce aggregates (Savazzini dos Reis et al., 2011; Shirazi, 2011). As far as concerns its value chain, since natural stone does not need to be produced, a part of impacts is avoided. Nevertheless, impacts related to the cut of benches, to the transformation into slabs/tiles and to the management of the relative waste have to be considered. Other issues of concern are mostly related to the areas located near the extraction site, such as the risk of turbid aquifer in case of processes using water (Doveri, 2008) or the concentration of atmospheric particulate matter in case of dry processes or lorry transportation of blocks passing near built-up areas (Cuccia, 2011). As far as concerns the society, ornamental stones are an important resource for the economy of the local community. Anyway, an important drawback is that quarrymen are exposed to some working risks mostly due to the high weight of the benches they cut and transport. Moreover, people of the local communities generally show concern about the transformation of the mountains, the problem of abandoned wastes and of the particulate matter in the air.

To sum up, the production chain of ornamental stones is a complex system, where variables of different nature interact. In order to enhance the stone sector, studies that involve the environmental, economical and social dimensions of sustainability should be considered. A way for evaluating the sustainability is the Life Cycle Assessment (LCA), a scientific tool that allow to calculate the potential impacts of a product/process, and which is standardized by UNI 14040-44 regulations (ISO, 2006) and by the ILCD guidelines (European Commission, 2010). In the field of ornamental stones, some LCA have already been performed in the major stone production countries (Traverso et al., 2010; Gazi et al., 2012; Catarino, 2016; Natural Stone Council, 2008). Nevertheless, the main obstacle is that currently, in LC databases (such as Ecoinvent, Thinkstep, ELCD), there is no availability of stone production LC datasets. For this reason, assessments performed with secondary data are often incomplete or inaccurate due to the high number of assumptions and approximations. In Brazil, the CETEM research center (Centro de Tecnologia Mineraria) already published datasets related to the Brazilian stone production chain (Castoldi et al., 2012). Nowadays CETEM is updating the datasets with the new technologies commonly employed in Brazilian stone quarries and transformation plants.

The main aim of the work presented in this paper is to create and make available specific datasets related to the stone production chain, with reference to the Italian production.

2. Objectives

Different objectives led to focus the study on the Life Cycle Inventory (LCI) of the Italian ornamental stone production chain (gneiss and marble). First of all, this study aims to establish a reference point of the current environmental sustainability performances of the Italian stone sector. The LC datasets will be available as open source data in order to allow the scientific community and the stone enterprises to develop detailed LCA of specific stone productions. In this way it will be possible to identify which processes majorly contribute to the environmental impacts and, consequently, how the sector could be improved. Another important goal of the study is to allow stone enterprises to perform environmental declarations in order to face the competition with other construction materials and with other countries. Finally the study could be used to give to consumers scientific information about the environmental performance of this natural material.

3. Methodology

This study is focused on the production techniques which are currently most diffused in the Italian stone sector. The investigations were carried out for the

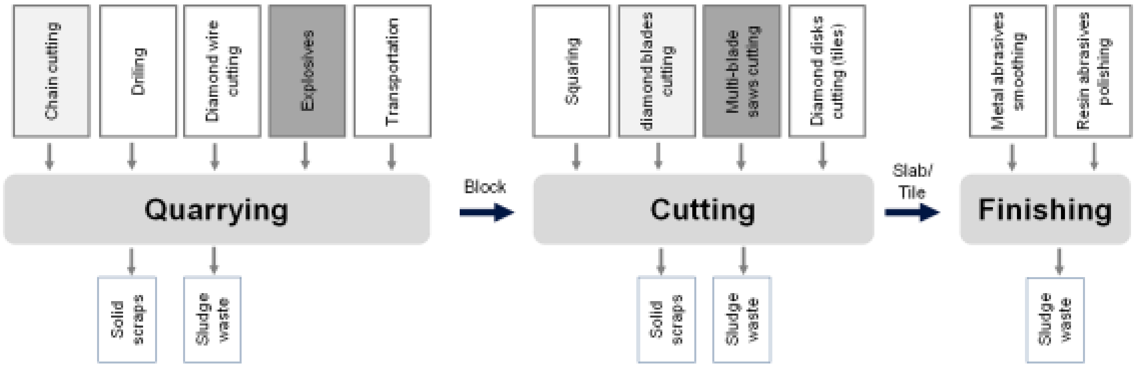

Figure 1. Scheme summarizing the techniques that were investigated on-site. Light grey boxes are related just to marble production chain; dark grey boxes to gneiss production; white boxes to both marble and gneiss productions.

phases of extraction, cutting and polishing. The technological representativeness and the precision of data ware achieved through the collection of a high quantity of primary data: quantitative data of energy and resources were directly collected into quarries, transformation plants and enterprises producing cutting tools. When data were not available or covered by industrial secret, secondary data from technical sheets, literature or LC databases were also used. All the relevant flows in the production chain were analyzed in order to create the LC datasets. Fig. 1 summarizes the processes that were investigated. In this study the temporal representativeness is from years 2013 to 2016, while the geographical representativeness is:

- The Carrara basin, for the marble production.
- The basins of Verbano Cusio Ossola (VCO) province, for the gneiss production.

Datasets with average values of each process were then created with Gabi 6 software. Nevertheless, the input quantities of the processes are regulated through parameters which allow the adaptation of the model to specific productions. Through the parameters, the quantities of materials and energy can be directly modified in the model to calculate the specific LCA of specific enterprises. On the base of the datasets created, a complete Life Cycle Assessment was carried out. The system boundaries of the LCA are from-cradle-to-gate (from the extraction to the finished product), and the functional unit is 1 m^2 of polished slab/tile.

4. Results

This section shows how datasets were created through the case of the bridge cutting technique (Fig. 2). This latter is a technique commonly used in transformation plants for cutting slabs into tiles. A bridge structure supports and gives a rotation movement to a steel disk with sinterized diamond sectors fixed on its perimeter (Fig. 3). The abrasive action of diamond sectors is responsible of the cutting.

Quantitative data concerning resources and energy related to this technique were collected in the Italian transformation plants of both Carrara and Verbano Cusio Ossola province. In this paper it is showed the process with the average values for the gneiss cutting, collected in VCO transformation plants and firms. The production of a tile with the bridge cutting technique requires some input resources: the stone slab, the cutting frame, electricity, diamond disks and water. In order to calculate the impact given by the only process of cutting(and not of the cumulative impact till that moment), the impacts related to the extraction of stone blocks are left out of the system boundaries of this process. According to the primary data collected on-site, a sintered diamond disk with diameter d = 600 mm averagely cuts 200 m^2 of gneiss. After this period diamond sectors are removed, while the steel composing the disk can be regenerated, usually between 5 and 10 times for the gneiss cutting. Then the steel looses the optimal tension and it is usually sent to recycle. From these data it was possible to calculate the resources necessary for cutting 1 m^2 of tiles with dimensions (20 cm x 20 cm x 3 cm). Since databases do not contain the diamond disk dataset, data about its production were collected through on-site investigation and literature. Secondary data were used for the electricity employed during the bridge cutting process. Water has no impacts since it is continuously recycled in a close loop, while the impact related to the frame production is not accounted because it is irrelevant considering the long lifetime of this machine (Fig.4a).

As shown in Fig. 4b the production chain of a diamond disk was modeled. The inputs are: the electricity necessary for welding diamond sectors on the disk and for the rectification; the diamond sectors; the stainless steel of the disk. Since the steel of the disk is recycled at its End of Life, the environmental credit of the recycling is accounted. Fig. 4c shows the process of diamond sectors production; according to the data provided by a VCO enterprise producing cutting tools, the production is composed by the following phases:

1. Mixing of metal and diamond powders

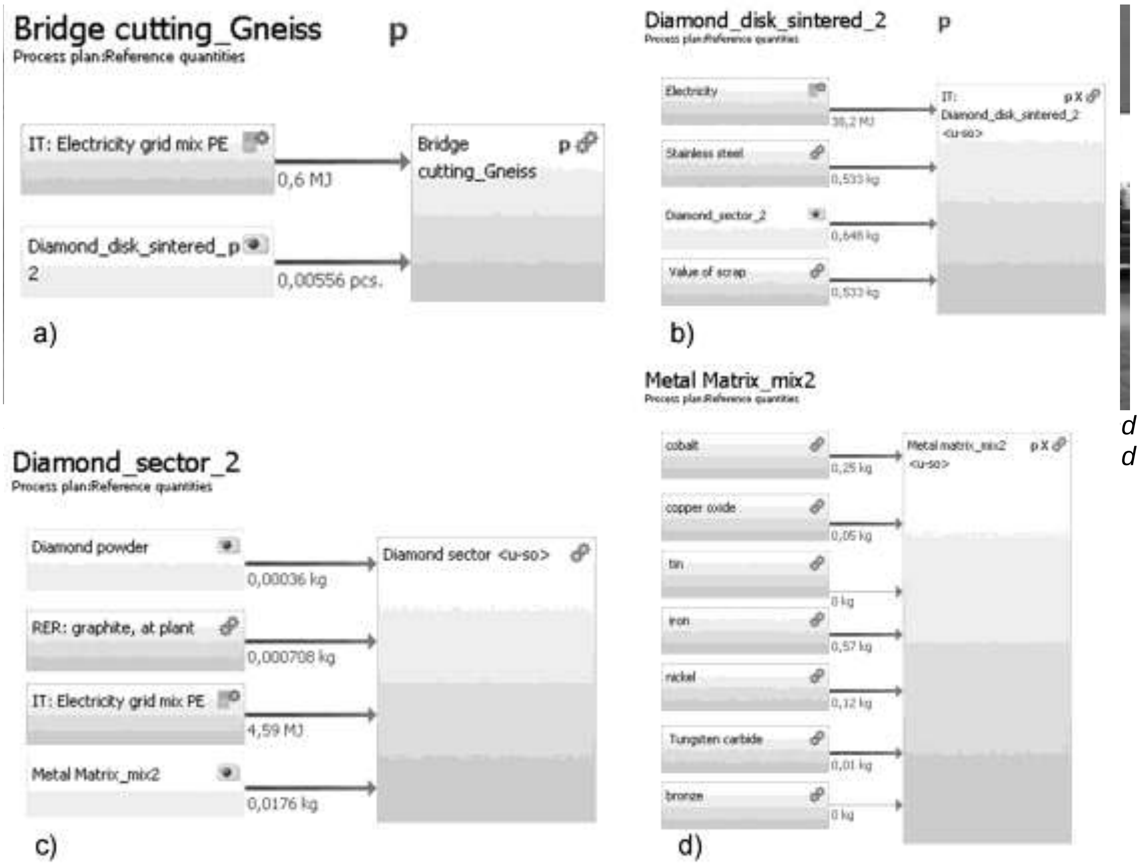

Figure 4. Process of the diamond disk cutting technique, modeled with Gabi software on the basis of data collected in transformation plants and enterprises located in Verbano Cusio Ossola Province (Italy).

2. Cold pressure of the powders
3. Cooking of the diamond sector in graphite moulds

The metal matrix can vary a lot from one firm to another. Average values from technical sheets were inserted in the model, as it is shown in Fig. 4d.

The LCIA of the bridge cutting has been calculated with the ReCiPe 1.08 Midpoint method for the impact categories of Climate Change, Metal depletion, Ozone depletion and Fossil depletion. As it can be seen from the percentage values showed in Fig. 5, for all the categories, the impacts due to the production and consumption of the diamond disk are higher than the impacts due to the electricity necessary for the cutting itself. Fig. 6 shows the impacts related to the production of a sintered diamond disk. As it can be noticed, the inputs contribution varies according to the impact category that is taken into account.

For the impact categories of climate change and fossil depletion the process that mostly contribute is the electricity employed for the sinterization of the diamond sector. The production of the metal matrix is the responsible for the

96% of the impacts related to the metal depletion, while the production of the diamond powder has the major impact to the ozone depletion.

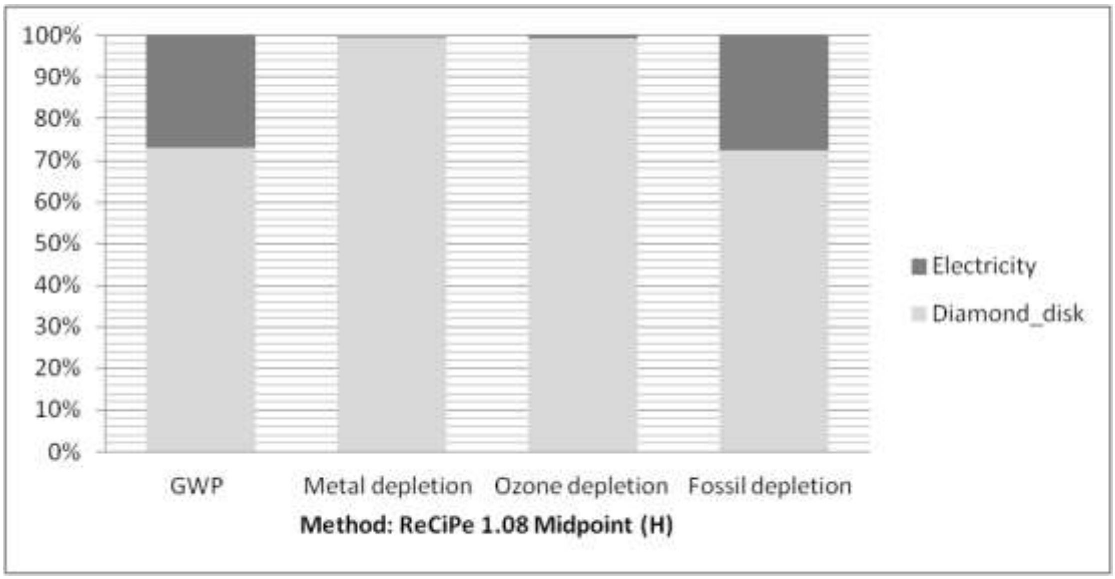

Figure 5. Percentage impact contribution of the input flows related to the diamond disk production chain (ReCiPe 1.08 Midpoint method).

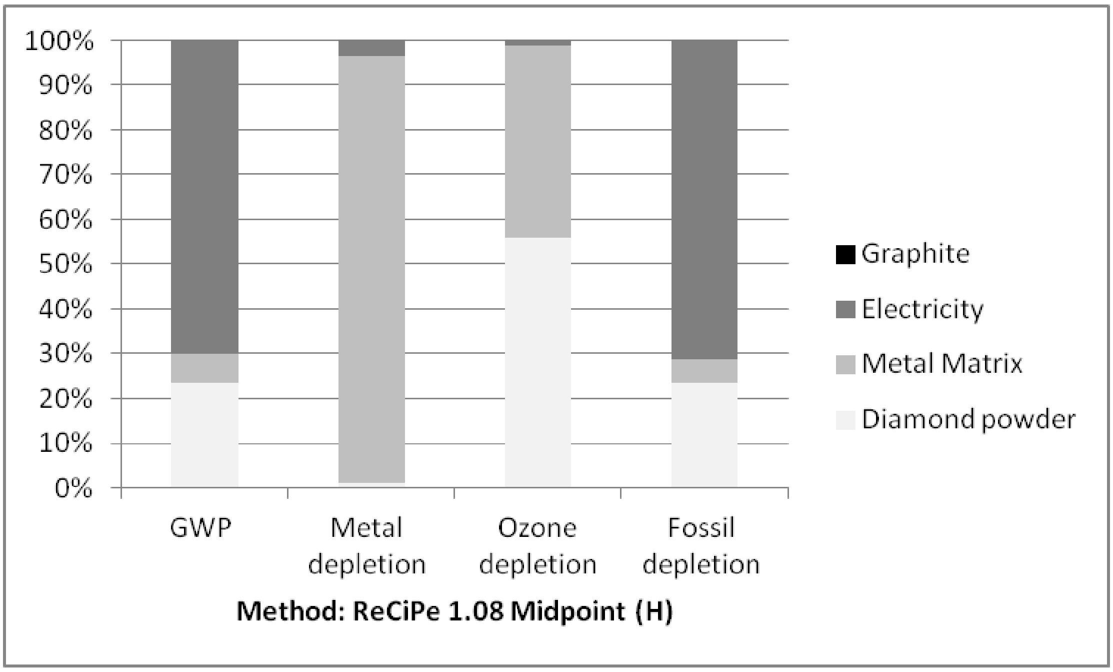

Figure 6. Percentage contribution to four impact categories of the diamond disk cutting technique. The highest impacts are given to the production and consumption of the disk, while the electricity for performing the cutting has a lower impact.

5. Conclusion and further developments

The study presented in this paper is focused on the environmental life cycle impacts related to the Italian ornamental stone sector. Since nowadays LC databases do not contain detailed information on technologies and processes the stone production chain, the main aim is to create and publish detailed datasets on the most common and significant processes of this sector. The study is part of a PhD project, which will end in November 2017. To this date, all the datasets will be completed. Data will be validated and made available through their publication in a network where interested people will be able to easily access. These datasets could indeed be a starting point for stone enterprises who want to assess their environmental sustainability in order to enhance their processes or to produce certificates helping them to face the competition with other products and countries.

In collaboration with the research center CETEM (Centro de Tecnologia Mineral) of Rio de Janeiro (Brazil), the study of Social Life Cycle Assessment related to the stone production chain is under development. The aim is to create Social datasets for both the Brazilian and the Italian stone sectors according to the UNEP/SETAC indications (UNEP/SETAC, 2013).

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