Life Cycle Sustainability Assessment: an implementation to marble products

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Abstract Sustainability is today an overused word in different political and scientific contexts. Several methodologies and tools have been carried out and implemented for assessing sustainability performances in different sectors. A new meaningful contribution for assessing products and processes is represented by Life Cycle Sustainability Assessment (LCSA). This methodology assesses sustainability performance of a product through its entire life cycle, from the extraction of raw materials, to production, use and disposal. This methodology integrates all three pillars of sustainability, by measuring positive and negative impacts to environment, economy and society at microeconomic level.
Starting from the consideration that the marble sector is considered one of the most productive in the Sicilian region, an implementation of LCSA and its results on marble is presented in this work.

1 Introduction

The ambitious target of sustainable development, that according to Bruthland report, "means a development that meets the present generation needs without compromising the opportunity of the future generations to meet their owns" is the main objective of local and national governments. This goal is getting particular important for the building sector that presents a high economic, mainly positive, and environmental, mainly negative, impact.
Sustainable development includes the balance of social, economic and environmental factors and the only possible development, which can guarantee the same opportunities and quality of life to the present generation and to the future

ones. It guarantees a balance among environmental protection, resource use and technology development [1].

Building sector is considered a strategic compartment for achieving a sustainability production and consumption; in fact its energy use is about 40% of the world energy one.

Building products include several kinds of products such as building materials and buildings themselves. Its variety makes this sector particularly interesting to assess in term of sustainability performances.

Among others, marble products play a significant role for Italian economy. There are two Italian main basins that are considered the first and the second more productive areas: Massa & Carrara basin (north of Italy) and Custonaci basin (Trapani, Sicilian province). The first one is well known and its main product, "Bianco di Carrara", has been used and exported in all parts of the world for centuries. Its use and extraction can already be found during Roman Empire (48-44 a.C.). In the recent years, "Perlato di Sicilia", the most important marble extracted in Custonaci basin, has improved its position in the market. It represents a meaningful resource for the Sicilian economy that it is mainly based on the tertiary and agriculture sectors.

In spite of this background few studies have been developed to assess the sustainability performance of this important building material [2].

Hence the focus of this work is the assessment of sustainability performance of "Perlato di Sicilia".

Because only few studies have been carried out on this product until now and they mainly focused on the environmental performances, primary data have been collected and a specific set of indicators for measuring the economic and social dimensions have been identified. The primary data have been collected by two representative companies, called, for privacy reason, A and B through this paper, sited both in the Custonaci basin.

The sustainability performance of this product has been assessed by a life cycle thinking approach, where the entire product life cycle has been considered [3]. The procedure used here is called Life Cycle Sustainability Assessment (LCSA) and a set of indicators to consider social, economic and environmental factors has been identified and implemented here.

Life Cycle Sustainability Assessment (LCSA) can be formally defined as [4, 5, 6]:

$$LCSA = LCA + LCC + S\text{-}LCA \quad (1)$$

Where LCA is Life Cycle Assessment, procedure standardized by ISO 14040-44 [7, 8, 9], LCC is Life Cycle Costing [10] that focuses on the economic impacts along the product life cycle, and Social Life Cycle Assessment (S-LCA) that focuses on social impact [11] and it is considered the less developed among these three procedures.

2 Life Cycle Assessment to marble

LCA has already been implemented for other natural stone floor coverings and an implementation has been carried out on the "Perlato di Sicilia" [12]. In these studies further primary data have been collected and used in the present applications. The analysis does not include all product life cycle, cradle to grave, but includes the extraction of raw materials, the cutting and finishing steps and all the transports from a plant to another. The use phase has not considered because its impact are so low that can be neglected and the disposal step is geographically and temporally so far from the working process, that the assessment is very difficult and impracticable. The functional unit chosen is the cubic meter (m^3) according to other studies and references for this kind of product [13, 14].

The life cycle inventory has been carried out and all input and output have been identified and calculated. The Life Cycle Impact Assessment has been implemented by using midpoint categories and the characterization factors used for the modelling are taken from CML-IA 2007 [15].

It was possible to get more detailed information for the company B, where the all input and output have been differentiated for each group of products: tiles and slabs. Instead for the company A, all data referred to both products and, consequently, a differentiation have not been done (figure 1) according to data availability.

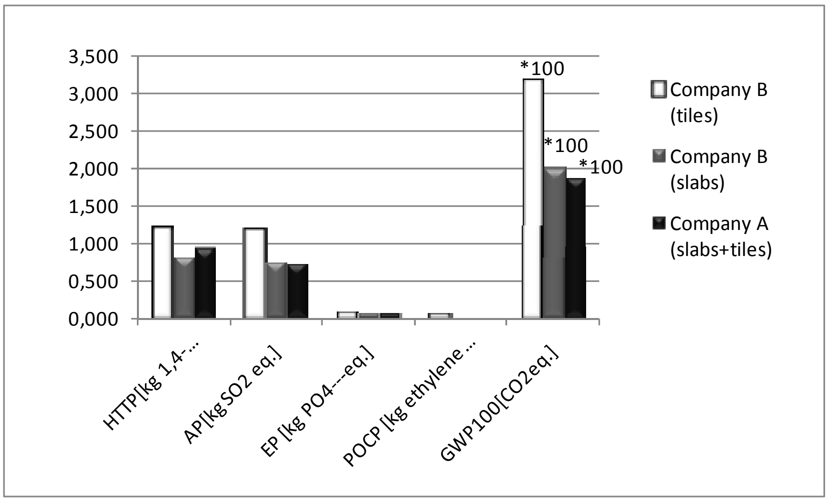

Fig.1: Comparison of LCA results of A and B companies. (HTTP = Human Toxicity Potential ; AP = Acidification Potential; EP = Eutrophication Potential; POCP = Photochemical Oxidation; GWP = Global Warming Potential).

Anyway, the comparison of the two companies shows that the company B has a higher environmental impact than the company A. This probably is due to a better choice of the equipment and to a more careful management regarding energy and fuel use.
LCA considers more indicators than those reported in figure 1, but here only the indicators of the occurred environmental impact of marble are reported.

3 Life Cycle Costing to marble

The LCC is a procedure to assess all costs and revenues that occur along the product life cycle. This procedure is complementary to LCA and it should be implemented to the same system. It has not been standardised yet but a handbook and a code of practice have been published [16, 17]. The LCC includes also the externalities such as carbon taxes, waste costs and similar. In this application, as externalities the waste management costs have been considered; as matter of the fact according to the regional and national laws these are the main environmental costs that occur by these kinds of industrial activities. All costs included in this assessment are reported in the figure 2.

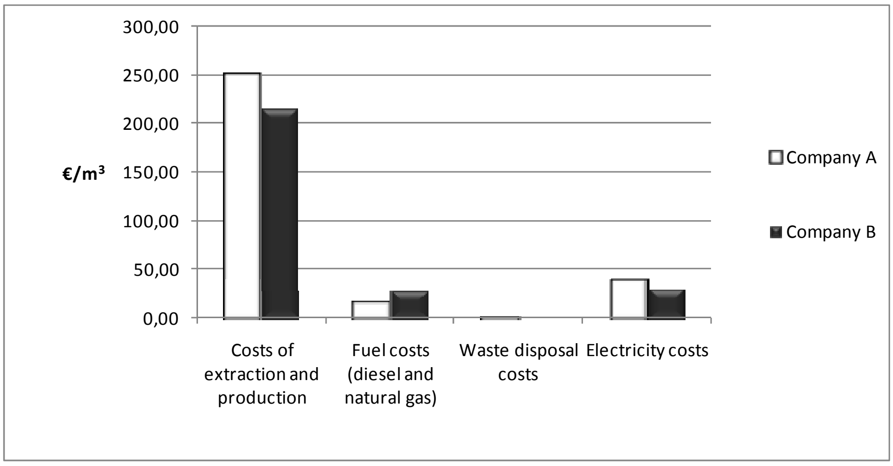

Fig.2: All costs included in the LCC of "Perlato di Sicilia".

For each category reported in the figure 2, the difference between the two product life cycles is small. This is justified by the fact that both activities are in the same basin and regional contest and the equipment level is quite similar.

4 Social Life Cycle Assessment to marble

The third component of sustainability assessment consists of the Social Life Cycle Assessment (S-LCA), It is defined as the social impacts assessment of all product life cycle [18, 19]. It is still considered in its infancy, especially when compared to the methodological development level of the other two components, but a lot of efforts and improvements have been made by the scientific community to define this evaluation in the last years. Two main approaches can be identified: the first related to the Danish school that considers the S-LCA more related to the company behaviour and, consequently, its evaluation is focused more on social conducts of the company and its main suppliers [20, 21] without necessarily taking into account all product life cycle. The second approach has been introduced by the Social LCA guidelines carried out by UNEP/SETAC life Cycle Initiative [22]. In this second case the S-LCA is conducted in parallel to the LCA, by following the same steps but where instead of environmental impact, the social ones are evaluated. This second approach has been preferred in this work because our main goal is to obtain a complete sustainability assessment of the considered product.

According to guideline five groups of main stakeholders have been identified: workers, consumers, local communities, society, and value chain actors. For each stakeholders group different social impacts subcategories have been identified and a methodological sheet for each subcategory have already been drafted [22]. According to guidelines a screening to identify the most impacted stakeholders have been carried out and all relative stakeholder categories have been considered. In this study, the most affected stakeholder group according to the activity is workers.

The guidelines do not establish which set of indicators should be used for each subcategory, but in the methodological sheets draft some direction and suggestions are given. In this application a combined top-down and bottom-up approach has been implemented to identify a valid set of indicators [23]. It manages to consider all aspects assumed as valuable for the society and the ideal indicators are matched with data availability.

All results have been reported for functional unit of product according to the other two assessments. The best social performance has been obtained by the A company as it is shown by the figure 3 and 4.

The average monthly salary per working hour and per employee is from 1.265,39 to 2.009,01 €. Both values are acceptable according to the minimum wage for the extraction and manufacturing of natural stone materials imposed by the regional law.

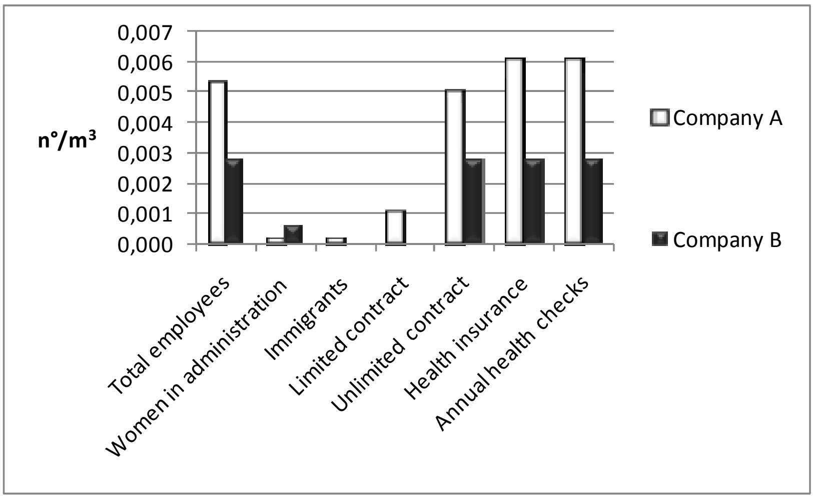

Fig.3: **Social indicators of workers stakeholder category.**

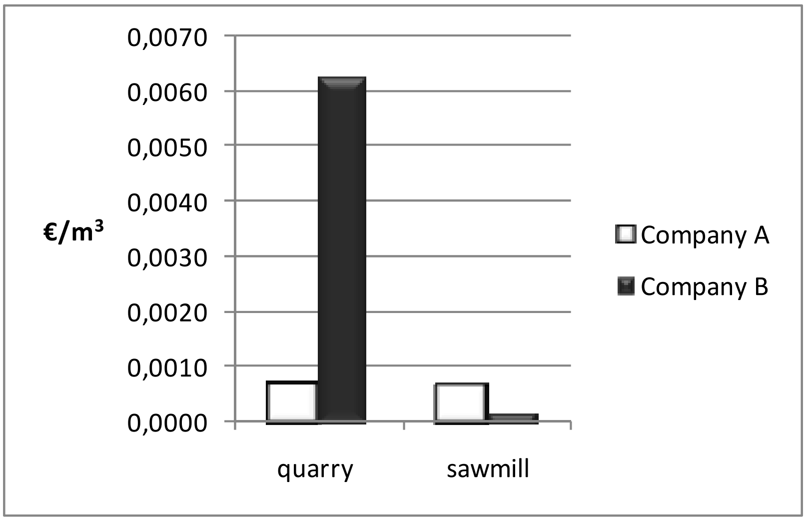

Fig.4: **Monthly salary of employee of quarry and sawmill.**

5 Life Cycle Sustainability Assessment

A complete Life Cycle Sustainability Assessment of the product is obtained by the parallel implementation of all three methodologies introduced in the previous

paragraphs [24]. All three evaluations have been carried out to the same systems and all indicators have been reported to the same functional unit, m^3 of marble. The collection of the data has been carried out in the same period, by questionnaires and surveys of the assessed plants and their workers.
The evaluation has shown that the best environmental performance has been reached by the company A, although this company has the worst economic one. The company A has also reached the best social performance except for the average wage per hours and number of women employees: both values are in fact lower than company B ones.
The obtained results are not so straightforward to identify the best product for all three pillars of sustainability, so further considerations should be made. According to the LCA procedure the assessment should not be made to decide which product is better, but only to compare the products on the base of a transparent procedure that can support decision-makers towards a more sustainable product.
Than, actually the results could be summarized in one or more aggregated indexes that in few values show the aggregated sustainability performance [25]. It can not be done without some considerations about how to weight all indicators. The weighting procedure should be carried out with support of a consultation process that involves the affected stakeholders [26]; that is why a flexible and easy to use tool should be implemented to support decision-makers. It concerns another important point of LCSA implementation but it will, however, not be considered in this article both because the point has not yet been thoroughly enough discussed in the LCA community and it could be too early.

6 Conclusions and discussion

The LCSA has been implemented for the first time to marble products to evaluate and to compare two production processes of "Perlato di Sicilia" by a life cycle approach. This product has been chosen because it represents a meaningful industrial activity for the economy of Sicilian region and any study was implemented so far for assessing its sustainability performances.
A meaningful part of this work regards the data collection; all data presented in this work are primary data and have been directly collected from two representative production plants of Custonaci basin. It represents the second most productive basin of Italy and the first of Sicily.
This first implementation allows identifying strengths and weakness of the products and their life cycle, but it also limits and potentialities of LCSA methodology. According to the reference, the LCSA has been implemented by a

combined implementation of LCA, LCC and S-LCA. All procedures have been implemented to the same system and the results are related to the same functional unit. The main difficulties are regarding to the S-LCA, where a definitive and commonly accepted set of indicators has still missed. A set of indicators has been identified by combined top-down and bottom-up approach and then the obtained results of social impacts of "Perlato di Sicilia" have been presented in this work.
The obtained results have shown that the A company presents a better environmental and social performances but, in the same time, it has the highest costs and the lowest average salary for employees and for the working hours.
These results are meaningful to address each company to improve their performances and to introduce a competitive market towards a sustainable production.

7 References

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