INTERSECTORIAL REUSE OF WASTE AND SCRAPS FOR THE PRODUCTION OF BUILDING PRODUCTS: STRATEGIES AND VALORIZATION OF WASTE

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Received: December, 2014; Revised final: June, 2015; Accepted: June, 2015

1. Introduction

Heavy metals can pose health hazards to man and during the last decades, one of the effects of a power-intensive industrial development, with the progress of the consumer culture, is the increasingly indiscriminate use of natural resources (OECD, 2012). In the last years, the inclination to consider the environment as an inexhaustible resource from which to draw benefits without any regulation and control, has generated several problems (availability of resources, social equity, etc). Every year, the Global Footprint Network, an international think tank that provides Ecological Footprint accounting tools to drive informed policy decisions, communicates the official date of the "Earth Overshoot Day" (the date on which natural resources consumption exceeds the Earth Planet capacity production for that year). In

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2014 (Global Footprint Network, 2014), this date has been in August: in just eight months, humankind has used the same quantity of resources which the planet Earth regenerates in a year. It represents a dramatic situation that we should not underestimate and we should monitor.

The interest of European Commission in this topic emerges from many initiatives which have been put in place recently. The most representative are:

- the "Thematic Strategy on the Sustainable Use of Natural Resources", to reduce the environmental impacts associated to resources use, and the "Thematic Strategy on the prevention and recycling of waste" (European Commission, 2005);
- the "Waste Framework Directive", that includes two new recycling and recovery targets to be achieved by 2020: 50% preparing for re-use and recycling of certain waste materials from households and other origins similar to households, and 70% preparing for re-use, recycling and other recovery of construction and demolition waste (European Commission, 2008a);
- the "Sustainable Consumption and Production Action Plan", SPC (European Commission, 2008b), that is contributing to improve the environmental performance of products and increase the demand for more sustainable goods and production technologies;
- the "Eco-innovation Action Plan", EcoAP (European Commission, 2011c), that started from the success of the experimentations conducted within the ETAP plan and, on the basis of the obtained results became its natural succession for development and promotion of eco-innovation in EU member countries;
- the ten-year strategy plan for growth and jobs, called "Europe 2020" (European Commission 2010), that has been launched to overcome economic crisis through the improvement of current growth models and to create favourable conditions toward a circular economy, supporting initiative as "The resource-efficient Europe flagship" and "The Roadmap to a resource efficient Europe";
- the long period strategy, called "Roadmap 2050" (European Commission, 2011b), that aims to reducing greenhouse gas emissions by at least 80% below 1990 levels by 2050 and to promote and developing a low carbon economy.

Nowadays the European scenarios confirm that there is a favourable climate to change the typical industrial production, oriented to unlimited waste production (Fig. 1), into a more sustainable system. Indeed, results from the 365th Eurobarometer (European Commission, 2013; Luca and Ioan, 2014; Martinez et al., 2014) estimate that the 95% of the European population believe that buying "green products" is the right thing to do for satisfying new environmental requirements (there are many people who are careful to the products information and in particular to their composition/production).

The environmental awareness has set the conditions for the research of alternative ways to produce new materials and to design new products, not only from virgin raw materials. So, a research group of the ABC Dept. (Architecture, Construction Engineering and Built Environment) of Politecnico di Milano, has been working for several years about the topic of pre-consumer waste/scraps intersectorial reuse for the production of new products.

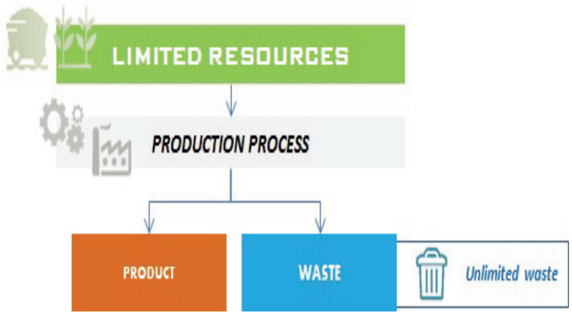

Fig. 1. Linear cycle – typical production model of industrial supply chain

The research focuses on the building sector supply chains investigating waste that are output of various production sectors and that potentially could be introduced in the building sector creating new products and improving the environmental quality of existing products and the process. Currently the sectors examined are the production of: wood, ceramics, stone, aluminum, concrete, paper, glass, mais, textiles and steel. Obviously, many are the sectors which could be integrated in this study, but this first phase is oriented to provide a methodology that, if pursued, could be able to involve interest at a larger scale.

The topic of the reduction of raw materials consumption is also being considered by an increasing number of companies, which are working on the optimization of the supply chains, through the contributions of new topics, such as the blue economy (Pauli, 2010) and the systemic design (Bistagnino, 2011). Stakeholders' involvement addresses the achievement of several important results in a short period. Moreover, European Commission initiatives simplifies those actions oriented to the eco-innovation (European Commission, 2011b), with active contributions and resource sharing.

The main contribute of this research work is the setting up of a material flows management system. The goals of the research are: the improvement of the environmental profile of products through an integration of recycled content (Bilgin et al., 2012; Pacheco-Torgal and Jalali, 2010; Rajput et al., 2012; Ulsen at al., 2013) and the set-up of an information system that supports the identification of opportunities of reuse/valorization of the waste coming from various productive sectors destined for disposal in landfill (Borsellino et al., 2009; El-Mahllawy, 2008; Silvestre et al., 2013). The research starts from the study of the most significant supply chains inside various sectors, analyzing the input/output and defining typologies and characteristics of waste/scrapes (Jin Choi et al., 2013; Kizinievic et al., 2013; Madurwar et al., 2013).

The data obtained from analysis phase have been collected in a matrix useful to identify feasible strategies and scenarios for the valorization of waste by using them in the construction sector as secondary raw materials.

2. Material and methods

One of the best strategies to promote product and process innovation is to create synergies and connections among companies (also operating in different sectors); moreover sharing information (Verganti, 2009) and knowledge is a basic step to ensure a project success. The contribution of the research "*The usefulness of useless. Cross-sectorial evaluation of waste in construction*" is to support the sharing of information between industrial sectors for a better use of waste as secondary raw material. The goal is to outline how it is simple to create industrial scenarios (not only at local level) aiming at mutual and global environmental performance improvement (Buenrostro et al., 2014; Hidalgo et al., 2014; Popescu et al., 2012). If we consider the geographical area interested by growth or extraction (for example: natural stone, wood, clay, and so on), it is clear that in a specific region there could be a significant concentration of environmental impacts (waste, dump, pollution). If we consider waste, if local decision makers collaborate among each other, they can decide to improve their processes, for example establishing a presence on the territory of a supply chain which uses, as raw material, waste and scraps of an other sectors. In this way individual and collective benefits could beincreased exponentially through a system based on intersectorial exchange of waste that within new processes can became secondary raw material (positive externalities overcome the negative ones, creating a balance).

The ideal supply chain scheme (Fig. 2) represents the cycle that materials should follow in order to enhance the proposed system. Starting from a typical situation of extraction or growing, the raw material follows its life cycle, passing through each stages and creating: a product, a pre-consumer scrap (object of interest in this work) and a post-consumer scrap (not the subject of this study, but it could be implemented in the matrix).

In order to enhance the environmental profile of the product the hypothesis is that the last two ones (pre and post consumer scraps) have to be reused or in the same supply chain or to other sectors. It is clear that decision about this reuse should be evaluated with appropriate tools; at this aim, Life Cycle Assessment could be assumed, as it is an internationally recognized and reliable method for assessing the environmental performance. LCA analysis allows to compare different scenarios/strategies, using for the inventory the quantitative data collected in the matrix; the results can support the decision-making process of different stakeholders (manufacturers, local public institution, etc.). LCA (Bribiàn Zabalza et al., 2011; Lavagna, 2008) provides a real assessment of the impacts at local (e.g. land use) and global scale (e.g. GWP). In this way, the result can support the choice of the strategies that can improve local realities giving results on a global scale (ERVET, 2005, 2009).

2.1. The reuse of waste/scraps to reduce environmental impacts

One of the key topics to reduce environmental impacts is represented by the recycling of waste/scraps derived from industrial productions and raw materials supply chain (pre-consumer waste). This type of waste/scraps is more easily to be mapped, tends to be produced with an annual fairly constant quantity and be uniform in its composition, unlike the post-consumer waste. Starting from considering waste and scraps as a resource it is possible to outline some alternative ways to encourage products sustainability and then to promote eco-innovative initiatives, in line with new environmental requirements (European Commission, 2005, 2011a).

The first phase of the research work concerns the study of different supply chains (not only related to the building sector), and the definition of waste and scraps typologies by analysing their material flows (input/output). One of the most important steps is the production processes mapping. Indeed, through the division of supply chain in "manufacturing steps", it is possible to outline the less efficient stages of the process (for example which are the steps that generate more scraps or waste) and to identify the specific type of waste/scraps which have been generated (for the individuation of the best reuse).

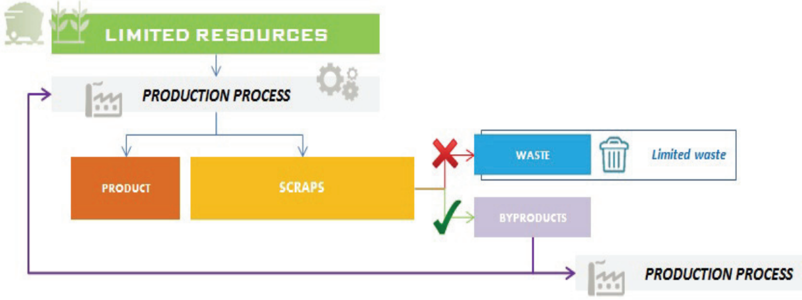

Fig. 2. The ideal supply chain

For example, considering the stone sector, the major quantity of scraps derives from the extraction and blocks squaring phases, and it is realistically quantifiable between 30 and 70% of the extracted material (the percentage depends on the extraction tipology, the lithotype and quarry characteristics). The consciousness of this situation allows to identify strategies and reuse scenarios, especially preferring upcycling processes (in this case it is possible to reuse the scraps as raw material for the artificial stone production, a new material with better performance than the natural stone).

The main contribution of the research is a matrix, which is going to be gradually implemented with new information, intended as a support to make preliminary assessments and to motivate strategic policies (at local and global level). The matrix contains information related to various production sectors and can be implemented with new chains and the related information. Actually the matrix is based on specific data reporting quantities and characteristics of scraps/waste coming out from specific manufacturing steps.

The matrix is structured in five different information levels (Fig. 3). At the first level of the matrix (Fig. 4) are listed the supply chain and the corresponding manufacturing steps. They are classified with a code which derives from a typical italian filing system (Ateco 2007 created by ISTAT, the national statistic centre accordingly to the European classification "NACE Rev. 2 – Statistical classification of economic activities").

For each manufacturing step waste and scraps typologies are classified with a code, which derives from CER catalogue (a European method to classify the typology of waste), and with an additional code for a better definition. The definition of materials potentially available (considering waste as resource) enables decision-makers to understand how and where they could develop new manufacturing process.

In the second level (Fig. 5), it is possible to split the production into different main steps (before use); each step generates some scraps, which can be reused as a secondary raw material in other industry sectors. For example, in the case of the stone production, the scraps deriving from the cutting (identified in the matrix with the code 01.04.13 CUT) can be reused for the realization of products assembled on supports, such as mosaics or precast facedes. In this case the reuse of the scrap, in addition to the environmental benefits involves a process of upcycling.

The third level of the matrix provides information on the locationing of the scraps. For example, if in an industrial district(Fig. 6), the amount of waste/scraps is considerable (both for quantities and availability), it is possible to:

- activate new supply chains (deriving from the studies about possible reuse);
- improve current industrial strategies (with the aim of reducing the amount of waste/scraps);
- evaluate those materials which can be transferred in another supply chains.

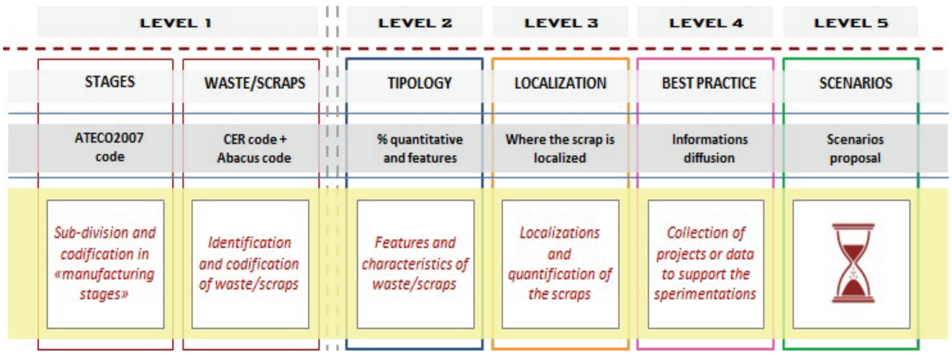

Fig. 3. The conceptual scheme of the matrix and the subdision into level of detail

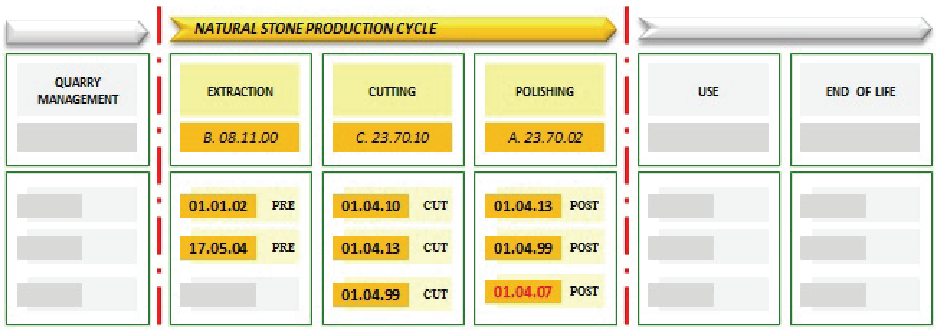

Fig. 4. Natural stone production cycle (level 1) - subdivision of a typical supply chain in "manufacturing stages"

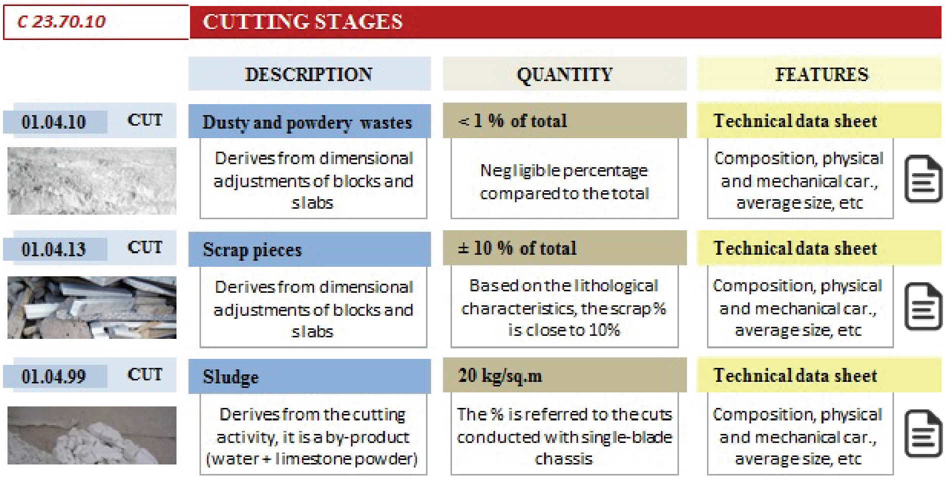

Fig. 5. Natural stone production (level 2) - definition of type of scraps and characteristics

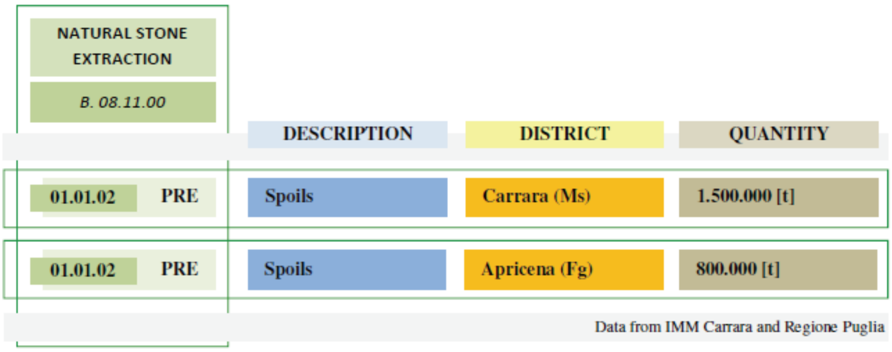

Fig. 6. Natural stone production (level 3) - geographical location and definition of quantity

The third level of the matrix is very important for the activation of strategic scenarios because it allows to quantificate the amount of waste that might became second raw materials, in a specific area. An hypotethical artificial stone producer, for example, may need natural stone scrap for his production and so he may decide to establish synergies with some companies operating in the stone sector. With this matrix, he could identify both the area of higher concentration of stone industries and the byproduct more responding to his needs and especially the quantity of available material. In this way it is possible to create a strong collaborations among companies achievable the entire production chain, in order to set conditions for the institution of an "Eco Industrial Park" (Biali et al., 2014; Chertow et al., 2000; Lowe, 2011; Lowe et al., 1997, 1996).

The fouth level of the matrix, pursuing the aims of activations of new productions, collect contributions and original experiments conducted starting from a specific waste/scraps in other productive contexts. An Eco-industrial Park (Pauli, 1997) could promote the reuse of all by-products obtained from production activities. The goal is the reduction of the waste production and especially the environmental improvement of production processes and products profile. The achievement of this goal is possible only through a radical innovation process starting from the proposal of new industrial scenarios, the development of new products design and the acquisition of new markets. Another key strength of this research work is the focus on recycling methods which move toward the so called "upcycling" process (waste or scraps should not be considered as second-rate materials but as a resource similar to virgin raw materials). Indeed, by identifying similar characteristics between scraps and raw materials, it is easier for the decision maker to assess the replacement of virgin raw materials with secondary raw materials. Thinking so, the positive externalities generated may allow to overcome negative externalities and the environmental improvement obtained could be available for everybody (the raw material is more, the landfills are not feeded, the product environmental profile is improved, the final product can be considered as a sustainable material, etc).

3. Results and discussion

The results of this research work are:

- definition of the matrix and structuring into five divided levels, four of which are already implemented at the experimental level
- application of the matrix to ten manifacturing sectors;
- implementation of information relating to the ten sectors on the quantity and on the characteristics

of the scraps

- test of the application of matrix on the stone supply chain, with geographical mapping of waste
- elaboration of data and construction of hypothetical scenarios of reuse
- proposal of use of LCA method for the evaluation of the data collected in the matrix
- testing of the LCA on the stone supply chain and definition of reusing scenarios

Below are some examples of the possibility to reuse scraps with profitable results, encouraging processes of upciclyng, and environmental improvements: the reuse of scraps deriving from ceramics sector in the same production process or as raw material for the production of other ceramic products (bricks, panels, etc), or self compacting concrete; the reuse of scraps deriving from wood sector for the production of remineralized wood useful for the production of insulation panel or floor surface, this use is better than the use as fuel for heating system (case of downciclyng).

4. Conclusions

The study has showed that the waste production is a common practice in almost all industry sectors; in some cases the amount produced is very important (this trend can be identified mainly in the sectors involved by the extraction or coltivation of raw material) and the scraps percentage can be rise even up to 70% of the amount extracted/coltivated (tipically in the stone or wood sector). Currently, in many companies, the waste/scraps are landfilled and this praxis is not profitable for the companies. If they decide to reuse the scraps in the same or other supply chain (with a strategy that could be oriented and supported by the contribute of this research work), they could have a significant economic gain (optimization of the raw material, reduction in cost of waste disposal, improvement of the environmental profile of the product, etc).

The research aims at creating a platform from which to get information suitable to support the development of forms of industrial ecology. Pursuing this goal, the creation of new production cycles (in symbiosis with the existing ones) becomes easier, and this result is the starting point for an efficient contribution to the environmental impacts reduction.

The next step of the research is the implementation of the matrix with new information and data, together with the elaborations of the design guideline for products made by using waste or scraps. The definition of new products, made by waste/scraps, (more simply the identification of sectors where is possible the waste/scraps reuse) could steer the producers towards new more sustainable company policies, from a small scale to all production scales. Another important aspect, in this research work, is the possibility to quantify and contextualize the information about the amount of waste/scraps available on the territory. This allows to set up a continuative scenarios of reuse and valorization of waste/scraps (in the logic of the opening of new production chains, based on the material recovered, have to consider the constant presence of the recovery materials, otherwise it becomes difficult to establish efficient synergies). To achieve this result, the research group is developing a GIS mapping system, which takes official data and becomes a local management instrument, supporting decision-makers who have the task of establishing strategic plans for environmental development.

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