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GYPSUM AS SECOND RAW MATERIAL TO BE USED ENDLESS TIMES IN GREEN BUILDING*

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Abstract

The building sector, which has always been the cause of high energy consumption and significant CO_2 emissions both in the production phase and in the use and demolition of buildings, needs to make important changes. The latest technological innovations, the use and reuse of different types of sustainable materials and the possibility to power factories with renewable energy, led to a new concept of building called Green Building. The aim of the paper is to present a strategy for the application of circular economy to the building sector through the implementation of a new productive line on the company "Gipsos Srl", in order to create plasterboard which, through specific recycling processes and grinding, selection, cooking and refining operations, ceases to be a special waste and it will be fully recovered and reintroduced endlessly in the production process.

Keywords: circular economy, green building, gypsum, recycling, second raw material

1. Introduction

The main purpose of circular economy, which is defined as "an economy designed to regenerate itself" (MacArthur, 2013), is the creation of a new model of production and consumption in which today's goods become tomorrow's resources in order to create a virtuous circle and replace the concept of "end of life" with the one of "reconstruction". (Stahel, 2016) The circular economy is linked to the concept of eco-effectiveness, which

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refers to the transformation of products and the flows of raw materials associated with them in order to create a deep relationship between ecosystems and future economic growth. The final goal is not about minimizing the flow of materials “from cradle to grave”, but to redesign the cyclic industrial metabolism, according to the “from cradle to cradle” theory. In this way an asset does not loses its status as a resource and it may even gain quality through an upcycling process and it will be possible to create a synergy between industrial systems and natural ecosystems (https://www.europarl.europa.eu/). There are two types of material flows: the biological ones, capable of being reintegrated into the biosphere, and the technical ones, intended to be revalued without entering the biosphere. A perfect functioning of the circular economy will allow us to reach the 100% of efficiency in the use of resources. For reaching this goal, a special attention must be paid to various elements such as wastes, which either do not exist or are close to zero, and products that should be designed and optimized for disassembly and reuse. Eliminating waste from the industrial chain by reusing materials allows significant savings in production costs and less dependence on resources with consequent operational and strategic benefits. Nowadays the linear model used up to the second half of the twentieth century, based on the typical “take-make-use-dispose” scheme, also known as Brown Economy, is less and less usable, since it requires enormous quantities to work of matter and energy which are cheap and easily available. This inevitably clashes with current environmental problems such as environmental warming and thinning of the ozone layer and places limits on development (Lippit, 2012). Already in 1966, some economists began to reflect on the idea of a circularity of the economy but the first time that, on a political level, the linear economy was questioned was in 1987 when the WCED (World Commission on Environment and Development) gave a definition of sustainable development within the Brundtland report (WCED, 1987). The circular economy is also the result of numerous industrial ecology studies, concerning those particular organizations of the industrial system that aim to create closed-cycle processes in which the waste of one production process becomes a resource for another, eliminating the problem of unwanted by-products. However, only in 2000, the “cradle-to-cradle” (C2C) theory was finally introduced. This theory consists in preserving and enhancing the ecosystems and biological cycles of nature and in maintaining production cycles at the same time in order to activate an economy that would be able to grow without causing the increase of environmental pressure.

In 2019 the European Commission signed the Green Deal, a plan in which a new Industrial Strategy was defined for the implementation of the circular economy in all sectors with the aim of making Europe the first climate-neutral continent by 2050 (https://ec.europa.eu). The strategy was first applied to sectors with high intensity or high environmental impact, such as textiles and construction (Arfò et al., 2019). The ecological transition will be supported by the Plan of investments, in particular through the instruments of the Transition Fund and the Plan for sustainable investments. The circular economy process ends up with the marketing of secondary raw materials deriving from treated waste that can be reintroduced into production processes, only if it is possible to enhance the resources through recycling. Secondary raw materials are excluded from the waste regime both if they come from expressly identified recovery activities, and if they do not require any treatment based on what the Ronchi Circular provides (Ministero dell’Ambiente, 1999). After the exit into force of the Ronchi Circular, many secondary raw materials into the by-product regime, which is related to all those materials that originate from a production process that did not have their production as a purpose, but which in any case, can be used by the manufacturer or third parties without requiring any treatment (https://www.tuttoambiente.it/). Secondary raw materials can be generated within a national economy, but they can also be traded, imported or exported, as it is the case with virgin raw materials. From a legal point of view the only limitation in the use of SRMs concerns the fact that these materials in many countries cannot be used even after a successful process to remove pathogenic microbes and stabilize organic matter. This barrier prevents the wholesale application of these materials, especially compost, on agricultural land, despite the evidence of the increase in soil and crop quality after application, because they are potentially harmful to health and health environment (Schreck et al., 2017). However, the secondary raw materials market is constantly evolving. To create circular systems, it is necessary to resort to industrial symbiosis, which refers to the complex of exchanges of resources between two or more different industries (Astarita, 2017; Frosch, 1994). Therefore, the practical application of these concepts requires an integrated approach, cooperation between companies and the identification of possible synergies within an economic and territorial system (Munda and Matarazzo, 2020). There are three models for creating circular systems: the first refers to the development of industrial symbiosis districts and follows a bottom-up line, as it does not derive from a previous project but it is developed through company agreements; the second model is linked to eco-industrial parks, industrial networks that require State intervention due to their complexity. This model is a top-down path that first of all requires careful regional and territorial planning to favor the symbiotic integration of small and medium-sized enterprises; they will benefit from growing economies of scale and cost reductions; the third model relates to the creation of networks that connect operators and experts for the creation of symbiotic systems (Ehrenfeld, 2004).

The circular economy and industrial symbiosis can therefore play a key role in the Community's economic recovery, while ensuring environmental protection in accordance with attempts to mitigate the consequences of climate change. Industrial symbiosis represents a strategy for closing the cycles of resources and the timing of their use within a specific territorial economic area, through collaboration between different companies based on the synergistic possibilities offered by their geographical proximity (Chertow, 2000). Just as ecosystems do with the reduction of waste at the source and the creation of closing loops of the cycle, industrial symbiosis tries to design an industrial system characterized by relationships of functional interdependence in which the waste products of a line of work become a valuable input for other companies' production lines (Matarazzo and Baglio, 2018). In this way, industrial symbiosis allows a group of companies to jointly maximize profit through the internalization of their externalities, in order to create important benefits for the company system and the community, both in economic and environmental terms. Thanks to this new model of industrial policy, companies can become more competitive, improve their performance by allowing local communities to coexist with industrial systems, without giving up a healthy environment (Desrochers, 2010). A significant example of an industrial ecosystem based on industrial symbiosis is that in the Danish city of Kalundborg, the first concrete configuration of industrial ecosystems theorized by Frosch and Gallopoulos (Chertow, 2012).

There is a delicate balance between the economic and environmental spheres that can sometimes be compromised, which is why the circular economy today represents a key model of production and consumption based on the concept of “from cradle to cradle”. From this point of view, the green building sector is acting with a lot of interest in the design and construction of sustainable buildings. Due to the current high energy consumption and harmful emissions, the entire sector is moving to introduce or enhance materials that ensure a perfect integration with the environment and an excellent recyclability at the same time. The Green building is a growing sector even in Sicily where more than 5% of private homes were made with eco-sustainable materials and techniques over the past few years.

The development of green building in Sicily is supported by various associations, such as the Green Building Council Italia (GBC Italia), a non-profit association to which the most competitive and qualified companies operating in the green building field belong and which is active in Sicily through the appropriate division, called Chapter Sicily. The mission of Sicily is to support the relationships between members and GBC Italia, promote the culture and practice of sustainable construction and promote training initiatives aimed at members and those in the community interested in green building (http://www.gbcitalia.org/) The subject of this case study is Gipsos Raddusa ltd a company that has been a leader on the national scene for 50 years for the extraction, cultivation and industrial processing of gypsum, a decidedly eco-sustainable material suitable for the construction industry. The case study is about the implementation of a recycling system for plasterboard that allows to give a new life to the gypsum contained in it while maintaining its chemical-physical qualities intact. In this way it can be reused infinite times both in gypsum plasters than in the production of the plasterboard itself. Needless to say the aim of the study is to present a different use of gypsum, especially in its transformation and continuous reuse technique, applied to a Sicilian company, leader in the field of gypsum production: Gipsos ltd.

The generic term of gypsum (from the Greek γύψος and from the Latin gypsum) indifferently indicates two substances known and used for millennia: a mineral and an industrial product that derives from it. Natural gypsum is very plentiful in nature, where it constitutes the gypsum stone; Italy is rich in deposits, including those along Lake Iseo, the Adriatic side, the Emilian Apennines and in Sicily (Turco, 1990). For over five thousand years, gypsum stone has provided a very useful material in the field of construction, where it was used even before air lime, as demonstrated by the examination of works dating back to peoples of ancient civilizations, such as the Egyptians and, in particular, the plaster on the walls of their tombs, the cases for the mummified bodies and the various objects.

After the Roman Era, the knowledge of the gypsum stone transformation and use was lost and only in 1200 there were the signs of the first attempts to use gypsum as a material for stucco and construction found in Italy (Lugli, 2019). Currently, there is a significant recovery in the consumption of gypsum, the use of which has extended to new fields of application including that of plastics, prefabricated elements for buildings and thermal and acoustic insulation. The use of gypsum in Sicily is linked to the presence of the gypsum-sulphurous formation corresponding to the salinity crisis in the Messina area, but in Sicily the bases of interest also includes the provinces of Agrigento, partly Trapani, Caltanissetta, Enna and various inland areas (Campisi, 2018). The Gipsos company is located in Raddusa, an Italian town belonging to the province of Catania, but located in the border area between Enna, the plain of Catania and the Erei Mountains. The quarry under cultivation, owned by the company, allows a selection of primary materials "in the open", which guarantees the purity of the gypsum before it is transported to the nearby plant for grinding, selection, cooking and refining: through this extraction technique, in fact, the material is chosen for purity, compactness and absence of inclusions. Inside the quarry, the mineral gypsum is found in nature in the form of large and more or less deep layers of calcium sulphate crystals. The production process of Gipsos Ltd begins with the extraction and continues with different phases, whose the most important is the cooking one. Using a belt, the stone is loaded into the continuous cycle Greblex rotary kiln, which represents the heart of the plant.

This oven allows the most precise monitoring and control of the temperature, time and humidity variables during the delicate firing phase of the raw gypsum, on which the grip, strength and shrinkage characteristics of each finished product depend, with the appropriate additives. The Greblex oven is served by three new generation burners fueled with natural gas. Each cooking cycle lasts about 1 hour and 30 minutes, and in any case the oven unloading never happens before the pyrometric barrel signals a temperature of 165°C (www.gipsos.com). The Greblex kiln has been fueled by methane, which in itself allows a considerable reduction in emissions; in addition, the company takes care to constantly check all the emissions of the furnace through test reports carried out annually by other company, which carries out samples on the operation of the plant. The gypsum extracted follows two different sales lines, one directly linked only to the extraction and grinding phases, so as "raw" material, and the second relating to the so-called premixed products, packaged with cooked gypsum, called scagliola, and various additions. The main product of the first line is Agrigip, that is the finely ground pure gypsum; the second line, on the other hand, presents a complete range of gypsum-based premixes for building.

2. Materials and methods

The construction sector is going through an important moment of transformation. In a market that is increasingly oriented towards sustainability, where companies and consumers are showing increasing attention to environmental issues, the construction sector is also evolving in this direction (Ingrao et al., 2019). Among the results obtained from the various analysis of traditional buildings, the element that most stands out from the others is energy consumption. The possible cause of a large consumption of electricity in traditional buildings has been identified: usually, about 10-15% of the total building heat lost occurs through the windows, due to the loss of radiant heat through them. While about 25% occurs through the roof and 35% through the external walls; therefore, in a scenario where the material has low insulating properties, an alarming amount of energy expenditure will be devoted to heating and cooling in their respective seasons. Consequently, in the overall panorama the civil and residential sector is heavily involved in energy consumption, with an average contribution of about 40% in Europe relative to traditional energy sources (Kahhat et al., 2009). What in traditional construction seems to create the maximum impact on the environment are the external wall systems in insulated concrete. In general, all concrete-based exterior wall systems, such as insulation or concrete blocks, require a significant amount of energy. Another element that represents the cause of a strong environmental impact of traditional buildings is the emissions of polluting gases: the 193 million buildings in the European Union cause, globally, about 50% of SO_2 (sulfur dioxide) emissions, 22% of NOx emissions (nitrogen oxides), about 10% of particulate emissions and, more generally, one third of total greenhouse gas emissions (GHGs). Of all these emissions, two thirds are caused by residential buildings, while the remainder by commercial buildings (Balaras et al., 2005). Carbon dioxide (CO_2) is one of the most dangerous greenhouse gases, and the traditional construction sector is responsible for around 23-40% of its emissions. The intensity with which carbon dioxide is emitted in the production of cement is about one ton of CO_2 per ton of cement produced (www.archive.ipcc.ch.it). A building built according to the principles of green building produces about 20-25% less greenhouse gas emissions than a building with a concrete or steel structure (MacMath et al., 2000). In addition to energy consumption and harmful emissions, the environmental impacts of traditional buildings can be of different nature. Among these, the generation of waste associated with the use of building materials typical of traditional construction can be one of the main causes in creating negative impacts on the environment. According to some estimates, the construction of a 186 m^2 building generates around 3,692 kg of waste (Pecorino et al., 2018). The negative side of this is that landfills cause environmental deterioration due to CO_2, methane and leachate, all produced during the anaerobic decay process (Chang, 2020).

3. Results and discussion

The company Gipsos Raddusa Ltd, in the next decade, want to improve its ecological footprint introducing a new project, which has as its primary purpose that of investing in a total recovery system of plasterboard and after creating a real line for the production of plasterboard: the gypsum recovered through the system could thus be exploited both in the current production lines and for the production of gypsum, generating a considerable saving of virgin material.

Construction and demolition waste currently account for around 30% of all waste generated in Italy and Europe. Most of these materials go to landfill, although many of them could be reused, which is why the European Commission has also started to take an interest in the subject and has moved to create the “Gypsum to Gypsum” (GtoG) project, which demonstrates how this precious mineral can be recovered and reused. The main objective of this project is to change the way gypsum-based waste is treated, transforming the European market to achieve higher recycling rates. The innovative concept of the “GtoG” includes integration into the supply chain, a fundamental element for the success of the project. The purpose of the Gipsos company is to join this project, first among the Sicilian companies that deal with the processing of gypsum, and start its production with a view to continuous and indeterminate recycling and the transformation of waste into a resource according to criteria set out in Article 6 of the Waste Directive. Moreover, landfilling of gypsum-based waste involves significant problems for human health and the environment, as it involves potential emissions of greenhouse gases such as methane (CH_4) and carbon dioxide (CO_2), due to degradation anaerobic of the cellulosic component of the plasterboard, and above all hydrogen sulphide (H_2S), which arises from the fact that the sulphates contained in the plasterboard, if disposed of together with biodegradable organic waste, react with other substances and form this dangerous and flammable gas, which causes negative even in small concentrations. Finally, what drives Gipsos to introduce itself in this field is the ease with which it is possible to reintroduce recycled gypsum into the production cycle, in cutting with natural gypsum, in the production of gypsum-based plasters and, in the near future, of plasterboard, creating a “Closed-loop recycling”. According to an internal survey carried out by Cagema, the Association of the Italian Lime, Plaster and Mortar Industry, an estimate was made by region of the potential market for the quantities of waste (scraps) of plasterboard: according to these estimates, in Sicily the the potential market value, including construction and demolition waste, amounts to 5,689,000 sq m; the table was estimated for 2020, but before the health emergency, which is why it is a decidedly overestimated value for 2020, but, for simplicity, imagining a constant growth of 3% per year until 2030, the estimated values are still consider growing. From the values shown in the table, it is possible to note that the value of gypsum waste in Sicily tends to increase over the years up to approximately 10,000 tons in 2030. It is therefore essential for Gipsos Ltd to choose the most appropriate plant. for current and future plaster waste. Gipsos, in collaboration with Assogesso, has developed a first Business Plan relating to this new project, with reference to one year (Table 1).

Table 1. Quantitative for geographical areas of gypsos waste and demand in cementeries to 2030

Geographical areas	*2020*		*2025*		*2030*	
	Gypsum waste t	*Demand of gypsum in cementery*	*Gypsum waste t*	*Demand of gypsum in cementery*	*Gypsum waste t*	*Demand of gypsum in cementery*
North West	46,088	231,196	53,426	273,224	61,935	301,661
North East	34,818	138,413	40,360	163,574	46,789	180,599
Centre	26,887	163,561	31,167	193,294	36,130	213,412
South	24,663	161,293	28,586	190,614	33,140	210,453
Sicily	7,822	58,330	9,066	68,933	10,510	76,108
Sardinia	3047	25,926	3532	30,639	4095	33,828

The recycling model requires that the maximum percentage of gypsum material destined for recycling is post-consumer, i.e. material coming from renovation, dismantling of buildings or various scraps of plasterboard. To properly collect this material, the most efficient way is to create transfer stations that surround the recycling plant. The material is brought to the transfer stations through special waste transporters, which in some cases can make use of waste bins dedicated to plasterboard and which, once full, are transported directly to the plant. Once the material is introduced into the system, we know that it is composed of 94% gypsum, 6% paper and less than 1% metals.

While the paper and metals are inserted in alternative recycling flows, the gypsum is subjected to a specific production process that involves different processing stages. First, the incoming loads of drywall, wet and dry, are dumped onto a tipping floor, where they are cleaned by hand of metals, plastics and other debris. The gypsum waste, now pure, is loaded into a large feeding hopper, where, through the sorting belt, a quality control agent can order the material and check it to verify the suitability of the raw material. The conveyor belt then moves the material under an electromagnet which removes the small fragments of ferrous metal. The material is subsequently conveyed to an area where the separation between the paper coating and the plaster core takes place. Of these products, the paper is further processed to be recycled and used in a wide variety of applications; gypsum, on the other hand, can be obtained in particles of different sizes depending on the needs and characteristics of the machinery, normally the dimensions do not exceed 1 millimeter, and is then reused in dry walls, where it is mixed with virgin or synthetic gypsum to create new trim panels. Furthermore, recycled gypsum, when combined with raw gypsum, produces a more desirable consistency for the manufacture of new gypsum products.

4. Concluding remarks

According to the ISPRA Urban Waste Report, the percentage of separate waste collection increased in 2018, a fundamental aspect of a good system of Circular Economy. While considering the health emergency only a “provisional” variable compared to the results, up to now positive, obtained through the implementation of the circular economy system, in reality, scholars are not yet satisfied with the results achieved.

They believe that we must deal with increasingly scarce natural resources (Overshoot Day always falls earlier every year) and ever greater CO_2 emissions (415 ppm were achieved in April 2019, a value never recorded before). Precisely for this reason, there is still a long way to go if we want to find a way to apply this new model by changing the habits and mentality of citizens. In the field of construction, for example, in Italy it has been observed that in recent years the summer electricity consumption of buildings has begun to exceed the winter one. This is caused by a higher level of comfort required by users and by the more frequent seasonal fluctuations in temperatures, due to climate change.

Therefore, the innovations required are still many, and they continue to grow over the years and with the advancement of new needs. The project to implement a total plasterboard recovery system represents a great opportunity. Moreover, this technological innovation represents an important circular economy intervention for green building, which can benefit the whole sector with less use of resources and less production of waste.

Following the implementation of this project, the company's future goal is to introduce a water recovery system, released into the atmosphere in the form of water vapor during the firing of gypsum, so that this can fully replace all the water resources necessary for the eventual implementation of a plasterboard production line. The intent of Gipsos is to enhance the Sicilian plaster market, as a material that can perfectly replace traditional ones.

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