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DECARBONIZATION OF THE CEMENT INDUSTRY – PRODUCTION OF SOLID FUEL FROM NON-HAZARDOUS WASTE*

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Abstract

Marine litter is a major environmental problem, with widespread responsibility and effects on The Circular Economy indicates an economy able to minimize waste and pollutants production and, in the meanwhile, to shut down energy and raw material availment through a cyclical flow of matter similar to that which occurs in nature. This work concerns the management of special non-hazardous waste and the innovative techniques adopted for energy recovery from these: the goal of the study is to investigate the possibility of producing a solid fuel (RDF - Refuse Derived Fuel) from special waste management residues. We analyzed the case study CON.TE.A., a consortium located in Misterbianco (Catania) - Italy, that works on the selection of packaging collected in differentiated form, transformation of the pruning of the green residues into compost and of the inert waste into construction material. In particular, the RDF is produced, within the consortium, through the mechanical-biological treatment which is a process divided into mechanical pre-treatments, biological treatments and mechanical post-treatments.

Keywords: circular economy, RDF, waste management, sustainable process, mechanic-biologic treatment

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1. Introduction

The traditional economic development model put in place by industrial and post-industrial civilizations is generally characterized by an economic-environment opposition relationship (Lacy et al., 2016). The linear economy is an expression that describes the current model of economic growth, an expression in which the term "linear" refers to the flow "from the cradle to the grave" followed by most of the natural resources (Curcuruto et al., 2018). This linear flow is the consequence of the historically affordable and abundant supply of resources, which has led companies and leading nations to focus on providing customers with an ever-increasing volume of goods. The model of linear exploitation of resources according to "business as usual" logic would mean dealing with an ever-greater volatility in the prices of raw materials and natural resources (Curcuruto et al., 2018). The overcoming of fundamental planetary limits: the earth has already exceeded 3 of the 9 fundamental planetary limits identified by a group of 28 internationally renowned scientists: the extinction rate (loss of biodiversity), the concentration of carbon dioxide and the fixation of atmospheric nitrogen (Toni, 2015).

The Green Economy hinges on the safe and clean production of goods, the maintenance of natural ecosystems, the minimization of climate-altering emissions and the anthropogenic effect on the climate, without neglecting the efficient use of non-renewable resources and the maximization of the use of renewable ones. Within this model, the "more focused" model of the Circular Economy has found space especially in recent times (Vazzano et al., 2018). Only now this approach has made room for itself in the dominant thought, as a necessary and not residual choice, abandoning the linear logic of production, consumption, elimination of goods (Cristina and Tassara, 2019).

The term "Circular Economy" means an economy capable of minimizing the production of waste and pollutants, and at the same time minimizing the use of energy and raw materials, through a cyclical flow of material similar to that which occurs in nature. It is an approach that is also defined as "from cradle to cradle", borrowing the typical terminology of life cycle assessment, since it underlies the need for post-production and post-consumer waste to become resources for a new production cycle (Bigi et al., 2016; Matarazzo et al., 2019). The circular economy, in order to be implemented, requires that all choices be made following some fundamental operational principles, essential for the functioning of the economic system from a circular point of view (Arfò et al., 2019). The main ones include the need to design without waste (design-out waste): in a circular economy, waste does not exist and is eliminated starting from design. Biological materials are non-toxic and can be easily returned to the soil through composting or anaerobic digestion (Tuccio et al., 2019). Technical materials, polymers, alloys and other man-made materials, are designed to be recovered, regenerated and updated, minimizing the energy required and maximizing the conservation of value (Munda and Matarazzo, 2020; Toni, 2015). The adoption of models in line with the principles of the Circular Economy has been included among the strategic priorities of the European Union because it represents an opportunity for growth and development in terms of competitiveness, innovation, environment and employment (EC, 2014). There are five main business models of the circular economy, which can be applied individually or in combination with each other (Iraldo and Bruschi, 2014). The circular supply chain includes companies that have the ability to supply resources totally from renewable sources, from reuse and from recycled, recyclable or biodegradable materials and which in turn are based on circular production chains for the aspects of production and consumption (Guadagnino et al., 2018). This model makes it possible to push market demand towards a lower use of non-renewable and sometimes scarce resources, as well as reducing the quantity of waste and removing system inefficiencies (EC, 2015).

This paper deals with the issue of circular waste management not only for the topicality that characterizes the sector, just think of the various scandals and emergencies that occur in Italy, but above all for the possibility it offers to transform waste from the production system, representing a danger for man and the environment, and a burden for the community, in an asset both from the point of view of environmental sustainability and from an economic point of view. The circular economy in Italy is now worth 88 billion in turnover, 22 billion in added value, or 1.5% of the national added value; moreover, we are talking about a sector that employs over 575 thousand workers. Waste management, as part of activities for the protection of the environment and the management of natural resources, achieves an estimated production of 25 billion euros, generating 7.1 billion euros of added value, equal to 0.4% of GDP. To pursue this objective, the case study is presented in an entrepreneurial reality, CON.TE.A., operating in the environmental services sector, for over a decade, at Misterbianco in the province of Catania. CON.TE.A. represents a platform for the recovery of non-hazardous waste, in order to highlight the investments and management processes adopted or whose implementation is planned for the future, with a view to the green economy.

2. Case Study: CON.TE.A.

The interface between separate collection and recycling consists of platforms in which different operations are carried out, both to separate homogeneous commodity fractions, collected jointly in the multi-material collection, and to improve the quality of the collected material, and to select within the same fraction different qualities to be sent to different types of production plants. CON.TE.A., acronym for Consorzio Tecnologie per l'Ambiente, represents a fervent company operating for over a decade in the environmental services sector, resulting from the desire of young entrepreneurs to promote and manage environmental synergies aimed at optimization of the waste recovery chain. The chapter contains the description of the historical framework and the activity carried out by this Consortium. Furthermore, it develops the analysis of the important innovations that are intended to be made, to the case study, with a view to the circular economy and the potential investments that the platform intends to make to increase its effectiveness and efficiency in the context of overall integrated waste management (Ministerial Decree 59, 2007). The Environment Technologies Consortium carries out its business in Sicily, at the Misterbianco plant, in the province of Catania. It was founded in 2004 by a group of partners and initially the spirit of the Consortium was different: in fact, the intent was to create a structure in which many people, mainly transporters, could converge. In 2005 Centro Commerciale Edile s.r.l., the original manager of the plant, obtained the authorization of the competent authority to carry out waste recovery activities in the simplified procedure provided for in Articles 214/215/216 of the Legislative Decree 152 (2006) and in compliance with the provisions contained in the Ministerial Decree 22 of February 5 (1998). By registering with the provincial register, Centro Commerciale Edile s.r.l. started the recovery of waste paper, cardboard and paper products; packaging, waste glass and other waste and glass fragments; glass cullet; waste iron, steel and cast iron; waste non-ferrous metals or their alloys; plastic waste and used plastic packaging from separate collection; ceramic and inert waste; waste deriving from tanning operations and the use of leather; textile waste and wood waste. In 2015 CON.TE.A. requested the Single Environmental Authorization introduced in 2013. The latter was issued in 2016 and must be renewed in 2031. CON.TE.A. today it is registered in the National Register of Environmental Managers in category 8 (brokerage and trade of non-hazardous/or hazardous waste without holding the same) and class E (total annual quantity treated greater than or equal to 3000 tons and lower and 6000 tons). The plant of the CON.TE.A. Consortium occupies an area of about 20,000 square meters, and is organically divided into two macro sectors, the public and private sectors, dedicated to the following waste recovery activities: selection of packaging collected in differentiated form; transformation of green pruning residues into composted soil improver and transformation of inert waste into building materials. In the first sector, the waste coming from separate collection flows. This flow can be configured either as mixed packaging (CER code 150206), i.e. multi-material collections, or as packaging of glass, paper and cardboard, plastic, metal (steel and aluminum) and wood, i.e. single material collections. The selection and eventual volumetric reduction of packaging waste, resulting from public separate collection and destined for CONAI supply chain consortia, absorbs a high percentage of the production capacity of the CON.TE.A. Consortium. The service is mainly aimed at selecting packaging in mixed materials, coming from separate collection, for the subsequent subdivision according to the component material, be it plastic, glass or metals, and for the reduction of foreign fractions. The recovery activities carried out by the consortium can be summarized as: recovery (R13) of plastic and paper and cardboard packaging waste, glass packaging waste, wood waste, metal waste and end-of-life tires and multi-material packaging waste; recovery (R5) of inert waste; recovery (R3) of compostable waste. The table 1 represents the trend in the quantities of waste managed by the Consortium in recent years.

Table 1. Trend in the quantities of waste managed in recent years (CON.TE.A.)

2017	***2018***	***2019***
Ton 50758	Ton 50385	Ton 59233

The most important innovation that took place in the dry fraction selection sector is represented by the advanced technology of automated sorting which allows to significantly increase the results of the recovery of waste from urban separate collection and to reduce the quantities of waste to be disposed of in landfills. Some of the most used and emerging technologies are summarized below: 1) Laser Induced Breakdown Spectroscopy or LIBS: it is an elementary analysis technique which is based on the measurement of the atomic emissions generated by a sample surface subjected to laser rays; (Conte et al., 2018). 2) X-ray transmission: technique based on the transmission of a high intensity X-ray beam (Bindi et al., 2016). 3) Optical selection: technique that uses sensors (cameras) based on the identification of waste fractions through visual / tactile signals such as the color, shape, texture and size of the materials; 4) Spectral imaging based sorting: this technology combines both the spectral reflection method and the spectral image processing method (Achino et al., 2019).

3. Materials and methods

Community waste legislation is organized into different levels that address and regulate the issue of waste from different points of view. A first group is represented by horizontal legislation which has the main task of establishing the general reference framework for waste management, defining the principles, purposes and main definitions. (Grosso and Vito, 2008). This framework includes the “New Waste Directive”, approved in 2008 (EC Directive 98, 2008), which repealed Directive 2006/12/EC (EC Directive 12, 2006), Directives 75/439/EEC (Directive 439, 1975), on waste oils and 91/689/EEC on hazardous waste (Directive 689, 1991). The fundamental focus of the Directives is represented by an “order of priority” of what constitutes “the best environmental option in waste legislation and policy". At the head of this order is prevention. Then, respectively, reuse and recycling follow which in turn must be preferred to the "energy valorisation of waste" (recovery) as they represent the best ecological option. Disposal is provided as a last resort. Therefore, Member States "should not promote, where possible, the disposal in landfills or the incineration of recycled materials" (EC Directive 98, 2008). These general provisions are accompanied by a series of rules on specific topics. The most significant are: Directive 1987/101/EC (EC Directive 101, 1987), makes the treatment of waste oils by regeneration a priority; EC Directive 66 (2006), relating to batteries and accumulators containing dangerous substances, aims to guarantee the functioning of the single market by establishing rules for their collection, recycling, treatment and disposal; Directive 2000/53/EC (of the European Parliament and of the Council, "relating to end-of-life vehicles" (EC Directive 53, 2000); Directive 2002/95/EC, with the aim of reducing the environmental impact generated the presence of hazardous substances in electrical and electronic equipment (EC Directive 95, 2002). From December 2, 2015, the European Commission launched a package of measures to promote the circular economy, consisting of a European Action Plan and four new directive proposals that modified the European regulations on waste management. After publication in the Official Journal of the EU on June 14, the four directives that make up the new European regulatory package on the circular economy entered into force on July 4, 2018 and must therefore be implemented by July 5, 2020. The directives are as follows: EU Directive 849 (2018), EU Directive 850 (2018), EU Directive 851 (2018) and EU Directive 852 (2018). Directive 2018/851/EU, which amends the Framework Directive 2008/98/EC, first of all included in the latter the definition of "non-hazardous waste", "urban waste", "construction and demolition waste", "waste foodstuffs", "material recovery" and "extended producer responsibility regime" to clarify the scope of these concepts. It also establishes the separate collection of textile waste (mandatory from 2025) and organic waste (by 2023). The Ronchi Decree was repealed by part IV of the Legislative Decree of April 3, 2006 n.152 "Environmental Regulations" (Legislative Decree 152, 2006). This Decree derived from the Law 308 (2004) which provided for a complete review of the entire Italian regulatory body on environmental issues and underwent numerous changes over the years (Agricola et al., 2006).

The Consolidated Environmental Act refers to the following principles: precautionary, according to which all necessary measures must be taken to avoid damage to the environment by those who carry out activities that could cause them; of prevention, aimed at the preparation of measures to limit the risk of damage to the environment and the "polluter pays" principle, under which anyone who causes damage to the environment is required to compensate it (Agricola et al., 2006). The Consolidated Environmental Law, through art. 188, specifies that the producer and all subsequent holders are obliged to initiate a series of procedures underlying the waste management process and to bear the related costs even if they no longer have physical possession, remaining responsible for the correct management of the waste throughout the production chain. This responsibility ceases in the event of the delivery of the waste to the public collection service, or in the event of the delivery of waste to persons authorized to carry out recovery or disposal activities (Laforgia et al., 2004; Stefanis, 2009). The undifferentiated collection is destined, instead, to plants where mechanical-biological treatment operates: mechanical treatment means the application of mechanical operations of shredding, screening and compaction both to obtain recyclable product components from the dry fraction of the waste, and to prepare the organic fraction to subsequent biostabilization treatments (De Stefanis, 2009) and biological treatment means a process of mineralization of the most degradable organic components and the sanitation and pasteurization of the waste mass. The outputs of the process can be: compost production, RDF production, biostabilized production to be disposed of in landfills, biogas production for the generation of thermal and/or electrical energy. Biological treatment includes aerobic digestion, bio-drying or anaerobic digestion (Laraia, 2002). The advantages linked to the correct and effective integrated management of waste have a dual nature: environmental and social. From the first point of view, it notes that the drastic reduction in the amount of waste produced radically decreases the pollution of the soil, water, air and ecosystems. Thanks to the prevention, reuse, recycling and recovery of waste from anthropogenic activities, an exponential saving of renewable and non-renewable resources would be obtained, but above all a significant improvement in the health of the planet. Reducing the volume of plastic, paper, glass, wood, metal packaging and so on would improve the well-being of water and their ecosystems, forests, terrestrial fauna and protect the integrity of the aquifers. The energy problem is closely related to environmental protection both because the most used energy sources are fossil ones, such as oil and coal, whose combustion is highly polluting and responsible for the increase in the greenhouse effect and consequent climate changes, and for the very serious risks associated with particular sources of energy, starting with nuclear power. Thanks to the energy recovery of waste carried out through efficient waste-to-energy plants, the production and use of SSF and biogas, it would be possible to reduce a large share of the consumption of energy sources and to record a substantial reduction in polluting emissions.

4. Results and discussion

The CON.TE.A. Consortium is authorized to produce alternative fuels derived from waste (i.e. the so-called RDF) but intends (unfortunately in the not near future) to obtain authorization for the production of SSF-Fuel and plan to adequately structure the area to be reserved for this activity. The project foresees that the treatment plant is mainly fed by industrial waste and waste, for the production of high quality SSF, and that it is installed inside an industrial warehouse whose structure is closed and in constant depression in order to avoid emissions to the outside world (Ballabio et al., 2019). The production process of the SSF provides that initially, the incoming waste is subjected to a mechanical treatment (carried out cold), aimed at reducing its size and selecting the fragments thus obtained, separating the usable components from the extraneous ones (such as inert materials and biodegradable substances). The different material fractions are separated according to their weight, size and composition (Carli Roma, 2018). The processing includes a main shredding phase, which is followed by various screening and selection phases, up to a final refining. The initial mass of the waste, reduced to fragments, can possibly be further processed to take the form of pellets (www.iltruciolo.it). The overall costs (budget costs) of the following project fall into two categories: investment costs and management and maintenance costs. The investment costs in turn include those relating to the preparation of the area, the construction of buildings and the plant and the acquisition of machinery. These costs are difficult to estimate a priori but it is assumed, on the basis of investments made in similar plants, a minimum output of €15,000,000. The table 2, on the other hand, shows the expected operating costs assuming an incoming flow of non-hazardous waste equal to 60,000 tons/y (technical potential of the plant) and that: 1) the plant delivers the SSF outgoing to co-combustion in cement plant; 2) produces an average quantity of 22,000 t/y of SSF, of approximately 3,000 t/y of fractions to be sent to the landfill and it is able to recover a quantity of ferrous and non-ferrous metals equal to approximately 1,700 and 109 t/y respectively; 3) the unit rate for landfilling is equal to €60/t; 4) finally, the estimate of the economic benefit of the SSF, on the production and consumption chain, leads to a value of €210/t, of which 14% represents the share due to the production plant (Rigamonti et al., 2019).

Table 2. Cost items expressed in [€ / year] which include the data obtained by processing the questionnaires filled out by the tmb plant managers.

Cost item	***[€ / year]***
Management costs	
Staff	500,000
Electric energy	576,000
Annual depreciation cost	700,000
Maintenance cost	550,000
Delivery rates and transport costs for outgoing flows	
Co-combustion SSF	-638,000
Dry fraction with waste-to-energy	0
Dry fraction with landfill	0
Recovery of ferrous metals	-34,240
Recovery of non-ferrous metals	-13,625
Refuse and landfill waste	180,000

Based on this, and in order to estimate the "monetary income" resulting from the sale of the SSF, a value of €29/t was assumed as the sale price. It should be noted that the costs, shown in the table above, were estimated on the basis of the average costs recorded in the reference sector (Rigamonti et al., 2019). It is appropriate to highlight the economic savings resulting from the production of SSF for the company. Assuming an entry of 166 t/d of waste, an average cost of refining the SSF equal to €10/t, an average cost of landfilling equal to €60/t and a quantity of fractions produced to be sent to the latter equal to 50%, it can be assumed that if the SSF is not produced, the daily costs amount to €4,980/d (166*0.5*60).

If, on the other hand, the fuel is produced and the fraction to be sent to the landfill is reduced to 5%, the daily cost will be equal to €290.5/d (166*0.5*0.05*70). This example shows a saving of €4,689.5 per day or €56.5/t (www.ecocarbon.it). There are several terms, acronyms and acronyms that identify SSF in Europe: the first definition of "waste fuel", i.e. CDR, was given with Legislative Decree 22 (1997) (the so-called Ronchi decree). From the European Waste Catalog, "combustible waste" is defined with the initials 19 12 10; this abbreviation communicates (with the first two pairs of numbers: 19 12) that it is "waste produced by mechanical treatment" (for example: selection, shredding, compaction, reduction into pellets) of other waste (UNI 9903, 2004). The objective of Ministerial Decree No. 22 was to promote the production and use of particularly high-performance secondary solid fuels to replace conventional fuels for environmental, economic and geopolitical purposes (Tortora et al., 2015). Ministerial Decree No. 22 of February 14, 2013 distinguishes between "SSF Solid Secondary Fuel", which remains a waste pursuant to Article 183 of the TUA, defining it as "solid fuel produced from waste that complies with the classification and specification characteristics identified by technical standards UNI CEN/TS 15359 and subsequent amendments and additions"; "SSF-Fuel"- the so-called end of waste - which is no longer a waste pursuant to Article 184 ter TUA on the termination of the lification of waste and which the Ministerial Decree defines as "the sub-batch of secondary solid fuel for which a declaration of conformity is issued in compliance with the provisions of Article 8" (Ministerial Decree 22, 2013). The SSF is produced exclusively in plants authorized in the ordinary procedure in compliance with the provisions of Part Four of the TUA, or pursuant to Title III-bis of the Second Part of the same and in any case with environmental quality certification according to the UNI EN15358 (UNI EN 15358, 2011) or, alternatively, registration pursuant to the current community regulations on the voluntary participation of organizations in a community eco-management and audit system (EMAS).

5. Concluding remarks

The caloric replacement of fossil fuels with alternative energy sources in Italy went from 17.3% in 2017 to 19.7% in 2018. Considering that in 2008 the replacement rate was just 6%, we are witnessing a progression essentially due to the increase in the quantities of alternative fuels used in the area following the issue of the necessary authorizations (AIA) and to the rationalization of the production park in favor of sites that can exploit fuels deriving from waste. However, the Italian cement industry is still far from the thermal replacement levels of its European competitors.

Unfortunately, in Italy, the low use of the SSF is due, first of all, to the complex bureaucratic process: in fact, it requires from the proposer an amendment to the AIA, which often pushes the competent authority, with different reasons, to start, in addition to the procedure to update the AIA, also the procedure for the release of the "Integrated Environmental Assessment" (VIA), making the authorization process heavier, both in terms of costs and time. If the operation of all cement plants is linked to the issue of AIA, the use of SSF is authorized with more stringent emissions limits and requirements than running on fossil fuels. If those who produce SSF at the service of an integrated cycle of waste, mainly urban, have a constant incoming flow and therefore need to find a final location quickly and constantly, the demand for cement factories is exposed to fluctuations in the economic cycle. Given these conditions and without contracts already signed by potential users, there are no economic margins to produce SSF-Fuel, which still requires greater costs, both in the production and use phases. It is clear that without public incentives for the use of SSF-Fuel for cement factories and power plants, for the commitment to its continuous use as a replacement for coal and for the increase of plants authorized for use, it is difficult to imagine a future for this alternative fuel. In addition to cement factories, the use of SSF would ideally improve the economic and environmental performance of thermoelectric plants as well. The SSF could, in fact, progressively replace at least a part of the 15.2 million tons of coke and steam coal consumed each year in the country, effectively fighting what appears to be, in all respects, the number one enemy of the climate. A larger-scale use of SSF would also improve the energy balance, which is almost totally dependent on imports.

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