Circular Economy and Industrial Symbiosis in Sicily

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Abstract. Aim of this paper is to present the state of the art of the Industrial Symbiosis in Sicily, a region of southern Italy. The strengths, the limits and the obstacles to its spread of the initiatives carried out by public institutions and private companies are studied. In order to overcome the issues of the previous initiatives, the research proposed in this paper will pivot on a first phase of investigation based on the collection of data and feedback from the main stakeholders (interviews and questionnaires). Such knowledge will be preparatory to understand the main needs of the industries of this territory and will orient to the development of the most valuable and effective tools that can concretely help operators to achieve the goals of the Industrial Symbiosis.

Keywords: symbiosis, circular economy, supply chain, database, CO2 reduction, sustainable manufacturing.

1 Introduction

The growing demand and the limited supply of resources, especially for some raw materials that are becoming rare, force companies to take into account the risk of dependence on few suppliers and the increase of costs. Moreover, the supply of some raw materials has often very high environmental impacts while the search for new sources can be uneconomical too. In 2014, Working Group on Defining Critical Raw Materials of the European Commission defined 54 critical raw materials for Europe, since 90% are imported from non-EU countries and mainly from China[1]. Events such as the Covid19 pandemic and the recent war in Ukraine have highlighted the impact of this dependence on Asian countries on our economy. Building a Circular Economy and achieving Industrial Symbiosis allow to reduce this subordination, not only, it helps reaching Sustainable Development Goals (SDG) 12 and 13. SDG are a collection of 17 interlinked global goals designed to achieve a better and more sustainable future for all, they're intended to be achieved by 2030. SDG 12 "responsible consumption and production" is meant to ensure good use of resources, improving energy efficiency, sustainable infrastructure, and providing access to basic services, green and decent jobs and ensuring a better quality of life for all[2]. SDG 13 "climate action" mission's is

"take urgent action to combat climate change and its impacts"[3]. As reported in [2], Italy occupies the 25th place in the ranking, regarding SDG 12 the comment is "Significant challenges remain. Score moderately improving, insufficient to attain goal" and SDG13 "Major challenges remain. Score moderately improving, insufficient to attain goal" with a specific attention to CO2 emission.

According to the definition given in[4], Circular Economy (CE) is a generic term to define an economy designed to regenerate itself. In a CE, "material flows are of two types as described by McDonough and Braungart: biological nutrients, designed to re-enter the biosphere safely and build natural capital, and technical nutrients, which are designed to circulate at high quality without entering the biosphere". The CE is therefore an economic system planned to reuse materials in subsequent production cycles, minimizing waste[5]. Since a company is not always able to reuse its waste internally, which can be transformed into second raw material for another, in this paper we will consider the Industrial Symbiosis (IS) that, according to [6], is the interaction between different industrial plants, grouped in districts or at a distance that still allow to make the operation feasible in order to maximize the reuse of resources (normally considered waste), the sharing of knowledge and skills between companies. IS may be considered as a realization of the CE within the industrial landscape [7].

Digital technologies could be critical enablers of CE by tracking the flow of products, components, and materials and making the resultant data available for improved resource management and decision making across different stages of the industry life cycle [8]. As highlighted in [9] the entire business world is impacted by new technologies that rapidly change and evolve, presenting new challenges and opportunities. This evolution applied in manufacturing is called Industry 4.0 [10]. The relationship between the CE and Industry 4.0 technologies has been explored by [11, 12], they agree that Industry 4.0 adoption has a positive relationship with sustainable production and sustainable production has a positive relationship with CE capabilities. Among these, certainly the one that has a very high potential impact is Artificial Intelligence. In the last decade we saw the development of the Internet of Things (IoT). More commonly used objects have sensors that communicate with each other. The growing use of IoT and artificial intelligence can provide valuable help for the implementation of CE in efficient and green industries of the future. As stated in [13], the come to light of digital and smart technologies provide an opportunity to win the challenge of the CE. The amount of data generated during the production, use and disposal of goods is well suited to the characteristics of Big Data. These can be analyzed by applying big data business analytics and artificial intelligence to highlight trends, optimize logistics and direct the management of production flows with the help of IoT. According to [12] developing big data analytics capability has to become a business priority in order to effectively build competitive sustainable supply chain (SC). Big data facilitates several aspects of circular strategies, such as improving waste-to-resource matching in IS systems via real-time gathering and processing of input-output flows.

In this paper we present the state of the art of IS in Sicily and the initiative created to promote it. We chose the biggest Italian island, because in a small way it represents the average Italian and European supply chain. In the region there are SME (small me-

dium enterprise) dealing with: food transformation, furniture making, electromechanical companies, manufacture of non-metallic and metallic products, manufacture of plastic products, beverages, chemicals, electronics, machinery and equipment, repair and installation, etc. In the period between 2011 and 2015, Sicilian stakeholders and policy makers were involved regional project with Government incentives for the "Development and implementation of a regional platform of industrial symbiosis" [14]. In this paper the results of a survey about the spreading of IS in Sicily is used to identify the current lacks and propose a new approach to help concretely the stakeholders to achieve IS. This paper is structured as follows. Section 2 provide the research context and the literature review regarding CE and IS. Section 3 present the state of the art of IS in Sicily. Section 4 provides the description of the research methodology adopted. In section 5 conclusions and expected results are presented.

2 Research context

The European Union noted that the enhancement of CE would encourage sustainability and competitiveness of businesses in the long term, helping to:

- preserve resources, including some which are increasingly scarce, or subject to price fluctuation;
- save costs for industries;
- unlock new business opportunities;
- build a new generation of innovative, resource-efficient businesses;
- create local low and high-skilled jobs;
- create opportunities for social integration and cohesion.

The benefits of CE are numerous: reports indicate that CO2 emissions could be reduced by up to 70% and create new jobs. [15, 16] report success stories of numerous entrepreneurs who are making an impact to develop the CE and who create collaborations that use circular business models from which "circular start-ups" were born. According to [17], moving to CE requires a systemic change in the design of products, business models and SC in order to reduce waste, promote internal reuse of waste, favor the production and design of goods that can be repaired, and enable a flow of goods from consumers back to manufacturing companies (reverse logistics), and more. In [18] is underlined that, despite the growing attention on circular supply chain management, several areas are open for investigation, such as SC integration, collaboration and coordination mechanisms. Industrial symbiosis (IS) can also be considered as an example of CE at the meso level, like the eco-industrial parks. The micro level regards the single company, that, applying CE strategies, can find potential source of growth, increased market share and profitability, despite at the macro level, the CE paradigm involves cities, regions and nations. [19] emphasized how IS generates environmental and economic advantages, such as lower resource consumption, raw materials savings and lower treatment costs. Industrial districts (IDs) are characterized by the localization of many small and medium-sized businesses in a given industry, integrated through a complex network of economic and social interrelationships [20]. In the last decades, the ID

as a socio-economic organizational model has been suffering from the effects of globalization [21]. According to [11], we believe that a transition to CE, through IS, has the potential to change the destiny of a declining ID towards new growth. In a recent literature survey of information systems [22], existing tools were categorized into six different types based on their facilitation approach: 1) open online waste markets, 2) facilitated synergy identification systems, 3) industry sector synergy identification, 4) social network platforms and communities, 5) industrial symbiosis repositories, 6) region identification systems for industrial symbiosis. With respect to previous works, this paper presents a methodology that can be used to implement a pilot software platform for improving the IS mechanisms.

3 Industrial symbiosis in Italy and Sicily

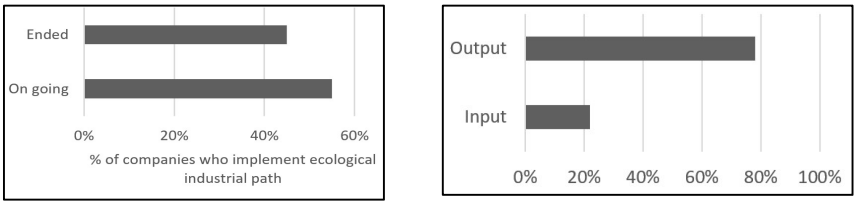
One of the first public initiative, aimed at creating a network of companies, is ENEA's Sun Network. Since 2015, it aims as an Italian reference for operators who want to apply industrial symbiosis. It currently brings together 39 partners from universities, political institutions, research institutions, private companies and technological networks. The activity planned was the "Development and implementation of a regional platform of industrial symbiosis" [14]. In [23] a good summary of the activity done in the project is presented. The Sicilian productive system was then investigated and companies were involved in operative meetings for resources sharing, potential synergies individuation and to acquire data for platform validation (http://www.industrialsymbiosis.it/). Potential synergies verification was performed, from a technical, regulatory, logistic and economic point of view, for a selected group of categories. Operative handbooks on some specific case studies were produced. On the basis of the results, some critical issues emerge: 1) the low grade of diversification of participating companies that was not fully representative of the actual productive system so limiting the information on the potential matches; 2)the disequilibrium between observed supply and demand due to the prevalent interest of participating companies in finding out alternative solutions for the disposal of their residues rather than to find alternative supplies for their processes; 3) the excessive offers of services and expertise; 4) companies concern about a potential increase in controls on their activities. It must be highlighted that there are also private enterprises, such as Sfridoo®, whose mission is to generate industrial symbiosis between companies by offering them projects and market tools to convert waste in a resource. It is clear from several publications[24–26], that there are various activities aimed at achieving the CE and specifically at creating industrial symbiosis in Sicily, but they are limited to innovative and virtuous companies, which have sought other companies to collaborate with. The driving element is the concept of Zero Waste [27], that is to reconvert as much as possible the production scraps into secondary raw materials, looking for who can use them to produce or goods or energy.

A first survey on the spreading of the industrial symbiosis in Sicily, involved 20 private companies. Data collected focus on 1) participation or not to any form of industrial symbiosis and reasons, 2) classification of the residual resource, 3) transfer or acquisition of residual resources, 4) business sectors of companies and 5) value appreciation of residual resources. It has been observed that the 53% of the company that have been

interviewed had the opportunity to adapt and obtain excellent results in the field of industrial symbiosis, 15% tried to apply sustainable politics without any success, and for a 32% any approach has been taken. Analyzing the answers, it is deduced that the causes of this failure are different:

- Industries and the main stakeholders are not being aware of the phenomenon of industrial symbiosis;
- Companies reuse all waste and residual production resources internally so they don't need to exploit a corporate interdependence;
- Industries own certain assets that cannot be treated as secondary raw materials due to presumed regulatory problems.

The reasons that push the 53% of the companies to choose an ecological industrial path are essentially focused on the respect for the environment, on the enhancement of local resources and, finally, on the entitlement of competitive advantages (Figure 1.a). As regards to the residual resource, we have seen that the most shared belongs to the material classification and in only one case to the energy classification. In the IS we distinguish the companies that introduce the residual production resources (output), valued and considered secondary raw material, into the "network", and the companies that are organized to acquire these resources and implement them in their production process (input). From this research, it emerges that the prevalent cases are related to the transfer of residual output to other companies, with only the 22% of companies which choose to acquire the resource (Figure 1.b).



a. b.

Fig. 1. a. Status of the process of industrial symbiosis; b. Residual resources: moved or acquired (Output/Input)

In the Sicilian system of IS, the main sector of origin of resources is agriculture, followed by the textile sectors for clothing and furnishings and those dedicated to manufacturing and carpentry for construction. The target sectors of the output include activities such as breeding, the manufacture of wooden products and cosmetics, tailoring and the production of non-distilled fermented beverages. It was found that the 67% of the exchange of resources for most companies of the Sicilian territory takes place through an economic enhancement in favor of the producer; this is one of the many economic advantages deriving from IS. The remaining part, representing the 33% of the companies interviewed, chooses the alternative that does not take into account any economic contribution. Choosing an ecological industrial path implies an important behavioral change in entrepreneurs who have to adopt a more careful approach about

waste production and an efficient use of resources. While for some companies there are neither barriers nor criticalities, a good percentage of companies still require solutions to specific problems. The difficulties found mostly derive from the lack of harmonization of EU legislation, of consistent incentives and a real circular regulation. In addition, both the limits dictated by distance and the presence of quality problems during the production cycle, still limit the desire of Sicilian companies to create a strong network of IS.

4 Research proposal

4.1 Methodology

The methodology requires the fulfillment of three different activities: data collection, data analysis and the automation of the process. The first phase will be devoted to the understanding of which district is ready to seize the opportunities generated by CE. The second phase will be dedicated to data analysis and database creation. During the third phase the automation of the platform will be carried out.

Data collection. A sample of supply chain located in a specific geographical area of Sicily will be selected. The chance to conduct a survey to understand strengths and weaknesses of the previous initiatives which were put in place to promote IS will be one of the main preliminary activities to carry out. Starting from [11] review, the necessary information that will be asked to companies refers to the types and quantities of resources consumed, the types and quantities of waste and by-products produced and the conversion processes, all backed by economic information concerning the exchange. This will allow us to evaluate what resources can be recovered from waste or by-products, what waste or by-products can be used as raw material and last, what technologies and processes are necessary for the conversion. In addition, information regarding availability and requirements of resources in terms of quantity, time and price should be collected. It is important to evaluate the distance among the entities exchanging resources, and the profitability related to the exchanges [7]. Moreover, a detailed study of the production process aimed at reducing waste and enhancing it as a secondary raw material will be proposed to the companies. An important step to achieve is to collect the list of the manufacturing software (ERP, MES, etc.) which are the most used; in fact, one of the main goals of this research project is to interconnect the software platform object of the next phase -to the companies, offering APIs to query and update the database.

Data analyses. A database to collect the information about the processes of the industries, the raw materials which they need, their production scraps and waste will be created. This will allow to match the supply of scrap/waste with the demand for secondary raw materials. It also helps to identify which companies can collaborate with each other based also on the geographical position of the companies, with the target to reduce CO2 emissions.

Criteria of weakness and strengths. The analysis of the initiatives in which the companies have been involved will be the starting point of the proposed research. Criteria will

be prepared to objectively highlight strengths and weaknesses to use them as a starting point for our work.

Automation of the platform. In a next step, we aim to implement a set of APIs that will help the companies to update and query the database automatically. All data must be collected and made available for consultation by companies. Access must be simple and intuitive, in Italian, in order not to exclude any user.

5 Conclusions

In this paper, the state of the art of the IS in Sicily has been analyzed. It has been observed that there is a big room of interventions from research institutions, public and private companies to improve the current situation. The diffusion of the internet technologies, such as Internet of Things, Cloud Computing, Artificial Intelligence gives now the opportunity to improve the initiatives that have apparently failed in the past. This study puts the basement for the implementation of a software platform for the IS. The expected results of the next steps of this research project are the following:

- analyze what has been done up to now to promote IS in Sicily;
- build a database that facilitates the exchange of information and favors the dissemination of a culture of CE in the Sicilian supply chain;
- facilitate the transition from linear to CE of SMEs in the area;
- reduce the use of natural resources as raw materials, with the consequent reduction of energy, CO2 and costs;
- reduce the amount of waste destined for landfills.

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