**INDUSTRIAL SYMBIOSIS IN SICILY: PERSPECTIVES AND CRITICALITIES**

**1AGATA MATARAZZO, 1ROBERTA TERNULLO, 2LAURA CUTAIA, 3LUDOVICA OLIVERI, 1SERGIO ARFO’, 3DIEGO D’URSO,**

**3FERDINANDO CHIACCHIO, 2ANTONELLA LUCIANO**

1Department of Economics and Business, University of Catania, Corso Italia 55, Catania, Italy

2Italian National Agency for New Technologies, Energy and Sustainable Economic Development – Department for Sustainability, Resource Valorization Lab, ENEA – Casaccia Research Centre, Rome, Italy

3Department of Electrical, Electronics and Computer Engineering, University of Catania, Italy

E-mail: 1amatara@unict.it, 2laura.cutaia@enea.it , 3ludovica.oliveri@phd.unict.it

ORCID: 10000-0003-1537-1915

**Abstract:** The principles of circular economy present a production and consumption model that involves sharing, reuse, repair, reconditioning and recycling of materials and resources. In particular, the phenomenon of industrial symbiosis, a process in which a company's waste products and by-products become raw materials for another company or for another production process, which in turn creates an interdependence between companies in which energy and waste circulate uninterruptedly without refuse products. This study is based on the measurement of the circularity of the economy, inspired by the new UNI 1608856 standard and on the analysis of Sicilian good practices, according to the provisions of UNI 1608977, by the definition and measurement of appropriate indicators. The paper aims to analyze and collect data relating to the Sicilian eco-industrial framework, analyzing the critical issues and the opportunities of the industrial symbiosis system within Sicilian companies. To achieve this goal, a questionnaire developed in collaboration with ENEA was administered. The questionnaire investigates the successes and failures of causes related to the implementation of a path of industrial symbiosis within companies. Byprocessing the results, it was possible to observe how Sicilian companies relate to the system of industrial symbiosis.

**Keywords:** Industrial Symbiosis1, Circular Economy2, Environmental Sustainability3, Production Cycles4, Materials Recycling5

**1.1** **Introduction**

The growing demand and the limited supply of resources, especially for some raw materials that are becoming more and more rare, force companies to take into account the risk of dependency on a few suppliers and the increase of production costs. Moreover, the supply of some raw materials often has very high environmental impacts and the search for new sources can be uneconomical too. Inspired by the living systems, Circular Economy is a production and consumption model that, unlike the linear economy approach, allows an enhancement of the product life-cycle by becoming a second raw material where product components are kept within the economy wherever they are productively useful in order to create additional value (Deselnicu, et al., 2018). Circular Economy entails reusing, repairing, recycling, leasing and sharing running materials and products as long as possible, together with the use of green energy, so that waste can be reduced to the minimum and the goods of today become the resources of tomorrow. The reason why we need to abandon the take-make-dispose model lies in the scarcity of raw materials. In fact, since the industrial revolution brought innovations that allowed us to have access to various products at affordable prices from all over the world, at the expense of nature environment, we have taken part in a comfortable yet unsustainable finite supply chain of resources that cannot work in the long-term. (Ellen MacArthur Foundation, Cowes, 2019). Besides, energy consumption has dramatically increased, negatively impacting our environmental ecosystem in terms of greenhouse gas emissions and biodiversity loss. Moreover, the fact that raw materials are limited implies rising costs for Countries that depend on other Countries for the supply of their natural economic resources. (Ellen MacArthur Foundation, Cowes, 2015). In general terms, the European Union noted that the enhancement of circular economy would encourage sustainability and competitiveness of businesses in the long term, helping to:

* preserve resources, including some that are increasing becoming 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 circular economy are numerous: reports indicate that CO2 emissions could be reduced by up to 70% and create new jobs and report success stories of numerous entrepreneurs who are making an impact on the development of the circular economy and creating collaborations that use circular business models from which “circular start-ups” were born (Veleva and Bodkin, 2018). There are several ways to achieve circular economy: design aimed at reducing waste and internal reuse of waste, using of materials that can be easily disposed of or reused, producing and designing of goods that can be repaired, or the flow of goods able to come back from consumers to manufacturing companies (reverse logistics), and more. Since a company is not always able to reuse its waste internally, which can be transformed into second raw materials for another industry, in this paper we will consider the *industrial symbiosis* that, according to (Chertow, 2000), 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 (Henry et Al, 2020).

In this paper we present the results of a survey conducted about the spreading of industrial symbiosis in Sicily and the initiative created to promote it. Afterwards, we propose a new research concerning a data collection system (questionnaire and database) and some possible feasible tools for data analysis that can operationally support operators to achieve industrial symbiosis (VV. AA.,2014).

The term “symbiosis” derives from the observation of biological and symbiotic connections which normally take place in nature. Here, materials, reserves and energy are related to a concept of mutual support in a reciprocally beneficial way (Veleva and Bodkin, 2018). These kinds of resources – material, energetic and water – represent a priceless raw material to manufacturing lines of companies which try to reduce production waste and process effluents. Symbiosis between companies mainly takes place through three actions:

1. Utilizing scraps or by-products in place of commercial products or raw materials;
2. Sharing utilities and plants to use and manage resources, like steam, energy, water and waste;
3. Supplying services aimed to satisfy common needs such as security, hygiene, transport and the management of refuse.

* 1. **Review of the literature**

The Italian sustainable system is always more adopted and implemented in Italian companies, but it is necessary to enhance it to make it even more efficient according to territorial features (VV. AA., 2015.). Actually, industrial symbiosis is an interaction with which many companies work together to improve the land itself. ENEA, the National Agency for new technologies, energy and economic sustainable development, indeed, keeps looking at the Italian circular framework through R&S allocations and expenses (Wijkman and Skanberg , 2015).

The aim of this paper consists of analyzing how Italy, and especially Sicily, can use industrial symbiosis policies together, analyzing the data obtained of a study developed by ENEA, and distributed to many Sicilian companies. The survey examines successful and unsuccessful cases related to the implementation of an industrial symbiosis itinerary inside companies. In particular, it evaluates:

* What motivates companies to choose this kind of itinerary;
* The features of resources (classification, provenance and target sector, etc.);
* The number of parties involved;
* Advantages and effects;
* The economic value of the good;
* The legal status of the good at the moment of trade;
* If the industrial symbiosis itinerary was interrupted or is still ongoing;
* Elements of facilitation and obstacles which were rediscovered along the way;
* If the practice used is innovative or consolidated with the potential annexed conditions for replication or expansion;
* Lastly, data of organization and compiling’s representative.

The summary of the paper is the following: outline of ENEA’s history and the successive development of the SUN net; presentation and discussion of the survey; analysis of three specific case studies; and, finally, the main economic and environmental benefits found.

This study allows us to acquire essential information about available resources recyclable inside companies: waste materials, refuse, skills and services (Munda and Matarazzo, 2020). These results were obtained first of all thanks to the compilation of suitable input-output tables and, later, through the proposal of efficiente synergies between companies (Van Buren et al (2016). According to this approach, therefore, the industrial symbiosis realization goes through:

* Interconnection between traditionally separated interlocutors (net);
* Knowing the chances present on the territory through data banks analysis. These can be of two types: georeferenced, GIS-based (Geographic Information System (Ramadoss , 2018), or not;
* The availability of expert skills able to take and offer solutions of industrial symbiosis.
* The platform was designed for Sicily, but it can be used for the whole of Italy, and the territorial extension of the application would be greater, stimulating opportunities for encounter between supply and demand of resources (Elia et al.,2020).

In July 2015, the paper “The experience of the first industrial symbiosis platform in Italy”53 was published in the Environmental Engineering and Management Journal, reporting the first approach to the implementation of the Industrial Symbiosis platform promoted by ENEA (Pollitt et al.,2015). The objectives of the project are: To provide a methodology and a tool for the implementation of Industrial Symbiosis on a regional scale; To implement an IS platform as a support to SMEs to identify opportunities in the region (MacArthur, 2013). Therefore, the organizational and executive approach replies on: Network activation (McDonough and Braungart , 2002); Planning and implementation of the platform architecture; Analysis of the Sicilian production sectors and related data collection (Matarazzo, et al., 2018); Inolvement of companies (Ghisellini et al.,2016).

* 1. **Materials and Methods**

The survey distributed by the Italian Network of Industrial Symbiosis SUN to the various Sicilian companies was aimed at analyzing and verifying the Sicilian eco-industrial framework. It is important to examine how Sicily stands towards the industrial symbiosis system to understand how many steps it has made and how many more it will have to do for improving the approach with industrial ecology. In fact, constant research and data collection are necessary tools to be aware of facilitating elements and eliminating barriers (Henry et al., 2020). The sample interviewed includes 21 Sicilian companies both small and medium-small. The response, as can be seen from Graph 1, comes mainly from 76% of the agricultural sector, followed by the textile, electronic, wood-furniture, port and industrial services. Furthermore, the legal sites of the companies interviewed are located, in order, in the provinces of Catania, Syracuse, Enna and Ragusa.

The questionnaire is mainly formed by multiple-choice questions, but there are also questions that require open answers to better specify, for example, the details of the production process or the results found by Sicilian companies.

**Graph 1: T**he sectors interviewed with the questionnaire

0.8

0.7

0.6

0.5

0.4

0.3

0.2

0.1

0

Agricultural

Electronic

Wood Furniture Port services

industriali

Textile

**1.4 Results and discussions**

The survey is aimed at monitoring the Sicilian sustainable framework. From the first data acquired, it can be seen how, among the Sicilian companies interviewed, 48% have successfully undertaken industrial symbiosis itinerary, achieving excellent results. 9% attempted to start a symbiosis policy for the enhancement of their own residues or for the use of by-products from other activities, but without being able to complete these initiatives. 43% of the companies interviewed did not try symbiosis path for various reasons, such as:

* Not being aware of the phenomenon of industrial symbiosis (43%);
* Internally reusing all waste and residual production resources, without the need to exploit a corporate interdependence (47%);
* Owning certain assets that cannot be treated as by-products due to presumed regulatory problems (10%).

Among the successful cases, as can be seen from the Graph 2, the agricultural sector triumph once again, followed by textile, electronic, wood-furniture and services (port and industrial) sectors (Basile et al., 2020). The reasons that push 48% of companies to choose an industrial ecological path are essentially focused on respect for the environment, on the enhancement of local resources and, finally, on the desired enjoyment of competitive advantages. With regards to the residual resource, it can been seen that the most exploited one belongs to the material classification with the presence of only one case, instead, of energy classification. Secondly, compared to the 30% of companies that choose to acquire the resource as an input and implement it in their production process, it can be seen from the Graph 3 how the cases in Sicily are connected to the transfer of the residual output to other companies.

The sectors of origin of residual resources, the protagonist of the Sicilian system of industrial symbiosis, is the agricultural one, followed by textile sectors for clothing and furnishings, electronics, those dedicated to the cultivation of cereals and manufacturing and carpentry for construction and, finally, from the tertiary sector.

**Graph 2:** Sectors of origin of resources from waste

Agents and representatives of fabrics for clothing and furniture

Agriculture, forestry and fisheries

Manufacture of other wooden and joinery elements for the building industry

 Cultivation of cereals

Manufacture of diodes, transitors and their electronic devices

Other activities

On the other side, the target sectors include activities such as breeding, manufacturing of wood products and cosmetics, tailoring, production of non-distilled fermented beverages and fresh confectionery, retail trade, treatment and disposal of hazardous waste (Graph 3).

**Graph 3:** destination sector of residual resources

Tailoring and tailor-made outerweare

Manufacture of toilet products: perfumes, cosmetics, soaps and the likeper toeletta:

Retail

Manufacture of other wood’s products

 Sheep and goat breeding Manufacture of concrete products for the building industry

Production of other non-distilled fermented beverages

 Treatment and disposal of hazardous wastes

Manufacture of textile fabrics and articles of such material

Production of fresh pastry

The exchange of resources for most Sicilian companies takes place through an economic enhancement in favor of the producer for 50%, an improvement which is evidently responsible for the multiple economic advantages deriving from industrial symbiosis. 40% of the companies interviewed choose the alternative for which, instead, it is the user who bears the burden, while the remaining 10% faces the exchange without any economic enhancement. The transport of the goods and cost of reaching the destination sector may depend on the manufacturer, the user or third parties. It is noted, how in Sicily, most companies prefer to place this type of burden on the manufacturer, although, the difference with the burden borne by the user is minimal. At the time of the exchange, the preponderant legal status is combined that of 40% of the secondary raw material, with the remaining 60% being divided equally between by-products and waste.

The facilitating elements found by companies along their itinerary of industrial ecological implementation certainly reflect the conditions for which the circular process is both simple and rapid and, moreover, an important behavioral change derives from the realization of this project. Entrepreneurs are more aware of waste and want more efficient use of resources.

In contrast, if 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; Consistent incentives; A real circular regulation.

In addition, both limits dictated by distance between the companies and the presence of quality problems during the production cycle still do not fully reconcile the desire of Sicilian companies to blend with the reality of industrial symbiosis (MacArthur, 2013).

The analysis tool associated with this last chapter, namely the processing of the data relating to the survey, was able to underline, in the concrete business reality of Sicily, the advantages deriving from the adoption of this circular process (Fichera et al., 2020)

In fact, by reconstructing testimonies of the various companies subjected to the test, it is shown how industrial symbiosis can:

* Reduce environmental waste;
* Ensure a lower consumption of raw materials, obtaining, thanks to recycling, a lower environmental impact;
* Enhance the waste, transforming it into a resource;
* Cancel the cost of waste disposal;
* Enhance the local territory and its resources;
* Benefit from competitive advantages, thus placing companies in a privileged position compared to others;
* Implement sustainable innovative actions in sectors where there is an uncontrollable waste of resources;
* Facilitate sectors of resource destination, especially when the exchange of the asset does not involve an economic enhancement;
* Allow to add a new line of products, moreover natural;
* Favor initially low investments;
* Change the attitude of entrepreneurs, who are increasingly aware of the need for a production system and a country-system inspired by environmental principles.

In summary, the production residue, which must submit all the legal requirements to be managed as a by-product, can be transferred as a “resource” from one company to another with significant economic advantages:

* For the assignor company 🡪 reduction of annual waste management costs and increasing income in the event of an exchange with economic enhancement;
* For the Company that uses the by-products 🡪 a reduction in production costs.
* Creation of new business networks and new market opportunities;
* Improvement of business relations with external parties.

From an environmental perspective, instead, the efficient use of natural resources in production processes reduces the demand of eco-systemic goods and services, and determines a lower impact of production activities through the containment of emissions into water and the atmosphere, the prevention and reduction of waste and subsequent disposal in landfills, etc.

Socially, an aspect not yet considered in the chapter, the management of some residues as by-products produces: New occupations and profesional figures or the retraining of the existing workforce; The reduction of health and social costs related to waste disposal; A cultural change within society that favors the meeting of the various interested interlocutors.

Therefore, the implementation of this business model creates important advantages for both the business system and the community, thanks to the increase in the overall competitiveness and efficiency of local production systems, the reduction of pressure on ecosystem services and on the biodiversity of the territory and, finally, to the improvement in the quality of life of communities

* 1. **Conclusions and future perspectives**

The gap between northern and southern Italy, in terms of industrial resources, human capital and economic efficiency, is also evident in the ability to respond and innovate the environmental field.

Among the 432.000 Italian industrial and service companies that invested, in the 2015-2018 period, in green products and technologies, 215.495 were active in the north. This means that, in the five-year period under consideration, 29,3% of the companies located in the north invested in a green way, including 28,7% only in Piedmont, compared to 26,1% of the companies in the central regions and in the 24% of companies in the South. The companies which invest in green economy are also companies more suited to exports (51% increase exports versus 38% of others), which lead to more innovation (76% versus 61%) that grow in terms of employment (19% versus l’8%), that expect an increase in turnover (26% versus 18%).

Employees committed to activities classified as “green jobs” in 2018 grew until 3.100.000 units, representing 13,4% of total employment (in 2017 it was 13,0%). Also in this case, and to a significant extent, there is a concentration in the northern regions: 56,3% of green jobs, compared to 51% of total employees.

The data on recycling indicates the exceptional level of environmental management of waste now reached in many regions, especially in the North of Italy. But the most relevant data for circular economy is the strong concentration of industrial recycling capacity in the northern regions. 67% of total waste sent to Italy for material recovery is treated and managed in the northern regions, which produce 59% of the total waste. Despite the variety of economic, environmental, competitive, and commercial benefits, Sicily has still to advance and seize opportunities in the circular economy and sustainable development. Without a doubt, entrepreneurs are increasingly aware of what is needed nowadays inside and outside companies. In fact, Sicilian companies are gradually moving towards the industrial ecological front, bringing home excellent results and thrilling not only the market, but also the citizens, who are proud of the progress of their region. In any case, the road seems still long and troubled. Indeed, Sicilian companies complain of the lack of a real circular regulation consistent with EU legislation, of facilitating the construction of infrastructures. Moreover, in some cases, specific difficulties have also been encountered in accessing relevant information and assessments. Therefore, a regulatory and economic facilitation can only increase Sicily’s approach to an important system such as that of industrial symbiosis. For the future, Sicilian companies will benefit from a greater expansion of networks and platforms, which facilitate contact between suppliers and receivers in their sector, and from greater territorial cohesion. The results analyzed show how almost half of the sample of considered companies has already implemented with success an industrial symbiosis system, based on the recovery of production waste and on the exchange of these with other companies. However, of course, much remains to be done in order to obtain an increasingly widespread success of the practice under consideration, also to seize the great opportunity still present in the South of Italy.

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