PROCEEDINGS

The industrial symbiosis for the national circular economy strategic plan

Symbiosis Users Network – SUN
Proceedings of the sixth SUN Conference

November 8th 2022

Edited by Tiziana Beltrani and Marco La Monica

La Simbiosi Industriale per la Strategia Nazionale di Economia Circolare

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INTRODUZIONE

La simbiosi industriale (SI) è riconosciuta a livello nazionale e internazionale quale strumento essenziale per aumentare la competitività, ridurre la dipendenza dalle materie prime, rilanciare l'economia e aumentare la capacità degli ecosistemi industriali e territoriali a compensare gli squilibri esogeni. In Italia, la Strategia Nazionale per l'Economia Circolare, nell'ambito delle 63 riforme fondamentali per l'attuazione degli interventi del Piano Nazionale di Ripresa e Resilienza, ha individuato nella simbiosi industriale un modello produttivo necessario per la transizione verso l'economia circolare. Tale strategia prevede il sostegno allo sviluppo di progetti sul tema, anche attraverso adeguati strumenti normativi e finanziari.

A livello europeo, la Commissione consultiva per le trasformazioni industriali (CCMI) nel suo documento *"Prevedere i cambiamenti strutturali e settoriali e ripensare le culture industriali: verso nuove frontiere di ripresa e resilienza nelle diverse parti d'Europa "* del 2022, ha specificato che la diffusione e implementazione di strategie di circolarità e di simbiosi industriale favorisce la decarbonizzazione, l'efficienza e la produttività dei sistemi industriali e territoriali.

Vista, dunque, la crescente rilevanza della tematica, su iniziativa di SUN, del CTS di Ecomondo e di ENEA, l'8 novembre 2022 si è svolta ad Ecomondo la sesta edizione della conferenza della Rete Italiana di Simbiosi Industriale SUN – Symbiosis Users Network dal titolo *"La simbiosi industriale per la strategia nazionale di economia circolare"*.

L'obiettivo della conferenza è stato fornire una panoramica dei progressi compiuti finora in Italia sulla simbiosi industriale e ragionare circa le prospettive future con il contributo degli intervenuti. Questa edizione della conferenza, in particolare, ha offerto l'opportunità di presentare cosa la Strategia Nazionale per l'Economia Circolare prevede per la simbiosi industriale e discutere circa le opportunità per la promozione della simbiosi industriale nel nostro Paese.

La presentazione dei casi studio ed esperienze ha richiamato l'attenzione sull'importanza della simbiosi industriale come motore fondamentale nel processo di transizione verso un'economia circolare. I vari esperti, stakeholder e rappresentanti di istituzioni pubbliche e private che hanno condiviso le loro esperienze e buone pratiche hanno offerto una panoramica ampia sul percorso fatto finora in Italia sulla simbiosi industriale.

Sono stati presentati alcuni esempi di simbiosi industriale che affrontano tematiche strettamente industriali ed altri maggiormente di carattere metodologico. La ricerca, e le esperienze legate alla standardizzazione nonché l'analisi e la diffusione delle buone pratiche sono stati altresì punti di interesse e confronto durante il convegno.

I contributi qui raccolti riflettono la varietà di soggetti coinvolti sul tema della simbiosi industriale, provenienti dal mondo industriale, dalla pubblica amministrazione e dal mondo della ricerca e ci auguriamo possano insieme contribuire ad una maggiore e sistematica applicazione della simbiosi industriale nel nostro paese. Desideriamo, infine, ringraziare tutti coloro che hanno contribuito alla conferenza con il loro apporto di esperienze e riflessioni, tutti coloro che ci hanno onorato con la loro presenza e tutti coloro che hanno reso possibile la pubblicazione di questo lavoro.

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INTRODUCTION

Industrial Symbiosis (IS) is recognized nationally and internationally as an essential tool for increasing competitiveness, reducing dependence on raw materials, boost the economy and increasing the capacity of industrial and territorial ecosystems to compensate for external imbalances. In Italy, the National Strategy for the Circular Economy, as part of the 63 fundamental reforms for the implementation of the National Recovery and Resilience Plan, has identified industrial symbiosis as a production model needed for the transition to the circular economy. This strategy foresees support for the development of projects on industrial symbiosis, with the aim of adequate regulatory and financial tools.

At European level, the Consultative Commission for Industrial Change (CCMI) in its document "Anticipation of structural and sectoral change and reshaping industrial cultures — up to new borders of recovery and resilience in the different parts of Europe'" of 2022, specified that the dissemination and implementation of circularity and industrial symbiosis strategies supports decarbonisation, efficiency and productivity of industrial and territorial systems.

Therefore, given the growing relevance of the topic, SUN (Symbiosis Users Network), the Scientific Technical Committee of Ecomondo and ENEA promoted the sixth edition of SUN conference at Ecomondo on November 8th 2022 on "The industrial symbiosis for the national circular economy strategy".

This conference aimed to provide an overview of the progress made so far in Italy on industrial symbiosis and discuss future outlooks with the contribution of the participants. This edition of the conference, in particular, offered the opportunity to present what the National Strategy for the Circular Economy foresees for the industrial symbiosis and discuss about the opportunities for its promotion in our country.

The presentation of the case studies and experiences drew attention to the importance of industrial symbiosis as a fundamental driver in the transition process towards a circular economy. The various experts, stakeholders and representatives of public and private institutions who shared their experiences and best practices offered a broad overview of the progress made so far in Italy on industrial symbiosis.

Some practical examples of IS were presented: some of them were focused on industrial applications, some others were on methodological issues. Research and experiences related to standardization as well as the analysis and dissemination of good practices were also themes of interest and discussion during the conference.

The proceedings reflect the variety of subjects involved on industrial symbiosis, coming from industry, from public administration and from research. We hope they can together contribute to a greater and more systematic application of industrial symbiosis in Italy. Finally, we wish to thank all those who contributed to the conference with their experiences and contributions, all those who honored us with their presence and all those who made the publication of this work possible.

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THE IMPORTANCE OF CO-DESIGN IN THE DEVELOPMENT OF AN INDUSTRIAL SYMBIOSIS PROJECT

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ABSTRACT

From the collaboration between two B Corps, GARC (construction company) and InVento Innovation Lab (among the first B Corps certified in Italy and partner of B Lab Europe) an innovative training on circular economy and change making process have been developed for suppliers and partners, with the aim of developing the industrial symbiosis project REBOOT. REBOOT, launched in 2021 by Garc's subsidiary GARC Ambiente, aims to become a regenerative business network, which uses business as a positive force to foster a more just, inclusive and respectful society for the biosphere. Its success depends, in addition to research and innovation, on the relationship between people, i.e. through participatory co-design where synergies such as skills, assets, objectives and needs arise. Other key elements are: transversal partnership networks, transparent processes, advantage in exploiting existing and already used technologies with a renewed awareness, disruptive eco-innovation actions, inspired by the regenerative economy.

Keywords: *industrial symbiosis; B Corp; co-design; circular economy; regeneration*

Introduction

The construction sector is one of the main sources of consumption of materials and generation of special construction and demolition waste (the so-called C&D). Out of 100 billion tons of materials used each year, 38.8 are used in construction. The sector is responsible for the consumption of about 50% of all raw materials extracted worldwide: 42 billion tons per year [1]. The consumption of cement generates 3% of global emissions in the production phase alone, to which those due to transport and installation must be added [2], while buildings are responsible for 40% of primary energy consumption (mostly from non-renewable sources) and for 36% of CO_2 emissions. Furthermore, waste produced domestically is made up of approximately 45% of C&D waste (8.5 million tons in 2019) [3]. In the construction sector, however, a real circular revolution is underway, [2] of which GARC spa, a construction and waste management certified B Corp company, and InVento Innovation Lab, a B Corp certified social enterprise specialized in environmental and regenerative training and consultancy [4], have chosen to be protagonists.

Methods

GARC spa, together with its subsidiary GARC Ambiente, is committed to supporting the implementation of circular and regenerative models through an industrial symbiosis project (REBOOT). REBOOT involves the exchange of resources in order to create a common benefit, for companies and communities. The project, launched in 2021, is now in the development stage thanks to the search for eco-innovations together with a process of activation and co-design of partner companies. To this end, InVento Innovation Lab developed and carried out an activation path for GARC between March and June 2022, addressed to companies involved by GARC within the sector, with the specific purpose of setting the REBOOT symbiosis project in motion.

The REBOOT project

Based on the theoretical and practical principles that characterize a process of industrial symbiosis [5,6], the REBOOT project intends to put into practice the transition from a linear economy "consume, produce, dispose" to a circular economy, working on the five impact areas of B Corp: Governance, Workers, Community, Environment, Customers. In this way, it is possible to take into account the complexity of variables and elements that interact in daily processes, such as social, economic, energy, environmental, cultural and relational aspects. By leveraging an evolved and dynamic industrial district such as that of the "Via Emilia", the objectives of REBOOT are to promote the enhancement of resources and materials, reduce waste disposal and improve efficiency in the use of natural resources. By doing so it aims to decrease dependence of production on virgin raw materials and reduce the environmental impact of processes, making them sustainable for people and the ecosystem. The group of companies involved (GARC suppliers and partners) is comprehensive with respect to the necessary products and services in the complete life cycle of the built environment. In fact, it includes companies producing and trading green building products (e.g. Kerakoll spa, Imper Italia s.r.l., Unical SpA - Buzzi Unicem SpA group), construction companies (Garc spa, Mollo spa, Hilti Italia), IT service providers (Enerbrain srl), leading automotive companies and innovative technologies in general (Ducati Motor Holding SpA and Automobili Lamborghini SpA), automation and electrical distribution companies (Schneider Electric), waste treatment and disposal companies (Garc Ambiente spa).

The co-design path

Co-design is an approach that attempts to actively involve multiple stakeholders (e.g. employees, partners, customers) in the design process to meet their needs and enable them to be the active changemakers of their world. This approach, which relies on techniques and tools aimed at developing solutions that recognize and respond to the needs and rights of all at the ecosystem level, effectively responds to constantly evolving challenges on a local and global scale. [7, 8, 9, 10]. From the point of view of the facilitation process, the first important element is to ensure its objectives and aims are clear. A second significant condition is, for all parties involved, to be open to dialogue and active listening. There must be adequate resources, financial and human, to be able to plan, conduct and manage the process until the final decision is made [11]; moreover, the time and space in which the process takes place must be suitable for the group of people and the task to which it is called [12]. Starting from these principles, InVento Innovation Lab devised a cycle of workshops aimed at the design of industrial symbiosis solutions. First, InVento organized a training module designed to provide a common knowledge base on matters related to the 2030 Agenda, the B Corp and Benefit models and circular economy. Then, two workshops were held, the "Challenge Workshop" and the "Activism Workshop", led by expert facilitators on circular and regenerative economy. Finally, participants were provided with a toolbox, with various guidance materials and help on how to participate in the workshops. For the meetings, a large space was chosen, suitable for the number of participants and with broad views of the surrounding nature.

Challenge workshop

With the aim of analyzing the companies' business models, participants were divided in one group per company and asked to analyze all life stages of a company service or product of their choosing, following the basic principles of the Life Cycle Assessment (LCA). First the system boundaries were identified and then the main inputs and outputs (extracted materials and raw materials necessary for the process, assets, energy, machinery, infrastructures, main waste, main emissions). Participants were then invited to identify actions, good practices and projects to inspire change within their business and production models, taking into account: waste hierarchy, use of renewable energy sources, use of organic and non-toxic raw materials, business models (e.g. Product-As-A-Service, Upcycling, Life-extention) [13]. In order to foster the generation of ideas, in the toolbox, a set of cards for regenerative design was provided, divided into three categories (Materials and production, Products and services, Finance and Organization), which suggest actions to be implemented or templates to apply. The result was, for each group, a project presented in a plenary session.

Activism workshop

Based on the results that emerged in the Challenge Workshop, and in particular on the partnership needs expressed by companies, in the Activism Workshop two new working groups were created. The groups combined representatives of different companies with the aim of creating the conditions for collaboration between companies of the GARC supply chain within the model of industrial symbiosis. As a result, starting from the inputs and outputs of the production processes selected during the Challenge Workshop, participants generated two new projects of industrial symbiosis working on a canvas for circular design, which helped them identify objectives, characteristics and impacts of the project. The two outcomes were presented in a final plenary session, through a storytelling pitch, in order to launch a call to action to continue the process.

Figure 1. Some of the tools provided to the participants to the Challenge and Activism Workshops

Results

An idea that stands out among those generated by the working groups is a B2B (business-to-business) web platform for the exchange of industrial waste, aimed at optimizing the use of secondary raw materials and matching companies with differing businesses. The platform would collect technical data on the different materials obtained through laboratory tests and also would focus on reducing the logistical impacts created by any exchanges. The participatory design has also highlighted friction factors that must be taken into account in order to make a service more functional, such as a B2B platform for the exchange of resources in a broad sense, which is already tested, started and available (e.g. platform Symbiosis) [14].This, together with other ideas, shows the need of companies for innovative solutions in relation to processes along with new services or products. Also taking into account inputs emerged from the partners, the GARC Ambiente research center subsequently launched some in-depth studies related to eco-innovation: e.g. reconversion of materials resulting in useful raw materials for the ceramic industry, (e.g. bricks, cement and marble resins); recovery of waste materials in the textile industry; recovery of waste carbon fibers in the automotive sector; reconversion of plastic materials for the fabrication of products by means of 3D printing processes;

the reuse of plastic, wooden and other materials in bituminous and cementitious conglomerates.

The database allows to catalogue more than 1000 users and producers of industrial by-products. A first database inspection allows to highlight that about 65% of the companies are Producers and the other are Users. Then it is evident that mainly the companies which originate by-products are interested in the possibility to find a suitable way to reuse them. Table 1 reports the companies showing their regional location.

Conclusion

REBOOT is an industrial symbiosis project, implemented through a bottom-up approach, based on specific agreements between interlocutors [5, 6], which will create an interconnected territorial community for the exchange of materials, energy, skills or services. The co-design process was dedicated to companies that committed to deeply question their business models. This allowed to validate the importance of participation and of direct involvement of subjects as a key element of an innovative system of industrial symbiosis, that intends for strong relationships to be the main binding force. To this end, the creation of a "protected environment" was crucial. Training moments to create a common language were alternated with moments of inspiration, through the presentation of best practices of circular economy. Opportunities to network and build new partnerships were promoted through the sharing of ideas and needs, and through the co-design of solutions. The key elements of the success of REBOOT which emerged are: cross-sectional partnerships formed by subjects with complementary skills; transparent processes in which the exchange of information regarding the secondary raw material generated in the various production processes is facilitated; involvement of partners through co-planning, in order to better identify their needs, integrate their processes and prevent friction factors in the implementation of actions; the advantage of exploiting existing technologies that are already being used (e.g. BIM models, material passport) within an industrial symbiosis project with renewed awareness; disruptive eco-innovation actions, inspired by regenerative economy, which aim to replace raw materials in different supply chains thanks to the selective recovery of waste.

References

1. Di Stefano D. (2021). Cemento: Il materiale più distruttivo del mondo o una leva dell'evoluzione? Materia Rinnovabile numero 38 / Edilizia circolare, November 2021
2. Bompan E. e Caffi M. (2021). Unreal Estate: un nuovo modo di costruire, Materia Rinnovabile, Numero 38 / Edilizia circolare, November 2021

3. National Center for Waste and Circular Economy, Special Waste Report, Year 2021, ISPRA Report n. 345/2021
4. Sanford C. (2017). The Regenerative Business: Redesign Work, Cultivate Human Potential, Achieve Extraordinary Outcomes, October 10, 2017
5. Cutaia L. e Morabito R. (2012). Ruolo della Simbiosi industriale per la green economy, Uno strumento innovativo per la chiusura dei cicli delle risorse, EAI Speciale I-2012 Verso la green economy
6. M.R. Chertow (2000), Industrial Symbiosis: Literature and Taxonomy. Annual Review of Energy and Environment, 25: 313-337
7. Kuiper G. (2007). Participatory planning and design in the downtown east side: reflections on Global Studio Vancouver. Australian Planner 44, 52–53. doi: 10.1080/07293682.2007.9982573
8. Peña, D., Allen, D. J., Hester Jr., R. T., Hou, J., Lawson, L. L., et al. (2017). Design as Democracy: Techniques for Collective Creativity. Island Press: Washington, DC. doi: 10.5822/978-1-61091-848-0
9. Mitchell, V., Ross, T., Sims, R., and Parker, C. J. (2015). Empirical investigation of the impact of using co-design methods when generating proposals for sustainable travel solutions. CoDesign 12, 205–220. doi: 10.1080/15710882.2015.10 91894
10. Trischler, J., Pervan, S. J., Kelly, S. J., and Scott, D. R. (2018). The value of codesign. J. Serv. Res. 21, 75–100. doi: 10.1177/1094670517714060
11. Manconi L. (2015). Vantaggi e criticità dei processi partecipativi, FORMEZ PA, October 2015
12. Harrison Owen (2008). Open Space Technology – Guida all'uso, Genius Loci Editore.
13. Bompan Emanuele, Brambilla Ilaria Nicoletta (2021), Che cos'è l'Economia Circolare, Ambiente Edizioni
14. ENEA (2011-2015). Project "Supporto allo sviluppo produttivo nel Sud: interventi pilota per la sostenibilità e competitività del turismo e delle aree industriali", funded by MIUR

TOWARDS AN INDUSTRIAL SYMBIOSIS NETWORK IN MARCHE REGION: AN EXPLORATORY RESEARCH

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ABSTRACT

The enactment of industrial symbiosis (IS) networks requires the creation of synergies between organisations of traditionally separate industries (Chertow, 2000). To encourage inter-organisational collaboration, it is crucial to recognise local needs and make evidence about the potential benefits that IS may generate (Albino and Fraccascia, 2015). It requires a comprehensive investigation of the socio-economic conditions of the area and the identification of the key challenges hampering the exchange, sharing, or transaction of excess resources (including materials, energy, and water). As part of the "Connetti Marche" project, this research aims to explore the potential of an IS network in the hinterland of Macerata. The study is based on primary and secondary data oriented to characterise the economic activities first and engage relevant actors in perception surveys then. Specifically, semi-structured interviews have been performed. Data have been elaborated through SWOT analysis. Results reveal a high presence of manufacturing and artisan companies, mainly SMEs. Although IS represents an inspiring doorway, most companies do not recognise the added value that industrial synergies may provide to the economic rebound of the hinterland of Macerata (Italy). Only organisations operating in the food, chemical, construction and plastic sectors perceive the competitive advantage. The results reveal the need to involve different spheres of knowledge to increase awareness, stimulate new mindsets, and address cultural barriers by promoting a new way of doing business.

Keywords: Industrial symbiosis; network; Marche region; circular economy.

Introduction

Literature on circular economy highlights the role of inter-organisational collaboration in fostering resource efficiency in manufacturing sectors. One of the business models based on this mechanism is represented by Industrial Symbiosis (IS), i.e., the creation of corporate synergies based on services, scraps, energy valorisation and sharing [1, 2]. The first form of IS was applied in 1961 by companies located in the Industrial area of Kalundborg (DK). Started with a cooperative project between the Statoil refinery and the gypsum manufacturer Gyproc, it counts more than thirty resource exchanges today [3]. The analysis by Jacobsen [4] reveals a yearly reduction of 130.000 t of CO_2 and 15.000 $ of saving. The demonstrated economic, environmental and social gains have fostered the diffusion of multi-faceted industrial ecosystems worldwide. An emerging industrial practice is represented by Eco-industrial Parks (EIPs) [5,6]. Unlike Kalundborg, this form of IS relies on top-down approach, targeted investments and prior design of business synergies. In the USA, the Federal government encouraged the first EIPs in the Nineties [7]. Consolidated EIPs are primarily present in China today [8]. EIPs exist in UK, Germany, Spain and Italy, too [7]. In this regard, Italian EIPs evolved towards the so-called ecologically equipped production area (EEPA) based on unitary management of industrial facilities, including wastewater, energy plants, R&D and managerial centres. While EEPAs are developed in confined industrial areas, recent forms of IS go beyond geographic proximity [9] and industrial districts to embrace broader territorial areas, higher volume of exchange and consequently, the cost-effective economy of scale [9, 10]. An example is represented by the United Kingdom's National Industrial Symbiosis Programme (NISP) where the median distance materials travelled within a symbiotic relationship is 20,4 miles [11]. In addition to the UK, Italy registers most of the IS initiatives based on facilitated synergies turning on companies' network configurations [12].

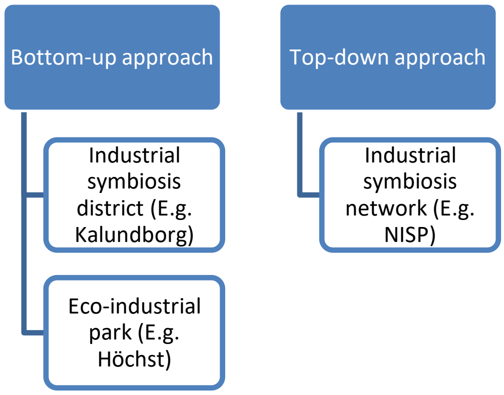

Figure 1. Forms of industrial symbiosis

Like the UK, Italian initiatives are based on the use of interactive platforms and the activation of partnerships [13]. The first experiment was implemented in South Italy, with 80 SMEs engaged and 690 potential matches identified [14]. Other experiments have been done in Emilia Romagna, Lazio, and Veneto [15, 16]. This work presents the results of exploratory research conducted in a not-scrutinised Italian region. As part of the "Connetti Marche" project, the study investigates the potential of IS to revitalise an industrial area hit by an earthquake in 2016. Following the ENEA [13] methodology, the paper summarises the walkway for an effective IS network implementation in a context characterised by small-medium sized and family-run organisations with diverse industrial settings.

Methods

The ENEA methodology is based on three main steps, including: 1. analysis of the productive sector; 2. data collection and 3. companies engagement and involvement through facilitation processes [13]. In this study, the sectorial analysis has been performed by collecting and elaborating data from the AIDA database.

Network activation relies on a stakeholder engagement plan. A relevance-interest matrix and a net map have supported the classification of target actors and the outline of perception surveys [18]. As opposed to those assessing factual knowledge, the perception survey used in this research aim to a. collect information about how organisations acquire, interpret, and organise the environment in which they operate; b. help measure the extent to which such perceptions affect the potential for a IS network. So, semi-structured interviews were performed. Interviews have been then transcribed and coded. Finally, data have been summarised in a SWOT analysis.

Results

Area of analysis

Around 166,661 economic activities are located in the region, of which 94% are micro-organisations, followed by small (5,3%), and medium (0,5%), while only 0,1% are big corporations. The economic trend from 2010 to 2020 shows the prevalence of wholesale and retail trade organisations, followed by the agriculture, construction and manufacturing sectors. The prevailing manufacturing industries are footwear and leather (19%), metallurgical activities (14%), furniture and wood companies (12%), textile and clothing enterprises (12%), followed by enterprises operating in the food, beverage and tobacco sectors (9%). The hinterland of Macerata contains 1,252 economic activities with a high presence of agricultural, forestry and fishing activities (see Fig.2). The manufacturing industry mainly includes food and beverage, metal, textile and footwear companies. The area is isolated from the rest of the region but contains the excellence of Made in Italy.

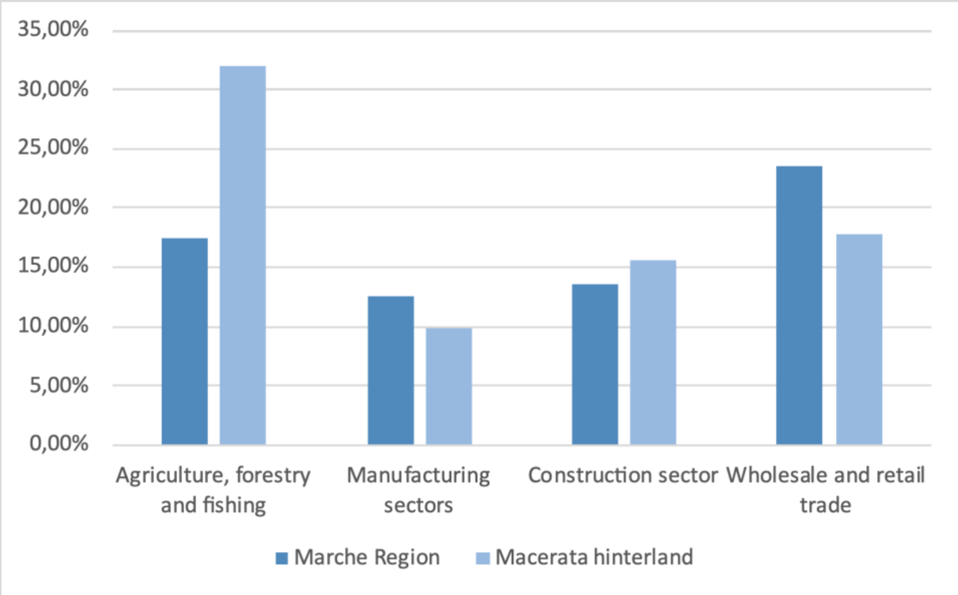

Figure 2. Economic trend in Marche region and Macerata hinterland (2020)

Interviews

The pilot project was based on the engagement of the most relevant organisations, detected after a stakeholder analysis. Specifically, 24 companies have been involved in interviews, of which 33% manufacture metal and glass-based products, 21% come from the furniture industry, and 13% are in the food sector. The remaining companies operate in the textile, plastics, wood and construction industries. The market is mainly international, while suppliers are local or national.

Questions about raw materials and waste have been posed first to stimulate interest and attractiveness towards the efficient use of resources. Regarding the supply chain, only 15 of 24 companies reveal an issue linked to unstable supply and price volatility. At the same time, only seven companies claim to use industrial residues as inputs to production processes. Concerning waste management, all mentioned the problem posed by packaging waste. Only the companies working in the furniture and leather sectors reveal the shortage of waste recycling facilities in the area. Food producers showed a high interest in waste valorisation.

The preliminary questions paved the way to introduce IS and examine the perception of local actors about this model. Most of the respondents showed a genuine interest in the initiative, overshadowed by a sceptical mode about its successful implementation in the area.

The relevance of local settings led the researchers to examine better the context in which the organisations occur. Social, economic, political, spatial and temporal aspects have been considered. Context data have been integrated with perception information in a SWOT analysis (see Fig. 3).

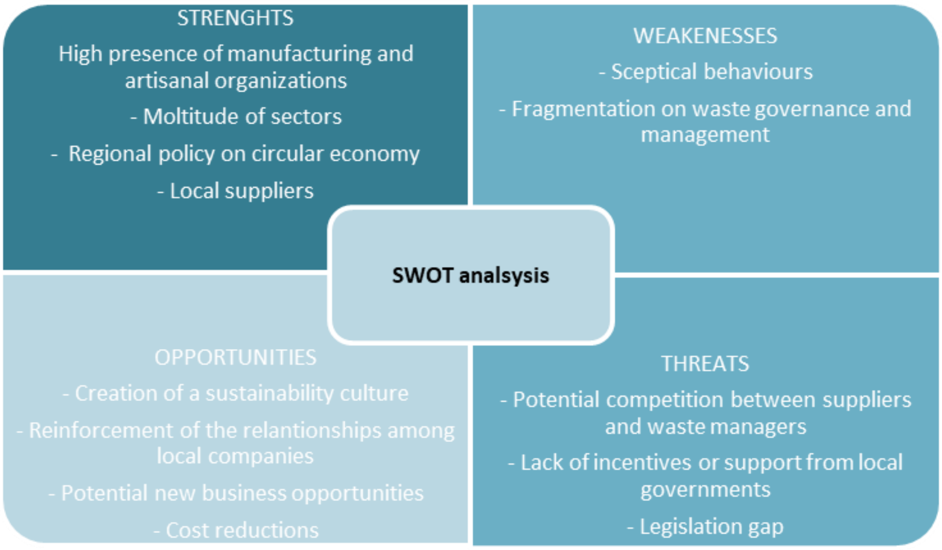

Figure 3. SWOT analysis

The SWOT analysis reveals the presence of a non-supportive environment reflected in the industry's scepticism, mainly motivated by a lack of information and, at the same time, attitude to innovate. The regional law on circular economy represents a good starting point to unlock normative and cultural barriers. However, a continuous, interactive awareness process is necessary to push new organisational models and consequently, new business culture.

Discussion and conclusion

The study highlights the perception of business players in a not-scrutinised industrial towards inter-organisational collaboration. Family-run businesses characterise the hinterland of Macerata with a long tradition in footwear, furniture and quality craftsmanship [18]. Despite the Made in Italy excellence, enterprises struggle to incorporate innovative practices into their organisations. The local supply of raw materials and semi-finished products represents an additional opportunity to design synergies among local businesses. The local business culture makes the implementation of IS network arduous.

Training activities and dissemination actions may increase the interest of local industrial players to rethink their businesses. Additionally, roundtables, focus groups, and more in general, multi-stakeholder dialogue may promote knowledge sharing, which can activate mutual trust and potential business opportunities. All these conditions prove the necessity of a new research area relying on new forms of IS for distinctive industrial sites where synergies become the outcomes of shared spheres of knowledge. The interplay between public and private entities remains fundamental to stimulating interests across different industries, including not only business and industrial players but also governmental entities, public agencies and research organisations, respectively supporting the provision of incentives, the promotion of innovative territorial processes and the implementation of new organisational models.

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References

1. Chertow, M. R. (2000). Industrial symbiosis: literature and taxonomy. Annual review of energy and the environment, 25(1), 313-337.
2. Albino, V., & Fraccascia, L. (2015). The industrial symbiosis approach: A classification of business models. Procedia Environmental Science, Engineering and Management, 2(3), 217-223.
3. Chopra, S. S., & Khanna, V. (2014). Understanding resilience in industrial symbiosis networks: Insights from network analysis. Journal of environmental management, 141, 86-94.
4. Jacobsen, N. B. (2006). Industrial symbiosis in Kalundborg, Denmark: a quantitative assessment of economic and environmental aspects. Journal of industrial ecology, 10(1-2), 239-255.
5. Chertow, M. R. (1998). The eco-industrial park model reconsidered. Journal of Industrial Ecology, 2(3), 8-10.
6. Chertow, M. R. (2000). Industrial symbiosis: literature and taxonomy. Annual review of energy and the environment, 25(1), 313-337.
7. Gibbs, D., & Deutz, P. (2007). Reflections on implementing industrial ecology through eco-industrial park development. Journal of Cleaner Production, 15(17), 1683-1695.
8. Hong, H., & Gasparatos, A. (2020). Eco-industrial parks in China: key institutional aspects, sustainability impacts, and implementation challenges. Journal of Cleaner Production, 274, 122853.
9. Lombardi, R., & Laybourn, P. (2012). b. Redefining Industrial Symbiosis. Crossing Academic–Practitioner Boundaries. Journal of industrial ecology, 16(1), 28-37.
10. Eleonora Foschi, Alessandra Bonoli (2017). The Sustainable Regeneration of An Industrial Area As Urban Laboratory Of Circular Economy And Industrial Symbiosis. SUN Proceeding.
11. Jensen, P. D., Basson, L., Hellawell, E. E., Bailey, M. R., & Leach, M. (2011). Quantifying 'geographic proximity': experiences from the United Kingdom's national industrial symbiosis programme. Resources, Conservation and Recycling, 55(7), 703-712.
12. Domenech, T., Bleischwitz, R., Doranova, A., Panayotopoulos, D., & Roman, L. (2019). Mapping Industrial Symbiosis Development in Europe_ typologies of networks, characteristics, performance and contribution to the Circular Economy. Resources, conservation and recycling, 141, 76-98.

13. Cutaia, L., Luciano, A., Barberio, G., Sbaffoni, S., Mancuso, E., Scagliarino, C., & La Monica, M. (2015). The experience of the first industrial symbiosis platform in Italy. Environmental Engineering and Management Journal, 14(7), 1521-1533.
14. Cutaia, L., Morabito, R., Barberio, G., Mancuso, E., Brunori, C., Spezzano, P., & Cappello, F. (2014). The project for the implementation of the industrial symbiosis platform in sicily: the progress after the first year of operation. In Pathways to Environmental Sustainability (pp. 205-214). Springer, Cham.
15. Foschi, E., & Bonoli, A. (2017). THE SUSTAINABLE REGENERATION OF AN INDUSTRIAL AREA AS URBAN LABORATORY OF CIRCULAR ECONOMY AND INDUSTRIAL SYMBIOSIS. 2017 ENEA, 25, 43.
16. Iacondini, A., Mencherini, U., Passarini, F., Vassura, I., Fanelli, A., & Cibotti, P. (2015). Feasibility of industrial symbiosis in Italy as an opportunity for economic development: Critical success factor analysis, impact and constrains of the specific Italian regulations. Waste and biomass valorisation, 6(5), 865-874.
17. Nelson, T. (2008). Perception question. In P. J. Lavrakas (Ed.), Encyclopedia of survey research methods (pp. 580-580). Sage Publications, Inc., https://dx.doi.org/10.4135/9781412963947.n374
18. Costa, I., & Ferrão, P. (2010). A case study of industrial symbiosis development using a middle-out approach. Journal of Cleaner Production, 18(10-11), 984-992.

A SURVEY ON THE INDUSTRIAL SYMBIOSIS IN ITALY – PRELIMINARY RESULTS

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ABSTRACT

Working Group 1 of the SUN -Symbiosis Users Network developed a questionnaire aiming at identifying best practices, achievements, drivers and obstacles to the development of industrial symbiosis in Italy. The mandate of the Working Group 1 was to understand the degree of national implementation of industrial symbiosis, but also to identify any critical issues that hinder its effective and efficient application. The results of the survey may be used to define and propose new policies supporting the industrial symbiosis. A wide and open knowledge on best practices may also stimulate companies and local authorities to find new opportunities and solutions to improve circularity of industrial processes. Preliminary results show that only half of the players participating in the survey achieved a positive result and that most of the best practices indentified involves a material exchange in industrial sectors. Also the role of by-products is limited, with a relevant role still played by wastes and end of waste materials.

Keywords: Industrial symbiosis; by-products; best practices; main drivers; obstacles.

Introduction

Industrial symbiosis, by improving the productivity of resources and reducing the production of waste, which represent two important indicators for measuring the level of circularity of a country, plays a strategic role in improving the level of circularity of the Italian economy, which is already positioned in Europe as protagonist, [1]. Positive experiences of industrial symbiosis can contribute significantly to the achievement and improvement of this positioning. Some of them are well-established economic activities with a long tradition, to the point of not even being perceived as such, while others are highly innovative and can represent an important element of discontinuity, necessary to achieve a higher degree of circularity in the national economy. But there is still ample unexpressed potential [2]. Not only economic but also environmental and social results at the organizational level stem from the strategy execution and the technology and natural resources utilization in the production system, according to the legislation. Consequently drivers and barriers affect the success of industrial symbiosis initiatives [3] such as colocation and proximity, economic reasons, and by-product destination as well as barriers such as asymmetries, dependency, cost, risk, and environmental regulation [4]. Best practices should be therefore highlighted and experiences, both positive and negative, should be shared between operator and stakeholders in order to improve the role of industrial symbiosis in our economy [5] and to measure the level of IS implementation at different scales and with different methods [6, 7].

The Working Group 1 of the SUN -Symbiosis Users Network launched survey through a questionnaire aiming at identifying best practices, achievements, drivers and obstacles to the development of industrial symbiosis in Italy. The mandate of the Working Group 1 was to understand the degree of national implementation of industrial symbiosis, but also to identify any critical issues that hinder its effective and efficient application.

The results of the survey are mainly intended to be used by other Working Groups of the Symbiosis Users Network in order to define and propose new policies supporting the industrial symbiosis. Results may also be used by any other stakeholders having an active role in the industrial symbiosis to drive their decisions. A wide and open knowledge on best practices may also stimulate companies and local authorities to find new opportunities, getting in touch with new operators and find innovative solutions to improve circularity of industrial processes.

Methods

The study is based on a questionnaire developed by the Working Group 1 of the SUN -Symbiosis Users Network [8]. The questionnaire was shared between the other Working Groups in order to collect comments and input for improvements and finally published in a web-based tool on the SUN -Symbiosis Users Network website.

The survey is divided in three section, depending on the experience of the respondent. The first section is addressed to companies that have successfully implemented industrial symbiosis paths, while the second section is addressed to companies that have tried to initiate a symbiosis path but were not able to complete it and finally the third section is dedicated to companies that have never embarked on industrial symbiosis.

First section content

First section is structured in a way to get a full picture of the symbiosis action, including a detailed description of the symbiosis action, drivers and success factors.

The first section, is structured with questions aimed at investigating:

a) the reasons that prompted the company to start paths of industrial symbiosis;
b) the characteristics of the shared resources in terms of typology (material, energy, service), legal status (by-product, end of waste, secondary raw material, waste), flow (sold or acquired resource), quantity, economic value;
c) the business sector of the companies involved;
d) the achieved benefits;
e) the elements of facilitation;
f) the problems and barriers encountered;
g) the use of industrial symbiosis measurement systems or standards for measuring environmental performance.

The full set of question is detailed in Table 1.

Table 1. Set of questions of section 1

Section 1 – Questions content
• Rationale • Classification of the resource (material, energy, service, competence) • Resource as input/ output • Further details about the resource • Sector of origin of the resource • Sector of destination of the resource • Quantity • Number of subject involved • Results, impacts, benefits, outcomes (in term of economy and employment) • Instruments for measuring industrial symbiosis and/or standards for measuring environmental aspects • Results, impacts, benefits, outcomes (in termo of environment and circularity) • Economic value • Responsible for the trasport of the resuource • Legal status of the resource • Starting date • Actual status • Ending date • Facilitation elements • Obstacles/difficulties/limits • Established/innovative practice • Replicability/Expansion conditions • References • Company and contacts

Second section content

Second section aims at investigating the difficulties faced when the company have tried to apply a new symbiosis action but have not managed to complete the identified paths. In this case the questions are in part those of the previous section with the exception of information on economic valorisation and facilitation. The full set of question is detailed in Table 2

Table 2. Set of questions of section 2

Section 2 – Questions content
• Rationale • Classification of the resource (material, energy, service, competence) • Resource as input/ output • Further details about the resource • Sector of origin of the resource • Sector of destination of the resource • Obstacles/difficulties/limits • Established/innovative practice • Further details about the difficulties • Company and contacts

Third section content

Third section aims at investigating the difficulties faced when the company tryed to apply a new symbiosis action. The full set of question is detailed in Table 3

Table 3. Set of questions of section 3

Section 3 – Questions content
• Rationale (not aware of symbiosis, no residue to exchange, residues already used internally, performance concerns, regulatory limits, lack of internal compentence, lack of RD resources, other)

Results

To date, 61 Italian companies have participated in the survey, most of which operating in Sicily (41%) followed by companies operating in Lombardy (16%), Tuscany (13%), Emilia Romagna (7%), Marche (5%) , Lazio, Veneto and Campania (3%), Valle d'Aosta and Friuli Venezia Giulia (2%).

The survey revealed that more than half of the companies (56%) have started a path of industrial symbiosis, declaring a success rate of 49% in terms of successful conclusion of the process (Figure 1a). Among these, the main sector of activity is manufacturing (63%), followed by water supply services, management of sewage networks and waste management (15%), by the agriculture, forestry and fishing sector (11%), construction (4%), wholesale trade (4%) and electricity supply (3%) (Figure 1b).

However, the analysis of the shared resources revealed that only in 27% of declared successful cases, the legal status is by-product, while in 40% of cases the resource transferred is classified as “end of waste” or secondary raw material and in 23% it consists instead of waste (Figure 2a). Therefore, it must be assumed that the actual cases of industrial symbiosis represent a portion of those declared, bringing the percentage of companies that have actually implemented industrial symbiosis pathways to 13%.

The shared resources were materials for the 80% and energy for the remaining 20% of the energy (Figure 2 b and c).

The transfer of resources mainly takes place through an economic valorisation in favor of the producer (47%), which therefore benefits from the economic advantages deriving from the industrial symbiosis. In 40% of cases, on the other hand, the transfer of resources takes place without any economic valorisation and therefore the competitive advantages mainly derive from the reduction of the costs for residue management and for the supply of raw materials (Figure 2d).

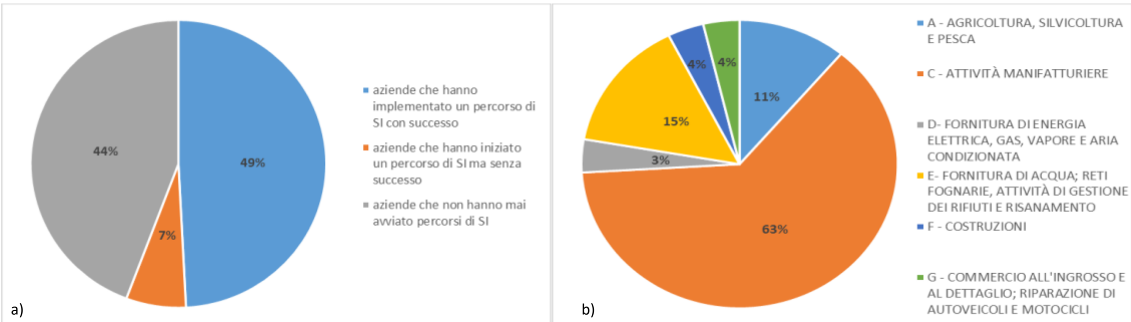

Figure 1. a) State of implementation of the SI declared by the companies and b) sector of activities

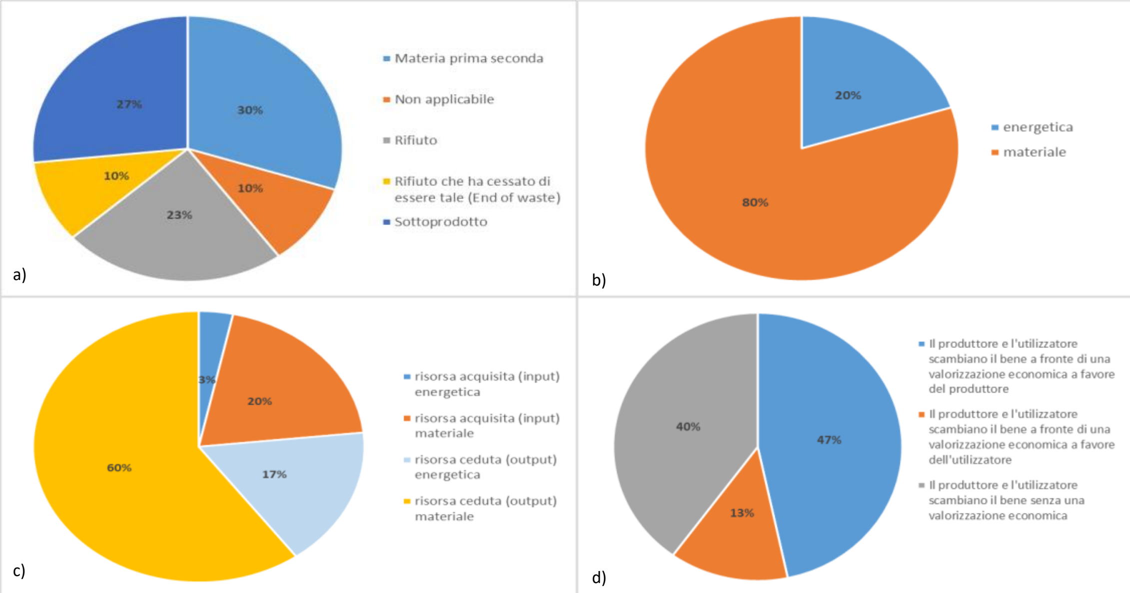

Figure 2. Type of shared resources and economic valorisation: a) legal status of the transferred resources; b) characteristics of the resources transferred; c) type of flow (acquired or sold); d) economic valorization

Conclusions

Even if the sample of this survey is limited and the representativeness cannot yet be considered sufficient to draw a full picture, the preliminary results clearly show that there are still relevant obstacles to industrial symbiosis in Italy. Preliminary results show that only half of the players participating in the survey declared to achieve a positive result. The main obstacles can be identified in the lack of incentives, in particular for those activities which may compete with well-established linear economies, and the regulatory uncertainty which affect in particular the legislation on by-products and wastes. Improving the knowledge of best practices may therefore help the actors of the industrial symbiosis to get a higher level of recognition by the market, the final consumers and the legislator.

Most of the best practices identified involves a material exchange in industrial sectors. Energy exchange is less relevant, probably to the higher constrains due to the transport and storage, while the exchange of services and/or competences is probably still not yet perceived as a symbiosis action.

Relevant to notice that the role of by-products is limited, with a relevant role still played by wastes and end of waste materials. This element can be directly linked to the regulatory uncertainty and the fact that by-product legislation is still not fully recognized by the industrial operators and local authorities.

The experience conducted by the Working Group 1 also shows that the questionnaire was well balanced and targeted but the coverage needs to be improved in order to increase the representativeness of the results. This will be one of the goal of the future activities of the Working Group 1 of SUN.

References

1. Circular Economy Network, 2022. 4° Rapporto sull'economia circolare in Italia
2. Neves, A.; Godina, R.; G. Azevedo, S.; Pimentel, C.; C.O. Matias, J. The Potential of Industrial Symbiosis: Case Analysis and Main Drivers and Barriers to Its Implementation. Sustainability 2019, 11, 7095. https://doi.org/10.3390/su11247095
3. Miguel Afonso Sellitto, Fábio Kazuhiro Murakami, Maria Angela Butturi, Simona Marinelli, Nelson Kadel Jr., Bianca Rimini, Barriers, drivers, and relationships in industrial symbiosis of a network of Brazilian manufacturing companies, Sustainable Production and Consumption. 2021, 6: 443-454. https://doi.org/10.1016/j.spc.2020.09.016
4. Walls, J. L., & Paquin, R. L. (2015). Organizational Perspectives of Industrial Symbiosis: A Review and Synthesis. Organization & Environment, 28(1), 32–53. https://doi.org/10.1177/1086026615575333
5. Oughton, C., Kurup, B., Anda, M. et al. Industrial Symbiosis to Circular Economy: What Does the Literature Reveal for a Successful Complex Industrial Area?. Circ.Econ.Sust. 2022, 2:1317–1344. https://doi.org/10.1007/s43615-022-00153-1
6. Luca Fraccascia, Ilaria Giannoccaro, What, where, and how measuring industrial symbiosis: A reasoned taxonomy of relevant indicators, Resources, Conservation and Recycling. 2020:157: 104799. https://doi.org/10.1016/j.resconrec.2020.104799
7. Luca Fraccascia, Ilaria Giannoccaro, Vito Albino. Ecosystem indicators for measuring industrial symbiosis. Ecological Economics. 2021: 183: 106944. https://doi.org/10.1016/j.ecolecon.2021.106944

SUN questionnaire on industrial symbiosis https://www.sunetwork.it/attivita/gruppo-di-lavoro-1/questionario.html

DEFINITION OF POTENTIAL INDUSTRIAL SYMBIOSIS PATHS BASED ON THE TRANSFER OF EAF BLACK SLAG

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ABSTRACT

Italy is the leading European producer of electric arc furnace steel. Within this production cycle, the main by-product is the slag. Today the slag is mainly used in the constructions; however, almost 30% of the black slag produced in Lombardy is still disposed of. It is important to investigate new applications for this industrial waste; the application proposed in this study is the use of slag as a filler for rubber matrix to create a new material that is sustainable in economic and environmental terms. In this context, possible symbiotic paths between the steel sector and the rubber sector have been named through the AIDA database and ATECO 2007 codes. This geographical subdivision was then flanked by the classification by size of enterprises. The management of EAF slag has been as waste and by-product, highlighting the advantages that this latter case would imply in a context of industrial symbiosis.

Keywords: Black slag; EAF slag; industrial symbiosis; steelmaking; waste reuse

Introduction

Italy is the leading European producer of electric arc furnace steel (ie from ferrous scrap) with an annual production of about 17-20 million tons[2]. Within this production cycle, the main waste is the black slag which represents about 10-15% of the produced steel [6,12,13]. Today the slag is mainly used in the building field as an artificial aggregate for road construction, and cement and concrete production[5,8,9,11]; however, from an estimate by Federacciai (Sustainability Report 2021 [3]) it was highlighted that almost 30% of the black slag produced is still disposed of in landfills, with a much higher percentage than what happens on average in the EU (based on EUROSLAG data, the percentage of steel slag disposed of in landfills in the main EU countries is estimated to be around 15%)[3].

It is therefore of fundamental importance to study new applications for this industrial waste; the application proposed in this study is the use of slag as a filler for elastomeric matrices to create a new material that is sustainable in economic and environmental terms.

In this context, possible symbiotic paths between the steel sector and the rubber sector have been identified through the AIDA database and ATECO 2007 codes: 24.00.00 "Iron and steel industry - Manufacture of iron, steel and ferroalloys" and 22.19.09 "Manufacturing of other rubber parts n.e.c.". in-depth also at the provincial level. This geographical subdivision was then flanked by the classification by type of enterprise (micro, small, medium and large) in accordance with the European Union Recommendation no. 2003/361 / EC. From a regulatory point of view, the application of the by-product regulation articulated in art. 184-bis [10], introduced in Legislative Decree 152/2006 is studied for the case of EAF slag highlighting the critical issues related mainly to the burden of proof [1]. The management of slag as a by-product in a context of industrial symbiosis was deepened, identifying the possible flows, actors and economic advantages.

Methods

Management of EAF sla gas by product

In the already implemented system of transfer of EAF slag as by-product as artificial aggregate, the producer of the EAF black slag commercializes material with CE marking, proving that the characteristics follow those declared in accordance with the UNI 13242 standard on recycled aggregates. The manufacturer must therefore have a factory production control manual, or a set of verification and control procedures that are conducted on the entire process, thus ensuring that it can promptly find and correct any deviations of the material from the declared characteristics.

In this context, to enhance the amount of slag currently disposed of, in this study it is proposed to integrate the current cooperation (building sector) with that involving the innovative application of slag as filler for rubber matrix in fine grain size.

The flows map sees the crushing of the slag for the recovery of the metal, after which the coarse particle size fraction (by-product) can be destined for the building sector which uses it as a substitute for natural aggregates and the fine fraction (by-product of the by-product) can be used as a filler in polymeric matrices (**Error! Reference source not found.**).

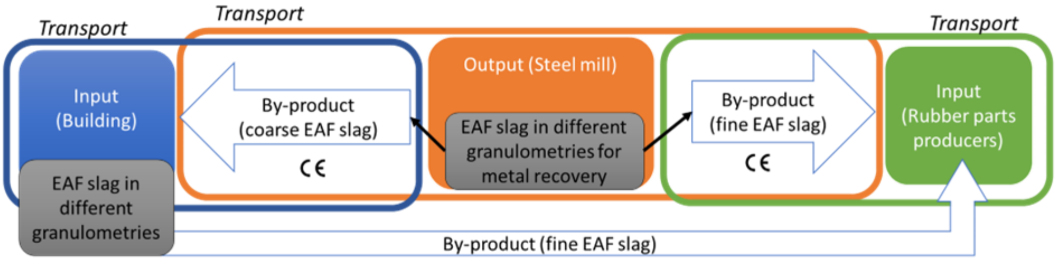

Figure 1. Possible flows of EAF slag as a by-product in a context of Industrial Symbiosis.

Management of EAF sla gas by product

The actors involved into this potential industrial symbiosis have been named by AIDA database based on ATECO 2007 codes. In Italy, economic activities can be classified according to the type of business and ATECO is the classification of economic activities adopted by ISTAT for statistical purposes, that is, for the production and dissemination of official statistical data. On the basis of ATECO criteria [7], companies operating in the steelmaking belong to number 24.00.00 "Iron and steel industry - Manufacture of iron, steel and ferroalloys", that operating in rubber parts production belong to number 22.19.09 "Manufacturing of other rubber parts n.e.c." and that operating in building sectors belong to numbers 23.51 "Concrete Production", 42.11 "Construction of roads and highways", 23.61 "Manufacture of concrete products for construction".

Moreover, thanks to the same database it was possible to define a further classification by size of enterprise: micro, small, medium, and large following European Union Recommendation no. 2003/361 / EC.

Thanks to a questionnaire completed by 3 Lombard steel mills, economic considerations were done.

On the basis of the potential symbiotic flows, the regulations that regulate the by-product (specifically slag as a by-product), and the technical characteristics of rubber filled with EAF slag (for details see [4]) considerations relating to advantages , disadvantages and criticalities relating to the new use of slag in the context of industrial symbiosis between the steel sector and the rubber sector have been made.

The results are summarized in Figure 5.

Results

The Italian large-size enterprises belonging to the aforementioned sectors, have been geographically subdivided by region, as shown in **Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**. It emerged that about 50% of large-size business in the steel and rubber sectors are in Lombardy so that this region was subdivided also in provinces.

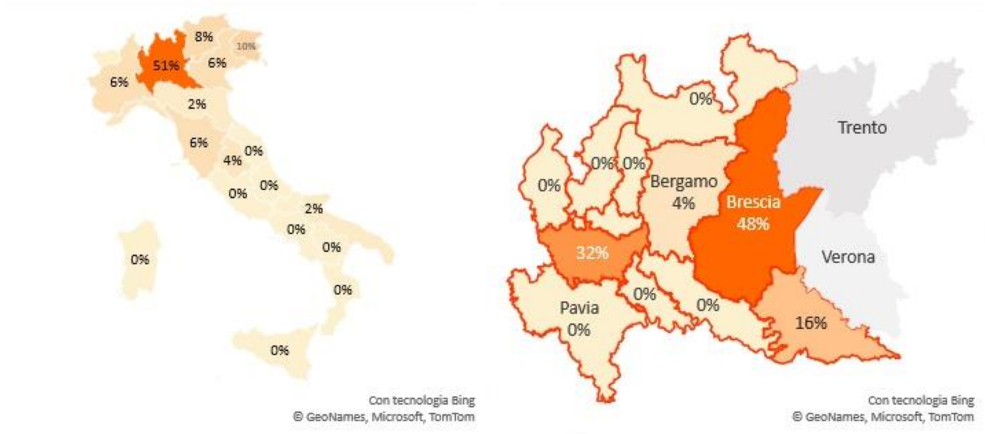

Figure 2. Regional and provincial subdivision of large-size enterprises ATECO 2007 24.00.00 Iron and steel industry - Manufacture of iron, steel and ferro-alloys.

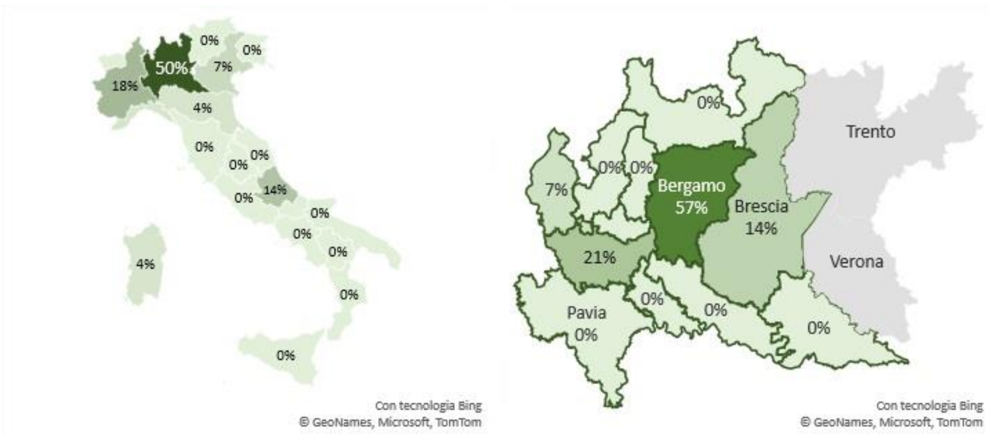

Figure 3. Regional and provincial subdivision of large-size enterprises ATECO 2007 22.19.09 Manufacturing of other rubber parts n.e.c.

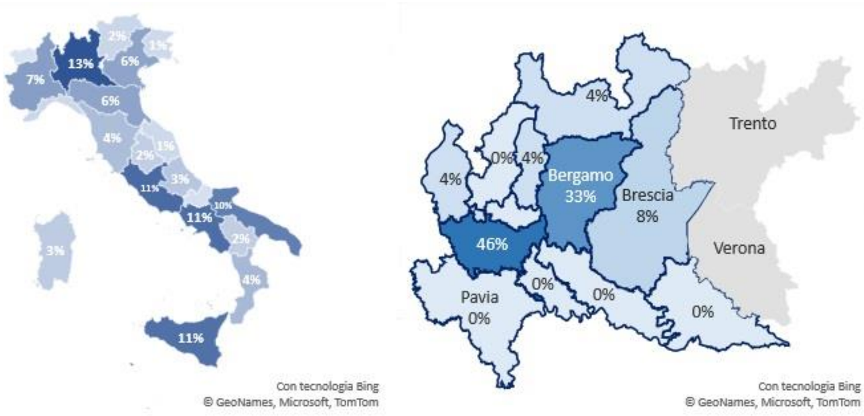

Figure 4. Regional and provincial subdivision of large-size enterprises ATECO 2007 23.51 Concrete Production, 42.11 Construction of roads and highways, 23.61 Manufacture of concrete products for construction.

	PROCESS	DETAILS	BENEFITS	CRITICAL ISSUES
OUTPUT	Grinding	crushing with jaw crusher and iron removal cone or hammer mill and iron removal mill fed with sizes <30mm (2 passes to obtain 100% less than 0.1mm)	+ 5/8% recovered metals compared to coarse sizes	Energy-intensive process estimated cost about 40 € / ton
INPUT	Compounding	Compounding of slag as filler in the polymer matrix for a moulding	The formulation of each compound is to be defined according to the final application	
INPUT	Moulding	The non-vulcanized compound is heat-moulded to produce vulcanized rubber items. The problems related to the process will have to be addressed in relation to the formulation of the compound.	faster vulcanization	Higher viscosity
REGULATION	BY-PRODUCT			
REGULATION	The national regulation of the by-product is articulated in art. 184-bis	No need for explicit authorization by specific entities and the general nature of some of the conditions set do not ease the burden of proof. Failure to prove the conditions results in criminal consequences (unauthorized waste management pursuant to Article 256 of the Consolidated Law on the Environment), resulting in a disincentive.		Burden of proof
REGULATION	paragraph 1	Establishes the conditions that the substance or object must meet to be considered a by-product and not a waste		
REGULATION	paragraph 2	Supports the possibility of adopting measures to establish qualitative or quantitative criteria to be met so that specific types of substances or objects are considered by-products and not waste		
REGULATION	DM n.264 13/10/16	Establishment at the Chambers of Commerce of a public list of by-products in which producers and users of by-products can register. It does not form an enabling requirement but only has the function of facilitating exchanges.	Facilitating the exchange of by-products	
REGULATION	SLAG AS BYPRODUCT			
REGULATION	UNI EN 1744-3 Tests to determine the chemical properties of the aggregates	Verification of conformity of aggregates of iron and steel origin for non-related uses. The test results must follow the limits imposed by the Ministerial Decree of 5 March 1998 "Identification of non-hazardous waste subjected to simplified recovery procedures" (with the addition of the Mo set at 0.15mg / l)		it is a specific procedure for the use of slag as an artificial aggregate and therefore in coarse grain size (32-16mm)
REGULATION	SLAG AS WASTE			
REGULATION	EN 12457-2 Conformity test for leaching of granular waste and sludge	Verification of conformity for the leaching of granular waste and sludge. The results of the test must follow the limits imposed by the Ministerial Decree of 3 August 2005 "Definition of criteria for the admissibility of waste in landfills" or by the Ministerial Decree of 5 March 1998 "Identification of non-hazardous waste subjected to simplified recovery procedures"	More severe test Experimental data have shown how the incorporation of slag particles (<0.1mm) in virgin NBR makes the material suitable for disposal as inert	
CHARACTERISTICS (EAF slag as filler in NBR Standard)[4]	Processability	Rheometric curve to assess the vulcanization kinetics	Faster vulcanization (Possibility to reduce the amount of accelerators in the formulation)	Risk of defects on the finished piece Higher viscosity, higher moulding pressures
CHARACTERISTICS (EAF slag as filler in NBR Standard)[4]	Mechanical properties	Hardness	It increases in proportion to the% of slag	
		Tensile properties	Elastic modulus increase	Reduction of stress and deformation at break (like other inert fillers)
		Compression properties	The stress needed to achieve equal deformations increases	
		Stress relaxation	Up to 10% v / v of added slag there are no detrimental effects	From 20% of added slag, it may have a loss of tightness.
		Compression set	Up to 10% v / v of added slag is still good	From 20% of added slag, it exceeds 15%.
		Dynamic-mechanical behaviour)	Damping capacity unaffected	
	Physic-chemical properties	Density	It increases in proportion to the% of slag	
		Swelling behaviour in solvent (toluene)	Greater dimensional stability	
	Thermal properties	Thermal capacity	Reduction of the insulating capacity of the rubber	
	Magnetic properties	The slag gives the rubber more or less strong magnetic properties depending on the type of slag	Possibility of handling rubber parts by means of magnets, reducing the risk of damage caused by clamping tools	

Figure 5. Summary of the assessment of the reuses of EAF slag as by-product.

Discussion and conclusion

The present study focuses on the possible benefits derived from the management of EAF black slag as by-product with specific focus on the reuse of it as filler for polymeric matrix in view of industrial symbiosis. The slag can be considered of the by-product as its production is unavoidable and it is functional to the steel production itself. Slag represents more than 90% by mass of all by-products of iron and steel production. Italy is the European leading producer of steel by EAF, so as black slag consists in about 10-15% of the produced steel it is estimated that it produces about 2.3Mt of black slag every year. To implement a new industrial symbiosis based on the EAF black slag transfer it was mandatory to study the geographical distribution of steelmaking industries. This study has been carried out thanks to AIDA database focusing on ATECO 2007 code 24.00.00 “Iron and steel industry - Manufacture of iron, steel and ferroalloys”. It was found that more than 40% of the companies working in this sector is in Lombardy, where more 50% of the Italian large-scale enterprises (according to European Union Recommendation no. 2003/361 / EC) are located. Unfortunately, it was estimated by Federacciai in its Sustainability report 2020 that 27% of black slag in Lombardy it is still disposed of, unlike the European average of 15%. This could be attributable to the fact that Italy produces a greater quantity of slag and moreover concentrates it in Lombardy, so it is plausible that the construction sector that uses it as an artificial aggregate is not be able to absorb more of it. Because of this it is necessary to investigate innovative applications of EAF black slag, and that proposed in the project of which this study is part, is that of the reuse as filler for rubber matrix thanks to the geographical proximity of the rubber parts producers with steel mills, requirement for the industrial symbiosis implementation. The geographical distribution of these last companies has been carried out thanks to AIDA database focusing on ATECO 2007 code 22.19.09 “Manufacturing of other rubber parts n.e.c.”. Also, in this case more than 50% of the Italian large-scale enterprises is in Lombardy. These results suggest that that there are prerequisites for the implementation the industrial symbiosis so that possible scenarios and actors involved are defined. The management of the slag has been discussed as “waste” and “by-product”, whit a digression on the “end of waste”, in particular a brief economic assessment of the costs and benefits of the innovative application of slag has been carried out. It was showed that not only does the reuse of slag bring economic benefits to steel mills if it is valued as an artificial aggregate (application currently in use), but the economic benefits could be even greater if it is valued as a filler. Indeed, in fact, facing a higher processing cost, the reduction in particle size below 0.1mm of the slag would make it a sustainable and cheap allowing to save virgin rubber. Steel mills could even make a profit from selling the slag as a filler, and rubber producers could save virgin material with consequent environmental benefits.

References

1. Daniela Claps, Laura Cutaia, Tiziana Beltrani, et al. 2020. L'applicazione della disciplina del sottoprodotto in Italia quale leva strategica per la competitività delle imprese: uno scenario giuridico amministrativo in evoluzione. Symbiosis Users Network – SUN Proceedings of the fourth SUN Conference.
2. Federacciai. 2021. Relazione Annuale 2021. .
3. Federacciai. 2021. Rapporto di sostenibilità 2021. .
4. Anna Gobetti, Giovanna Cornacchia, and Giorgio Ramorino. 2022. Reuse of Electric Arc Furnace Slag as Filler for Nitrile Butadiene Rubber. JOM.
5. J. Guo, Y. Bao, and M. Wang. 2018. Steel slag in China: Treatment, recycling, and management. Waste Management 78: 318–330.
6. Soraya Hosseini, Salman Masoudi Soltani, Paul S. Fennell, Thomas S.Y. Choong, and Mohamed Kheireddine Aroua. 2016. Production and applications of electric-arc-furnace slag as solid waste in environmental technologies: a review. Environmental Technology Reviews 5, 1–11.
7. Istituto Nazionale di Statistica. 2007. CLASSIFICAZIONE DELLE ATTIVITÀ ECONOMICHE ATECO. ISTAT. Retrieved July 1, 2022 from https://www.istat.it/it/archivio/17888.
8. J.W. Lim, L.H. Chew, T.S.Y. Choong, C. Tezara, and M.H. Yazdi. 2016. Utilizing steel slag in environmental application - An overview. IOP Conference Series: Earth and Environmental Science.
9. Ismael Matino, Valentina Colla, Teresa Annunziata Branca, and Lea Romaniello. 2017. Optimization of By-Products Reuse in the Steel Industry: Valorization of Secondary Resources with a Particular Attention on Their Pelletization. Waste and Biomass Valorization.
10. Ministero della tutela dell'ambiente e del territorio. 2006. Norme in materia ambientale. (GU Serie Generale n.88 del 14-04-2006 - Suppl. Ordinario n. 96). La gazzetta ufficiale della repubblica Italiana.
11. D. Mombelli, C. Mapelli, S. Barella, C. Di Cecca, G. Le Saout, and E. Garcia-Diaz. 2016. The effect of microstructure on the leaching behaviour of electric arc furnace (EAF) carbon steel slag. Process Safety and Environmental Protection 102: 810–821.
12. N.M. Piatak, M.B. Parsons, and R.R. Seal. 2015. Characteristics and environmental aspects of slag: A review. Applied Geochemistry 57: 236–266.
13. S. K. Singh, Prabhat Vashistha, Ramesh Chandra, and Anand K. Rai. 2021. Study on leaching of electric arc furnace (EAF) slag for its sustainable applications as construction material. Process Safety and Environmental Protection 148.

ANALYSIS OF POSSIBLE SCENARIOS FOR THE VALORIZATION OF WASTE FROM THE MARCHE'S CONSTRUCTION AND AGRIBUSINESS SECTORS

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ABSTRACT

The current production system involves a linear process: you take raw materials, use them to make your product, and generate waste. This has inevitably led to the overexploitation of the planet's resources and problems with the disposal of disproportionate amounts of waste. The system is clearly in crisis and this is not helping the economy at all, much less the climate emergency to which, if anything, it is contributing. Industrial symbiosis presents itself as a solution that can reduce polluting emissions and achieve a profitable and sustainable economy. Its implementation requires that the right conditions be in place to succeed in creating a true network of companies in connection with each other. The paper includes in the initial part an excursus on industrial symbiosis practices with some examples and then focuses on the area of interest, analyzing the business fabric and dissecting it through choice criteria in order to highlight possible situations favorable to this methodology. The work was carried out during the internship activity at Enea, as part of the Marlic project for the Marche region. However, the study aims to seek replicable solutions in places and contexts even different from the one examined; the goal is to further demonstrate the effectiveness and efficiency of the methodology by offering plausible alternatives.

Keywords: Circular Economy; Industrial Symbiosis; Waste, Recycling.

Introduction

Today's production system is in crisis, and highlighting this are the difficulties in sourcing materials, scarcity of resources, and saturation of waste disposal capacity, which inevitably limit the economic growth of many businesses. The linear model is not sustainable economically, let alone environmentally. The circular economy is the most sensible alternative if economic development is to be achieved while respecting the environment and its resources [1].

For this purpose, Industrial Symbiosis is positioned as a highly effective tool, capable of creating an interconnected network for the exchange of by-products, energy, knowledge and information for the benefit of all participants. The work was carried out during the internship activity at ENEA, as part of the Marlic project, funded by the

Marche regional program, which aims to set up a regional collaborative research laboratory in areas affected by the earthquake on the issues of eco-sustainability of products and processes for new materials and on demanunfacturing. To this end, a preliminary analysis was carried out on some sectors of interest in the business fabric of the Marche region in order to derive hypothetical scenarios of waste valorization from a circular perspective.

Methods

The methodology used for the analysis involved definite steps. In the initial phase, there was the identification of the sectors of interest for the study, based on an assessment of economic and environmental indices, and the subsequent identification of the relevant entrepreneurial realities in the Marche region through AIDA databases, using the ATECO 2007 commodity classification. Next, a characterization of the entrepreneurial fabric, exploiting Istat, Ecocerved and Chamber of Commerce data. Next, the focus shifted to the economic context in which the identified companies fit and then to the identification of input and output resource flows that characterize the supply chain and related production processes. Finally, a literature search was carried out to identify the technologies and methods of valorization of the by-products coming out of the aforementioned processes and, therefore, possible scenarios of industrial symbiosis hypothesized for the companies in the Marche region, but also replicable in contexts and places other than the latter.

Results

The methodology applied to the sectors of interest returned potential collaborations for companies in the Marche region, expressed by synergistic layouts showing the resource flows and ATECO codes of the companies involved.

Construction & Demolition Sector

The first of the two sectors analyzed was Construction and Demolition, identified by ATECO 2007 codes F:41, 42, 43. The choice was mainly due to the quantities of special waste produced by the said sector (about 3 percent of the total for the Marche region) and the disposal problems arising from it [2][3][4]. The analysis of resource flows in input and output to the production process suggested a valorization scenario involving the reintroduction of by-products and waste within the same cycle, after appropriate reprocessing entrusted to intermediate companies. In Figure 1 the synergistic layout expressing the potential collaboration identified, in Figure 2 a possible symbiotic cluster hypothesized by geolocalizing some companies in the Marche region.

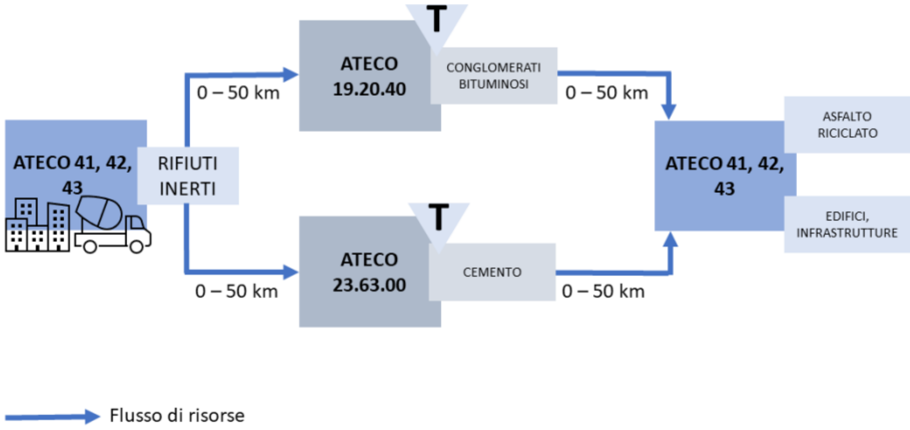

Figure 1. Example of synergy diagram (layout) for the enhancement of waste produced by the said sector

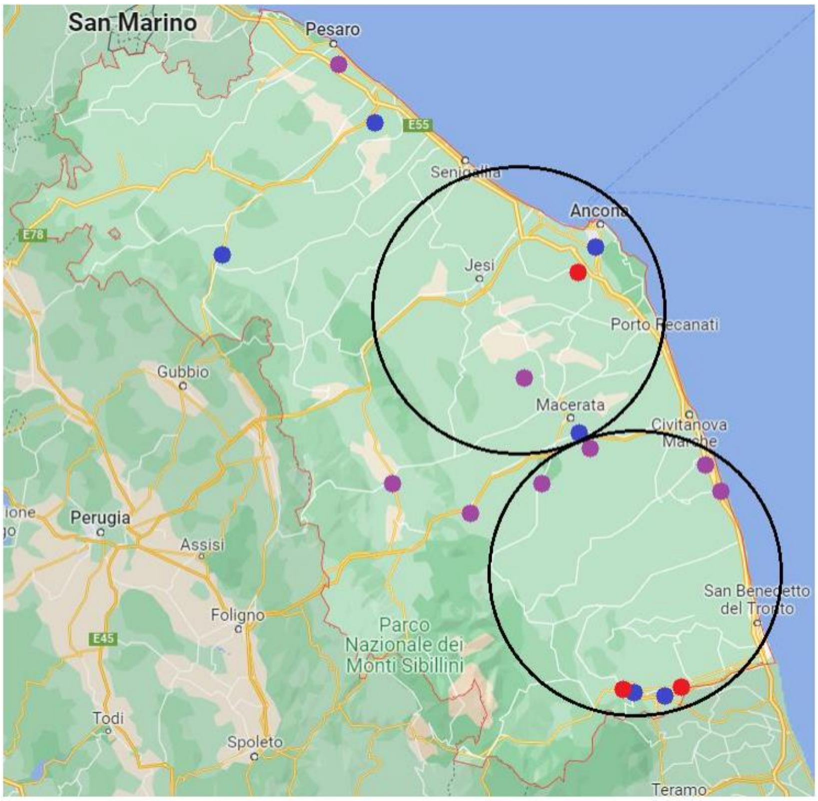

Figure 2. Example Geolocation of the industries involved in the synergies

Agri-food sector

The second sector taken into analysis is the agri-food sector, which encompasses both the primary sector (ATECO code A) and the food and beverage industry (ATECO C: 10 and 11).Already by themselves, the Marche region's enterprises carrying out primary activities in the territory account for 16.9 percent of the total, it is a sector with high economic significance and capable of involving numerous business entities.[5] Again, input and output resource flows were studied, possible synergistic collaborations identified and symbiotic clusters hypothesized in the Marche region. In detail, only the wine (Figure 3) olive (Figure 4), meat (Figure 5a and 5b) and fishing (Figure 6) industries were considered, as they are more widespread in the territory.

Figure 3. Wine industry

Figure 4. Olive industry

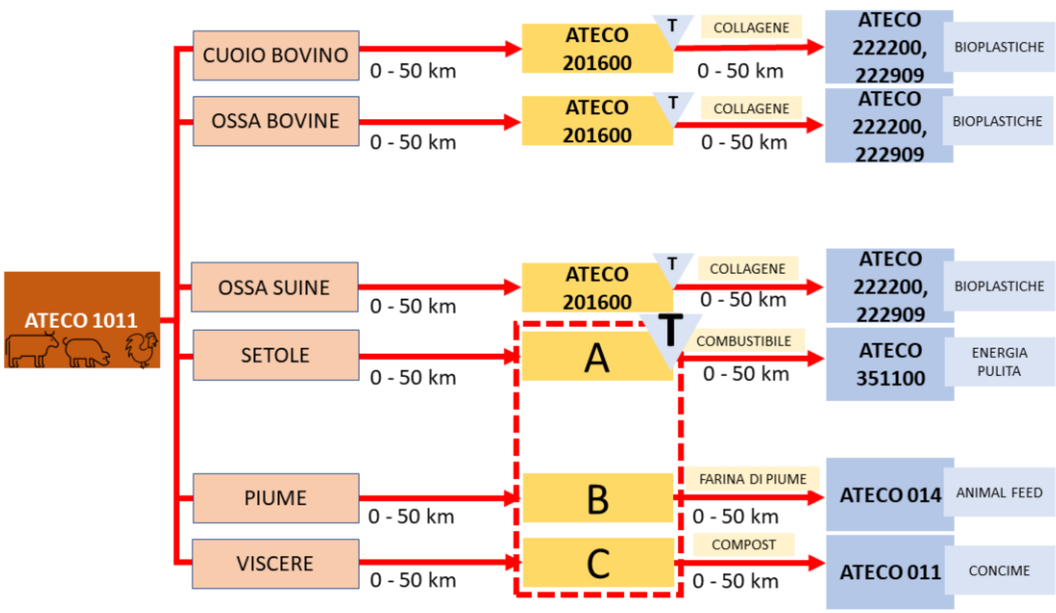

Figura 5a. Meat industry (cows and pias)

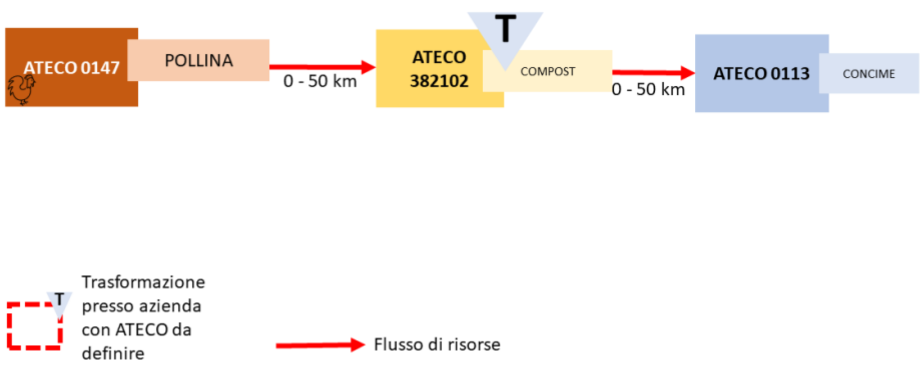

Figura 5b. Meat industry (poultry).

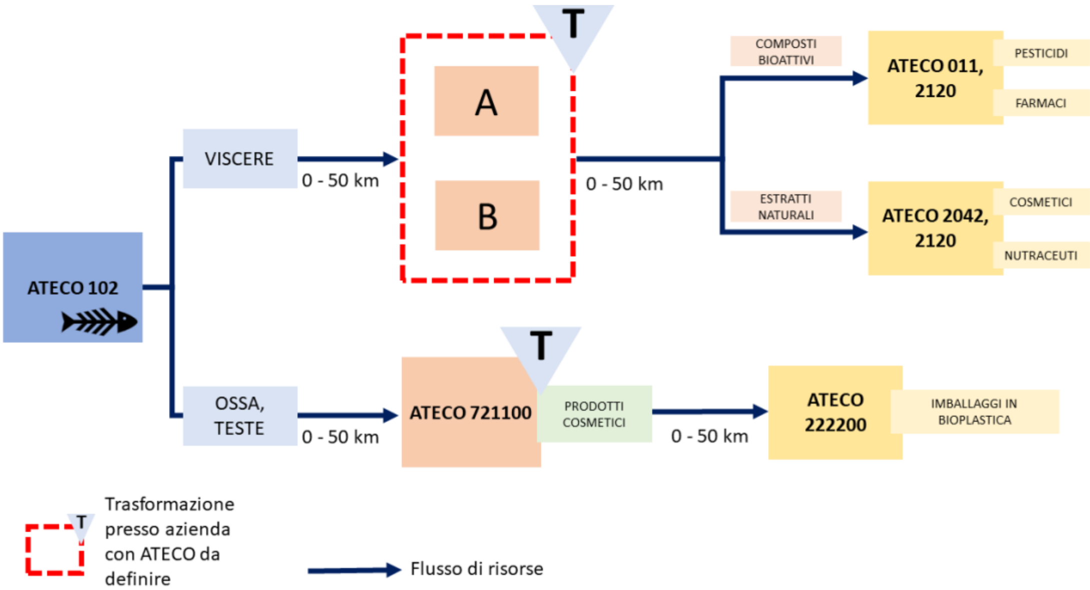

Figura 6. Fish industry

Conclusions

The analysis showed that there are possible matches between companies that can valorize by-products and move to a circular production model. However, symbiotic compatibility alone is not enough for the implementation of an Industrial Symbiosis network. First of all, it is necessary to assess the resulting economic convenience for the companies participating in it;[6] in this paper, a maximum distance constraint of 50km was imposed for symbiotic clusters in order to ensure at least plausible convenience with regard to the logistics factor. Another aspect that needs to be taken into consideration is the current regulations regarding the reuse of by-products and, in general, this type of synergy between companies. Added to this is the need to build trust among project stakeholders and to raise awareness of the issue among all possible participants in the symbiosis network.

References

1. Chertow M.R. (2000), Industrial symbiosis: literature and taxonomy, Annual review of energy and the environment, vol. 25, n. 1, pp. 313-337.
2. ISPRA, (2021), Rapporto Rifiuti Speciali 2021.
3. ISPRA, (2022), Piano Nazionale Gestione Rifiuti.
4. Legambiente, (2021), Rapporto Cave 2021, https://www.legambiente.it/wp-content/uploads/2021/07/RapportoCave-2021.pdf.
5. Camera di Commercio delle Marche, (2022), Imprese Attive in Italia per Territorio, Settore Ateco e Tempo, https://opendata.marche.camcom.it/stockimprese.htm?url=https://opendata.marche.camcom.it/data/Stock-Imprese-AttiveItalia.json&f2v=22.

6. ENEA: A. Luciano, G. Barberio (2016), Potential Improvement for the Methodology for Industrial Symbiosis Implementation at Regional Scale.

INDUSTRIAL SYMBIOSIS NETWORK: A CHECKLIST TO ASSESSES THE POTENTIAL OF LOCAL COMPANIES

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ABSTRACT

Industrial Symbiosis Networks (ISN) are emerging as sustainable options to enable cooperation among multiple supply chains and to optimise the use of material and energy resources within a geographical area. Companies are currently still slightly involved in ISN because they struggle to invest time and economic resources in these cross-industry networks. The aim of this contribution is to propose a preliminary assessment checklist to evaluate the potential of a company to be part of an ISN. As object of evaluation SMEs are chosen since they usually show criticalities for lack of organizational capabilities or resources. The proposed checklist includes quantitative and qualitative aspects within different thematic areas, declined in hierarchical layers. The output of the assessment is a readiness rating to create IS synergies. Future developments include the submission of the checklist to a sample of Italian SMEs for collecting rankings and designing potential ISNs.

Keywords: *Assessment tool; Industrial Symbiosis; checklist; symbiosis readiness; SMEs.*

Introduction

The volume of waste produced globally will double by 2050 and the vast majority of this will be not safely managed for the planet [1]. In particular, industrial waste is currently almost 18 times higher than urban waste [2]. This makes waste management a complex issue for companies that requires proper attention immediately. For this reason, wastes and by-products from an industrial facility are increasingly considered as resources instead of scraps. Industrial Symbiosis (IS), a practical approach of Circular Economy (CE), promotes a circular system of entities where the outputs of one industry are incorporated into the production cycle of another business as an alternative raw material. Companies are usually co-located and collaborate in order to share materials, energy, infrastructures, knowledge and services [3]. The cooperation among actors belonging to Industrial Symbiosis Network (ISN) contributes to increase economic, environmental and social benefits [4, 5]. However, matching resources to be transferred and promoting IS through companies encounters several barriers. These include environmental policies, lack of trust and support among involved actors, economic barriers, and low level of information sharing [6]. Companies are currently still slightly involved in ISN because they struggle to invest time and economic resources in these cross-industry networks. To foster IS adoption, the awareness of having potential to participate in ISN can be an initial step toward developing synergies. Only few studies assess preliminary conditions to take part of IS scenarios or evaluate the IS readiness of a company [7, 8, 9]. The aim of this paper is to propose a preliminary assessment checklist for diagnosing the potential to engage ISN. As object of evaluation SMEs are chosen since the global entrepreneurial fabric is essentially constituted by them and they usually show criticalities for lack of organizational capabilities or resources, that precludes them to tackle new opportunities. The paper is organized as follows: Section 2 presents the approach behind the checklist creation and its architecture, Section 3 details the dimensions of the checklist, while the last Section 4 suggests potential applications and future research steps.

Methods

The checklist presented in this work originated from a literature review and interactions among IS experts. The basic idea is to assess a company through the checklist and obtain a score to classify the company readiness for IS scenarios implementation. The awareness of the ability to create IS partnerships and synergies facilitates the decision-making process and encourages the company to undertake actions for increasing the circularity of resources [8, 9]. Starting from the definition of IS [4] and inspired by the assessment tools proposed by Azevedo et al. [8] and Agudo et al. [9], the following Figure 1 represents the IS checklist architecture together with relevant notations.

Layer	IS CHECKLIST						
i.	Company details						
ii.	*Areas i*	Environmental sustainability	a1	Business awareness and maturity	a2	Input-output resources	a3
iii.	*Metrics j*	Certifications	m11	Level of data sharing	m21	Input resource identification	m31
		Sustainability statement	m12	Privacy policy	m22	Waste identification	m32
		Environmental Management System (EMS)	m13	Flexibility and openness	m23	Waste destination	m33
		...	...	...	...	...	...
iv.	*Units k*	ISO 14001	u111	Use of digital platforms	u211	Water	u311
		EMAS	u112	Data availability	u212	Energy	u312
		Ecolabels	u113	Data quality	u213	Material	u313
		...	...	...	...	...	...
		Environmental score	**E**	**Business awareness score**	**B**	**Resources score**	**R**
Partial checklist score Y1							
v.	*Additional dimensions h*	Territorial context	d1				
		Potential economic savings	d2				
		...	...				
Total checklist score Y2							

Figure 1. IS checklist architecture

The IS checklist architecture is declined in hierarchical layers according to an increasing order of detail, i.e., (i) company details, (ii) areas, (iii) metrics, (iv) units, (v) additional dimensions. The adopted notations are introduced in Table 1.

Table 1. IS checklist indices and parameters.

Indices		**Parameters**			
i	Areas, $i = 1, \dots, I$	a_i	Weight of the area i, with $\sum_{i=1}^{I} a_i = 1$	E	Environmental score
j	Metrics, $j = 1, \dots, J_i$	m_{ij}	Weight of the metric j of the area i, with $\sum_{j=1}^{J_i} m_{ij} = 1$	B	Business awareness score
k	Units, $k = 1, \dots, K_{ij}$	u_{ijk}	Single score of the unit k of the metric j of the area i	R	Resources score
h	Additional dimensions, $h = 1, \dots, H$	d_h	Weight of the additional dimension h, with $d_h \in (-1; 1)$	Y_1	Partial checklist score
				Y_2	Total checklist score

The checklist covers three thematic areas: (1) environmental sustainability, (2) business awareness and maturity, and (3) input-output resources. Every area returns a score (E, B, R) to be weighted with (a_1, a_2, a_3) to get the partial checklist score (Y_1).

$$Y_1 = a_1 \cdot E + a_2 \cdot B + a_3 \cdot R \tag{1}$$

Where:

$$E = \sum_{j=1}^{J_1} m_{1j} \cdot \frac{\sum_{k=1}^{K_{1j}} u_{1jk}}{K_{1j}} \tag{2}$$

$$B = \sum_{j=1}^{J_2} m_{2j} \cdot \frac{\sum_{k=1}^{K_{2j}} u_{2jk}}{K_{2j}} \tag{3}$$

$$R = \sum_{j=1}^{J_3} m_{3j} \cdot \frac{\sum_{k=1}^{K_{3j}} u_{3jk}}{K_{3j}} \tag{4}$$

Then, (1) is integrated examining additional dimensions, such as the territorial context in which the company operates (d_1) and the potential economic savings from IS synergies (d_2). The relationship between (1) and the total checklist score (Y_2) is described below.

$$Y_2 = Y_1 \cdot \prod_{h=1}^{H} (1 + d_h) \tag{5}$$

(d_h) is in the range $(-1; 1)$ and if it is negative, it will act as reducer of (Y_1), while if it is positive, it will act as amplifier of (Y_1).

Results

The first area of the checklist (1) aims at collecting data about the environmental practices implemented by the company in its business activities [8]. Metrics or indicators for the sustainability assessment of a company includes environmental certifications, i.e. ISO 14001 [10], EMAS [11], Ecolabels [12], the presence of the sustainability statement and the implementation of the Environmental Management System (EMS). This checklist area can be extended with several other KPIs to assess sustainability within organizations [13, 14]. The section is based on the assumption that if a company is not inclined to environmental practices, it will be more likely that it will not be committed to create IS synergies.

The second area of the checklist (2) has the purpose of understanding the level of willingness of a company to cooperate with other entities to create IS partnerships and to share information concerning business input-output resources. One of the main factors identified as restraining IS process is the lack of information sharing and the lack of trust [15]. Quantitative metrics in this section are more complex to identify for the difficulty to measure them through objective parameters. The level of data sharing, the rigidity of the privacy policies and the level of business openness and flexibility are metrics quantifiable with rating scales, i.e., Likert scale. This checklist area can be extended with dimensions that analyses company's enabler factors to IS implementation (i.e., trust, information, infrastructures) [9].

The third area of the checklist (3) targets the object of transfers in IS scenarios. To create IS synergies, outputs of a company are matched with inputs of another industrial process subject to technical, environmental, economic and legislative constraints. The IS material tracking identifies and quantifies all significant material inputs and outputs of a company to suggest opportunities for material sharing among ISN partners and for more efficient use of resources [16, 17]. Inputs and outputs identification, in terms of type of resources, quantities, and destinations are crucial data to assess the potential of a company to engage ISNs [18].

The three checklist areas collect information mostly related to private data about the company under evaluation. The proposed assessment tool suggests to consider other two dimensions for providing an overall final score: the territorial context in which the company operates and the economic savings statement within an ISN. Metrics related to the territorial context includes the sparsity of NACE and EWC codes [19], in terms of number of different economic activities and wastes available in the surrounding area, existence of real cases of IS synergies already implemented, presence of IS enablers, i.e.

ENEA. The potential economic savings dimensions can be calculated by economic estimations of raw material purchase costs, transport costs and disposal costs.

Conclusions

One of the principal barriers to the adoption of Industrial Symbiosis (IS) is the commitment to develop and participate into synergy projects. The awareness of having potential to participate in Industrial Symbiosis Networks (ISNs) and benefit from it can be an initial step toward developing IS partnerships among companies not involved yet. The aim of this paper is to propose a preliminary assessment checklist for companies to diagnose the potential to engage ISN. The checklist covers three different thematic areas, declined in hierarchical layers. The first section of the checklist returns a partial score (Y_1) that has to be revised with additional dimensions to obtain the total checklist score (Y_2). Since the global entrepreneurial fabric is essentially constituted by SMEs and they usually show criticalities in organizational strategies and economic resources, as potential objective of evaluation of the checklist a sample of regional SMEs will be chosen. Once scores will be calculated, the setting of a ranking allows to classify companies readiness for IS scenarios implementation, and threshold levels distinguish the different business potentials to engage promising ISNs. The proposed tool can be extended with other metrics and further adjustments should be made in order to be as flexible as possible to different contexts and industries. The full digitalization of the tool should be addressed in next research steps for automating the calculation of scores and integrate new functionalities for ISN design.

References

1. United Nations (2022). The Sustainable Development Goals Report 2022. Department of Economic and Social Affairs (DESA).
2. S. Kaza, L.C. Yao, P. Bhada-Tata, F. Van Woerden (2018). What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development, Washington, DC, World Bank.
3. M.R. Chertow (2000). Industrial symbiosis: literature and taxonomy. Annual review of energy and the environment, 25(1), 313-337.
4. D.R. Lombardi, P. Laybourn (2012). Redefining industrial symbiosis: Crossing academic–practitioner boundaries. Journal of Industrial Ecology, 16(1), 28-37.
5. H.S. Park, S.K. Behera (2014). Methodological aspects of applying eco-efficiency indicators to industrial symbiosis networks. Journal of Cleaner Production, 64, 478-485.
6. A. Golev, G.D. Corder, D.P. Giurco (2015). Barriers to industrial symbiosis: Insights from the use of a maturity grid. Journal of Industrial Ecology, 19(1), 141-153.
7. D.C. Pigosso, A. Schmiegelow, M.M. Andersen (2018). Measuring the readiness of SMEs for eco-innovation and industrial symbiosis: development of a screening tool. Sustainability, 10(8), 2861.

8. J. Azevedo, I. Ferreira, R. Dias, C. Ascenço, B. Magalhães, J. Henriques et al. (2021). Industrial symbiosis implementation potential—An applied assessment tool for companies. Sustainability, 13(3), 1420.
9. F.L. Agudo, B.S. Bezerra, L.A.B. Paes, J.A.G. Júnior (2022). Proposal of an assessment tool to diagnose industrial symbiosis readiness. Sustainable Production and Consumption, 30, 916-929.
10. International Organization for Standardization. Available online: www.iso.org (accessed on 11 October 2022).
11. EU Eco-Management and Audit Scheme. Available online: www.ec.europa.eu/environment/emas/ (accessed on 11 October 2022).
12. EU Ecolabel. Available online: www.environment.ec.europa.eu (accessed on 11 October 2022).
13. M. Longo, M. Mura (2017, April). Assessing sustainability within organizations: The sustainability measurement and management lab (SuMM). In International Conference on Sustainable Design and Manufacturing (pp. 339-346). Springer, Cham.
14. E. Baglieri, V. Fiorillo (2014). Indicatori di performance per la sostenibilità. Greentire S.C.R.L.
15. A. Neves, R. Godina, S.G. Azevedo, C. Pimentel, J.CO. Matias (2019). The potential of industrial symbiosis: Case analysis and main drivers and barriers to its implementation. Sustainability, 11(24), 7095.
16. L. Cutaia, A. Luciano, G. Barberio, S. Sbaffoni, E. Mancuso, C. Scagliarino, M. La Monica (2015). The experience of the first industrial symbiosis platform in Italy. Environmental Engineering and Management Journal, 14(7), 1521-1533.
17. L. Cutaia, T. Beltrani, V. Fantin, E. Mancuso, S. Sbaffoni, M. La Monica, M. (2020). Resources audit as an effective tool for the implementation of industrial symbiosis paths for the transition towards circular economy. In Industrial Symbiosis for the Circular Economy (pp. 43-56). Springer, Cham.
18. O. Stéphane, Q. Jean-Baptiste, S. Charles-Xavier, L.M. Gwenaël, M. Mouad, B. Alexandre (2019, June). A cross-sectorial synergies identification methodology for industrial symbiosis. In International Conference on Sustainable Design and Manufacturing (pp. 229-240). Springer, Singapore.
19. Eurostat. Available online: www.ec.europa.eu/eurostat (accessed on 13 October 2022).

MEASURING THE CIRCULAR ECONOMY IN THE AGRI-FOOD SECTOR AN UMBRELLA REVIEW

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ABSTRACT

One of the challenges to be faced in the transition from a linear to a circular economy is the development of tools to assist this transformation process. Furthermore, it is necessary to define indicators to assess the degree of circularity and measure the actual environmental benefits of the new economic paradigm. This paper, which is inspired by the 'umbrella reviews', aims to summarise and discuss the results obtained so far in the agri-food sector by analysing the literature reviews in this field. The aim is to highlight the need to strengthen methodological research to find standardised solutions towards the definition of common rules for the evaluation of circularity and to help future research. In general, a unique and specific system of indicators and tools for the agri-food sector, as well as the development of data for life-cycle-based tools and new impact categories are needed.

keywords:. *Agri-food; circular economy; sustainability; measurement tools; indicators; life cycle thinking*

Introduction

Increasing world population and changing consumption patterns are driving the search for solutions and tools toward sustainable and circular economy (CE) also in the agri-food industry, that generates significant economic, environmental and social impacts [1]. It is important to accelerate the path from a linear economy (LE), based on "take-make-waste," to a model in which natural resources are not considered unlimited and the loads on the environment due to human activities are contained. CE can be widely applied in the agri-food sector bringing social, economic and environmental benefits [2]. Often “circularity” and “sustainability” are used interchangeably, but the former is mostly implemented as a tool to achieve the latter [3]. This study aims to provide the state-of-the-art research on indicators and tools of CE by taking methodological inspiration from an "umbrella review," popular in the field of medicine, which integrates the results of different literature reviews for a quick analysis of evidence related to a specific topic [4]. The analysis covers reviews that classified and analysed indicators and tools used in the agri-food sector to study the degree of circularity and support the transition to and implementation of CE strategies, providing further insights for future research.

Methods

Scopus, Ebsco Discovery Service and Google Scholar search engines were used with the following keyword combinations: agri-food OR "agri food" OR agricultur*; "circular economy" OR circularity; indicator OR measur* OR metric; review. Papers from case study reviews that use indicators and tools to assess circularity and guide the transition to the CE in the agri-food sector were identified. Seven papers relevant for the purpose of the research were finally selected.

Results

The study by Poponi et al. [5] identifies 102 indicators to measure CE and aims at understanding in which spatial dimensions (SD) — macro, meso, micro — and areas of sustainability (AS) they can be applied. Esposito et al. [6], on the other hand, aim at assessing how models of CE can evolve and develop. Velasco-Muñoz et al. [7] conduct two reviews: one on papers that mainly analyse the indicators used in the literature, and the other on papers that analyse also, or exclusively, assessment tools, which include performance indicators related to different aspects. This issue is dealt with also in the works by Stillitano et al. [8] and Silvestri et al. [9]. The former analyses the usefulness of life-cycle-based tools for the evaluation of CE. The latter investigate indicators within sustainability and CE assessment tools with respect to the three pillars — environmental, social and economic — based on the strategic objective for which they are applied. On the other hand, the analysis by Silvestri et al. [10] focus on energy indicators, considering that the agri-food activities are energy intensive. Finally, Kyriakopoulos et al. [11] emphasise the technological advances, including those in agriculture, on which existing methods of CE assessment are proposed and applied.

Regarding SDs, the macro-level indicators found assess, in order of frequency: impacts of the agri-food sector on sustainable development, impacts of human activities on ecosystems and the economy, impacts along the life cycle, and the load on the ecological system. At this level, the indicators are almost equally distributed among the 8 domains: Water; Soil; Energy; Waste; Cost, Value and Productivity; Equality; Knowledge and Innovation (thus excluding the "Air" domain) [5]. At the meso level, there are fewer indicators, which mainly regard the "Energy", "Cost, Value and Productivity" and "Equality" domains. In order of frequency: indicators based on life cycle, indicators assessing the burden on the ecosystem, and measurement and sustainable development indicators [5]. Finally, at the micro level, again in order of frequency, we found indicators that measure: the effects of production methods and choices on the life cycle, the burden and level of criticality on the ecosystem, the consequences of choices from an economic and social perspective, and the contribution on sustainable development of a product or a company. Overall, indicators are spread across all application areas and cover all relevant aspects but not all of them can be used at all three levels [5]. Moreover, only a limited number is found at the meso level. The focus on the micro level is also found in Stillitano et al. [8]. Among the papers analysed, only eight use specific CE indicators and all of them consider the smaller dimension. Concerning tools, at the micro level researchers use the LCA, WF (Water Footprint) and CF (Carbon Footprint) methodologies. However, the meso level is the most studied dimension, due to the need to consider the entire supply chain rather than a single actor. At this level, LCA is the most widely used tool, then WF and LCA combined with Life Cycle Costing (LCC), CF and Multicriteria Analysis (MA). Macro-level tools are poorly applied [6]. Life cycle-based tools are very popular in the agricultural sector. They are useful to measure the evolution of the adoption of circular models and for considering the shift of environmental loads from one phase of the life cycle to another or from one environmental compartment to another [7]. These tools are mentioned by analysing their usefulness and the most popular impact categories suitable to assess circular agriculture as a driver of sustainability. LCA can contribute to CE through the development of industrial ecology [11], influencing waste and resource management. In addition, several variables are required to assess the benefits of CE throughout the life cycle, since it influences environmental, economic, and social aspects, so making the assessment more complex [11]. Silvestri et al. [9] note that studies using LCA mainly aim at assessing energy and environmental efficiency, and the tool is often used to monitor environmental policy action. Most of the studies use LCA to measure exclusively the benefits of implementing CE practices [9,11], followed by Social-LCA (S-LCA) and WF [6]. Other studies use LCA combined with other tools such as CF, LCC, WF, and Input-Output Analysis (IOA) [8]. In addition: the food-waste-energy nexus, life-cycle energy assessment, SWOT (Strengths, Weaknesses, Opportunities, and Threats) and TOWS (Threats, Opportunities, Weaknesses and Strengths) analysis, life-cycle inventory and externality assessment (ExA) [6] and absolute sustainability-based life-cycle assessment (ASLCA) [10]. Within LCA, the most evaluated impact category is global warming, as the agri-food sector is considered to account for considerable greenhouse gas emissions [10]. Then, eutrophication, human toxicity and ecotoxicity, depletion of non-renewable resources, stratospheric ozone depletion, acidification, land use, renewable resources, photochemical oxidant formation, and particulate matter [11] are used. Impact categories related to carbon, nitrogen and phosphorus fluxes are the most significant for agricultural systems. In addition, endpoint indicators are considered. The most widely used assessment method is ReCiPe, followed by CML (Centrum voor Milieuwetenschappen in Leiden) and ILCD (International Reference Life Cycle Data System) [8]. In addition to LCA, the contextual use of the cumulative energy demand indicator (CED) and the primary energy demand indicator (PED) [8] is noteworthy. Most indicators refer to the environmental dimension, followed by economic ones. On the other hand, social aspects are poorly investigated and applied [8]. However, the overall picture may change if a fourth technical dimension is added. Relevant indicators measure different technical aspects, such as energy consumption and/or material use, especially in relation to efficiency. Therefore, considering four pillars, most indicators fall under the technical dimension [7].

The reviews analysis shows that there is a scarcity of studies focusing on measuring CE in the agri-food sector [5]. However, there are several indicators for assessing circularity that cannot provide an overall assessment. Most of these indicators were originally designed to measure efficiency improvements in LE, then adapted for CE (e.g., technical indicators to measure efficiency) [7]. Efficiency improvements have not led to positive impacts on many environmental aspects. Therefore, it would be appropriate to move to the concept of eco-efficiency for a more radical approach to CE. This would lead to greater mutual benefit between ecological and economic systems [7]. In the agri-food sector, it is important to have geographic and temporal context-specific data available when making comparisons as this may influence the results. There are no indicators that can be adapted to all agricultural contexts and to all productions. Regarding data quality, some indicators are based on easily obtainable statistics, others on simple measurements. However, the useful information may not be available, making application more difficult [7]. Concerning SDs, many studies refer at most to two dimensions (micro, micro and meso, meso and macro). Moreover, it seems that there are few studies currently focusing on the meso level and especially at the eco-industrial park level [8]. There is a need for cross-sectional indicators on SDs. This would allow the implementation of CE strategies that can more easily cover three systemic and economic levels to generate positive effects from a community perspective [5]. Indicators that assess new aspects and areas not yet considered (such as bio-based products) are needed [5]. The challenge for the transition to a CE and its measurement in agri-food can be faced through the harmonization and integration of tools and indicators. This can avoid the risk of bias in the analysed context [8,9]. Holistic view of the system under study avoids shifting impacts from an environmental aspect to another and from a DS or area of sustainability to another. Different assessment tools lead to different results that are difficult to compare [6]. Obviously, it is difficult for researchers to consider the large number of different variables that occur in the entire life cycle, from an environmental, economic and social perspective [11]. To move towards CE, the involvement of the stakeholders in the supply chain is essential. Therefore, a common circularity assessment tool is needed. This would allow comparison of circular performance and practices across different supply chains with vertical (between stages) and horizontal (across supply chains) collaboration [6]. The use of lifecycle-based tools is essential for these assessments, if accompanied by specific indicators that measure circularity. There is a lack of attention to social aspects, although they are sometimes mentioned with S-LCA [8]. MFA seems to be a good support for assessing circularity, and IOA applied to a product's life cycle allows the assessment of environmental impacts to be integrated with the effects of positive or negative economic shocks and potential influences on the economy. The "materials circularity indicator" is still one of the most robust tools for assessing CE. It includes all stages of a product's life cycle in the same way as LCA but, when assessing circularity, the analysis of only one life cycle is not sufficient because each circular pattern influences the next one [8]. Therefore, to extend the boundaries of the system to processes that close the cycle (e.g., recycling and reuse in the next cycle) is necessary to integrate the two methodologies [8]. Most studies narrow the system boundaries by focusing on the use of energy and material resources, and this is not sufficient to measure the degree of circularity, which in turn cannot define the sustainability of a product or process. Circularity remains a goal to be achieved, rather than something to be measured, but sustainability is measured more [8]. Researchers rarely use circularity indicators along with impact indicators, and the boundaries of system analysis are not broad enough to have a well-rounded circularity perspective [8].

Conclusions

The umbrella review has revealed the need to develop a single, common system of indicators for measuring CE in the agri-food sector. In particular, there is a need to develop new indicators, complete the overview of existing ones, and accompany it with an analysis of their level of application, also taking into account technological innovations and integration with current models of CE. However, few sector-specific indicators exist, even if they succeed in covering all dimensions of sustainability. Robust assessment methods are needed for the sector, especially in the meso SD. Assessment tools should integrate the three pillars of sustainability — environmental, social and economic — that can highlight strengths and weaknesses.

They should be user-friendly and able to compare environmental and economic performance to create and evaluate new models of sustainable and circular agro-industrial production within supply chains. For proper use of lifecycle-based tools, it is necessary to increase the quality and quantity of data available in the databases by developing specific datasets for each supply chain, as well as implement technological tools to capture data in real time saving time and economic resources (e.g., IoT - Internet of Things). Common circular performance assessment tools for all agri-food supply chains are essential for making comparisons across different stages and different supply chains to guide strategic and consumer choices. At the same time, diversification allows to be more accurate and reliable. In addition, the impact categories of life cycle analysis tools should include indicators that can measure the level of innovation and cooperation in the system, which are considered crucial for the transition to a circular and sustainable system.

References

1. Turi A., Goncalves G., Mocan M., "Challenges and competitiveness indicators for the sustainable development of the supply chain in food industry", Procedia – Social and Behavioral Sciences. 2014, 124:133-141;
2. Zabaniotou A., "Redesigning a bioenergy sector in EU in the transition to circular waste-based Bioeconomy-A multidisciplinary review", Journal of Cleaner Production. 2018, 177:197-206;
3. Walker A.M., Opferkuch K., Roos Lindgreen E., Raggi A., Simboli A., Vermeulen W.J., Salomone R., "What is the relation between circular economy and sustainability? Answers from frontrunner companies engaged with circular economy practices", Circular Economy and Sustainability. 2021, 1-28;
4. Fragkos K.C., "Reflective practice in healthcare education: an umbrella review", Education Sciences. 2016, 6(3), 27;
5. Poponi S., Arcese G., Pacchera F., Martucci O., "Evaluating the transition to the circular economy in the agri-food sector: Selection of indicators", Resources, Conservation and Recycling. 2022, 176:105916;
6. Esposito B., Sessa M.R., Sica D., Malandrino O., "Towards circular economy in the agri-food sector. A systematic literature review", Sustainability. 2020, 12(18):7401;
7. Velasco-Muñoz J.F., Mendoza J.M.F., Aznar-Sánchez J.A., Gallego-Schmid A., "Circular economy implementation in the agricultural sector: Definition, strategies and indicators", Resources, Conservation and Recycling. 2021, 170:105618;
8. Stillitano T., Spada E., Iofrida N., Falcone G., De Luca A. I., "Sustainable agri-food processes and circular economy pathways in a life cycle perspective: State of the art of applicative research", Sustainability. 2021, 13(5):2472;
9. Silvestri C., Silvestri L., Piccarozzi M., Ruggieri A., "Toward a framework for selecting indicators of measuring sustainability and circular economy in the agri-food sector: a systematic literature review", The International Journal of Life Cycle Assessment. 2022, 1-39;
10. Silvestri L., Silvestri C., Forcina A., De Luca C., "A review of energy-based indicators for assessing sustainability and circular economy in the agri-food production", Procedia Computer Science. 2022,

200:1756-1765;

11. Kyriakopoulos G.L., Kapsalis V.C., Aravossis K.G., Zamparas M., Mitsikas A., "Evaluating circular economy under a multi-parametric approach: A technological review", Sustainability. 2019, 11(21):6139.

BIO NWALL AND ARCHITECTURAL-PLANT ENGINEERING MODULAR SYSTEM

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ABSTRACT

Co-working and home-working will increasingly need spaces integrated with technological facilities and modular solutions capable of adapting to the technological development and implementation that takes place within the spaces we live in, while fully respecting the safety of living and working environments. From this assumption, the idea was developed to study and realise a "smart" wall consisting of an interspace ready to accommodate all the technological networks needed for the correct use of the living space. This "smart" wall has been developed by integrating the use of innovative materials with issues of environmental compatibility and reuse. The advantages introduced by moving from traditional building systems to advanced technologies such as the proposed, can be summarized as achieving comfort conditions with efficient resource management to true linguistic interaction with technology and buildings.

Keywords*: Automation; Circular economy; Functional upcycle; Industrial symbiosis; By-product, Recycling.*

Introduction

The construction and design world is currently facing new issues related to the need to create spaces increasingly integrated with technological systems that include, in addition to traditional water, gas and electricity supply systems, also plant engineering networks for home-building automation, data transmission and IoT. The future has in store further needs still which the Bio nWALL solution looks all set to satisfy.

Networks are constantly evolving and require modular, multi-functional solutions that can be installed and maintained quickly and effectively, and which are able to easily adapt to the changing needs of people in living spaces or workplaces.

The devices, networks and apparatuses which today occupy physical spaces on walls, tables, racks, and are physically connected through cables and cable trays, no longer simply become technical equipment, but true human-sized interfaces that have to be designed and produced in compliance with the concepts of sustainability, developing circular-economy paths with the commitment of different actors in the development of innovative industrial symbiotic processes.

These simple concepts motivated the research path which led us to develop and realise the BIO nWALL project, a construction system with a double series of modular panels for the creation of walls, in the interspaces of which can be easily installed complete networks of home automation systems and components typical of a traditional or advanced technological system (switches, temperature and humidity sensors, lighting, power sockets, data sockets, lighting systems, etc.).

Methods

From offices to large collective spaces, technology is pervasive with many functions and supports essential for the rational and effective management of all the plant engineering that constitutes the smart systems of a building, indispensable for its efficiency. Thanks to domotics (home automation), the “logical” repositioning of field technologies (a power command on a switch, for example) becomes simple thanks to IPAM (IP-address management) and parametric control of data, either from sensors or sent to field devices via a data bus. Yet the problem of the “physical” repositioning of a technical component remains. From this assumption, the idea was developed to study and realise a “smart” wall consisting of:

- a first series of modular panels fastened to the existing building structure;
- a second series of panels, equally modular and connected to the previous ones, which can be easily removed and repositioned;
- an interspace – created this way – ready to accommodate all the technological networks needed for the correct use of the living space.

All the panels are made of FSC material, i.e. panels that use wood components from responsibly managed forests and, if necessary, are supplemented with recycled material. The system, developed by nLAB and the regional Apea "CARTONECO", was therefore created to respond to this need and finds in the use of industrial residues, exchanged between the companies of the group and classified as by-products and not waste, the salient aspects of a circular economy and reuse of materials no longer sent to landfills.

BIO nWALL has been developed by integrating environmental compatibility of construction materials issues and reuse of same (functional reuse), required by the new Minimum Environmental Criteria, wth focus on the use of innovative and, at the same time, sustainable materials, also classified as FSC in the case of wood panels.

For some connecting elements (panel-wall), by-products have been used that acquire a new life, thanks to a careful design that makes the most of the upcycle through a new use of materials from industrial supply chains, often considered as production "waste" and thus developing - in addition to an element of effectiveness and efficiency - a product with a high level of "functional upcycle".

The focus on this specific argument derives from the very nature of the construction market and the related consumption of resources. Data from the 2019 ISPRA/SNPA report [1] do in fact show that around 30% of energy and raw material consumption is linked to this sector, and even more negative is the figure for waste production, which amounts to around 57 million tonnes from the demolition and/or redevelopment of living spaces.

Faced with this alarming picture, we therefore considered it essential to develop a solution which, thanks to its characteristics, reduces energy consumption and waste produced by the building redevelopment process, while cutting CO_2 emissions through the use of manufacturing processes and industrial supply chains integrated in the circular economy.

The concept of "functional" efficiency takes shape with

- quicker installation (less use of resources);
- reusability of the system which allows, thanks to simple movements and interlocking readjustment, the redevelopment and re-functionalisation of building spaces.

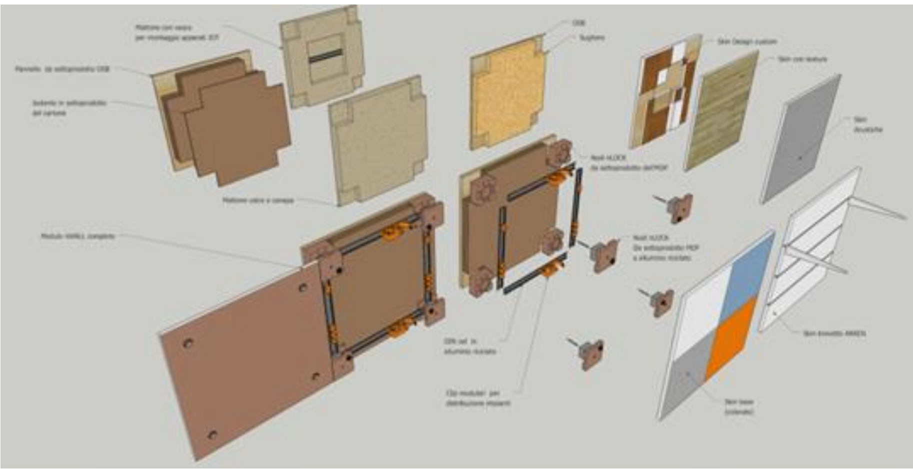

Figure 1. Exploded view of the components of the Bio-nWall system

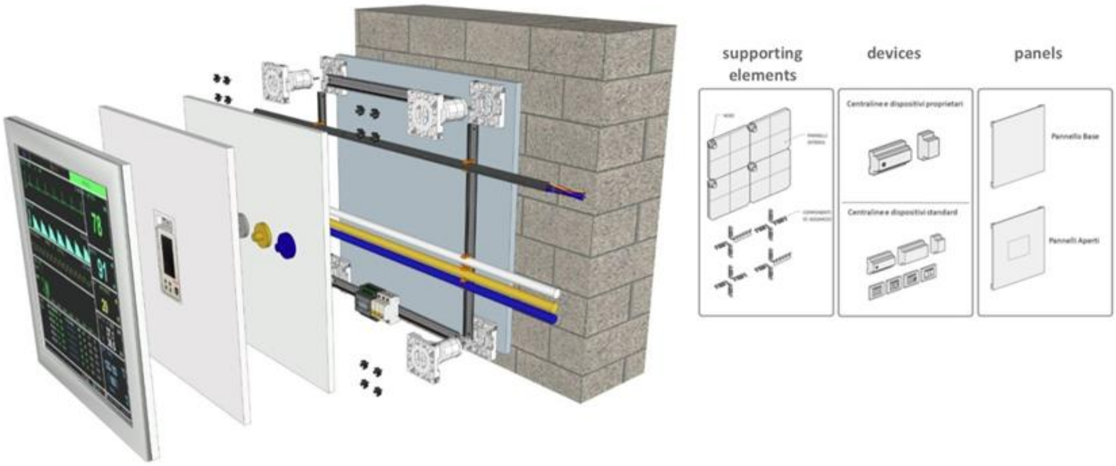

Figure 2. Stratigraphy and technological levels (Support, Plants, Panel)

Results

The development of this type of technological solution involved the collaboration of the nLAB-CARTONECO group with the facilities of the Lazio Region, in particular the Spazio Attivo incubator in Colleferro, which represented a further opportunity for more in-depth research work.

- The traditional building sector is the natural outlet for the modular technology of the BIO nWALL project for the construction of equipped walls, with particularly easy access to technical networks, thereby simplifying routine and special maintenance operations.
- In the GDO (Great Distribution Organized), in Retails or Office center, (some example of bulding typology) the nWALL system creates smart wall and shelving systems for fitting out sales areas. The system is able to natively host the technological solutions linked to the need to monitor and automate retail to the public (smart shelves, modular panels that can be repositioned according to layouts, able - for example - to register customer purchases by means of special sensors).
- With regard to healthcare, the system has specific applications that take into account very special needs such as radiation protection or surfaces with antimicrobial function.
- The acoustic fittings include panels with highly efficient and adaptable sound absorption solutions for different frequencies, or acoustic panels (integrated loudspeakers) for sound distribution, thus allowing the study layout to be adapted

to the different position of instruments or listening points, all with a customisable finish design.

In addition to all the issues related to the use and reuse of materials and their manufacturability on an industrial scale, research and development work also focused on the optimisation of the components of the technological system (docking nodes, support structures, etc.) through a reduced use of moving parts. The design and engineering work was, therefore, based on the theories of Compliant Mechanisms together with verification tests in the field, on "physical" prototypes made by 3D printing, and subsequently on the end product.

Some of the benefits and strengths introduced by moving from traditional construction systems to advanced technologies such as the one developed by us can be summarised as follows:

- building system set up for IoT home automation standards and industry 4.0 criteria production;
- application market broadened and simplified by offering a solution that combines architectural-functional and plant-engineering maintenance aspects;
- reuse and revival of traditional building component industrial production plants (growth of satellite activities);
- solutions compatible with new environmental legislation and the various protocols (FSC, CAM, GBC, LEED, etc..).

The strong points that distinguish technology of this type are:

- use of environmentally sustainable materials from FSC-certified supply chains;
- customisable design with production in 4.0 industrial supply chains (finishing panels);
- simple “wall/installation” “design-function” integration;
- reduction of construction costs (product/installation and modification times);
- ease of maintenance in the event of faults;
- easy relocation of installations in the event of renovations or redesigning of spaces;
- high modularity and adaptability to different building types;
- circular and environmentally-friendly materials in line with the various environmental protocols (FSC, etc.);
- high energy efficiency (both passive and active);
- compatibilitỳ with all current market plant-engineering component standards.

Conclusions

Homes, offices, shopping centres, large-scale retail trade or spaces such as co-working and home-working, will increasingly need modular solutions capable of adapting to the technological development and implementation that takes place within the spaces we live in, while fully respecting the safety of living and working environments.

Walls thus become a crucial node and an increasingly evolved object to resolve both technical and functional aspects, providing systems developed with sustainable management and production logics.

The end result is the achievement of comfort conditions (field sensors) with efficient management of resources (lighting, microclimate) up to a real linguistic interaction with technology and buildings.

References

1. Report SNPA n. 8/2019 - Consumo di suolo, dinamiche territoriali e servizi ecosistemici. homepage — Italiano (isprambiente.gov.it)

ECOLOGICAL TRANSICTION INDUSTRIAL SYNERGY AS COMPLEMENTARY TOOL TO ECO-DESIGN

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ABSTRACT

The objective of this paper is to show that is possible to define a standard, universal model to support industrial synergies between companies that belong to different industries and located in diverse geographical districts. In particular, we describe a universal, scalar and easy to repeat methodology to implement industrial synergies and we prove that it helps to lower cost of waste management and it can be a complimentary tool to eco-design in the ecological transiction.
Indeed, industrial synergy deals with the interaction among several entities with the purpose to maximize waste recycle and to share knowledge and skills in order to get relevant economic and environmental benefits. Moreover, from an economic point of view, companies take advantage by lowering waste management costs and increasing revenues by selling by-products to third parties. From an enviromental point of view, industrial synergies allow companies to implement circular business model in a complementary way to eco-design that in the short term shows entry barriers due to costs of setting up conversion of production processes. Power to Gas technology can be used to produce biomethane. The particular aspect is that the plant can utilize the CO_2 removed by gaseous waste through an upgrading process.

Keywords*: Industrial synergies, by-product, second raw materials, eco-design, circular economy.*

Introduction

This document describes our standard and universal procedure to implement industrial synergies between companies belonging to different industries and located in diverse geographical districts. This procedure is divided into two macro areas of consequential activities named respectively Procedural Methodology and Operating Methodology.

Methods

Both Procedural and Operating Methodologies are based on our practical experience and the proper understanding of the legal requirements to handle waste as by-product or second raw materials. They refer to two different steps of industrial synergies: the first one identifies and selects the most performing matches among different entities, the second one is made up by technical and operating activities to implement synergies.

The Procedural Methodology

- First Phase

  Assessment of production processes and waste management of Client1 has be done in order to establish which kind of waste can be reused as second raw material or as by - product. In both cases, it is necessary to identify a target market to be addressed. Then, a selection of companies has been defined according to their industrial processes that need to be able to receive and reuse our second raw materials or by - products. This selection can be done among our portfolio or thanks to a specific scoutinga activity.

- Second Phase

  Tests are run to verify the possibility that Client2 can reuse second raw materials and by - products in its production processes. Technical standards, legal and administrative requirements and profitability are also evaluated.

- Third Phase

  Coordination of all the stakeholders involved in the industrial synergy process.

The Operating Methodology

- First Phase

  Accurate analysis of waste production processes of Client 1 and its physical and chemical features.

- Second Phase

  Use of results coming from the First Phase to identify all the possible ways to treat the waste: to manage it as by product or second raw materials and the related market to target. Furthermore, in this step, tests are made to verify the real possibility to handle waste as by product or as second raw material.

- Third Phase

  Identification of Client 2 that matches with Client 1 and coordination the storage and treatment of Client 1's waste in order to transport it to the Client 2 as by product or as second raw material and to use it in new production processes.

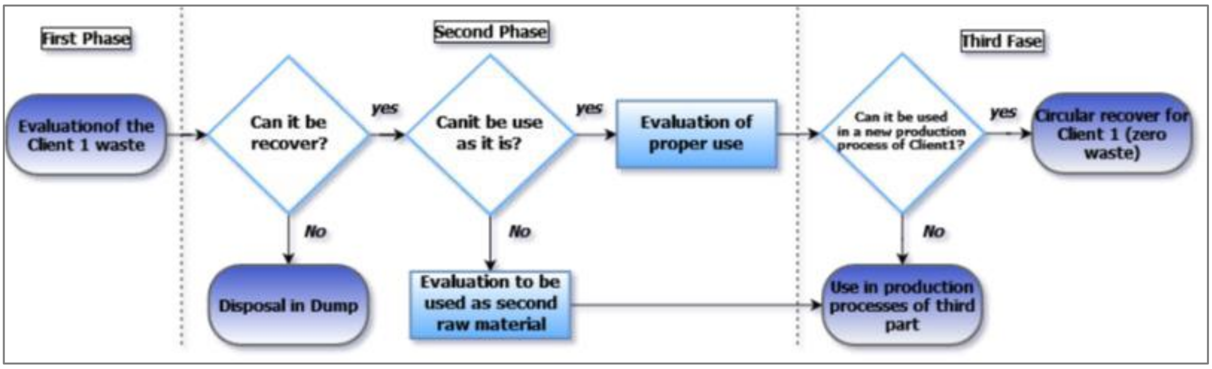

Figure 1. Standard and universal procedure of industrial synergies

Case Study

Partner

- Client 1: Mario De Cecco S.p.a. is a leader company in the professional workwear and in the distribution of protective equipment markets. Nowadays it is able to satisfy orders coming from all over the world thanks to its huge production sites deposits and 400 employe es.
- Client 2: Nazena S.r.l. is an innovative start up focused on recovering fabrics scraps.
- Broker cat.8 e environmental consultant: GM Ambiente & Energia S.r.l.

Object

To reinsert the fabric scraps of Client 1 into the production processes of Client 2.
It will be able to reuse those to produce the following items:

1. new packaging to transport products (clothes)
2. space dividers
3. coat hanger and labels for clothes

Moreover, we show that selling the box + lid to third parties bring earning instead of generating cost of waste management.
Project started from August 2022.

Procedure

GM Ambiente & Energia gets back and transfers Client 1 clothes as second raw material to Client 2 that is in charge to treat them to obtain natural fibre. Those fibres are compressed and put together to produce packaging throughout a mechanical and chemical treatment with natural ingredients. Indeed, Nazena is able to guarantee the reuse of clothes coming from De Cecco thanks to an upcycling, patented process that turns them into a strong and versatile material to use according to different needs. The treatment process is divided into the following steps:

1. Pick up the second raw materials from Client 1;
2. Cleaning and selection of the material according to its colour;

3. Removal of any external elements: buttons, metallic inserts, paillettes, other things;
4. Unravelling of material and reconversion in fibre;
5. Fibre treatment with natural adhesive. Any chemical elements are used in this process. Following,
6. the fibres are stretched out on a sheet, shaped and dried;
7. Mold and assembly of packaging.

Valuation

Functional unit (UF): n.1 box + lid.

Size: 40x40x11 cm; Weight: 1kg

1. Textile reused by Client 1:
   A. Fabric/clothes used to produce n.1 box: 1,1 kg (1 trouser, 1 t-shirt and 1 sweatshirt)
   B. Buttons and other ornaments: 0,555 kg
   C. Clippings and trimmings: 0,052 kg
2. Reduction of environmental impact of reused box vs. traditional box:
   A. Water 8lt vs. 10 lt
   B. Energy 25kWh vs. 45 kWh
   C. Organic glue 0,05 kg vs. chemical glue and impregnating agent 0,08 kg
   D. 26,701 Ton of CO_2 less due to avoiding burned fabric
3. Cost / benefit related to reused boxes:
   A. Traditional process: n.100 boxes
   B. Innovative process with industrial synergy n.20 boxes

Results

The main results coming from the industrial synergy between Client 1 and Client 2

- Reduction of environmental impact throughout industrial synergy;
- Reduction of waste sent to dump;
- Production of recycled packaging that can be sold to third parties.

	TRADITIONAL SERVICE	U.M	Cost €	INNOVATIVE SERVICE GM	U.M	Cost/Earnings
Purchase and transport €/unit	1,50 €	100	150,00 €	18,00 €	20	360,00 €
Waste Management* €/Kg	1,70 €	100	170,00 €	0,00 €	0	0,00 €
Sales of functional units to third parties €/unit	0,00 €	0	0,00 €	20,00 €	20	400,00 €
Cost €			320,00 €			360,00 €
Earnings €						400,00 €
TOTAL						40,00 € (Earnings)

Figure 2. *Cost and benefit of industrial synergy*

Related to the cost of waste management Euro/kg of clothes.

Comparison along the life cycle of product per unit: n.1 traditional box vs. innovative box.

Conclusions

GM Ambiente & Energia is able to get back and transfer Client 1's clothes as second raw material to Client 2 that treats them to obtain natural fibre. Those fibres are compressed and put together to produce packaging throughout a mechanical and chemical treatment with natural ingredients. This packaging allows Client 1 to cut costs related to mono use packaging and waste management.

In conclusion, we demonstrate that industrial synergies can be an efficient and effective way to ecological transaction in alternative to eco-design.

Environmental and Economic Performance Indicators in Composting Pilot Plant in Sicily

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ABSTRACT

With a view to the circular economy and industrial symbiosis, the NRRP finances projects aimed at implementing technological innovation strategies towards eco system innovations, in particular in waste management. The objective of this paper is to carry out a detailed social, environmental, economic and financial analysis of two anaerobic composting plants. Of these, environmental performance indicators will be quantified relating to the collection of organic waste and incoming materials deriving from Sicilian municipalities that give the existing plant under analysis. These data will be compared to the indicators relating to the potential quantities of conferment and the economic and social repercussions that will occur on the territory.

Keywords***:*** *Industrial Symbiosis; Waste Management; Environmental and Social Performance Indicators; Circular Economy*

Introduction

Compost consists of the biological process in which the organic material decomposes thanks to the action of microorganisms, giving life to the compost. In the case of municipal solid waste, it is called industrial composting which corresponds to the transformation activity of the wet fraction of said waste [1].

Compost is the result of the bio-oxidation and humification of a mixture of organic materials by macro and microorganisms in particular conditions, more simply, compost is the material that derives from the composting process and it is a rich material of organic matter such as proteins, carbohydrates and nutrients [2].

Compost can be validly used as a fertilizer and soil improver in many sectors, but also in the replanting of trees and shrubs.

Composting can be divided into the following operational phases:

- mixture preparation
- bio-oxidation
- maturation.

Preparation of the mixture: the choice of materials for the preparation of the mixture and the methods of mixing are fundamental in order to obtain a homogeneous mass, which allows the penetration of air so as not to favor the initiation of active anaerobic degradation reactions.

The ratio between carbon and nitrogen is of particular importance, as if it is too low the process risks evolving towards an excessive release of ammonia and its performance worsens, while if it is too high the process slows down or stops everything for lack of necessary nutrients [3]. Another important factor to consider for the preparation of the mixture is the need to guarantee the presence of easily degradable material inside, which will constitute the energetic substrate of the first microorganisms and at the same time the choice of materials that have a certain optimal humidity rate [4]. Bio-oxidation: in addition to the mixture, the mass is sent to the Bio-oxidation phase in which the most easily assimilated organic fraction undergoes a microbial attack, associated with the consumption of oxygen and the release of carbon dioxide. Phase characterized by a rise in temperature up to levels of 55°/60°, with which two important effects are obtained: the first consists in the elimination of pathogenic genes and seeds of wild plants, the second in a decrease in the microbial load due to a form of self-sterilization operated by the high temperature [5].

Maturation: finally the process enters a maturation phase in which the temperature drops below 45 ° C, favoring the ionization of the external surfaces in the heap by bacteria and fungi and it is in this stage that the humification takes place that will characterize the qualities of the compost. The ripening phase can last for months and ends with the lowering of the pile up to the values of the atmospheric one.

Once fully ripe, it can be subjected to a refining treatment, in order to further fragment the material and remove any impurities. Oxygen is of fundamental importance as it is an indispensable element for an absolutely aerobic process; it can be supplied in two ways: forced ventilation by blowing pumps and/or mechanical turning.

To carry out the desired processes and obtain an excellent compost, it is necessary to take into account the levels of some fundamental elements such as: the oxygen content present in the masses which must be between 5% and 15% and the level of humidity in the composting that it goes from 50% to 55% if these values are not respected the whole process is blocked.

There are also some control indices that can be taken into consideration to better control the evolution of composting, such as the ratio of carbon and nitrogen, pH and the presence of humic substances [6]. Depending on the technology adopted, composting plants are classified according to the methods of controlling the environmental parameters.

Therefore, if the composting process is carried out outdoors, the plants are classified in "open systems", if in a protected environment in "closed systems".

In open systems, the mixture of the materials to be subjected to oxidation is placed on waterproofed concrete slabs, in larger plants, the turning is carried out with mechanical blades which, however, can slow down the transformation of the organic substance. In closed systems, the oxidation reaction is carried out in a completely controlled environment, generally they are protected preparations, or real horizontal or vertical axis reactors are built [7].

Methods

The study takes into account the whole life of a product, from raw materials, their processing and transformation, as well as the energy needed to reach the finished product.

The analysis continues evaluating the phases of transport and utilization, predictable maintenance, to final disposal, not to mention the potential reuse and recycling of components or parts of the product. Through a study of LCA the stages and the moments when more environmental problems are concentrated can be identified and at the same time, those who will have to take responsibility (producer, user and so on.). By using this type of analysis the information necessary to achieve the improvement is obtained. Moreover, the attention of companies to environmental issues is greatly appreciated, both by institutional lenders, who reward these efforts by granting favorable conditions and rates for eco-efficient businesses; by commercial partners, who prefer to have relationships with companies that implement "responsible" management systems. Finally it should be emphasized that a voluntary adaptation of all regulations related to the control of pollution, allows companies to avoid administrative penalties and fines envisaged in the case of non-compliance. One of the limitations of LCA lies, however, in the difficulty of comparing the results from different studies [Giacon, 2009]. These rules, shown in the Table 1, have been developed by the Technical Committee ISO/TC 207 and constitute the international reference standard for LCA studies (European Commission, 2010). This standard specifies the framework, principles and requirements to carry out the evaluation studies of a life cycle and to disseminate them by reports.

Results

The production process within the pilot plant begins with the weighing phase of the trucks containing the wet fraction to be delivered; later, this waste is deposited in a special first storage area. Subsequently, the mixing of the wet fraction with the previously shredded pruning cuttings takes place, this mixture will be used to carry out an accelerated bio-oxidation, inside a bio container for 15 days at a temperature starting from 40 degrees and then in the next phase it will reach 55 degrees, a phase that can be defined as sanitizing also due to the collection of dripping liquids transpired by specially installed machinery.

Conclusion

As highlighted in Table 1, through an accurate and detailed study of the business processes, the following data was extrapolated and entered, collected in order to be able to carry out an LCA analysis as correct as possible.

Table 1. *Preliminary data from the plant*

VARIABLES	UNIT	TIME
INPUT QUANTITY ORGANIC FRACTION WASTE	8.616 tons	YEAR
QUANTITY OF COMPOSTING PRODUCED	300 m3	YEAR
COST OF LABOR	13.000 Euro	YEAR
COST OF MAINTENANCE	24.000 Euro	YEAR
COMPOST SALE PRICE	0,15 Cent a quintale	
ACCIDENT FREQUENCY IN THE PLANT	0	YEAR
WATER CONSUMPTION	2 Tankers da 10.000 Liters	WEEK
ENERGY CONSUMPTION	42.000 Euro	YEAR
STAFF	1 Administrative	1 Driver

The goal set by the company is certainly to better evaluate the various activities present within a set of activities with the related environmental impacts, to be possibly reduced over time. The company also has its production process analyzed quarterly in order to maintain quality standards given the certifications it holds.

Some phases of the LCA technique, such as impact assessment, are still at an early stage. There is still considerable work to be done and practical experience to be gained in order to further develop the practical operational level of the assessment of the life cycle. The scope, the limits, the level of detail of a study depend on the subject and the use envisaged.

The depth and the width of a LCA can differ considerably depending on the objective of a particular study. Because each technique has its limitations it is important to understand those of the LCA:

- The nature of choices and assumptions made during a study (e.g. Setting the boundaries of the system, choose the data sources) can be subjective;
- Due to the assumptions made, the models used to analyze the inventory may not be suitable for all kinds of environmental impact;
- The results of studies centred on regional and global issues may not be suitable for local applications;

- The accuracy of the studies may be limited by accessibility and the availability of interesting data, or data quality by their type or the lack thereof.

If it is desired that the LCA effectively includes environmental aspects related to products or processes, it is essential that it retains its technical credibility while allowing for a flexible, practical application at a reasonable cost.

References

1. Ruzzenenti, M. (2004). L'Italia sotto i rifiuti, Jaca Book, Milano, 65.
2. Polprasert, C. (2007). Organic Waste Recyclinh, IWA Publishing, Bangkok, 89.
3. Centemero, M. Zanardi, W. (2008). Il trattamento biologico dei rifiuti urbani in Italia: compostaggio, trattamento meccanico-biologico, digestione anaerobica, Dario Flaccovio Editore, Milano, Italy, 2-12.
4. Laforgia D., Perago A., Pigneri A., Trevisi A.S., (2004), Gestire i rifiuti, Maggioli editore, Dogana, 88-89
5. Coleman, 2003 Coleman, T., Masoni, P., Dryer, A., McDougall, F., (2003), International expert group on life cycle assessment for integrated waste management., International Journal of Life Cycle Assessment, 8, 175-178;
6. Ingrao et al, 2019 Ingrao C., Selvaggi R., Valentia F., Matarazzo A., Pecorino B., Arcidiacono C. (2019), Life cycle assessment of expanded clay granulate production using different fuels, Resources Conservation And Recycling, 141, 398-409.
7. Fichera S.S., Arfò S., Huang Y.L., Matarazzo A., Bertino A., (2020) Circular Economy and Technological Innovations in Steel Industry, Procedia Environmental Science, Engineering and Management, 7, 9-17;

Circular Economy indicators in Sicilian wine sector

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ABSTRACT

The transition to the circular economy within our country involves the quantification of appropriate indicators that determine the actualization of sustainable policies within different companies. The objective of this paper is to experimentally quantify appropriate indicators to verify the circularity of the economy in a sector with a high impact on the environment such as the wine industry. Special indicators have been quantified regarding the area of water management (Direct Water Scarcity Footprint and Non-Comprehensive Direct Water Degradation Footprint), atmospheric emissions (GHG and CO2 emissions) and waste production.

Keywords**:** *Circular Economy; Enologic Sector; Air Micropollution Indicators; Water Quality Management*

Introduction

A circular economy model is therefore a model of production and consumption that is opposed to the linear model of "take-use-dispose" in order to achieve a transformation that allows to reduce the impact that human activities have on the environment [1]. Instead, it involves "sharing, lending, reusing, repairing, reconditioning and recycling existing materials and products for as long as possible". In this way, the goods that are at the end of their life are transformed into resources for other lives, closing the cycle of industrial ecosystems and reducing waste [2]. All circular economy actions must be quantifiable so that their performance can be concretely assessed but to do so it is necessary to define precise parameters of measurability so as to be able to effectively analyze the benefits and carry out activities that allow greater transparency both for the consumer and for the market [3].

In particular, through the measurement of circularity, the objectives that are pursued consist in evaluating the transition process and the efficient use of resources, supporting companies in defining new strategies and monitoring progress towards sustainability and decarbonization objectives [4]. The MCI indicator is the only one that simultaneously evaluates the loss of materials in the production process and the durability of the product with the aim of improving the decision-making process in the design phase [5]. The RBR expresses the savings achievable through the recycling of a product compared to the environmental costs due to the use of unrecycled raw materials and their disposal [6]. Finally, the RMC measures the final internal consumption of products in terms of equivalent raw materials, i.e. raw materials used in the entire production chain of the products consumed and represents the material footprint of the product [7]. The bottling phase has a high environmental impact since the glass bottle production processes involve high emissions and require a high energy requirement [8]. Despite this, one cannot think of replacing glass with cardboard or with polyethylene terephthalate bottles because, according to many wine producers, glass is the only container that preserves its quality.

Methods

The territory indicator shows how the company meets environmental, social, ethical and economic requirements and helps to understand how to intervene in areas where it is possible to improve [9]. The analysis of the water indicator serves to assess the quantitative and qualitative impacts, due to the consumption and degradation of the quality of the fresh water used in the field and in the cellar. Two categories of impact are identified with their respective indicators:

“Direct Water Scarcity Footprint”: measures the potential water scarcity due to direct consumption of blue water volumes in m H_2O-eq / year;

“Non-comprehensive Direct Water Degradation Footprint” also known as “gray vineyard water”: provides an estimate of the potential degradation of the water quality status, corresponding to the volume of virtual water that allows you to report below the legislative or eco-toxicological limits for any contamination of the water body due to pesticides and fertilizers used in the agricultural phases.

It is expressed in terms of m^3 H_2O / year [10].

The first level analyzes six sub-indicators:

Defence. Evaluate the potential environmental risk associated with the use of crop protection products;

Fertilizations. Analyzes the impact of the three macronutrients nitrogen, phosphorus and potassium, depending on the fertilizer used and the methods of application, the characteristics of the soil and the needs of the vineyard;

Organic substance. Examines the effect of soil management practices on the evolution of organic matter through a calculation based on the ratio between the organic matter that is introduced into the soil with organic fertilizers, compost, cover crops and crop residues and the recommended levels for the vineyard;

Compaction. It expresses the influence that the various mechanical operations carried out in the vineyard have on the compaction of the soil;

Erosion. Consider the activities related to the control of surface runoff waters;

Landscape. It measures the presence of areas with natural vegetation or planted by the winegrower for an indirect assessment of the company's biodiversity. For each of these sub-indicators a sustainability value is given, observable in the table below, which will allow us to understand which sectors are in which the company is sustainable and in which not and also to understand which vineyards will need to be worked on. to improve its performance.

The second level, on the other hand, concerns the attribution of an overall judgment on the management of the examined vineyards which for the company in question is equal to 0.29 (excellent), which means that the management implies the minimum impact [11].

The air indicator studies the Greenhouse Gasses (GHG) of all the processes carried out by the company: from the vineyard activity to the storage of the finished product. The sources of emissions considered in the inventory are six, based on the provisions of ISO 14064-1: 2018110: direct emissions of GHG.

- Indirect GHG emissions from imported energy; ISO 14064-1: 2018, Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals, Genève;
- Indirect GHG emissions from transport (eg transport and distribution of goods purchased by the organization, home / work trips of employees);
- Indirect GHG emissions from products used by the organization;
- Indirect GHG emissions associated with the use of the organisation's products (category not considered in the Organization AIR indicator because it is outside the reference boundaries);
- Indirect GHG emissions from other sources.

Discussion and Conclusion

The quantification of the previous indicators is a good starting point to understand how to act on the aspects that are taken into consideration by them. In applying the territory indicator it is possible to understand the impact that wine production has on the territory in which it operates, in particular from this point of view, the company tries to minimize the environmental consequences through the interventions seen in previously [12]. As for the economic benefits, it can be said that the company will reduce, first of all, the costs of production and disposal thanks to the careful use of energy and local raw materials; it will also minimize waste through the resale of pomace and the use of chestnut poles and bio-degradable wood ties in the vineyard [13]; will see its sales increase because consumers are increasingly attentive to sustainability and their respect for the environment will lead them to prefer companies that are committed day by day to safeguarding the territory; it will obtain more guarantees and less risk on the products it uses, working with suppliers who in turn apply the principles of sustainability [14].

References

1. S. Geisendorf, F. Pietrulla, (2017). The circular economy, and circular economic concepts: a literature analysis and redefinition. Thunderbird International Business Review, 771-782.
2. T. Mancuso, S. Arfò, M. Di Mauro, A. Matarazzo, A.P. Froio, A. Scuderi, (2022). Application of SOSTAIN to Wine Sector in Sicily as Sustainability Management Tool. Journal of Biomedical Research & Environmental Sciences, 3, 302-306.
3. C. Gazulla, M.Raugei, P. Fullana, (2010). Taking a life cycle look at crianza wine production in Spain: where are the bottlenecks?. International Journal of Life Cycle Assessment, 15, 330-337.
4. R. Devesa-Rey, X.Vecino, J.L. Varela-Alende, M.T. Barral, J.M. Cruz, A.B. Moldes, (2011). Valorization of winery waste vs. the costs of not recycling. Waste Management, 11.
5. M. Lieder, A. Rashid, (2016). Towards circular economy implementation: a comprehensive review in
6. context of manufacturing industry. Journal of Cleaner Production, 115, 36-51.
7. R. Iannone, S. Miranda, S. Riemma, I. De Marco, (2015). Improving environmental performances in wine production by a life cycle assessment analysis.\ Journal of Cleaner Production, 111.
8. C.Ferrara, G. De Feo, (2018). Life Cycle Assessment Application to the Wine Sector: A Critical Review. Sustainability, 395, 1-16.
9. N. Golinucci, M. Rocco, F. Inzoli, E. Colombo, (2019). La questione degli indicatori, Equilibri. Rivista per lo sviluppo sostenibile, 1, 103-109.
10. A. Vercesi, G. Spezia, M. Fregoni, (2002). Viticoltura di precisione per le zone viticole e il vigneto. L'informatore agrario, 13.
11. J. Kirchherr, D. Reike, M. Hekkert, (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation and Recycling, 27, 221-232.
12. K. Schoer, J. Weinzeltel, J. Kovanda, J. Giegrich, C. Lauwigi, (2012). Raw Material Consumption of the European Union-Concept, Calculation Method, and Results. Environmental

Science&Technology, 46, 8903-8909.

13. Merli R., Preziosi M., Acampora A., (2017), Sustainability experiences in the wine sector: toward the development of an international indicators system, Journal of Cleaner Production, 172, 3791-3805.
14. Moraga G., Huysveld S., De Meester S., Dewulf J., (2021), Development of circularity indicators based on the in-use occupation of materials, Journal of Cleaner Production, 279, 1-13.
15. Mancuso T., Arfo S., Di Mauro M., Matarazzo A., Froio A.P., Scuderi A. (2022), Application of SOSTAIN to Wine Sector in Sicily as Sustainability Management Tool, Journal of Biomedical Research & Environmental Sciences, 3(3), 302-306.

ASSESSING ENVIRONMENTAL AND SOCIAL BENEFITS OF INDUSTRIAL SYMBIOSIS IN URBAN RESIDUES MANAGEMENT

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ABSTRACT

The main objective of this work is to presents the results of a comparison of the sustainability, through a Life Cycle Assessment (LCA), of three different management scenarios of waste, wastewater, and their related energy systems management in regions where there is an unsustainable approach in waste and wastewater management with effects on environmental impact, energy demand and economic activities. The results highlight the beneficial effects of the integration of different plants (Waste to Energy - WtE, Anaerobic digestion - AD, wastewater treatment plant - WWTP) in a symbiotic nexus. The results show that the recovery of separately collected wastes leads to an important reduction in the impact of Municipal Solid Waste (MSW) management but a synergic introduction of energy recovery (by means of AD and WtE) and its symbiotic use to support the anaerobic digestion, wastewater reuse, and sludge recovery processes significantly increase the sustainability. The proposed approach based on a waste-wastewater-energy nexus, could support the aforementionedse regions to fill the gap and increase the overall circularity.

Keywords*: Industrial Symbiosis; Waste; Wastewater reuse; Anaerobic digestion, Energy, recovery, sludge.*

Introduction

Southern Mediterranean regions continue to have disjointed [1,2] and unsustainable management of waste, wastewater, sludge and associated energy (produced/required) with no longer justifiable environmental burdens and a disparity in management between North and South-East countries of European Union.

Although climate change has intensified the already present problem of water scarcity [3] and wastewater reuse [4,5] is still substantially absent even if the use of a combination of different actions (e.g. advanced treatment, restricted irrigation, drip irrigation, stabilization reservoirs) can help in significantly lower the potential risks. The main obstacles is represented by the high costs of the additional wastewater treatment (i.e. tertiary phase) and above all to the energy costs needed to distribute the reclaimed water resource at the agriculture areas. These costs make the reclaimed wastewater not competitive with the limited natural water [6].

In addition, significant delay in the planning and construction of plants for the valorisation of recyclable material and for a sustainable management of the residual waste (i.e. not taking into account the 10% landfill limit in 2035 as expected by the European Directives) is observed in these regions. The strong opposition of population [7,8], which also affects political decisions, to accept plants for energy recovery, both from the organic fractions and residual waste [9] doesn't help to fix this gap. This opposition is driven from - often unjustified – health-risk fears, from more concrete odours [10] and properties depreciation issues and, above all, from the lack of a real knowledge on the cost/benefits ratio of including the energy recovery as complementary and not antagonistic to material recovery [11]. As a consequence in these regions there is a still abnormal use of landfill and the prospectively dangerous dependence - for the residual waste and WWT sludge management - on other regions of the country or - even worst - on foreign countries with all the aspects related to the economic, environmental and legal implications of cross-border waste transportation and to the loss of resilience.

In that light present work faces the comparison of three different management scenarios (a current one, two future ones) of waste, wastewater and related energy systems in Southern Europe regions - thoroughly analysed in terms of mass and energy balances [12] - by expanding the perspective in terms of their different environmental burden characterization [13].

Methods

This section reports the goal and defines the scope and the inventory analysis phases of the LCA, according to ISO 14040 and ISO 14044.

Goal and scope

The aim of this work has been to carry out an environmental comparison of three alternative scenarios pertaining to the management of MSW and wastewater in a large metropolitan area in a Southern European region. The considered area has a population of about 2 million, in terms of waste production, and an equivalent population of 545,000 in terms of WWTP capacity [12]. The overall amounts of MSW, i.e., 1.021.181 t/y, and of wastewater, i.e., 33.101.120 m3/y, represent the functional unit of the study. The composition that has been assumed for the MSW is specific for the case study, as previously described by Mancini et al., 2021 [12].

The compared scenarios (Figure 1), again according to [12]] are:

- Low material and low energy recovery Scenario (A - current);
- High material – low energy recovery Scenario (B - future);
- High material – high energy recovery Scenario (C – future symbiosis).

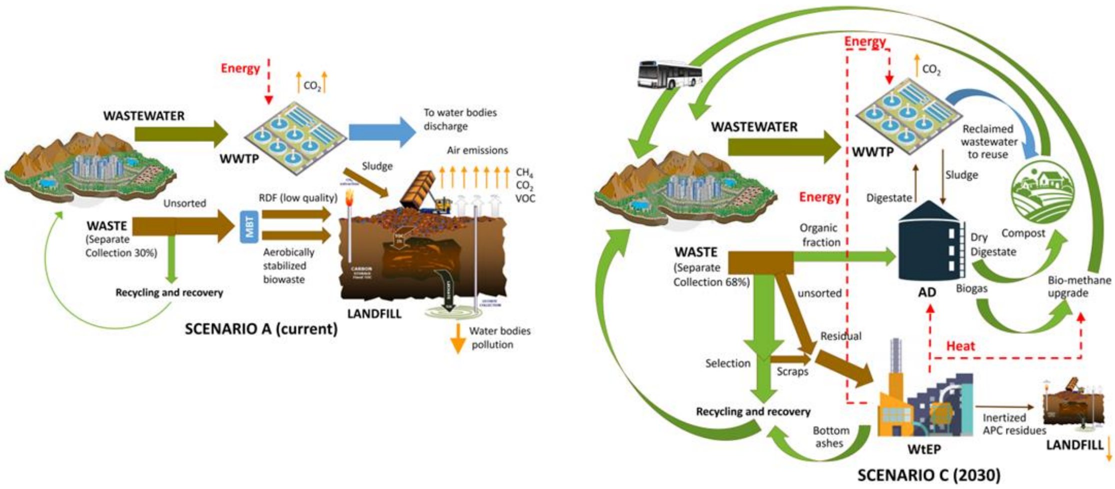

Figure 1. *Scenario A- Current and Scenario C- Future (the Waste-Wastewater-Energy Nexus through Industrial Symbiosis). Scenario B is similar to Scenario A except for the percentage of separate collection which is 68% instead of 30% and for the MBT which is not present in scenario B. (Modified from Mancini et al., 2022 [12])*

In order to include the avoided productions of energy and material due to the by-products such as energy and recovered materials (i.e. biomethane, compost, recycled plastics, recycled paper, recycled glass, etc.) the System Expansion is used. Biomethane and compost production replaces respectively the natural gas production and the generation of chemical fertilizers and peat.

The plant building and equipment assembly are not included within the system boundary, because their related impacts over the entire life of the plants can be considered less significant with respect to the corresponding waste management impacts [14].

Inventory analysis

In the inventory phase, the required quantitative data defining inputs/outputs of material and energy flows to/from the systems have been collected. Foreground data for the main processes, as included in each scenario, were extracted from (Mancini et al., 2021) [12] by considering the waste input and outputs for each process as well as the energy consumption/production. Other data, as specified in the following paragraphs, are retrieved from literature. Ecoinvent 3, is used to collect background inventory data for materials, fuels, chemicals, avoided energy and materials, and for final landfilling of wastes.

Results

Climate Change (CC)

Results are reported in Figure. 2a. The negative contribution in the Scenario -A, mainly arise from the recovery of the separately collected streams and, as a minor contribution, from the energy recovery from the biogas produced in AD of sludge and from the LFG. The positive contributions to CC is mainly due to the landfilling of the outpus streams of the MBT and other scraps, and in minor extent to the energetic recovery of the plasmix (note that the carbon in plasmix is fully non-renewable origin and hence only power production is assumed) and other processes including wastewater treatment, sludge pre-thickening, AD od sludge, sludge dewatering, as well as mechanical selection and OF composting. Note that the overall indicator for the composting process results positive, meaning that the process consumptions and emissions are higher than the benefits arising from substituting conventional fertilizers. In the Scenario, even if there is a reduction in landfilling, it still causes a relevant impact because of the significant amount of landfilled residual waste. At the same time, an increase in the benefits that arise from the enhanced recovery of the separately collected streams can be observed. The impact of the energetic recovery of plasmix increases, because of the increased amount of separately collected plastics and considering that the quality of the separately collected materials not change. The increased separate collection also leads to an increased amount of OF. As the composting is not able to efficently valorise the OF, the positive impact increases On the overall, the “CC” indicator for Future scenario results 85% lower than the “CC” calculated for the current scenario. With the Future symbiosis scenarios, the perspective changes dramatically. The positive impact of landfilling is no more appreciable (only few residues from some processes are still landfilled and the total of them is mostly inert). The relevant savings coming from the energy recovery in WtE process add to those provided by the recovery of materials from waste separate collection. Also savings arising from the recovery of bottom ash are not negligible. To obtain these advances, some additional positive impacts need to be paid as sludge digestate drying. An important negative contribution comes from the avoided production and use of natural gas, which is substituted by the biomethane production. This negative contribution is much larger than the positive impacts related to OF anaerobic digestion.

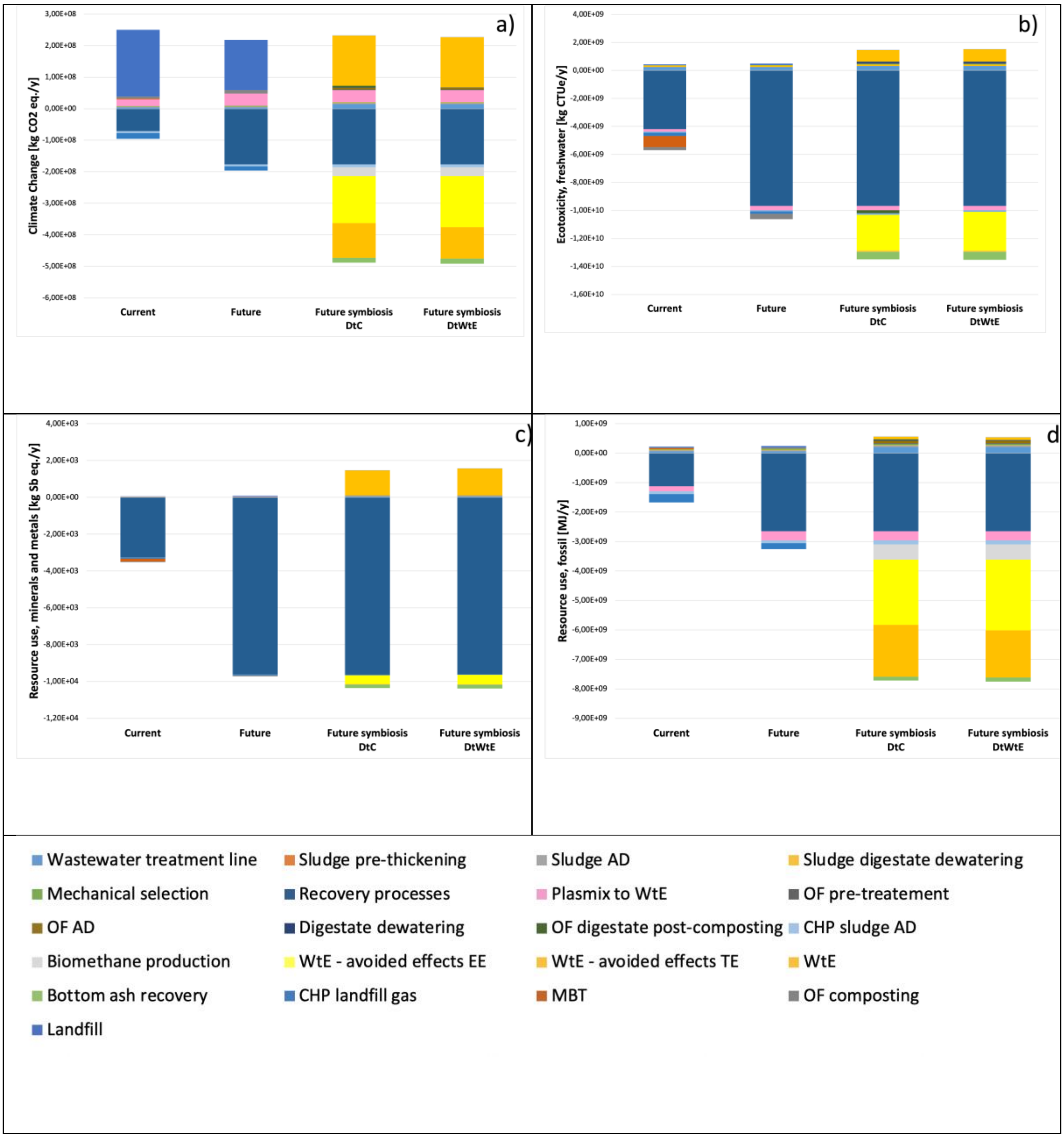

Figure 2. *Contribution analysis: a) Climate Change; b) Ecotoxicity freshwater; c) Resource Use, minerals and metals; d) Resource Use, fossils.*

Ecotoxicity, freshwater (E,f)

Results are reported in Figure 2b. Considerations such as those reported for climate change are valid. For this indicator the positive impacts of landfilling are negligible and low compared to the negative ones. Negative contributions are associated to processes where energy or matter is recovered: the most important contribution comes from the recovery of the separately collected streams, others contribution are due to plasmix WtE recovery, CHP from sludge AD, WtE and bottom ash recovery. The contribution due to the direct OF composting or to the digestate composting is negative, because the avoided effects of fertilisers production are greater than the impacts related to the consumption for the process. Quite the opposite, the biomethane production process does not provide negative contribution to this indicator since the savings due to the natural gas use and production are not able to compensate those for the upgrading consumptions. The reduction in the impact is evident moving from the current scenario - through the future scenario - to the future symbiosis scenario.

Resource use, minerals and metals (RUmm)

This indicator depends on the recovery of mineral and metal resources from the recovery process of the separately collected streams. However, there are also some non-negligible positive impacts related to the consumption of chemicals for the FGT in WtE process. This contribution, shown in Figure 2c) explains the reason why the Future symbiosis scenarios have worse indicator values (6-7%) than the Future scenario. A reduction of this indicator is evident in the two future scenarios (of 178% and 156%, respectively) with respect to the current scenario.

Resource use, fossil (RUf)

Results are reported in Figure 2d. The larger amount of digestate sent, after drying, to the energy recovery in the WtE case, increase the savings more than the increased energy consumption for the drying itself. Moreover, the importance of the production of biomethane from the separately collected OF, instead of its composting, is clear for this indicator.

The contribution of the selection and recovery processes for the material recovery

Figure 3 shows the contribution of the selection and recovery processes for the material separately collected for the two future scenarios (B and C) and the different relevance for each indicator which depends on the processes used in the recycling and on the avoided process in the production of virgin materials. The contributions of the selection and recovery of paper and cardboard, glass, metals, wood, textiles and WEEE to the Climate Change are negative, meaning that the balance - between the effects of processing the waste to obtain the recycled materials and the avoided production of the same amounts of recycled materials – is negative (i.e. there is an effective benefit). The main contributions come from glass and metal recycling. On the contrary, plastic recycling delivers a positive contribution to Climate Change. This is due to the non-renewable CO_2 emissions generated by combusting the plasmix, in WtE. This effect could be reduced by reducing the scraps from the plastic selection, thus reducing the undesired non-recyclable plastics in the separate collection of plastic packaging. However, the benefit of recovery the energy content of the plasmix is highlighted by the Resource use, fossil indicator, where the avoidance of the extraction of fossil fuels is acknowledged. Each indicator presents a final negative value, meaning that – on the overall – the positive impacts deriving from selection and recycling processes are largely exceeded by the savings.

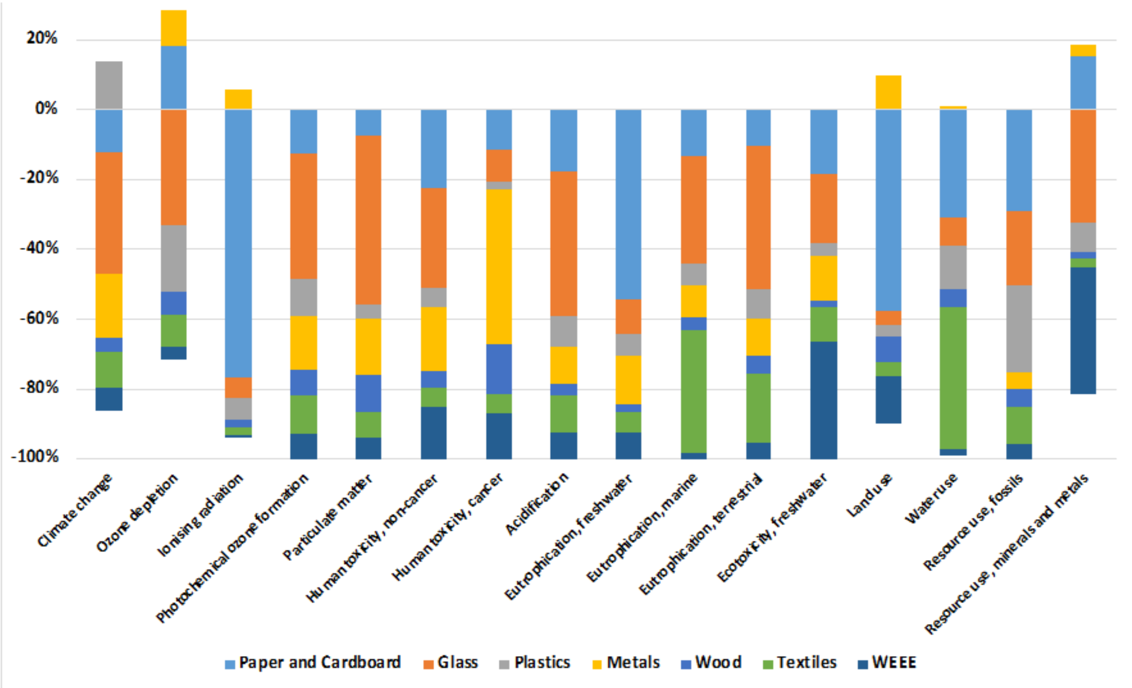

Figure 3. *separately collected materials contribution to the total effects of the subprocess "Mechanical selection", "Recovery processes" and "Plasmix to WtE", as reported in Figure 2a-d for the two future scenarios (B and C).*

Discussion and Conclusion

The improvement in all the indicators (except Resource use, minerals and metals) for the symbiosis scenario, compared to the Future one, are determined by the introduction of two energy recovery processes: biomethane production from the anaerobic digestion of OF and the combustion of mixed MSW, dried digestate and scraps using the heat and electricity produced in the WtE plant. Both of the processes for the CC indicator provide an overall negative contribution (i.e., the algebraic sum of positive and negative values, for WtE and AD/biomethane), thus indicating a CO_2 sink. This study has demonstrated, by means of an LCA, that an integrated approach (the C Scenario) - based on industrial symbiosis - is by far the most sustainable. The LCA results have shown that an important reduction of the impact of MSW management is achieved through the recovery of materials collected separately, but there is still a large gap to be filled in the improvement of the environmental performances. Such a gap could be filled by the introduction of energy recovery (by means of anaerobic digestion and Waste-to-Energy processes) and its symbiotic use to support the anaerobic digestion, wastewater reuse and sludge recovery processes. The use of a limited amount of the electricity produced by the WtE recovery of the residual waste dramatically enhanced the chance of reusing wastewater, as a result of the lowering of the energy costs of the water resource associated with the required WWT tertiary phase and its pumping to irrigated areas. Switching from the composting of an organic fraction to its anaerobic digestion represents a significant contribution toward improving environmental performances. Some possible uses of part of the recovered thermal energy have been proposed in the analyzed symbiosis scenario, such its use to enhance and fully exploit AD biogas production, and to dry the digestate, so as to exploit its energy and material (ashes). This route has shown better environmental performances than the agronomic use of the composted digestate for almost all the indicators, except for those that are influenced to a great extent by the chance of saving conventional fertilizers, which, in turn, depends on the effective and specific nutrient content of the compost. The effective final use of the remaining recovered thermal energy should be evaluated, in future developments, by enlarging the boundary system, to include, for example, some external housing or industrial thermal users, by collecting data about their needs and prioritising the substitution of those currently used energy sources showing the lower efficiency and/or higher pollutant impacts. The proposed symbiotic model should be intended as a modern bio-refinery process which is able to provide electricity, heat, and biomethane to industrial districts and / or surrounding cities, to significantly increase circularity – also through a sustainable reuse of wastewater - and to cause a drastic reduction of the disposal of waste in landfills, so favoring a significant rapprochement toward the New Green Deal promoted by the European Union in these regions, which are clearly lagging behind.

References

1. Wang X, Guo M, Koppelaar RHEM, van Dam KH, Triantafyllidis CP, Shah N. A Nexus Approach for Sustainable Urban Energy-Water-Waste Systems Planning and Operation. Environ Sci Technol 2018; 52: 3257−3266. https://pubs.acs.org/doi/10.1021/acs.est.7b04659.
2. Gu Y, Dong Y, Wang H, Keller A, Xu J, Chiramba T, Li F. Quantification of the water, energy and carbon footprints of wastewater treatment plants in China considering a water–energy-nexus perspective. Ecol Indic 2016; 60: 402–9. https://doi.org/10.1016/j.ecolind.2015.07.012.
3. European Envoronmental Agency. Water resources across Europe — confronting water stress: an updated assessment. 2021. doi:10.2800/320975
4. Fatta D, Alaton IA, Gokcay C, Rusan MM, Assobhei O, Mountadar M, Papadopoulos A. Wastewater Reuse: Problems and Challenges in Cyprus, Turkey, Jordan and Morocco. European Water 2015; 11/12: 63–9.
5. Barceló D, Petrovic M. Waste Water Treatment and Reuse in the Mediterranean Region. Springer-Verlag Berlin Heidelberg; 2011.

6. Canaj K, Mehmeti A, Berbel J. The Economics of Fruit and Vegetable Production Irrigated with Reclaimed Water Incorporating the Hidden Costs of Life Cycle Environmental Impacts. Resources 2021;10:90. https://doi.org/10.3390/resources10090090.
7. Hosseini S, Esfahani AM. Obnoxious facility location. In: Zanjirani Farahani R., Hekmatfar M. editors. Facility Location. Contributions to Management Science, Heidelberg: Physica; 2009, p. 315-345. https://doi.org/10.1007/978-3-7908-2151-2_14
8. Lober DJ, Green DP. NIMBY or NIABY: A logit model of opposition to solid-waste-disposal facility siting. J Environ Manage 1994; 40(1): 33-50. https://doi.org/10.1006/jema.1994.1003.
9. Perkoulidis G, Papageorgiou A, Karagiannidis A, Kalogirou S. Integrated assessment of a new Waste-to-Energy facility in Central Greece in the context of regional perspectives. Waste Manage 2010; 30: 1395–406. https://doi.org/10.1016/j.wasman.2009.11.021.
10. Luciano A, Mancini G, Eleuteri A, Torretta V, Viotti P. The modelling of odour dispersion as a support tool for the improvements of high odours impact plants. Environ Technol 2017; 38(5): 588-597. https://doi.org/10.1080/09593330.2016.1205146.
11. AlQattan N, Acheampong M, Jaward FM, Ertem FC, Vijayakumar N, Bello T. Reviewing the potential of Waste-to-Energy (WTE) technologies for Sustainable Development Goal (SDG) numbers seven and eleven. Renewable Energy Focus 2018; 27: 97-110. https://doi.org/10.1016/j.ref.2018.09.005.
12. Mancini, G., Luciano, A., Bolzonella, D., Fatone, F., Viotti, P., Fino, D., 2021. A water-waste-energy nexus approach to bridge the sustainability gap in landfill-based waste management regions. Renewable and Sustainable Energy Reviews 137 (2021) 110441.
13. Wang D, Tang YT, Sun Y, He J. Assessing the transition of municipal solid waste management by combining material flow analysis and life cycle assessment. Resour Conserv Recycl 2022;177:105966. https://doi.org/10.1016/j.resconrec.2021.105966.
14. Evangelisti, S., R. Clift, C. Tagliaferri, P. Lettieri, A life cycle assessment of distributed energy production from organic waste: Two case studies in Europe, Waste Management. 64 (2017) 371–385. https://doi:10.1016/j.wasman.2017.03.028.

3 TOOLS FOR CLIMATE NEUTRALITY; CARBON CREDITS, CARBON FARMING AND CARBON STANDARDS

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ABSTRACT

Climate change has become a topic of strong economic interest. Objective parameters show that a process of biosphere transformation is taking place. To achieve the European goal of climate neutrality, it is necessary to identify technical tools for measuring the environmental impact by implementing effective intervention actions. The parameter for the objective measurement of the qualitative variations of the biosphere is carbon dioxide, CO_2, a new frontier of comparison in economic markets. One of the tools that would allow subjects operating in the agro-forestry field to reach the condition of "carbon neutrality" is represented by carbon farming on which a guideline of the European Commission was published in 2021. Carbon farming represents a natural solution for carbon removal and include good soil management practices to increase carbon sequestration and storage from the atmosphere to soil and biomass [1].

Keywords: *Climate change; Climate programs; Climate neutrality; Carbon sequestration; CO_2.*

Introduction

Climate risk is an issue closely linked to economic flows. This is a responsibility for all the supply chain players who are called to fight against climate change, which will have effects on the movement of goods. There is evidence of how a transformation of the biosphere is taking place and today the attention of the scientific community that is questioning the causes of this change and the consequences that this brings with it, is affecting every aspect of life, but it is also looking for solutions, increasingly urgent, to a climate that changes mainly due to anthropogenic activity. The European Union has set itself a very ambitious goal that can be reached through the collaboration of all the parties involved, to be the first neutral continent towards climate-changing emissions by 2050, following the sustainable development goals and reducing emissions by 55% by 2030 compared to 1990 levels [2]. The question becomes finding tools capable of guaranteeing credibility in the market with respect to the climate issue. Tools have to be able to identify the role played by a subject within the economic chain in which it operates in order to program a clear, achievable and declarable action plan to its stakeholders.

The international legislative context will have to require the players operating on the market to consider the impact of climate risk on the economic value of the goods they sell. To do this, the CO_2 measurement will become a financial valuation index. It is therefore a question of creating the conditions so that the debtor, source of CO_2 emissions into the atmosphere, can dialogue with the creditor who can dispose of environmental assets suitable for the storage of these emissions. The ability to evaluate carbon dioxide therefore becomes a preparatory activity for the planning of active neutralization interventions that will determine a financial shift of the asset, towards parameters of environmental reward, allowing debtors to meet the subjects creditors [3]. The production chains will be asked to re-evaluate the economic principles of exchange historically applied by spreading a new value index in the market, based on carbon.

Tools and Methods

Climate neutrality in the agro-forestry sector can be achieved by the synergy of three instruments that will acquire more and more importance in the coming years: carbon credits, carbon farming and carbon standards. The carbon credits, according to the definition of the ISO 11646 standard, which provides specifications for the implementation of the national system for voluntary market management of CO_2e credits deriving from projects to reduce emissions or increase GHG removals, are units of reduction of emissions or increase in the removal of greenhouse gases generated by projects, each corresponding to 1 t CO_2e eligible to be exchanged and sold on the market [4]. This market may be the mandatory one (eg EU-ETS system) but in recent years the voluntary offsetting initiatives that refer to the voluntary carbon market have been gaining importance. It is an economic reality that allows virtuous subjects who want to demonstrate their commitment to fight climate change, to meet and buy carbon credits to offset their emissions or sell these credits generated by certified carbon sequestration projects. These carbon shares are precisely the carbon credits that can be generated by carbon farming projects, nature-based solutions of carbon removal including good soil management practices to increase the ability to absorb carbon from the atmosphere and storage in the soil and biomass [5]. A European Commission guideline on carbon farming was published in 2021, anticipating a bill under discussion by the end of 2022 [1]. To achieve climate neutrality, carbon credit generating solutions such as carbon farming must be regulated and this is where carbon standards come into play. They are climate programs that have carbon management as their main topic, which provide the rules for creating projects aimed at mitigating climate change. These standards can be written by private or public entities and can apply to a specific geographic area or apply worldwide. They allow a subject to take steps to measure their environmental impact

and implement effective intervention actions on this front. In Italy, for example, UNI/PdR 99:2021 was published in April 2021 [6], which refers to a climate program, βneutral, as an example of a national program in the field of climate neutrality which includes, among others, a methodology for calculating the increased carbon sequestration through organic farming. This methodology provides a guideline for writing a project which, using the principle of additionality, according to which an increase in the carbon stock or a reduction in emissions would not occur in the absence of a project, allows to quantify the carbon credits stored on agricultural land [3].
The quantifications are performed using the scientific method. A climate program such as βneutral, follows the MERC approach which is based on the measurement of greenhouse gas emissions from a given activity, on avoiding emitting greenhouse gases, reducing and compensating for emissions that cannot be avoided [7]. The measurement of GHG emissions must take place following internationally recognized standards (UNI EN ISO 14064-1 and UNI EN ISO 14067) which represent the theoretical starting point. The purpose of these standards is to identify the context to be analyzed and then proceed to a collection of methodological and timely information that allows the designer to model the collected data [8,9]. To avoid emissions accounted for, a climate strategy must be prepared along the entire supply chain, long-term emission reduction objectives must be chosen and valid; recognized offsetting projects must then be chosen, which respect the principles of additionality. The MERC approach is effective if it ensures compliance with the carbon balance in nature. The correct functioning of the cycle of this element is fundamental for the good health of all ecosystems present on our planet.

Results

In Italy there are several virtuous examples of companies that have presented projects to offset emissions and generate carbon credits through nature-based solutions expendable on the voluntary carbon market and validated in accordance with UNI/PdR 99:2021 practice. In particular, during 2022, 21 companies were certified according to Program 2 of βneutral, the climate standard for climate neutrality cited above. These companies have submitted carbon sequestration projects generating a quantity of voluntary carbon credits to be spent on the voluntary carbon market. βneutral also includes another part, Program 1, which allows for the certification of emissions compensation projects after the implementation of a carbon reduction strategy. For compensation, a company in program 1 must purchase βneutral credits and credits recognized by the Program itself. To date, there is 1 company certified according to the compensation Program which has acquired credits from a company certified according to Program 2. To date, all companies in Program 2 are certified according to the "Organic

Agriculture" methodology and 4 of them are active in the credits market. Among these 4, 2 companies support the transfer of credits internally to βneutral Program, allowing 2 companies in Program 1 to offset their emissions. The location of βneutral companies mainly concerns north-east of Italy, but there are many italian areas where is possible to think about sustainable strategic solutions to achieve climate neutrality. In this context it is necessary to make southern companies aware of the possibilities offered by βneutral and distribute awareness of the climate issue throughout the country [3,10].

Discussion and Conclusion

Climate neutrality and its achievement are complex issues that can be achieved thanks to the synergy of different subjects, public and private. Thanks to the ever wider diffusion of carbon standards, in the future it will be possible to witness an ever greater development of the voluntary carbon credits market, which will be able to draw on an ever-increasing number of subjects who want to offset their emissions by contributing to the mitigation of climate change and to an economic flow beneficial to the environment. Following the standards, companies, public administrations, private organizations and all interested parties are called to identify how much their actions may have contributed to the increase in the thickness of the terrestrial greenhouse, to intervene with concrete actions in order to restore the effectiveness of the coverage. To do this, it is probable that the debtors will have to dialogue with the creditors.

References

15. European Commission, Directorate-General for Climate Action, Radley, G., Keenleyside, C., Frelih-Larsen, A., et al., Setting up and implementing result-based carbon farming mechanisms in the EU: technical guidance handbook, Publications Office of the European Union, 2021.
16. https://climate.ec.europa.eu/eu-action/climate-strategies-targets/2050-long-term-strategy_it
17. βneutral – Programma che identifica progetti GHG per le emissioni, le riduzioni e le rimozioni di gas serra.
18. UNI 11646 - Gas ad effetto serra - Specifiche per la realizzazione del sistema nazionale di gestione del mercato volontario dei crediti di CO2e derivanti da progetti di riduzione delle emissioni o di aumento delle rimozioni di GHG.
19. https://carbonsink.it/articoli/il-mercato-volontario-del-carbonio-un-importante-contributo-per-la-lotta-al-cambiamento-climatico/
20. UNI/PdR 99:2021 - Linee guida per il calcolo, la riduzione e la compensazione delle emissioni di gas serra di organizzazioni e prodotti, e requisiti per i progetti di generazione di crediti di carbonio.
21. RETE RURALE NAZIONALE 2014 2020 - Il prototipo della piattaforma di calcolo delle emissioni a livello di azienda zootecnica e la valutazione di pratiche di compensazione. Presentazione di Isabella Foderà (ISMEA) per l'evento "Il distretto agricolo zootecnico forestale: un nuovo

approccio territoriale per la mitigazione dei cambiamenti climatici" del 21/12/2020.
22. UNI EN ISO 14064-1:2019 - Gas ad effetto serra - Parte 1: Specifiche e guida, al livello dell'organizzazione, per la quantificazione e la rendicontazione delle emissioni di gas ad effetto serra e della loro rimozione.
23. UNI EN ISO 14067:2018 - Gas ad effetto serra - Impronta climatica dei prodotti (Carbon footprint dei prodotti) - Requisiti e linee guida per la quantificazione.
24. http://www.bneutral.it/

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