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"Gheorghe Asachi" Technical University of Iasi, Romania

CIRCULAR ECONOMY INITIATIVES IN THE MARCHE REGION: IMPLEMENTING OF INDUSTRIAL SYMBIOSIS WITHIN THE MARLIC PROJECT AND MAPPING REGIONAL SKILLS AND GOVERNANCE

Antonio Picarelli[1*], Tiziana Beltrani[2], Emanuela De Marco[3], Marco La Monica[2], Erika Mancuso[2], Silvia Sbaffoni[2], Flavio Scrucca[4], Marco Antonini[5], Laura Cutaia[6]

[1]Smart Grids and Energy Networks – SGRE - ENEA, Piazzale Enrico Fermi, 1, Portici, Italy
[2]Laboratory Tools for Sustainability and Circularity– SSC - ENEA, Via Anguillarese, 301, Rome, Italy
[3]Section Integrated and Nature-based Solutions for Urban Regeneration – NATURB – ENEA, Via Anguillarese, 301, Rome, Italy
[4]Section for the support of the ICESP platform – ICESP - ENEA, , Via Anguillarese, 301, Rome, Italy
[5]Regenerative Circular Economy Laboratory - BIOEC – ENEA, Via Anguillarese, 301, Rome, Italy
[6]Division Circular Economy - EC – ENEA, Via Anguillarese, 301, Rome, Italy

Abstract

To reduce material use in production, we should embrace circular economy (CE) principles. Industrial symbiosis (IS) enables material, expertise, and service exchanges, though legislative and technical limits restrict local efforts. The MARLIC project was initiated in response to the necessity of establishing a central point of reference in the Marche region in Italy, to develop new materials and promoting circular use. This study aims to present the findings of two activities conducted by ENEA. The first activity involves the application of a methodology for the identification of roles and skills within the CE sector in the region, along with the collection of evidence useful for the proposal of an organisational framework at the regional level. In this regard, according to the evidence obtained, it can be supposed that the best organizational model for CE skills systematization can be achieved by creating a specific regional structure for CE and resource management. The second activity is a pilot IS application with local enterprises, following ENEA's methodology. In a workshop, 30 companies identified 85 matches and over 300 shared resources, including paper, leather, and plastic. The strong participation and positive feedback from organizations at the IS workshop show their commitment to enhancing process circularity and applying IS for improved environmental sustainability. Furthermore, the parallel activity of identifying a regional governance model for CE has provided a more concrete definition of the path towards transitioning from linear to circular production models.

Key words: circular economy, governance, industrial symbiosis, marches, resources circularity, skills on circular economy

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1. Introduction

The concept of a "circular" economy entails the production of goods and services through the reintroduction of materials into industrial ecosystems or their economic revaluation through reuse, recycling, and recovery, thus avoiding the waste that typically occurs in a "linear" economy. This approach intervenes across all stages of the product lifecycle, from design to end-of-life management. In a circular economy (CE), the value of products and materials is preserved for as long as possible, shifting away from the traditional linear model of production and consumption. This shift represents a departure from the notion of waste minimization towards a holistic perspective that reconciles economic and

* Author to whom all correspondence should be addressed: E-mail: antonio.picarelli@enea.it; Phone: +39 3396662097.

environmental interests, recognizing them as interconnected rather than conflicting. The CE embraces a broader concept of well-being that encompasses both economic prosperity and environmental sustainability. Moreover, the CE fosters the development of sustainable business models capable of closing production cycles efficiently and making more effective use of resources within a given area. One notable strategy within this framework is Industrial Symbiosis (IS), which involves the exchange and sharing of resources (such as raw materials, water, energy, waste, services, skills, etc.) among companies and other stakeholders in the region. This approach enhances the competitiveness of industrial activities and enriches the local territory by maximising the utilisation of resources within the community rather than dispersing or outsourcing them. The IS was defined as "*the economic exchange of material flow, resources and residual waste in a multiple, collaborative network facilitated by trust, available information and existing stimuli*" (Agudo et al., 2022). The transition to a CE and sustainable development represents a significant challenge for society at large and for organizations. The European Commission has established the framework for this paradigm shift with the adoption of the European Green Deal (European Commission, 2019) to achieve climate neutrality by 2050 and the new Circular Economy Action Plan (European Commission, 2020). These initiatives aim to conserve resources and material value while reducing waste and residues.

In Italy, the National Strategy for the Circular Economy (NSCE) (MASE, 2013) was approved alongside the National Waste Management Program through Ministerial Decree No. 259, dated June 24, 2022 (MASE, 2022). The NSCE serves as a programmatic document outlining actions, measures, and objectives to advance institutional policies towards a CE. It identifies IS as one of the nine key areas of intervention necessary to achieve this transition in Italy. Furthermore, the NSCE supports the development of projects in this area through specific regulatory and financial instruments, demonstrating the country's commitment to advancing CE principles. However, while the benefits and potential of IS are clear, there are numerous political, regulatory and fiscal barriers, not to mention those related to innovation and business culture, which tend to hinder the spread and adoption of this practice. The barriers are often cultural, linked to a lack of knowledge about the benefits of collaboration and exchange between companies, a reluctance to invest in innovation because it is considered 'risky', or a general lack of awareness of the existence of different options for managing waste resources. In addition, the low price of raw materials makes the cost savings from adopting IS-based business models unattractive. The lack of legislation to support the management of many types of waste contributes to the lack of viability of material exchange between companies. This article illustrates the activity carried out by ENEA (Italian Agency for New Technologies, Energy and Sustainable Economic Development) within the MARLIC (Marche Applied Research Laboratory for Innovative Composite Materials) project on IS. The Marche region, nestled in central-eastern Italy between the Apennine mountains and the Adriatic Sea, spans roughly 9.500 square kilometres. With six provinces comprising its territory, the Marche boasts a population of approximately one and a half million residents from a demographic standpoint (Assocalzaturifici, 2024).

The MARLIC project (2023) aims to establish a regional focal point for the advancement of new materials, with a specific focus on biomaterials and the adoption of circularity principles in the utilization and reutilization of raw and secondary materials within the Marche region. The project consortium comprises 21 local companies and 5 university and research centres. The project's activities are organized into two distinct, sequential actions:

- the first project concerns the development of biomaterials and mixed advanced materials studying the utilization of new raw and/or secondary materials;
- the second project follows a circular approach through a "De-manufacturing with a view to CE according to the rules of the 4Rs (Reduce, Reuse, Recycle, Recover).

Moreover, the project represents the first structured attempt to enhance the CE and implement IS in the Marche region. Among the project activities, ENEA oversaw those related to the following topics:

- identification of roles and competencies within the CE sector in the region, along with the collection of evidence to support the proposal of an organizational framework;
- establishing an IS pilot through the facilitation of IS workshops with local businesses and stakeholders based on ENEA's methodology.

Although IS is recognized, even by the SNEC as one of the most effective strategies for transitioning production systems towards a CE, there are typically no dedicated regional structures to support this approach. Regional offices, for example, are traditionally organized by specific competencies, separating waste management from industrial policy functions. For this reason, the two activities outlined above aim to identify the competencies and roles associated with the CE and particularly with IS, while also implementing a pilot initiative to guide businesses in the practical application of this strategy.

The project activities progress along two concurrent development paths. This paper endeavours to accurately depict the project and its activity advancements on CE. Therefore, the document structure is arranged into two sections corresponding to each sub-activity. The first activity is focused on the identification of actors and skills within the reference territory. This is crucial to implement CE actions inside it and to ensure an effective ecological transition. Therefore, to support the proposal of a specific circular organizational model tailored for the Marche region, a specific methodology was applied to identify the institutional actors and technical skills in

the field of CE at a regional level, basically through: a) mapping the state of the art and creating a database of skills and roles on the CE key areas; b) consulting the identified relevant/skilled actors; c) collecting evidence/recommendations useful to define an organizational model to structure CE skills. The second activity is instead dedicated to the establishment of an IS pilot in the targeted region.

The aim of this pilot activity is to provide the companies participating in the workshop with a concrete opportunity to compare and exchange information on possible and available resources. A methodology validated by ENEA will facilitate the exchange of information and the subsequent processing of the data collected during the workshop. Once the potential synergies have been identified, the aim is also to help the companies overcome the obstacles that prevent the implementation of a symbiosis path. This is done by providing them with the regulatory and technical information that is functional for the effective realisation of the synergy, which can be further replicated in the future by other companies sharing the same type of resources.

According to a validated methodology due to decades of experience on this issue. In 2010 ENEA started the development and implementation of an IS network model thanks to several projects in Italian regions (Cutaia et al., 2014, 2015, 2016a, b; La Monica, 2016; Luciano et al., 2016). ENEA's sustainability laboratory has effectively applied its methodology to assist companies in achieving IS matches within the MARLIC project. As part of the project, an IS workshop was convened and took place at the University of Camerino. The creation of an IS pilot in the Marche region passes through different steps of the well-established ENEA methodology: (a) stakeholder individuation in the designed area (b) preliminary activities for the IS workshop (c) development of the IS workshop (d) identification of the significant flow resources and data analysis (e) identification of the synergies and in-depth analysis from a technical and economic point of view. The initial phase involves identifying stakeholders in the Marche region. An analysis conducted in the targeted area reveals a significant presence of firms in the manufacturing sector, accounting for approximately 76.7% of the total participation in the IS workshop. Notably, the area has a longstanding history in the footwear sector. Furthermore, the industrial sector linked to footwear includes a diverse array of companies engaged in the processing and manufacturing of plastic/rubber materials, as well as the tanning and leather industries.

In Italy, the tanning sector comprises 1.154 companies as of 2022, with a total turnover of 4.2 billion euros (UNIC, 2021). A significant portion of the leather produced is primarily destined for the footwear industry, accounting for approximately 32.8% of its usage. This evolution is attributed to both the progress of materials utilized in footwear production, such as those for internal and external soles and the necessary co-evolution of key industries within the footwear production chain.

2. Material and methods

ENEA approaches for the two project activities are outlined below. Firstly, the identification of CE competencies in the targeted territory involved combining surveys to gather field data. Secondly, leveraging ENEA's methodology for IS workshop organization and management, the effort to engage stakeholders within the region proved challenging yet significant.

2.1. Identification of roles and competencies in the Marche region

Combining surveys with other search methods is generally recognized as a valid opportunity to gather data. Researchers commonly adopt different approaches to gather and collect data for a specific purpose (Taherdoost, 2021) and different sources such as experiments, surveys, interviews, and questionnaires are normally used to achieve primary data, also in qualitative research (Kabir, 2016, Taherdoost, 2021). Moreover, specific "practical" approaches that also rely on a structured engagement with the target actors are adopted when the object of the (re)search (such as CE competencies intended to be mapped as reported in the literature (Ferreira and Matias, 2021), was not extensively examined by the literature or identified case studies.

The methodology developed by ENEA to identify roles and competencies related to the CE key areas in the Marche region, therefore followed a combined practical approach consisting of three working steps, , summarised in the methodological approach diagram in Fig. 1. The steps are as follows:

- Desk mapping, for preliminary identification of institutional actors and skills;
- Consultation of relevant/competent actors, to deepen the comprehension of roles and competencies;
- Summary of evidence/recommendations useful to support the proposal of an organizational model to systematize CE skills, based on the outcomes of the previous steps.

The methodological approach is summarized in Fig. 1. The desk mapping was aimed at defining the state-of-the-art skills and roles related to the CE key areas at the regional level and, therefore, it was aimed at providing the main information regarding the various relevant actors. An appropriate data collection sheet was created to properly store information characterizing the various subjects in terms of internal organization; institutional contacts (registered office, operational offices, telephone, email, website etc.); type of subject (e.g. organisation, agency, research centre etc.); relevant structures in the territory (offices, laboratories etc.); relevant skills for CE topics. A web search was therefore carried out, focussing on relevant public bodies (e.g. Region, University etc.) and using specific keywords related to CE topics, to define a list of reference "macro-structures" (MS).

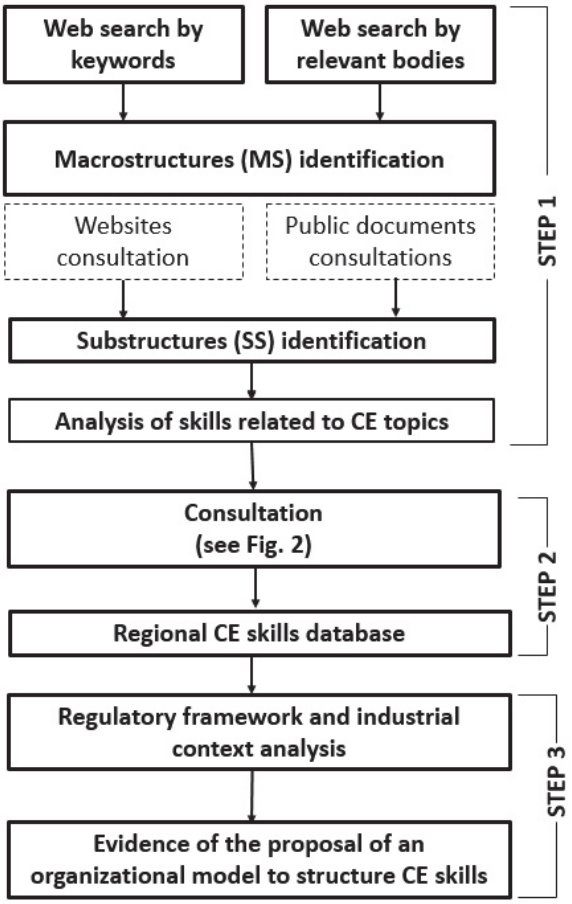

Fig 1. Methodological approach adopted by ENEA (source ENEA)

Subsequently, through the consultation of the websites (and their specific sections) and the freely available documents on the web regarding these MS (such as declaratory statements, organizational charts, etc.), a list of "sub-structures" (SS) was defined and classified according to the key CE topics (e.g. Production, Consumption, Waste Management, Secondary Raw Materials, …). At the end of this phase, the first version of the CE skills database was developed, and the consultation of the relevant identified actors was carried out to detect in detail the skills of each one of them, thus integrating and deepening the first identification of CE skills developed during the desk mapping phase. The consultation was implemented through a survey tool specifically developed by ENEA following the process formulated by Peterson (Peterson, 2000), also adopted by other authors for CE skills identification (Sumter et al., 2021).

Such an approach was followed to realize an effective survey and, therefore, to carefully determine the types of questions to be asked, their specific wording and order based on the study's objective, and using as much as possible a non-academic phrasing. When a research project requires information from an individual's questionnaire construction is one of the most delicate and critical activities and it is fundamental to ask the "right questions", i.e. the questions able to provide valid and reliable information at the aim of the project itself.

For the sake of brevity, it is not possible to list all the questions of the survey, that were organized in specific sections to collect general information regarding the reference body, its structures in the territory and its peculiar skills regarding CE topics. Regarding CE skills detection, questions aimed to categorize them by CE key area (Design, Production, Consumption, Waste Management, Secondary Raw Materials, Innovation, Distribution/logistics, Financing/investments), also asking for information useful to characterize skills by type (political / programmatic, administrative, technical/ technological skills etc.). Other sections of the questionnaire were instead aimed at detecting synergies and collaborations between the different actors, to have a more in-depth understanding of the subjects themselves and their relationships with the territory and to identify any overlaps or gaps in skills.

The survey contained both open and closed-ended questions and it was developed in Google Forms to easily share it with the respondents and simply collect answers. To check the proper operation of the online form and the clarity/comprehensibility of the included questions, the survey was preliminarily tested through an internal small-scale pilot involving ENEA researchers. The sample of participants for the

consultation consisted of the relevant actors identified during the desk mapping phase, that were involved following the methodological approach illustrated in Fig. 2. In this working phase, the role of the ENEA office at the University of Camerino was fundamental to identify the contact person to be actively involved in the survey for each identified MS or SS. The responses to close-ended questions were analysed to obtain quantitative statistical data regarding the sample, while the answers to open-ended questions were coded and categorized to obtain clustered evidence from them. At the end of this step, the first version of the CE skills database was completed with detailed CE skills.

To support the proposal of an organizational model for structuring CE skills and supporting companies in undertaking CE actions and initiatives, moreover, two other relevant aspects have been explored, i.e. the regulatory framework, in terms of laws and regulatory measures relating to the CE, including regional guidelines for Ecologically Equipped Industrial Areas (EEIA), and the industrial context, in terms of willingness to collaborate through circular approaches and IS.

2.2. Establishing an IS pilot and organization of workshop

Since 2010, ENEA has developed an ecosystem of integrated tools to support companies in facilitating IS, which is a cooperative systemic approach for sharing and transferring resources (by-products, energy waste, services, skills and expertise) so that one company's waste can be used by another as a raw material. ENEA started the development and the implementation of an IS network model thanks to three projects in different Italian regions: the "Eco-Innovation Sicily" project (Cutaia et al., 2014, 2016a, b; La Monica, 2016; Luciano et al., 2016), the "Green Project - Industrial Symbiosis" in Emilia-Romagna (Cutaia et al., 2014, 2016a), and the "Industrial Park of Rieti-Cittaducale" project in Lazio (La Monica, 2016).

These experiences provided the basis for the design and implementation of the first Italian IS platform, the SYMBIOSIS® platform, aimed at companies and other operators in the territory to match demand and supply of resources and to activate transfers also through an expert connection system (Cutaia et al., 2015). The methodology developed by ENEA is based on three basic pillars:

- The language of symbiosis i.e., the identification of a shared language articulated in the Format Sheets (FS) for the collection of information, both company master data and input and output resources;
- Communication with companies, which aims to establish mutual, collaborative and continuous communication throughout the symbiosis implementation;
- Knowledge and experience, i.e., all the knowledge that allows ENEA to intercept synergies, not only those identified during the workshops but also those that to be realized need to include intermediate processes that allow the resources coming out of a production process to become suitable for reuse in a third production process. ENEA's IS platform is also part of this pillar.

The objective is to initiate a structured action of the Marche region on IS through the methodology. ENEA has managed the above activity by applying its methodology for the implementation of IS, which is based on a "horizontal" "network" approach and whose objective is to create synergies between supply and demand with respect to the resources made available or requested during the IS workshop.

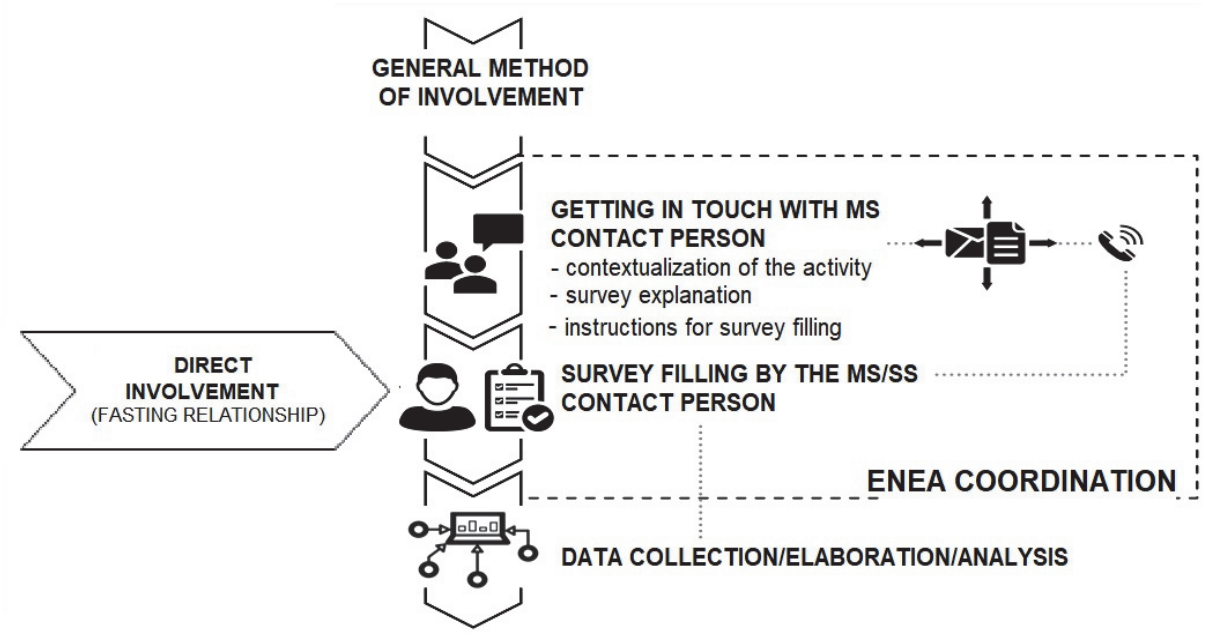

Fig. 2. Methodological approach for the consultation of relevant actors (source ENEA)

These activities include:

- *Involvement of actors on the ground:* The involvement of companies from different production sectors is one of the basic requirements to intercept potential synergies, even unseen ones;
- *Preparatory activity for IS workshop:* The organization of the workshop among the companies involved as fundamental moments of comparison, knowledge and exchange of information and data.
- *Workshop with collection of resources and identification of initial synergies:* A phase of elaboration and systematization of the collected data in which potential exchanges are identified;
- *Ex-post data processing*, uploading data into the SYMBIOSIS® platform to identify other potential exchanges;
- *Workshops with companies* for in-depth study of certain aspects and issues related to resources and processes;
- *Preparation of Operational Manuals* for one or more groups of synergies.

Following the IS workshop, ENEA catalogued, processed and standardized the data collected during the event. The first activity was to digitize the important amount of data collected and to catalogue them based on the model developed by ENEA during previous experiences. The resources, shared by the companies that took part in the event, were then indexed through the creation of a code that uniquely identified them. This code is made of a) a company code (exclusively determined), b) resources typology (INPUT/OUTPUT), and c) its sequential number (Eq. 1).

$$M000^{(a)}\ /\mathrm{YYYPUT}^{(b)}/000^{(c)} \quad (1)$$

3. Result and discussions

The outcomes of the project endeavours are highlighted below. The process of identifying roles and competencies has resulted in the identification of numerous pertinent stakeholders encompassing regional public administration, university entities, and business associations. ENEA spearheaded the IS workshop with support from local associations, held in Camerino. Thirty (30) local companies spanning diverse production sectors actively participated in the event. Distinct criteria were established for delineating various macro-categories of resource flows. Consequently, eight macro-categories were identified: plastic, paper, tissue, services, wood, skins, organic, and miscellaneous.

The activities carried out reflect the Marche Region's commitment to CE themes, also demonstrated through specific regulatory initiatives. Findings from the assessment, as well as discussions with companies and stakeholders during the IS pilot program, reveal that the business community is highly attentive to CE issues and is interested in the IS mechanism, seeing it as an opportunity to improve resource efficiency.

Thus, there are clear opportunities for system-wide eco-innovation: regional authorities could advance these by promoting actions that facilitate IS, while other public or private actors might also capitalize on businesses' openness to adopting new business models, such as IS. The pilot program not only identified potential synergies among participating companies but also highlighted their strong inclination for collaboration - a crucial foundation for the effective application of CE strategies in general and IS in particular.

3.1. Identification of roles and competencies in the Marche region

The desk mapping phase allowed to identification of a total of 26 relevant/competent actors including MS (12) and SS (14), belonging to regional public administration and regional bodies (9), universities and research centres (6) and also to business associations (11), as shown in detail in Table 1. The consultation phase involved 18 actors among the 26 identified and, in particular 3 MS and/or SS belonging to regional public administration and regional bodies, 6 MS and/or SS belonging to universities and research centres and 9 MS and/or SS belonging to business associations, and a total of 12 survey responses were collected.

Table 1. Number and characteristics of the identified relevant actors (source ENEA)

Type of subject	*MS*	*SS*	*Total*
Regional PA	2		2
Regional Bodies	2	5	7
Universities	4		4
Research Centres	2		2
Business Associations	2	9	11
TOTAL	12	14	26

Figures 3 and 4 show some of the main general results obtained from the analysis of the collected responses. The strategic role of these key CE areas of expertise was evident, with strong external collaborations beyond the MS/SS. Ten out of the 12 involved actors responded to a question regarding awareness of similar structures/expertise on key CE topics, identifying Design, Waste Management, Innovation, and Financing/Investments as the primary areas of focus. The gathered information also highlighted that these collaborations led to significant positive results, including participation in international and national projects, clusters, and platforms, all of which are considered very valuable by the involved actors.

Furthermore, analysing the given suggestions on how collaborations between structures could be improved, it can be asserted that the identification and collection of the real needs of the various stakeholders

(regarding enterprises), as well as the sharing/coordination/aggregation of CE expertise, are considered key elements by the involved actors. On the other hand, it emerged a lack of skills regarding other CE key areas of expertise, such as Secondary raw materials and Training. Moreover, detailing the analysis of results, it is noteworthy that skills regarding Design, Consumption, and Waste Management are declared by the actors belonging to regional PA and regional bodies, while universities and research centres, in addition to these, also declared skills on Production, Consumption, Innovation and Financing/investments. Skills regarding Secondary raw materials are instead declared only by the actors belonging to business associations.

These results show a context that seems to be characterized by a lack of relevant skills on the key aspect of resource efficiency (in particular, for institutional actors), in which broadening and improving such expertise appears particularly strategic to support the implementation of specific CE projects/activities. It is also worth noting that this evidence indirectly confirmed the soundness of the other project activity related to establishing an IS pilot/organizing specific workshop.

The review of the regulatory framework showed that the Marche Region legislated on CE consistently and coherently in the last five years, with 9 published regional laws having some specific reference to the CE scope. It is therefore quite clear the Region's intent to create a systematic skills model focused on CE and the regulatory field can be considered a strong driver to develop knowledge and skills in this priority area.

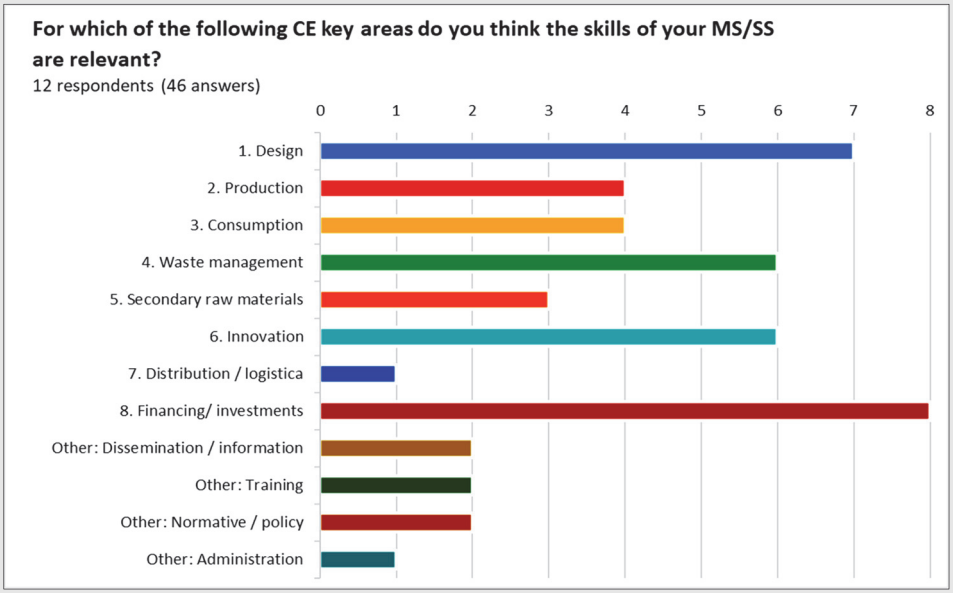

Fig. 3. Outcomes from returned questionaries': CE skills classification(MS= macro-structures; SS=sub-structures) (source ENEA)

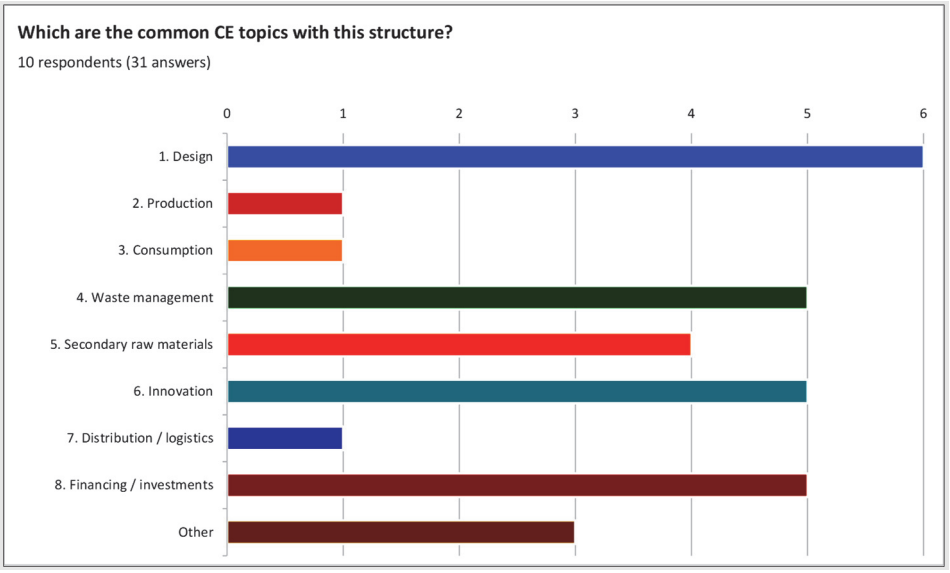

Fig. 4. Outcomes from returned questionaries: structures common CE skills (source ENEA)

In detail, the EEIA regional guidelines already mentioned and strongly requested an industrial model in line with the principles of CE, which should facilitate small and medium-sized enterprises (SMEs) in achieving an improvement in their environmental performances, through the provision of infrastructures and high-quality common services and allowing the control and reduction of the cumulative impacts generated by all SMEs.

The analysis of the regional industrial context identified four industrial clusters focused on the CE - Manufacturing, E-living, Agrifood and Furniture. These clusters play a strategic role in advancing projects and promoting clean processes and technologies within the regional economy. At the regional level, cultural barriers to CE seem partially overcome by companies' willingness to collaborate on various CE-related projects, particularly in IS.

3.2. Establishing an IS pilot and organization of workshop

The workshop was coordinated by ENEA, aided by local associations, and took place in Camerino. Thirty (30) local companies from various production sectors were actively involved in the event. Figure 5 illustrates the distribution of various production sectors, categorized by the ATECO code of the companies. Additionally, the macro-sectors of the companies were identified: companies in the "*manufacturing sectors*" are depicted in blue, those in the "*production and distribution of water, sewerage, and waste management*" category are represented in yellow, companies in the "*services of communication*" and "*agriculture, hunting, and forestry*" sectors are shown in red and green respectively, and companies in the "*legal activities and consultancy*" sector are highlighted in orange. Figure 5 highlights a predominant presence of companies in the manufacturing sector (76.7%), with a notable concentration in the "*manufacture of rubber/plastic material articles*" (6 companies, accounting for 20%). Furthermore, an analysis of the size distribution of participating companies was conducted based on current reference legislation (MISE, 2005), revealing a relatively even distribution across size categories, with a slight majority of large companies (30%), followed by micro (26.7%) and small firms (23.3%).

Figure 6 shows the geographic distribution of the companies attending the IS workshop, according to the ATECO classification of economic activities. The data obtained from the workshop underwent post-processing, and, with more than 300 shared resources (as outlined in the next table) the outcomes show a total of 85 matches identified. Companies shared mainly material resources (88% in number), then services & skills (11%) and lastly energy (1%).

Specific criteria were defined for the creation of different macro-categories of resource flows. The following 8 macro-categories were therefore identified: plastic, paper, tissue, services, wood, skins, organic, and other. Based on this classification into macro-categories, those with the highest number of shared resources and synergies were pinpointed. Specifically, the "leather," "paper/cardboard," and "plastic/rubber" sectors garnered the most attention from both an economic and quantitative perspective. Consequently, a detailed analysis was conducted on these sectors, resulting in the identification of three distinct flow diagrams (Figures 7-9). The continuous line represents synergies from the IS workshop, while the dash-dot line depicts those from ENEA's data post-processing. These diagrams contain information about the companies engaged in potential synergies.

The IS workshop focused on potential synergies involving Ethylene-vinyl acetate (EVA) polymer. EVA, a thermoplastic commonly used in the footwear industry, is essential for crafting outsoles and midsoles known for their excellent shock absorption. During manufacturing, EVA is injected into heated molds to shape these components. In Fig. 7, the EVA waste resource is denoted by the unique identification code M003/OUTPUT/001 within the flow diagram about plastic/rubber materials. The annual quantity of this material amounts to approximately 94,000 kilograms. Such quantities underscore the potential for reusing or recycling the material, suggesting a potentially beneficial pathway due to the substantial volume involved. To guarantee adequate polymer flow within the mould, gates and runners (channels through which the plastic flows from the injection moulding machine into the part cavity) are essential. Their dimensions may vary based on the size and shape of the parts to be produced, but they can represent up to 20% of the total weight of the midsole (Bianchi et al., 2023).

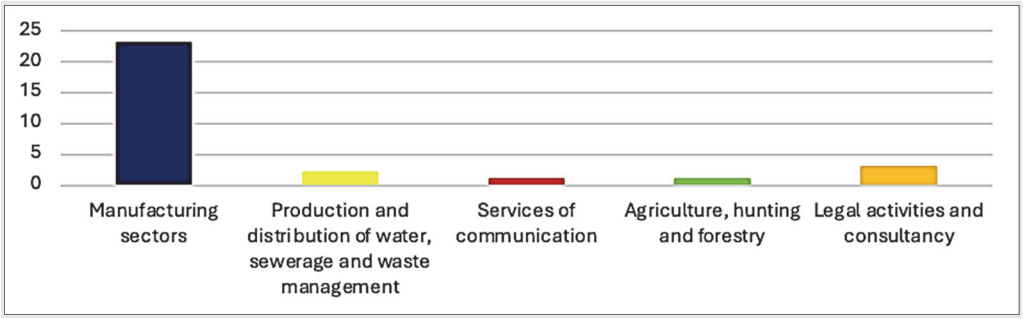

Fig. 5. Production sectors of the thirty companies that participated in the IS workshop (source ENEA)

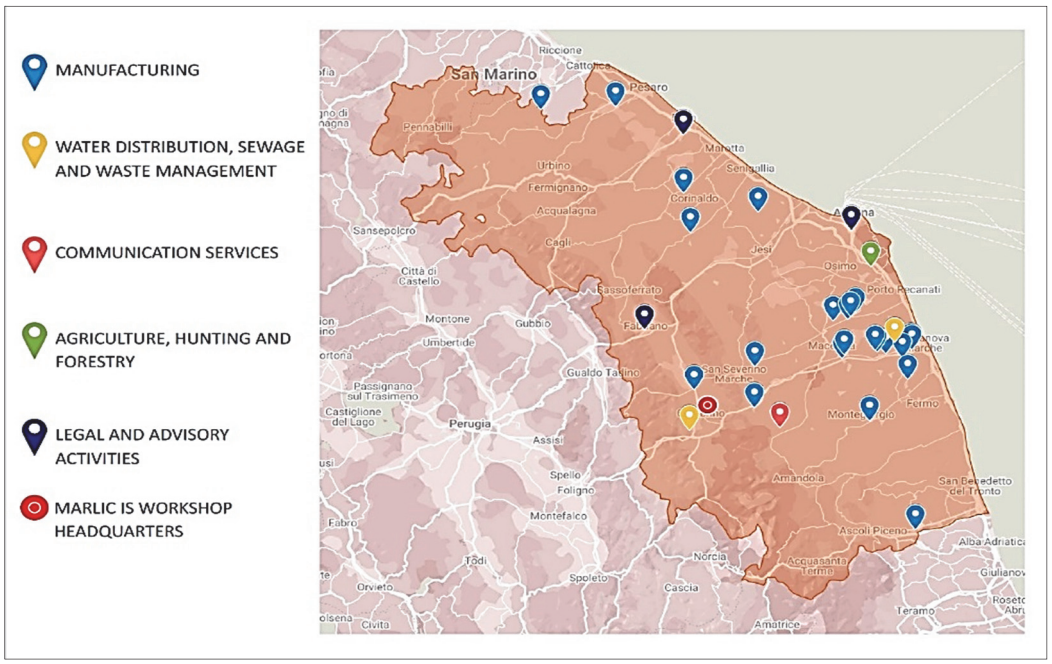

Fig. 6. Location and type of companies participating in the MARLIC IS workshop (Source ENEA)

Table 2. List of resources emerged during the IS workshop (source ENEA)

Competence/Service	***34***
Competence/Service	34
Materials	***280***
water	7
carbon	2
paper and cardboard	29
chemicals	19
composites	3
sludge	5
rubber	7
inert	13
wood	24
metals	17
mixed	16
oil	6
organic	21
plastics	67
RAEE	7
textile	33
toner	1
glass	3
Energy by-product	***3***
energy	3
Total	***317***

Currently, there is no concrete evidence that a real industrial process can recover and reutilize EVA scraps/waste. The footwear annual production is, in 2022, equal to 23.9 billion pairs, most of which contain EVA soles (World Footwear Yearbook, 2023). It is hence evident the importance of the recycling and reuse of materials from footwear production (Muthu and Li, 2021). In scientific literature, numerous studies have been conducted to assess the viability of alternative recovery systems for EVA waste. For instance, Lopes et al. (2015) utilized EVA waste as a filler for natural rubber, styrene-butadiene rubber, and acrylonitrile-butadiene rubber in compression while Pavia Junior et al. (2021) evaluated the recovery of EVA micronized and added to the virgin material. The outcomes that emerged from the workshop in the Marche region show evidence of the possible synergistic integration of EVA scarps/waste in a virtuous loop of recycling. The evaluation with industry experts has underscored the potential of technologies already capable of facilitating the reuse of this material within the existing production cycle, requiring only minimal technical adjustments to the process.

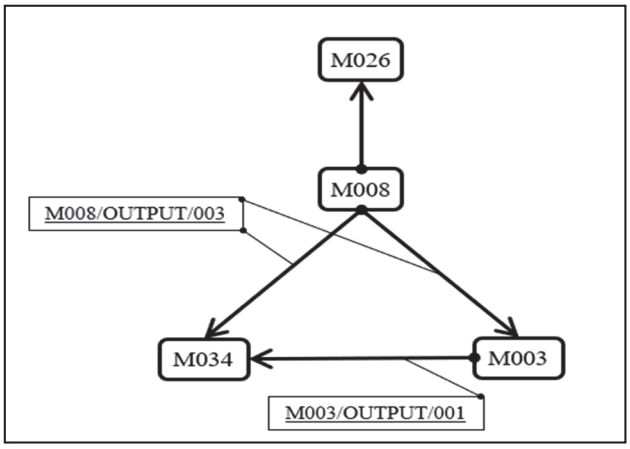

Fig. 7. Flow diagrams related to plastic/rubber flow material (source ENEA)

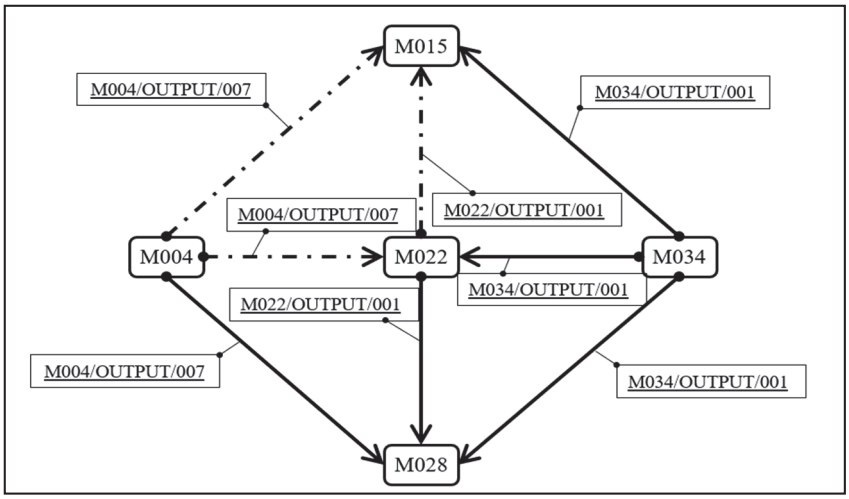

Fig. 8. Flow diagrams related to leather flow material (source ENEA)

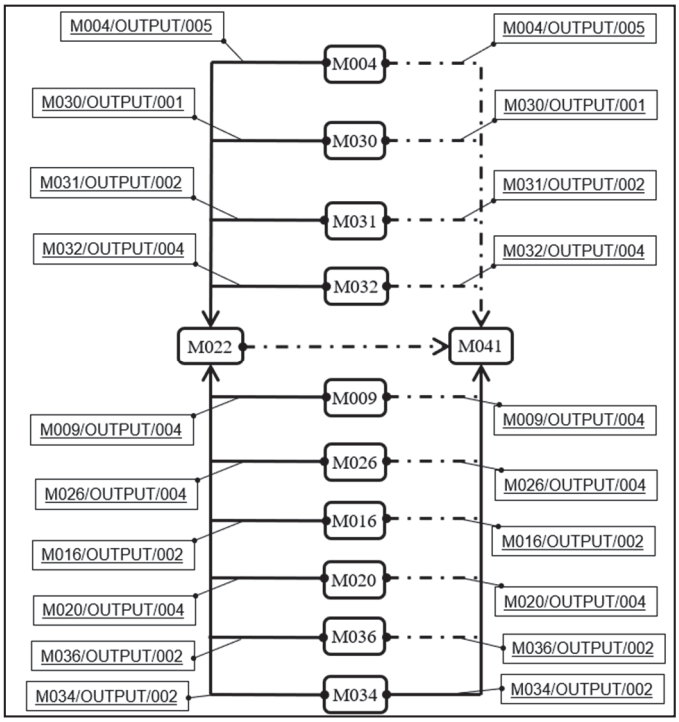

Fig. 9. Flow diagrams related to paper/cardboard flow material (source ENEA)

This material is currently disposed of in large quantities due to high production rates. However, ENEA's consultations with local stakeholders and companies reveal a tangible opportunity for recycling under specific technical conditions. Furthermore, a feasible recycling pathway already exists, even though market demands often favour the use of virgin materials due to technical constraints and brand motivations. Midsoles made from partially recycled EVA material may exhibit slightly lower performance compared to those made from entirely virgin material. However, cited studies have confirmed the possibility of effectively utilizing this waste to manufacture footwear components with mechanical performance comparable to virgin ones (Lopes et al, 2015, Paiva Junior et al., 2021).

The identified symbiosis scenarios offer promising economic benefits and enhanced resource efficiency for participating companies. They also provide opportunities for the region to leverage economies of scale, reducing both resource consumption and waste disposal.

The interest of companies and stakeholders in this initiative is demonstrated by the feedback received from IS experience. Most of the participants, whose opinions on the activity were collected through an evaluation questionnaire, rated the workshop as a good opportunity to establish a network of cooperation and information exchange between companies in the region, as well as an opportunity to get in touch with other companies in the area and their different needs.

4. Conclusions

The MARLIC project involved two parallel activities that dealt with the implementation of the CE in the Marche region. In particular, the first concern was to recognize the skills and related governance that exist in the region. The second aim was to demonstrate the effectiveness of the IS approach and the interest of the production system in its implementation through the implementation of a pilot activity.

The first activity focused on mapping skills and governance related to the CE in the Marche Region, indicating that the subject is addressed from various angles. Moreover, it is dispersed across different areas of governance and lacks integration within a dedicated structure. Conversely, discussions during events such as the IS meetings and engagements with local stakeholders underscore a significant interest in embracing CE solutions, including symbiosis.

Therefore, to promote and simplify the transition toward a "circular region" paradigm, it would be advantageous to establish a governance model (the specifics of which, in terms of functions, stakeholders involved, funding etc. represent a future development of the research here presented) that consolidates and, if possible, harmonizes the diverse functions and expertise of the CE. This model, aligned with the principles outlined in earlier regulatory documents like the EEIA regional guidelines, should also streamline the procedures for launching businesses in the production sector. Additionally, it should engage companies in an ongoing enhancement of environmental performance and encourage a trajectory toward environmental responsibility for both individual companies and the broader economic system.

The results from the first phase of activities have been discussed and made available to interested public and private stakeholders. These findings could serve as a basis for reorganizing and refining skills related to the CE, to enhance their organizational effectiveness and address any gaps in integration. As previously noted, at the time of the analysis, there was no clear reference to IS, either in terms of competencies or in the presence of bodies to facilitate and support it at the regional level. However, the IS workshop revealed significant interest from local companies in this approach, despite the absence of specific regional policies and organizational actions. It is therefore desirable that public authorities and relevant stakeholders build on this analysis to encourage a broad and systematic adoption of IS across the region.

In the IS workshop, organised on October 2022 by ENEA with the collaboration of University of Camerino. Camera di Commercio delle Marche, and Confindustria Macerata, about 30 companies, coming from several industrial sectors, shared 220 output and 97 input (88% as materic flows, 11% as skills and services, and 1% energy). During the IS workshop, over 85 potential synergies were identified. Eight macro-categories (namely plastic, paper, tissue, services, wood, skins, organic, and others) were identified for materic flows. Specific focus, with flow diagrams, was then realised for matches regarding scraps of leather, paper/cardboard, and plastic/rubber.

It should be emphasized that the identified synergies are potential; however, all involved companies have been provided with the necessary information to mutually activate and implement the operational, organizational, and commercial agreements needed to bring these synergies to life. The decision to proceed rests with the independent initiative and confidentiality of each company involved, in consideration of the boundaries of authority held by the research organization that conducted the workshop.

However, given the importance of the footwear industry in the Marche Region, which includes 1099 companies (representing 30.8% of the total on a national basis) and 16961 employees (23 % of the total), with a business export volume of 12.7 billion euros, the opportunity was taken to explore further a specific synergy that emerged. This synergy would enable significant regional-scale advantages, as the EVA flow under review can facilitate multiple collaborations among the companies involved. Recovering production waste and EVA from unsold footwear can create a circular system within the same production chain.

Thus, particular attention was for the last, given the potential of extensive use of EVA polymer in footwear production processes, particularly due to the significant presence of this industrial sector in the Marche region, as well as an estimated huge amount of such a kind of waste materials, seems to be an interesting CE solution (enabling the closing of the cycle in the same sector). The synergy identified, in particular, involved 4 companies, resulting in an EVA flow of 94000 kilograms per year. Despite the strong interest in this strategic supply chain for the region, to date, even if technologies for reusing that waste are potentially available, the related market, and thus the potential of IS, is un-exploited, showing, therefore, a significant potential that can be harnessed, both in terms of efficiency improvement and in system-wide eco-innovation.

The literature analysis confirms the potential for reusing EVA scraps, although current technologies do not guarantee that recycled products will match the technical characteristics of new ones. Discussions with stakeholders at the IS workshop identified key bottlenecks hindering the practical development of an EVA scrap recycling pathway. The strategy must be multifaceted - technical, regulatory, and market-driven, focusing on consumer engagement campaigns around products made from recycled EVA material, resolving outstanding technological gaps, and addressing legislative inconsistencies concerning recycled EVA use.

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