Waste Biomass Valor
DOI 10.1007/s12649-016-9625-y

ORIGINAL PAPER

Potential Improvement of the Methodology for Industrial Symbiosis Implementation at Regional Scale

A. Luciano[1] · G. Barberio[1] · E. Mancuso[1] · S. Sbaffoni[1] · M. La Monica[2] · C. Scagliarino[3] · L. Cutaia[1]

Received: 15 November 2015 / Accepted: 30 June 2016

Abstract
Purpose An improvement of the methodology used for the implementation of the first industrial symbiosis platform in Italy is proposed aimed at solving some critical issues encountered during its application at a regional scale in Sicily.
Methods The investigation mainly focused on the phases of companies' involvement and operative meeting organization. The different sectors characterizing the companies participating in the meetings were analyzed and compared with the productive system features in the investigated area. Resources shared by the companies during the operative meeting and the individuated potential matches were analyzed, as well.
Results Several critical issues were identified: (a) the low grade of diversification of participating companies that was not fully representative of the actual productive system so limiting the information on the potential matches; (b) the disequilibrium between observed supply and demand due to the prevalent interest of participating companies in finding out alternative solutions for the disposal of their residues rather than to find alternative supplies for their processes; (c) the excessive offers of services and expertise; (d) companies concern about a potential increase in controls on their activities.
Conclusions Solutions were proposed to increase the "biodiversity" of the firms, the level of companies knowledge on the potential for substituting their input resources, the control of "alien" species and to promote greater confidence in the symbiosis approach between the companies, as well as a greater awareness between the same stockholders. Finally the encouragement of paths that are not so financially attractive but that can have a strong positive impact on the environment is proposed.

Keywords Industrial symbiosis · Synergies · Waste · Regulation · Biodiversity

Introduction

In recent years there has been unprecedented growth in the demand for resources, whose supply has proved to be subject to significant limitations [1]. This called into discussion the current economic system and the concept of circular economy started to develop in response to the crisis of the traditional model. The circular economy model can be especially important in Italy, the second manufacturing country in Europe, characterized by lack of resources and by an unwieldy and ineffective industrial waste management system. Specifically, in the southern regions, the lack of knowledge of new but available technological solutions for residues recovery, forces many companies, especially the smaller ones, to dispose large quantities of waste with high costs with the consequent reduction of their competitiveness on the market.

A strategical appropriate policy, aimed at optimizing the use of resources, through the most complete and conscious use of the residues of industrial activities, is considered necessary, particularly in these regions, where the lack of an

✉ A. Luciano
antonella.luciano@enea.it

[1] Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Casaccia Research Centre, Via Anguillarese 301, Rome, Italy

[2] University "La Tuscia", Viterbo, Italy

[3] Freelance environmental consultant, Rome, Italy

Published online: 09 July 2016

effective long-term regional planning often severely affects the overall efficiency of the industrial waste management system. This deficiency prevents companies to identify strategic lines in able to increase their sustainability.

Industrial Symbiosis (IS) can contribute to this goal, by engaging traditionally separate industries in a collective approach to obtain competitive advantages by involving the physical exchange of materials, energy, water and/or by-products [2]. Specifically IS application can contribute to the systematic reuse of waste and by-products, which minimizes the need to extract natural resources and the depletion of environment, according to the internationally recognized waste hierarchy (EU, 2008). Within this framework a market of secondary resources and services arises, which should be promoted and supported within the companies. Companies can be selected and involved to improve their individual economic and environmental performances. As a consequence also the region or the district where they are located benefits of the enhanced environmental quality [3]. In Europe, the Resource Efficiency Flagship Initiative and the subsequent Roadmap for a Resource Efficient Europe have recommended that opportunities to exploit resources efficiency through industrial symbiosis should be a priority for the members in the European Union [4].

Development of IS depends on several factors including: (a) the characteristics of the productive sector in term of typology, activities diversification [5, 6] and size of the enterprises [7–11]; (b) the level of technological innovation [12]; (c) the intensity of participation and interest of the local companies and stakeholders; (d) national and local specific regulations. Nowadays many technological innovation are promptly available in the form of BAT (best available technologies) and their application to the industries cover a wide range of opportunities. As clearly emerges from the analysis of IS applications, the bottlenecks are mainly focused in the grade of participations and trust of both the local companies and stakeholders and the lack of appropriate legislative instruments simplifying IS implementation [13–16].

Governmental intervention, through specific policies, could positively influence a wide range of factors [17]. Supranational policies, based on regulations, directive, and decisions, provide a conjunct response to transnational challenge and set specific goals that can be translated into national policies even in a more ambitious way. Each member state of the EU should internally adopt and adapt the European policy to surmount the legal and administrative hurdles pertaining to the definitions of "by-products" and "end of a waste". In this regard huge efforts are made to define the criteria that the waste flows must meet in order to no longer being considered as waste. These include criteria for aggregates, paper, glass, metal, tires and textiles. Criteria have already been approved for scrap metal, glass and copper. A waste declassification would help companies in reducing the uncertainty of trade-off and to obtain a value from the wastes in the direct marketing of the secondary products with an acceptable level of risk. Subnational policies, developed at the level of the region or municipality are aligned with national objectives; however, to boost symbiosis approaches, they should be implemented site-specifically in order to exploit local context factors.

The first experience of Symbiosis platform in Italy was presented in Cutaia et al. [16]. Preliminary activities focused on the consultation with stakeholders, in Sicily region and at national level. The Sicilian productive system was then investigated and companies were involved in operative meetings for resources sharing, potential synergies individuation and to acquire data for platform validation. Potential synergies verification was performed, from a technical, regulatory, logistic and economic point of view, for a selected group of categories. Operative handbooks on some specific case studies were produced. These handbooks include European, Italian and regional regulations, guidelines, technical regulations, standards, logistic and economical issues. The handbooks also describe the pathways to be followed starting from the initial idea to the actual implementation of the match. Aim of these dossiers is to support companies in implementing matches.

According to Jensen et al. [5], the key for a successful industrial symbiosis program is to build on existing opportunities in brownfield industrial systems since the level of diversification in these mature industrial systems create an environment where opportunities can be identified and facilitated more easily. On this basis, the efforts were concentrated in East Sicily (prevalently Catania and Siracusa districts) were the greatest number of companies and the greater number of industrial activities is concentrated.

This paper, through a critical analysis of the results obtained from the first experience of the industrial symbiosis platform in Italy, aims to propose an improvement of the applied methodology in order to solve some critical issues encountered during its application at the regional scale in Sicily [16].

The ENEA Methodology

The activities promoted by ENEA within the framework of the project for the development and implementation of the first Italian Platform for Industrial Symbiosis in Sicily involved different steps [16]:

- design and implementation of the platform architecture, ICT (Information and Communications Technology) and database tools;

- network activation and promotion activities through stakeholders involvement at regional (Sicily) national and international level;
- analysis of productive sectors in the region;
- companies involvement and operative meetings organization;
- individuation of matches and potential synergies;
- synergies verification from a technical and legislative point of view;
- handbooks preparation;
- platform updating with the information gained through synergies verification.

The analysis of companies to be involved started from a previously developed database containing information on more than 2000 companies. Data were collected from regional productive districts, chambers of commerce, universities, industrial associations and companies' web sites. Further efforts were addressed in the most productive area of the Region (i.e. Catania and Siracuse districts).

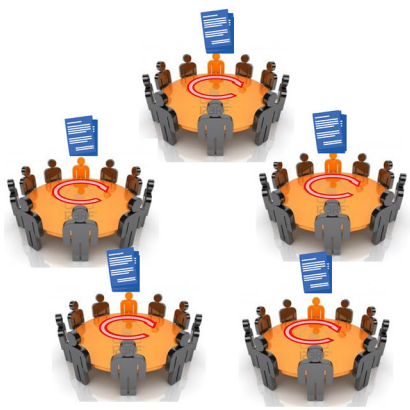
All the sectors were considered, when contacting companies, in order to have the most diversified composition. Invitation emails were sent to a selected number of companies present in the database. The selection was made using a threshold value on the minimum number of employees. Almost 1000 companies were informed and invited for each event. For a more capillary diffusion, invitations were also made by ENEA's local partners (Confindustria Catania, Chambers of Commerce of Siracuse and the Department of Industrial Engineering of the University of Catania). A group of 500 companies were directly contacted through phone calls in order to provide a more efficient representation of the overall goal of the meetings and to increase the interest of the companies.

According to the ENEA methodology, and following the NISP approach [13], companies were asked to fill in input–output data sheet before the meeting and to indicate resources to share within the proposed approach. In this early stage the collected information was intended just as "potential" being necessary, for a real implementation of each exchange, specific agreements that fall outside of the aims of ENEA project. Resources included: (a) materials, (b) energy, (c) services, (d) skills. "Services" were intended as every kind of support resources/activities such as transportation, available storage space, that are not thoroughly utilized by the company and which can be partially shared with other participants, after proper agreements. The same applies to "skills" but, in this case, the term refers to the skills and competences that can be shared if not completely exploited. ENEA input–output table foresees taxonomy for the inventory of input–output data of companies using the code systems officially used in Italy (according EU regulation) for different kind of inventories. The resource "materials" could be identified using the EWC code (European Waste Catalogue) if classified as waste, or using ProdCom code if considered as by-product.

The data received by email were further updated and improved during the meeting (with a specific focus on sharing and matching between companies) and after the meeting (when ENEA sent back to the companies the list of shared resources for their final control).

The meetings were organized in working groups. Round tables, each one containing 10 delegates and 1 facilitator from ENEA, were formed (Fig. 1a). Companies, at each table, exchanged information about the resource they wanted to share, using specific input–output sheet (Fig. 1b). More details are reported in Cutaia et al. [16].

Information (input–output) exchanged within each table were then exchanged between the other tables with the supervision and the contribution of the facilitators so significantly increasing the potential matches between all the companies (Fig. 1a).



input

Resource (description)	Resource (name)	Resource (type 1)	Resource (type 2)	ProdCom (if type 2b)	NACE (if type 1c)	Availability	Amount	Unit
		a) materials b) energy c) services d) skills	b) by-product			yearly batch		

output

Resource (description)	Resource (name)	Resource (type 1)	Resource (type 2)	EWC (if type 2 a)	ProdCom (if type 2b)	NACE (if type 1c)	Availability	Amount	Unit
		a) materials b) energy c) services d) skills	a) waste b) by-product				yearly batch		

Fig. 1 Round tables and information exchange phase (**a**); input–output sheet for collecting resources information (**b**)

Potential matches as individuated during the meetings were successively verified by ENEA staff.

A selection of the most interesting potential synergies, or group of synergies, was performed and specific operative handbooks were prepared, collecting, analyzing and systematizing information on technical, regulatory, logistic, economic and other issues influencing the possibility to put into effect the proposed synergies. In general the handbooks describe the pathways to follow in order to move from the first idea to the actual implementation of the match.

Results and Discussion

In order to improve the described methodology some of the results obtained from the its first application in Sicily are discussed together with the related issues.

Analysis of the Interest of Companies in IS

The main sectors of activities of the companies in the selected districts (Catania and Syracuse districts), as evaluated from the performed inventory (database), are represented by manufacturing (34 %) and agriculture (15 %). Other important sector were wholesale and retail trade (10 %), accommodation and food service activities (10 %), professional, scientific and technical activities (8 %) and construction (7 %) as represented in Fig. 2. Among the group of companies (almost 500) directly contacted by phone calls, 145 delegates applied for registration to the events and 98 were present on the total of the two events.

Starting from the fact that all sectors were considered for the companies' invitations, the comparison with the sectors of the companies participating the meetings allows to define the different interest in the initiative. The sectors mainly represented in the meetings, with the respect to the companies attending the meetings, were manufacturing (33 %) and professional, scientific and technical activities (13 %). Other sectors with a lower but significant presence were water supply, sewerage, waste management and remediation activities (12 %), transportation and storage (9 %) and construction (8 %).

In Fig. 2 a comparison between the percentage distribution of the whole companies versus the distribution of participating companies is presented. It emerges the lack of a strong correspondence between the two distribution. For instance the agriculture sector is represented in the meeting only for one/third (1/3) respect to their potential in the territory. A similar argumentation can be proposed for wholesale and retail trade. Others sectors were instead present with a higher percentage respect to their real presence in the territory. This is the case of water supply, sewerage, waste management and remediation activities

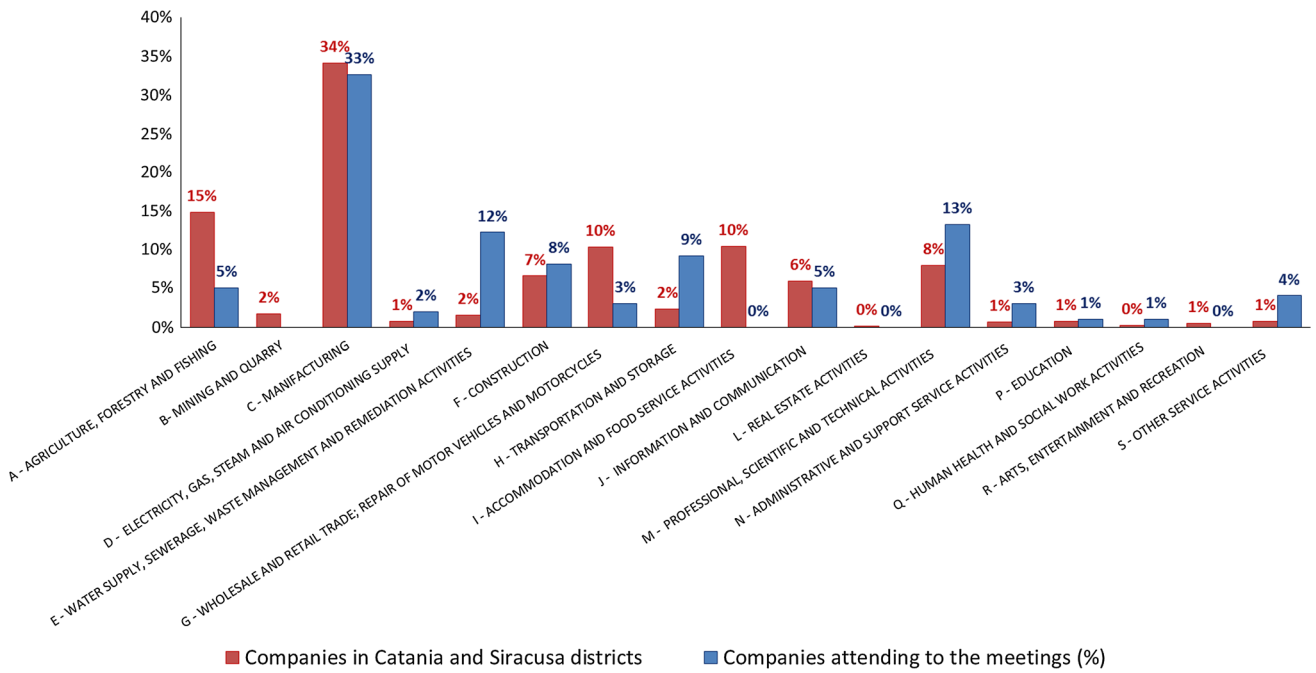


Fig. 2 Comparison between the percentage composition of the whole companies distribution versus the distribution of participating companies (percentage distribution of companies in Catania and Syracuse districts was evaluated on the total companies in the database, whereas the percentage distribution of companies attending the meeting was evaluated on the participating companies in order to compare the representative of sectors in the two data sets)

sectors, represented with a six to one ratio (6/1), service activities, and transportation and storage represented with a four to one ratio (4/1) and professional, scientific and technical activities (13/8).

This result gives evidence of one of the potential issue of the proposed methodology where the "biodiversity" of the meeting tables can be only partially representative of the effective "biodiversity" showed by the companies in the observed territory.

In a certain extent this implies that the potential matches are restricted only to subsets of the territory. Possible causes are related to the intrinsic characteristics of the companies (small size, small attitude to innovation like in the case of agriculture companies or interest in selling services and consulting like in the case of professional activities and services and waste and wastewater management sectors). It is in fact demonstrated that the cases of successful IS have been led by large enterprises that are highly consumption-intensive in materials and energy, and could boost SMEs initiative [7, 8, 10, 11]. The influence of enterprise size in companies interest is shown in Fig. 3 that represent a comparison between the mean number of employees (for each sector) of the companies in the district and the mean number of employees (for each sector) of the companies attending the meetings. It is evident, when comparing with the results from Fig. 2, as the size of companies is only one of the factors affecting the attitude of a company to be involved in a process to improve the efficient use of resources (e.g. waste and wastewater management sectors).

A second fact is attributed to the current procedure in companies involvement, whose potential improvement is suggested in the following sections.

Table 1 shows the participation rate, for each sector (companies of a certain sector attending the meeting vs contacted companies of the sector) and the representative rate of each sector (companies of a certain sector attending the meeting vs total companies of the sector in the investigated area).

Analysis of the Resources Shared by the Companies

Companies showed interest to share 406 output resources and 179 input resources of different categories. From these a total of 694 potential matches were identified.

As represented in Fig. 4, the interest of the companies in sharing resources was mainly addressed to "materials" (48 % of the input resources and 62 % of the output resources) and expertise, consultancy and services (34 % of the input resources and 29 % of the output resources). Energy accounts for only 6 % of the input and 2 % of the output resource, whereas equipment accounts for the 8 % of the input and 2 % of the output resource. Logistics and transportation represent 2 % both of the input and of output resources. Also potential matches were related prevalently to materials (51 %) and expertise, consultancy, services

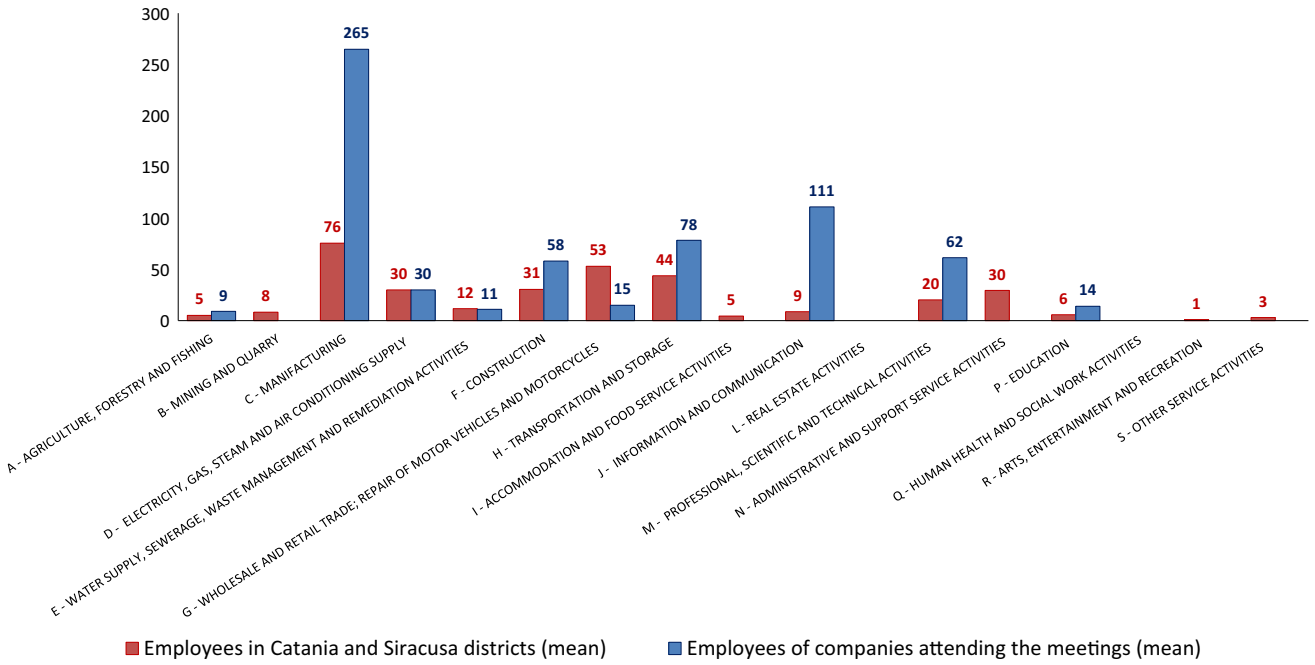


Fig. 3 Comparison between the mean size of companies (employees), in the two investigated districts, and the mean size of companies attending the meetings for all sectors

Table 1 Participation and representative rates for each sector

NACE codes	Participation rate (%)	Representative rate (%)
A—Agriculture, forestry and fishing	5	4
B—Mining and quarry	0	0
C—Manufacturing	16	12
D—Electricity, gas, steam and air conditioning supply	50	33
E—Water supply; sewerage, waste management and remediation activities	100	100
F—Construction	18	16
G—Wholesale and retail trade; repair of motor vehicles and motorcycles	7	4
H—Transportation and storage	100	50
I—accommodation and food service activities	0	0
J—information and communication	12	11
L—Real estate activities	0	0
M—Professional, scientific and technical activities	25	22
N—Administrative and support service activities	60	60
P—Education	17	17
Q—Human health and social work activities	50	50
R—Arts, entertainment and recreation	0	0
S—Other service activities	67	67

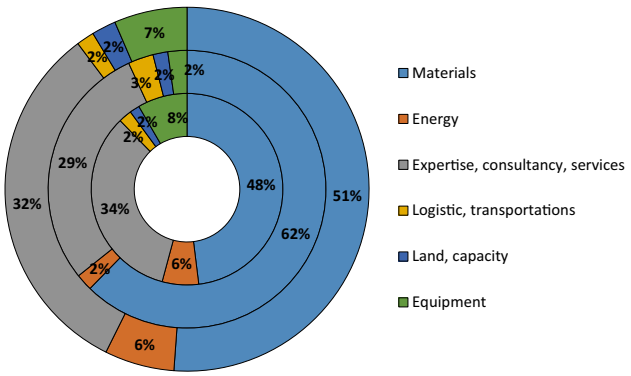


Fig. 4 Percentage of shared resources (input–output) and potential matches in each category. (*inner ring* = input resources, *intermediate ring* = output resources, *outer ring* = matches)

(31 %). Matches related to equipment and energy were 7 and 6 % respectively.

The prevalence of the exchange of materials, as already reveled by Fig. 4, is confirmed in Fig. 5. However it emerges here, more clearly, the impacting presence of expertise, consultancy and services component. This

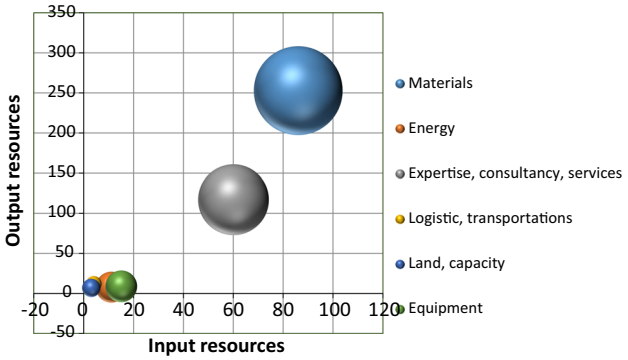


Fig. 5 Intensities of potential matches for each category related to the quantities of declared resources (input and output)

presence can be seen as an "alteration" in the composition of the table due to a strong attempt, from these companies, to sell their services.

Even if this component is functional to the whole local production sector, it certainly alters the equilibrium of tables compositions like an "alien" entities/communities so shifting the local and "natural biodiversity" of the system.

Figure 6 shows the ratios between inputs, outputs and potential matches. The great difference between input and output resources, as proposed by the participating companies, shows that the main interest for participating companies is to find out solutions for their residues that can be alternative to the disposal, while the attraction for alternatives supplies for their own activities is a less relevant. On the other hand the chances to find out potential matches are greatly encouraged when companies contextually search for alternative supply showing interest in sharing input resources (as in the case of energy and equipment) as in equilibrate an biodiversified ecosystem.

A deeper examination of results for sub-categories, confirm this outcome, as showed in Fig. 7. Companies were mainly interested in sharing output such as packaging (13 %), plastics and plastic products (11 %), electrical and electronic compounds (10 %), metals and metal products, paper and paperboard (8 %) and materials from agriculture (7 %). The interest of companies for inputs was mainly addressed to foodstuffs (20 %), organic chemicals (15 %), paper and paperboard and fuels (7 %), construction, demolition, excavation materials (6 %). Again, a greater difference between supply (input) and demand (output) was observed for most of the subcategories.

As a consequence, potential matches were prevalently related to paper and paperboard (19 %), plastics and plastic products (13 %). Other waste stream involved were electrical and electronic (8 %), metals and metal products (7 %), water, materials from agriculture (6 %), construction, demolition, excavation materials and industrial minerals/sludge (5 %) categories respectively.

Discussion

On the basis of the results, as obtained from the implementation of the first industrial symbiosis platform in Italy, some critical issues emerged. Some of these issues were directly evidenced in the elaboration of the collected information, reported in the previous section, whereas others emerged during the talks with the companies.

Starting from these issues the following consideration were argued to improve the adopted procedure and to refine the whole systematic methodology for IS implementation at a regional scale.

The first critical issue is represented by the fact that the participating companies can show more interest in offering their residues (outputs), rather than in demanding alternative inputs (e.g. waste to be used as raw materials) for their activities. This was certainly determined by the lack of knowledge, among the companies, on the technical chances to replace the supply of traditional raw materials with residues from other production cycles.

It is possible to partially remedy this problem, in the phase of companies involvement, before the meeting, by considering the following actions:

- Pre- analysis of the declared resources as contained in the input–output sheet precompiled by the companies, before the meeting, on the basis of the specific codes (EWC if wastes, NACE if services).
- Preliminary selection of the companies that can, in a technologically proved and sustainable way, reuse these residues in their production processes. Available technical knowledge and specifically developed handbooks can be useful at this stage.
- Provide the selected companies with a short targeted information leaflet, as a synthesis of the information contained in the handbooks, on the potential use of the highlighted "available" resources in their production

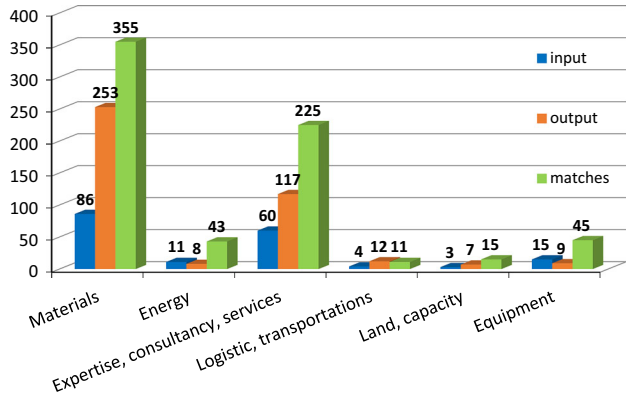


Fig. 6 Inputs, outputs and potential matches

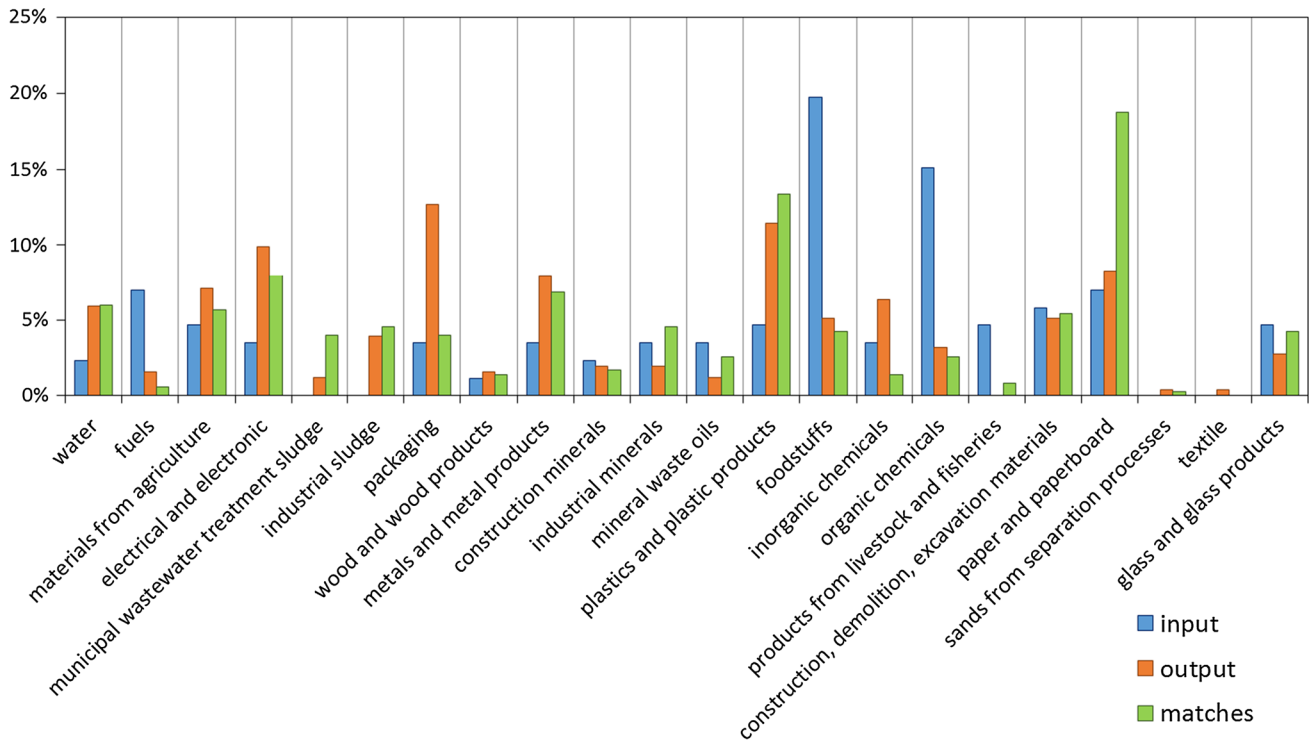


Fig. 7 Materials shared during the meetings and potential matches

cycle to stimulate their active participation in the meeting.

These additional actions could ensure a more balanced and biodiversified participation that could significantly increase the number of potential matches and the possibility of a "potential" match to be transformed into a real opportunity.

In fact the level of diversification (here called biodiversity in analogy with natural systems) in industrial systems create an environment where opportunities can be identified and facilitated more easily [6]. Thanks to the biodiversity, nature does not know the term "waste", because residues produced by some species are reused by other ones. In the same way industrial systems, if adequately diversified, can intrinsically contain symbiosis opportunities. The transition from "potential" to "actual" opportunity depends on the "knowledge" an evolution of the "instinct" in the natural species. Here "knowledge" is intended, for instance, as the wealth of information in companies about the opportunities to replace the supply of traditional raw materials with residues from other production cycles.

A second critical issue is represented by the companies' concern of a potential increase in controls exercised by the control and authorization system still anchored in traditional logics and reluctant to the change in the procedures.

So the need for a simplified approach in authorization and controls procedures emerges together with the need for the implementation of a regulation in favor to IS application. In this sense it is particularly important the presence and participation of local stakeholders and control authorities, directly to the round tables during the operative meetings. This participation could ensure a greater confidence to the companies, but also greater awareness of the same stockholders on the real potential of the propose symbiosis approach and the future issues to face.

A third critical issue regards the typologies of declared (input–output) resources and consequentially the potential matches. First of all, resources declared were mainly packaging (plastics and plastic products), and paper and paperboard. The market of these materials in Italy is managed through national consortia which are no-profit private systems with a social character established and regulated by law operating in order to achieve the recycling objectives concerning all types of packaging.

Finally a fourth critical issues consist in the size of the company. From the talks with companies it has been observed that bigger companies have spontaneously start some symbiosis paths addressed to their residues valorization and reuse, whose disposal cost were high, with interesting economic return. On the other hand, for smaller companies, where economic advantages are less evident but environmental returns could still be high, it could be useful to provide incentives (in term of regulatory management simplification or taxes savings) to increase the capitalization of the matches.

Conclusions

The analysis of critical issues as emerged from the first application of ENEA symbiosis platform in Sicily was here utilized to improve the methodology and to increase its efficiency.

The potential methodology upgrade mainly focus on the companies' involvement and meetings management phases.

The main identified critical issues are:

- Low grade of diversification of participating companies affected the composition of the round tables that was not totally representative of the productive sectors and able to maximize real matches between input and output.
- the disequilibrium between supply and demand. The interest of participating companies is mainly addressed to find out solutions, alternative to the disposal, for their residues, rather than to find supplies alternatives for their activities.
- the excessive offers of services and expertise.
- companies concern of a potential increase in controls on their activities as result of symbiosis approach implementation.

Proposed solutions were:

- to introduce a pre-screening aimed to increase the biodiversity of the firms respects to the effective distribution within the productive sectors and a consequent solicitation/involvement of the "missing" companies.
- Preliminary selection of the companies that can, in a technologically proved and sustainable way, reuse these residues in their production processes providing this selected companies with a short information leaflet, extracted from ENEA handbooks where first technical information can be found for the potential use of the highlighted "available"resources so stimulating their participation to the meeting.
- control of "alien" species (companies that mainly want to sell their services).
- increase the presence and participation of local stakeholders and control authorities during the operative meetings in order to ensure greater confidence in the symbiosis approach to companies, as well as a greater awareness of the same stockholders of the real potential of the approach and of the future issues to solve.

- Encouragement of paths that are not so financially attractive from a different management but that can have a strong positive impact on the environment (e.g. agriculture residues management).

Acknowledgments The authors wish to thank Confindustria Catania, the Chamber of Commerce of Siracuse and the University of Catania, in particular professor Giuseppe Mancini, for the support they gave for meetings organization and network implementation in Sicily.

References

1. Krautkraemer, A. J.: Economics of Natural Resource Scarcity: The State of the Debate. Washington (2005)
2. Chertow, M.R.: Industrial symbiosis. In: Cleveland, C.J. (ed.) Encyclopedia of Energy, pp. 407–415. Elsevier, New York (2004)
3. Ashton, W.S.: Managing performance expectations of industrial symbiosis. Bus. Strategy Environ. **20**(5), 297–309 (2011)
4. Laybourn, P., Lombardi, D.R.: Industrial symbiosis in European policy. J. Ind. Ecol. **16**, 11–12 (2012)
5. Jensen, P.D., Basson, L., Hellawell, E.E., Bailey, M.R., Leach, M.: Quantifying 'geographic proximity': experiences from the United Kingdom's national industrial symbiosis programme. Resour. Conserv. Recycl. **55**, 703–771 (2011)
6. Jensen, P., Basson, L., Penn, A.S., Leach, M.: The role of geospatial industrial diversity in the facilitation of regional industrial symbiosis. Centre for Environmental Strategy, Guildford (2011)
7. Beers, D.V., Biswas, W.K.: A regional synergy approach to energy recovery: the case of the Kwinana industrial area, Western Australia. Energy Convers. Manag. **49**, 3051–3062 (2008)
8. Salmi, O.: Eco-efficiency and industrial symbiosis—a counterfactual analysis of a mining community. J. Clean. Prod. **15**, 1696–1705 (2007)
9. Shi, H., Chertow, M., Song, Y.: Developing Country experience with ecoindustrial parks: a case study of the Tianjin economic-technological development area in China. J. Clean. Prod. **18**, 191–199 (2010)
10. Van Berkel, R.: Cleaner production and eco-efficiency initiatives in Western Australia 1996–2004. J. Clean. Prod. **15**, 741–755 (2007)
11. Yang, S., Feng, N.: Case study of industrial symbiosis: Nanning Sugar Co., Ltd. in China. Resour. Conserv. Recycl. **52**, 813–820 (2008)
12. Lifset, R., Graedel, T.E: Industrial ecology: goals and definitions. In: Ayres, R.U., Ayres, L.W. (eds.) A Handbook of Industrial Ecology. ISBN 1 84064 506 7 (2002)
13. Laybourn, P., Morrissey, M.: National Industrial Symbiosis Programme: The Pathway to a Low Carbon Sustainable Economy. International Synergies Ltd, Birmingham (2009)
14. Lombardi, R., Laybourn, P.: Redefining industrial symbiosis. J. Ind. Ecol. **16**, 28–37 (2012)
15. Schiller, F., Penn, A., Druckman, A., Basson, L., Royston, K.: Exploring space, exploiting opportunities: the case for analyzing space in industrial ecology. J. Ind. Ecol. **18**, 792–798 (2014)
16. Cutaia, L., Luciano, A., Barberio, G., Sbaffoni, S., Mancuso, E., Scagliarino, C., La Monica, M.: The experience of the first industrial symbiosis platform in Italy. Environ. Eng. Manag. J. **14**(7), 1521–1533 (2015)
17. Costa, I., Massard, G., Agarwal, A.: Waste management policies for industrial symbiosis development: case studies in European countries. J. Clean. Prod. **18**, 815–822 (2010)