The development of industrial symbiosis in existing contexts. Experiences from three Italian clusters

Raffaella Taddeo[a1], *Alberto Simboli*[a], *Anna Morgante*[a],

[a] *University "G. d'Annunzio", Department of Economic Studies, V.le Pindaro 42, 65127 Pescara, Italy*

Suren Erkman[b]

[b] *University of Lausanne, Institute for Earth Surface Dynamics, Mouline Area, 1015 Lausanne, Switzerland*

E-mail address: r.taddeo@unich.it; a.simboli@unich.it; morgante@unich.it; Suren.Erkman@unil.ch

Please cite as:

Taddeo R., Simboli A., Morgante A., Erkman S. (2017) The development of industrial symbiosis in existing contexts. Experiences from three Italian clusters. Ecological Economics Vol. 139, pp.55–67. ISSN 0921-8009. http://dx.doi.org/10.1016/j.ecolecon.2017.04.006

[1] Corresponding author. Tel.: +39-085 4537941; Fax: +39-085 4537956.
E-mail address: r.taddeo@unich.it

The development of industrial symbiosis in existing contexts. Experiences from three Italian clusters

ABSTRACT

It is acknowledged that Industrial Symbiosis (IS) is not only a technical phenomenon; socio-relational, organizational, and cultural issues come to light in its development as well. This is much more evident when an IS relies on existing contexts. Industrial network and clusters have been proven to be one of the best models of local industrial development, and they can be considered also a favorable starting context for IS projects. The relations between traditional and symbiotic networks have been deeply investigated, but the complexity and the scientific and practical implications of the topic render the discussion still open. The present article contributes to this debate by clarifying the dynamics of the IS development in connection with the features of existing industrial clusters. The study proposed uses the results and the experiences gained by the authors in three case studies previously conducted, in order to develop an interpretative framework for assessing the potential and the limits for the development of IS-based scenarios. Empirical evidences show both the role of significant technical factors in designing the IS and the role played by non-technical factors in promoting and preventing its potential implementation.

Keywords: industrial ecology; industrial symbiosis; industrial clusters; contexts; case study.

1. Introduction

In the literature there is much debate on how to make Industrial Symbiosis (IS) effective within different contexts. This issue primarily involves technical factors, influencing the choice of the solutions that can be more suitable than others and thus the form in which the IS may occur. It is also strictly related to how non-technical factors may affect its development. According to Boons and Baas (2006) ‘‘*IS activities are shaped by the context in which they occur, described in terms of cognitive, structural, cultural, political, spatial and temporal embeddedness*’’, the comprehension of the role of such factors can provide both methodological and practical insights towards the IS development (Chertow and Ehrenfeld, 2012; Jensen et al., 2011a).

Local industrial agglomerations can be considered a favorable context for the establishment of symbiotic synergies, due to the geographic proximity and the general tendency to collaboration of companies (Erkman and Van Hezik, 2014; Hewes and Lyons, 2008; Sterr and Ott, 2004; Wallner, 1999). In accordance with Deutz and Gibbs (2008), the present article uses the term “Industrial Clusters” (ICs) to indicate the various operating forms of such agglomerations, including the renowned Italian *industrial districts*, that since the 70s have become a representative paradigm, at a global level. An extensive literature on economic geography and organization studies highlighted the features of such a model of local development. The studies often focused on the technological and the socio-economic aspects, especially the interactions amongst the local companies and territories (Becattini, 2004, Porter, 1990; Marshall, 1928); the environmental dimension has been less considered. More recently, the IC model has been facing its own limits, mainly imposed by the global competition (De Ottati, 2009; Guerrieri and Pietrobelli, 2004; Lazerson and Lorenzoni, 1999); in this perspective we consider IS to be a great opportunity for its revitalization.

The present article deals with the development of IS in existing ICs, by analyzing the results and the experiences gained from three case studies conducted by the authors in the Italian Region of Abruzzo (Simboli et al., 2014, 2015; Taddeo et al., 2012). Through the framework, we try to clarify: 1) what technical and non-technical factors can affect the potential development of IS in such contexts and 2) how they can (positively or negatively) act. The following sections respectively present: the theoretical background of the study; the three case studies previously conducted; the methods and the framework used; the results of the analysis and their discussion. Finally, the conclusions are outlined.

2. Theoretical background: an overview

Already in 1996, Cohen-Rosenthal and McGalliard highlighted the importance of inspiration from studies on industrial networks or clusters for the development of policies in order to stimulate eco-industrial collaboration. In 2003, in investigating the implementation of sustainable development within local and regional economic development strategies, Gibbs highlighted the need of multidimensional approaches that draw upon economic geography and regional economics on trust, cooperation and “untreated interdependencies” (rules, routines and networks that form the basis of regionally or locally specific material and non material assets). It is precisely the multidimensionality that is one of the keys for the interpretation of the phenomenon. Mirata (2004) reviewing the factors influencing the development of three IS programs in the U.K. (in the early stages) argued that the nature of the companies and the industrial history of the region influence the progress of the programs, concluding that, a promising approach in developing IS networks is to “*rely on the body of knowledge developed under inter-organizational relationship/collaboration and networking/cluster fields*”. The relation between IS and the positive externalities deriving from co-located companies, the so-called “agglomeration economies”, has been the focus of an analysis presented by Chertow et al. (2008); the authors outlined how particular industrial configurations can be suited to different types of IS. The difficulties in changing routines embedded in industrial companies’ behavior, and the interconnections between the techno-sphere and the social system dimensions has been addressed in a study involving an IS program in Rotterdam (Baas and Huisingh, 2008). A conceptual step forward has been made by Deutz and Gibbs (2008), who wondered if industrial ecosystems could be conceived as environmentally-based variants of traditional ICs. After having examined the similarities and the differences between the two models, they recognized that the different nature and object of the transactions -products *versus* wastes/scraps- is one of the main limits for the inclusion of industrial ecosystems in a cluster perspective.

Networking, both social and material, is a common theme of recent studies concerning the development of IS in existing and long-standing industrial contexts (MacLachlan, 2013). Some of them have deepened the role of tacit and explicit knowledge and ICT tools in order to enhance collaboration (Grant et al., 2010), others have focused on the approach of the embeddedness, associated with the concept of trust (Doménech and Davies, 2011) or proximity (Schiller et al., 2014), for the application of Social Network Analysis (SNA). Furthermore, the role of external factors and agents in the emergence and evolution of IS have been faced, outlining the effects of governmental interventions (Costa et al., 2010) through policies and legislation or the combined action of top-down (planned/goal directed) and bottom-up (self-organized/serendipitous) mechanisms (Paquin and Howard-Grenville, 2012) for the facilitation of the IS development.

Some authors focused their efforts on defining analytic frameworks. Most of all, we agree with the approach followed by Jacobsen and Anderberg (2004) and Ashton (2009). The former, in a study based on the Kalundborg eco-industrial park, proposed an analytical scheme focusing on three different aspects of the development of IS in existing networks: physical preconditions and possibilities (concerning the identification of the energy and material flows within the network); economic and environmental effects (concerning the potential benefits deriving from the IS collaborative action and exchanges); central conditions and mechanisms behind the development of IS networks (concerning other contextual factors than physical and economic ones that can influence the creation of IS). Ashton, in assessing regional industrial ecosystems, considers functions, economic transactions, policy context and social interactions and the role of external forces in driving changes. The interpretative framework that is proposed in the present article takes into account these settings, adapted to the analyzed context and the specific conditions of the study.

3. The context and the previous case study research conducted

This section describes briefly the empirical contexts and the three previously conducted studies. More details about the methods, the tools used and the data detected in each case study are available in the original articles (Simboli et al., 2014, 2015; Taddeo et al., 2012) and the related annexes.

The ICs analyzed respectively operate in the chemical, automotive, and agri-food industries. They are all located in the Italian Region of Abruzzo (figure 1).

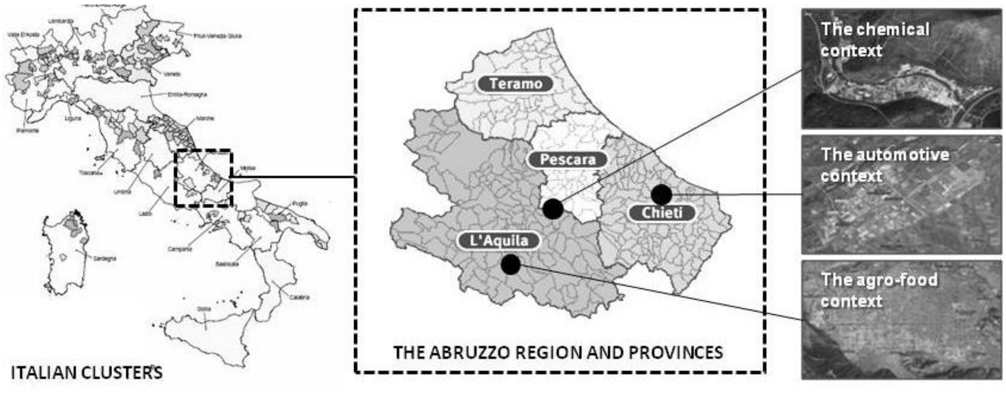


Fig. 1. The ICs, the Abruzzo Region and the three selected clusters.

Their main features are described in table 1.

Table 1 The most relevant features of the three clusters analyzed.

	BCS	**VDS**	**FFAC**
Period of birth	early ‘900	‘70	‘50
Sectors involved	Basic chemicals	Automotive	Agri-food
Reason/s of birth	Planned as strategic chemical site	Establishment of large automotive companies due to government incentives	Industrialization of a rural area after drainage
Cluster size (extension of the area)	5 km	15 km	20 km
N° of companies settled-in the whole area (sample analyzed)	5 (5)	< 100 (18)	About 330 (23)
Sizes of companies	Medium and large companies	Large and small companies	Micro-family, Small and Medium companies
Processes detected	Basic chemicals (Hydrogen peroxide; Sodium Percarbonate; Sodium Hydroxide; Hydrochloric Acid; Sodium Silicate); Pesticides, Silicates	Metalworking, molding, machining, assembly, coating, plastic manufacturing, finishing - stickers/paint/coatings-, cabling, transportation and services	Farming (horticultural), crop-processing (juice, carrot puree, frozen potato, dumpling and pies), Sugar factory (under restructuring)
Energy plants	1 (dedicated)	-	1 (dedicated)
Existing relations (prevailing)	Supply and utilities sharing	Supply chain (in the form of network of SME)	Competition and supply
Current economic state	Crisis/dismantling	Maturity/Decline	Maturity/Decline
Urbanized areas within the area	1 municipality	4 municipalities	10 municipalities

Presence of a specific coordinating body	Local Observatory for the Chemical Industry	CISI consortium (especially represented by the President of CISI)	Provincial Association of Agricultural Producers
Other local stakeholders	Local delegates of Ministry of Economic Development; Province of Pescara; Chamber of commerce	Chamber of commerce; Industrial Association; Foundation for disadvantaged workers	Chamber of commerce; Industrial Association
Presence of Waste treatment/recycling companies	No local waste treatment or recycling companies detected	No local waste treatment or recycling companies detected	No local waste treatment or recycling companies detected

The first case study conducted (BCS) was related to an exploratory research project, funded by the local government for the revitalization of the chemical site (Taddeo et al., 2012). The results obtained and the experience gained during this first study led the authors to replicate the research, in the form of academic studies and in collaboration with local stakeholders, in the two other contexts, whilst maintaining the methods and the structure of the original research (Simboli et al., 2014, 2015). In all cases long-standing ICs in the maturity stage have been selected. Each study was conducted in two phases: a literature review, and an on-site survey. Mixed methods have been used: quantitative for the analysis of the technical aspects of the symbiosis (data from local databases and questionnaires administered) and qualitative for the other aspects investigated (data from focus groups and meetings). The questionnaires were developed with reference to the scheme drawn up by Heeres et al. (2004). The meetings and focus groups were convened and managed by the local partners, with the support of researchers, involving the most important companies of the three contexts. They were held at the beginning, in the middle and at the end of projects, in order to present the progress made, encourage and support an exchange of views and initiatives amongst the various stakeholders involved. The role of the researchers was active as regards the collection of the first type of data and as participant observers for the others. The analysis of all the case studies ended at the stage of the IS scenarios design; two pilot tests have been conducted on specific solutions. Both qualitative and quantitative data obtained were used to set the framework and for the analysis presented hereafter.

4. The interpretative framework

4.1 Approach

The empirical evidence of the aforementioned case studies prompted us to further investigate some aspects related to our research. In particular, besides the technical factors, non-technical factors, defined as “embedded” in the context (Schiller et al., 2014; Doménech and Davies, 2011; Costa and Ferrão, 2010) have been considered. We deemed this further deepening capable of providing both methodological and applicative contributions for IS studies and for the policies of sustainable local industrial re-development, especially in countries, such as Italy, where long-standing ICs are widespread.

In building the framework, we considered the relations between the evolutionary dynamics of existing traditional ICs and the development of IS as the most relevant. Jacobsen and Anderberg (2004), used this relation on the ex-post analysis of the successful case of Kalundborg eco-industrial park. What we wish here is to try to capture the effect of various factors that, converging in the design stage of the IS, can promote or prevent its subsequent practical development.
According to Costa and Ferrão (2010) and Mirata (2004), the approach followed is mainly inductive; the case studies results are here used for a comprehensive analysis, drawing on the principles of multiple case study and interpretative research (Yin, 2014; Walsham, 1995; Eisenhardt, 1989). Since the focus is on socio-technical contexts, the used data and information have a qualitative and quantitative nature. The structure of the framework and the categories of factors identified derive both from the IS literature and from the research empirical experiences. Quantitative data are used mainly in relation to technical factors (processes, flows, key drivers); qualitative data are used for the "non-technical" and socio-relational factors.

4.2 Description

We believe that the most significant factors influencing the development of an IS in an existing context may derive from different stages of its life-cycle. As mentioned, from the analysis of the *current state* of the context, influencing factors may arise; they are contingent to the first stages (design) of development of the symbiosis and have primarily a technical nature. This factors are attributable to the context itself (processes and flows) or to other surrounding elements. In analyzing a context characterized by strong interrelationships between the variables and actors of the technical world of production and those of the surrounding socio-economic world, it is not possible to ignore why and how it was born and what facts and rules have guided its growth. Therefore, other remarkable factors are related to the way in which the IC *evolved*, and to the forces that prevail in promoting or preventing changes within the system, particularly in the light of the changes associated with the development of an IS. At the same time, from the life-cycle stages *following* the development of the IS, relevant influencing factors may derive. The perspective of an alternative path for a local sustainable growth can be a great reason to motivate decision makers and local actors. The extent of these motivations can be assessed in advance with regard to how they perceive the potential changes associated with the development of the IS.
The framework was therefore created to include these categories of factors, that refer to respectively:

a) *Current state of the context* (factors contingent to the development of the IS).

We include in the "current state" category, structural factors such as the nature and the characteristics of the processes and the material and energy flows detected within the contexts, as well as other contingent factors (the scale of the site, the level of homogeneity of the industries involved; the presence of infrastructures, the current regulations, the active participation of stakeholders in providing data and organizational support).

b) *Previous state of the context* (factors behind the development of the IS).

Jacobsen and Anderberg (2004) define this category as "*mechanisms behind the development*". It is the result (especially in long-standing contexts) of factors and forces that are embedded in people and organizations (culture, experiences, knowledge, roles and operating rules and routines). These may have a technical but also a non-technical nature and may differ from a context to another.

c) *Future -potential- state of the context* (factors beyond the development of the IS).

In this section, we include the perception of the local stakeholders on future effects/potential benefits and on the "ability" of the IS to become part of business as usual and to be integrated in the existing processes and organizations.

In figure 2 the interpretative framework is sketched.

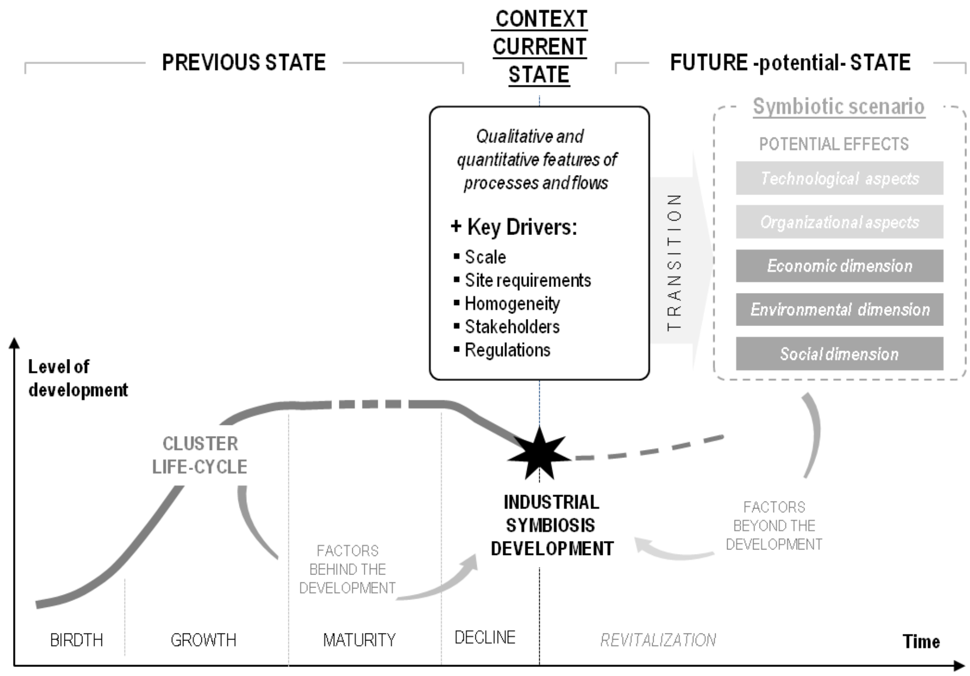


Fig. 2. A representative scheme of the framework.

5. Results and discussion

This section describes and discusses some of the most significant empirical evidences that emerged from the case studies comprehensive analysis, following the interpretative logic of the framework presented.

a) ***Current state of the context***

i. Structural factors

Processes carried out, technologies, scale factors, raw materials, typical wastes are some of the significant elements in order to define the solutions for an IS development; the most relevant ones emerged are shown below.

The *chemical* sector has been historically recognized as a suitable, but critical, context for the development of an IS (Reniers et al., 2010; Heeres et al., 2004; Desrochers, 2002); the first case study confirmed this point. The nature, the large size of the plants and the continuity of productions had relevant impacts on the quantity and quality of the flows detected (e.g. Hydrogen peroxide, Sodium Percarbonate, Hydroxide, Hydrochloric Acid, Sodium Silicate), that can be efficiently managed on-site, in an IS perspective. On the other hand, the use of toxic or hazardous substances (used as auxiliary materials, catalysts and reagents), as well as a significant energy demand have also emerged. A turbo gas power station that partially feeds the chemical plants (less than 20% of its potential is used internally by the cluster) and also provides them with steam and demineralized water.

In the *automotive* cluster, a network of SMEs, suppliers of the Honda motorcycle company local plant, was examined. As table1 shows, the SMEs were mainly involved in secondary processes; the final assembly and delivery stages were indeed performed by the final producer. In the presence of different and complementary processes, limited volumes and types of non toxic and valuable process scraps (steel, aluminum, rubber and plastics) were being produced. Two additional factors that emerged were the strong seasonality of demand (monthly sales reduction ranges from 40% to 60% from September to December) and the rapid obsolescence of machineries and equipments. Their joint action generates periodic underutilizations of plants and workers, and a permanent reserve of production capacity, also due to the presence of obsolete (but still functioning) machines. The volumes of waste flows were also affected by production fluctuations. The energy needs were not particularly relevant; however, the presence of high-precision machinery required high quality energy supply (no stops, spikes, etc.).

The *agri-food* IC brought to light the presence of large volumes of homogenous vegetable and non-vegetable waste flows. Regarding the former (not considered in our study), the companies have yet developed individual management strategies (as fertilizers or for animal feeding), whilst for the latter, considerable inefficiencies have emerged, related to the extensive use of auxiliary materials in different stages of the production chain (cultivation, conditioning, packaging, logistics and transportation). These materials consist mainly of plastics, but also include paper, cardboard, wood, and metals (Briassoulis et al., 2013). The main applications concern film mulches, drip irrigation tapes, row covers, tunnels, silage bags, and different sizes of containers. The high seasonality and uncertainty of production volumes represent further technical factors that impact significantly on the extent and regularity of input and output flows in this sector.

Solutions proposed –The structural factors described above have primarily affected the range of solutions that could be considered suitable to the contexts analyzed; in particular, collaborative IS-based solutions for the management of the material wastes flows were proposed.

The solutions based on *material exchange* were viable mostly in contexts characterized by the presence of primary processes. This is the case of the chemical site, where companies were willing to use local by-products and scraps to feed their processes (e.g. silica) and also to share utilities (power, steam and demineralized water). On the other hand, in clusters focusing on manufacturing and secondary processing (horizontally specialized, as in FAFC or by supply chain competences, as in the VDS) solutions that are based on the direct use of waste and by-products have rarely been viable, as these were lacking in the technical possibilities of materials processing. In such cases, *sharing* solutions were preferred, mainly focusing on the common local management of waste. This allowed for multiple benefits for the companies involved to be obtained, deriving from synergies and economies of scale in material processing and transportation and from the use of a productive reserve capacity. This is the case of a common recycling platform proposed for the VDS, that entails the use of old plastics extrusion machines to obtain granules of secondary materials (Simboli et al., 2014).

In some cases, it was possible to experience less-used IS solutions. This is the case of *repairing*, which was implemented in the FAFC in relation to the HDPE bulk containers. Their technical and economic features (mass and homogeneity, price, poor aesthetic value and rapid turnover due to breakages), related to the presence of a plastics processing company, have also facilitated the diffusion of such a practice. In addition, even the *material substitution* has proved to be a feasible hypothesis. For example, in the FAFC, this happened by allocating (out of the cultivation season) part of the land to crops for the production of bioplastics, which can be reused on-site for the production of mulching sheeting (currently one of the most critical waste). In the automotive context, the possibility of implementing a *product take-back* strategy, in order for the end-of-life of motorcycles to be managed on-site, was also considered. The solution was proven to be technically feasible and gained the interest of companies (positively influenced by the nature of the existing processes and competences); this was subsequently blocked by other contingent factors, which are discussed in more detail below.

Companies have not shown particular interest in improving the management of energy flows, either because they were considered as non-critical (as in the case FAFC) or because they were already dealt with (BCS site) or because they were dependent on the national grid (VDS).

In all the three contexts it was also possible to engage external partners: a company that recovers precious metals from used catalysts and a company for surface coatings in the case of BCS; an aluminum foundry in the case of VDS and industrial companies for the processing of plastics, wood and paper (as satellite activities of the agri-food sector), in the case of FAFC. In some cases, they are available to establish their plants in the production areas.

The main categories of materials flows considered and the symbiotic scenarios proposed for the three contexts are summarized in Appendix A and B.

ii. Other factors

In this section, the role of other promoting/preventing factors that have occurred at the stage of IS design is described. In the previous studies (Simboli et al., 2014, 2015; Taddeo et al., 2012), these were called “Key Drivers”. They are presented here in a comparative summary, highlighting their positive (+), or negative (-) influence in the development of the IS (table 2).

Table 2 The Key Drivers: issues emerged from the case studies.

	BCS	**VDS**	**FAFC**
1. GEOGRAPHICAL AND TECHNICAL REQUIREMENTS OF THE SITE Strategic location, availability of resources, and the presence of utilities within the industrial site. (Jensen et al. 2011b; Hewes and Lyons 2008; Roberts 2004; Chertow 2000)	Located on the banks of a river. **(+/-)** Communications: an airport (40 km); a commercial port (80 km); a highway (1 km); a railway station (1 km). **(+)** On-site utilities: steam, compressed air, natural gas, drinking water and industrial/demineralized water and electricity. **(+)** Combined cycle power plant Shared facilities: a laboratory, maintenance and repair shops, design and planning services, security services, an infirmary, administrative offices, a guest house, a canteen, and a laundry. **(+)**	Localized within one of the major industrial areas of the region (over 100 companies operating in the automotive industry). **(+/-)** Communications: a highway (10 km), a railway (15 km), an airport (50 km) and a commercial port (35 km). **(+)** No energy facilities close to the network. **(-)**	Good geographic position (in the middle of the Region). **(+)** Communications: an airport (100 km); a commercial port (120 km); a highway (10 km); a railway station (10 km). **(+)** No energy facilities close to the network (except for the gas power plant that feeds the sugar refinery. A feasibility study for the establishment of a biogas energy plant is being carried out). **(-)**
2.HOMOGENEITY /HETEROGENEITY OF INDUSTRIES Number of industries and processes involved in the IS (Reniers et al. 2010; Sterr and Ott 2004)	The initial industry homogeneity of the chemical companies involved could be enriched by the potential establishment of new nearby firms involved in complementary industries. **(+/-)**	Companies mainly focused on second-level processing and the sub-assembly of components. **(+/-)** Two main sectors (metals and plastics cover over 80% of the flows within the network). **(+/-)** Materials are, in general, not subject to chemical transformations. **(+/-)** High complementarity (process developed to provide the same client). **(+/-)**	High degree of homogeneity of processes and materials amongst the agri-food companies (this favors the development of solutions related to crop wastes, but it severely limits the possibilities for input/output exchange of auxiliary materials). **(+/-)** The level of heterogeneity increases considering the companies settled as a result of the industrialization of FAFC. **(+)**

3.ACTIVE PARTICIPATION OF THE STAKEHOLDERS Local governments, agencies, key individuals, communities (Sakr et al. 2011; Hewes and Lyons 2008; Heeres et al. 2004)	Financial support and coordination of local and regional government. **(+)** Stakeholders involved: local, regional and national government agencies; representatives of local companies; potential future tenants in the IS. **(+)** Key players: the Local Observatory for the Chemical Industry (for the coordination of the activities of the stakeholders and for setting up periodic round-tables to present the progress, encourage and support an exchange of views and initiatives amongst the various stakeholders and for maintaining relations with the territory). **(+)**	No specific support (including financial) or sponsorship. **(-)** Stakeholders involved: external patronage of the Chamber of commerce and the Association of the Industrialists of the Province of Chieti (this facilitated the detection of general economic data and information, and was useful in bringing to light potential sources of criticalities of the project). **(+)** No coordination body ("creator of trust"), formally recognizable as the Champion, and no "key figure" was identified. **(-)** A spontaneous "catalyst" action was played by the President of the CISI, facilitating data collection and the involvement of the SMEs. **(+)**	No specific support (including financial) or sponsorship. **(-)** Stakeholders involved: external support of the Association of Agricultural Producers (this facilitated the collection of technical and economic data and helped to identify potential sources of project criticalities). **(+)** No coordinating body or key individual was identified. **(-)**
4.REGULATORY SYSTEM Environmental legislation and standards (Costa et al. 2010; Chertow 2007; Gibbs and Deutz 2007)	**Regulations** EU Level: Directive 2008/98/EC (+) Italian legislation: D.lgs 152/2006 and D.lgs n°205/2010 and subsequent modifications **(-)** LOCAL: Regional ad Provincial waste management plan **(+/-)** **Action plans** EU, National and Local **(+)** **Founding measures and programs** EU, National and Local **(+)**		

Among the above mentioned, according to literature (Costa et al., 2010; Chertow, 2007; Gibbs and Deutz, 2007), the environmental regulations, policies and standards have emerged as one of the most critical factor for the development of an IS in a given area or region. We have considered three categories of tools that can influence companies' behavior: regulations, action plans and founding measures/programs. If the latter two categories could certainly have a positive effect on the development of the IS, the former (regulations) may generate two types of effects. On the one hand, they define higher efficiency standards and this stimulates a reactive behavior of the companies involved; on the other hand, they can limit the use of certain solutions, or generate inequalities among different countries. In Italy (due to the still limited transposition of the Directive 2008/98 EC), industrial companies cannot use directly the scraps generated by other companies -usually classified as wastes- as raw materials for their own processes. In the cases of VDS and FAFC this restriction forced to design IS scenarios including the presence of companies authorized to perform a pre-treatment of the scraps and to dispose of unusable waste. This makes it difficult to develop internal relations and it reduces the economic efficiency of the symbiotic solutions.

b) *Previous state of the context*

i. Technical factors

- *Location factors.* The origin of the clusters emerged as one of the most indicative factors of how it can evolve toward an IS. For example, the "location factors" (Renner, 1947) that led to the initial establishment of the companies, greatly influence the current typology of the cluster (Markusen, 1983) that it has derived from and its distinctive features (e.g. dimension of companies; products and processes involved; prevailing technological standards; workforce needs; presence of utilities; logistics and other support activities), for instance:

a) ICs *planned*, or emerged to exploit a *unique or specific resource* (oilfield, cultivable land, a given raw material), may lead to the development of ICs that are characterized by a certain level of process homogeneity; these are the cases of BCS and FAFC, respectively;
b) ICs born after the establishment of a *large/leading manufacturing company* in a given territory may be characterized by the presence of several complementary processes and material flows, which depend on the nature and the complexity of the final productions; this is the case of the VDS;
c) backward areas, which are industrialized because they are promoted by *government incentives or tax reliefs* for companies, or for the presence of *generic factors* (low cost of labor and infrastructures) led to the development of ICs, in which no specific industries/processes or structural relation may be detected.

A different typology of the ICs may promote or hinder the development of a certain type of IS. It can also affect the nature and the direction of flows, the degree of cooperation/competition amongst firms, the presence or absence of key nodes in the network. A proper and timely identification and comprehension of these aspects may be useful for the selection of the most appropriate approach to be followed. Insights in this sense may arise from the interactions of the studies on IS with industrial and economic geography studies.

- *Technological and organizational "substrate"*. Another factor influencing the development of an IS revealed to be its technological-organizational features. The higher or lower aptitude of a given context to accept new production or organizational solutions may depend, for example, on the type of the processes and on the level of knowledge established during time. The presence of this "substrate" becomes particularly evident and significant in the case of existing ICs.

A representative example is the VDS case study. In recent decades, the high level of technological and organizational complexity achieved by the automotive industry contributes to the fragmentation of activities within supply chains; suppliers are often specialized in specific process steps, whilst final producers focus on the assembly and distribution of those products (Mercer,1995). Such a separation of roles and activities had significant consequences in the perspective of the IS development. The SMEs involved in the VDS case study, currently preside process technologies, technical knowledge and expertise and also most of the wastes; however, they primarily suffer the weight of inefficiency. This is one of the reasons why they demonstrated to be the more responsive ones to the solutions proposed. In addition, the similarity between production and recycling processes facilitated the development of synergies and collaborative strategies, allowing companies to use the machinery in a more efficient way. The SMEs suppliers, that in innovation studies are historically classified as agents “towed” by large companies and final producers (Pavitt, 1984), here appear as the pillars upon which an IS may be built.

ii. Non-technical factors

- *Existing relation*s. The formal and informal relations between organizations have confirmed to be another important factor in an IS development, recognized as vehicles of diffusion of knowledge and as capable to enable changes (Fischer ,2001; Granovetter, 1973).

Comparing the three contexts, it emerged that the relations amongst the companies were quite different. In VDS, which was the more structured network, all the companies knew each other and there were supply relations, but also competitive and collaborative ones (Ceci et al., 2010). In the case of BCS, there was not competition, but only some supply relations. In the case of FAFC, more competition relations emerged. The focus groups also revealed that the actors in every context, had already worked together, especially in joint purchasing or new market penetration, or R&D activities, but never in the joint management of waste. This attitude may act in favor of the development of new forms of collaboration as the IS, but also signals a cultural lag and a reluctance to share some kind of data and information. The use of tools such as the SNA is giving support in mapping and interpreting the role of relations in IS (Ashton, 2009; Doménech and Davies, 2011).

- *Local community*. The communities’ involvement has been recognized as a critical element in the development of IS (Gibbs et al., 2010; Roberts, 2004). One of the most important features of the communities within ICs is the system of rules and values, which are expression of a local ethic of work, family and reciprocity (Becattini, 2004; Brusco and Paba, 1997); studies also highlight general trends toward the reinforcement of the internal socio-cultural dynamics over time, giving rise to organizational inertia, path dependence and lock-in phenomena (Martin and Sunley, 2006; Arthur, 1989; Hannan and Freeman, 1977). For these reasons, their support must be carefully considered, already in the first stages of the IS design, and must be also managed in the long-term, because it is essential in building a culture for the sustainable local growth.

In our research, the most relevant empirical evidence in this regard emerged from the BCS case study (Taddeo et al., 2012). The local community, which was actively involved in the research project through their delegates (major and labor union) had a crucial negative influence on the decision-making process, such as to lead the companies and local government to abandon the project, despite the technical feasibility of the study and the availability of the stakeholders. The main problem concerned the opposition of the population to the management of waste flows in the area. Further investigations allowed us to understand the reasons of such an opposition. Firstly, there was a lack of knowledge about the issue of the project and the dissemination of information from delegates to community was a failure. Secondly, and most importantly, previous negative experiences acted against the project: in the past, the BCS had been a protagonist of an environmental scandal related to an illegal dump of toxic materials found near the production site. As a consequence, the local community still considered concepts such as recovery or recycling of waste and scraps, as sources of problems instead of potential resources.

c) *Future -potential- state of the context*

i. Potential economic, environmental, social effects (benefits and criticalities)

In the last phase of each case study, especially during meetings and focus groups, efforts were focused on bringing to light the potential benefits, the criticalities and other synergies that may potentially derive from the solutions proposed. The projects did not include economic feasibility studies; however, it was possible to make some observations through pilot tests and simulations. Potential economic and environmental benefits clearly emerged, mainly related to disposal and transportation activities, to the reduced use of virgin materials and to the development of recycling activities. Indirect potential benefits also derived from the secondary raw materials sale, from the access to financing plans and from new investments (e.g. the establishment of the new tenants). Besides these aspects, other significant elements emerged in the design stage that local actors perceived in favor of the IS development were:

- the prospective use of *recyclable materials* (especially metals, plastics, paper and cardboard, and wood) to reduce costs and impacts related to the current inefficient management;
- the possibility to exploit the *seasonality* of production activities (especially in the agricultural and motorcycle industries) for the future development of complementary activities;
- the potential *establishment of companies* that are available to buy their scraps as secondary materials in order to feed their own process.

Elements perceived as discouraging factors were:

- the *fragmentation and/or the low size of companies*, that may limit the capacity for them to be engaged in a long-term project;
- the *complexity* and *costs* of implementation of some solutions;
- the *distrust* about the future evolution of policies and regulations on wastes treatment;

– the *uncertainty* about the volumes and the characteristics of collected waste.

ii. Potential for integration

The three case studies highlight the potential of IS in producing systemic changes, at different levels: some of the proposed solutions do not require relevant economic or technological shifts and the organizational dimension of the systems is slightly involved (e.g. the collective management of scraps); other solutions mostly impact on the managerial and organizational dimensions, and marginally modify technologies (e.g. the sharing of obsolete equipment to recycle materials or the development of a local common recycling platform); some improvement measures require a series of radical shifts, both on products and process technologies and on the economic dimension of the system (e.g. the end-of-life collection and management of final products). The concrete implementation of these solutions may also imply the initiation and/or the settlement of new activities, as for example:

- activities that can be *easily integrated into existing processes* (e.g. scraps sorting);
- activities that require the *collaboration of two or more companies* (e.g. recycling platforms);
- activities that require the *involvement of other companies or external partners* (e.g. the final producer in the VDS; the external companies in the BCS; the industrial companies in the FAFC);
- activities that may encourage the *creation of new companies* in the industrial area (e.g. the production of artifacts from secondary raw materials and/or in the recovery/recycling and services activities) or the *localization of the production activities* (e.g. the aluminum foundry in the VDS; the metal recycler in the BCS).

The implementation of the solutions mentioned can produce in the long-term significant changes in the structure, relations and the operation of the ICs; in order for them to become effective it is necessary that the actors of the territory become aware of the potential of IS, by including it in the strategic planning choices. The complexity of a symbiotic scenario has emerged as one of the main cognitive and communication barriers with respect to the actors involved, whose greatest difficulty lies in the inability to understand how to start the process of change. To partially bridge this gap, in the case of VDS, we developed in collaboration with the provincial association of the industrialists, a training project on industrial ecology approaches and tools for production managers of the companies involved in the project. A problem that still exist in this respect, is how to make the agents involved aware of the tangible benefits that can result from the IS adoption. Future research efforts should include the development of simplified tools for the integrated assessment of the economic and environmental performance of IS scenarios (e.g. exploiting *environmental footprinting* or *life-cycle based* approaches and tools).

Table 3 summarize all the recurring contextual factors included in our interpretative framework, including references to the contexts in which one or more factors were analyzed or have emerged as significant.

Table 3 Contextual factors included in the framework

	CONTEXT LIFE-CYCLE STAGES		
	Previous state **-Factors behind the development-**	*Current state* **-Factors contingent to the development-**	*Future -potential- state* **-Factors above the development-**
Predominantly technical aspects	- LOCATION FACTORS **[BCS; VDS; FAFC]**	- STRUCTURAL FACTORS (characteristics processes carried out, technologies, scale factors, raw materials, typical wastes) **[BCS; VDS; FAFC]**	- ECONOMIC BENEFITS ***[VDS (pilot test); FAFC (pilot test)]*** - ENVIRONMENTAL BENEFITS ***[VDS (pilot test); FAFC (pilot test)]***
↓	- DYNAMICS OF CHANGES (technological and organizational substrate) **[VDS]**	- OTHER CONTINGENT FACTORS (KEY DRIVERS) • Geographical and technical requirements of the site • Homogeneity /heterogeneity of industries • Active participation of the stakeholders • Regulatory system **[BCS; VDS; FAFC]**	- SOCIAL BENEFITS ***[not assessed]***
Predominantly non-technical aspects	- FACTORS EMBEDDED IN PEOPLE AND ORGANIZATIONS • Culture, • Experiences, • Knowledge, • Roles and routines **[BCS; VDS]**	- EXISTING RELATIONS **[VDS]** - ROLE OF LOCAL COMMUNITY **[BCS]**	- "ABILITY" OF THE IS TO BECOME PART OF BUSINESS AS USUAL (existing processes and organizations) **[VDS]** - PERCEPTION OF THE LOCAL STAKEHOLDERS ON FUTURE EFFECTS/POTENTIAL BENEFITS ***[BCS; VDS; FAFC]***

5.1 Final remarks

Empirical evidences emerged through the use of framework show a general positive "technical" attitude of the analyzed ICs toward the development of IS. T he proximity of production plants, the availability of infrastructures, utilities and services, the high volume and homogeneity of easily recyclable wastes, the limited presence of hazardous materials, the willingness of companies and stakeholders are the structural factors of the ICs that played the most significant role in promoting the potential development of the IS. The seasonality of productions and the presence of obsolete -but functioning- machineries may also enable the development of new complementary activities, for example related to material treatment and recycling. An alternative use of this reserve of production capacity may also contribute to face the problems related to the rigidity of labor industry, by giving seasonal, early-retired and surplus workers the opportunity to be employed in the new activities that could result from the IS implementation.

Equally evident is the presence (in each one of these contexts) of existing forms of synergistic collaborations, which can be considered as a *"kernel"* of IS (Chertow, 2007). This is valid for the sharing utilities of the BCS with regard to the use of the power plant, or for the jointly logistics services in the case of VDS, or for the use of food wastes for animal breeding in the FAFC. These examples are relevant (highlighting the propensity of firms to share and collaborate), but they must be viewed as sporadic initiatives, resulting from the need to save money, rather than by the desire to be more sustainable. Thus, they lack a prospective and a strategic vision.

Other remarkable reflections concern the forces and the entities prevail in promoting or preventing changes within the system. The dynamics of change in ICs are driven by mechanisms and rules that are hardly measurable and controllable; the full understanding of these aspects may provide useful insights on how the ICs may address the development of an IS and what levers act in order to facilitate the achievement of positive results. Amongst the main business drivers emerged, there is the realization by the companies of their inefficiencies and of the synergies offered by the IS through the adoption of collaborative solutions. The simplicity, the time and the cost of implementation are amongst the elements that they take into account for the selection of solutions that can be implemented. The results give grounds for believing that in such contexts, the definition of a "modular" design of the IS scenario and a stepwise path for its development (Jacobsen and Anderberg, 2004), in which each subsequent solution is based on the previous one, can lead more easily to a successful implementation.

At the same time, relevant influences may derive from the local actors' perception of effects of the IS development, in relation to the potential revitalization of the context and the suitability of the solutions proposed. The synergies and the economic, social and environmental benefits, which are achievable from mutual exchanges and joint activities established, can be considered as an additional external economy (Deutz and Gibbs, 2008; Renner, 1947), that renders territories identifiable and attractive for new companies and funding. These are aspects that can significantly influence the attitude of the territories toward the IS.

Knowledge, communication and learning revealed to be equally crucial, both for companies and the community in order for an adequate cultural background to be created. The technological and organizational substrate, the existing relations, the "local culture", the system of values, and adverse events in past life-cycle stages should be useful as well for the development of IS in existing ICs.

6. Conclusions

Theoretical contributions and empirical evidence indicate that the features of the context are crucial elements in defining successful IS. In the present article, an interpretative framework has been proposed for interpreting the development of IS in ICs as starting contexts. Three different IS-based scenarios focused on the material flows management were analyzed, considering the contextual factors that may affect their development. The framework is based on the three most significant stages in ICs life-cycle: the *current state*; the *previous state*; the *future -potential- state*. From the analysis of the current state of the context, technical factors emerge as relevant (structural factors, other contingent factors), but also non-technical factors may greatly influence the IS development (existing relations and local community). Other factors are related to the way in which the IC evolves (location factors; dynamics of changes; factors embedded in people and organizations) and from the life-cycle stages following the development of the IS (potential benefits of the IS; “ability” of the IS to become part of business as usual; perception of the local stakeholders on future effects). The framework allowed us to better understand their role and to analyze them systematically. The questions that we believe are still open, especially in the perspective of a greater generalization of findings, are: i) What are the key factors and their role in other contexts? ii) Is there a specific relationship among some factors (e.g. age, industry, structure) and the role they played in each context? Is it possible to build a taxonomy? iii) How to shape contexts towards the adoption of an IS? Future developments of our research activities will be focused in investigating these aspects.

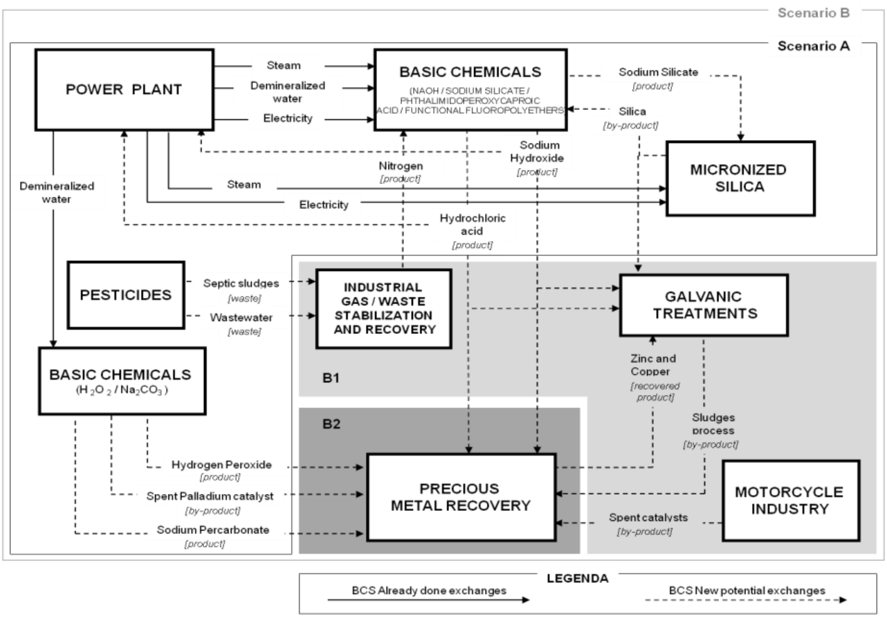
References

Arthur, W. B., 1989. Competing Technologies, Increasing Returns, and Lock-In by Historical Events. The Economic Journal. 99, 116-131.
Ashton, W.S., 2009. The structure, function, and evolution of a regional industrial ecosystem. Journal of Industrial Ecology. 13, 228-246.
Baas, L.W., Huisingh, D., 2008. The synergistic role of embeddedness and capabilities in industrial symbiosis: illustration based upon 12 years of experiences in the Rotterdam Harbour and Industry Complex. Progress in Industrial Ecology – An International Journal. 5, 399-421.
Becattini, G., 2004. Industrial Districts. A New Approach to Industrial Change, Edward Elgar Publishing, Cheltenham.
Boons, F., Baas., L., 2006. Industrial symbiosis in a social science perspective. Discussion proposal for 3rd Industrial Symbiosis Research Symposium, 5–6 August, Birmingham, UK.
Briassoulis, D., Hiskakis, M., Babou, E., 2013.Technical specifications for mechanical recycling of agricultural plastic waste. Waste Management. 33, 1516-1530.
Brusco, S., Paba, S., 1997. Per una storia dei distretti industriali italiani dal secondo dopoguerra agli anni novanta, in: Barca, F. (Ed.), Storia del capitalismo italiano dal dopoguerra ad oggi. Donzelli Editore, Roma, pp. 265-332.
Ceci, F., Iubatti, D., Simboli, A., 2010. Communication flows in SME network: the C.I.S.I. consortium case, in: Passiante, G. (Ed.), Evolving Towards the Internetworked Enterprise. Springer, London, pp. 175-185.
Chertow, M.R., 2000. Industrial symbiosis: literature and taxonomy. Annual Review of Energy and Environment. 25, 313-337.
Chertow, M. R., 2007. “Uncovering” industrial symbiosis. Journal of Industrial Ecology. 11, 11-30.
Chertow, M.R., Ehrenfeld, J., 2012. Organizing self-organizing systems. Toward a theory of Industrial Symbiosis. Journal of Industrial Ecology. 16,13-27.
Chertow, M.R., Ashton, W.S., Espinosa, J.C., 2008. Industrial Symbiosis in Puerto Rico: environmentally related agglomeration economies. Regional Studies. 42, 1299-1312.
Cohen-Rosenthal, E., McGalliard, T.N., 1996. Designing Eco-Industrial Parks: The United States Experience. United Nations Environment Programme. Industry and Environment, 4.
Costa, I., Ferrão, P., 2010. A case study of industrial symbiosis development using a middle-out approach. Journal of Cleaner Production. 18, 984-992.
Costa, I., Massard, G., Agarwal., A., 2010. Waste management policies for industrial symbiosis development: case studies in European countries. Journal of Cleaner Production. 18, 815-822.
De Ottati, G., 2009. An industrial district facing the challenges of globalization: Prato today. European Planning Studies. 17, 1817-1835.
Desrochers, P., 2002. Industrial ecology and the rediscovery of interfirm recycling linkages: historical evidence and policy implications. Industrial and corporate change. 11, 1031-1057.
Deutz, P., Gibbs, D., 2008. Industrial Ecology and Regional Development: Eco-Industrial Development as Cluster Policy. Regional Studies. 42, 1313-1328.

Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives.
Doménech, T., Davies, M., 2011. The role of embeddedness in industrial symbiosis networks: phases in the evolution of industrial symbiosis networks. Business Strategy and the Environment. 20, 281-296.
Eisenhardt, K.M., 1989. Building Theories from Case Study Research. Academy ofManagement Review. 14, 532-550.
Erkman, S., Van Hezik,C., 2014. Eco-industrial Parks in Emerging and developing Countries: Achievments, good practices and lessons learned. A comparative assessment of 33 cases in 12 emerging and developing countries. UNIDO Draft report. Vienna: United Nations Industrial Development Organization.
Fischer, M.M., 2001. Innovation, Knowledge Creation and Systems of Innovation. The Annals of Regional Science. 35, 199-216.
Gibbs, D., 2003. Trust and networking in inter-firm relations: the case of eco-industrial development. Local Economy. 18, 222-236.
Gibbs, D., Deutz, P., 2007. Reflections on implementing industrial ecology through eco-industrial park development. Journal of Cleaner Production. 15, 1683-1695.
Gibbs, D., Deutz, P., Proctor, A., 2010. Industrial ecology and eco-industrial development: A potential paradigm for local and regional development?. Regional Studies. 39, 171-183.
Granovetter, M.S., 1973. The strength of weak ties. American Journal of Sociology. 78, 1360-1380.
Grant, G.B., Seager, T.P., Massard, G., Nies, L., 2010. Information and Communication Technology for Industrial Symbiosis. Journal of Industrial Ecology. 14,740-753.
Guerrieri, P., Pietrobelli, C., 2004. Industrial districts' evolution and technological regimes: Italy and Taiwan. Technovation. 24, 899-914.
Hannan, M.T., Freeman, J.H., 1977. The Population Ecology of Organizations. American Journal of Sociology. 82, 929-964.
Heeres, R.R., Vermeulen, W.J.V., de Walle, F.B., 2004. Eco-industrial park initiatives in the USA and the Netherlands: first lessons. Journal of Cleaner Production. 12, 985-995.
Hewes, A.K., Lyons, D.I., 2008. The humanistic side of eco-industrial parks: champions and the role of trust. Regional Studies. 42, 1329-1342.
Jacobsen, N.B., Anderberg, S., 2004. Understanding the evolution of industrial symbiotic networks - the case of Kalundborg, in: van de Bergh, J.C.J.M, Janssen, M.A. (Eds.), Economics of Industrial Ecology – Materials, Structural Change and Spatial Scales. MIT Press, Cambridge, pp. 313-335.
Jensen, P.D., Basson, L., Leach, M., 2011a. Reinterpreting Industrial Ecology. Journal of Industrial Ecology. 15, 680-692.
Jensen, P.D., Basson, L., Hellawell, E.E., Bailey, M.R., Leach, M., 2011b. Quantifying 'geographic proximity': experiences from the United Kingdom's national industrial symbiosis programme. Resources, Conservation and Recycling. 55, 703-712.
Lazerson, M., Lorenzoni, G., 1999. Resisting organizational inertia: the evolution of industrial districts. Journal of Management and Governance. 3, 361-377.
MacLachlan, I., 2013. Kwinana Industrial Area: agglomeration economies and industrial symbiosis on Western Australia's Cockburn Sound. Australian Geographer. 44, 383-400.
Markusen, A., 1983. Sticky places in slippery space: a typology of Industrial Districts. Economic Geography. 72, 293-313.
Marshall, A., 1928. Principles of economics, Mcmillian & Co Ltd, London.
Martin, R., Sunley, P., 2006. Path dependence and regional economic evolution. Journal of Economic Geography. 6, 395-437.
Mercer, G., 1995. Modular Supply in the 1990s: the Keys to Success, in: Mckinsey (Ed.), Europe's Automotive Components Business, 2nd Quarter, pp. 112-135.
Mirata, M., 2004. Experiences fromearly stages of a national industrial symbiosis programme in the UK: determinants and coordination challenges. Journal of Cleaner Production. 12, 967-983.
Paquin, R.L., Howard-Grenville, J., 2012. The Evolution of Facilitated Industrial Symbiosis. Journal of Industrial Ecology. 16, 83-93.
Pavitt, K., 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. Research Policy. 13, 343-373.
Porter, M.E., 1990. The Competitive Advantage of the Nations Free Press, New York.
Reniers, G., Dullaert, W., Visser, L., 2010. Empirically based development of a framework for advancing and stimulating collaboration in the chemical industry (ASC): creating sustainable chemical. Journal of Cleaner Production. 18, 1587-1597.
Renner, G.T., 1947. Geography of Industrial Localization. Economic Geography. 23, 167-189.
Roberts, B.H., 2004. The application of industrial ecology principles and planning guidelines for the development of eco-industrial parks: an Australian case study. Journal of Cleaner Production. 12, 997-1010.
Sakr, D., Baas, L., El-Hagger, S., Huisingh, D., 2011. Critical success and limiting factors for eco-industrial parks: global trends and Egyptian context. Journal of Cleaner Production. 19, 1158-1169.
Schiller, F., Penn, A.S., Besson, L., 2014. Analyzing networks in industrial ecology – a review of Social-Material Network Analyses. Journal of Cleaner Production. 76, 1-11.

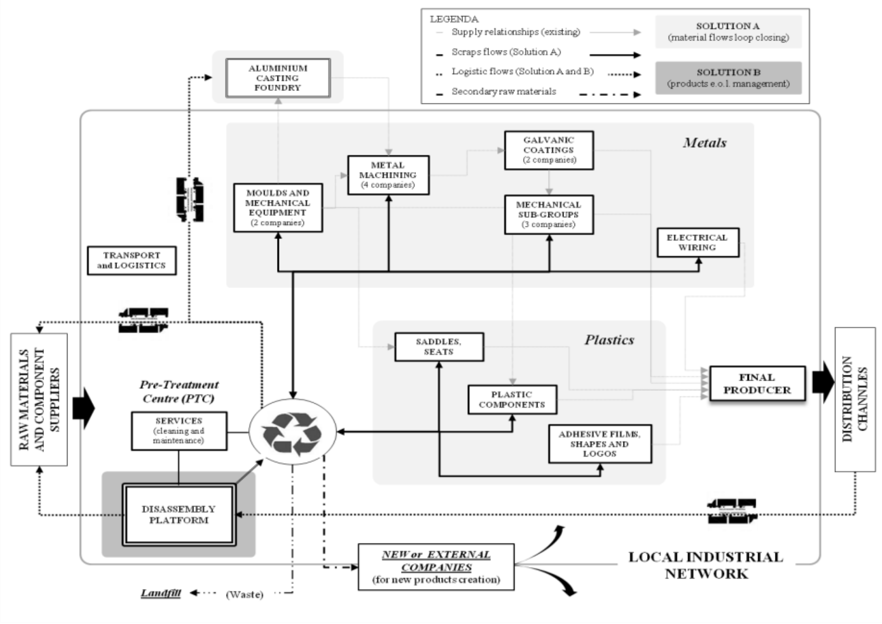
Simboli, A., Taddeo, R., Morgante, A., 2014. Analysing the development of Industrial Symbiosis in a motorcycle local industrial network: the role of contextual factors. Journal of Cleaner Production. 66, 372–383.
Simboli, A., Taddeo, R., Morgante, A., 2015. The potential of Industrial Ecology in agri-food clusters (AFCs): a case study based on valorisation of auxiliary materials. Ecological Economics. 111, 65-75.
Sterr ,T.,Ott, T., 2004.The industrial region as a promising unit for eco-industrial development reflections, practical experience and establishment of innovative instruments to support industrial ecology. Journal of Cleaner Production. 12, 947-965.
Taddeo, R., Simboli, A., Morgante, A., 2012. Implementing eco-industrial parks in existing clusters. Findings from a historical Italian chemical site. Journal of Cleaner Production. 33, 22-29.
Wallner, H. P., 1999. Towards sustainable development of industry: networking, complexity and eco-clusters. Journal of Cleaner Production. 7, 49-58.
Walsham, G., 1995. Interpretive Case Studies in IS Research: Nature and Method. European Journal of Information Systems. 4, 74-81.
Yin, R.K., 2014. Case Study Research: Design and Methods, Sage Publishing, Beverly Hills.

Appendix A. The scenarios proposed for the three case studies.



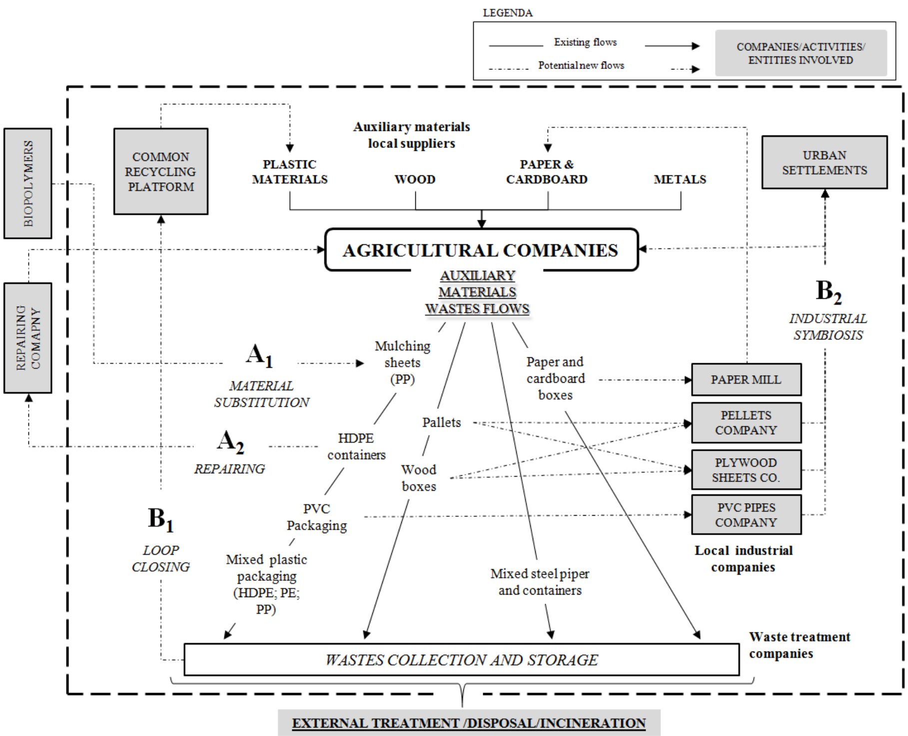
a) The potential symbiotic scenario proposed for the BCS

BCS - The proposed symbiotic scenario is composed of two solutions, identified as A and B. Solution A includes only the BCS companies; B is composed of A and two potential added options: B1, that includes three companies operating in the Val di Sangro Industrial area and B2, that includes also a spontaneous tenant coming from a neighboring Region. As shown, the implementation of solution A could allow to establish four new exchanges; adding the option B1, it would be possible to establish six new exchanges; finally, through the addition of the option B2 further eight exchanges could be established.



b) The potential symbiotic scenario proposed for the VDS

VDS - The solutions that define the proposed scenario are A and B. SOLUTION A is focused on industrial scraps (light grey areas). The collective management of scraps, aimed at integrating recovery and recycling activities within the current scopes of the CISI, represents an easily adoptable solution. It is structured in three different options: A1- the recycling of scraps within the local industrial network for the re-production of the same output; A2 - the recycling of scraps within the local industrial network for the re-production of different outputs; A3 - the pre-treatment and selling of scraps as secondary raw materials. This option is suitable for those materials whose internal recycling is not convenient or is technically not feasible. The implementation of this solution necessarily includes the service company of the CISI, which is authorized to handle wastes and the creation of a Pre-Treatment Centre (PTC) that could be established by exploiting the surplus of the working machines and equipment recognized within the CISI companies. SOLUTION B is focused on the end-of-life management of products (grey area). It provides the establishment, in collaboration with the final producer, of a manual disassembly platform within the PTC. As the distribution to retailers is managed by the transportation service of the CISI, the same service can be usefully exploited for the collection of products and treatment of materials at their end-of-life.



c) The potential symbiotic scenario proposed for the FAFC

.

FAFC - The scenario proposed for the FAFC includes two sets of solutions: A and B. Type A solutions can be implemented by individual companies (they are not considered in this research). The type B solutions (B1 and B2) include collective measures and are explained as follows. B1- Development of a common local recycling platform. The platform could catch flows of homogeneous materials (especially Agricultural Plastic Wastes - APWs), pre-treat and recycle them internally or sell them to other companies as secondary raw materials. This could enable the establishment of new activities with additional benefits for the area. B2- Involvement of other industries. Such solution include the non-agricultural companies settled in the FAFC, they are: i) a paper mill, interested in receiving paper and cardboard wastes; ii) a company that produces PVC sewer pipes, willing to use a percentage of plastic wastes in addition to virgin materials; iii) a company that produces pellets and plywood panels, interested in wood and cardboard wastes. Potentials uses considered for the materials deriving from the solutions described include the creation of agricultural support devices (e.g. sewage drain pipes, greenhouse materials) or secondary logistics devices (e.g. road signs) or the heating of local settlements

Appendix B. The material flows detected in the three case studies**.**

	DESCRIPTION	AMOUNT (kg/year)	DESTINATION
BCS	***Basic Chemicals (Hydrogen peroxide / Sodium Percarbonate) – P***	2,800,000	Raw material
	Basic Chemicals (Sodium Hydroxide/Hydrochloric Acid/Sodium Silicate) – P	10,565,500	Raw material
	Silica – BP	23,000	Secondary raw material
	Spent Catalyst – BP	3,600	Treatment for recovery and reuse of precious metals
	Sludge (septic) – W	5,500	Treatment for disposal
	Sludge (galvanic process) – W	319,000	Treatment for recovery of metals (average content: Zn= 46,25g/Kg; Cu=0.049 g/Kg)
	Wastewater – W	56,740	Treatment for reuse
	LEGENDA: P= Product; BP= By-product; W= Waste		
VDS	***Ferrous metal shavings and turnings***	2,534,297	A - B - C - D – E
	Ferrous metal dust and particles	1,642,448	A - B - C - D - E – F
	Non-ferrous metal filings and turnings	1,352,045	B – D
	Sludges and filter cakes	313,380	A - B - C - D – G
	Iron and steel	275,741	A - B – D
	Non-ferrous metal dust and particles	226,295	A - C - D - H – I
	Mixed packaging	158,180	B - C - D - L – M
	Paper and cardboard packaging	103,875	B - C - D - L – M
	Machining emulsions and solutions free of halogens	61,200	B - C – N
	Plastics shavings and turnings	37,895	H – N
	LEGENDA: A) 20 km; B) 20 km; C) 70 km; D) 110 km; E) 40 km; F) 180 km; G) 267 km; H) 26 km; I) 208 km; L) 22 km; M) 74 km; N) 82 km -sites of treatment and landfill-		
FAFC	***Mulching sheets (PP and nonwoven)***	1,903	Disposal
	Films and packaging (PE, HDPE, PS)	58,841	Disposal
	Boxes and pallets (wood)	1,100	Internal heating
	Mixed packaging (plastics, paper, cardboard)	3,275	Disposal/external recycling
	Tires	4,520	Disposal /external recycling/waste to energy
	Iron and steel scraps	5,400	External recycling
	Used oils*	2,200	Mandatory consortium for used oils
	Spent oil filters*	176	Mandatory consortium for used oils
	Spent batteries*	115	Treatment and disposal
	Septic sludge*	8,980	Treatment and disposal
	Mixed packaging* (containing residues of hazardous substances)	432	Treatment and disposal
	Other mixed materials* (containing residues of hazardous substances)	95	Treatment and disposal
	*LEGENDA: *Special and/or hazardous waste. Abbreviations: PP, polypropylene; HDPE, high-density polyethylene; PS, polystyrene.*		