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THE EXPERIENCE OF THE FIRST INDUSTRIAL SYMBIOSIS PLATFORM IN ITALY

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Abstract

This paper reports the activity, promoted by the Italian agency for new technologies, energy and sustainable economic development (ENEA), in the framework of the project for the development and implementation of the first Italian Platform for Industrial Symbiosis implemented in Sicily (2011-2015). The goals of the project were: to provide a methodology and an instrument for industrial symbiosis implementation at regional scale, to implement a IS Platform as a support to SMEs to individuate symbiosis opportunities in the region.
The whole approach includes: network activation, platform architecture design and implementation, analysis of the productive sector in Sicily, data collection and companies involvement. In particular the paper focuses on the activities developed for companies' network creation trough a preliminary analysis of the predominant productive sectors followed by the organization of operative meetings in Sicily for companies' involvement, analysis of potential synergies and resources sharing, and finally platform population. During the first two meetings more than 80 SME were linked giving rise to almost 400 output resources and almost 180 input resources. More than 690 potential matches were found between the participating enterprises showing interesting opportunities both for substituting resources with waste products in real and virtual cases and for sharing waste management services and infrastructures. The discussion occurred during the meeting has remarked the significance and the consequences of the regulatory and control system on IS application, underlining the necessary participation of local stakeholders and control authorities. It has also emerged the need to identify predominant productive activities in well-defined territorial contexts where to investigate the specific/local tangles taking into account legislative and technical-economic feasibility. Technical dossiers on three main resource streams (wastes from processing stone materials; plastics and agro-industrial wastes), which may generate the more interesting potential synergies, are being processed. These dossiers include European, Italian and regional regulations, guidelines, technical standards, logistic and economical aspects useful for supporting companies in synergies implementation. Results of this activity will also be used to improve the algorithm in the platform to find synergies.

Key words: industrial symbiosis, platform, resources, synergies, waste

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1. Introduction

In industrial ecosystems efficiency and optimization of resources and energy, waste minimization and enhancement of the products represent an important strategy in a perspective of circular economy (Atasu et al., 2008). Industrial ecology is aimed at closing and optimizing cycles of matter and energy (Bringezu, 2003; den Hond, 2000; Korhonen, 2007), developing a systemic approach of the industrials systems (Graedel and Allenby, 2003).

Industrial symbiosis (IS), which represents one of the main features of industrial ecology, aims to increase the efficiency in the use of materials and

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energy (Chertow, 2004). It examines cooperative management and exchange of resource flows—particularly materials, water, and energy—through clusters of companies (Chertow and Ehrenfeld, 2012).

IS approach reflects the recent European strategies of decoupling economic growth, environmental impacts and natural resource consumption through the promotion of a more sustainable circular economy as clearly identified in different programming and financing documents of the European Commission (EU COM, 2011, 2012, 2014a, 2014b).

IS application at local scale 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 accelerated within companies. Each member state of the EU must internally adopt and adapt the European policy to overcome the legal and administrative hurdles pertaining to the condition of by-products and the end of a waste product's life (Costa et al., 2010).

In this regard huge efforts are being made to define the criteria that waste flows must meet in order to no longer be 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 reduce the uncertainty of trade-off and realize the value from wastes with a risk that can be accepted by them in the direct marketing of the secondary products. Therefore the whole process for IS application pass through a sensitization of public authorities, political actors and stakeholders on IS benefit waste declassification needs. For this reason in recent years ENEA promoted several activities at both regional and national scale for enterprises, stockholders sensitization on IS environmental and economic benefit and for authorities and public actors involvement in the process of waste declassification.

With specific regard to existing models of industrial symbiosis it is possible to differentiate a first model of a cluster of companies in a geographically confined space which exchange resources often called an eco-industrial park. The second model is a network of companies that has no strict requirement of geographical proximity, often spread over large areas (Agarwal and Strachan, 2006). The spatial scale most suitable for cycling has been largely investigated by many authors (Lambert and Boons, 2002; Lyons, 2005; Sterr and Ott, 2004; Yang and Lay, 2004). Lombardi and Laybourn (2012) state that the possibility for IS application is no longer limited in geographical proximity.

There is no preferable spatial scale at which loop closing should be organized: loop closing is dominated by the spatial economic logic of the transactions of the involved firms (Lyons, 2007). Larger regional areas, in fact, may be more suitable for closing material loops and creating sustainable industrial ecosystems. Larger areas may provide the necessary volumes to achieve the economies of scale required to ensure profitability, especially because heterogeneous wastes are generally dispersed widely across space and have often low economic value. Larger areas provide a greater variety of potential customers to consume the newly reconstituted items and solve problems of redundancy by providing alternative customers if or when a particular cycling transaction fails (Posch, 2004; Sterr and Ott, 2004).

Location may be useful to create possibilities for firms to work collaboratively towards more environmentally friendly designs, more effective waste management, and beyond (Chertow and Ehrenfeld, 2012). Jensen et al. (2011) conducted an interesting statistical analysis of synergies facilitated by the United Kingdom's National Industrial Symbiosis Programme (NISP), which represents the first national facilitated industrial symbiosis pilot programme. This article attempts to quantify geographic proximity and in the process provide practitioners with an insight into the movement trends of different waste streams.

However, the most important factor for developing IS relationships is collaboration amongst organizations (Bansal and McKnight, 2009; Chertow, 2000; Chertow and Ehrenfeld, 2012; Sakr et al., 2011). For this reason the presented project applied in Sicily, aimed at creating a symbiosis platform with the idea of the active participation of both SMEs and local stakeholders. The goals were: provide a methodology and a tool for industrial symbiosis implementation in this case at regional scale, implement a IS Platform as a support to SMEs to individuate symbiosis opportunities in the region. Facilitation of IS development using ICT tools together with identification of different tools and their application is investigated by Grant et al. (2010). The authors argued that, since ICT tools have been developed over time from an optimization and data sharing application toward a “community-building” tool, it has become more helpful to IS.

The goals were achieved through different steps: first of all the design of the architecture, then the analysis of the productive system in the region, data collection and companies’ involvement in operative meetings. Collected data were used for potential matches individuation, through a collaborative approach with the companies who participated in the meetings, and then they were analyzed in technical and regulatory terms to individuate potential synergies.

Technical dossiers on three main resource streams (wastes from processing stone materials; plastics and agro-industrial wastes), which may generate the more interesting potential synergies, were implemented to support companies in synergies actual realization.

2. Materials and methods

The Industrial Symbiosis Platform has been addressed in particular to small medium enterprises (SMEs) and other local operators to enable the transfer of resources (materials, energy products, water, services and expertise) and to offer other operational instruments (legal database, tools LCA and Ecodesign, Best practices database, etc.) The methodology for the realization and operation of the platform involved different steps from the beginning of the project (2011) till the programmed end (2015):

– design and the implementation of the platform architecture, ICT and database tools (the implementation is in training phase);

– network activation and promotion activities by means of stakeholders involvement at regional level (in Sicily) and at national and international level;

– analysis of productive sectors in the Region and realization of a broad database (DB) of companies in Sicily;

– operative meetings finalized to involve companies in the project, to have from them input-output related information, looking for potential synergies.

2.1. Matching between outputs and inputs in the ENEA's industrial symbiosis platform

The platform architecture, previously described in Cutaia et al. (2014a, 2014b), works on a GIS system where many different databases have been uploaded. One of these databases is that of the registered companies, that, through the www.industrialsymbiosis.it portal can provide their general information (name, address, activity sector by mean of Italian and European codes - Istat 2009; EUROSTAT, 2008 - and so on). Doing this the GIS system can localize registered companies in the map. Then, companies can go further and look for "cooperation" in terms of industrial symbiosis potential. In order to look for industrial symbiosis potential, registered companies can become "associated companies", providing their own information about inputs and outputs they want to share within the industrial symbiosis network.

Users are in this way encouraged to go from the "registered company" level to the "associated" one, also because in this way they can use all the functions provided by the platform (queries, DBs, industrial symbiosis matching). Another database contains the information about resources (input-output) which are geo-referred together with related companies. The information about resources is collected using Input-output tables (Fig. 1). ENEA input-output table foresees taxonomy for the inventory of input-output data of companies, taking into account as resources "materials, energy, services, skills" and using code systems officially used in Italy (according EU regulation) for different kind of inventories. Information asked in the input-output tables for collecting data are the more simplified available in order to allow companies to fill the tables with the less possible effort, since information asked are those already used by the companies for their normal management.

The first column specifies if the resource is an input (requested resource) or an output (generated resource). Second and third columns are two free text fields in which the company can specify the characteristics and a brief description of the resource. The fourth column reports the category of the resource:

a) materials,
b) energy,
c) services,
d) skills.

"Services" means every kind of support resources such as transportation, available storage space, etc. that are not used entirely by the company and which can be shared with other participants, after proper agreements. The same applies to "skills", but in this case it refers to the skills and competences that can be shared if not fully used. The fifth column ask if the resource, if materials, can be defined as waste or as by-product. Sixth seventh and eighth columns presents drop-down boxes with specific codes that describe the resource using the codes normally used by companies:

- ERC (European Waste Catalogue) is the classification of waste types according to Directive 75/442 / EEC. It is used if the resource is waste.
- PRODCOM Community Production): is the code that the European Union has adopted to harmonize statistical observations about industrial production, and consists of a list of products (these are generally "goods", but also including some industrial services) grouped according to the economic sector of the manufacturer. It is used if the resource is a sub-product.
- NACE or ATECO are classifications of economic activities. ATECO is a type of classification adopted by the Italian National Statistics Institute (ISTAT), whereas NACE is a taxonomy developed by Eurostat, the statistical body of the European Commission. It is used if the resource is a skill or service.

The last three columns require to specify quantities, unit of measure and if the quantity is batch (available only at specific intervals) or if it distribution during the year is continuous (yearly). An important aspect in collaborative IS platforms is the ontological issue (Cecelja et al., 2015; Raafat et al., 2013). The Platform allows for automatic input-output matching. In this way, associated companies can find matches and potential synergies. This characteristic represent the core and the novelty of the platform making it a valuable tool, not only for the IS practitioners, but also a as a service directly usable by companies. By now the Platform is in its test phase that will end in December 2015. The connection between an available resource and its possible destinations as input pass through an <origin, destination> string (Fig. 2).

OUTPUT / INPUT	Resource (description)	Resource (trade name)	Resource (type 1)	Risorsa (if type 1-a)	Resource [CER - if waste]	Resource [ProdCom - if by-product]	Resource [NACE - if skill or service]	Availability of resource	quantity	unit	notes
output			a) material	waste	01 01 02 rifiuti da estrazione di minerali non metalliferi			batch			
output			b) energy	by-product		07100000 estrazione di minerali metalliferi ferrosi		yearly			
input			c) service				A1.1.5 - Growing of tobacco				
input			d) skill				A2.4.0 - Support services to forestry				

Fig. 1. Input-output data collection table

The connection algorithm uses the logic “one-to-many” to find relations between the main characteristics of a waste/by-product from one company and its potential as an input resource for another company. Following the opposite direction the same algorithm allows verifying which resource, from different companies, can satisfy the quality specifications to allow the use, as an input resource, for a given company.

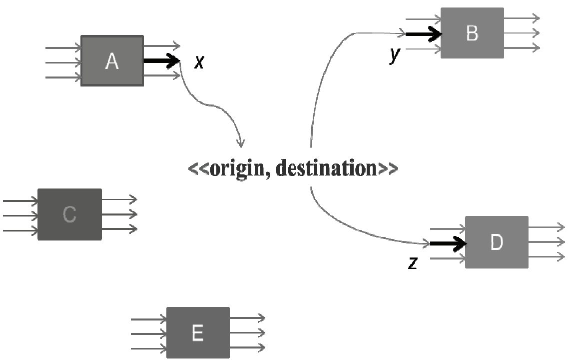

Fig. 2. Matching between outputs and inputs according with the <origin-destination> strings logic

One empty <origin, destination> string is shown in Fig. 3, showing information in this case for the connection of one output to its possible productive destinations. There is a similar, but inverted table, for the opposite direction (one input and its possible alternative supply). In other terms, searching for possible matches for output *x* of company A, the software finds two or more possible destinations as inputs for companies B or D as inputs *y* or *z*. The <origin-destination> string mainly contains:

- Resource’s information: resource’s description by means of EWC Code (or other appropriate code (ATECO/NACE or PRODCOM if the resource is not a waste); Resource’s origin and composition;
- Possible resource’s destinations using ATECO/NACE codes and information about its properties;
- Applicable regulations and technical norms;
- Others useful information (e.g. collecting managing systems).

The platform actually contains several filled <origin destination> strings covering all possible use of many resources, allowing for potential matches, some of them need to be verified in regulatory, logistic and economical terms. Then actually these strings represent potential synergies which will become effective once all the terms will be verified. The platform will be continuously updated and enriched with new filled strings enhancing in this way the possibilities of finding synergies between associated companies and their shared resources.

The <origin destination> strings and the relation between different databases (resources database and origin destination string database) allow addressing ontological issue, which is one of the most important arguments of debate (Cecelja et al., 2015; Raafat et al., 2013).

2.2. Network activation and promotion activities

Starting from the consideration that the first success factor in IS development is the establishment of network between companies and stakeholders and maintaining their continuous interest, mutual trust, and involvement (Sakr et al., 2011), several activities were continuously promoted at both regional and national scale for companies, authorities and stakeholders sensitization on IS environmental and economic benefit. For sensitization and dissemination purposes in 2011 ENEA registered the domain www.industrialsymbiosis.it and other equivalents and more in general, the reference website for the promoted activities (Cutaia et al., 2014a, 2014b). Starting from 2012 onwards ENEA promoted at Ecomondo Exhibition (the main Italian fair trade on environment held, yearly, in Rimini in November) a series of national Conferences on industrial symbiosis aimed at collecting experiences made on this topics and sensitizing political and institutional stakeholders in order to allow applications overcoming regulatory procedural barriers and promote industrial symbiosis strategy.

Local stakeholder’s involvement was carried out through contacts with Sicilia Region (Regional waste Agency), meetings and specific framework agreement signed between ENEA and Confindustria Sicilia (Sicilian association of Industrials) and ENEA and University of Catania.

Product description (output)	
EWC Code (or other appropriate code if the resource is not a waste)	
Origin	
Fiscal properties	
Composition properties	
Possible productive destinations (ATECO/NACE code)	
ATECO/NACE code	Input type (possible destination)
Applicable regulations and technical norms	
Others use full information (e.g. collecting managing systems)	
Abstract	
Key words	

Fig. 3. Example of <origin, destination> string (output to inputs direction)

In 2015 ENEA established the first Italian Industrial Symbiosis Network (SUN: Symbiosis Users Network). This network aims at being the Italian reference point in the field of Industrial Symbiosis through the support of scientific/research bodies as well as the participation of operative stakeholders (companies and institutions).

2.3. Research and analysis of companies to be involved

The Platform operates with the cooperation of companies (associated users) who have the core information needed for implementing the industrial symbiosis: data on outputs they want to share or inputs they want to have. Companies can share their input-output data on-line, as associated users through the website, or on-site, during operative meetings. In this stage, in which the platform is populated and tested, the engagement of companies requires to have private information (e.g. for each company the name of the responsible person, email and phone number). This information is not normally available from the data provided by Italian Institute of Statistic (ISTAT) or by other institution, which provides only information on sectors and size of companies at macro and meso level.

For this reason, in order to have a consistent number of companies to try to involve in the project, a database containing information on more than 2000 companies was developed collecting data from regional productive districts, chambers of commerce, universities, industrial associations and companies' web sites. The main information collected into the database was: geographic localization, name of the company, name of the owner, productive sector, number of employees and contact details (email and phone). The productive sectors were represented by the classification of economic activities ATECO (Istat, 2009) or NACE (EUROSTAT, 2008) codes. Companies listed in the compiled database are representative of part of the overall companies operating in Sicily, with a particular focus for the provinces of Catania, Siracusa (where operative meetings were held).

Starting from this DB an analysis of productive sectors and an evaluation of quantity and dimension of companies were made to identify the most productive areas in the region with a sectors diversification more suitable for the organization of operative meetings to begin symbiosis paths according to Jensen et al. (2012) that states that the key to successful industrial symbiosis programs 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.

Then, considering sectors, employees and location, groups of heterogeneous companies were selected and invited to take part to operative meetings aimed at sharing information about resources flows and wastes and looking for potential synergies. All the sectors were considered to contact companies in order to have a diversified composition. A threshold value on the number of employees has been fixed. This value varies according to the business sector.

2.4. Operative meetings

Two operative meetings, for a maximum of 50 delegates each one, were organized in most productive area of Sicily (East Sicily) with the main goal of involving companies in the project, get from them data, and at looking for potential synergies. The first meeting (Cutaia et al., 2014b) held in Siracusa in on March 28th 2014 with the support of the Chamber of Commerce. Sicilia Region gave their patronage to the workshop as Confindustria Sicilia did. The province of Siracusa was represented and did an oral presentation in the opening session as ENEA and the Chamber of Commerce did. The second operative meeting was held in Catania on October 24th 2014 with the support of Confindustria Catania and the collaboration of University of Catania (Department of Industrial Engineering).

For meeting organization, invitation emails were sent to a selected number of companies present in our database (almost 800 for Siracusa meeting and almost 1100 for Catania meeting). For a more capillary diffusion, invitations were made also by our local partners (Confindustria Catania, Chambers of Commerce of Siracusa and the Department of Industrial Engineering of the University of Catania).

A more restricted group of companies was directly contacted by phone, apart from emails they already received (200 for Siracusa Siracusaand 300 for Catania meeting) in order to better explain the goal of the meeting.

According to ENEA methodology before the meeting companies have been asked to fill in input-output tables with resources intended to be shared within the project. Those resources could be eventually be updated and improved during the meeting (with the specific work of sharing and matching between companies) and after the meeting (when ENEA sent back to the companies the list of shared resources by each company for their final control). Information shared by companies was included in the input-output database, checked and loaded on the ENEA platform in order to search for synergies using the “origin-destination” strings, in addition to those find during the meetings.

3. Results and discussion

3.1. Analysis of companies to be involved

The most productive areas in Sicily, on the basis of collected data, are represented by Catania and Siracusa provinces were the greatest number of companies (33%) with a greater number of employees is concentrated (52%) (Fig. 4). Theses areas were selected for the organization of operative meetings also because of a major interest and collaboration of local stakeholders (University of Catania and local industrial associations). The main sectors of activities for the companies listed in the database (Fig. 5), are represented by agriculture (32%) and manufacturing (27%).

The central zones of Sicily (Enna and Caltanissetta) are characterized by a productive sector prevalently rural based on agriculture activities (66%). Agriculture and particularly fishing are also well developed in the northern part of the island (Palermo and Messina (47%), Trapani and Agrigento (26%). In the south east (Ragusa) the manufacturing sector represents an important percentage (33%) together with agriculture (43%). Numerous farms for breeding livestock are present in this area.

Industrial production in this region is characterized by a few but important industrial centers. Industrial poles, in particular petroleum and chemical industries, are concentrated in eastern Sicily (Catania and Siracusa) (Fig. 5) where the manufacturing sector represents an important percentage (35%) subdivided prevalently, as reported in Table 1, in manufacture of food products (20%) manufacture of other non-metallic mineral products (16%) and manufacture of fabricated metal (13%).

3.2. Operative meetings results

A number of 44 delegates attended the Siracusa workshop, coming from 36 different companies prevalently from manufacturing and agriculture sectors (A) (37.1%) followed by water supply, sewerage waste management and remediation activities (E) (14.3%) and professional, scientific and technical activities (M) (14.3%). Also in Catania meeting, where 37 companies with 42 delegates participated, the main sector was manufacturing with a higher percentage respect to Siracusa meeting (47.2%), followed by electricity sector (13.9%) and professional, scientific and technical activities (13.9%) (Table 2).

The most represented manufacturing sector in Catania meeting (Table 3) was manufacture of food products (28%) followed by manufacture of other non-metallic mineral products (17%), manufacture of fabricated metal products (17%), manufacture of rubber and plastic products (11%), manufacture of electrical equipment (11%), manufacture of beverages (6%) and manufacture of chemicals and chemical products (6%).

During Siracusa meeting the main sector of participating companies was manufacture of computer (36%) followed by manufacture of food products (14%) manufacture of machinery and equipment (14%), repair and installation of machinery and equipment (14%), manufacture of rubber and plastic products (7%), manufacture of basic metals (7%), manufacture of fabricated metal products (7%).

The lower participation in Catania meeting of delegates from administrative and support service activities (N), human health and social work activities (Q), service activities and water supply, sewerage, waste management and remediation activities (E), resulted in a greater number of potential matches with almost the same number of declared resources (Table 4).

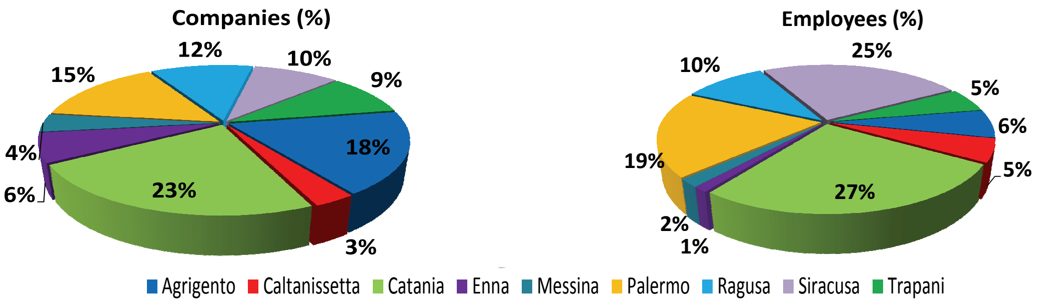

Fig. 4. Companies and employees (data from ENEA database)

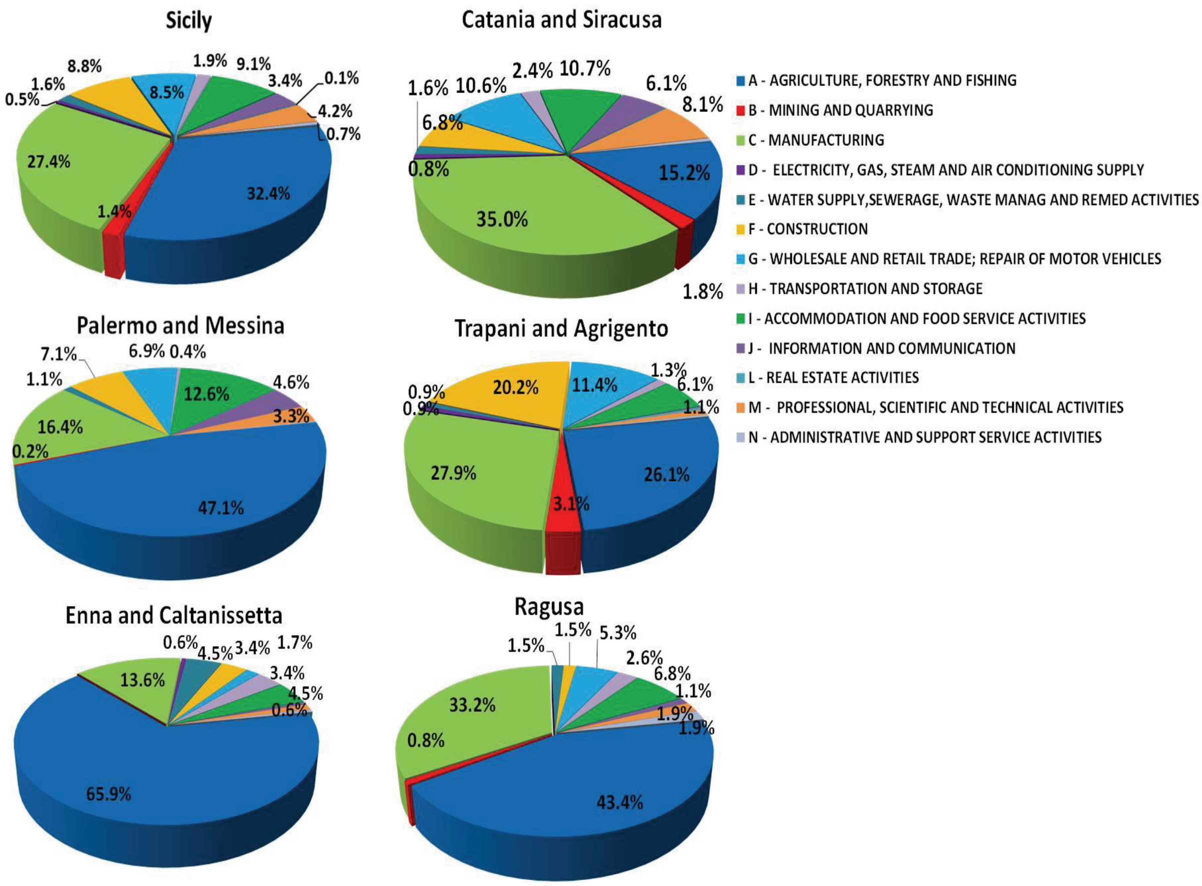

Fig. 5. Industrial sectors in Sicily (on the basis of ENEA database)

Table 1. Manufacturing Sector in Sicily and in Catania and Syracuse districts (on the basis of ENEA database)

	Sicily		*Catania and Siracusa districts*	
C- Manufacturing	*Companies (n.)*	*Companies%*	*Companies (n.)*	*Companies%*
C10 - Manufacture of food products	136	24%	51	20%
C11 - Manufacture of beverages	6	1%	3	1%
C13 - Manufacture of textiles	1	0%	0	0%
C15 - Manufacture of leather and related products	21	4%	1	0%
C16 - Manufacture of wood and of products of wood and cork	25	4%	18	7%
C17 - Manufacture of paper and paper products	2	0%	1	0%
C19 - Manufacture of coke and refined petroleum products	2	0%	2	1%
C20 - Manufacture of chemicals and chemical products	10	2%	3	1%
C22 - Manufacture of rubber and plastic products	11	2%	5	2%
C23 - Manufacture of other non-metallic mineral	99	17%	42	16%

products				
C24 - Manufacture of basic metals	6	1%	2	1%
C25 - Manufacture of fabricated metal products	75	13%	33	13%
C26 - Manufacture of computer	17	3%	11	4%
C27 - Manufacture of electrical equipment	13	2%	5	2%
C28 - Manufacture of machinery and equipment n.e.c.	29	5%	7	3%
C29 - Manufacture of motor vehicles	10	2%	1	0%
C30 - Manufacture of other transport equipment	11	2%	4	2%
C31 - Manufacture of furniture	23	4%	19	7%
C32 - Other manufacturing	4	1%	3	1%
C33 - Repair and installation of machinery and equipment	14	2%	11	4%
unknown	53	9%	36	14%
Total C- Manufacturing	568	100%	258	100%

Table 2. Delegates at the meetings for each industrial sector

	Siracusa meeting		*Catania meeting*	
NACE CODES	***Registered delegates (%)***	***Delegates to the meeting (%)***	***Registered delegates (%)***	***Delegates to the meeting (%)***
A - Agriculture, forestry and fishing	3.3	5.7	9.1	8.3
C - Manufacturing	36.1	37.1	37.9	47.2
D - Electricity, gas, steam and air conditioning supply	1.6	2.9	7.6	13.9
E - Water supply; sewerage; waste management and remediation activities	13.1	14.3	6.1	2.8
F - Construction	4.9	2.9	6.1	5.6
G - Wholesale and retail trade; repair of motor vehicles and motorcycles	1.6	0.0	9.1	8.3
H - Transporting and storage	6.6	8.6	6.1	8.3
J - Information and communication	6.6	2.9	1.5	0.0
M - Professional, scientific and technical activities	13.1	14.3	16.7	13.9
N - Administrative and support service activities	3.3	2.9	0.0	0.0
O - Public administration and defense; compulsory social security	0.0	0.0	1.5	0.0
P - Education	0.0	0.0	1.5	0.0
Q - Human health and social work activities	1.6	2.9	0.0	0.0
S - Other services activities	8.2	5.7	6.1	0.0

Table 3. Delegates at the meetings for manufacturing sector

	Siracusa meeting		*Catania meeting*	
C- Manufacturing	***Registered delegates (%)***	***Delegates to the meeting (%)***	***Registered delegates (%)***	***Delegates to the meeting (%)***
C10 - Manufacture of food products	17	14	26	28
C11 - Manufacture of beverages	4	0	9	6
C13 - Manufacture of textiles	0	0	0	0
C15 - Manufacture of leather and related products	0	0	0	0
C16 - Manufacture of wood and of products of wood and cork	0	0	0	0
C17 - Manufacture of paper and paper products	0	0	4	6
C19 - Manufacture of coke and refined petroleum products	0	0	0	0
C20 - Manufacture of chemicals and chemical products	0	0	4	6
C22 - Manufacture of rubber and plastic products	17	7	4	11
C23 - Manufacture of other non-metallic mineral products	0	0	17	17
C24 - Manufacture of basic metals	4	7	0	0
C25 - Manufacture of fabricated metal products	8	7	17	17
C26 - Manufacture of computer	21	36	0	0
C27 - Manufacture of electrical equipment	0	0	9	11
C28 - Manufacture of machinery and equipment n.e.c.	13	14	4	0
C29 - Manufacture of motor vehicles	0	0	0	0
C30 - Manufacture of other transport equipment	0	0	0	0
C31 - Manufacture of furniture	0	0	4	0
C32 - Other manufacturing	4	0	0	0
C33 - Repair and installation of machinery and equipment	13	14	0	0

Thanks to Siracusa meeting 109 output resources and 88 input resources of different categories were shared (Table 4). The resources shared by the companies were mainly "materials" (59% of the output resources and 59% of the input resources) and expertise, consultancy and services (34% of the output resources and 32% of the input resources). In the category "materials", companies were interested to share (Table 5) as output prevalently packaging (19%), plastics and plastic products (15%), metals and metal products (11%), organic chemicals (10%), water (8%), materials from agriculture (8%), construction and demolition wastes (6%).

As input the resources more requested were: foodstuffs (31%), organic chemicals (21%) and fuels, products from livestock and fisheries, construction and demolition wastes (6%).

A total of 165 potential matches were found, involving prevalently materials (53%) and expertise, consultancy and services (37%). Matches were mainly related to plastics and plastic products (16%), metals and metal products (16), municipal wastewater treatment sludge (11%), construction and demolition wastes (10%). From the workshop held in Catania good results have been achieved (Table 4): 529 potential matches were found starting from 187 outputs (37% materials, 35% expertise, 16% equipment) and 91 input resources (66% materials, 23% expertise, consultancy and services). The sharing was more balanced for output resources.

In the category "materials" (Table 5), companies were interested in sharing as output mainly electrical and electronic (14%), paper and paperboard (12%) and plastics and plastic products (8%). Potential matches were related prevalently to materials (50%) and expertise, consultancy, services (31%). In "materials" category, potential matches were individuated (Table 5) in paper and paperboard (25%), plastics and plastic products (13%) and electrical and electronic (8%).

In both meetings, companies involved in the most part of matches were those from manufacturing of food products; agriculture, manufacture of fabricated metal and non-metals products, and construction sectors.

Table 4. Resources shared during the meetings and potential matches

Resources	***Siracusa meeting (%)***			***Catania meeting (%)***		
	input	***output***	***matches***	***input***	***output***	***matches***
Materials	52	129	88	34	124	267
Energy	6	4	7	5	4	36
Expertise, consultancy, services	28	74	61	32	43	164
Logistic, transportations	1	9	6	3	3	5
Land, capacity	1	2	2	2	5	13
Equipment		1	1	15	8	44
Total	88	219	165	91	187	529

Table 5. Materials shared during the meetings and potential matches

Resources (materials)	***Siracusa meeting (%)***			***Catania meeting (%)***		
	input	***output***	***matches***	***input***	***output***	***matches***
water	2	8	7	3	4	6
fuels	6	2	1	9	1	0
materials from agriculture	2	7	6	9	7	6
electrical and electronic	6	6	9	0	14	8
municipal wastewater treatment sludge	0	0	11	0	2	2
industrial sludge	0	0	0	0	8	6
packaging	4	19	0	3	6	5
wood and wood products	2	1	0	0	2	2
metals and metal products	4	11	16	3	5	4
construction minerals	0	2	0	6	2	2
industrial minerals	4	0	8	3	4	3
Mineral waste oils	0	0	0	9	2	3
Plastics and plastic products	0	15	16	12	8	13
foodstuffs	31	5	2	3	6	5
inorganic chemicals	2	10	5	6	2	0
organic chemicals	21	2	3	6	4	2
products from livestock and fisheries	6	0	1	3	0	1
construction, demolition, excavation materials	6	6	10	6	4	4
paper and paperboard	2	5	1	15	12	25
sands from separation processes	0	0	0	0	1	0
textile	0	0	0	0	1	0
glass and glass products	4	2	3	6	4	5

3.3. Potential matches verification and potential synergies implementation

Because of the scale of the project, after the meetings a selection of the most interesting potential synergies, or group of synergies, was made, based on the number and amount of shared resources. For each one of these selected synergies specific operative handbooks are being prepared, collecting, analyzing and systematizing information on technical, regulatory, logistic, economic and other issues influencing the possibility to actually realize the proposed synergy, as well as quantities of materials or other resources involved.

Two categories of resources involved in potential synergies were selected:

- agro-industrial waste;
- construction and demolition wastes, residues of ornamental stone processing and other residue to be utilized in construction field.

In Fig. 6 an example of potential matches verification stage for the third category is reported, according with shared resources and involved companies (represented by a code). Similar flow diagrams were elaborated for the other categories. Continues lines represents matches find during the meetings, while dashed lines represent further synergies proposed by the authors. Faces synthetize the actual state in terms of existing barrier or state of the process (green=no barrier, yellow=some aspect to be further investigated, red=synergy cannot be implemented).

Basalt and mixed sawing silt, shot blasting residues and broken slabs can be re-used by a road construction company as aggregates and by others companies in bricks and ceramics production, after the verification of their physical-chemical characteristics (yellow face indicate only that companies need to provide more details on the physical and chemical characteristics). For these flows no legislative barriers were encountered, because such materials have been recently regulated by Italian law that has assimilated them to excavation materials that can be considered as byproducts. Reuse milled road, however, is a matter still debated. The verification of the possibility of using bottom ashes from special waste incineration in road construction is still on going. Similar destinations are actually implemented in other Italian region as well as the issue of bottom ashes, coming from different feed, and their reuse, were already investigated (Cossu et al., 2014). For these types of residues the most important issue to be addressed is related to the residues characteristics (Mancini et al., 2014a, 2014b).

Various metals can however be removed and recovered from bottom ashes by a combination of mechanical (e.g. crushing, sorting) and physical (e.g. magnetic and eddy-current separation) unit operations. Reducing the metal contents, the process could make these wastes comply with building material standards, thus increasing their recycling potential in the construction industry in compliance with the standard fixed by European (UE N. 305/2011) and Italian regulations.

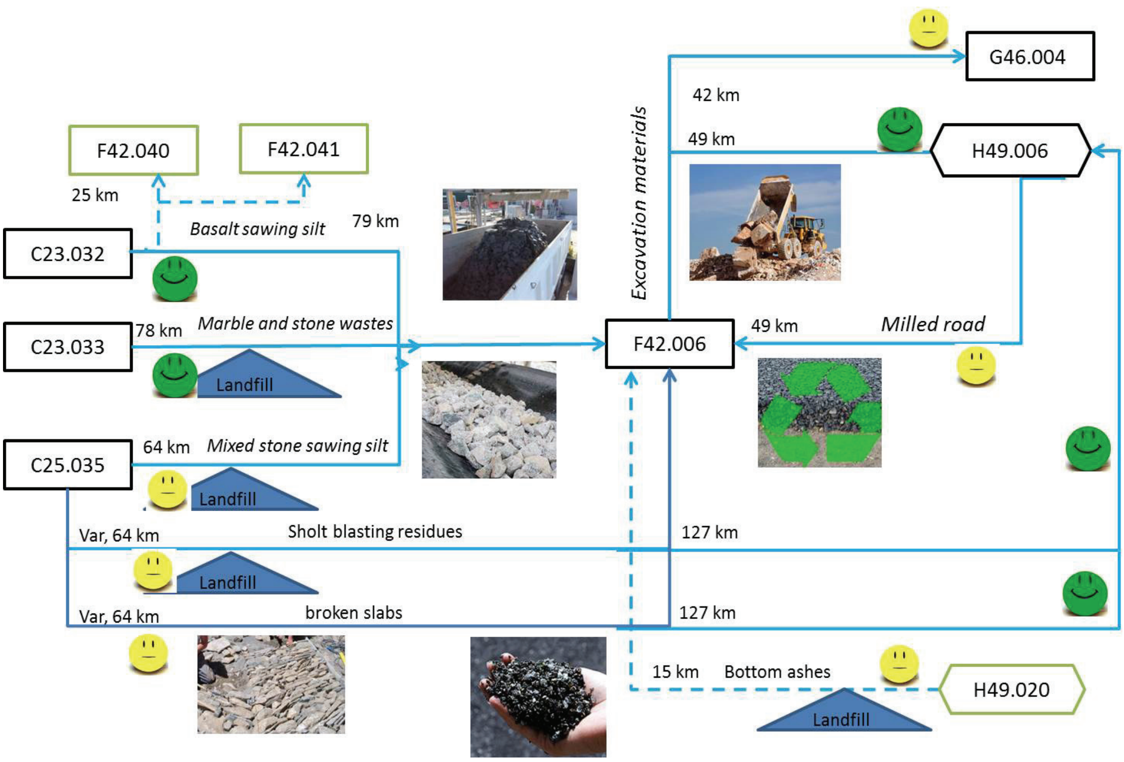

Fig. 6. Synergies verification in the field of construction/demolition and stone processing sectors

Interesting possibilities were encountered for agro-industrial by-products valorization in the region, both for sector size and its importance, and both for the possibilities of new plants development.

Biomass, and in particular agro-industrial wastes, provides a clean, renewable energy source, which could improve economic, energetic and environmental sectors (Gavrilescu, 2008; Lako et al., 2008). However technical aspects, concerning the methane production from codigestion of different sources, should be deepened, as well as the effect of several pretreatments (Battista et al 2015; Ruggeri et al., 2015) and the sulphur removal from biogas (Callegari et al., 2013).

Three different paths were identified for these flows: feed production, energy production (Gavrilescu, 2008) and compost production and the barriers were analyzed (Mateescu et al., 2008).No barriers were encountered in defining these synergies; the main issue is represented by quantitative and temporal distribution needed to ensure a suitable supply for the plants related to the requirements of the productions. Results of the activities above mentioned were used to develop technical dossier, in form of operative handbooks, helping companies in all steps for synergies' implementation.

These operative handbooks include European, Italian and regional regulations, guidelines, technical standards, logistic and economical aspects useful for supporting companies in synergies implementation. Additional meetings with companies and local stakeholders (such as local authorities), are scheduled by July 2015 to discuss all aspects contained in these operative handbooks. Results of this activity will also be used to update, with more information, the <origin-destination> strings, which represent the core of the platform for checking for matches between uploaded and available inputs and outputs.

4. Discussion

Many technical solutions for waste and by-product materials, water, and energy reuse between neighboring industries have been discovered and applied in the IS examples from all over the world. However, from the analysis of IS application (Jensen et al., 2011; Laybourn and Morrissey, 2009; Lombardi and Laybourn, 2012; Schiller et al., 2014) the potential for uptake of new synergies in the regions is often limited by a range of nontechnical barriers. These barriers include environmental regulation, lack of cooperation and trust between industries in the area, economic barriers, and lack of information sharing.

One of the main results of the discussion occurred during the meetings held in Sicily was the significance and the consequences of the regulatory and control systems. For this reason it was particularly important the presence and participation of local stakeholders and control authorities in all the phases of the project for industrial symbiosis implementation. The last part of the project is addressed (from July 2015 to the end of the year) in overcome barriers and obstacles to the actual implementation of synergies, specifically deeply investigated by means the realization of the two cited operative handbooks, addressed at involved companies as well as local authorities. Discussion and consultation meetings are foreseen for the month of July 2015 to be held in Catania with ENEA, companies and interested local authorities.

In some instances, regulatory actions encourage industrial symbiosis. Landfill bans in key European countries have driven symbiotic practices such as the reuse of organic wastes prohibited from land disposal in Denmark and the Netherlands. Very high tipping fees for waste disposal in Canada and climate change levies in the United Kingdom have been cited as stimulating innovation and action in by-product reuse. Although also in Italy there is a tax on waste disposal on landfill, since 1995, it has not had the desired results, because of low disposal costs. More efforts should be made by the political system to discourage disposal and encourage virtuous policies of reuse and recycling of waste and byproducts.

Another issue raised during the experience in Sicily is the difficulty in overcoming the distrust of companies approach. Policy makers and regulators are critical to creating the market conditions that incentivize IS and resource efficient behavior as well as policies and regulations that clarify definitions and responsibilities. Responsibilities, predictability and reliability are the key to overcome companies' distrust in in pursuing paths of symbiosis.

5. Conclusions

ENEA developed the first Industrial Symbiosis Platform in Italy implemented in Sicily. The platform, whose main objective launching Industrial Symbiosis through a geo-referred information system support, acts as a tool in the service of business and territory and also offers a range of tools that may be of interest especially for SMEs.

The core and the novelty of the platform are represented by the possibility to find matches by using an algorithm that links output with inputs (with a logic one-to-many) or vice versa, by means of <origin, destination> strings, linking one type of output with its potential productive destinations (or vice versa).

A methodology was followed for industrial symbiosis implementation at regional scale; some activities were addressed at the consultation with stakeholders, in Sicily and at national level; the Sicilian productive system was investigated and then companies were involved in operative meetings for resources sharing, potential synergies individuation and finally for platform population and validation.

During the meetings 80 SME were involved and almost 400 output resources and almost 180 input resources were shared by companies. More than 690 potential matches were found between the participating companies. Results also highlighted the needs of identify predominant productive activities in well-defined territorial contexts where to investigate the specific/local tangles involving legislative and technical-economic feasibility. So, potential synergies verification from a technical, regulatory, logistic and economic point of view was performed for a selected group of categories (agro-industrial waste; construction and demolition wastes, residues of ornamental stone processing and other residue to be utilized in construction field).

Operative handbooks on the cited two main resource flows, which may generate the more interesting potential synergies, will be developed. These handbooks include European, Italian and regional regulations, guidelines, technical regulations, standards, logistic and economical aspects and more in general describe the pathways to be done in order to go from the idea till the actual implementation of the match. Aim of those dossiers is support companies in implementing matches. On these operative handbooks specific discussion and consultation meetings are foreseen for the month of July 2015 to be held in Catania with ENEA, companies and interested local authorities.

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References

Agarwal A., Strachan P., (2006), Literature review on eco-industrial development initiatives around the world and the methods employed to evaluate their performance/effectiveness, On line at: http://www2.rgu.ac.uk/abs/National%20Industrial%20Symbiosis/Report%20for%20Databuild%20New.pdf.

Atasu V.D.R., Guide L.N., Van Wassenhove L.N., (2008), Product reuse economics in closed-loop supply chain research, *Production and Operations Management*, **17**, 483–496.

Bansal P., McKnight B., (2009), Looking forward, pushing back and peering sideways: Analyzing the sustainability of industrial symbiosis, *Journal of Supply Chain Management*, **45**, 26-37.

Bringezu S., (2003), *Industrial Ecology and Material Flow Analysis,* In: *Perspectives on Industrial Ecology*, Bourg D., Erkman S. (Eds.), Greenleaf Publishing Limited, Sheffield, UK, 338–342.

BattistaF., Fino D., Erriquens F., Mancini G. , Ruggeri B., (2015), Scaled-up experimental biogas production from two agro-food waste mixtures having high inhibitory compound concentrations, *Renewable Energy*, **81**, 71-77

Callegari A., Torretta V., Capodaglio A.G., (2013), Preliminary trial application of biological desulfonation in anaerobic digestors from pig farms, *Environmental Engineering and Management Journal*, **12**, 815-819

Cecelja F., Raafat T., Trokanas N., Innes S., Smith M., Yang A., Zorgios Y., Korkofygas A., Kokossis A., (2015), e-Symbiosis: technology-enabled support for Industrial Symbiosis targeting Small and Medium Enterprises and innovation, *Journal of Cleaner Production*, **98**, 336-352.

Chertow M.R., (2000), Industrial Symbiosis: Literature and Taxonomy, *Annual Review of Energy and the Environment*, **25**, 313-337.

Chertow M.R., (2004), *Industrial Symbiosis*, In: *The Encyclopedia of Earth*, Lifset R. (Ed.), On line at: http://www.eoearth.org/view/article/153824/.

Chertow M., Ehrenfeld J., (2012), Organizing self-organizing systems, Toward a theory of industrial symbiosis, *Journal of Industrial Ecology*, **16**, 13-27.

Cossu R., Fiore S., Lai T., Luciano A., Mancini G., Ruffino B., Viotti P., Zanetti M.C., (2014), Review of Italian experience on automotive shredder residue characterization and management, *Waste Management* **34**, 1752–1762.

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.

Cutaia L., Morabito R., Barberio G., Mancuso E., Brunori C., Spezzano P., Mione A., Mungiguerra C., Li Rosi O., Cappello F., (2014a), *The Project for the Implementation of the Industrial Symbiosis Platform in Sicily: The Progress after the First Year of Operation*, In: *Pathways to Environmental Sustainability. Methodologies and Experiences*, Salomone R., Saija G. (Eds.), Springer International Publishing.

Cutaia L., Mancuso E., Sbaffoni S., Luciano A., Barberio G., (2014b), *First Results of the Implementation of the Industrial Symbiosis Platform in Italy*, Proc. of Symbiosis International Conference, 19-21 June, Athens, Greece.

den Hond F., (2000), Industrial ecology: a review, *Regional Environmental Change*, **1**, 60–69.

EU, (2008), Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives, Official Journal of the European Union, L312, 3–30.

EU, (2011), Regulation No. 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC, *Official Journal of the European Union*, **L88**, 5-43.

EU COM, (2011), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Roadmap to a Resource Efficient Europe, European Commission, On line at: http://ec.europa.eu/food/safety/food_waste/library/docs/com2011_571_en.pdf.

EU COM, (2012), European Resource Efficiency Platform (EREP). Manifesto & Policy Recommendations, European Commission, On line at: http://ec.europa.eu/environment/resource_efficiency/documents/erep_manifesto_and_policy_recommendations_31-03-2014.pdf.

EU COM, (2014a), Horizon 2020 Work Programme 2014 – 2015, 1.2. Climate Action, Environment, Resource Efficiency and Raw Materials, On line at:

http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-climate_en.pdf.

EU COM, (2014b), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Towards a Circular Economy: A Zero Waste Programme for Europe, European Commission, On line at: http://eur-lex.europa.eu/resource.html?uri=cellar:50edd1fd-01ec-11e4-831f-01aa75ed71a1.0001.01/DOC_1&format=PDF.

EUROSTAT, (2008), Statistical Classification of Economic Activities in the European Community, On line at: http://ec.europa.eu/eurostat/ramon/nomenclatures/index.cfm?TargetUrl=LST_NOM_DTL&StrNom=NACE_REV2.

Graedel T.E., Allenby B.R., (2003), *Industrial Ecology*, Pearson Education Inc., New Jersey, USA.

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.

Gavrilescu M., (2008), Biomass power for energy and sustainable development, *Journal of Industrial Ecology*, **7**, 617-640.

ISTAT, (2009), Classification of economic activities NACE 2007, (in Italian), Metods and Norms, http://www3.istat.it/strumenti/definizioni/ateco/ateco.html?versione=2007.3.

Jensen P.D., Basson L., Hellawell E.E., Bailey M.R., Leach M., (2011), Quantifying 'geographic proximity': Experiences from the United Kingdom's National Industrial Symbiosis Programme, *Resources, Conservation and Recycling*, **55**, 703–71

Jensen P.D., Basson L., Hellawell E., Leach M., (2012) 'Habitat' Suitability Index Mapping for Industrial Symbiosis Planning, *Journal of Industrial Ecology*, **16**, 38-50

Korhonen J., (2007), Industrial ecology in the strategic sustainable development model: strategic applications of industrial ecology, *Journal of Cleaner Production*, **12**, 809–823.

Lambert A.J.D., Boons F.A., (2002), Eco-industrial parks: Stimulating sustainable development in mixed industrial parks, *Technovation*, **22**, 471–484.

Laybourn P., Morrissey M., (2009), *National Industrial Symbiosis Programme: The Pathway to a Low Carbon Sustainable Economy*, International Synergies Ltd, Birmingham, UK.

Lako J., Hancsók J., Yuzhakova T., Marton G., Utasi A, Rédey A., (2008), Biomass – a source of chemicals and energy for sustainable development, *Environmental Engineering and Management Journal*, **7**, 499-509

Lombardi R., Laybourn P., (2012), Redefining industrial symbiosis, *Journal of Industrial Ecology*, **16**, 28–37.

Lyons D., (2005), Integrating waste, manufacturing and industrial symbiosis: An analysis of recycling, remanufacturing and waste treatment firms in Texas, *Local Environment*, **10**, 71–86.

Lyons D.I., (2007), A spatial analysis of loop closing among recycling, remanufacturing, and waste treatment firms in Texas, *Journal of Industrial Ecology*, **11**, 43-54.

Mancini G., Viotti P., Luciano A., Fino D., (2014a), Full scale treatment of ASR wastes in a rotary kiln, *Waste Management*, **34**, 2347-2354.

Mancini G., Viotti P., Luciano A., Fino D., (2014b), On the ASR and ASR thermal residues characterization of full scale treatment plant, *Waste Management*, **34**, 448-457.Posch A., (2004), Industrial recycling networks: Results of rational decision making or "organized anarchies"?, *Progress in Industrial Ecology*,**1**, 112–129.

Mateescu C., Băran G., Băbuţanu C.A., (2008), Opportunities and barriers for development of biogas technologies in Romania, *Environmental Engineering and Management Journal*, **7**, 603-607

Raafat T., Trokanas N., Cecelja F., Bimi X., (2013), An ontological approach towards enabling processing technologies participation in industrial symbiosis, *Computers and Chemical Engineering*, **59**, 33– 46.

Ruggeri B., Battista F., Bernardi M., Fino D., Mancini G., The selection of pretreatment options for anaerobic digestion (AD): A case study in olive oil waste production, *Chemical Engineering Journal*, **259**, 630-639

Sakr D., Baas L., El-Haggar 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., Druckman A., Basson L., Royston K., (2014), Exploring Space, Exploiting Opportunities: The Case for Analyzing Space in Industrial Ecology, *Journal of Industrial Ecology,* **18**, 792–798.

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

Yang P.P., Lay O.B., (2004), Applying ecosystem concepts to the planning of industrial areas: A case study of Singapore's Jurong Island, *Journal of Cleaner Production*, **12**, 1011– 1023.