September 2016 Vol.15 No. 9 *ISSN 1582 - 9596*

Environmental Engineering and Management Journal

An International Journal

Material & Energy Recovery and Sustainable Development
ECOMONDO 2015

“Gheorghe Asachi” Technical University of Iasi

Environmental Engineering and Management Journal September 2016, Vol.15, No. 9, 1949-1961
http://omicron.ch.tuiasi.ro/EEMJ/

"Gheorghe Asachi" Technical University of Iasi, Romania

PROJECT *GREEN SYMBIOSIS* 2014 - II PHASE. RESULTS FROM AN INDUSTRIAL SYMBIOSIS PILOT PROJECT IN EMILIA ROMAGNA REGION (ITALY)

Laura Cutaia[1*], Claudia Scagliarino[2], Ugo Mencherini[3], Marco La Monica[4]

[1]ENEA, Centro Ricerche Casaccia - Via Anguillarese 301, Roma, Italy
[2]Free-lance environmental engineer – Via G. Molteni 141, Roma, Italy
[3]ASTER - Via Pietro Gobbetti 101, 40129, Bologna, Italy
[4]Tuscia University, - Via S.M. in Gradi 4, 01100, Viterbo, Italy

Abstract

The Project "Green - Industrial Symbiosis" (G-IS), in Emilia Romagna region (IT), took place in two phases: phase I, 05.2013 – 03.2014; phase II, 10. 2014 – 10.2015. During the first phase, it was completed the first part of the pilot project of industrial symbiosis (IS) in Emilia-Romagna, which involved 13 companies in the agro-industrial sector, 7 laboratories of the High Technology Network, with Unioncamere and Aster (promoters) and ENEA (technical and scientific coordinator). The first phase generated 90 potential synergies among the 10 companies that shared their input-output resources. During the second phase, promoted by ASTER and organized with the technical and scientific coordination of ENEA, some of the most interesting synergies of the first phase were selected, in order to go from the identification of potential synergies to its actual implementation. In particular, 3 pathways of industrial symbiosis were chosen, in which waste food industry outputs were destined to three different types of exploitation (production of biopolymers, nutraceuticals, energy recovery). The pathway that a resource must take to shift from being a company's output to another company's input, involves several steps that require compliance and verification of regulatory, technical, logistical and economic issues. All these factors have been examined and reported in 3 Operative Manuals for the companies involved, each one arranged for a different symbiosis' pathway. The manuals consist of two sections: an operative and a documental part (technical dossier). The operative part describes the transformation path of resources, with a layout in which each block and intermediate vector represent a passage of the resource (e.g. exit from the producing company, transport, valorisation). Under the layout, a synthesis table refers, for each stage, to the necessary requirements, reported in full in the technical dossier. Links on the synthesis table refer, for example, to laws or techniques that the specific flow, in each step, must comply with. These links also define, with a predefined color, if that aspect can be considered as an obstacle to the progress of the symbiosis.

Key words: circular economy, enhancement, restoration, symbiosis, synergy

Received: January, 2016; Revised final: August, 2016; Accepted: September, 2016

1. Introduction

Sustainability of production processes and the efficient and responsible use of resources are key issues, increasingly being seen as strategic for the economic development at European level: this supranational interest is stated within the "Europe 2020" strategy, for advancement of the economy of the European Union (EU Commission, 2010).

In particular, the transition towards a circular economy model is considered of fundamental importance for the achievement of a greater overall efficiency in the use of resources, increasing the competitiveness of European enterprises (EU

* Author to whom all correspondence should be addressed: e-mail: laura.cutaia@enea.it; Phone: +39 6 30483306

Commission, 2010). In the last few years, EU Commission presented several initiatives and documents regarding the transition towards this new paradigm: the "Resource Efficiency Flagship Initiative" (EU Commission, 2011a), the "Roadmap for a Resource Efficient Europe" (EU Commission, 2011b) and especially the new "Circular Economy Package" (EU Commission, 2015), consisting of an EU Action Plan for the Circular Economy that establishes a concrete and ambitious action, with measures covering the whole cycle: from production and consumption to waste management and markets for secondary raw materials.

Among the tools identified in the Action Plan as "key elements" for the transition, there is also Industrial Symbiosis (IS), a practice studied since almost twenty-five years and defined as "engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The keys to IS are collaboration and synergistic possibilities offered by geographic proximity" (Chertow, 2000).

Also at Italian level, national and regional strategies encourage the application of IS: two particularly significant cases are those of Lazio (Regione Lazio, 2014) and Emilia-Romagna (Regione Emilia-Romagna, 2014) "S3-Smart Specialization Strategies". Emilia-Romagna region also included industrial symbiosis within the "Regional Waste Management Programme", as a tool able to reduce waste quantity and to increase regional sustainability, materials reuse and raw materials saving (Regione Emilia-Romagna, 2014).

In Emilia-Romagna an IS application was also developed: the "Green-Industrial Symbiosis" project (G-IS project, in short), promoted by Unioncamere Emilia-Romagna and ASTER, with the technical coordination of ENEA, aimed at the dissemination of an IS culture in the regional territory (Cutaia et al., 2014). It was the first application of IS in Emilia-Romagna and one of the firsts in Italy, with the involvement of 7 laboratories and 13 companies from the agro-industry sector. Since it was a pilot project, it was decided to focus it on the chain of reuse and enhancement of agro-industrial waste, with particular (but not exclusive) attention towards solutions aimed at the production of materials with high added value. At the end of the first phase, the project identified 8 main resource streams, 28 feasible destinations, and 90 potential synergies involving not only companies participating in the project, but also other companies in Emilia Romagna. The experience showed also that the industrial and research ecosystem are quite favorable and interested towards the application of IS, but there are some regulatory issues to overcome (Iacondini et al., 2015).

For this reason, the analysis of the most significant synergies, identifying economical, logistics, technical and legal conditions for the implementation of the results, was the object of the project's second phase described in this paper.

The objectives of this work are to describe the methodology and the results of the second phase of this IS pilot application, and to underline the significant efforts developed in Emilia-Romagna region to increase the application and the knowledge on IS and the involvement of stakeholders, in order to solve main obstacles and facilitate the application of successful processes in the industrial system.

2. Case studies

2.1. Foreword: project context

The project "Green - Industrial Symbiosis, was aimed at spreading the culture of Industrial Symbiosis in Emilia - Romagna, through the creation of integrated, sustainable and innovative management models for production areas, with focus on supply chains for the treatment and the utilization of biomass from agro-industrial waste.

In the first project phase (Cutaia et al., 2014), many companies of the area participated in the activities and, in addition, also the laboratories belonging to the High Technology Network of Emilia - Romagna were involved, with two objectives: to use know-how in the field of Industrial Symbiosis owned by research centers and encourage steps towards innovation (and subsequent collaborations) between companies and the research community.

The activity of the first part of the project, following the collection and analysis of data sent by companies and laboratories, allowed the identification of 90 possible pathways of symbiosis, of which a summary diagram is represented in Fig. 1.

The second phase of the project, named as "Symbiosis 2014" (but in the rest of the paper always reported as "Green - Industrial Symbiosis" project), continued more operationally the activities undertaken by the project "Green - Industrial Symbiosis", aiming at the actual realization of the Symbiosis pathways identified in the first phase, from potential to real synergies. Due to time and resources constraints, to achieve the objectives of the project it was necessary to choose only some of the symbiosis pathways identified. The activity was carried out through the following steps:

- Selection of a group of 3 "major" synergies based on criteria of numerical relevance based on criteria of maximization of resources, flows and companies involved, flows involved and participation of companies already present in the first project phase.
- Gathering of required information, through meetings with the participants of the second phase and bibliographic research.
- Preparation of an Operative Manual for each synergy, containing issues related to implementation of the symbiosis identified and possible technological solutions used in similar cases (taking also into account authorization and control of relevant government agencies, as well as characterization of the synergies by laboratories).

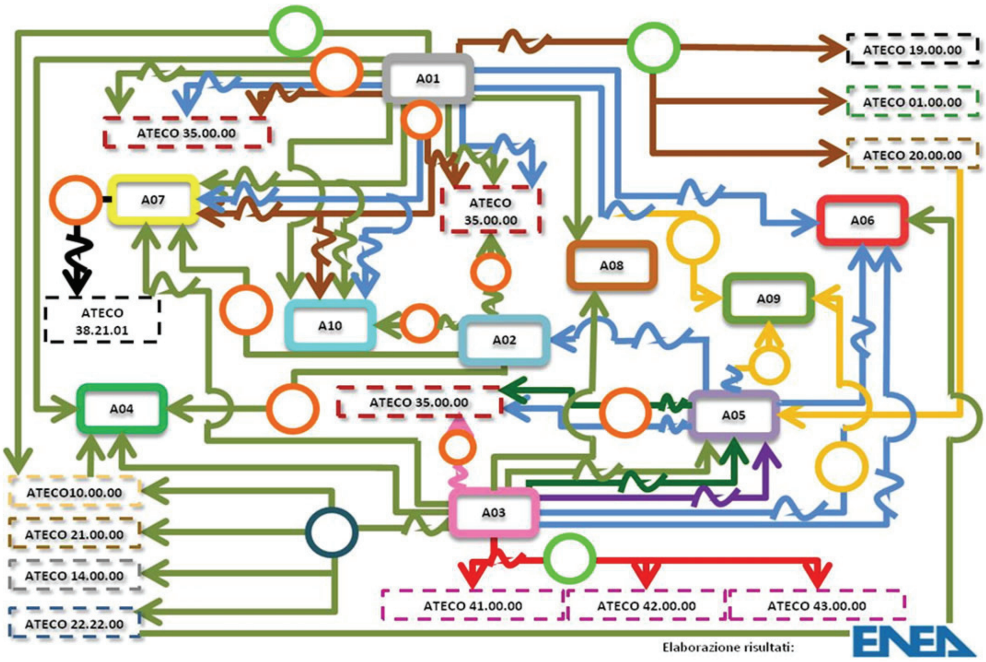

Fig. 1. Symbiosis pathways identified during the first phase of Project Green
A0X Participating companies, identified by codes for privacy reasons; Laboratories proposing the symbiosis; Flows of identified resources: each colour identifies a different flow; Productive sectors identified by the code ATECO (Italian correspondent of the NACE code) in which the resources can be used; Transformation required before reuse of a resource in another company

2.2. Selection of symbiosis pathways

The first step was the identification of the symbiosis pathways to be developed. The choice was based on the following considerations:

1. Production of nutraceuticals from agricultural and food waste: food scraps utilized are the skins and seeds of tomato. This synergy has been chosen for the significant impact it may have on the region. The Emilia - Romagna is among the top Italian region for tomato producers and companies processing tomatoes. For this reason it was decided to address the issue with one of the participating companies, in order to find viable solutions also for the other many companies in the industrial area. In Fig. 2 it is outlined the symbiosis pathway presented.
2. Energy production from agricultural and food waste: this solution was preferred to others especially for compliance with regulations, as in the same period in which the project was developed, Italy implemented the European Directive 2009/73/EC, which requires Member States to take measures to promote wider use of biogas and gas from biomass, the producers of which should get non-discriminatory access to the natural gas system. Developing this symbiosis, it was possible to analyze the new regulation and possible critical issues in its implementation. In Fig. 3 it is presented the diagram of this second symbiosis pathway.
3. Production of biopolymers from agricultural and food waste: this synergy was chosen because it involved the use of a technology not yet industrially developed. A present, in Italy the production of biopolymers from waste takes place only on a pilot scale, so it was considered important to conduct a focus on the subject, taking into account also the interest that is beginning to develop around the use of biopolymers in different industries. In Fig. 4 it has been schematically presented this last pathway of symbiosis.

2.3. Manuals

The three aforementioned pathways of symbiosis were analyzed and documentation, considerations and insights were collected and organized into 3 operative manuals. Objective of the manuals (and of the II part of the project G-SI) is to provide all relevant information to facilitate the implementation of symbiosis pathways identified during the two years of activity.

The "Operative Manual" is arranged in a first operating part (summary scheme) and a second documental part (technical dossier), to collect all the documentation necessary for helping to achieve the symbiosis pathway, trying to organize the material to be easily accessible and readable for non expert users.

The first part of the manual (summary scheme) consists of a Layout that summarizes the pathway of synergy identified and, in parallel, a Table describing the technical aspects of the pathway. The layout shows the pathway sequence for each phase of the synergy, from the generation of the output - waste - of a company until its use, with or without intermediate valorization process, by another receiving company. The Table shows, in correspondence with each block of the layout, specific aspects to consider for each stage of the pathway. In Fig. 5, an example of the layout can be seen with its corresponding table scheme reported.

Fig. 2. Symbiosis pathway I: production of nutraceuticals from agricultural and food waste

Fig. 3. Symbiosis pathway II: Energy production from agricultural and food waste

Fig. 4. Symbiosis pathway III: production of biopolymers from agricultural and food waste

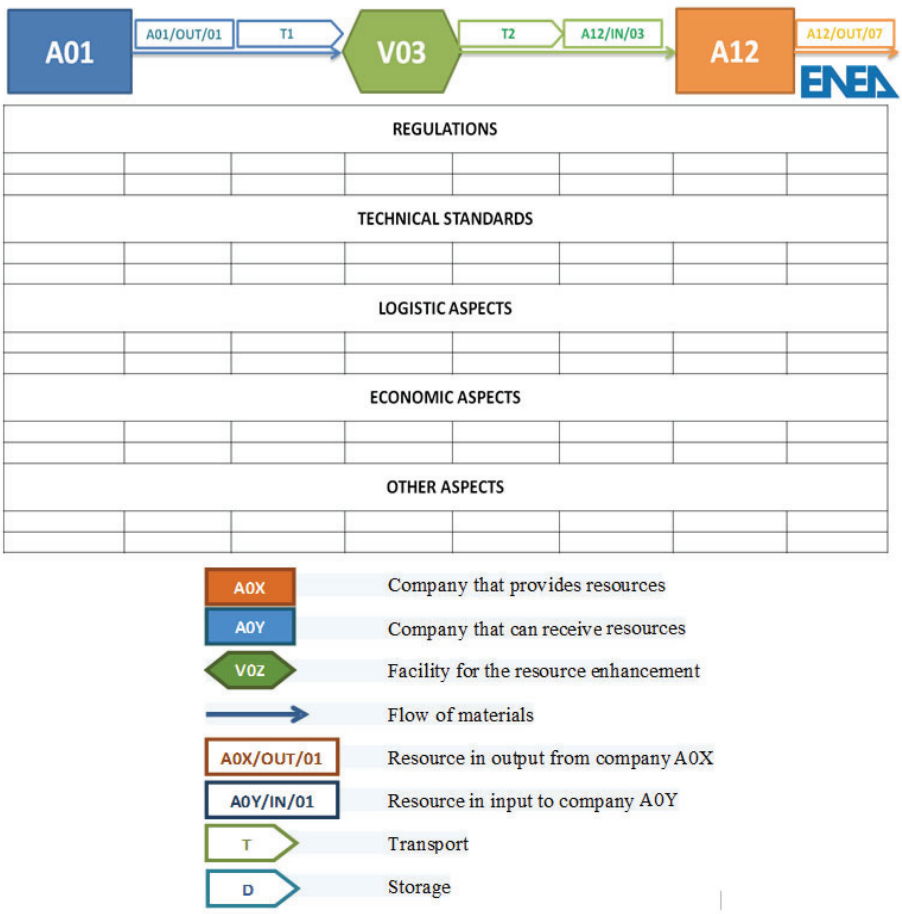

Fig. 5. Example of layout and summary Table included in the initial part of the Operative Manual

In detail, the layout is characterized by specific colors and shapes; the resources were codified for confidentiality reasons; arrows indicate the flow direction of resources.

The Table includes the basic elements of a synergy:

- Relevant norms and regulations;
- Technical Standards;
- Logistic aspects;
- Economic aspects;
- Other aspects.

"Other aspects" means specific situations that require detailed insights on a case by case basis.

These paragraphs were further divided to make the information more accessible and easy to understand. So, for example, norms and regulations paragraph is divided into: national, regional and local level. The Table was then filled with references to the documentation on the topic; each reference has a hyperlink to the document under consideration. Finally, the background of the cell presents different color based on the level of criticality of the topic: factors that may hinder the realization of synergy (red), that need to be further verified (yellow), that are compatible with the pathway (green), together with smart-tags (Fig. 6).

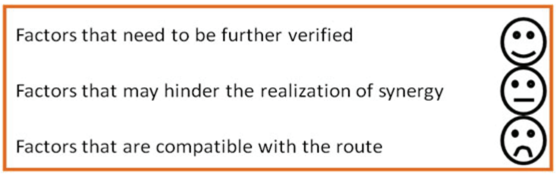

Fig. 6. Symbols used to identify the criticality within the Table in the Operative Manual

In the manual are also present cards describing the specific resources used in synergy, filled in by the companies, and a card filled in by the laboratory that summarizes the proposed valorisation process (or processes). This information was important to decide the type of synergy and figure out which type of valorisation intermediate process is necessary for the actual implementation of the synergy. The first part of the manual ends with a geo-referencing of involved companies that helps to assess the economic and regulatory feasibility of the proposed pathway: the geo-referencing was crucial in assessing both transportation costs for all resources involved in the synergy (economic feasibility) and compliance with local regulations of areas crossed by that pathway (regulatory feasibility). The technical dossier, which is the second part of the manual, is the collection of legislative, technical, scientific and other supplemental documents that are citied (and linked) in the summary table which is below the layout. Parts not strictly relevant to the subject were eliminated; a hyperlink is however present, for information completeness, to the complete documents.

The files can be used through the initial summary diagram, or read as a material in its own right. They were built with a logic that varies depending on the issues discussed but, in general, follow this pattern:

- Classification of the resource leaving the company providing the waste / resource;
- Resource Management: transportation, storage, collection etc.;
- Information about the valorization plant and process;
- Management of the resource by the receiving company;
- Output products;
- Economic considerations.

Each Manual can have all of these aspects or some of them, depending on the information collected and the steps required for the realization of synergy. The last part contains all sources used to prepare the technical dossier. Following, synthesis of the three manuals are presented.

2.3.1. Manual I: Production of nutraceuticals from agricultural and food waste

Wastes involved are skins and seeds of tomato. These types of waste, being classified as by-products, do not have problems of compliance with regulations. The laboratory "CIRI Agroalimentare" proposed to use these resources in a technological process of co-pressing of olives and tomato products that can transfer to the oily matrix lipophilic bioactive molecules, such as carotenoids by a mechanical-physical process. The optimized process will enhance the by-products of the tomato food industry enriching a product already known for its antioxidant content (olive oil) with bio-active compounds not naturally present (lycopene) by using only physical-mechanical processes without any solvents or chemicals. The procedure is simple and inexpensive and, once optimized the ratio olives/tomato by-product and identified the characteristics of the product and its conservation, will be applicable by oil mills already present on the national territory. Obtaining a new product made of olive oil and enriched in bioactive compounds of tomato could be very interesting not only for the food industry but also for dietary supplements companies. The option to use this product as a food requires complying with Italian and European legislation on food additives.

Issues identified for this synergy are of two types:

- Seasonal nature of the product;
- Preservation and storage.

In the first case the only viable solution is to program periods of production according to seasonal cycles of the resource. The second issue can be dealt with studies on storage periods and conditions to ensure that the product does not lose the required characteristics. For this concern, the time factor becomes important for the maintenance of the product. Logistically there are no major problems being the territory of Emilia - Romagna full of oil mills, thus allowing fast movements and ability to use more than one mill at a time.

The summary Table with its related synergy layout is provided below in Fig. 7.

The parts in yellow refer to the need to obtain the necessary authorizations for the sale of a new food product. In fact, food in which the use of lycopene as a component added is approved are already allowed, therefore that after the approval process there are no identifiable reasons why the product should not be accepted.

2.3.2. Manual II: energy production from agricultural and food waste

Agricultural and food waste considered for this synergy are: grilled tomato, grilled pea, skins and seeds of tomato and grilled bean for a first company, middling and chopped of durum wheat for a second company. The receiving company deals with the transformation of fruit and vegetables, and has therefore already similar waste to handle, thus showing an interest for the building of a biogas plant for energy production. The ability to integrate its products with those of other nearby companies has led the business to participate in the project, in order to receive advice and information on new regulations and technological system, and arrange agreements with companies that produce food waste that do not reuse. This synergy has been proposed by the "LEAP laboratory" that evaluated the waste and the best type of enhancement for the production of energy. The enhancement process proposed is that of anaerobic digestion (AD). The laboratory, based on the data provided by the companies, has carried out a feasibility study for the application of the AD process the waste produced, then assessed separately all streams, in order to determine, through the matter and energy budget as well as by an economic cost evaluation, best feasible and more efficient solutions from both environmental and economic point of view. Research has thus analyzed the following steps:

- estimation of the quantity of waste and by-products in various stages of processing, approximating their availability and characterization throughout the year;
- for each waste flow, identification of the AD technology most suitable for the treatment;
- sizing of the anaerobic digestion process, with prediction of output (digestate and biogas);
- study regarding use of the digestate/soil conditioner downstream of the AD process/post-composting;
- study regarding the use of the biogas produced in AD;
- assessment of the environmental impact and sustainability of the supply chain of AD for a perspective of life cycle LCA (Life Cycle Assessment);
- preliminary assessment of economic feasibility.

REGULATIONS							
Community					Authorized additives in food: 89/107/CEE		
National		Byproduct: Art. 184 D.Lgs 152/6			Regulations concerning the use of additives in food: DM 209/96		
TECHNICAL STANDARDS							
Features discard tomato		By-products of the tomato usable for new products					
Elements forming the skins and seeds of tomato		Elements forming the skins and seeds of tomato					
LOGISTIC ASPECTS							
Authorizations			Bubbles of transport for the certification				
INSIGHTS							
Oils of seeds of tomato					Application of bioactive compounds		

Fig. 7. Layout and table of synergy for nutraceuticals production from agricultural and food waste

Finally, a conversion into biomethane was proposed, since it can be transported in gas pipeline and employed for all uses of natural gas, even as fuel for internal combustion engines, ensuring better economic yields, thanks also to state incentives. As initially mentioned, during project development, the Directive 2009/73/EC has been implemented in Italy, thus the biomethane can get direct access to the gas pipeline system, making development of this synergy very interesting economically.

Also for this synergy, a first criticality analyzed was the seasonality of the products, dealt with the use of animal manure and the programming of food waste during different periods of the year. The large quantities available have been an incentive for the realization of a plant but it has been necessary to take into consideration the variability of the quality of by-products (size, humidity, quantity of nitrogen etc.). To solve all the listed problems, the plant should encompass sections of receipt, storage and pre-treatment for different waste flows.

From the regulatory point of view, a research about national and regional regulations on construction and operation of a biogas plant was carried out. Finally, administrative procedures and technical regulations to comply with, in order to access government incentives for the construction of new biomethane plants, were reported. One of the issues that emerged from the study is the distance of one of the companies, more than 70 km away from the company that should receive its waste. This could be an actual limitation, not making cost-effective the symbiosis pathway proposed.

The two layouts with summary table (for both companies) are shown in Fig. 8. The aspects to which particular attention should be paid are the constraints on construction and management of the new plant that, once fulfilled, will pose no obstacle for the realization of synergy.

2.3.3. Manual III: production of biopolymers from agricultural and food waste

The resources considered for this synergy are wastes from agriculture, wood processing, packaging, rags and absorbent materials. The enhancement proposed, both by ENEA and the laboratories “Cipack” and “Siteia Parma”, for these types of waste has been divided into two phases: an initial enhancement of the waste material should take place in a company dealing with thermoplastic compounds, then the enhanced material could be used in another company producing plastics, willing to convert some of its production in bioplastics. The two companies are already cooperating on other projects and in the past have developed new products testing innovative compounds together. Both companies are interested in trying to explore bioplastics market, supported by researchers who have developed, at least in pilot scale, the use of this type of waste for biopolymers production. The process to be used is currently being examined by experts of both the two companies and laboratory.

The major problem encountered in this synergy is on resources classification. At present, the materials described are classified by relevant norms as waste and landifilled.

The specific criteria needed for a waste to be classified as by-products are:

a. the substance or object shall be commonly used for specific purposes;

b. a market demand for such substance or object shall exists;

c. the substance or object fulfils specific technical requirements and meets existing legislation and standards applicable to products;

d. the use of the substance or object will not lead to overall effects adverse to environmental or human health.

A comparison with relevant public bodies (Environment Department of Emilia – Romagna region) was opened, to ask for a classification change of the resources, under article 184-ter of the fourth part of the Legislative Decree 152/2006 (Consolidated Environmental Law), which lists the features necessary for a waste to be considered as by-product.

Having considered the various aspects, it was concluded a change of classification for the concerned wastes could be requested. At present the request is still being considered by relevant authorities to allow the classification change; ENEA and ASTER are keeping open the dialogue for the resolution of this issue.

The layout and the summary table of the Manual are described in Fig. 9, pending aforementioned regulation change that will solve hindering aspects and unlock the synergy.

As the table shows, a very critical issue takes place from the classification of the stream as a “waste” instead of “byproduct”; in fact, for the Italian regulation, waste can be transported and treated only by authorized companies, limiting in this way the direct “industrial symbiosis” between waste producers and waste users.

3. Results and discussion

3.1. Strengths, weaknesses and potential improvements

The project began as a pilot project in Emilia - Romagna for testing and spreading the Industrial Symbiosis strategy within the region. In Italy in 2013, very few were aware of this tool for closing industrial cycles. ASTER, the promoter of the project in 2013, is a regional in-house company of the Chamber of Commerce (Unioncamere Emilia Romagna), working with local companies for technology transfer and innovation. ASTER main role, within the project, was networking, involving companies into the project, organizing meetings and workshops. At the beginning of the project ASTER asked ENEA (Environmental Technologies Technical Unit) to take part to the project in force of its experience on industrial symbiosis (Cutaia et al., 2015): ENEA took the role of scientific and technical coordinator of the project, setting the methodology, collecting and elaborating data, results and reports.

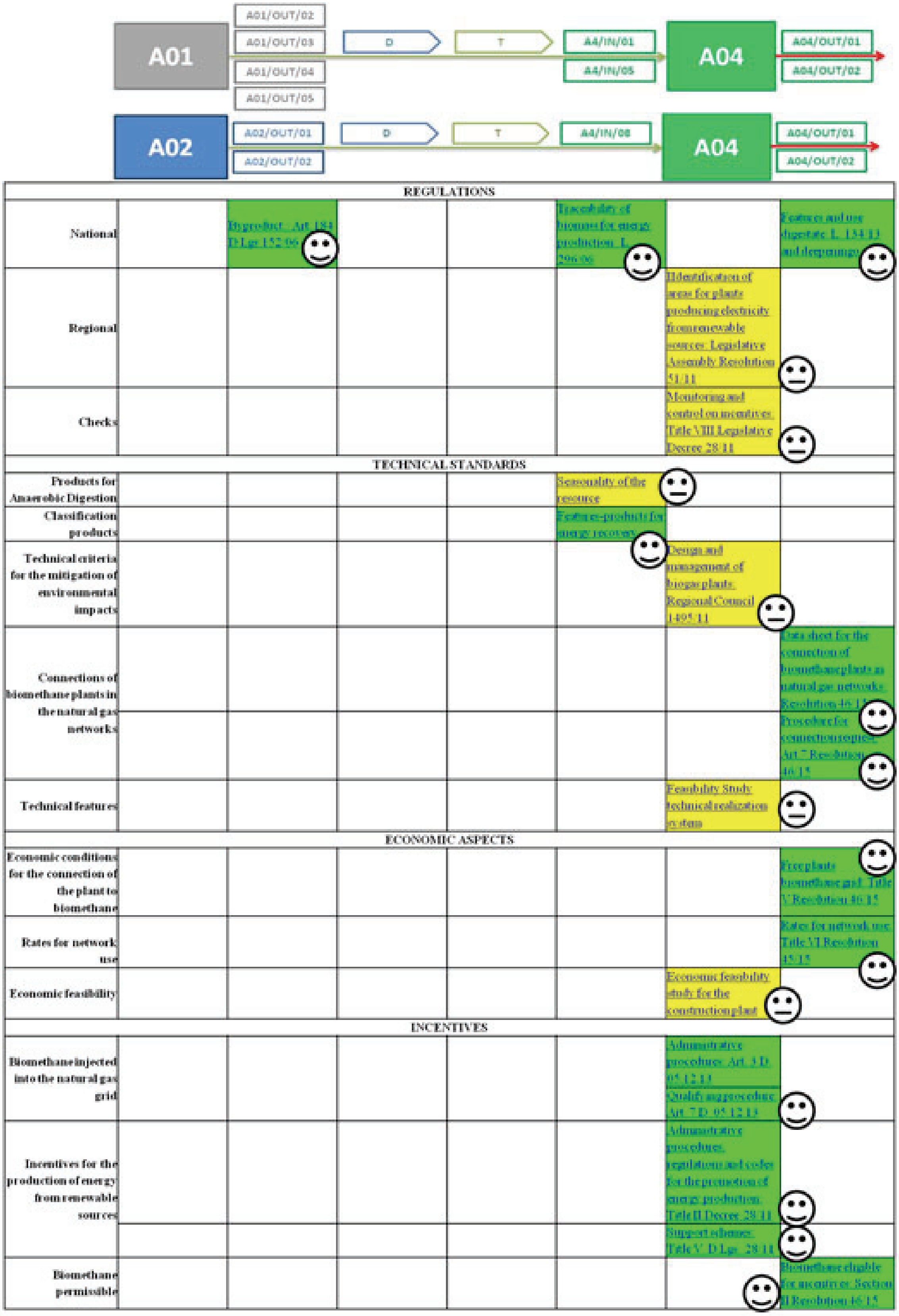

Fig. 8. Layout and Table of the synergy for energy production from agricultural and food waste

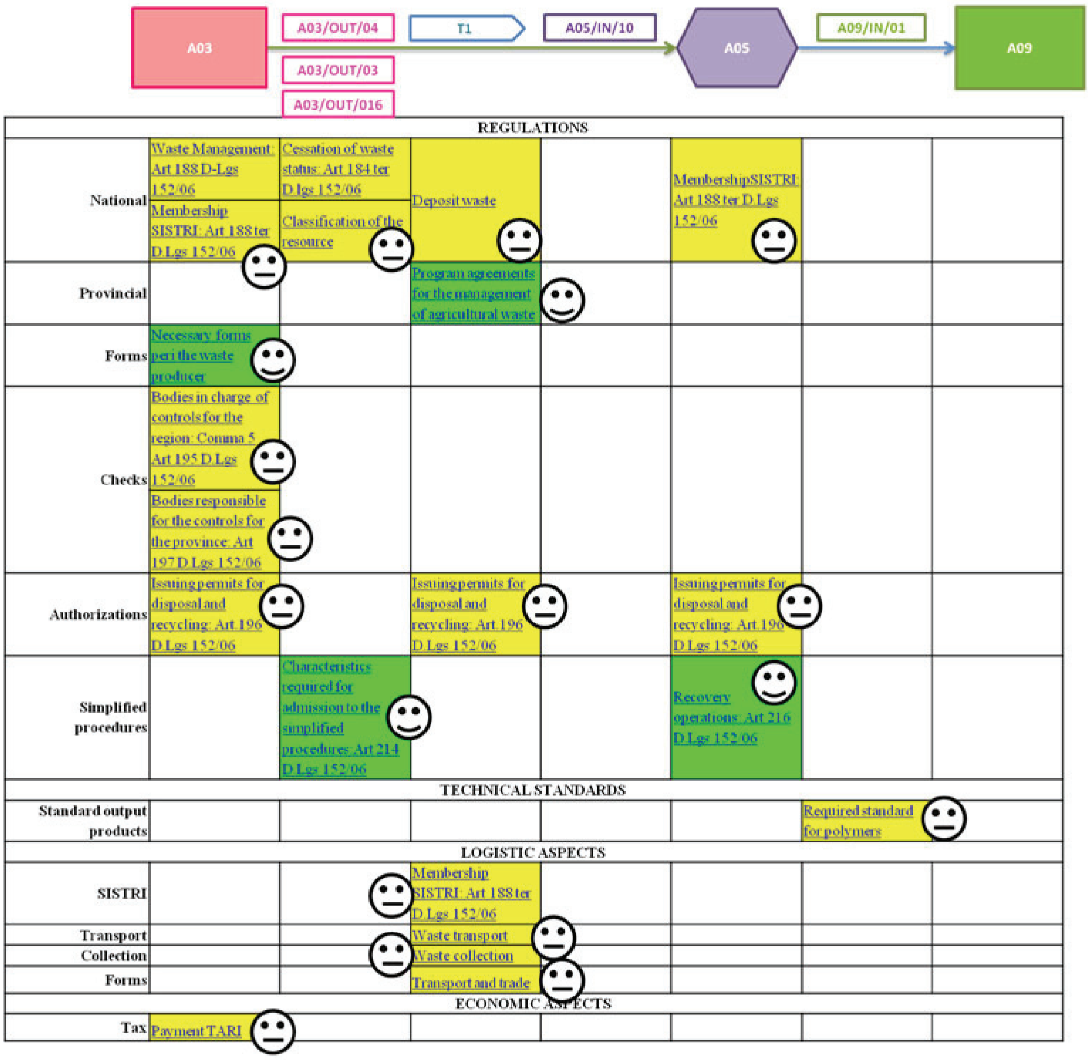

Fig. 9. Layout and table of synergy for production of biopolymers from agricultural and food waste

In addition, the Emilia-Romagna High Technology Network (HTN) was involved with the main goal of suggesting innovative reusing, recovery and recycling options for waste streams produced from involved companies. One of the strengths of the Project G-IS is having put together organizations with good knowledge of the area both from the industrial and the local government agencies point of view (ASTER), high expertise in research and international exposures (ENEA), together with a network of laboratories being very active in industrial research as well as in the study of regional issues (HTN).

The use of specific skills, cooperation and exchange of information has allowed a project started with limited funding and time to attract interest of companies, scientific research and industry sectors. This allowed the extension of the project in a second step, with the actual development of ideas only mentioned in the first part. The sharing of know-how of ENEA and HTN researchers allowed in some cases the development of new technologies for the exploitation of resources, in other cases, to find the most suitable and cost effective synergies, even though less technologically advanced.

Since the beginning of the project, a specific methodology was developed, which has showed its efficiency in both meetings with the participants and in information collection. In the meetings, steps necessary to achieve the proposed objectives and the tools to use were always explained. This allowed the continuous understanding by all participants of the requirements needed to achieve the objective. An ongoing dialogue with both laboratories and companies was kept constantly open, in order to dismiss doubts and get advice on how to optimize the process. The contacts were of various kinds: from meetings, to phone calls, to the intensive use of e-mails in order to minimize waiting times. Different data collection techniques were used: some formats, standards and tools already developed for a project by ENEA in Sicily have been reused (Eco-innovation Sicily, ENEA, 2011-2015) and adapted to the Emilia - Romagna context, while also other tools for situations that required specific material have been developed. The tools are designed to make the data more objective as possible and be able to collect the most important information in order to choose different synergies. The data collection forms, the arches <source, destination>, the synergies synthetic schemes and in general all the material produced during the project may be re-used and adapted in other programs of Industrial Symbiosis, citing ENEA.

An additional objective achieved by this project is to put together several companies in the area, various industrial sectors and local government authorities to share critical information. This allowed using the knowledge of both the companies and local authorities to find solutions, share ideas and develop projects where common objectives have been found. In addition to the synergies proposed by the project, cooperation between different companies was developed, that later allowed the launch of other projects, now completed.

The project begun in May of 2013 and ended in June 2015 suffered a time delay that created problems: changes in national laws, loss of interest of some individuals, development of new technologies. For the project G-IS, the inability to plan from the beginning time and resources to be used has certainly precluded the optimization of the different project steps, being in addition a pilot project among the first in Italy and thus has not able to benefit from the experience of previous cases studies. It has however created a new methodology, improvable indeed as hindered by inexperience, but which still had a good visibility in terms of publications and advertising.

During the project it became more evident a problem already known: the isolation between scientific research and industrial sectors. The Italian scientific research often suffers from little applicability of laboratory results in real industrial environment. Research is often brought to pilot scale and then abandoned for lack of funds, instead in this project the research results were proposed to business companies interested in developing new technologies. Two sectors that usually are not connected were linked, a small step forecasting possible future development.

3.2. Participation and interconnections created

In the last few months of the project we have submitted a questionnaire to the companies involved in order to assess: a) the main reasons impacting on the decision of a company to participate in industrial symbiosis pathways with other stakeholders; b) the main factors impeding the implementation of the industrial symbiosis; c) whether the methodology used in the project has fostered territorial cohesion. For achieving these objectives the questionnaire was divided into two parts.

First part: *"Industrial symbiosis between opportunities and obstacles"*. Through two matrix questions, the company delegates expressed their opinion on a set of items (respectively seventeen and sixteen) regarding to the objectives a) and b) using a rating scale from 1 (min) to 5 (max). In both cases, at the end of the two matrix questions the delegates could fill in few lines others important issues regarding the industrial symbiosis that were not present in the questionnaire.

Second part: *"Territorial cohesion"*. This part of the survey was based on concept of *territory* as "a system of economic and social relations, which make up the relational capital or the social capital of a certain geographical space" (Camagni, 2002) preferring a formal perspective of these relationships i.e. co-operation agreements among firms, among collective agents, among public institutions (Capello, 2007); and on concept of *cohesion* as density of relationships in a network (Salvini, 2005) focusing on the propensity to implement co-operation agreements among companies (Soda, 1998). On two lists of all companies participating in the project, the delegates had to mark, on the one hand, companies with which their company had already working relationships (production-subcontracting, services, marketing and export, logistics and transport, Research & Development) before the kickoff of the project; on the other hand, companies with which they had created new partnerships thanks to the project even beyond initiatives regarding to industrial symbiosis. We processed data through software UCINET 6 (Borgatti et al., 2002).

The questionnaire was submitted to the company delegates participating. Some delegates filled in the questionnaire during the conference *"Circular Economy: Experiences of Industrial Symbiosis in Emilia-Romagna"* which took place in Bologna, on the 5th of June 2015, as part of the fair *R2B - Research to Business*. The questionnaire with a short explaining text was emailed to other delegates which were not present at the conference. Data collection is over in September 2015. All delegates filled in and gave back their questionnaires.

3.2.1. Industrial symbiosis between opportunities and obstacles

According to the company delegates participating in the project G-IS the main reasons impacting on the decision of a company to participate in industrial symbiosis pathways with other stakeholders are in order of importance: 1) The opportunity to dispose of waste and by-products at a lower cost (4.08 points); 2) Higher revenues due to the opportunity of selling wastes and by-products (3.83 points); 3) The opportunity to buy at a lower cost scraps and by-products to be used in replacement of raw materials (3.58 points); 4) The creation of new partnerships and business networks (3.50 points).

On the contrary the main factors impeding the implementation of the Industrial Symbiosis are in order of importance: 1) The regulatory complexity and uncertainty (4.09 points); 2) The excessive bureaucracy (4.00 points); 3) The difficulty in finding other companies with which to realize the symbiosis (3.75 points); 4) The difficulty in estimating the costs and time of the investments and possible risks in planning and starting a partnership (3.50 points).

3.2.2. Territorial cohesion

Before the start of the project G-IS there were at least nine partnerships among the companies participated in the field of production (subcontracting), services, marketing and export, logistics and transport, R & D. Thanks to the project at least another six new relationships are created (See Fig. 10). Through a social network analysis an increase in the index of network cohesion from 0.1364 to 0.2273 (on a scale from 0 - no cohesion - to 1 - maximum cohesion) was measured. The project, therefore, has had a positive impact on strengthening the network of participating companies by 66% approximately. In particular LAB03 and A07 benefited most in participating in the project. If at the start of the project the two companies had only a relationship with the other participants, thanks to the project have created at least three more.

First of all it is important to note that the data collected through this survey are based on the companies having direct knowledge of many issues related to industrial symbiosis pathway thanks to the participation in the project G-IS. Analyzing the results we note that business opportunities push companies to implementation the industrial symbiosis as well as regulatory and information issues discourage them. On the basis of these results we emphasize that through the methodology used the project G-IS directly impacted a) on information obstacles reducing the difficulty in finding other companies with which to realize the industrial symbiosis; b) on the creation of new partnerships and business networks fostering in general a strengthening of territorial cohesion in the particular geographic space where it was made.

3.3. Next steps

The package of circular economy measures promoted by the European Commission implies that projects like the one proposed here can have a large development in the future. Industrial Symbiosis uses the resources available in a more intelligent and sustainable way. Many natural resources are not infinite: we must find a way to use them, behavior that is sustainable from an environmental and economic point of view, and it is also in the economic interests of companies to make the best use of their resources.

The possibility of solving problems of an area and the opportunity to find solutions even through sharing materials, energy, expertise and services fits perfectly with the vision of Circular Economy proposed by EU.

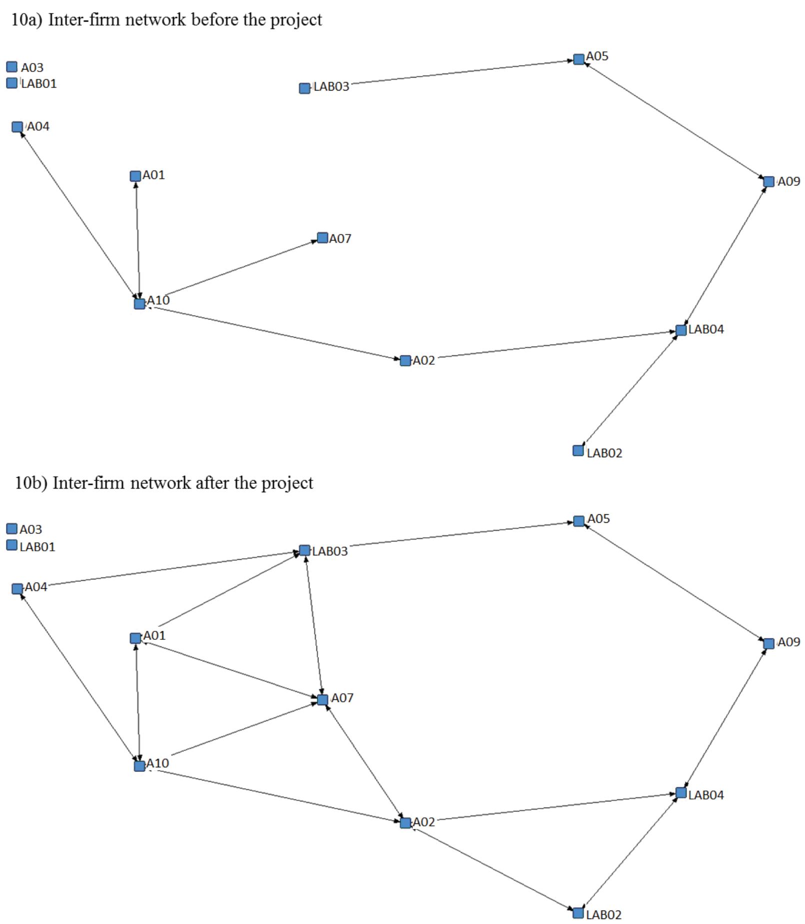

Fig. 10. Inter-firm network before (a) and after (b) the project G-IS

In a circular economy the value of products and materials is maintained as long as possible; waste and uses of resources are minimized and resources are maintained in the economy even when a product has reached the end of its life cycle, in order to reuse them several times and create additional value. This economical model can create jobs, promote innovations that can be a competitive advantage and a level of protection for people and the environment, while providing consumers with more sustainable and innovative products that can generate savings and improving life quality. In this context, Industrial Symbiosis promotion projects should find plenty of space and funding both at national and regional level.

The project G-IS has played the role of demonstrator of interest of companies in such an activity, as well as its technical feasibility. The strategy of industrial symbiosis is now addressed in the regional waste plan of Emilia Romagna Region and (RER, 2014a, b) in the regional regulation for Environmental equipped industrial areas (APEA) (Cavallo, 2013).

Now the project has ended. The authors hope that in this scenario of growing interest on industrial symbiosis new opportunities for the implementation of new projects on industrial symbiosis in Emilia Romagna will start, hopefully taking into account the experience already done and explained in this paper.

4. Conclusions

The work done within the G-IS project in Emilia Romagna shows a very good potential for the implementation of industrial symbiosis in such an area. Both industries as well as labs involved in the project did a really cooperative work, together with ASTER and ENEA, addressed at sharing resources and find valorization opportunities.

The approach used in the first part of the project was based on exchange of information on resources and on potential valorisation opportunities using specific data collection formats during several meetings and contacts between industries, labs and the working group During the first part of the project 90 potential synergies have been identified, starting from proposal made by companies directly during the meetings, from synergies proposed from labs (given shared resources) and from synergies proposed by the working group coordinated by ENEA.

In order to finalize potential synergies identified in the first phase of the project, potential synergies have been grouped and selected and for some of them an industrial symbiosis pattern has been traced and analytically described in operative manuals. This second part of the project had huge relations with local area conditions and specific applied regulations, as well as with local stakeholders and public bodies involved along industrial symbiosis patterns. The description of each part of industrial symbiosis pattern, from the production of the resource (waste or by-product) from one company till its utilization by one other company, has been "exploded" considering all possible aspects to be considered and respected by the "owner" or the "responsible" for the resource in each point of its pattern. The operative manuals, addressed at companies involved in the project and specifically in each industrial symbiosis pattern and at the moment fully available only for them, could be of general interest, for the replication of described synergies by other companies in the same area or even, could be used as a guide, for the implementation of such kind of synergies in other local conditions. Putting together and in a synthetic and systematic way all data, information and requirements needed for the actual implementation of a specific industrial symbiosis pattern has been considered really useful by companies involved in the synergies.

Moving from a pilot project, such as the Green Industrial Symbiosis project, towards a systematic, broad and continuous application of industrial symbiosis approach would require the availability of network connections and coordination, able to collect and valorize shared resources finding not only "one opportunity" but the "best opportunity" given the boundary conditions.

The EU Circular Economy package, published the 2nd of December 2015, could be a driver for implementing industrial symbiosis systematically as a strategy for saving resources.

References

Borgatti S.P., Everett M.G., Freeman L.C., (2002), UCINET 6 for Windows. Analytic Technologies, Harvard, On line at: https://sites.google.com/site/ucinetsoftware/home.

Camagni R., (2002), On the concept of territorial competitiveness: sound or misleading?, *Urban Studies*, **39**, 2395-2411.

Capello R., (2007), *Regional Economics*, Routledge, London.

Cavallo M., (2013), Industrial symbiosis and productive areas, *Environmental Engineering and Management Journal*, **12**, 265-268.

Chertow M.R., (2000), Industrial symbiosis: literature and taxonomy, *Annual Review of Energy and the Environmen*t, **25**, 313-337.

Cutaia L., Scagliarino C., Mencherini U., Iacondini A., (2014), Industrial symbiosis in Emilia-Romagna region: results from a first application in the agro-industry sector, *Procedia Environmental Science, Engineering and Management*, **2**, 11-36.

Cutaia L., Luciano A., Barberio G., Sbaffoni S., Mancuso E., Scagliarino C., La Monica M., (2015), The experience of the first industrial symbiosis platform in Italy, *Environmental Engineering and Management Journal*, **14**, 1521-1533.

Iacondini A., Mencherini U., Passarini F., Vassura I., Fanelli A., Cibotti P., (2015), Feasibility of industrial symbiosis in Italy as an opportunity for economic development: critical success factor analysis, impact and constrains of the specific Italian regulations, *Waste and Biomass Valorization Journal*, **6**, 865-874.

EU Commission, (2010), Europe 2020 Growth Strategy, EU Commission, On line at: http://ec.europa.eu/europe2020/index_en.htm.

EU Commission, (2011a), A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy, 26.7.2011, Brussels, On line at: http://ec.europa.eu/resource-efficient-europe/pdf/resource_efficient_europe_en.pdf.

EU Commission, (2011b), Roadmap to a Resource Efficient Europe, 20.9.2011, Brussels, On line at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0571.

EU Commission, (2015), Closing the loop - An EU action plan for the Circular Economy, Brussels, On line at: http://ec.europa.eu/priorities/jobs-growth-investment/circular-economy/docs/communication-action-plan-for-circular-economy_en.pdf.

EC Directive, (2009), Directive 2009/73/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in natural gas and repealing Directive 2003/55/EC, *Official Journal of the European Union*, L211, 94-136.

Regione Lazio, (2014), Smart specialization strategy (S3) Regione Lazio, On line at: http://lazioeuropa.it/files/140723/regione_lazio_smart_specialisation_strategy_luglio_2014.pdf.

RER, (2014a), Regional and Innovation Strategy for Smart Specialisation Regione Emilia-Romagna (RIS3ER), Regione Emilia-Romagna, On line at: http://www.regione.emilia-romagna.it/fesr/por2014-2020/documenti/documenti-approvati-ue/Allegato1ASmartSpecialisationStrategyEmiliaRomagna.pdf/at_download/file/Allegato%201A%20Smart%20Specialisation%20Strategy%20Emilia%20Romagna.pdf.

RER, (2014b), Regional Waste management Programme, Regione Emilia-Romagna, On line at: http://ambiente.regione.emilia-romagna.it/rifiuti/documenti/prgr-adottato/prgr-finale/at_download/file/PRGR%20Finale_alta%20risoluzione.pdf.

Salvini A., (2005), *Analysis of Social Networks: Resources and Mechanisms*, (in Italian), Ed PLUS, Pisa University Press, Pisa, Italy.

Soda G., (1998), *Networks between Companies: Models and Perspectives for a Theory of Coordination between Undertakings*, (in Italian), Carocci Editore, Rome, Italy.