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# Experiences of Industrial Symbiosis in Italy

Proceedings of conferences promoted by ENEA at Ecomondo  
in 2012, 2013 and 2014

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Edited by Erika Mancuso and Antonella Luciano

SYMBIOSIS  
USERS NETWORK



Italian National Agency for New Technologies,  
Energy and Sustainable Economic Development



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*Edited by Erika Mancuso and Antonella Luciano*

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## INTRODUCTION

In the framework of the strategies and tools for closing cycles of resources and circular economy, a growing interest stands out towards “industrial symbiosis”, a strategy addressed at making the residues of one activity available for another one. This approach is not only a potential factor of competitiveness for industrial activities, but also a developing asset for the region, in which all resources are exploited locally and not dissipated, delegated or given away to third parties.

The industrial symbiosis strategy for sharing resources can be activated among companies present within a region (network for industrial symbiosis) and in industrial areas or industrial clusters for the transition to the so-called “eco-industrial parks”, in Italy partly represented by APEAs (Ecologically Equipped Productive Areas).

The European Commission assigned to industrial symbiosis a strategic role in the efficient use of resources, clearly identified in various planning and funding documents. Networks for industrial symbiosis are strongly promoted in the recommendations of the “European Resource Efficiency Platform” (EREP) to support the EU towards a more efficient economy in the use of resources. In the “Roadmap to a Resource Efficient Europe” industrial symbiosis is identified as a tool to boost efficient production through a better use of raw materials, and an enhanced recycling of wastes and by-products. The growing interest of the European Union to the theme of industrial symbiosis clearly emerges from calls for funding specifically addressed to industrial symbiosis projects in the framework of Horizon 2020. The Communication COM (2014) 398 “Towards a circular economy: A zero waste programme for Europe” explicitly indicates the industrial symbiosis as a strategy to improve resource efficiency and the transition towards the circular economy. The European Commission, chaired by Jean-Claude Juncker also announced that by the end of 2015 will be launched a new directive on the circular economy, with even more ambitious goals.

The G7 "Alliance on Resource Efficiency" has identified the industrial symbiosis as one of the cornerstones for the resource efficiency strategy. An international workshop on this topic is scheduled in Birmingham on 29<sup>th</sup> and 30<sup>th</sup> October 2015 where ENEA has been invited to take part.

The interest on industrial symbiosis grows also in Italy and several projects have recently been developed. Furthermore, industrial symbiosis has been included as a strategy in several local programming tools. For example, in the waste management plan of Emilia Romagna region, industrial symbiosis is identified as an opportunity to achieve the goals of prevention of waste production, enhancement of regional production system and valorisation of critical fractions of waste by means of short chain re-use.

In 2014 the “Cartesio Network” wrote the "Charter for Development of Ecologically Equipped Productive Areas in Italy", signed by Emilia Romagna, Liguria, Marche, Piemonte, Sardinia and Tuscany Regions. The document promotes, among other things, "the environmental improvement in the production areas, encouraging [...] solutions of industrial symbiosis, environmental management and resources re-use”.

In July 2015, the Lazio Region has approved the "APEAs Guidelines" for the development of Ecologically Equipped Productive Areas in Lazio that include, among other requirements of APEAs, the use of industrial symbiosis between the member companies.

In the same year the "New Energy Plan for Lazio, Energy Saving and Efficiency" identifies the industrial symbiosis as an instruments of change in the development model, closely related to the objectives of economic and employment development through the decoupling between consumption and GDP.

The Friuli Venezia Giulia Region in the framework of the policy to support the development of the sectors regulated by the regional law 20 February 2015 n. 3, included the projects of industrial symbiosis in the eligible activities.

This collection of experiences wants to give evidence of activities done or ongoing in Italy on industrial symbiosis, the todays problems and outlooks through the works presented at conferences organized by ENEA at Ecomondo, Rimini, between 2012 and 2014: "The industrial symbiosis as a tool for the Green Economy "2012; "The experiences and state of the art industrial symbiosis in Italy" 2013; "The industrial symbiosis between theory and practice" 2014.

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## INTRODUZIONE

Nell'ambito delle strategie e degli strumenti per la chiusura dei cicli delle risorse e per l'economia circolare si riscontra un interesse sempre crescente verso la "simbiosi industriale" tramite la quale i residui di una attività non vengono smaltiti come rifiuti, ma valorizzati come risorsa da una diversa attività. Questo approccio costituisce non solo un potenziale fattore di competitività per le attività industriali, ma anche un fattore di arricchimento per il territorio, che vede l'insieme delle sue risorse valorizzate localmente e non disperse, delegate o regalate a terzi.

La strategia della simbiosi industriale per la condivisione delle risorse può essere applicata oltre che tra imprese, operatori ed organizzazioni presenti su un territorio (reti per la simbiosi industriale) anche nelle aree industriali o distretti industriali per la transizione verso i cosiddetti "parchi ecoindustriali", in Italia declinati in parte attraverso le APEA (Aree Produttive Ecologicamente Attrezzate).

La Commissione europea ha attribuito alla simbiosi industriale un ruolo strategico per l'uso efficiente delle risorse, chiaramente individuato in diversi documenti di programmazione e di finanziamento. Reti di simbiosi industriale vengono fortemente promosse nelle raccomandazioni della "European Resource Efficiency Platform" (EREP) per supportare la Unione Europea verso un'economia più efficiente sotto il profilo delle risorse. Nella "Tabella di marcia verso un'Europa efficiente nell'impiego delle risorse" la simbiosi industriale viene indicata come una delle strategie utili a stimolare una produzione maggiormente efficiente attraverso un migliore uso delle materie prime ed il riutilizzo dei rifiuti e dei sottoprodotti. Il crescente interesse della Comunità europea al tema della simbiosi industriale emerge chiaramente anche dai bandi di finanziamento a progetti specificatamente dedicati alla simbiosi industriale nel programma quadro Horizon 2020. La comunicazione COM(2014) 398 "Verso un'economia circolare: programma per un'Europa a zero rifiuti" prevede esplicitamente la simbiosi industriale tra le strategie da adottare per migliorare l'efficienza nell'uso delle risorse e la transizione verso un'economia circolare. L'attuale Commissione europea, presieduta da Jean-Claude Juncker ha, inoltre, annunciato che entro fine 2015 sarà varata una nuova direttiva sull'economia circolare, con obiettivi ancora più ambiziosi.

La "Alliance on Resource Efficiency" del G7 ha individuato la simbiosi industriale come uno dei punti cardine per la strategia per l'efficienza nell'uso delle risorse. A questo specifico tema è dedicato un workshop internazionale sulla simbiosi industriale organizzato dalla Gran Bretagna, in programma a Birmingham il 29 ed il 30 ottobre 2015. ENEA è stata invitata a prenderne parte.

L'interesse verso la simbiosi industriale si è registrato negli ultimi anni anche in Italia con lo sviluppo di diversi progetti dedicati alla chiusura dei cicli delle risorse e con l'inserimento della simbiosi industriale anche in alcuni strumenti di programmazione locale. A titolo esemplificativo, nel piano di gestione dei rifiuti dell'Emilia Romagna la simbiosi industriale viene individuata come una opportunità per raggiungere gli obiettivi di riduzione della produzione dei rifiuti, valorizzazione del sistema produttivo regionale e sviluppo della filiera corta di frazioni critiche che altrimenti si trasformerebbero in rifiuto.

Nel 2014 la Rete Cartesio ha elaborato la “Carta per lo sviluppo delle Aree Produttive Ecologicamente Attrezzate in Italia”, sottoscritta dalle regioni Emilia Romagna, Liguria, Marche, Piemonte, Sardegna e Toscana. Il documento promuove, tra le altre cose, “il miglioramento ambientale nelle aree produttive, incentivando [...] soluzioni di simbiosi industriale, gestione ambientale e riuso e risparmio delle risorse”.

Nel luglio 2015 la Regione Lazio ha emanato le "Linee Guida APEA" per lo sviluppo delle Aree Produttive Ecologicamente Attrezzate nel Lazio che includono, tra gli altri requisiti delle APEA, il ricorso alla simbiosi industriale tra le imprese aderenti.

Nello stesso anno il “Nuovo piano energetico del Lazio, Risparmio ed Efficienza Energetica” annovera la simbiosi industriale tra gli strumenti di cambiamento del modello di sviluppo, in stretta relazione con gli obiettivi di sviluppo economico ed occupazionale attraverso il disaccoppiamento tra consumi e PIL.

La Regione Friuli Venezia Giulia, inoltre, nell’ambito della politica di sostegno allo sviluppo delle filiere regolamentata dalla legge Regionale 20 Febbraio 2015 n. 3, ha inserito i progetti di simbiosi industriale tra le attività finanziabili.

Questa raccolta di esperienze vuole dare testimonianza delle attività che si stanno svolgendo in Italia sul tema della simbiosi industriale, delle problematiche presenti e delle prospettive future attraverso i contributi presentati ai convegni organizzati da ENEA ad Ecomondo, Rimini, dal 2012 al 2014: “La simbiosi industriale quale strumento per la Green Economy” 2012; “Le esperienze e lo stato dell’arte della simbiosi industriale in Italia” 2013; “La Simbiosi industriale tra teoria e pratica” 2014.

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# THE EXPERIENCE OF THE FIRST INDUSTRIAL SYMBIOSIS PLATFORM IN ITALY

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## Introduction

This extended abstract summarizes the ENEA activity in the framework of the project for the development and implementation of the first Italian Platform for Industrial Symbiosis implemented in Sicily. This activity (May 2011 - May 2015) represents the first systematic project developed in Italy for the implementation of industrial symbiosis at regional scale and, in general, in a certain geographical area. From the beginning of the project till now the role of industrial symbiosis has becoming more and more recognized by the European Commission [1, 2, 3, 4] as a tool for circular economy and the efficient use of resources.

## 1. Methods

ENEA, Environmental Technologies Technical Unit (now merged in Department for Sustainability (SSPT)), started the project for the development of a platform for Industrial Symbiosis in 2010, with the idea to create a tool enabling companies in sharing resources (materials, energy products, water, services and expertise) and able to offer other operational tools (regulation and BAT databases, quick LCA and Ecodesign tools, etc.) to companies and stakeholders cooperating and using that platform [5].

The Industrial Symbiosis Platform is based on mutual cooperation of different tools:

- Network activation and promotion activities by means of stakeholders involvement at local level (in this case in Sicily region) and at national and international level; implementation of the website for the promotion and dissemination and connection with users; registration of the logo “Symbiosis” and realization of the first Italian Industrial Symbiosis Network (SUN: Symbiosis Users Network; [www.sunetwork.it](http://www.sunetwork.it)) aimed at being the Italian reference point for Industrial Symbiosis;
- Design and implementation of the platform architecture, tools and database structure and taxonomy, data collection;
- Assessment and data collection of companies and productive sector operating in Sicily; Companies’ geo-referred database.
- Involvement of companies with on-line and/or in-site collaboration with the objective to sharing resources.

## 2. Network activation and promotion activities

In 2011 ENEA registered the domain [www.industrialsymbiosis.it](http://www.industrialsymbiosis.it) and other equivalents, as the project's website and more in general, the reference website for ENEA’s activities in Industrial Symbiosis. With the same aim a logo has been registered (Figure 1). The project website was put online and was available since November 2012, when ENEA promoted the first national conference on industrial symbiosis during the Ecomondo 2012 exhibition: “The industrial symbiosis as a tool for the Green Economy”. Local stakeholders’ involvement started in 2011. Contacts with Sicilia Region (Regional waste Agency) and Confindustria Sicilia were established and consultation meetings were held. A specific framework agreement, also on industrial symbiosis, was signed between ENEA and Confindustria Sicilia in 2012.

In March 2013 ENEA and International Synergies Ltd (ISL, UK) signed a framework agreement and in November, on a ISL initiative, the European Association of Industrial Symbiosis (EUR-ISA) was launched, with the participation of ENEA. In 2014, during Ecomondo, ENEA launched the first Italian Industrial Symbiosis Network (SUN: Symbiosis Users Network; [www.sunetwork.it](http://www.sunetwork.it)): the logo (Figure 2) is going to be registered and the first meeting is foreseen to be held in June 2015 in Rome.

Figure 1 – The ENEA Industrial Symbiosis Platform Logo



Figure 2 – The SUN Logo



This network aims at being the Italian reference point for Industrial Symbiosis through the support of scientific/research bodies as well as the participation of operative stakeholders (companies and institutions).

### 3. The ENEA Industrial Symbiosis Platform

The Industrial Symbiosis Platform is based on a Central Manager (at the moment ENEA itself) and on an integrated system of an ICT and DBs tools for the management of singles users (companies), their data (even on shared resources), and the connection between all those information (including synergies that can be found between users). In this platform there is a GIS system, where many different databases can be uploaded. One of those databases is related with registered companies, which, through the website can upload their general information (name, address, activity sector 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 tools provided by the platform (queries, DBs, industrial symbiosis matching). The relation between associated companies, their own input-output and possible synergies among companies goes through a connection string, named <origin, destination> which “links” one output with its potential productive destination sectors. These <origin, destination> strings are uploaded in a specific database, which can be updated according to new case studies and know-how coming not only from the central manager but also, and hopefully, from the network [5].

ENEA input-output table foresees a taxonomy for the inventory of input-output data of companies, taking into account “materials, energy, services, skills” as resources and using code systems officially used in Italy (according EU regulation) for different kind of inventories (e.g. Nace codes, ATECO codes, ProdCom, EWC) with which companies normally deal with.

Since ENEA is the designer and the owner of the Industrial Symbiosis Platform therefore future implementation and improvements of this tool are possible both for its implementation in Sicily and for any other implementation in other regions.

### 4. Productive sectors in Sicily

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 have or inputs they want to have. Companies’ involvement can be on-line, through the website or on-site, with specific meetings. In order to know and understand the Sicily’s productive system, a DB containing information on more than 2000 companies was developed collecting data from regional productive districts, chambers of commerce, industrial associations and companies’ web sites. Starting from this comprehensive DB, groups of heterogeneous companies were selected and invited to take part to operative meetings.

### 5. Operative meetings

Two operative meetings with companies were held in Siracusa (March 2014) and in Catania (October 2014) [6, 7].

In Siracusa the meeting was held in the headquarter and with the support of the Chamber of Commerce, with the participation and support of Sicilia Region, Confindustria Sicilia and province of

Siracusa. The meeting in Catania was held in the headquarter and with the support and the patronage of Confindustria Catania, and University of Catania.

Stakeholders' involvement was also important since the actual realization of industrial symbiosis in Italy is strongly influenced by the regulatory framework as well as by monitoring and control systems. During the meetings more than 410 resources were shared and more than 650 potential synergies identified.

After the meetings a further check was done with companies in order to confirm, modify or integrate information and data provided before and during the meetings. Some companies provided much more information than those provided only during the meeting. For this reason it is possible that further potential synergies can be identified, according to the large amount of inputs and outputs provided. The whole amount of information has been uploaded in the Platform and needs to be checked in order to identify further potential synergies.

## 6. Ongoing activities

The ongoing activity is the creation of technical dossiers on three main resource streams (Wastes from processing stone materials, construction and the demolition waste; plastics; biowaste) which may generate the more interesting potential synergies. These dossiers include European, Italian and regional regulations, guidelines, technical regulations, standards, logistic and economical aspects and more in general describe the pathway 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.

## 7. Conclusions

ENEA developed the first Industrial Symbiosis Platform in Italy implemented in Sicilia. The platform, whose main objective is to help in 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. In addition to the technical part of the project, some activities were addressed at the consultation with stakeholders, in Sicily and at national level.

Input-output data shared during, before and after workshops held in Siracusa and Catania took, as a first results, at identify more than 650 potential synergies for more than 410 resources shared. ENEA is still working with companies in the implementation of the pathways which carry from the idea till the actual implementation of potential matches. ENEA is also still working on several issues aimed at the implementation of the Platform in Sicily after the end of the project (May 2015) and on its implementation in other regions in Italy. At the same time ENEA is working the activities to be implemented for the first Italian Industrial Symbiosis Network (SUN: Symbiosis Users Network; [www.sunetwork.it](http://www.sunetwork.it)).

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# INDUSTRIAL SYMBIOSIS: SOME RESEARCH ISSUES AND CASE STUDIES

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## Introduction

In the last few decades, awareness that our growth-oriented society may be over-reaching the Planet's carrying capacity has been increasing. The cumulative environmental effects of human activities are becoming more evident. Then, the design and implementation of sustainable production systems raise in order to reduce dependency on raw materials and encourage optimal waste use and recycling. The traditional structure of production chain must be extended to include mechanisms for materials and energy recovery. Industrial symbiosis (IS) may be a useful approach to achieve this goal. Two industrial actors operate in IS when they exchange materials and energy to reduce costs, create value, and improve the environment. They share wastes, by-products, services, and information in a cooperative and synergistic way which is strongly supported by the geographical proximity [1]. Some research issues about IS systems on a local scale are open; in particular: 1) how to design IS exchanges within an industrial system in order to maximize environmental gains; 2) what is the effect of the spatial dimension on environmental and economic sustainability; 3) what is the role of cooperation among actors involved in symbiotic relationships.

Each of these issues has been addressed presenting theoretical models applied to actual cases.

## 1. Modeling material flows

A better understanding of material and energy flows among firms and production chains will help to meet the challenges associated with the development of IS initiatives. The Enterprise Input-Output (EIO) model may be a useful tool to achieve this goal [2]. Using this approach, each production chain can be modeled as a set of tightly interconnected manufacturing processes, constituting an input-output system, producing a specific good. In particular, each manufacturing process is conceptualized as a "black box" that produces outputs absorbing primary inputs and generating wastes. The amount of inputs absorbed and wastes generated is a function of the output produced and of the production technology adopted. The EIO model allows to easily estimate the environmental benefits due to IS approach, in terms of lower amounts of inputs absorbed and wastes disposed of in landfill by the production chain considered, and the economic ones, principally expressed in terms of reduction of input purchase costs and waste disposal costs [3]. This theoretical framework has been used for addressing the mentioned research issues through the case studies presented in the next section.

## 2. Results and discussion

For each research issue a corresponding case study has been considered.

The first case concerns the design of symbiotic flows within an industrial system. The adoption of IS within an industrial firm system is potentially able to discharge zero wastes and absorb zero inputs from outside. This particular condition has been defined "perfect symbiosis" by Albino et al. [4]. Perfect symbiosis occurs when for each waste  $a$  that substitutes the input  $b$ , the amount of  $a$  produced is equal to the amount of  $b$  required. Symbiotic exchanges can be *ex-novo* designed within an industrial system to guarantee the perfect symbiosis condition. However, an existing system where imperfect symbiosis occurs can be redesigned in order to achieve the perfect symbiosis. This redesign has been explored by Albino et al. [4] which studied the Santa Croce sull'Arno industrial district of tannery located in Tuscany. They identified the possible interventions to reach perfect symbiosis: 1) create new symbiotic flows from and to the system; 2) change the production level of outputs produced within the system; 3) change some production technologies; 4) providing incentives for the location of new firms within the system.

For the second research issue, the marble caves located around the cities of Barletta, Andria, and Trani in Apulia have been considered. The use of marble powder for the production process of concrete has been studied in order to investigate what is the effect of the spatial dimension on the environmental and economic sustainability of IS systems. Two different scenarios have been analyzed: a) traditional concrete production; b) concrete production with the use of marble powder. In particular, the economic and environmental impact of six potential marble powder suppliers whose location ranges between 9 and 60 km from the concrete production plant has been estimated. Numerical results from the analysis show that the use of marble powder in concrete production is able to generate environmental benefits, due to the reduction of water, energy, and aggregate use, reducing the costs of the concrete production. However, economic and environmental sustainability of IS relationship is strongly correlated with the location of marble powder suppliers.

Regarding the research issue of cooperation, Lambert and Boons [5] state that cooperation among firms is fundamental for IS relationships. The analysis performed by Albino et al. [6] aimed to better understanding the dynamics related to the actor's decisions to cooperate. The IS relationship considered concerns the use of exhausted tyres in cement production unit located in the Basilicata region. A game theory was applied to understand the behaviour of the two actors involved: the firm collecting tyres and the firm producing cement. Each actor can play two different strategies: 1) a fair strategy when he/she tries to establish the transaction because economic and environmental benefits arise for both actors; in this case he/she is available to get at least a minimum acceptable net benefit; 2) an unfair strategy when the actor tries to obtain the maximum net benefit associated with the transaction or prefers to reject it. Payoffs are evaluated as the net benefit for each player. Theoretical model built shows that there are no dominant strategies: the IS relationship only arises if at least one actor plays the fair strategy. The symbiotic transaction results in certain environmental benefits. However, as the transaction is highly dependent upon actors' behaviour, policy makers may encourage the establishment or the maintaining of the transaction, providing incentives to the involved actors.

### 3. Conclusions

Three different industrial cases have been studied in order to explore some research issues related to IS systems on a local scale. In all cases, the adoption of IS approach ensures economic and environmental benefits. Moreover, these cases confirm what the academic literature argues about the cooperation among actors and the geographic proximity of firms involved in symbiotic exchanges. However, from these studies other research issues need to be focused to exploit the benefit of IS. In particular, regulations and trust among actors seem to be the most relevant in fostering the establishment of IS relationships.

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# INDUSTRIAL SYMBIOSIS FOR INCREASING THE EFFICIENCY IN THE USE OF MATERIALS AND ENERGY

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## 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. From this comes the concept of industrial metabolism, intended as the whole process that includes resource fluxes through the industrial systems, their transformation and finally their disposal in minimum percentage, as waste.

Currently Industrial Ecology (EI) includes all those multidisciplinary contributions for the eco-optimization of the relationship between industry and the environment as a further step forward in the concept of sustainable development.

The industrial symbiosis, which represents one of the main features of industrial ecology, aims to increase the efficiency in the use of materials and energy, through the collaborations between companies that in the traditional linear metabolism of the industrial activities do not cooperate. These interconnected entities engender relations of symbiosis, e.g. integrated industrial complexes, in which the waste of some companies become raw materials for others, with a significant increase in the eco-efficiency of the system.

Some eco-industrial parks are structured as networks of companies that work together to efficiently share resources (raw materials, water, energy, know-how, infrastructure and natural habitat) and reduce costs, especially in waste management.

Through mutual collaboration, communities of companies have achieved collective economic, social and environmental benefits with economies of scale more significant than individual benefits deriving from improvements of individual performances [1].

## 1. Methods

The implementation of efficient industrial symbiosis needs the cooperation of the involved companies. The ability to interact and exchange information is a basic prerequisite for network creation and products exchange.

A list, certainly not exhaustive, of the benefits that the eco-industrial parks can potentially offer is reported below:

- reduction in the use of raw materials;
- improvement of eco-efficiency and pollution reduction;
- improved energy efficiency;
- reduction of wastes;
- economic valorisation of a growing number of by-products.

The creation of a cooperation network, consisting in materials and energy exchange, not only brings economic benefits for participating companies, but generates a reduction in pressure on the environment and reduction of natural resources use, without hindering the growth of productive activities [1].

## 2. Results and discussion

With reference at cases available at international level, following considerations can be done. A first consideration regards the interventions scale, of small level in most cases. Interconnected networks, whose nature is not linear, generate a total value not necessarily equivalent to the value of individual interventions, and often require a “purpose” economy instead of the traditional scale-economy, typical of the widespread and now pervasive global-economy.

A second consideration comes from case studies, from which it is possible to underline a strong linkage between productive activities and territory. Among experts is increasingly widespread belief that Industrial Ecology (IE) is a tool of great potential since it adheres to the core principles of the latest environmental policies. The IE is, in fact, in line with the principles of eco-efficiency, dematerialisation and decarbonisation of the economy and it starts from the hypothesis – is useful to confirm it once more - that there should be cooperation between economic and ecological systems.

In the case of IE a further consideration is about the need to study and manage extremely complex systems, whose actions and effects not necessarily can deal with expected ones.

Indeed, it has been found experimentally that, often, can happen adverse effects, not foreseen.

The success of the principles of IE is therefore an undeniably complex challenge, which also needs a clear communication of concepts and solutions extremely elaborate, to be transferred to other contexts according to peculiarities of the receptor ecosystem (social, environmental and economic).

In the meantime, it is necessary to define planning and design alternatives that are positive and feasible through pilot projects that will represent good examples, transferable and replicable.

### **3. Conclusions**

The implementation of what briefly above described is extremely significant in the case of industrial districts and production chains. This topic is actually on debate for the development of mature economies (such as the European one in general and Italian one in particular) in which networks for information exchange, services sharing, energy and material scraps exploitation and the quality on the whole product chain are important requirements to address the global challenge.

The application of IE needs support strategies in order to do investments in supply chains and manufacturing districts, or even in industrial area to be ecologically equipped, for better environmental management practices. Support strategies can be useful in order to let the companies understand, gradually, the advantages coming from eco-innovation and eco-innovative approaches.

A starting point is still represented by the development of studies and on-site experiences, from which to metabolize and recognize the shortcomings and redirect implementation paths.

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# TREATMENT AND VALORIZATION PLANTS IN MATERIALS RECOVERY SUPPLY CHAIN

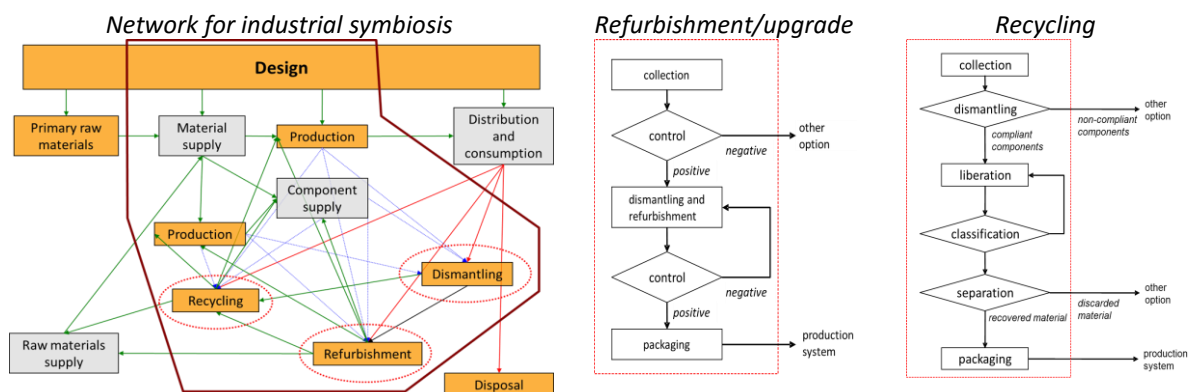
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## Introduction

Aim of industrial symbiosis is to create synergies between industries in order to exchange resources (by-products, water and energy) through geographic proximity and collaboration [1]. By optimizing resource flows in a “whole-system approach”, a minimization of dangerous emissions and of supply needs can be achieved. Resources exchanges are established to facilitate recycling and re-use of industrial waste using a commercial vehicle. Several paths can be identified in order to establish an industrial symbiosis network (Figure 1, left), in relation (i) to the life cycle phase (raw material, component, product) and (ii) to the nature (material, water, energy) of the resource flows to be exchanged. Sometimes by-products and/or waste of an industrial process have to be treated and valorized in order to become the raw materials for others. In particular, two main treatment processes can be identified: refurbishment/upgrade for re-use (Figure 1, center) and recycling for material recovery (Figure 1, right). A brief overview of technological and economic aspects is given, together with their relevance to industrial symbiosis.

**Figure 1 – Diagram of a network of a potential network for industrial symbiosis (left), and the schemes of refurbishment/upgrade (center) and recycling (right) treatment**



## 1. Treatment processing for refurbishment/upgrade and for recycling

According to the internationally recognized waste hierarchy (Directive 2008/98/EC on waste), re-use is preferred to both recycling and disposal, because it is associated with less environmental impact. Re-use implies the prolongation of products (or their components) use by improving and/or increasing their performance and/or functionality up to a level at which they can be re-sold in order to extend the life-span [2]. Table 1 reports an overview of the main technological and economic aspects in refurbishment/upgrade treatment processes aimed to re-use, and a synthetic discussion of their relevance in industrial symbiosis.

The purpose of recycling treatment is to recover materials from waste products and components by applying various liberation, classification and separation processes, with a suitable quality to re-apply them in the same or in another production system [3]. Moreover, the economic context affects the prevailing market conditions in recovered materials, influencing also processing issues. Most technological and economic aspects are the same, or very similar to the above-mentioned ones in Table 1. In Table 2 further aspects, specific to recycling processes, are reported, and a synthetic discussion of their relevance in industrial symbiosis is given.



**Table 1 – Technological and economic aspects in treatment for refurbishment/upgrade**

<i>Technological aspects</i>	<i>Relevance to industrial symbiosis</i>
Eco-design	Products eco-design may reduce material requirements and energy intensity, over the whole life cycle, can enhance material recyclability, by adopting renewable resources and can affect product durability. It effectiveness may improved if producers receive direct feedback benefit from their efforts to make products easier to re-use (or recycle).
Standardization	It is necessary at component, product and infrastructure level, in order to guarantee traceability, durability and reliability. Individual tracking of products.
Non-destructive dismantling	Manual processing of dismantling operation may be needed to achieve an acceptable quality for the retrieved components. Dismantling to the module level allows inspection and replacement of broken modules. Technology upgrading may be achieved by replacing outdated components with more technologically advanced ones.
<i>Economic aspects</i>	<i>Relevance to industrial symbiosis</i>
Markets for used products/components	Markets can assure increased revenue, but require acceptable and guaranteed quality for the retrieved products/components.
Costs for high quality products/components	High quality products/components allow to reduce (and avoid) costs, however costs may arise related to the scale of refurbishment, so processing costs may be higher than business value of products/components.

**Table 2 – Technological and economic aspects in treatment for recycling**

<i>Technological aspects</i>	<i>Relevance to industrial symbiosis</i>
Eco-design	Eco-design tools can deliver a basis for standardized and automated disassembly activities. Automatic assembly can be challenging in case of dismantling operation.
Standardization	Standardized connection systems can facilitate disassembly in recycling centers. Materials labelling can enhance their traceability and reliability.
Complex process layout	Different stakeholders are involved, from collection to material recovery: proximity may not be assured. Further, within the same installation, advanced methods and technologies are needed to obtain recovered material of suitable quality.
Liberation and separation	Efficiency in separation of low-grade and heterogeneous material is needed to obtain high-quality recovered materials. Liberation of hardy fractions is challenging.
<i>Economic aspects</i>	<i>Relevance to industrial symbiosis</i>
Markets for recovered materials	Markets can assure increased revenue, but require value-added materials, improved quality and security of supply.
Costs for high quality recovered materials	Transport costs may be relevant considering the location of the involved stakeholders (collectors, recyclers, end-users, etc.).

## 2. Conclusions

Industrial symbiosis network sometimes needs intermediate steps to treat waste flows in order to achieve high-quality in exchanged resources, in particular in products/components and materials. Several examples can be described, e.g. in the construction and demolition sector (e.g., deconstruction instead of demolition, zero waste and life-cycle approach in new buildings), in automotive industry (e.g., products/components re-use, technological innovation in low-grade and high-value non-ferrous metal recovery), in Waste Electronic and Electric Equipment (WEEE) (e.g., re-use network, benefit from producer responsibility – IPR, EPR schemes - in end-of-life management).

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# FIRST CONSIDERATIONS ON THE APPLICATION OF INDUSTRIAL SYMBIOSIS IN ITALIAN ECOLOGICALLY EQUIPPED INDUSTRIAL AREAS

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## Introduction

The idea of Industrial Symbiosis is developing all around the world, and also in Italy some experiences indicate that there is a growing interest for this kind of approach.

However, there are still some points that need to be addressed, if we want to have a clearer picture about its possible diffusion, its potential beneficial effects, and the conditions to make it successful.

## 1. Definitions

Besides the expressions of “Industrial Symbiosis” and “Industrial Ecology”, different terms are commonly used in scientific literature, but also in administrative contexts, that include a form of industrial symbiosis.

For example, the concrete experiences of industrial symbiosis are referred to as “Green Industrial Parks” [1], or “Eco-industrial Parks” [2], or also “Ecologically Equipped Industrial Areas” [3]: probably these terms comprise a certain meaning overlap; however, a review of these expressions could even reveal some specific sense.

Furthermore, a more quantitative approach to assess the success of an industrial symbiosis case study should generally be introduced, instead of a simple description of the closure of some previously open flows.

This could be made by the application of some methodologies for the quantification of environmental impacts, e.g. LCA [4], which could provide environmental benefits in terms of amount of waste diverted from landfill, or CO<sub>2</sub>-equivalents not emitted, or non-renewable sources saved; or other procedures which could supply some figures about the relative importance of the introduced symbiosis with respect to the market volume of the exchanged resources.

## 2. Italian experiences

Apart from the case of the Industrial Symbiosis Platform recently conceived in Sicily Region (by the agreement between ENEA – Italian Agency for New Technologies, Energy and Sustainable Economic Development, and the Regional Federation of Industries), other attempts of introducing some principles of Industrial Symbiosis has been performed also in Italy.

In particular, some so-named Ecologically Equipped Productive Areas (APEA, in Italian) have been established in different Italian Regions, as in Emilia Romagna. However, often the aims are more specifically addressed at pooling and sharing different services, rather than closing economical and technical cycles. For instance, these goals are set: energy saving (buildings and public lighting); cogeneration from biomass and district heating; environmental protection (wastewater and rainwater recovery, green safeguard); waste management (separate collection).

Maybe, the envisaged future constitution of different technological platforms, at different levels (national, regional), could be the occasion, if an excessive stress on the specialization of the different supply chains is avoided, of making many productive sectors interact each other, in a synergic way, building beneficial networks.

## 3. Some critical parameters for the constitution of eco-industrial parks in the world

In a review of different case studies found around the world, on the scientific literature and in some informative websites, a number of critical parameters have been pointed out, which must be considered to estimate the validity of the initiative:

- among the parks that are promoted, some have only been planned, while some others have already been realized;
- in many cases, the intervention have been made as a recovery of old productive sites, while other times are entirely newly conceived;
- who are the owners / the promoters? If they are public bodies or private companies, the interests could vary greatly, ranging from the economical to the ecological – social perspective. An economic support, further to the contribution of the single companies present in the area, could be provided by an external fund;
- they can be mono- or multi-sectorial districts;
- the number of players could vary in a wide range: the obtainable outcome and the degree of interaction is strictly dependent on the amount of organizations that take part to the initiative
- no type of environmental certification exists at the moment, which could encompass an entire industrial park or district.

#### **4. Conclusions**

Notwithstanding the different expressions used to identify the applications of industrial symbiosis, many examples can be found around the world.

They can be distinguished by several parameters, and the number of participants, the contribution of public funding, as well as the possibility of working on new situations, instead of recovering old plants, are all critical points that could make an initiative successful or not.

A quantitative approach to validate the significance of an application of industrial symbiosis is always recommended, in order to better evaluate the possible exportability of the model.

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# AN INDUSTRIAL SYMBIOSIS PROJECT FOR THE TARANTO PRODUCTIVE DISTRICT

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## Introduction

The manufacturing district of the province of Taranto, located in the south east Italy in the Apulia region, is characterized by the presence of the big industry together with a large number of small and medium-sized enterprises. The most important firms are: ILVA, a steel making plant with a maximum production capacity of 11.5 Mt/year of steel; two thermal electric co-generation power stations, located in the ILVA site, that use exhaust gas to produce electricity and steam; Cementir, a cement factory that uses blast furnace slag from the steelworks to produce cement; ENI refinery with a maximum production capacity of 6.5 Mt/year of refined crude oil; the area of the port of Taranto, the third biggest in Italy, composed of a military port a commercial port and an industrial port used mainly by the steelworks factory, the refinery and the cement factory; Appia Energy, a power plant that manages waste to produce refuse derived fuel (RDF) for its electric energy power station; the Alenia Composite site (of the Finmeccanica Group) that produces sections of the Boeing 787 Dreamliner fuselage; the Dreher/Heineken brewery, one of the largest in Italy with a maximum beer production capacity of 200 Ml/year.

For a long period, the production area was declared a high risk of environmental crisis, because of the large amount of pollutants being discharged into the environment by the enterprises of this area. Therefore, searching for possible solutions that can alleviate the environmental impact of manufacturing activities, while safeguarding jobs, is always a current issue. One possible solution may be sought in the application of the industrial ecology tools and particularly in that of industrial symbiosis (IS) to the province of Taranto.

These considerations gave birth to the project "Application of principles and tools of industrial ecology to a wide area", funded by the Foundation Caripuglia; the aim of the project was to identify current and new potential industrial symbiosis interactions among the firms located in the area.

## 1. Methods

The objective of the project was performing a feasibility study of the possible application of IS approaches to the industrial sector of the Taranto province. Specifically this work aimed to identify hot-spots and critical issues of the provincial industrial district and also aims to identify current and some new possible IS interactions among the firms of the district, in order to develop background information that could be used in the future as a first step towards a practical implementation of IS projects within the province. In order to achieve the above mentioned objectives the work was organized as follows.

For the application of industrial symbiosis to a large area, there is no standardized methodology, so the research methods adopted proceeded as follows. The first stage involved an economic and environmental study of the productive district in order to identify who the potential actors could be in a IS scenario applied to the district. Following this first stage, waste and energy analysis were performed. Based on the collected information, some possible synergic-symbiotic interactions to optimize the exchange of matter and energy, for the industrial district, were developed. Finally some preliminary ideas of further development of IS in the district were formulated.

## 2. Results and discussion

As regards the economic analysis, the project highlighted that, together with the largest firms mentioned above, there is a large number of small and medium-sized enterprises; when considering the provincial industrial firms registered as active units, 23% of these operate in the food and drink sector, 20% in the metal products sector, 10% in the clothing sector, 10% in the non-metal bearing

mineral products sector and 7% in the wood products sector. From an environmental point of view, as expected, the most impacting industrial firms in the province are the large ones that were previously identified during the economic mapping of the area. The main emissions and impacts of these large industrial complexes are typical of industrial areas (e.g. CO, CO<sub>2</sub>, sulphur oxides, Nitrogen oxides, dust, noise) with the addition of benzo[a]pyrene, heavy metals, dioxins and volatile organic compounds which are typical emissions of steelworks plants and refineries.

By analyzing the provincial information concerning the industrial waste generated in 2008, what emerges is a yearly production of 3.17 Mt of waste, whilst 3.99 Mt are recovered or disposed during the same year. This implies that nearly a million t of waste is originating from outside of the province. Of the waste produced, over 53% is produced from thermal processing and one quarter is due to construction and demolition activities. The waste recovered, approximately 3 Mt/year, mostly originates from thermal processing (50%) and from the construction and demolition activities (29%). However 90% of the recovery includes activities such as composting, land filling, spreading on ground and stocking for future recovery. Such activities could be substituted with others that involve a more efficient and useful recycling of the waste.

For what concerns energy, by looking at the data regarding the consumption per sector, what emerges is that the industrial sector is responsible for 87% of the energy consumption whilst other sectors (residential, tertiary, agriculture and transport) are responsible for the rest. When considering the transformation losses in terms of cooling water, a total of 1018 kt is sent out to sea without any heat recovery from the main power stations in the province. Of this total 88% derives from the steelworks power stations.

Starting from these data the project identified some new possible symbiotic interactions that could be achieved in the province. For each of the types of waste, some alternative uses were identified as reported in Notarnicola et al. (2012) [1]. For example, the 1.5 Mt/year of blast furnace slag, generated by the steelworks plant, 85% of which is exported to south America, could be used to produce asphalt based paving, marine embankment containment, bricks, mineral wool, improvement of soil structure, glass and fertilizers. The 1.5 Mt/year of basic oxygen furnace slag, generated by the steelworks and currently used for land filling, could be used to produce cement, road construction material and systems for phosphorous removal from waste water.

### **3. Conclusions**

The study entailed in this project has highlighted various aspects of the possibility of implementing IS into the industrial district of the Taranto province. The economic, environmental, waste and energy analysis of the provincial industrial sector has identified who the key players of a IS scenario in the province could be. Moreover the study has identified some of the new possible IS interactions in the province, especially among the larger industrial complexes. The effective creation of such synergies represents a chance to make the Taranto province industrial system more competitive and environmentally sustainable.

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# NATIONAL INDUSTRIAL SYMBIOSIS PROGRAMME (NISP): CONNECTING INDUSTRY, CREATING OPPORTUNITY

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## Industrial Symbiosis

Industrial symbiosis identifies unused resources and waste streams from one industry for use by another. The idea of industry finding uses for non-product outputs (by-products and waste) is not a new one [1]. The practice fell out of favour in the 20<sup>th</sup> century due to: cheap and abundant energy, resources, and disposal options; subsidies that discouraged recycling; and regulations preventing reuse [2]. Recent volatility in commodity prices, along with the rise of the sustainable development agenda, is now leading many stakeholders (public and private) to reconsider this position.

Industrial symbiosis (IS) engages diverse organisations in a network to foster eco-innovation and long-term culture change. Creating and sharing knowledge through the network yields mutually profitable transactions for novel sourcing of required inputs, value-added destinations for non-product outputs, and improved business and technical processes [3]. Various delivery models of IS have developed around the world; key differences are the geographic scale of the effort (organisation to organisation, organisations in a defined area such as an industrial park or zone, across a city or region, national or international) and whether the IS opportunities (called synergies) are actively facilitated by expert practitioners. The model devised and managed by International Synergies Limited is a facilitated model operating at the national scale in the United Kingdom, and at other scales around the world. International Synergies Limited has developed global expertise in IS, instigating programmes in Europe, Asia, Africa, and North and South America.

## 1. NISP in Europe

The National Industrial Symbiosis Programme (NISP) was initiated by International Synergies Limited in 2003 in 2 English regions and Scotland. In 2005, the UK government provided the investment necessary to roll out NISP nationally. The NISP network has been running on a UK national level for the past eight years, engaging different industries (of different sizes and capacities), government bodies and research organizations, to identify and facilitate economically viable solutions to business challenges.

NISP has been identified by the European Commission as the most effective resource efficiency policy amongst 120 reviewed across the world [4]. NISP has been proven to stimulate economic growth, create new jobs and help businesses make the transition to a low carbon economy – all while generating a net contribution to the Treasury. NISP delivers these benefits to the UK economy for outstanding ‘value for money’ 2005-2013 (Table 1). Independent economic analysis [5] has demonstrated that NISP has generated €1.7 billion to €2.9 billion of Total Economic Value Added (TEVA) for the UK economy, equating to a multiplier effect on Government investment of between 53:1 and 88:1. NISP’s impact stimulates increased Income Tax, Corporation Tax and Value Added Tax for UK Government.

Industrial symbiosis is increasingly seen as a strategic tool for delivering economic development, green growth, innovation, and resource efficiency. NISP was cited as best practice under the EU Waste Framework Directive (2009) and incorporated as best practice in the Resource Efficiency Flagship Initiative, part of the Europe 2020 growth strategy for Europe whose vision is a “smart, sustainable and inclusive Europe.” The launch of the Resource Efficiency Flagship Initiative led to the publication of the *Roadmap for a Resource Efficient Europe* (2011), which recommends exploiting resource efficiency gains through IS as a priority for all member states. DG Enterprise and Industry has since incorporated IS into its policy *Sustainable industry – Going for growth & resource efficiency* (2011); DG Regions into *Connecting Smart and Sustainable Growth* (2012); and DG Environment into

*Opportunities to business of improving resource efficiency* (2013). As recently as March 2014 the final report of the European Resource Efficiency Platform (EREP), Manifesto and Policy Recommendations states that Member States “should foster a network of industrial symbiosis initiatives.”

**Table 1 – Externally verified results from NISP England, 2005-2013**

<i>Externally Verified NISP Outputs (England)</i>	<i>2005 - 2013</i>	<i>5-Year Persistence</i>	<i>Investment per unit of output</i>
Additional Sales	€251 M	€1,255 M	3.6 cent per € income
Cost Savings	€257 M	€1,285 M	3.6 cent per € income
Jobs Created	10,000	N/A	N/A
CO <sub>2</sub> Saved	8 Mt	42Mt	74 cents per t
Water Saved	15 Mt	73Mt	43 cents per t
Waste Diverted from Landfill	9 Mt	47Mt	67 cents per t
Hazardous Waste Eliminated	420 kt	2Mt	€14.99 per t
Virgin Material Saved	12 Mt	60Mt	53 cents per t
Private Investment Leveraged	€380+ million	N/A	N/A

## **2. Success factors of NISP**

Three factors are critical for an IS programme to successfully deliver outputs: an extensive network of organizations, expert practitioners dedicated to facilitating the opportunities, and a fit-for purpose data management system. Taking each of these in turn:

The network is the channel through which NISP collects resource data and identifies potential synergies. By engaging a diverse network (including companies, innovators, entrepreneurs, regulators, academics, regional government), the programme creates the conditions that foster innovation – connecting the problem solvers with the real challenges being faced by businesses wanting to improve performance. An emphasis on demand-led innovation drives close collaboration with entrepreneurs, researchers, academics; and a relationship with the regulator gives access to information about the nature and location of materials that could be turned from wastes to resources while clarifying the regulations to businesses.

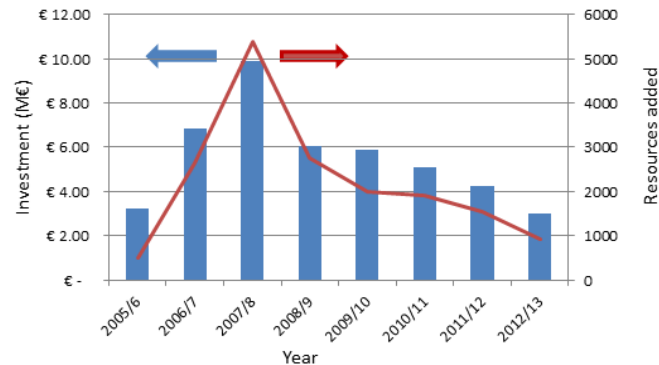
The plethora of ideas identified through the network does not carry through to completion unassisted. It is not sufficient to identify, for example through a waste exchange, that one party has waste sand, and another needs an inert filler for a consumer product application, if the two parties are not traditionally within each other’s’ supply chain. The expert facilitators’ role is to stimulating the breadth of thinking critical to identifying novel connections. S/he proactively intervenes as needed to make connections and facilitate communication across sectors. The role further requires shepherding opportunities through to completion, in some cases helping to navigate around technical, financial, or regulatory barriers. The ideal expert facilitators have industrial experience, the ability to marry data and expert knowledge, and work with regulators and technology providers to enable IS activity.

As the network grows, so does the amount of data that needs to be managed effectively. Regulatory data is a welcome addition to the data set, but the core of the data coming directly from companies tends to derive from process flows that are not regulated and thus not reported. Based on the experience of managing data from over 15,000 companies, International Synergies developed the SYNERGie™ database platform specifically to manage the large quantities of data with a taxonomy designed to facilitate creating matches between resources. The taxonomy also allows for classification of non-waste resources (including expertise, logistics, excess capacity, furniture and equipment, for example) as those resources also often can be rehomed.

Experience in the UK further evidences the need for investment (largely in expert facilitators) to deliver outputs.

In Figure 2, investment in NISP is charted (left axis in blue) with resources captured (and thus available for synergies, right axis in red). A strong correlation between active facilitation and outputs is evident – the database alone is not sufficient to deliver outputs.

**Figure 2 – Correlation between government investment in NISP England (a proxy for staffing levels, left axis in €Millions) and resources added to the SYNERGie™ database (right axis) for 2005-2013, demonstrating the importance of active facilitation**



### 3. Innovative Industrial Symbiosis

Key locational factors affecting business investment are many and varied: infrastructure (transport and services), physical location, availability of skilled labour, cost and supply of raw material inputs, cost and management of by-products and waste, availability of finance and capital. The relative importance of these factors varies with industry sector; across industries, however, increasing environmental standards and volatile commodity markets are powerful drivers. This trend is not a short-term one and efficiency in using resources is becoming a major factor in competitiveness.

Mapping resource data from thousands of companies enables us to understand what and where materials, energy, water, technical innovation, capacity and logistics are in a given area. If used effectively alongside other regional and national datasets, this intelligence-based IS can inform regional spatial planning by identifying recoverable and reusable resource assets and identify and attract sustainable inward investment. It can also be used to identify geographic regions or sub regions that are prime candidates for eco-industrial cluster development. Industrial symbiosis has been adopted for economic development by cities and regions around the world, ranging from Birmingham UK to Turkey.

International Synergies continue to develop new strategic applications for industrial symbiosis, particularly related to regional economic development and regeneration that complements the demand-led model described above by making the connection between successful symbiosis, wealth and job creation. An example of this can be seen in the City of Birmingham, which played host to the first International Working Conference on Applied Industrial Symbiosis in 2012. More recently, Birmingham City Council (BCC) looked at ways to ‘exploit’ industrial symbiosis to help achieve its vision for a low carbon future for Birmingham, creating links between planning framework and policy, sustainable energy and CO<sub>2</sub> emissions reduction and the green economy. As part of this, BCC commissioned International Synergies to undertake a study looking at industrial symbiosis as a development approach for an established industrial area, a large part of which has been designated as Tyseley Environmental Enterprise District, one of six economic zones in the city.

The study highlighted many opportunities to support immediate and long term business growth and helped create a vision for the future. The study identified commercial opportunities for the recovery of precious metals, rare earth elements and other critical materials from local resource flows in the enterprise district that would yield immediate business benefits and the potential to reduce future dependence on imports. The study also provided BCC with key intelligence on opportunities to generate low carbon fuel, pinpointing energy technologies and feedstock available to meet local energy requirements and reduce carbon emissions.



*“Birmingham is wholly committed to sustainable urban development, which is underlined by the city’s Green Commission and Carbon Roadmap. Our role as chair of the EUROCITIES Environment Forum reinforces our commitment to working with European partners to tackle waste and resource inefficiency issues. I am delighted that Birmingham-based International Synergies Limited is leading the way through its widely respected industrial symbiosis programme, the application of which is rapidly gaining traction globally. It is now up to our cities and businesses to embrace the industrial symbiosis model to help meet their own resource efficiency challenges.”*  
*Sir Albert Bore, leader of Birmingham City Council*

#### **4. Conclusions**

Facilitated industrial symbiosis has proven itself a powerful tool to advance resource efficiency and eco-innovation. There are many delivery models of IS, however, the factors critical for success include an extensive network of organizations, dedicated expert practitioners to facilitate the opportunities, and a fit-for purpose data management system. This business-led, facilitated model has been successfully deployed around the world as a pathway to a low-carbon sustainable economy, advancing delivery against the climate change and resource efficiency agenda.

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# INDUSTRIAL SYMBIOSIS AND ENVIRONMENTAL EQUIPPED INDUSTRIAL AREAS

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## Introduction

A national law in Italy defines the features of *Environmental Equipped Industrial Areas* (EEIAs). EEIA is an industrial area with environmental high quality standards and innovative services for enterprises. EEIA's concepts include aspects related to eco-industrial park and cluster environmental management.

The law introduced EEIAs in 1998 and stated that Regional Authorities could issue regional acts to define the EEIA's development in their territories.

In 2010-2011, ERVET carried out a survey about the development of EEIAs in Italy [1]. The survey has been promoted by Cartesio Network, a network aimed to diffuse sustainable practices at cluster level. Emilia Romagna Regional Authority is member of the Cartesio Steering Committee and ERVET is member of Cartesio Scientific Committee.

EEIAs have conditions that ease the development of industrial symbiosis (IS). In this paper will be analyzed the diffusion of EEIAs in Italy and advantageous features for IS.

## 1. EEIAs' state of the art

EEIAs are ruled by a national law. This law defines three main characteristics [2]:

- EEIAs have systems and infrastructures for protection of health, safety and environment
- EEIAs are characterized by a centralized management of infrastructures and services
- companies sited in an EEIA are exempt from environmental authorizations acquisition

An EEIA's design is driven by some principles:

- Health and hygiene in job places
- Air, water and soil pollution prevention
- Waste recycle
- Waste water management
- Resources sustainable use
- Industrial risks prevention, management and control
- Sustainable mobility of people and goods.

EEIAs represent an opportunity to integrate environmental protection, land planning and enterprises competitiveness [3]. EEIA principles demand high performances in infrastructures, plants and services for enterprises.

The main innovative aspect of an EEIA is the EEIA's manager. The manager is the driving force of the area and is responsible for collective infrastructures and centralized services.

Actually the Italian Regions that issued regional acts on EEIAs are Abruzzo, Calabria, Emilia Romagna, Liguria, Marche, Piedmont, Puglia, Sardinia and Toscana.

In every regional law, the foreseen steps to become an EEIA are the following:

- definition of industrial area manager
- environmental analysis of industrial area
- environmental program of industrial area
- monitoring of industrial area environmental performances

Examples [4] of detected infrastructures are:

- collective waste platform
- renewable fonts energy production plant
- collective water treatment plant
- landscape mitigations.

The survey identified some dozens of industrial areas engaged in a qualifying path towards EEIA. This path is running but surely is not ended. The economic crisis has, from 2008, slowed down the investments and, consequently, the full development of EEIAs.

The figure of the EEIA's manager is growing, but is new for Italian industrial system. The role of EEIA's manager is aimed to:

- EEIA environmental performances monitoring
- environmental program management
- EEIA management of energy, waste, mobility and safety
- management of industrial area's plants and common spaces
- territorial marketing
- technical and administrative support to enterprises.

Today only some industrial areas have developed green innovative centralized services for enterprises, but the skills able to fully push the environmental performances of EEIA could be gradually developed.

## **2. Opportunities for Industrial Symbiosis in EEIAs**

The development of IS at industrial area scale in Italy has to match these difficulties: lack of investments, reduction of industrial areas growth, manufacturing sector crisis, little dimension of industrial areas, productive characterization.

But an EEIA is not a traditional industrial area. As explained in previous paragraph, some features has the potential to strongly support the IS [5]. In particular:

- the presence of an EEIA manager and centralized services as area management of waste, energy and water
- environmental analysis and performances monitoring that foresee analysis of raw materials and waste (mapping of input/output)
- definition of an environmental program that can be aimed to support the development of IS, eco-design and SMEs competitiveness
- simplifications for enterprises, supporting the closed cycle of materials.

## **3. Conclusions**

EEIA is a suitable tool to develop industrial Symbiosis. Big opportunities are related to the presence of a cluster manager that can guarantee: availability of data, integrated management and strong connection with companies.

Moreover, every EEIA has an environmental program aimed to pursue sustainability and competitiveness. Program has quantified targets. These targets could involve waste recycling and resource efficiency. Industrial Symbiosis is a way to reach these targets.

EEIA system could boost IS not only inside a single industrial area, but also among areas, on the basis of a network of EEIA manager active at regional scale (as for the Emilia Romagna region). This network is able to detect and exploit exchange opportunities of material, energy and water.

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# INDUSTRIAL SYMBIOSIS AND PRODUCTIVE AREAS

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## Introduction

The close relationship between economy, employment and social progress is the basis of the strategic policies of the European Union in Europe2020. Not by chance the keywords of the policies in the coming years will be sustainability [1], inclusiveness and intelligence. From an operational point of view, this means betting on a society based on the respect for the environment, innovation and new technologies, on equal opportunities for the different segments of citizens Europe is composed of. Also in Italy, now aware of the challenge represented by green economy, we have tried to translate the opportunities and potential into concrete projects that can be realistically pursued. The “Roadmap for the green economy” presented each year at Ecomondo shows many productive areas to invest in: eco-innovation, eco-efficiency, recycling and renewability of materials, efficiency and energy conservation, development of renewable energy sources, environmental protection and enhancement of ecosystem services, development of eco-agricultural sectors and development of sustainable mobility. With the green economy, ecology and economy go hand in hand with each other.

## 1. Methods

An attempt to apply the principles of green economy in the relevant sectors of European economies has been achieved through the development of eco-industrial parks and through the promotion of projects based on the principles of territorial marketing and, more specifically, on green marketing aimed at promoting the local development. The characteristics of eco-industrial parks [2] can be summarized as below: planning of exchanges of resources between the businesses settled in the industrial park, integrated system for the minimization of the use of energy and raw materials in the industrial park, integrated system for the minimization of waste material, construction of environmentally, socially and economically sustainable relationships between the businesses settled in area, integration among all the activities in the area and among those and the environment.

Organizational and conceptual models are gradually emerging and they distinguish different types of eco-industrial parks. Indeed, we can identify some main types: *industrial symbiotic system*, aggregation of only industrial assets and activities with relations of exchange of waste-resources and integrated management systems for resources; *mixed system*, aggregation of not only industrial assets but also agricultural, residential and service ones, where the aggregation is based on the recovery and the re-use of resources; *virtual symbiotic system*, network with the exchange of resources between industrial activities not distributed in the territory.

The development of eco-industrial parks may also represent an original path with a high impact to the theory of Gunter Pauli dealing with Blue Economy. The conceptual proposal of G. Pauli is intended to reproduce in industrial processes the same mechanisms that operate in ecosystems and in the cycles of transformation of energy and natural resources. This principle is defined by G. Pauli biomimicry, in order to emphasize the strict adherence of industrial processes to ecological ones. Closing cycles of resources will reset the impacts on the surrounding environment, it will increase the energy and environmental efficiency, it will encourage the research and development of new and improved technologies based on knowledge and innovation processes. Finally, there will be positive effects on economy, on jobs, on new businesses. Ultimately it sets in motion a truly virtuous circle able to generate development, knowledge, innovation and wealth on a large scale, especially in those areas of the world that are in search of new projects that can guarantee increased prosperity and quality of life for population [3, 4].

## **2. Results and discussion**

How to spread sustainable practices in the Mediterranean productive areas enhancing at the same time the attractiveness of territories by developing strategies for green marketing. These are, very briefly, the objectives of the project MER (Governing Innovative Marketing and Industrial Areas), a project developed within the European MED Programme. This programme aims at stimulating the interregional cooperation between European countries in the Mediterranean area: France, Italy, Spain, Greece, Portugal, Slovenia, Malta, Cyprus. The thematic areas covered by the programme are some of the most important for the economic and social development of the Mediterranean countries: renewable energy, innovation and technology transfer, sustainable mobility, cultural and environmental heritage are some of the main issues experimentation and cooperation initiatives. In this context, the project MER is based on the principle that the green promotion of territories and industrial areas is a key value to invest on. MER project will work to make green marketing a tool for integrated governance of industrial areas, contributing to improve the competitiveness and attractiveness of the Med area according to Europe 2020 targets for a sustainable growth [5].

All the countries participating in the MED Programme take part to the MER project through the following organizations: Province of Bologna (lead partner of the project), ENEA, Informest (Institution for the development of international cooperation of the Regions Friuli Venezia Giulia and Veneto), University of Algarve (Portugal), MIEMA (Malta Intelligent Energy Management Agency), FVMP (Valencian Federation of Municipalities and Provinces , Spain), CEEI Valencia Business and Innovation Centre (Spain), UIRS Urban Planning Institute of the Republic of Slovenia, Anatoliki Development Agency (Greece), Chambers of Commerce of Nice (France). Within MER there will be the arrangement of both tools to encourage the awareness of good practices developed in the different countries of the Mediterranean addressed to the partners of the project and tools for the network of stakeholders that can be involved in the development of marketing actions and in the design of actions for the governance of production areas. Wide space will be reserved to study visits open to entrepreneurs and experts (or actors belonging to specific areas crucial to the local economy), to the realization of integrated guidelines to develop services and actions for the management of productive areas; to training packages for operators and for economic and institutional actors involved in local development. The project, in its final part, also intends to produce documents commitment for the cooperation for green marketing underwritten by entrepreneurs, local authorities, business associations, research centers and universities. The aim is to clarify and make explicit the commitment of economic actors to act jointly. All these efforts are aimed at developing with determination local marketing strategies and to promote green economy [5, 6] in the European regions participating in this important European initiative.

## **3. Conclusions**

The green marketing applied to productive areas is a still largely unexplored theme. While there are many experiences in the field of marketing for green products and services, there are few proposals for green marketing targeted to whole areas [6]. Anyway the local development and competitiveness of the European countries in the coming years will depend more and more on the capacity of these areas to offer innovative services to businesses. The European regions of the Mediterranean area can effectively intercept the demand for high quality of life and high environmental quality, that are becoming increasingly important social themes, and they can use these common needs to effectively promote their industrial areas. As in the past, there were forms of green supply chain in production, today it is essential to focus on optimizing tangible and intangible exchanges between companies, by applying industrial symbiosis at the national level. The principles of biomimicry and closing cycles of resource use in the productive areas may represent factors of innovation, efficiency and can minimize wastes and adverse impacts on the environment. Close the circle as nature does can become economically, as well as ecologically, convenient.

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# FEATURES, POTENTIAL AND LIMITS OF INDUSTRIAL SYMBIOSIS DEVELOPMENT IN EXISTING LOCAL PRODUCTION SYSTEMS. ANALYSIS OF THREE ITALIAN CASE STUDIES

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## Introduction

Industrial Ecology (IE) and Industrial Symbiosis (IS) engages communities of co-located companies in a cooperative management of material and energy flows in order to increase their economic and social performances from an eco-compatible point of view.

The Italian model of industrial development found in Local Production Systems (LPS) its highest form of affirmation [3]. According to several authors, two key aspects of the IS are the collaboration between companies and the possibilities offered by territorial proximity [4], two items recognized as typical of the LPS Italian. These conditions should make them ideal settings for the development of IS. The paper presents different case studies on three LPS present in the Abruzzo region operating in the chemical sector (Province of Pescara), in the automotive sector (Province of Chieti), and in the food industry (L'Aquila Province) [5, 6, 7]. For each of the three contexts alternative solutions inspired by the IS were proposed. The characteristics and potential of development of the IS were then discussed in order to highlight the possible contributions both methodological application.

## 1. Methods

The study focused mainly on the analysis of material flows (products, by-products and waste) and the synergies between the involved companies. The proposed solutions allow identifying alternative scenarios related to an eco-efficient management of these flows.

Research activity was structured into two phases: a preliminary desk analysis and an on-site data collection. The desk analysis started with a literature review. The on-site activity was performed by using questionnaires, technical reports, direct and e-mail interviews of the leaders, site visits and focus groups. Data were collected in a database and used to identify potential development of the IS and the most suitable approach for the specific characteristics of each context.

## 2. Results

Preliminary analysis showed a regional manufacturing particularly rich in highly diversified industrial settlements between them, from the standpoint of historical, geographical and sectorial.

Under the three contexts above mentioned, some factors were assessed as potentially relevant to the development of industrial symbiosis: *the level of analysis; the technical equipment and infrastructure of the area; homogeneity of enterprises; the involvement of stakeholders; the regulatory system.*

The level of analysis for each case study consists of a set of enterprises co-localized in a specific area, with internal distances between 5 and 25 km away. This geographical dimension is typical of Italian LPS, unless extended for an entire region, but large enough in terms of variety and number. The contexts had a good plant equipment and infrastructure although in some cases an underutilisation of resources and potential collaboration between companies were found. In one of the three case study a plant for the production of energy was present (chemical LPS).

Each one of the singles case study, corresponding with a particular industrial area, is quite homogenous in its composition; nevertheless the three industrial areas are quite different each other and, according to studies carried out, a good complementarity has emerged, such as to highlight interesting synergic possibilities at regional level.

Stakeholder involvement has played a significant role in each examined context, in terms of availability and support from government bodies and local authorities, associations, research centres and public opinion.

With regard to the regulatory system, to date, in Italy there are laws that encourage the adoption of eco-industrial development strategies at local level, even if still little applied. On the other hand, the current rules on waste management prevent direct reuse of waste material from other companies and this requires the presence, in the case of implementation of solutions based on IS, at least one person authorized to carry out such activities.

### 3. Conclusions

The three analysed contexts have shown, in general, a good predisposition to accept the proposed solutions. From the standpoint of theoretical interpretation, the research confirms the need to address the development of the IS through a systemic view of the involved phenomena, through a holistic perspective, which takes account of all the presents elements and their relations. From the methodological point of view there is a need to use a multidisciplinary approach, based on contributions from various disciplines, such as the regional economy, the social sciences, studies of organization and innovation. From the application point of view, it is shown the innovative character that distinguishes solutions based on IE that affects the related processes of adoption and diffusion.

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# INDUSTRIAL SYMBIOSIS AS AN OPPORTUNITY FOR THE DEVELOPMENT OF ENVIRONMENTAL EQUIPPED INDUSTRIAL AREAS

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## Introduction

As an element of Industrial Ecology, Industrial Symbiosis may become an excellent tool to improve industrial development with particular focus on the Environmental Equipped Industrial Areas (EEIAs, in Italian APEA - Aree Produttive Ecologicamente Attrezzate).

The Industrial Ecology is based on 11 principles written by Allenby in 1955 [1] which are focused on prevention of waste production, green chemistry, synthesis of non-toxic compounds and use of renewable energy sources. Two of these principles inspire also the Industrial Symbiosis:

- industries have to favour recycling pathways of the resources rather than the extraction and use of raw materials;
- a cross border network must be promoted between materials suppliers, users and companies, in order to cooperate in the view of packaging minimization as well as maximization of recycling and reusing of materials.

Industrial Symbiosis (IS) is the sharing of resources (i.e. services, infrastructures and resources) among industries in order to add value, reduce costs and improve the environment [2, 3].

In Italy a national law (D. Lgs. 112/98) introduced, in 1998, the concept of Environmental Equipped Industrial Areas (APEA, in Italian). EEIAs are characterized by a sole infrastructures and services management aiming at health, safety and environment protection. The implementation of Industrial Symbiosis in these areas is not expressly required by the National regulation. Nevertheless, IS appears to be an excellent planning tool both in the creation of new industrial areas and in the conversion of existing ones [4].

The EU strategies (Horizon 2020 and Cohesion Policy 2014-2020 on the European economy priorities) as well as the regional strategies (S3 Emilia-Romagna Region – Regional technological priorities) strongly encourage the application of IS.

## 1. Report

Industrial Symbiosis gave real results in terms of economic development, saving, reduction of CO<sub>2</sub> emissions and social cohesion worldwide [5,6]. Such good results have been obtained also in Europe, e.g. in the UK, where the background can be considered similar to the Italian context. Several case studies for technical feasibility have been performed in Italy, even if the implementation of IS appears to be infrequent and not commonly known. The difficulties in Industrial Symbiosis application in Italy are mainly due to:

- regulatory and permissions barriers;
- lacking or wrong communication with companies;
- lacking of an impartial coach/leader coordination body;
- lacking of spirit of collaboration between industries;
- resistance by the industries to share sensitive data concerning output materials/resources.

It is not known by the authors an Italian census on case studies, with particular focus on the IS feasibility in terms of either permissions or regulation as well as in terms of existing barriers and socio-economical background. Such information could help choosing the right path and identifying the problems to be solved, in order to improve industrial feasibility of technological and operative processes analysed.

This issue represents a good opportunity for enhancing economic parameters, and for creating new job opportunities.

With a study of existing case studies, the aim is to verify the influence of industries, legislation and willingness to technological innovation have in Italy on the application of these principles.

## 2. Results

The interest towards the concepts of Industrial Ecology and Industrial Symbiosis is increasing in Emilia Romagna Region.

For example, ASTER (Consortium for Innovation and Technology Transfer in Emilia-Romagna), Unioncamere (Italian Union of chambers of commerce, industry, craftsmanship and agriculture) with the technical-scientific coordination of ENEA (Environmental technology technical unit) implemented the "Green economy and sustainable development" project on agro-industry.

Agro-industrial companies, companies using agro-industrial by-products/residues as input resources, research bodies able to perform technical and technology transfer assessments, project managers, an innovation centre, experts in current regulations and territorial policy will be engaged in order to develop further evaluations on Emilia Romagna context. This multi-disciplinary study will be structured in the following steps:

- initial collection of data: technical and scientific studies concerning different industrial sectors (bibliographic research, contact with researchers);
- evidence of real application of the processes (contact with researchers and with companies);
- identification of the barriers for the failed projects;
- identification of the strength points for the successful projects;
- conclusions: identification and illustration of the right methodology for industrial implementation of IS. For comparison, the study may be carried out also on regional, national or international level.

## 3. Conclusions

The check of successful implementation of Industrial Symbiosis processes in Italy represents a further step aimed at demonstrating companies the practical feasibility of models being efficient and effective under social, economic and environmental point of view. Such models can be adopted in EEIA design as well as in productive areas which are interested in an integrated environmental management.

The above said checks has to consider the differences in language, codes, units of measure in order to be as representative and as exhaustive as possible for the regional, national and European territorial context.

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# DEVELOPMENT OF AN INDUSTRIAL ZEROWASTE ECOSYSTEM: INSTRUCTION FOR USE

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## Introduction

A recent study on the development of eco-efficient products [1], highlighted how in the last years, the need to address the issues about unsustainable use of natural resources and waste management, is increased. In such contest the project LIFE+ Mo.Re. & Mo.Re. (More Reusing and More Recycling - LIFE08 ENV/IT/437) tried to give attention to this need. Its object was the establishment of local industrial ecosystems, where the consumption of energy and materials is optimized, and the processing residues can use as raw materials for another process. Mo.Re. & Mo.Re. was an European project started in January 2010, co-financed by the Regione Lazio with the participation as partners of: Province of Rieti, University "La Sapienza" of Rome, Nova Consulting and SDIe Group.

## 1. Methods

Mo.Re. & Mo.Re project was born from the idea to apply the concepts of the market (supply and demand), to waste management, considering the territory not only as a source of waste (supply) but as an area where processes of waste recovery and recycling are or should be localized. The methodology included an initial mapping of the territory, which involved all the production systems in the two geographical areas chosen for the application (Province of Rieti and the Castelli Romani area), as well as associations and local authorities.

Eight supply chain of waste were defined [2]; for each type of waste gap between the "profile of recycling locally available" and the "profile of the production of waste" have been defined. The subsequent comparison allowed defining, for each chain, the "map of the offer" [3], which is a description of each waste material with information about the quantity, availability, and also a technical and qualitative description indicating the possible uses and reuses.

The final step involved the definition of methodologies and application tools to implement the actions necessary to fill any gap previously found [4]. This study has highlighted the need to consider, since from the preliminary stages, the processes of recovery and recycling of waste, as main factors of territorial planning. This allows to understand, in the planning stage, how the flows of materials and energy could be exchanged in the context of industrial complexes and to apply the model of industrial symbiosis [5,6], with a 'close cycles'. The industrial symbiosis ensures that production and consumption of energy, raw material consumption, production and waste management are integrated in an industrial development and the waste from an industrial process is used as production inputs for other processes.

## 2. Results and Discussion

The production system of the "Castelli Romani", one of the two studied areas of the Mo.Re.&Mo.Re. project, shows the prevalence of small and medium enterprises and a widespread handicrafts; there are strong links with the neighbouring Tiburtino, Pontino and Frusinate industrial poles; while seems more recently the spread of tertiary activities and research. This area also presents difficulties and delays in the delivery of infrastructure that not correspond with the demographic and socio-economic dynamics of the recent decades. Currently this area is at a real crossroads on the one hand the qualification o environmental, cultural, business, residential and infrastructure system, to enhance an endogenous development; on the other hand the risk of a worsening of the already heavy subordination to the dynamics of Rome, with consequent loss of identity and aggravation of phenomena of commuting and congestion. Based on collected data [7,8], there was evidence that the area of the Castelli Romani could opt for an industrial symbiosis model according to the characteristics of the territory and the programmatic predictions.

In this area shall be, provided a park for all municipalities of productive activities and of specialized services and on areas equipped for handicraft activities and services for local with a limited size. In general in the entire area can be adopted exchange procedures differentiated in relation to:

- trade in an eco-industrial park;
- exchanges between enterprises outside of a park;
- exchanges between companies virtually organized in a wider territory.

Looking ahead, in the context of territorial policies for the management of waste from production activities, local authorities could usefully apply a business model similar to that adopted in recent years in the UK, where “regional agencies, that operate as independent facilitators providing experts who contact companies of all sizes and from all sectors, have been created thanks to the National Industrial Symbiosis Program, NISP.

### 3. Conclusions

Mo.Re. & Mo.Re project laid the basis to begin a process of change in the management of waste which in particular local authorities should convey. It is necessary to develop a regional policy of waste based on industrial symbiosis. This activity requires a big effort mostly to local governments that have to develop complex policy actions that, in large part, have been traced and outlined in the documents produced during the Mo.Re. & Mo.Re project [3,4,7,8]. In particular, the area of the Castelli Romani, could start immediately a political experimentation oriented to the creation of a zero waste eco-industrial district. In this territory participation, education, culture, infrastructure could feed sustainable economic development, ensuring a high quality of life for citizens and businesses and providing responsible management of natural and social resources, through participated governance.

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## PODEBA: AN INDUSTRIAL SYMBIOSIS CASE

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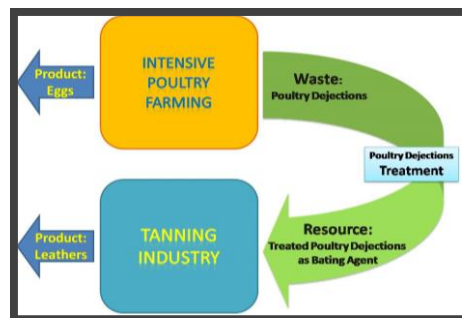
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### Introduction

LIFE project PODEBA (LIFE10 ENV/IT/365, Use of poultry dejections for the bating phase in the tanning cycle) represents the demonstrative phase of an industrial symbiosis case, where the byproducts of agro-industrial production (output) are used, after proper treatment and transformation in DPM (deodorized and sanitized poultry manure), as technical products (input) for tanning industry (bating phase). The goal of the project is DPM application instead of impacting standard industrial formulations for leather production with the reduction of environmental impact and water and resource saving. The use of Poultry Dejections (PoDe) has an historical background due to their content of extracellular enzymes which can weaken the three-dimensional structure of derma, breaking elastin and collagen, swelling and preparing de-limed pelts for tanning phase. This use was abandoned because of high olfactory impact. Within the PODEBA project, different types of PoDe have been tested with different kinds of hides and skins and with the aim to obtain different final leather products (garments, bags, shoes, upholstery). Not all kind of PoDe can perform with the same efficiency both for odour aspects and for pelt maceration in terms of leather structure and cleaning surface. The project, coordinated by ENEA, was carried out together with 3 Italian and Spanish SMEs. Italy and Spain represent 90% of European leather sector. The use of DPM in tanning cycle could drain 2-3% of Italian PoDe production.

**Figure 1 – PODEBA as an industrial symbiosis: transformation of waste from intensive poultry farming into a resource (Poultry manure as bating agent) for tanning industry**



### 1. Methods

PoDe were taken from intensive poultry farms in order to have available amount that are large enough for industrial application and to obtain a standardized final product quality. As provided for in the project, PoDe Bio-Treatment was performed according to the European patented process "A process for maturing and stabilizing biomasses under reduction of smelling emissions" [1], in order to speed up bio oxidation processes and deodorize final product. Treatment consists in adding the patented formulate (VAP) to dried manure directly inside bioreactors (big bags). In bioreactors, manure matures at least for 120 days by means of static batch processes; at the end the big bags are ready for marketing. Two generations of DPM were produced with a slightly modified VAP recipe, which ensures sanitary conditions. Laboratory tests for the use of DPM as bating agent were carried out in order to check its efficiency in comparison with standard formulate (SF) and define the appropriate use condition. Another aim of the test was to verify the effect of the bating agent on olfactory impact both as far as the bating floats and the leather products.

Bating trials were carried out on cow hides which were then treated in order to obtain tight items (for shoes and leather goods) and soft items (upholstery garments) [2]. Furthermore, leather samples were subjected to different quality control processes according to international standards (EN-ISO) to verify their suitability for use in the manufacture of footwear (breaking strength, tensile strength and breaking elongation).

## 2. Results and discussion

The results of laboratory tests, reported in Table 1, are related to standard conditions with SF (Biozym MC/N). The patented PoDe bio-treatment ensures sanitary conditions, but only the new VAP recipe (the one used for the second generation DPM) solved the olfactory issue and was suitable for the purpose of this project. In fact, in the second generation, the new bio-treatment recipe allowed to obtain a DPM that was suitable for bating, since the smell developed during the bating process was very weak, it was not a problem for workers and no effect on finished leather. Final leathers were characterized and properties measured: those obtained with DPM showed pleasant appearance, fine-grain and adequate smoothness, softness, flexibility, and grain firmness. The physical parameters measured in final leathers showed that the recommended values for the manufacture of footwear were achieved. Leather structure, surface cleaning, odours during process, and smell on finished leather were very close to the standard. Implementation of this symbiosis is a strategy to prevent waste production, to save resources and to reduce environmental impact, consistently with the need of European leather producers to exploit more efficiently their raw materials in order to remain competitive in the global market place. It represents a waste prevention device because PoDe are directly treated and transformed into a technical product right on the farm. It saves resources since each ton of DPM used as bating agent prevents the use of 0.3-0.6 t of ammonium sulphate. Also wastewater load is reduced during bating phase by using DPM: more than 40% for TKN and ammonia.

**Table 1 – Results of the odour qualitative analyses of a test without bating agent (without), a first generation PoDe sample (A), and second generation tanning agent ( P), compared to SF**

Trial code	Odour			Final Leathers	
	Smell during process	Smell on wet blue leather	Smell on finished leather	Leather's structure	Cleaning surface
Without	bad	bad	No	quite harder	less
A	bad	bad	No	similar	similar
P	quite similar	weak	No	very similar	similar

## 3. Conclusions

The bio-treatment is suitable to transform PoDe (animal by-product) into a technical product (DPM), a bating agent for tanning. This gives rise to a potential case of industrial symbiosis between agro-industry (egg production) and the tanning industry, as developed in a European project carried out in Italy and Spain, countries that represent 90% of the European leather sector. Technical viability was demonstrated for different types of leather (soft and tight items), for different raw materials (hides, skins) and for different articles (shoes, upholstery). If this solution were applied it could require large amount of PoDe to be transformed into bating agent, (2-3% of Italian PoDe production), reducing the environmental impact.

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# CASE STUDY SPREMBERG: RDF-FUELED CHP PLANT FOR A PAPER MILL

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## Introduction

*TBF+Partner AG* has designed and supervised all construction and commissioning activities relevant to a Combined Heat & Power (CHP) plant located in Germany and fueled by Refuse Derived Fuel (RDF), whose purpose is to supply energy (both steam and electricity) to the local paper mill. Waste products of the paper mill are also used as fuel, in order to feed the CHP plant.

The paper mill of Spremberg is owned and operated by the private company *Hamburger Rieger GmbH*. It started operating in 2005 and its production capacity is 310,000 t/yr.

From 2008 to 2013 a special purpose company named *Spreerecycling GmbH* has undertaken the construction of the above mentioned RDF fueled CHP plant.

## 1. Context description

In Germany, as in more and more EU-countries, the direct disposal of waste into landfill is banned. Furthermore there was no waste-to-energy facility in the surroundings of the Spremberg paper mill. Therefore since 2005 all wastes generated by the industrial plant (mainly pulper and sludges) have been disposed at significant costs.

The process steam (middle pressure level) required by the paper mill has been supplied by a coal-fired thermal plant, whilst electricity has been purchased from the grid. As pulp and paper industries are highly energy-consuming, the energy-related costs are high.

For all these reasons, *Hamburger Rieger GmbH* has taken the decision of constructing its own CHP plant in the paper mill's industrial area, to be fed by RDF available on the market.

*Hamburger Rieger GmbH* has appointed *TBF+Partner AG*, to develop the RDF-fueled CHP plant's design and to follow its construction, start-up and commissioning.

## 2. RDF-fueled CHP plant description

The best configuration of such a RDF power plant has been determined and designed by *TBF+Partner AG*, in order to comply with all needs and requirements of the Spremberg paper mill: high availability, highly variable steam flow demand (varying from 8 to 95 t/h) and important fluctuation in small time intervals (seconds).

The plant is composed by one incineration line, having a conventional grate furnace and a heat-recovery boiler. The flue gas treatment system consists in a quench, gas conditioning (with active coal and hydrated lime) and fabric filter. This configuration allows to respect the emission limits as prescribed by the local regulations.

In order to guarantee the steam supply to the paper mill, the CHP plant also includes two auxiliary boilers. They are permanently in a stand-by status, in order to face sudden stops of the incineration line, as well as possible steam shortfalls.

Middle pressure (MP) steam is provided to the paper mill through a controlled MP extraction in the condensing steam turbine. Continuous operation is guaranteed by two air-condensers: the main one serves the LP steam flow of the turbine, while the second one is used in case MP steam is not required by the paper mill. Adequate redundancies have been designed, in order to guarantee the security of supply required by the paper production process.

The RDF power plant has been erected close to the paper industry and the two plants are connected through pipe-racks for required utilities (i.e. steam, electricity, etc.).

### 3. RDF-fueled CHP plant main data

The RDF-power plant's main characteristics are resumed in the following Table 1.

**Table 1 – RDF-power plant's characteristics**

Description		Value	Unit of measure
Fuel	RDF	196,400	t/yr
	Pulper	10,000	t/yr
	Sludges	31,600	t/yr
	Total	238,000	t/yr
Oven	Waste flow	240,000	t/yr
	Heat capacity	1 x 110	MW
Auxiliary boilers	Heat capacity	2 x 35	MW
	Steam pressure / temperature	11 / 220	bar(a) / °C
Steam production	Nominal steam flow	135	t/h
	Steam pressure / temperature	41 / 400	bar(a) / °C
Electricity	Max. electric energy production	23	MW
Process steam	Process steam nom / max	75 / 95	t/h
	Process steam pressure / temperature	220 / 11	°C / bar(a)

The investment costs for the CHP plant are around 140 Mio. EUR, including electrical, mechanical and civil works as well as all additional costs (design phase, permitting and realization). Its construction works have been divided in 13 functional lots: all interfaces and battery limits through the various lots have required important coordination activities, which have been assured by *TBF+Partner AG*, with the role of Owner's engineer.

CHP plant construction activities started in 2010 and they have been completed by the end of 2012. Start-up activities have been completed in mid-2013. Since then the plant is successfully running.

### 4. Conclusions

The Spremberg power plant has allowed the paper mill to secure a stable and time-lasting energy supply, with competitive prices and independent from external providers: both in terms of electricity and process steam supply. In addition to this, the process wastes (pulper and sludges) disposal costs have been drastically cut.

Many paper mills have undertaken similar investments in the past: Spremberg paper mill is namely only one of the several TBF's references in the paper industry.

It can be therefore stated that wastes and paper industry are a good and well-proven example of industrial symbiosis, where wastes are really resources and not refuses.



# MATHEMATICAL OPTIMIZATION FOR THE STRATEGIC DESIGN AND EXTENSION OF DISTRICT HEATING NETWORKS

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## Introduction

District heating systems (DHS) provide the heat generated in a centralized location to a set of users for their residential and commercial heating requirements. The use of Mathematical Optimization techniques for the strategic design of such networks is strongly motivated by the high cost of the required infrastructures but is particularly challenging because of the technical characteristics and the size of the real world applications. It has received relatively little attention in literature with mainly non-linear models for little instances [1] and empirical simulations [2].

## 1. Method and Objectives

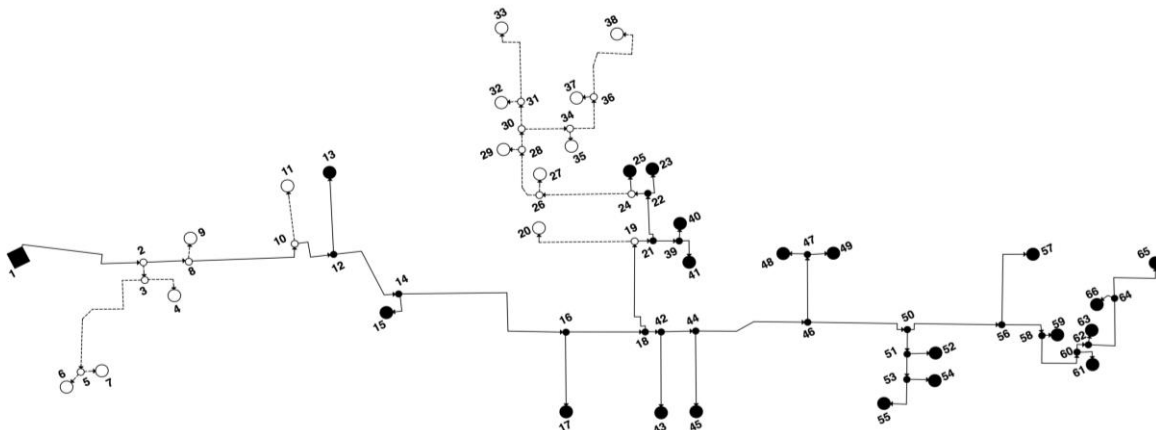
We present a mathematical model based on linear programming and graph theory, developed to support DHS planning. A DHS can be represented by a graph as shown in Figure 1, where the plant is represented by the square node and existing and potential users are identified by solid and empty large circles, respectively. Existing (forward) pipes are drawn as solid directed lines, while potential pipes are represented by hashed ones. The existing and potential intermediate tee nodes (pipe connections) are shown as solid and empty small circles, respectively.

The main objective is the selection of an optimal set of new potential users to be connected to the existing thermal network, maximizing revenues and minimizing infrastructure and operational costs. Further developments of the model are related to existing client contract changing evaluations, selection of the optimal path of pipes through which a potential user can be connected and other strategic analyses that take into consideration yearly construction budget limitations and alternative energy commercialization tariffs. The model considers steady state conditions of the hydraulic system and takes into account the main technical requirements of the real world application.

## 2. Results and discussion

We briefly describe testing of the model conducted on a portion of a real world network, defined during the Innovami Project financed within the regional program PRRIITT, activated by Emilia-Romagna regional authority to promote and support industrial research and technology transfer.

Figure 1 – The real-world network used within Innovami project



**Table 1 – Real world data**

User	Type	Demand (kW)
13	E	1400
15	E	400
17	E	1050
23	E	250
25	E	150
40	E	200
41	E	350
43	E	1050
45	E	1050
48	E	300
49	E	300
52	E	400
54	E	400
55	E	400
57	E	500
59	E	250
61	E	400
63	E	350
65	E	400
66	E	500
4	P	1200
6	P	300
7	P	450
9	P	100
11	P	100
20	P	250
27	P	150
29	P	200
32	P	650
33	P	450
35	P	300
37	P	50
38	P	100

The structure of the network is depicted in Figure 1 and further details can be found in Table 1 where every user node is classified as an existing one (E) or a potential one (P) with the related thermal demand. The existing network is about 4.3 km long and the total length of the potential pipes is slightly less than 1.9 km. Specific data are also defined for the cost of the heat exchangers, depending on the users' demand class, for the potential pipes depending on their diameter and length and for the revenues of the sale of energy. In addition, the maximum pressure at the plant is 9 bar, the minimum pressure at each node is 2 bar and the minimum pressure drop at a user' pipes is equal to 0.5 bar. The model is solved through IBM ILOG Cplex. Two different scenarios are considered, the first one considers a time horizon of 10 years for the computation of net present value of the network. The second considers a reduced time horizon of 5 years only in which pipes costs are reduced by 10% and the user's fee for the connection to the network are increased by 50%. The results we obtained follow: in Scenario 1 the potential users 4, 6, 7, 9, 27, 29, 32, 35 and 37 are selected, while in Scenario 2 the optimal set of potential users to be connected includes 4, 7, 9, 27 and 29. By comparing the two solutions we may observe that some users, such as 11 or 20, are not compatible with the connection in both scenarios. This is either due to the relatively small demand compared to the length of the pipe required to connect them that may make them unprofitable, or to the insufficient capacity of the network due to the limits of the pressure at the plant that does not allow to connect all potential users even when they are profitable (as, for example, user 33). Some other users, such as 6 and 32, which turn out to be selected with the longer time horizon are instead no longer profitable in the second scenario even if the capacity of the network would allow connecting them. Since the optimal solutions for this network can be obtained in few seconds of computation by using IBM Cplex solver, it is evident the great value for decision makers of the model we propose for the evaluation of several alternative scenarios to support the decision process. In particular, we run tests on random networks that we generated through a C++ code with an increasing number of existing and potential nodes and we found out that networks with 1000 existing nodes and 500 potential nodes were easily solved in 29 seconds.

### 3. Conclusions

A valuable tool to support strategic decisions analyses for the optimal incremental design of district heating networks has been studied. An implementation of the model has been incorporated by Optit Srl, an accredited spinoff company of the University of Bologna, into a software tool called Opti-TLR, based on a public domain GIS for the representation of the network and of the solutions. Opti-TLR has been used in the last three years in several projects of DH network design by several mayor utility companies in Italy (i.e. Turin with 116 potential clients and Asti with 865 potential clients). Comparison with hand-made solutions showed average savings of the 30% of the initial investment.

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# THE INDUSTRIAL SYMBIOSIS IN THE REGIONAL WASTE PLAN

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## Introduction

The Regional waste management plan of Emilia Romagna Region has been adopted according to the provisions of the Regional Committee Resolution n. 103 (3 February 2014), and thus can be still modified during 2015. This Plan has the following main goals:

- reduction of impacts on environment and health deriving from waste production and waste management (as stated by the EU Council Directive 2008/98/CE);
- fostering the effective compliance with the European waste hierarchy, which considers as first option the prevention of waste production, followed by materials recovery and, as last option, the disposal.

## 1. The prevention program

According to the article 199 of Legislative Decree 152/06, the regional waste management plans provide a prevention program of waste generation, developed on the basis of the national program of prevention of waste, that:

- Describes the existing prevention measures;
- Fixes more fitting measures;
- Defines the objectives of prevention.

The waste prevention programme of Emilia Romagna Region encourages the practical application of the reduction of waste generation through several actions engaging industries, citizens and Public Administration with the following objectives:

- per capita municipal waste production reduced up to 15-20% with respect to 2011;
- total industrial waste production reduced up to 6% with respect to 2010.

Based on already done experiences as well as on stakeholders recommendations, the regional plan identifies 8 actions (Table 1) which can be integrated in future with additional actions according to a continuous improvement model.

Table 1 – Actions of the prevention programme

Life Cycle phases	Related actions
Production	P.1 - Sustainable design
Distribution	D.1 - Small and big distribution
Consumption	C.1 - Green Public Procurement
	C.2 -Sustainable consumption
Use	U.1 – Waste of goods and resources
End-of-life	F.1 - Reuse
	F.2 - Allocation
	F.3 - Disposal

These prevention actions are mainly focused of municipal waste while the Industrial Symbiosis (IS) is almost completely addressed to special waste.

## 2. The Industrial Symbiosis and the Regional waste plan

Since the achievement of the reduction goals for industrial waste is regulated mainly by market rules, the Plan defines only general strategies and actions.

In this framework, partnership tool is crucial: agreements between main stakeholders of different industrial sectors in order to reduce waste production among different life cycle phases (of goods and services) with the involvement of institutions, industries, research bodies, citizens, associations and third sector.

Industrial Symbiosis represents an important tool and an opportunity for waste prevention and reduction since IS links the following actions:

- reduction of waste production;
- valorisation of regional production system;
- development of short distribution chain.

And, moreover, IS produces economic and environmental benefits.

Thus, Industrial Symbiosis should be encouraged through specific programme agreements and contracts as well as through memorandum of understanding (also for research and experimental activities). New and innovative proposals and project ideas for industrial cooperation may arise from the analysis of the regional industrial production background. The results which can be achieved may allow defining models to be replicated in regional area.

As government body, the Region can:

- facilitate the connections between stakeholders (industries which produce by-products/waste, industries which transform/increase the value of the by-products, research bodies, final users);
- Contributing in defining the framework in which the cooperation between the various actors can be developed;
- disseminate the knowledge of the best practices on waste streams management.

The Italian current regulation (in particular lett. c of comma 1 of Article 184-bis of the Legislative Decree 152/2006) does not help the diffusion and application of Industrial Symbiosis in Italy. Under this regulatory framework it is crucial to intercept the material streams before they become waste! Moreover, to be a by-product, the material generated by a production industrial process has to fulfil the requirements set by the current regulation.

### **3. Conclusions**

The implementation of Industrial Symbiosis can contribute to improve the competitiveness of the regional production system; in addition, this tool is consistent with the regional strategy which, as first objective, has the waste prevention.

As a government body, the Region can facilitate the process by defining a clear reference framework in order to find the most effective solutions overcome problems in interpretation as well as in the implementation which can influence single cases of industrial symbiosis.

# RESULTS OF “GREEN - INDUSTRIAL SYMBIOSIS” PROJECT IN EMILIA ROMAGNA REGION

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## Introduction

An Industrial Symbiosis pilot project was developed within the “Green Economy and Sustainable Development” project in Emilia-Romagna region (IT), organized by Unioncamere Emilia-Romagna and ASTER, with the technical and scientific coordination of Environmental Technologies Technical Unit (now merged in Department for Sustainability (SSPT)) of ENEA; in addition, researchers of the Emilia Romagna High Technology Network have contributed to the project with their scientific and technological expertise. Objective of the project was the development of cross-relations between production sectors, industrial research and territory and boosting circular economy. Since it was a pilot project (the first ever made in the region), it was decided to focus on the chain of reuse and enhancement of agro-industrial waste and residues, with particular (but not exclusive) interest towards solutions aimed at the production of materials with high added value [1].

## 1. Methodology

The application of Industrial Symbiosis has been developed in 9 months, from the end of June 2013 to the beginning of March 2014. Main steps of the project were:

1. Selection of companies and research laboratories to be involved into the project; this task was finalized by Aster, which was the local organizer and promoter of the project and which has a deep knowledge of the industrial network in Emilia-Romagna region. In particular 13 companies, 7 research labs, 1 local authority were invited to take part into the project; promoter, organizer and technical and scientific coordinator (Unioncamere, Aster, ENEA) completed the group.
2. Organization of a Focus Group by Aster, addressed at companies and labs, where ENEA presented Industrial Symbiosis concepts, ENEA’s activity in that sector, and formal contribution was asked to each participant in the project.
3. During the focus group companies were requested to fill-in input-output tables [2], for sharing information on resources used and waste/by-products generated by their production processes; those tables were already prepared by ENEA and previously used in an ongoing project for the implementation of the first Industrial Symbiosis platform in Italy (ENEA, 2011-2015).
4. After the focus group, 10 out of 13 companies provided the requested information filling-in input-output tables; for the development of the project each company was identified with a code (ID code), useful both for data elaboration and for assuring confidentiality. ENEA processed those data in order to send it to the laboratories for their contribution; the role of laboratories role was, in fact, to provide indications about how to valorise resources shared by companies, suggesting technologies and valorisation processes for a productive reuse of industrial scraps. This step was realized using ENEA’s know-how and tools: in particular the <origin-destination> string’s logic [2] and the <origin-destination> strings [2] info collection tables were used. In other words, laboratories gave their contribution filling-in a <origin-destination> string for each resource, shared by companies as an output, for which they could provide one, or more than one, potential destination or, vice-versa, one or more than one potential origin for resources requested by the companies as an input. Laboratories filled-in the <origin-destination> strings and returned them to ENEA for data elaboration.
5. Starting from resources shared by companies and <origin-destination> strings accordingly compiled by laboratories, ENEA processed the data provided in order to identify potential synergies between companies.

6. Results were presented during a meeting with companies and laboratories in order to have their feedback and their actual interest in exploring potential synergies addressed by the project.
7. According to feedback given by companies and labs in the previous step, ENEA provided a further elaboration with the suitable potential synergies.
8. Results of the project were presented in a final meeting organized by Aster, during which also regional stakeholders were involved.

## 2. Results and discussion

Through collaboration of laboratories (LEAP, CiriAgro, CiriEna, Siteia Parma and Cipack) and ENEA, eight main flows were identified: agro-food scrap, industrial lime, packaging, building construction and demolition waste, textile waste, oil refining and natural gas purification waste, waste of woodworking, digestate.

For some synergies, a preliminary processing for enhancement of the resource is required, whereas in others a direct recovery can be assumed. Paths towards final destination to one or more of the participating companies were provided; in addition, also others possible destinations, identified by the ATECO code (i.e. through the codes of classification of economic activities), were suggested. This choice allowed leaving open more chance for participation of other companies not involved in this initial phase of the project, but also the possibility of finding other additional synergies regarding companies already participating. In the end, the following synergies were found:

- 14 paths of Industrial Symbiosis identified by the laboratories,
- 14 paths of Industrial Symbiosis identified by ENEA,
- 19 synergies proposed by the laboratories,
- 50 synergies proposed by ENEA.

The intervention was concluded by stressing that the results presented are potential synergies, but their actual realization needs further steps in economic, logistical, technical and legal – administrative areas, not addressed in the pilot project.

## 3. Conclusions

The application of Industrial Symbiosis has highlighted almost 90 potential synergies both between the 10 participating companies and between these and other companies located in the surrounding area. Results of the project are interesting not only for the large amount of matches but also for the interest in Industrial Symbiosis as a tool for enhancing circular economy.

The actual implementation of synergies, from the idea to its practical realisation, is the object of a second phase of the project, which is ongoing (10.2014 – 06.2015). In this second phase, the following issue will be taken into account for each investigated synergy: Budget and economic issues; Logistics; Technical aspects; Legal and administrative aspects, involving local authorities and control bodies. In parallel, some of the potential synergies previously identified were explored also thanks to the activities carried out in “Pioneers Into Practice” project: staff exchanges between project participants, in order to carry out feasibility studies, were realized [3].

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# SOLAR DISTRICT HEATING BY PARABOLIC TROUGH

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## Introduction

The public company Forlì Città Solare has built a solar thermal power plant in Villa Selva, Forlì (Italy). This is an example of circular and sustainable economy around the APEA (Area Produttiva Ecologicamente Attrezzata). The solar plant was co-financed with the POR FESR 2007-2013 European projects.

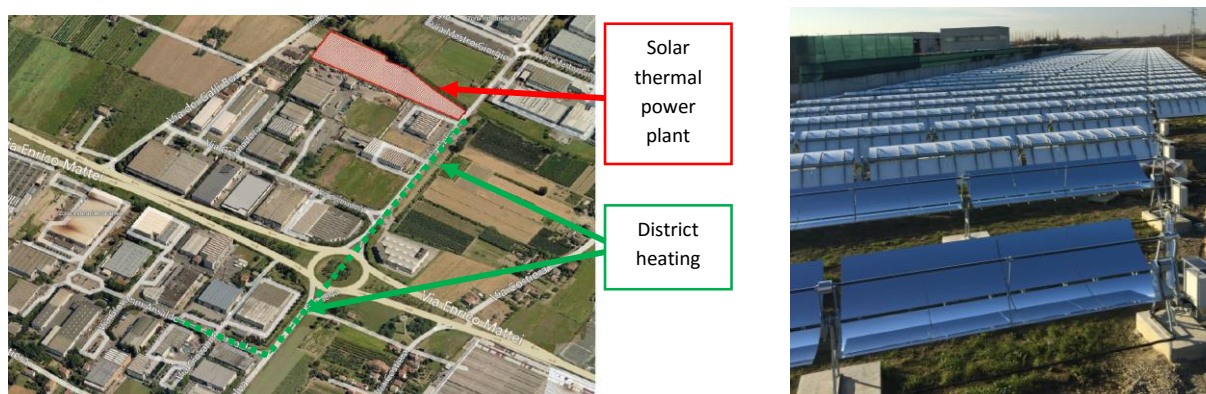
An important challenge is to find a way for renewables and carbon-pricing policies to interact in a manner that they take advantage of synergies rather than trade-offs [1].

In this framework a demonstrator of solar based renewable was realized by public companies in Forlì, Italy, that relies on solar parabolic trough that delivers thermal energy to district heating. The main purposes were to realize with mature technologies energy plant with zero emissions, sustainable both from economic and environmental point of views.

## 1. The solar thermal power plant and his users

The solar thermal plant converts solar energy into heat that is delivered to facilities located in the same industrial area by district heating.

Figure 1 – Aerial view of solar thermal power plant and detail of parabolic trough

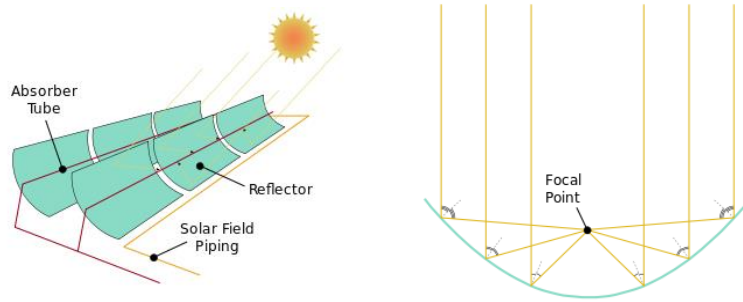


### *Solar thermal plant*

Figure 1 shows an aerial view of the area where the solar thermal plant is located; the part highlighted in red is about 20,000 m<sup>2</sup> and includes 36 parabolic troughs, with a global occupancy of about 2,800 m<sup>2</sup>. The parabolic troughs exploit optical reflection in order to concentrate solar radiation into the focal point. The operational principle is known since long time, Archimedes used heat ray during the Siege of Syracuse (214-212 B.C.) to destroy enemy ships with fire. It has been suggested that a large array of highly polished bronze or copper shields acting as mirrors could have been employed to focus sunlight onto a ship, using the principle of the parabolic reflector as a solar furnace.

A one-axis dynamic control system is used to ensure continuous tracking of maximum solar radiation into the focal point, Figure 2.

**Figure 2 – Principle of operation of parabolic troughs**



In the focal point of the mirror is located the pipe that delivers the carrier fluid: diathermic oil. Diathermic oil thanks to its thermal performances can transport heat with high efficiency. It is operated at about 175 °C and the overall thermal power is about 1.4 MW. The expected thermal energy per year is about 1,300 MWh. The following section describes how oil exchanges heat with district heating.

*District heating*

The district heating network is made of two isolated steel pipe DN125 whose linear extension is of about 1,100 m. The pipes run underground and deliver heat to the factories, the former delivers heat at about 140 °C the latter is the return path at about 110 °C.

Table 1 reports the major parameters of solar thermal plant and district heating.

**Table 1 – Main parameters of solar thermal plant and district heating**

	<i>Main parameters</i>	<i>Values</i>
1 –Solar thermal plant	Overall area	20,000 m <sup>2</sup>
	Area of parabolic troughs	2,800 m <sup>2</sup>
	Thermal peak power	1,400 kW <sub>t</sub>
	Carrier fluid	Diathermic oil
	Oil temperature	175 °C
	Annual energy production	1,300 MWh
2 –District heating	District heating linear distance	1,100 m
	Pipe type	2 isolated DN 125
	Carrier fluid	Superheated water
	Temperature of input pipe	140 °C
	Temperature of return pipe	110 °C

**2. Expected results**

The power plant meets the following results: it is a power plant at zero emissions; it is a replacement of fossil fuels; it is a plant sustainable from economic point of view. The storage is not required as district heating does not require it. Moreover, it is an additional energy source that replaces fossil fuels in summer and spring.

Major results are reported in Table 2 Energy production is estimated assuming a nominal number of direct sun days, i.e. clear and fair weather conditions [2]. Experimental results will be available on summer.

**Table 2 – Major results**

<i>Parameters</i>	<i>Value</i>
Energy production (per year)	1,300 MWh <sub>t</sub>
Fossil fluid Energy Savings (per year)	135,000 Nm <sup>3</sup> gas
Green House Gas reduction (per year)	260 t CO <sub>2</sub>



**Figure 3 – Photo of the solar thermal plant and detail of a parabolic trough (right)**



### **3. Conclusions**

The solar thermal plant realized at Forlì, Italy is a demonstration of renewable technologies. It delivers heat energy from the sun to an industrial area thanks to an existing district heating. It allows reducing impacts of heat consumption into environment and economics. From the economic point of view it increases the self-production of energy in an industrial area, thus allowing significant savings when the return of the initial investment is completed.

The plants the first step of an overall re-qualification of an industrial area that includes actions on mobility, ICT, waste management.

The plant potential can be extended installing absorption refrigerator machines at the final user premises, converting heat into cool energy and extending its flexibility. This option is fully consistent with district heating.

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# HOW THE REGULATORY FRAMEWORK AFFECTS THE FEASIBILITY OF INDUSTRIAL SYMBIOSIS DEVELOPMENT IN ITALY

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## Introduction

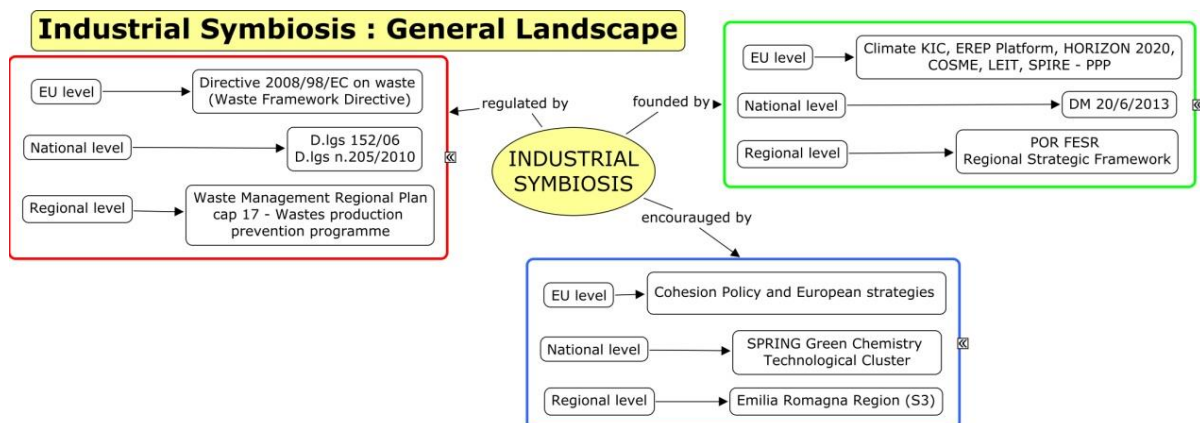
Industrial Symbiosis is strongly encouraged by European Commission, as described in the Communication [1] - A Stronger European Industry for Growth and Economic Recovery and in related documents. In this work Italian efforts to introduce the legislation will be analyzed and compared with the international state of the art.

In 2012 the Commission defined some Priority Action Lines to define European Industry of 21st Century. The first one is called: “Markets for advanced manufacturing technologies for clean production” and asserts that tomorrow's factories will increasingly adopt sustainable business models such as Industrial Symbiosis to recover materials and dissipated heat and energy. The Commission considers these technologies as an important business opportunity [2]. Policy coordination of EU and Member State policies and stakeholder efforts are enhanced through a dedicated Task Force on Advanced Manufacturing for Clean Production. It is a European Commission working group aimed at fostering the development and adoption of advanced manufacturing for clean production by European industry. In 2014, the Staff Working Document of the Task Force [SWD(2014)120] reports that more than 1.000 industrial companies participated in the UK's National Industrial Symbiosis Programme (NISP), which by promoting the collaboration of different organisations has been able to reap very substantial benefits, both economic (£ 100 million) and environmental (3.4 million t CO<sub>2</sub> reductions) through the coordinated use of materials, energy, water and/or by-products and the sharing of assets, logistics and expertise. In Horizon 2020, the EU Framework Programme for Research and Innovation in 2014- 2020, a significant part of the budget (17.6%) will be dedicated to promote leadership in enabling and industrial technologies, including advanced manufacturing technologies.

## 1. Materials and work context

A general landscape of the influencers of a successful implementation of Industrial Symbiosis is reported in Figure 1 [3].

Figure 1 – Industrial Symbiosis: General Landscape



The new Cohesion Policy 2014-2020 Programming Cycle expects that national and regional authorities develop research and innovation strategies aimed at the “smart specialization, in order to allow an efficient use of structural funds and to increase synergies between EU, national and regional authorities. All the Member States Regions have been called to draw up their Smart Specialization Strategy outlines [4]. Developing operationally the SSS strategies, different technological specializations were decided to be strategic for each territory, taking into account the peculiarities of every area [5]. In Emilia Romagna five specializations were identified: Agrifood, Building, Mechatronics, Healthiness industries and Creative and cultural industries. In the first three specializations, Industrial Symbiosis and resources management were included as key–subjects. The application of Industrial Symbiosis in Italy subordinated to the waste legislative framework, D.Lgs 152/06 (transposal of the Waste Framework Directive 2008/98/CE) and its amendment, D.Lgs n. 205/2010. Legal complexity often discourages the entrepreneurs’ attempts to apply sustainable processes to reuse industrial byproducts. A deeper knowledge on economics aspects for researchers and a common language between industry and research could help the industrial application of many sustainable processes. Communication towards enterprises and collaboration between different enterprises and production chains has to be improved. A strong coordination plan from a leader institution is needed. Positive examples of intervention of good policies abroad are known: first of all the NISP project in UK and the Kalundborg Industrial Park in Denmark [6] could be studied. In Italy the first initiative promoting Industrial Symbiosis has been performed by ENEA in Sicily [7].

## 2. Conclusions

Sustainability in waste management and resource efficiency is one of the main goals defined by the European Commission to go towards an economic recovery in Europe. Industrial Symbiosis demonstrated to be a good tool to reach the EC objectives and Italy has to work develop it, following some best practices from other countries. Starting from good policies, the Government could start a positive pathway able to change the behavior of Public Administrations, industries and researchers, giving them the instruments to activate effective public–private partnership (PPP).

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# CIRCULAR ECONOMY AND INDUSTRIAL SYMBIOSIS: A SURVEY IN ECOMONDO 2014

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## Introduction

During the 18th Ecomondo International Fair in Rimini, ENEA and University of Tuscia took the opportunity to submit to visitors a survey with two different types of questionnaires on industrial symbiosis. As the industrial symbiosis and the circular economy are topics of today's interest and importance and ENEA itself is implementing projects on these topics, the survey had a double purpose:

- assess, through a basic questionnaire, the level of awareness on industrial symbiosis and circular economy of people visiting Ecomondo (questionnaire proposed by ENEA stand);
- assess, through a more complex questionnaire proposed to participant to the conference "The industrial symbiosis between theory and practice"; aim of this more complex questionnaire was ask participants their opinion on main issues influencing the possibility to realize actual synergies between companies according to industrial symbiosis strategy.

## 1. Methodology

For the survey ENEA proposed two different types of questionnaires:

- the first, basic questionnaire, proposed by the ENEA stand to people visiting Ecomondo; this questionnaire had five yes/no questions and four multiple choice questions;
- the second, questionnaire for "experts", proposed to participant to the conference "The industrial symbiosis between theory and practice", which had three yes/no questions, three multiple choice questions, two matrix questions and one scaled question.

For some questions, in both cases, people filling-in the questionnaire could motivate in few lines their answers.

## 2. Results

### *Basic questionnaire (proposed at ENEA Stand)*

From 5 to 7 November, two hours a day on average, at the ENEA stand a researcher proposed the basic questionnaire. It was filled-in by 164 people (mostly self-employed, technicians, entrepreneurs, local administrators, researchers and students who operated, directly or indirectly, in the field of energy and environment).

The main results are:

- 92.7% of respondents knows ENEA; just over two-thirds of them (67.8%) knows that ENEA works in the fields of new technologies, energy and sustainable economic development;
- half of the respondents (50.6%) affirms to know the meaning of the "circular economy" term and 78.3% says that the most correct definition is "an economy in which the processes of production and consumption are able to recycle, reuse, repair and refurbish the materials and existing products, in order to limit to a minimum the use of new natural resources";
- Almost half of the respondents (47.9%) says to know the meaning of the "industrial symbiosis" term and 62,8% says that the most correct definition is "exchange of resources between two or more different industries, intending "resources" not only as materials (by-products or waste), but also waste-energy, services and expertise" [1].

- 17.1% says to know that ENEA is implementing the first platform of Industrial Symbiosis in Italy and 40% knows this information through magazines and newspapers.

It is interesting to note, in the end, that about 86% is strongly interested in these topics. The main reasons for this interest are, mainly, related with business opportunities and/or awareness on social and environmental issues.

*Questionnaire for “experts” (proposed at conference “The industrial symbiosis between theory and practice”)*

On 6 November 2014 a second type of questionnaire, more complex, was proposed to participant to the conference “The industrial symbiosis between theory and practice” organized by ENEA and CTS Ecomondo. Aim of the conference was show some of the most relevant initiatives of industrial symbiosis case studies and experiences implemented by companies, research bodies and other stakeholders; 25 out of 28 participants to the conference filled-in the questionnaire. 96% of interviewed people know ENEA and its field of activity. 92% of interviewed people knows the meaning of “industrial symbiosis” and 92% say that the correct definition is “*exchange of resources between two or more different industries, intending “resources” not only as materials (by-products or waste), but also waste-energy, services and expertise*” [1].

According to the whole results of the survey made with this questionnaire, main factors helping the implementation of industrial symbiosis are:

- increasing profitability;
- improving supply chain of goods and services;
- strengthen the company's image.

At the same time, main reasons hindering the implementation of industrial symbiosis in Italy are:

- poor infrastructure;
- inefficient public service;
- low level of trust between companies.

Most part of interviewed people (95.8%) is strongly interested in a implementation of a network for industrial symbiosis, with the aim of foster the application of industrial symbiosis pathways at local level. In their opinion, the main goals of this network could be:

- foster long-term culture changes towards sustainability (73.9%)
- foster creating and sharing knowledge (56.5%)
- foster eco-innovation (56.5%).

### **3. Conclusions**

Although survey was made on selected group of people already particularly interested in environmental issues, it has been observed, however, a distinctive curiosity and interest in industrial symbiosis and circular economy. The survey measured a particular interest in networking tools among various stakeholders (companies, research centers, associations, self-employed, institutions) in order to make the most for the implementation and diffusion of these new industrial policy approaches in Italy.

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## ROUND TABLE “INDUSTRIAL SYMBIOSIS BETWEEN THEORY AND PRACTICE”

This paper reports main findings of the round table which took place in the closing of the conference “The industrial symbiosis between theory and practice” November 6, 2014 organized by ENEA. The discussion was attended by Marco Conte, general deputy secretary of Unioncamere, Roberto Morabito Director of Department for Sustainability (SSPT)), Laura Cutaia, Responsible of Valorisation of Resources Laboratory (SSPT-USER-RISE) and other representatives of stakeholders and companies attending the conference.

Laura Cutaia opened the floor proposing some ideas for discussion, such as the regulatory framework, the role of the main actors in the control steps and mechanisms for the implementation of industrial symbiosis pathways. Other points for the discussion: the actual possibility for industrial symbiosis in relation with companies’ size, their characteristics and the knowledge of their resources streams in quantity and quality.

Roberto Morabito, opened the discussion by underlining that the European Commission since 2008 has worked to promote the efficient use of resources, in order to move towards a recycling society (at global level and at local level) and an eco-innovation system. In particular, industrial symbiosis can be seen as a tool for eco-innovation, which shall have positive feedback both on economy and on employment. Morabito, in his analysis, shows that in Italy there are technological, cultural and regulatory obstacles at the application of industrial symbiosis. In particular of particular concern are cultural obstacles, despite the companies have made great effort towards networks and partnerships, and towards the management of by-products and secondary materials. Furthermore, concerns come also from the regulatory framework of end-of-waste and by-products.

Marco Conte, general deputy secretary of Unioncamere, emphasizes the role of Unioncamere in the management of the Italian Register of Environmental Operators on behalf of the Ministry of the Environment (MATTM) and of some operators’ register (eg. FGas and WEEE). Regarding the industrial symbiosis, Conte believes that it is a tool useful not only for materials and energy, but more generally for eco-innovation and recycling. He believes that the implementation of the system explained by ENEA in its presentation (the Industrial Symbiosis Platform) could be enhanced through companies’ networks (concept already applied by Italian regulation), to support the development of these processes in the territory; industrial symbiosis should have in other words, “short lines”. Regarding this aspect, Unioncamere confirms its willingness to share, as part of the ENEA, the data in its possession, as it has a deep knowledge of the different economic systems, the companies that operate there, supply chains and industrial districts; that could be made linking and connecting companies data and waste production data (being both these DBs managed by Unioncamere). Conte also believes that in order to switch from theory to practice there is the need of pilot phases founded by public bodies to “convince” regulators (e.g. some applicative regulations on end-of-waste are still waiting for implementation), Regions (responsible for a part of regulations on waste and the control bodies (ARPA, the province, municipalities, police ...)); related this last point, for example, Unioncamere is organizing consultation tables with control bodies.

In order to start a pilot phase it is necessary to activate exceptions to the in force regulation, with the aim of let industrial symbiosis matches happen.

On the topic of waste, however, these exceptions could be problematic, causing concern in the population (which may fear possible threats to the territory and their health), and in the companies (which often prefer regulations with limits to comply with).

Conte concludes his speech focusing on the fact that, despite the complexity of legislation is a matter of fact, at present the worst enemy of industrial symbiosis is the crisis in which companies have to operate, in particular the cost of raw materials: when the market “does not pull”, the cost of raw materials decreases and the profitability of these processes goes down, because for the companies can be cheaper buy the raw materials rather than obtaining them from recycling; Conte gives the example of the plastic (currently is more cheaper to produce it from raw materials, rather than from recycling) and WEEE (removal could cost more than the total value of the materials that they get).

Enrico Cancila, of ERVET, a speaker at the conference, pointed out that often the law is useless, but that it would be desirable to have fewer laws and more controls (with reference to the so named “Terra dei fuochi”).

Conte replied that unfortunately, to implement pilot phases as that required to activate pathways of industrial symbiosis, derogations are necessary and that - when it comes to exceptions - there is always someone who stiffens.

Laura Cutaia emphasizes that, at present, there are waste treatment plants that does not have the certainty of having waste as feeding to ensure the operation of the plant, as it has been estimate that many streams escape controlled paths: for example, it is estimated that 700,000 tonnes of WEEE in Italy every year are not collected and treated within the “official” systems for WEEE management. Given this uncertainty, entrepreneurs have difficulty in investing in this sector. Cutaia believes that, in order to enhance the rate of collection and treatment, producers of WEEE (e.g. citizens) should have some positive feedback (even in terms of money) for their proper disposal of their WEEE (as in other countries in Europe already happens).

Claudia Scagliarino, speaker at the conference, mentions the question of the eco-tax for waste landfilling, which can vary greatly from region to region (e.g. quite high in Marche and Sardegna) and supports the need for a coupling between regulatory aspects and economic management waste.

In relation to this specific issue respond Conte.

Conte specifies that there are no companies leading their waste to landfilling by themselves but they have to pay authorized companies (for managing waste) which bring waste to its final destination. Emphasizes, however, that companies should understand that waste can generate wealth. Since the circularity must also be guaranteed by the economic point of view, the producer of the waste must have an economic return from its exploitation.

Andrea Zuppiroli, Emilia Romagna Region, on the eco-tax, points out that was established by the regions and it is a tribute to the landfilling of municipal and special waste, which varies between € 8.00 and € 20.00 ton. Depending on the context and the economic situation, the strategy of the tax



may not work anyway and the tribute should be conceived as a dynamic tool that is periodically updated.

With regard to the issue of waste disposal in landfills, to their non-recovery and the inadequacy of the legislation, Zuppiroli gives the example of the demolition materials caused as a consequence of the earthquake in Emilia Romagna: it was not possible to recover it as road foundations for the creation of the Cispadana road instead of 600,000 tonnes of virgin material, as proposed by the Region; demolition materials was used for the closure of landfills, as the rules on the recovery of inert materials as aggregates has such stringent technical specifications that many construction and demolition waste (C&D) cannot be reused (e.g. leaching tests with limit for COD 30 mg/l).

Zuppiroli points out that the current Italian regulatory system should change: technical and para-technical standards should not be laws, but administrative acts.

With his closing speech Roberto Morabito insists that waste management, if it becomes a business, lead to make the waste secondary raw materials. To achieve this we need many tools. The eco-tax can be one of these instruments, because its aim is to discourage the disposal of waste in landfills. Although Morabito agree with the use of this tool, however, believes that companies, especially SMEs, should be accompanied and supported in identifying virtuous paths alternative to landfill.

On the risk that the research sector could be self-referential, as mentioned during the conference, Morabito, expresses the need for contact with the companies, but considers that the cultural system of companies themselves should change; some of them, in fact, even with a proposal of eco-innovation, often they are not going to invest or risk. In this regard, argues that the system of incentives for innovation, particularly eco-innovation, is a proper tool for stimulating the business world, but that it must be a selective tool and that the funds should be not distributed as windfall funds.

Finally Morabito says that for the implementation of industrial symbiosis, and more generally of eco-innovation, the worlds of research, business and politics shall communicate and travel together.

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