SYMBI
Interreg Europe

CHAMBER OF COMMERCE OF MOLISE

A1.3 Good practice guide and benchmarking guidelines on ecosystems of byproduct and energy exchanges

May 2017

Table of Contents

1 Introduction

This paper was prepared by the Chamber of Commerce of Molise within the context of SYMBI activity A1.3. It outlines the results of an analysis of the best cases of industrial symbiosis projects in SYMBI partnership regions and the European Union as a whole, and describes a benchmarking methodology that will be applied to evaluate both potential and concurrent industrial symbiosis projects. The analysis was based on data collected by the SYMBI partners from all the EU.

After briefly presenting some key information about the SYMBI project and activity A1.3 the paper proceeds in presenting the key characteristics of best practices in industrial symbiosis based on the analysis of data for 48 successful industrial symbiosis projects all over Europe. Subsequently, the document proceeds in presenting 12 cases of industrial symbiosis that can be characterised as the most successful according to their compliance to the criteria of success developed in the methodology of activity A1.3. The document presents their score according to these criteria, their characteristics, and the lessons learned from the symbiosis projects in the countries where these cases are encountered.

Finally the document presents a benchmarking methodology based on a catalogue of conditions that can serve to check or estimate the success of an industrial symbiosis project.

2 Context of the SYMBI project

2.1 Background of the INTERREG Europe Programme

The INTERREG EUROPE programme (www.interregeurope.eu) promotes the exchange of experience on thematic objectives among partners throughout the European Union (EU) on the identification and dissemination of good practices, to be transferred principally to operational programmes under the Investment for Growth and Jobs goal, but also, where relevant, to programmes under the European Territorial Cooperation (ETC) goal. This will be done via the support and facilitation of policy learning, sharing of knowledge, and transfer of good practices between regional and local authorities and other actors of regional relevance.

INTERREG EUROPE is one of the instruments for the implementation of the EU's cohesion policy. With this policy, the EU pursues harmonious development across the Union by strengthening its economic, social and territorial cohesion to stimulate growth in the EU regions and Member States. The policy aims to reduce existing disparities between EU regions in terms of their economic and social development and environmental sustainability, taking into account their specific territorial features and opportunities. For the 2014-2020 funding period, cohesion policy concentrates on supporting the goals of the Europe 2020 strategy, which targets to turn the EU into a smart, sustainable and inclusive economy delivering high levels of employment, productivity and social cohesion.

2.2 The "SYMBI" project

The "Industrial Symbiosis for Regional Sustainable Growth and a Resource Efficient Circular Economy – SYMBI" project aims to improve the provisions and support the implementation of policy instruments and measures for the diffusion of industrial symbiosis, to add value, reduce production costs, and relieve environmental pressures through increased resource efficiency and greenhouse gas emissions. The overall improvement is anticipated to positively contribute in regional sustainable development and job creation.

Circular economy is an emerging model that keeps resources in the economy as long as possible. Resources can be reused, creating further value while relieving environmental pressures. Resource efficiency, as outlined in the circular economy model, is primarily based on: a) the "cradle to cradle" principle, focusing on eco-design and regenerative modes of consumption, and b) industrial symbiosis, which involves territorial synergies to manage waste and share services, utilities, and by-product resources. The territorial aspect of industrial symbiosis brings regions to the forefront of the transition towards circular economy.

Industrial symbiosis requires policy reforms measures at different levels. EU regions show very different levels of performance on each area relevant to industrial symbiosis, and advance at a different pace towards green growth models. There is thus a need to share and exchange practices, experiences, and knowledge within this fragmented context to: a) lift barriers by following successful examples, b) foster balanced territorial development and reduce disparities, and c) reverse the backwardness of least-favoured regions.

2.2.1 SYMBI activities

The SYMBI project brings together 9 partners from 7 countries to diffuse industrial symbiosis and align regional policies with the circular economy package of the European Commission (EC). To support the transition towards a resource efficient economy, the project includes a wide range of activities, focusing on promoting the interregional learning process and the exchange of experience among regional authorities. Project activities include:

- Evaluation and analysis of existing regional and national policies on industrial symbiosis and circular economy.
- Mapping the investment potential of participating regions in industrial symbiosis.
- Identification of good practices and benchmarking of eco-systems of by-product and energy exchanges.
- Prescribing green public procurement as an enabler of industrial symbiosis.
- Promoting public dialogue and consultation process to build consensus and ensure the successful implementation of regional action plans, through the support and participation of key regional stakeholders.
- Fostering interregional learning and capacity building through workshops, study visits, and policy learning events.
- Joint development of action plans to promote the improvement of the policy instruments addressed by the project.

- Increasing awareness, promoting and disseminating the project results and knowledge beyond the partnership.

2.2.2 SYMBI expected results

SYMBI will improve 8 policy instruments, relevant to the abovementioned policy areas; 6 of the managing authorities participate in the consortium, so as to secure the impact of the project. SYMBI activities will:

- Incentivise regional waste transformation systems and cross-sectoral synergies
- Promote the use of secondary raw materials
- Prioritise green procurement
- Unlock investments by regional and local financial actors
- Explore, assess, expand, and enhance current practices in ecosystems of industrial innovation
- Build consensus between regional stakeholders

2.3 SYMBI Activity A1.3

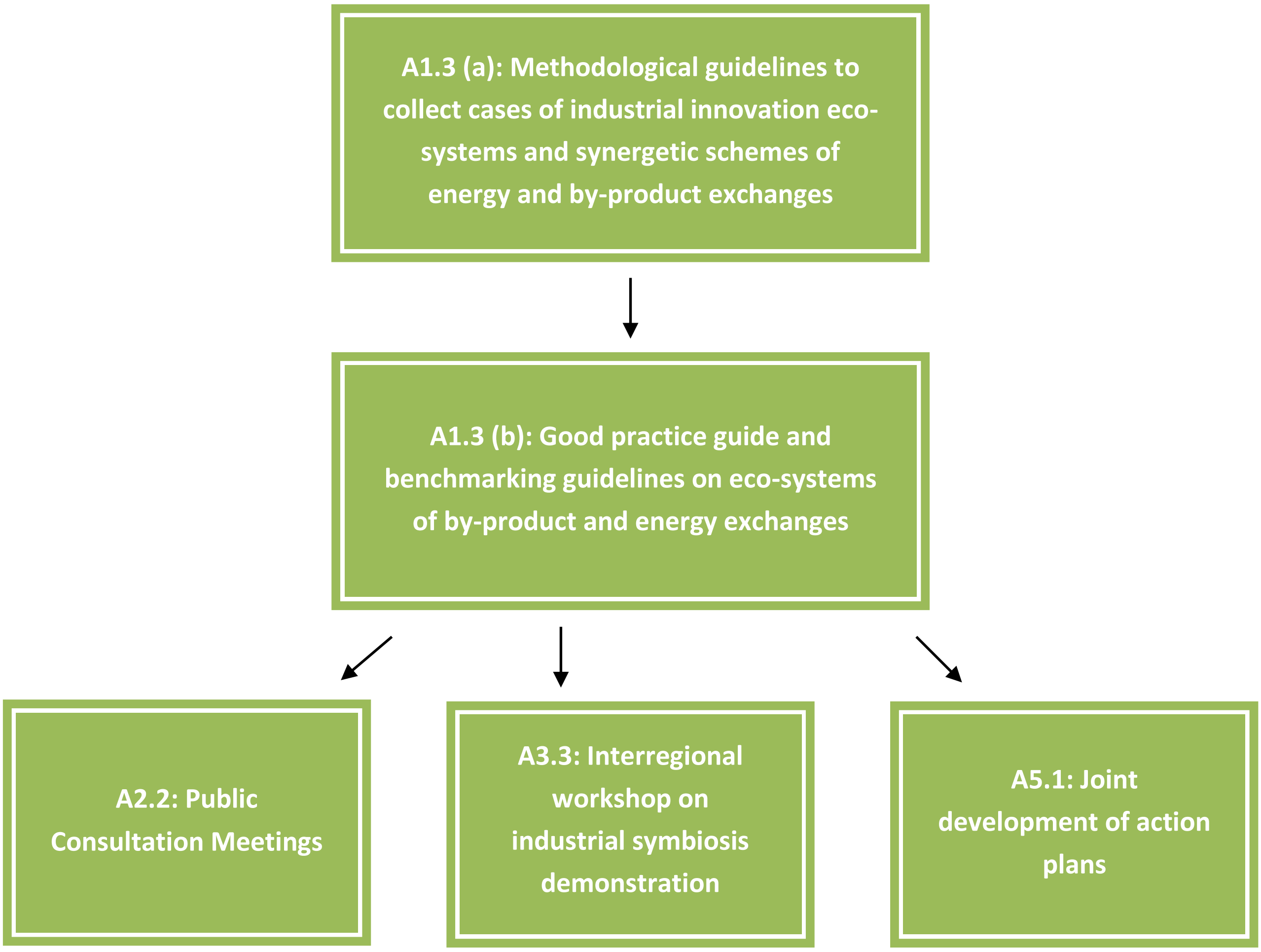
The SYMBI Activity A1.3 “Identification of good practices and benchmarking of ecosystems of by-product and energy exchanges” includes the collection and assessment of cases eco-systems of industrial innovation and synergetic schemes of energy and by-product exchanges.

Based on a survey methodology, the project partners will be able gather, assess, and analyse good practices and benchmarking of ecosystems of by-product and energy exchanges. All partners will conduct desk research at national level.

The analysis of the evidence collected will result in a good practice guide and benchmarking guidelines on ecosystems of by-product & energy exchanges that will enable policy makers and stakeholders to identify which solutions work best in the field of industrial symbiosis, study how they work, and adopt the best practices that are most suitable for their own regions.

2.3.1 Connections with other SYMBI activities

The results of SYMBI Activity A1.3 will provide input and support the implementation of the forthcoming interregional workshop on industrial symbiosis demonstration projects (Activity A3.3), the public consultation meetings (Activity A2.2), and the partners' action plans (A5.1), where relevant.

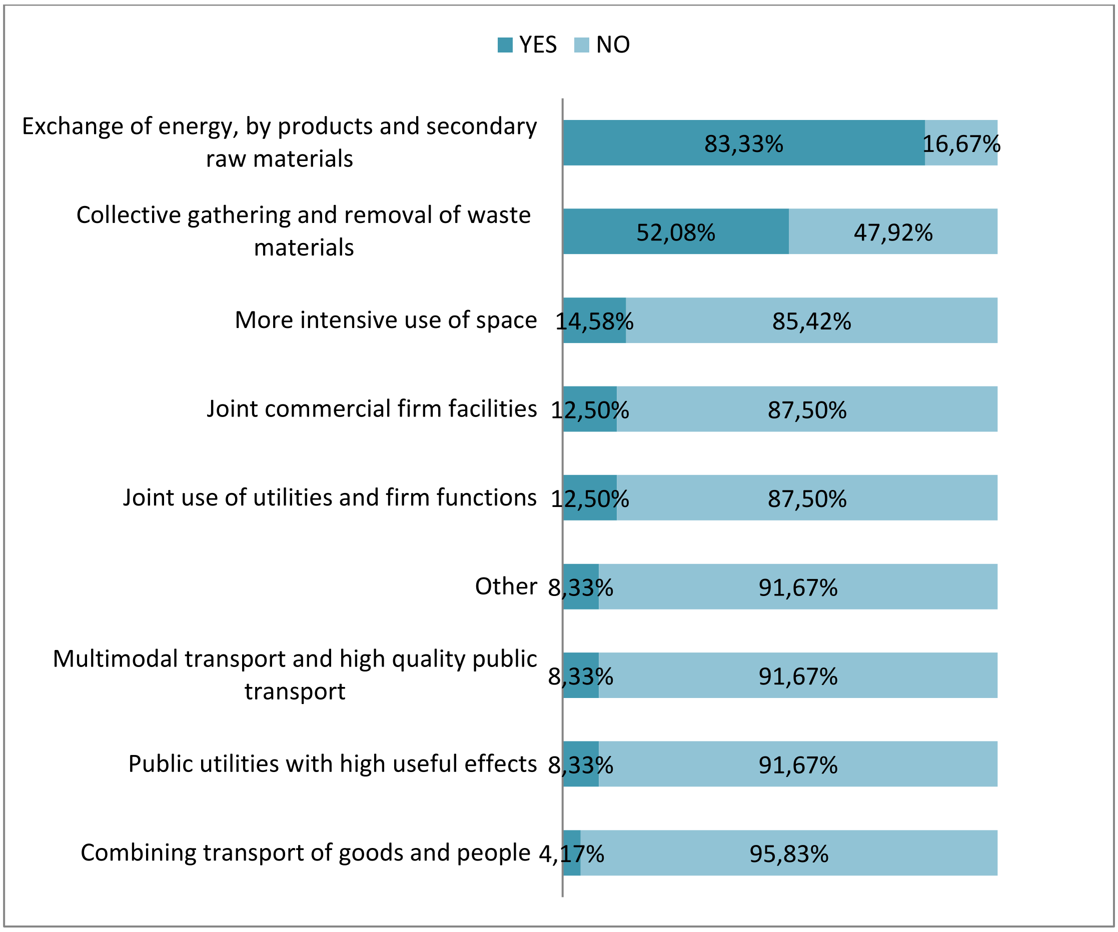


3 Overview of the findings

All data presented in this section were derived by the 48 cases of successful industrial symbiosis that SYMBI partners managed to locate and describe in the European Union, including 40 cases of energy and by-product exchanges. The 48 cases were described using the input paper supplied by the document "A1.3 Methodological guidelines to collect cases on industrial innovation ecosystems and synergetic schemes of energy and by-product exchanges", and can be seen in Annex 1 of this document. It is important to point out that the input paper consists mostly of multiple response questions, and, as a result, the positive responses in each outcome of the questions should not be aggregated. Having said that, it is now time to present the findings.

The fact that the exchange of energy, byproducts and secondary raw materials accounts for 83% of successful cases of industrial symbiosis shows that the latter is used in the EU as an instrument of promoting the circular economy model. More precisely the main types of cooperative activity in industrial symbioses across the EU can be seen in the following table:

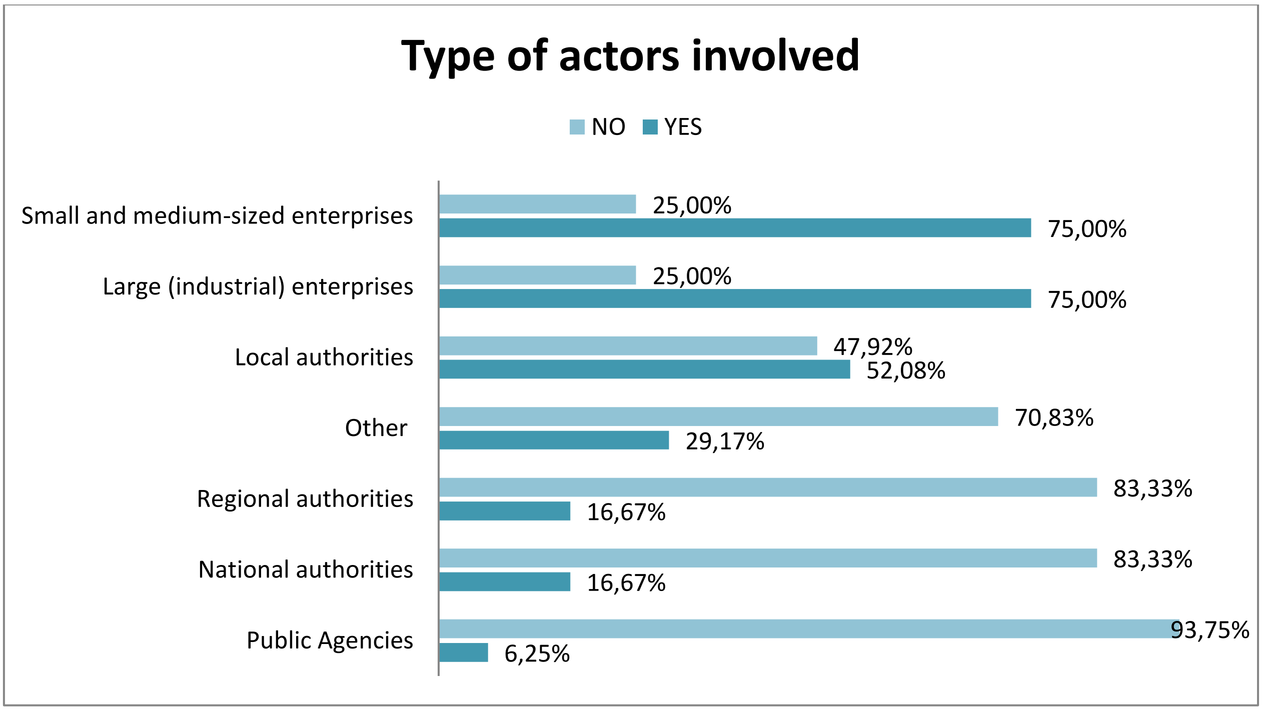
Type of cooperative activity amongst firms in industrial eco-systems



The results show that industrials symbioses almost always focus on energy by-products and secondary raw materials, and—in more than half cases—in the collection, gathering and removal of waste. Compared to these two, other types of activities are almost insignificant. What this means is that environmental considerations were vital for the formation of industrial symbiosis projects, since the types of activity of industrial symbioses are heavily skewed towards those that have direct impact on the sustainability of industries and are promoted by the EU as part of its strategy towards building a circular economy.

Beyond the type of activity, to be successful, industrial symbioses in Europe usually have to involve a number of different actors. Nevertheless, there are three key types of actors that were mentioned in more than 50% of cases. These types are the large industrial enterprises, the SMEs of each sector and the local authorities. These results are summarised in the following table:

Type of actors involved in successful industrial symbioses

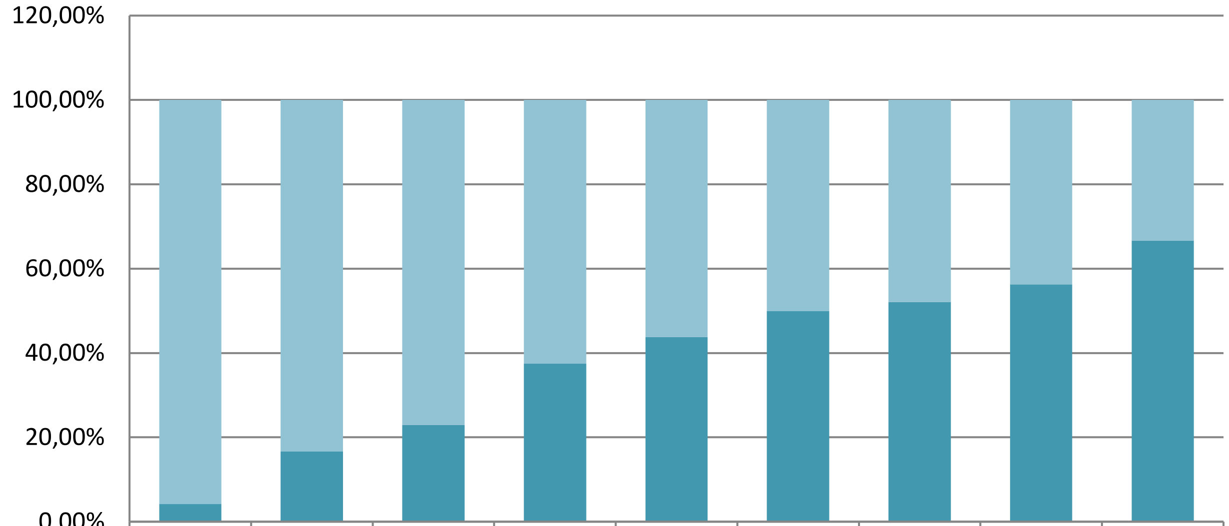


The results point to the importance of establishing a harmonious cooperative relationship between the key economic players and producers of each sector and the local authorities of the area in which the industrial symbiosis projects have developed. Of course the key economic players can be large corporations, small SMEs, or in the case of Sweden, farmers. In general, involving key players and establishing an effective and efficient cooperation with local authorities can be considered a necessary condition for the success of industrial symbiosis projects.

Moving on to the rationale for developing industrial symbioses, the analysis of the data shows that such projects emerge and are successful when they promote the sustainability of an industry/area by achieving objectives such as a) improving resource efficiency (67% of cases), b) promoting the use of sustainable bio-energy resources (56% of cases) and c) reducing CO_2 emissions (50% of cases). The second type of opportunities that industrial symbiosis can utilise for their success are cases where the symbiosis leads to greater economic benefits or, to be more precise, a) reductions in production costs (52% of cases), b) increases in profits and revenues (44% of cases), and openings of new markets for secondary raw materials (38% of cases).

This image stresses the fact that, despite the need to at least avoid economic damage, economic benefits are not the most important motivation for developing industrial symbiosis. The latter emerges usually when there are *primarily* environmental benefits that are accompanied by economic benefits. Hence, the emergence of industrial symbiosis projects cannot be considered an issue that the market can achieve without support, at least at the current level of industrial development in Europe. Finally, one last reason to develop industrial symbiosis, are the social benefits derived from the latter which were an addition to the preexisting options of the input form with regards to this question. More precisely, SYMBI partners mentioned mainly two types of social benefits: a) overcoming the presumption that industrial symbioses are costly, and b) offering businesses the opportunity to cooperate and hence, to develop a cooperative culture which is essential in late knowing capitalist markets.

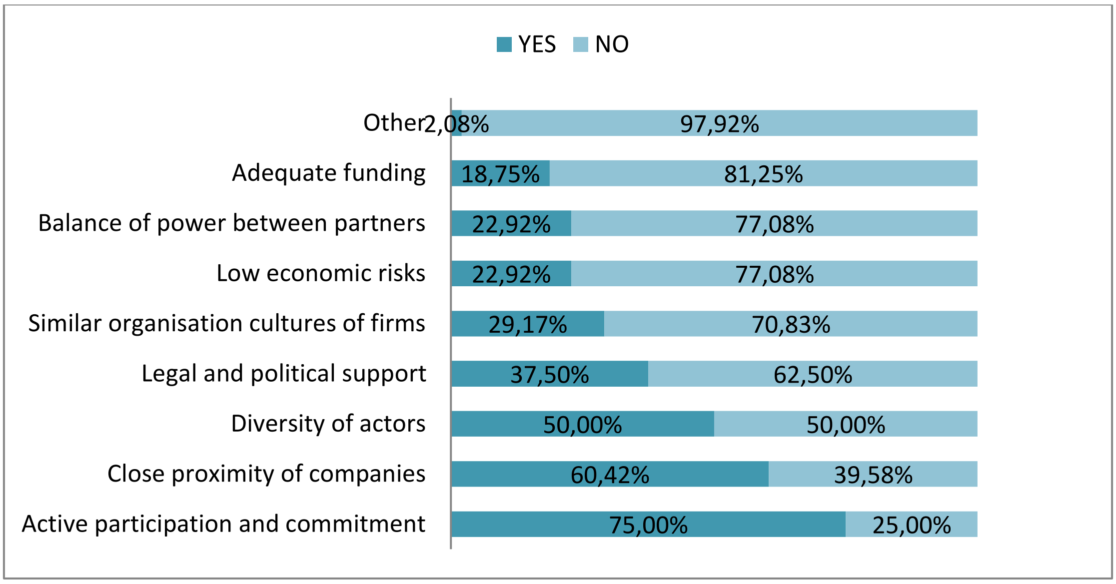
Needs and objectives for the deployment of industrial symbiosis projects



	Share risk	Access new markets	Other	Open new markets for secondary raw materials	Increase profitability, revenue	Reduce CO2 emissions	Reduce production costs	Promote the use of sustainable bio-energy resources	Improve resource efficiency
NO	95,83%	83,33%	77,08%	62,50%	56,25%	50,00%	47,92%	43,75%	33,33%
YES	4,17%	16,67%	22,92%	37,50%	43,75%	50,00%	52,08%	56,25%	66,67%

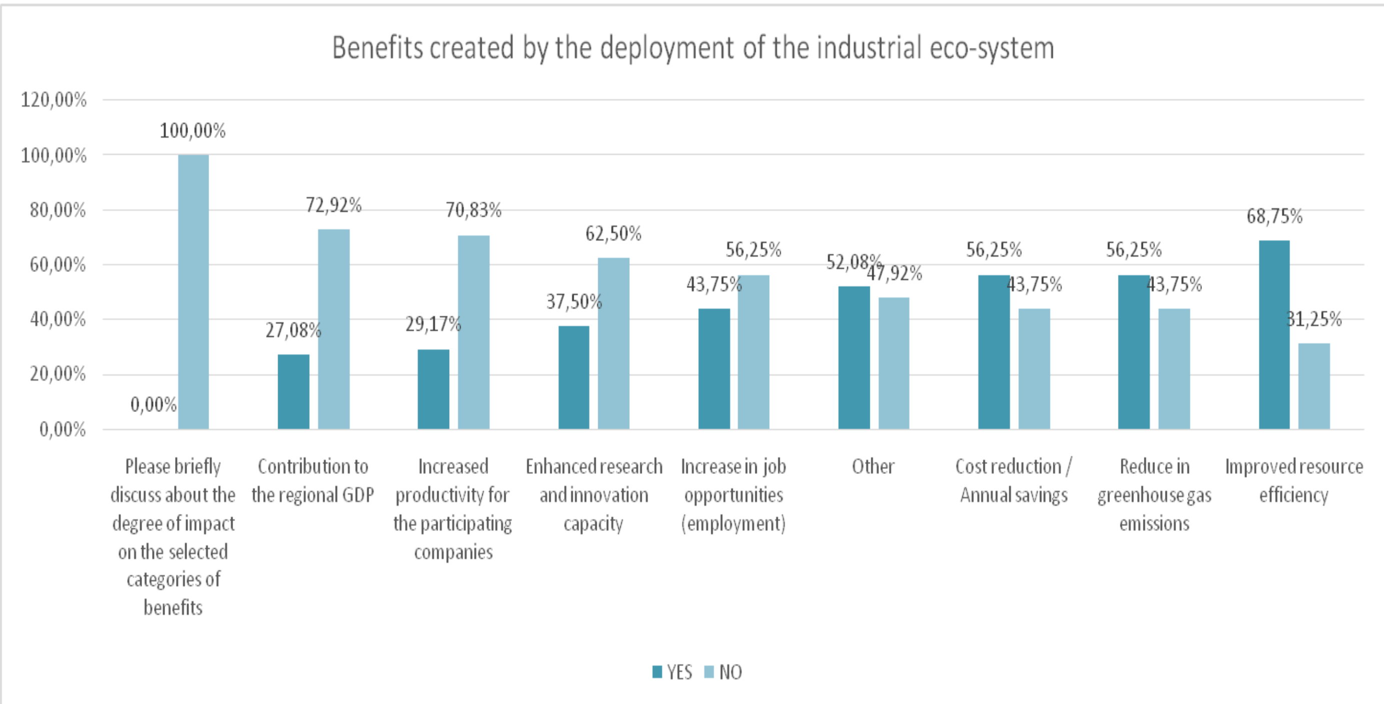
After locating the main incentives to engage in industrial symbioses, it is necessary to describe the success factors that determine the survival of such projects. The most important success factors for the proliferation of industrial symbiosis projects that were revealed by the desk research of SYMBI partners are the active participation and commitment (75%) and the close proximity (60%) of the companies involved in the project, followed by the involvement of a diversity of actors in each project (50%). Interestingly, the existence of legal and political support (38%), the provision of adequate funding and the low economic risks associated with each industrial symbiosis case are not listed as often (38%, 15% and 23% respectively). It is possible to conclude from these data that industrial symbiosis is possible even in sectors with high risk and low administrative and financial support, as long as a) there is active engagement of the companies and organisations involved in the symbiosis and b) the businesses involved are closely situated. Furthermore, the diversity of actors involved in a project can provide a further boost to its chances of success, probably because a greater diversity of actors generates a greater spectrum of knowledge and material and energy exchanges that can take place in a project. The key success factors for industrial symbioses projects are summarised in the following figure:

Success factors for industrial symbiosis projects



Successful industrial symbioses have a significant positive impact in the sustainability of the surrounding territory and the corresponding industrial or economic sectors. Industrial symbioses have been found by SYMBI partners to generate a number of environmental, economic and social benefits. The following figure provides an overview of the benefits generated by the industrial symbioses listed by SYMBI partners:

Positive impacts of industrial symbioses



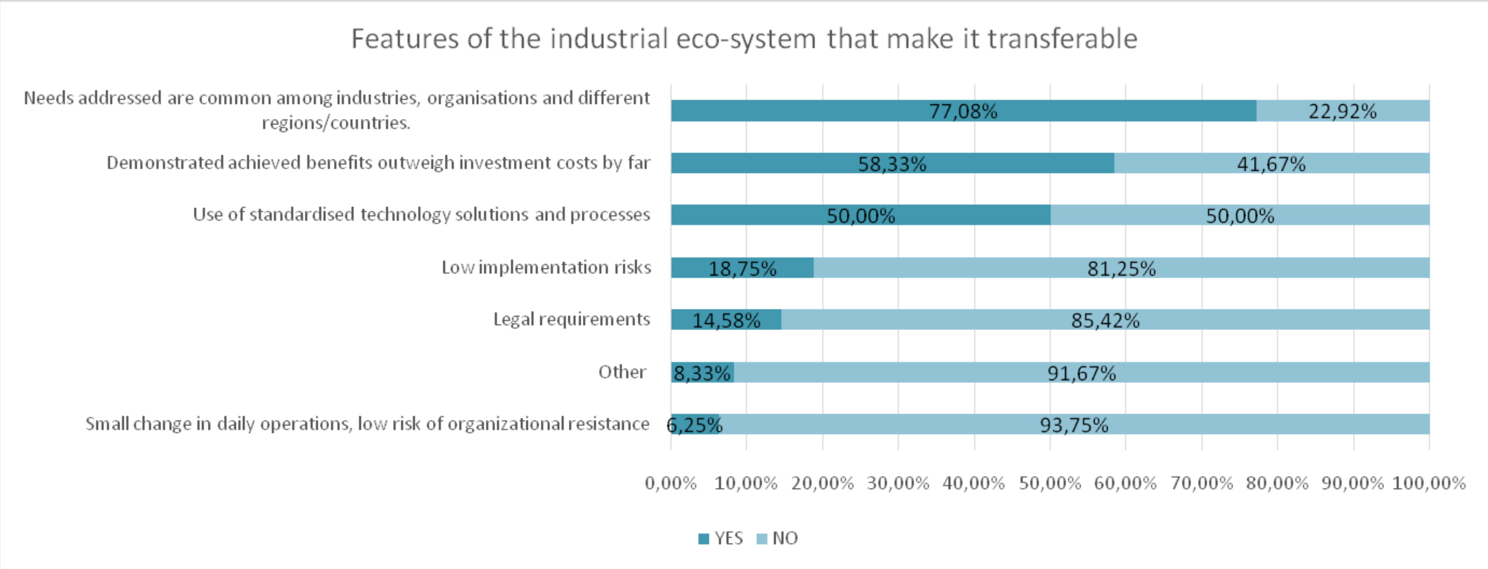
It is easy to see that the benefits most commonly listed are those related to sustainability, i.e. improving resource efficiency (69%) and reducing greenhouse gas emissions (56%), followed by economic and productivity benefits (cost reduction – 56%, increase in job opportunities – 44%). Special mention should be made to the fact that the data reveal significant social benefits as the outcome of industrial symbiosis (under the label "other"- 52%), in the form of increased collaboration and networking among businesses and organisations and in the form of improved awareness of sustainability issues and image of businesses operating in the various regions. These social benefits are further linked to the enhancement of research and innovation capacity that is caused by the formation of industrial symbioses and mentioned in 38% of collected best cases.

These results lead to the conclusion that industrial symbioses, even if they are initially formed to increase the sustainability level of some areas, they generate a wide spectrum of benefits including significant economic benefits. Hence, industrial symbiosis projects should be acknowledged by the authorities and businesses of regions as a production and consumption method with significant externalities that are not limited to sustainability improvements. In the competitive global markets, the contribution to the innovation and networking capacity of firms caused by industrial symbiosis projects, can be an important part of the necessary infrastructure to achieve a raise in the environmental and economic competitiveness of the EU.

Finally, after describing the benefits generated by successful industrial symbioses, it is necessary to analyse the scalability and transferability of these benefits, i.e. the scalability and transferability of successful industrial symbiosis projects. It is important to point out that scalability is under most circumstances a key component of the transferability of a production and consumption method. The development of alternative production and consumption models can be transferred usually better if it is applicable at a size that suits different regions.

Desk research in the 48 cases collected by SYMBI partners, revealed that industrials symbiosis is transferable when the factors presented in the following figure are valid:

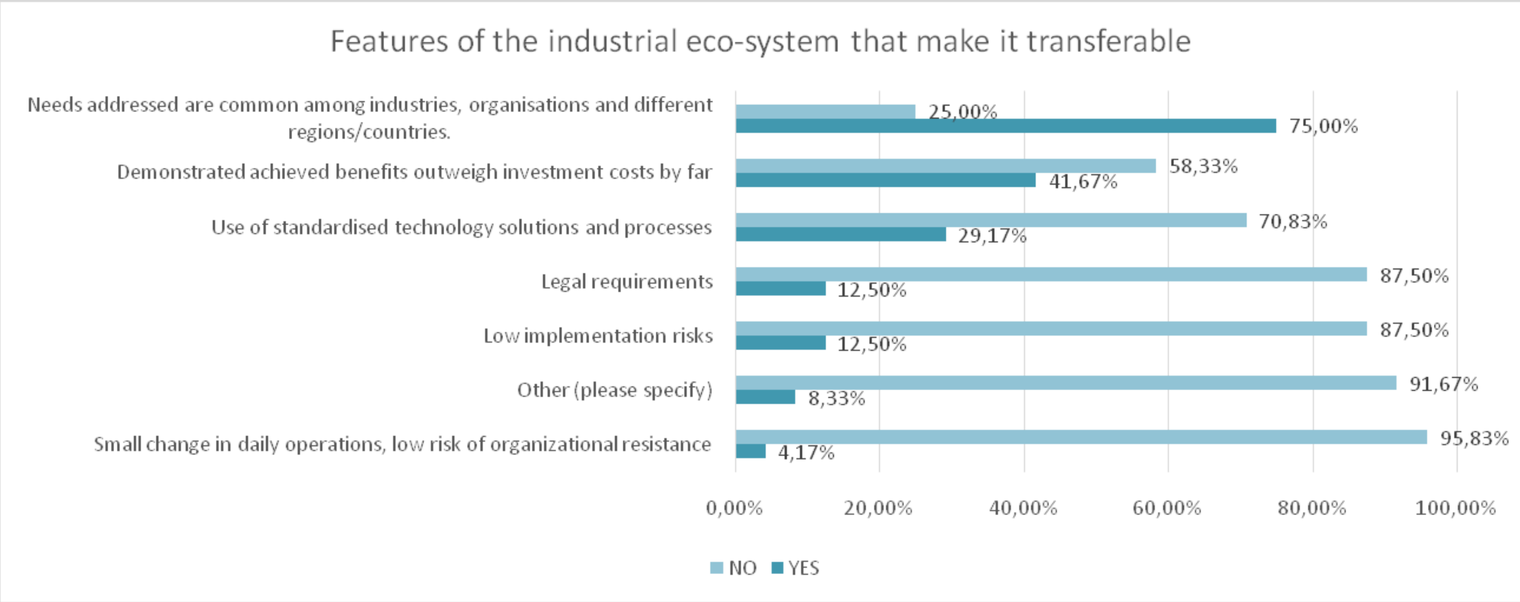
Transferability factors for industrial symbiosis projects (48 cases)



Readers of this document can see that the most important determining factor of the transferability of an industrial symbiosis project is the compatibility of needs addressed by the symbiosis among industries, organizations, regions and countries (77% of cases). The next key factors for transferring industrial symbioses are the existence of benefits that outweigh investment costs by far (58%) and the use of standardised technology solutions and processes (50%). Hence, it is possible to conclude that industrial symbiosis is transferred in the first place to address specific sustainability and resource efficiency needs, and secondly to achieve specific results (i.e. economic and environmental benefits. The transferability prospects are further strengthened if standardised technological solutions are applied.

However, the conclusions differ if one considers only the 24 cases of industrial symbiosis described by SYMBI partners that have already been transferred. The three factors mentioned previously are still the most important, however the effects of demonstrated achieved benefits and of the use of standardised technologies are significantly reduced (42% and 29% respectively). On the contrary, the effect of compatible needs addressed is at the same level (75%). Hence, it is possible to reach the conclusion that addressing needs that appear in other organisations, industries, and regions is the key factor for the scalability and transferability of industrial symbiosis practices. The conclusions about the transferability factors for the 24 already transferred industrial symbioses can be seen in the following figure:

Transferability factors for industrial symbiosis projects (24 already transferred cases)



Having finished the overview of the results of desk research, it is now time to proceed to the presentation of the specific best cases of industrial symbiosis that were found during the desk research.

4 Identification of best cases

4.1 Overview

Best cases of industrial symbiosis projects are those that comply the best in the criteria described in the following table:

Criteria for the selection of successful industrial symbioses

CRITERIA	SCORE					THRES HOLD
	1	2	3	4	5	
Level of solution impact	The industrial innovation eco-system addresses a unique problem within the boundaries of a specific industry and geographical scope	The industrial innovation eco-system relates to more than one problem encountered within the boundaries of the specific industry/geographical scope.	The industrial innovation eco-system relates to a unique problem encountered by more than one industry or sector in the area.	The industrial innovation eco-system relates to more than one problem encountered by more than one industry and broader geographical scope	The industrial innovation eco-system addresses a widespread issue that is relevant to all industries and geographical contexts	**3**
Number / type of achieved objectives and produced results	The practice has not produced tangible results or measurable benefits for the community (e.g. increased use of secondary raw materials)	The practice has reached some objectives but not produced measureable results	The practice has reached most of the objectives but not produced measureable results	The practice has reached most of the objectives and produced measurable results	The practice has resulted in significant and measurable results for the community. All planned objectives were met and tangible results were produced	**3**
Extent of problems encountered in implementation	Significant problems were encountered during the deployment / operation of the industrial innovation eco-system	The industrial innovation eco-system had some problems that hindered its implementation	The industrial innovation eco-system had only occasional problems that have not hindered its implementation	Participating organisations faced minor difficulties during the deployment of the industrial innovation eco-system	The deployment / operation of the industrial innovation eco-system had no problems or difficulties whatsoever.	**3**
Scalability of practice	Practice has been	Practice has been only	Practice has been	Practice has been	Practice has been	**3**

CRITERIA	SCORE					THRESHOLD
	1	2	3	4	5	
	implemented with the involvement of a limited number of organisations/companies	implemented within a small area affecting a limited number of organisations/companies	implemented in considerable urban or rural area involving a limited number of companies	implemented in considerable urban or rural area involving a significant number of companies	implemented in the entire city/urban agglomeration involving most of the industries operating in the area	
Level of transferability	Practice has not shown any indications of transferability to different settings/activities	Practice has shown indications of possible replication in a limited number of industries / geographical contexts	Practice has demonstrated strong potential of being replicated in different settings	Practice has been transferred to other industries	Practice has been transferred to more than one industries and geographical contexts	**3**

To identify the best cases, all 48 cases were checked to evaluate the degree that they satisfied these criteria. Among 48 cases, 12 were found to be more successful and to satisfy significantly better the 5 criteria described above. The main reason why 12 and not 10 cases (as asked by the methodology) were chosen as representative of best practices had to do with their qualitative characteristics that allowed for an understanding of various distinct types of industrial symbiosis. The scoring grid of the evaluation that led to the identification of these 12 cases can be seen in the table below:

Best cases scoring grid

Country	Industrial symbiosis project	Level of solution impact	Number / type of achieved objectives and produced results	Extent of problems encountered in implementation	Scalability of practice	Level of transferability
Slovenia	Dinos DROE UniREC	4	4	4	4	4

Spain	Manresa en Simbiosi	5	5	4	5	4
Italy	Giuliani Environment Srl	5	5	4	4	4
Poland	Waste Management and Recycling Cluster (WMRC)	5	5	5	5	5
France	Industrial Ecology Club of Aube (IECA)	5	4	5	5	5
	ArcelorMittal	5	4	4	4	4
	Industrial zone of Lagny Sur Marne	5	4	5	4	4
Sweden	Stockholm SymbioCity	5	5	5	5	5

Belgium	Kaiserbaracke	5	5	4	5	4
Netherlands	Industrial Symbiosis in Rotterdam	5	4	5	5	5
Germany	BASF	5	4	5	5	5
Portugal	Chamusca Industrial Symbiosis	5	5	5	5	5

4.2 Brief descriptions

4.2.1 Dinos DROE UniREC - Slovenia

Dinos d.d. established a subsidiary company, called UniRec, with the purpose to set up an industrial eco-system. The eco-system project, called “Plastic bottle for plastic bottle”, was thus initiated by Dinos. This industrial eco-system involved 3 companies, i. e. UniRec (Dinos), GastroPET and Fructal.

UniRec (Dinos) is a company which collects waste, sorts it and sell it to GastroPET.

GastroPET is a production company, which primary activity is the production of PET preforms. Company's main resources are secondary raw materials (coming from Dinos). GastroPET thus produces plastic bottles, which are bought by Fructal beverage company.

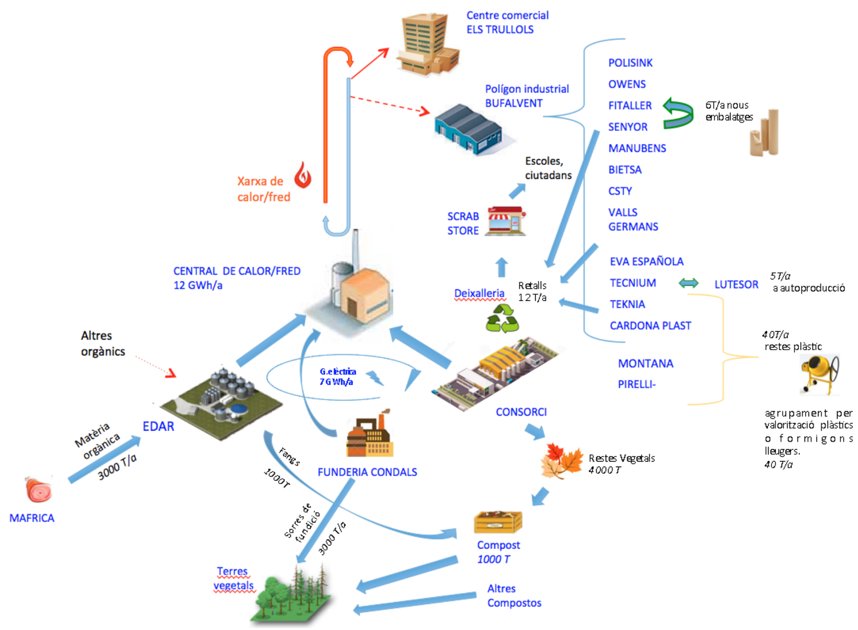
Fructal fills the bottle with the beverage. Those plastic bottles that are considered waste (due to non-compliance with the technical standards) and those collected through dedicated waste-collecting programmes (including schools), are returned back to UniRec (Dinos d.d.).

This is how that material loop is closed.

4.2.2 Manresa en Simbiosi - Spain

“Manresa en Simbiosi” is an initiative of the Council of Manresa (Catalonia) and the intermediation of Simbiosy (http://www.simbiosy.com/) with the purpose of implementing the first project of industrial symbiosis in Manresa (Catalonia) in order to maximize the efficient use of available resources, creating the basis for promoting synergies between companies / entities.

The industrial eco-system is still open for upcoming proposals, but there are several synergies already created between industries, as it can be seen in the image of the next cell.



4.2.3 Giuliani Environment Srl - Italy

Giuliani Environment Srl operates in Molise within the environmental sector. It was founded in 1998 through the transformation of the Francesco Giuliani company that operated since 1969 within the construction and environmental service sectors .

The Giuliani Environment Srl thanks to the continuous technological innovation, the exploitation of its know-how and the constant adaptation to the changing rules of the sector have enabled the company to become an important reference in the integrated waste cycle.

The Giuliani Environment Srl implements different activities, we hereby highlight those within the eco-industrial system: the composting and treatment of the paper from the urban waste collection.

Regarding the COMPOSTING activity, the Giuliani Environment Srl through a specific technique accelerates, controls and improves the natural process of the organic substances. This process, which takes place under controlled conditions, allows to obtain a biologically stable product, suitable for different applications: horticulture, industrial crops, fruit-growing, etc. In addition, the production of compost contributes to solving the problem of waste disposal, as the organic fraction represents about one third of the waste produced.

As regards the treatment of the PAPER, the Giuliani Environment Srl collects this waste, coming from urban separate waste collection, afterwards it selects and treats the paper waste according to the regulations. Subsequently, the paper is delivered to COMIECO consortium or directly to users, such as the paper mills.

Thanks to this process the paper becomes a secondary raw material ready for reuse.

4.2.4 Waste Management and Recycling Cluster (WMRC) - Poland

Waste Management and Recycling Cluster (WMRC) is a platform and an area of cooperation of companies, often competing with one another, which through synergy and access to specific resources (knowledge, new technology, people, etc.) may in the long run achieve more for their own quantifiable, economic development than when remaining outside of the group. Increasingly, however, clusters are built based on functional criteria (how best to meet the market) and thus the cluster participants cooperate on the principles of complementarity, not competition, creating a customer value chain.

WMRC was created in 2011. Now there are about 70 different organizations, i.e. SMEs, and large companies, universities, NGOs, which conduct effective cooperation. WMRC has become Key National Cluster in Poland in 2016.
Most of SMEs' recycled waste of electric and electronic equipment (WEEE) , but with the development of circular economy, the 3Re company (WMRC member) proposed to create industrial symbiosis with cluster members for promotion reuse. By keeping up with fast-changing trends in manufacturing of electronic devices such as mobile phones, smartphones, computers, tablets, touch screens, decoders, game consoles, monitors, printers and small domestic appliances, company started to reuse and refresh these devices. The company offered to share a value and better price for the part of WEEE which can be reuse. They introduced system for testing, recovery and dismantling monitors, PCs, laptops, RAM, etc. Chosen devices i.e. disks are scanned for bad sectors and other damage, and after, it they are repair on the basis of technical condition, cleaned and prepared for reuse.
The excess materials from companies is collected to provide them as raw materials for arts and crafts and/or making secondary products.
The presented system encourages companies to adopt a collaborative approach in all aspects of their business so that resources can be recovered, reprocessed and reused elsewhere in the industrial network either by themselves or by other companies. This approach of industrial symbiosis based on competitive advantage by promoting the physical exchange of materials, energy and byproducts.

4.2.5 Industrial Ecology Club of Aube (IECA) - France

The Industrial Ecology Club of Aube (IECA) initiated the industrial symbiosis between Cristal Union Factory and Appia Champagne enterprise. The aim of the project is to address long term issues pertaining to economic development and the regional planning.

Cristal Union Sugar Factory located near Troyes processes daily 25,000 t of sugar beets. The muddy water after washing sugar beets contains varied sediment granulation among other sand. As a result of muddy water treatment, sand is recovered. The sand is dirty and polluted; therefore, it cannot be used in agriculture industry, although it works well as a construction material. Since 1964 the sand has been stored on the fields within the radius of 30 km from the sugar factory, which results in high pollution and the development of landfill which cost Cristal Union from € 150,000 to € 300,000 per year. During the two months of beet campaign, 22,000-24,000 t of sugar beets were processed per day giving 15,000 t of sugar and 1,500,000 hectoliters of ethyl alcohol, the by-product of this process was sand (300 t/day).

In 2004 a partnership between Cristal Union and Appia Champagne (subsidiary of Effiage, company specializing in engineering) was established pertaining to the disposal of sand. With the agreement concluded between these companies, the sugar factory does not have to pay for sand storage and Appia Champagne obtains construction material free of charge. Thanks to the joint venture, Appia Champagne is able to reduce sand extraction from quarries which leads to cost reduction.

The enterprises have common transport of beets and sand by trucks so as to minimize the negative impact on environment (CO2 emissions) and reduce cost.

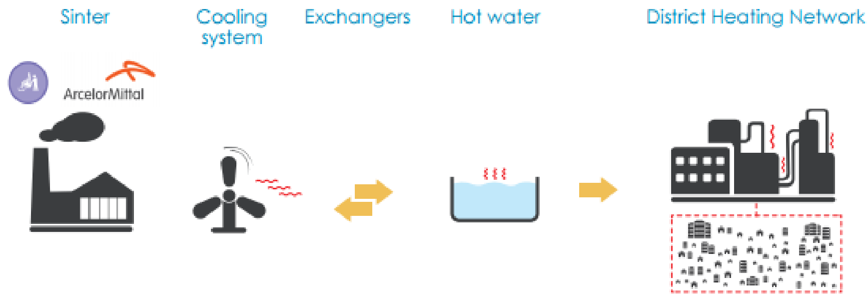
4.2.6 ArcelorMittal - France

Industrial symbiosis is exemplified by the recovery of heat from the exhaust gases from the steel manufacturing by ArcelorMittal in Dunkirk (France). In 1985 ArcelorMittal implemented an initiative concerned with sustainable development of industry by creating the district cluster in Dunkirk. The cluster is an example of cooperation between private and public entities, which has been successfully implemented for over 30 years. ArcelorMittal, along with the other industries in the cluster, provides heat as well as partially contributes to almost zero emissions of district heating of Dunkirk.

In ArcelorMittal heat recovery takes place during the first stage of the manufacturing process i.e. the sintering process of iron ores. The ore heated to 1,200 degrees C is later cooled in industrial blowers. Once the temperature has reached 400°C, the hot air is directed to the heat exchanger where it heats water. The hot water is sucked in a pump and drives to district heating network of Dunkirk. With more than 40 km of pipes it is possible to provide heat for various locations. The total power of the system installed in the ArcelorMittal company is 120 MW (this is the equivalent of 2400 gas boilers). The system implemented by ArcelorMittal is about 15-20% cheaper than fossil fuel.

The heat recovered in ArcelorMittal allows for supplying 6 000 housing units with heat. Thanks to ArcelorMittal, public facilities such as: swimming pools, hotels, colleges, universities are kept warm.

Additionally, the industrial symbiosis between ArcelorMittal and the district heating network of Dunkirk is one of interests the EU-funded EPOS project (Enhanced energy and resource Efficiency and Performance in process industry Operations via onsite and cross-sectorial Symbiosis).



4.2.7 Industrial zone of Lagny Sur Marne - France

The industrial zone of Lagny Sur Marne is managed by the local agglomeration authorities of Marne and Gondoire which provide dynamical development of the zone. The COMETHE (Conception of Methodological and evaluation Tools for Industrial Ecology) project has had an influence on the development of this zone.

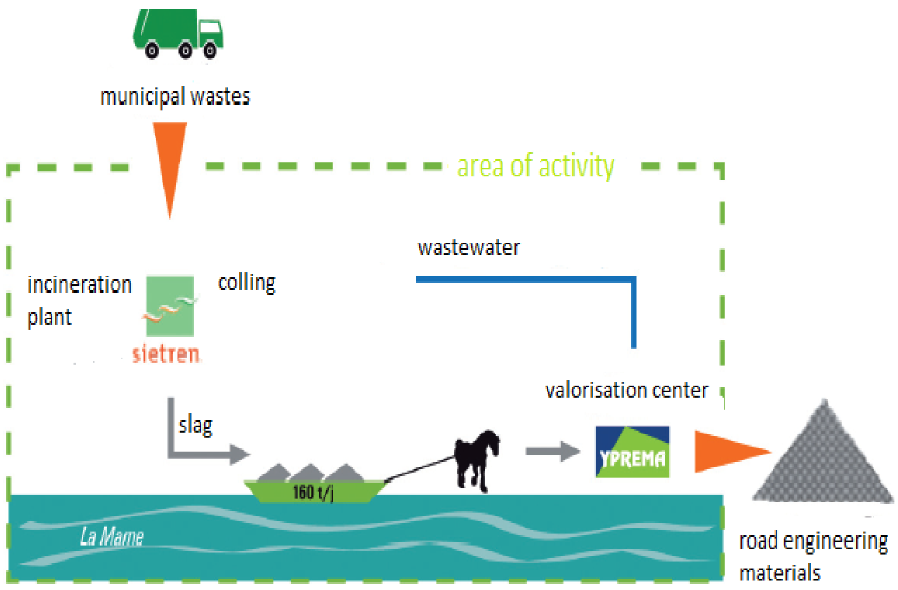
The main aspect of the successful symbiosis between the enterprise Yprema and Sietrem (Syndicat mIxte pour l'Enlèvement et le Traitement des REsidus Ménagers) are the complementarity of their activities as well as close proximity to each other.

Yprema is a company from the construction and public works sector. Yprema's activites focus on: using slag as a road construction material, and transporting wastewater to the association called Sietrem engaged in collection, processing and recycling of municipal waste. The Sietrem enterprise also owns the Municipal Waste Incineration Plant (MWIP) in St-Thibault-des-Vignes. On the other hand, Sietrem provides treatment of municipal waste, produces slag as a results of the incineration of the municipal waste and uses wastewater (from Yprema enterprise) for the process of slag cooling.

Yprema built a barge made of recycled aluminium for transporting slag. This barge is 20 meters long and 4.5 meters wide, which allows the transport of 80 tonnes of slag per crossing. Currently, there are two crossings a day, giving a total of 160 tonnes of transported slag. The barge is towed by horses, which shows high environmental awareness. It also contributes to minimizing CO2 emissions related to reducing road transport between two facilities.

Yprema has switched from road transport to pipelines directly connecting the two enterprises. Wastewater from treatment of slag (Yprema) is transported from valorization center by means of pipelines to the MWIP in Saint-Thibault-des-Vignes to be used in the process of slag cooling. MWIP in St-Thibault-des-Vignes uses 16,000 m3/year of treated wastewater to cool incandescent slag. Thanks to industrial symbiosis (reuse of wastewater from slag treatment), water consumption has been reduced by half.

Through their cooperative efforts, Sietrem and Yprema reduce costs and provide environmental benefits, including reducing greenhouse gases emissions (56 t of CO2 eq. per year) as well as creating more jobs at Yprema.



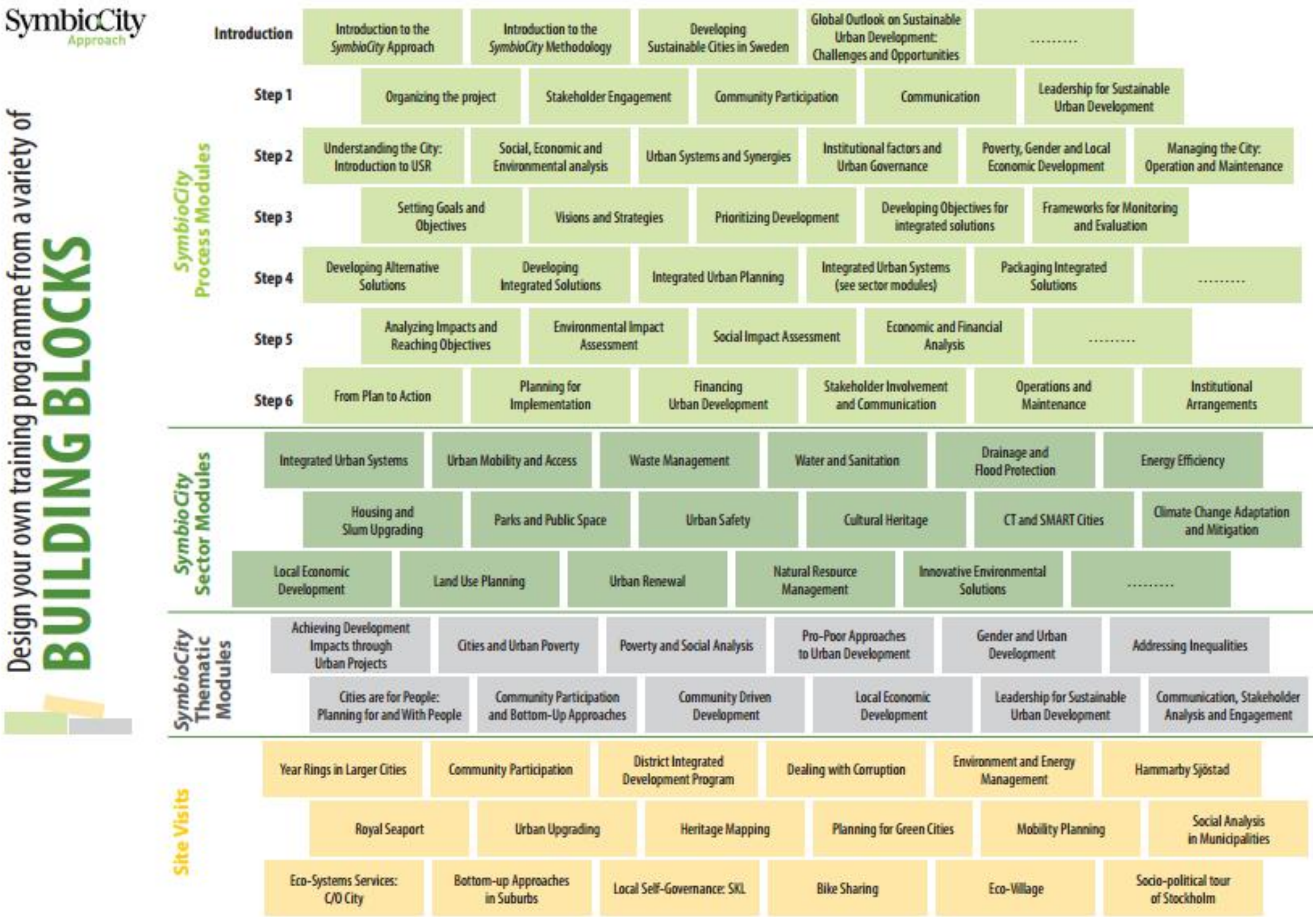
4.2.8 Stockholm SymbioCity - Sweden

SymbioCity is a Swedish government initiative run by Business Sweden and SKL International. Business Sweden oversees the SymbioCity trademark and promotes national exports on behalf of the Swedish government and industry. As part of Swedish international development co-operation, SKL International uses the SymbioCity Approach to support cities in developing countries to plan and build sustainably e.g. by identifying inclusive and innovative solutions.

SymbioCity Scenarios aim to increase awareness of some of the numerous opportunities available to local councils seeking to steer their cities towards sustainable development.

In this area there are many valid and different points of views and large- and small-scale solutions depending on differing conditions and cultures. Swedish expertise offers support and knowledge to help you to create your plan towards a more sustainable city.

SymbioCity is present at many areas:
WASTE OFFER: Focus on environment and health is driving a transition to better waste management.
URBAN TRANSPORT OFFER: The urban transport offer delivers mobility solutions, using multifaceted strategies to create maximum-efficiency networks for proactive cities.
URBAN AGLICULTURE OFFER: The urban The Urban Agriculture offer proposes a new way to cultivate food by building vertical greenhouses that reduce transport costs and emissions. This approach integrates with the city and saves money and the environment.
SUSTAINABLE AIRPORTS OFFER: A holistic and collaborative approach during building or redeveloping airports. Only then is possible to unlock synergies within and between systems: synergies that can deliver major benefits for safety and the environment – and cut costs. Interventions are often quite small and they make safety, climate, economy and social responsibility all go hand in hand.
GRID SOLUTION OFFER: SymbioCity find synergies in urban functions and unlock their efficiency and profitability. They integrate next-generation ICT with the electrical power grid, enabling greater and improved utilization of renewable energy sources. Smart grids also improve energy efficiency throughout the system, using intuitive user interfaces that involve and activate consumers.
ICT OFFER: ICT sews a fabric where new ideas can flourish and grow. It offers new ways to create jobs, growth and prosperity while driving sustainable development across the triple bottom line – social, economic and environmental.
SYMBIOCITY BIOGAS OFFER: The SymbioCity Biogas offer proposes practical ways to save money and energy by producing fuel from sewage and wasteSYMBIOCITY ***HEATING AND COOLING:*** SymbioCity takes a holistic approach to sustainable development. It is possible to find synergies in urban functions and unlock their efficiency and profitability. This is the key to Swedish design and manufacture of energy-efficient power supply and distribution systems.
SYMBIOCITY HOSPITAL SOLUTIONS: SymbioCity Hospital Solutions bring together the design and technologies for systems that substantially reduce energy consumption and make hospital services greener. Products and services include mainly heating and cooling, indoor climate control, automated waste and laundry collection.
SYMBIOCITY CLEANWATER OFFER: SymbioCity CleanWater offer is a business-led initiative that offers integrated water and wastewater treatment solutions from Sweden. SymbioCity CleanWater can design, construct, service and maintain solutions tailor-made to needs.



4.2.9 Kaiserbaracke - Belgium

The Kaiserbaracke industrial park is an example of a symbiotic system. The main reasons for the implementation of the industrial symbiosis were limited access to traditional raw materials and cost reduction (the system based on biomass is three times cheaper than the installations which use fossil flue). In 2004 an arrangement was initiated by three companies ie. Belwood, Delhez et Renogen, and in 2005 the company Holz Niessen joined. In 2006, the joint operations of the enterprises began. Companies act only as business partners. The total cost of the project amounted to € 40,000. The next stage of the project development was joined by Spi + ,the economic development agency for the province of Liège, which is responsible for the development of the infrastructure of the industrial park. The area where the park is located belongs to Amblève municipality.

The Holz Niessen company is a timber sorting centre. As a result of the wood sorting process at the Belwood sawmill, 50% of the wood is turned into finished and semi-finished products, with the remainder being bark, sawdust, and scrap wood. Production waste are used in 100% on-site to produce heat (Renogen company), pellet (Delhez company), semi-finished wooden products. As a part of the Renogen company, the co-generation centre allows for the production of heat and mechanical energy which is then converted into electricity. At

the Kaiserbaracke industrial park, wood is used as a raw material for energy production. Heat is used both to produce pellet in Delhez and wood plank in Belwood by drying sawdust. Surplus heat is sold to the public electricity network. Ashes from the combustion of biomass are used in the construction industry for the production of clinker or ballast. The Renogen company conducted research on turning the ashes from burned biomass to fertilizer, although the government of Wallonia has expressed its opposition.
The implementation of the project helps to: reduce carbon emissions and oil consumption during the year; create new jobs.

4.2.10 Industrial symbiosis (IS) in Rotterdam - Netherlands

Industrial symbiosis (IS) in Rotterdam began as the industrial ecosystem (INES) program in 1994 with the participation of 69 industrial companies. In 1994, several bilateral arrangements already existed, however the systematic holistic search for the possibilities of sharing resources across companies in the form of symbiotic linkages to use the language of industrial ecology and cooperation between industry and academic units were new in this region.

Currently, the port of Rotterdam is the largest sea port in Europe - hundreds of millions of tonnes of cargo are handled on an annual basis. The 175,000 people working in and for Rotterdam's port and whole industrial area. An extensive intermodal transportation network of rail, inland shipping, road, short sea and pipelines gives the port of Rotterdam the best possible connections to the rest of Europe (https://www.portofrotterdam.com/en/the-port/facts-figures-about-the-port).
In cooperation with the Province, power companies, industrial facilities and municipalities, the Port Authority uses the Deltaplan Energy Infrastructure to promote the construction of infrastructure which allows the residual heat and steam from businesses in the port area to be put to better use. It offers opportunities to the industrial sector itself, but also to the surrounding urban areas (e.g. as district heating) and to horticultural areas. The available infrastructure makes it possible to achieve considerable savings in power consumption. The system also provides a considerable reduction of emissions of CO_2 , NOx and particulate matter. Large-scale investments are required to create this infrastructure, as well as a joint effort by public and private parties.
Industrial processes in the port release large quantities of heat, steam and CO_2. Heat is generated only for the needs of chemical companies, greenhouse farming and households in the region. These energy sources can be exchanged cleverly via pipelines. It is one way to contribute to a sustainable port and ensure a profitable and sustainable business climate. Currently, the energy infrastructure includes the following routes (https://www.portofrotterdam.com/en/cargo-industry/energy-industry/energy-infrastructure):

- Nieuwe Warmteweg – 26 km underground pipe network which transports heat from waste and energy company AVR to the Rotterdam city centre where it is used for district heating;
- Leiding over Noord – 16.8 km pipeline, energy supplier Eneco transports residual heat from waste and energy company AVR in Rozenburg via Vlaardingen and Schiedam to the district heating network of Rotterdam;
- Steam network – 2 km stem network brings available steam to companies which need steam. Network links up AVR with chemical company Emerland Kalama Chemical (EKC) in Botlek;

- CO_2 capture and use – pipeline network of OCAP, CO_2 is transported from Shell Pernis and Abengoa to the greenhouse areas of Westland, where it is used to enhance the growth and quality of crops.

Five units (the Port of Rotterdam Authority, Gasunie, the Province of Zuid-Holland, Eneco and Warmtebedrijf Rotterdam) signed a letter of intent regarding the realisation of a main infrastructure for distributing heat to a variety of users, including private households, horticultural firms for the heating of greenhouses and companies in the province of Zuid-Holland. The name of programme is Warmtealliantie Zuid-Holland (Zuid-Holland Heat Alliance) (https://www.portofrotterdam.com/en/news-and-press-releases/zuid-holland-heat-alliance-setting-to-work-on-the-new-heat-network).

The firms in the port area produce a large amount of industrial residual heat. There is a possibility that the projects outside this area can also be incorporated in the network, including sustainable sources of heat like geothermal wells. The residual heat generated in the port of Rotterdam can potentially fulfil the annual heat requirement of over 500,000 households. This is one of the most important environmental benefit for this region and it could play a major role in achieving the adopted climate targets. The use and re-use of heat in the port of Rotterdam could help reduce the volume of fossil fuels used for heating. This could bring a further benefit - substantial reduction in CO_2 emissions.

According to the regional sustainability ambitions and the current public debate, the heat network in this area will not be relying on heat from coal-fired power plants.

4.2.11 BASF - Germany

BASF is the world's leading chemical company, operating in five segments: Chemicals, Performance Products, Functional Materials & Solutions, Agricultural Solutions and Oil & Gas. BASF has sites in more than 80 countries, including Europe, America, Africa and Asia. In BASF, the idea of Verbund was developed and it is indicated as a company strength. The Verbund idea is based on interlinking of production facilities, energy flows and infrastructure in a smart way. Moreover, know-how and customers are also connected.

Currently, the largest Verbund site in BASF Group is located in Ludwigshafen in Germany. Ludwigshafen Verbund Site was established in 1865 and now it is one of the six Verbund sites in the world. In this concept, one company uses resources of other companies in an efficient way, taking into account economic issues, social responsibility and environmental protection. By-products of one company are used as raw materials in other plants. It is an example of efficient and resource-conserving value-adding chains, which preserve resources and energy, minimize emissions, and reduce logistics costs. So, the production plants, energy flow (the waste heat of one plant provides energy to others), infrastructure, expertise and customers are connected and integrated. This gives rise to efficient value-adding chains ranging from basic chemicals to highly sophisticated products. Furthermore, one facility's by-products could serve as feedstock in other company. It provides a raw materials and energy savings, and avoids emissions, lowers logistics costs and makes use of industrial synergies.

Currently, the Ludwigshafen Verbund Site is the world's largest integrated chemical complex under single management. It is a largest BASF Verbund site with the area of 10 km^2, 106 km of roads, 230 km of rail, 2,850 km of pipelines and approx. 2,000 buildings. Site traffic is equal to 2,100 trucks daily and shipment 100,000 containers p.a. By the integration of transport system in one network (98 trucks approx. 2,100 daily - 30% of transportation volume, rail cars approx. 400 daily - 30% of transportation volume and barges approx. 20 daily - 40% of transportation volume), the reduction of logistics costs is achieved.

At Ludwigshafen Verbund Site there are 110 production facilities with around 200 production plants, including 35,972 employees. About 8000 products (based on raw materials) with a total volume of 8.5 million tonnes are currently produced in Ludwigshafen complex per year.

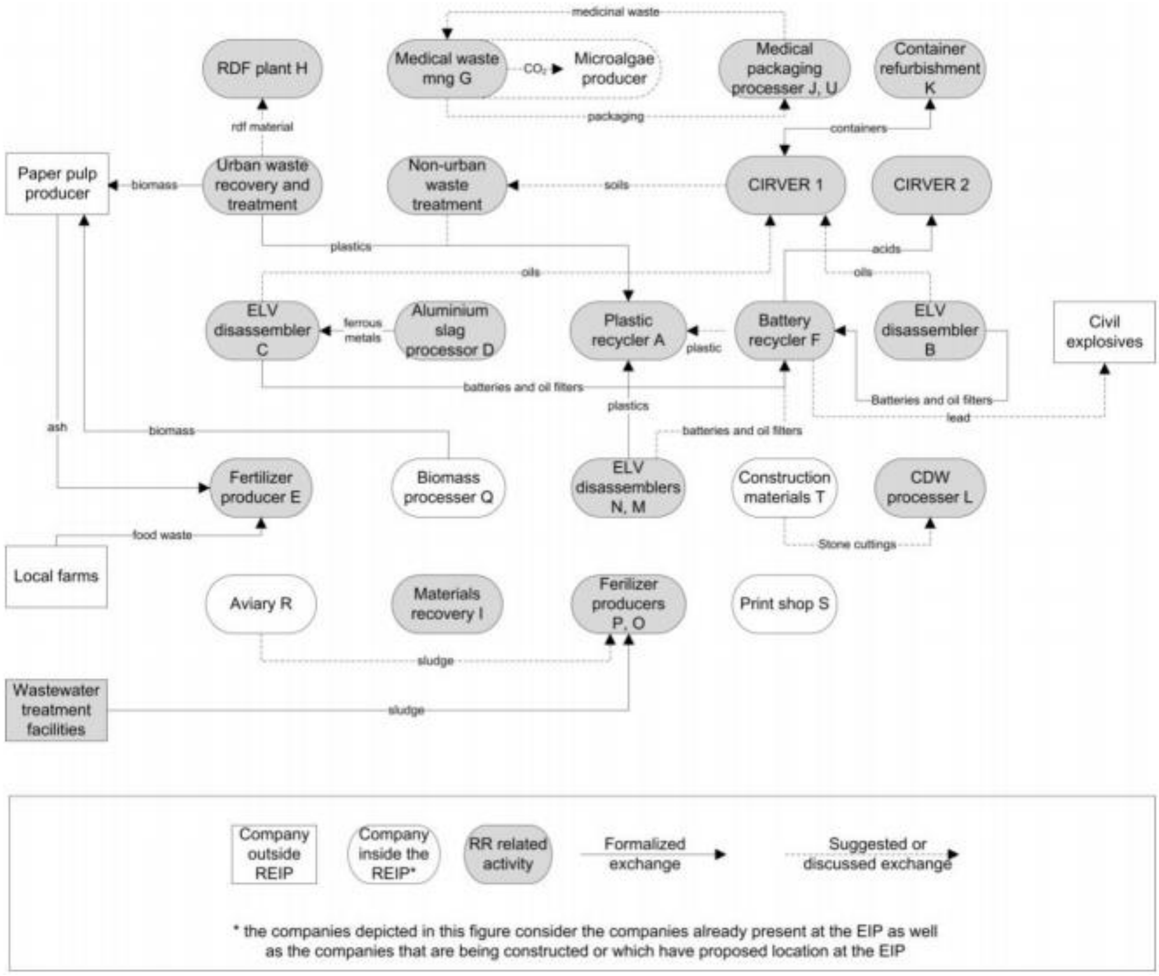
The Verbund idea is focused on four issues:

- Production: more cost-effective, safer and environmentally friendly production processes; savings of energy by means of efficient processes; avoiding of long transport routes (optimisation of transport),
- Technology: company unit for Engineering and Operational Excellence; strengthens BASF's global network,
- Customer: works closely with customers; interlinks markets and technologies,
- Employee: integration in one company in order to achieve success; sharing experience and knowledge; good and effective networking among Verbund employees; easy access for information at any time using special tablets and QR codes (digital transformation under the banner "BASF 4.0").

Global Know-How Verbund: Cooperation with many science and industry units (600 excellent universities, research centres and companies - approx. 10,000 employees in research and development) worldwide contributed to creation of an international and interdisciplinary Know-How Verbund. Expert knowledge is pooled into global research platforms. At the Ludwigshafen site, a part-time training programme for newcomers from other fields is offered, in order to qualify them for work in chemical industry.

4.2.12 Chamusca Industrial Symbiosis - Portugal

The waste management legislation in Portugal requires that licensed waste management operators treat all waste. Although there are no legal impediments that prevent a manufacturer to obtain a license to receive waste, the process can be bureaucratic and expensive, since it requires technological standards to assure the proper treatment for the waste. In this context, most of the waste recovered goes through Resource Recovery companies, since their main investment is in waste management and/or resource recovery. Taking advantage on a series of waste management regulations and waste recovery and treatment investments in their municipality, the local government in Chamusca reached for Industrial Ecology as a paradigm to develop the first eco industrial park in the country. The eco industrial park idea is based on waste disposal, and is realised for a lot of groups of waste (mainly urban waste, non-urban waste, medical waste, plastic, battery). It connect producers, farmers and local entrepreneur. In this context, industrial symbiosis was encouraged as an objective for the community and business alike; however, local government also understood that the current Portuguese waste management scenario favoured recycling of materials through RR companies. As a consequence, the larger waste treatment and recovery facilities at the park (e.g. two national centres for the recovery, treatment and disposal of hazardous wastes, a resource recovery and treatment centre for municipal waste and a treatment facility for nonurban wastes) soon began attracting recyclers of various natures (e.g. batteries, plastics, biomass), waste sorters (e.g. medical packaging) or disassemblers (e.g. end of life vehicles). It was in this setting that local government deployed several actions to promote the interaction between RR activities' managers themselves and with companies/institutions in the region surrounding the Relvao Eco Industrial Park. The result is that not only wastes are exchanged between manufacturers and some RR companies in the Eco Industrial Park, but services and waste materials are exchanged, or are in the process of being exchanged, between the RR companies themselves.


medicinal waste
RDF plant H
Medical waste mng G
CO2
Microalgae producer
Medical packaging processer J, U
Container refurbishment K
packaging
rdf material
containers
Paper pulp producer
biomass
Urban waste recovery and treatment
Non-urban waste treatment
soils
CIRVER 1
CIRVER 2
plastics
acids
oils
oils
ELV disassembler C
ferrous metals
Aluminium slag processor D
Plastic recycler A
plastic
Battery recycler F
ELV disassembler B
Civil explosives
batteries and oil filters
Batteries and oil filters
lead
plastics
ash
biomass
batteries and oil filters
Fertilizer producer E
Biomass processer Q
ELV disassemblers N, M
Construction materials T
CDW processer L
food waste
Stone cuttings
Local farms
Aviary R
Materials recovery I
Ferilizer producers P, O
Print shop S
sludge
Wastewater treatment facilities
sludge
Company outside REIP
Company inside the REIP*
RR related activity
Formalized exchange
Suggested or discussed exchange
* the companies depicted in this figure consider the companies already present at the EIP as well as the companies that are being constructed or which have proposed location at the EIP

4.3 Lessons learned

Country	Main lessons learned
Slovenia	• Industrial symbiosis projects have higher chances of success if there is: ○ enhanced mutual trust between companies ○ better cooperation among companies and stakeholders ○ greater awareness of the importance of such projects ○ the companies' will to cooperate in an industrial eco-system ○ ideas for new similar projects ○ spill-over effects are strengthened by attracting more stakeholders in the projects.
Spain	• The success of industrial symbioses is not determined by waste quantities, but by the will of people to change and get involved in circular economy projects.
Italy	• Belonging to an industrial symbiosis network of partners enable companies to develop mutual benefits and, at the same time, allows them to improve or strengthen their strategic positioning in the market.
Poland	• The reuse of waste within industrial symbioses is the preferred mode of recovery as reuse and repair of end-of-life products help reduce the increasingly growing waste amount. • By extending their life, product reuse within the context of industrial symbiosis enhances resource efficiency and saves energy, and thus reduces water and air pollution. • Industrial symbiosis can further develop if there are proper communications and agreements to share the profit among partners as well as rapid technological development for product reuse.
France	• Effective cooperation between the cooperating partners is crucial • Effective collaboration between members of the cluster has a significant influence in reducing emissions within the context of industrial symbioses. • Demonstrating that environmentally friendly solutions are cheaper than using fossil fuel is very important for the development of corporate social responsibility. • Short distances between participating companies are advantageous; • Complementarities of enterprises creates more chances for the formation of industrial symbioses • A similar organizational culture is an important factor for the development of industrial symbioses. • The representation of companies from different industries is an important factor for the success of industrial symbiosis. • The effective implementation of industrial symbiosis has led to a significant reduction in costs • Openness and effective cooperation is a key aspect of the implementation of industrial symbiosis.

Belgium	• Legal regulations are a very important factor influencing industrial symbiosis (for example, ash from the combustion of biomass can be used in construction industry, but it is not allowed in agriculture industry because of legal regulations in the region of Wallonia) • Location is a very important factor for the successful development of industrial symbiosis • Effective cooperation is one of the crucial factors on which the development of industrial symbiosis depends. • Limited access to traditional raw materials can affect industrial symbioses
Sweden	• Methods of applying industrial symbiosis should be adaptable to the needs and context of the area. • It is important to involve in an industrial symbiosis project personnel with the necessary skills and competences. • Industrial symbiosis can be more successful if it is a dynamic concept that offers something for everyone. • Industrial symbiosis should be designed in a way that allows for its application in developed, developing or transitional economies. • Industrial symbiosis should involve public and private actors alike.
Netherlands	• Specific local social circumstances should not be underestimated, as they can serve to stimulate mutual trust building between industries and create an environment for cooperative action • Industrial symbiosis should address the need of more than one organisation/actor (for example, heat networks offer a reliable, affordable and sustainable heat supply to both private households and companies) • Firms involved in an industrial symbiosis project should be autonomous. • All agreements in the context of an industrial symbiosis project should be based on commercially sound principles. • The development of the symbiosis should be voluntary but should also occur in close cooperation with government authorities • Short physical distances between participating plants are advantageous • Mutual management understanding, cooperative commitment, and the establishment of effective communication between participants are required.

Germany	• It is important to establish sustainable cooperation in one sector of the regional industry (for example integrate all chemistry-connected actors in the region).
	• The following are important success factors of an industrial symbiosis project:
	    o training and the adequate development of skills
	    existence strong company culture
	    high quality of communication
	    o employing regional divisions, corporate centres and research and functional units to support business development
	    applying a company strategy that is compatible with sustainable

	development goals o creating a positive image of the firms o adaptation of business optimally with customers' needs - taking into account the needs of customers and contribution to their success with innovative and sustainable solutions close partnerships with customers and research units, in order to develop new system solutions, customized products, functional materials, processes and technologies.
Portugal	• Waste management and the recovery of raw materials is easier than obtaining a permit for waste collection. • Eco-industrial park in Chamusca is an industrial symbiosis that benefits both communities and businesses.

5 Benchmarking

5.1 Conditions of success

Having analysed the successful cases of industrial symbiosis and identified & presented the 12 most important successful cases, it is now time to benchmark the characteristics of industrial symbiosis that can guarantee its success and transferability in Europe. Benchmarking in this case is meant to be the concretisation of the criteria for the selection of industrial symbiosis with the aim of providing a catalogue of key conditions for the success of industrial symbiosis that ecompasses all the aforementioned criteria. The cataslogue is designed to be used a) ***before*** the implementation of an industrial symbiosis prospect in order to estimate its prospects of success, and b) ***after*** the initialisation of an industrial symbiosis project to check its progress.

The rationale for developing the catalogue of key conditions is based on encompassing all aspects of the criteria for success of industrial symbioses. As a result, each condition will cover specific aspects of the following criteria, which were developed in the methodology:

a) Level of solution impact
b) Number / type of achieved objectives and produced results
c) Extent of problems encountered in implementation
d) Scalability of practice
e) Level of transferability

The aspects covered that correspond to each of these criteria are presented in the following paragraphs.

The *level of solution* impact can be evaluated by investigating the object of material and energy exchanges that take place in each industrial symbiosis project. The analysis of the data in the previous pages reveals that symbioses that include exchanges of energy by-products and secondary raw materials, and/or waste collection and exchange are usually more successful. The higher the compatibility of the materials and energy exchanges with the key agricultural and industrial sectors of an area, the higher the probability of success of an industrial symbiosis project and the better the prospects for achieving a high impact. Consequently, the conditions that should be included in the catalogue are the following:

1. Extent of exchanges of energy, by-products and secondary raw materials
2. Extent of waste collection and exchange
3. Compatibility of exchanges with key economic sectors of the area

The *number / type of achieved objectives and produced results*, can be evaluated by investigating the types and degree of positive impact that are generated (or are expected to be generated) by an industrial symbiosis project. Since our analysis has already identified the types of positive impact of industrial symbiosis project, the conditions that can be included in the catalogue are related to these types and to a pursued analogy between environmental, economic and social impacts. Hence, the conditions are the following:

1. Extent of (expected) improvements in the resource efficiency of the area
2. Extent of (expected) reductions in greenhouse gas emissions
3. Extent of (expected) reductions in production costs
4. Number of jobs (expected to be) generated by the industrial symbiosis project
5. Amount of extra income per job (expected to be) generated by the industrial symbiosis project.
6. Improved environmental awareness of the importance and feasibility of industrial symbioses
7. Extent of increases in network formation among organisations
8. Analogy in achieving environmental and economic benefits

The *extent of problems encountered in implementation*, can be evaluated by investigating the presence or lack thereof of key success factors in a proposed or concurrent industrial symbiosis project. Since the key success factors for industrial symbiosis have been identified as the active participation and commitment of organizations involved in an industrial symbiosis, the close proximity of companies and the participation of diverse organisations, the conditions that will be included in the catalogue are related to these three factors and are the following:

1. Expected or concurrent amount of financial resources that organisations participating in the project contribute to the project
2. Expected or concurrent number of personnel that is contributed to the project by organisations participating in the project
3. Distance between the organizations involved in exchanges that participate in the project.
4. Number of different types of organisations (i.e. large companies, SMEs, local authorities) that (will) participate in the project.

The *scalability of practice* can be evaluated by investigating several factors that affect the adaptation of an industrial symbiosis project in smaller or larger areas. These factors that were identified in the analysis of desk research data have to do with the flexibility of an industrial symbiosis project. Projects that are more flexible, i.e. can involve firms/organisations of many different types, regions and sectors can be easily scalable to the specific needs of a given region. Hence, the conditions for the scalability of a project are the following:

1. Extent of capability to realise the industrial symbiosis using different types of companies (large companies, SMEs)
2. Addressing resource efficiency needs of both small and large areas/organisations

Finally, the *level of transferability* can be investigated using a number of conditions that refer to the extent to which a specific industrial symbiosis concept has been applied to different regions, such as those below:

1. The type of industrial symbiosis has been replicated in more than one countries
2. The type of industrial symbiosis has been transferred in locales with different characteristics
3. Addressing the need for resource efficiency and energy and by-product exchange

5.2 Where to apply

The conditions described in the previous section are constructed so that the catalogue can be both concrete enough to benchmark any existing or proposed industrial symbiosis project and abstract enough to be adapted and further specified by specific regional authorities according to the needs of their territory. This level of abstraction allows for both drafting a specialised catalogue and for preserving the capability to compare benchmarking processes among different regions.

To be more precise, a territorial authority can further specialise the catalogue by updating it with information about the specific needs, organisations, sectors of the economy, and exchange materials that apply to its territory. For example, a regional authority in need of reductions in water consumption could redraft the condition “Extent of (expected) improvements in the resource efficiency of the area” in the form of “Extent of application of water reuse in the area”.

5.3 How to apply

Each territorial authority will evaluate all proposed or existing industrial symbiosis projects by carefully checking or estimating if and how they satisfy the conditions included in the aforementioned catalogue. For all industrial symbiosis, territorial authorities will assign a value from 0 to 10 to describe how much they satisfy the conditions for success of industrial symbiosis projects. The values will be added and then divided by the total number of conditions to develop an indicator of concurrent or expected success of an industrial symbiosis project. The mathematical formula for the indicator can be seen below:

$$I = \sum_{(n=20,\, i=1)} v_i / m_i$$

Where:

I: expected or concurrent degree of success

n: total number of conditions

v: value attributed in each condition

m: total number of conditions (20 in our case)

The following table can work both as a representation of the catalogue of conditions for success of industrial symbiosis as well as a template for the evaluation of such projects:

#	Conditions for success of industrial symbiosis projects	Value (0-10)
1	Extent of exchanges of energy, by-products and secondary raw materials	
2	Extent of waste collection and exchange	
3	Compatibility of exchanges with key economic sectors of the area	
4	Extent of (expected) improvements in the resource efficiency of the area	
5	Extent of (expected) reductions in greenhouse gas emissions	
6	Extent of (expected) reductions in production costs	
7	Number of jobs (expected to be) generated by the industrial symbiosis project	
8	Amount of extra income per job (expected to be) generated by the industrial symbiosis project.	
9	Improved environmental awareness of the importance and feasibility of industrial symbioses	
10	Extent of increases in network formation among organizations	
11	Analogy in achieving environmental and economic benefits	
12	Expected or concurrent amount of financial resources that organisations participating in the project contribute to the project	
13	Expected or concurrent number of personnel that is contributed to the project by organisations participating in the project	

#	Conditions for success of industrial symbiosis projects	Value (0-10)
14	Distance between the organizations involved in exchanges that participate in the project.	
15	Number of different types of organisations (i.e. large companies, SMEs, local authorities) that (will) participate in the project.	
16	Extent of capability to realise the industrial symbiosis using different types of companies (large companies, SMEs)	
17	Addressing resource efficiency needs of both small and large areas/organizations	
18	The type of industrial symbiosis has been replicated in more than one countries	
19	The type of industrial symbiosis has been transferred in locales with different characteristics	
20	Addressing the need for resource efficiency and energy and by-product exchange	
TOTAL	**Sum of values :**	
INDICATOR VALUE:		

6 Annex 1

The following table constitutes the input paper form designed to be used by SYMBI partners in order to present successfull cases of industrial symbiosis projects.

SYMBI - Industrial Symbiosis for Regional Sustainable Growth & a Resource Efficient Circular Economy		
Activity 1.3: Identification of good practices and benchmarking of ecosystems of by-product and energy exchanges		
Collection of good practices on ecosystems of by-product and energy exchanges		
Title:		
A. CASE IDENTITY		
LOCATION	**Country:**	
	Region:	
	City/Town: *(if applicable)*	
ACTIVITIES / MAIN FOCUS	**Geographical level of implementation**	☐ National ☐ Regional ☐ Local
	Type of cooperative activity amongst firms in the industrial eco- system	☐ Exchange of energy, by products and secondary raw materials ☐ Joint use of utilities and firm functions ☐ Collective gathering and removal of waste materials ☐ Combining transport of goods and people ☐ More intensive use of space ☐ Public utilities with high useful effects ☐ Joint commercial firm facilities ☐ Multimodal transport and high quality public transport ☐ Other (please specify)

DURATION	Time of implementation	

B. CASE DESCRIPTION	
Type of actors involved (choose all that apply)	☐ Large (industrial) enterprises ☐ Small and medium-sized enterprises ☐ National authorities ☐ Regional authorities ☐ Local authorities ☐ Public Agencies ☐ Other (please specify)
Please briefly describe the industrial eco-system	
Image (if available)	
C. NEEDS, BARRIERS AND SUCCESS FACTORS	
What were the main needs and objectives for the deployment of the industrial eco-system?	☐ Promote the use of sustainable bio-energy resources ☐ Improve resource efficiency ☐ Access new markets ☐ Share risk ☐ Open new markets for secondary raw materials ☐ Reduce CO2 emissions ☐ Increase profitability, revenue ☐ Reduce production costs ☐ Other (please specify)
What are the main difficulties encountered during the deployment / operation of the industrial eco-system?	☐ Regulation / limited support by local policy makers ☐ Funding, lack of financial resources ☐ Lack of expertise / skills of existing employees within firms ☐ Imbalance of power between partners ☐ Different organisational culture within firms ☐ Economically unsound or risky exchanges

	☐ Lack of motivation and commitment among firms ☐ Lack of geographical and technological proximity of firms ☐ No problems encountered Other relevant info provided: ……………………………….
Why such industrial symbiosis approach has been effective? What are the success factors?	☐ Close proximity of companies ☐ Diversity of actors ☐ Low economic risks ☐ Adequate funding ☐ Balance of power between partners ☐ Similar organisation cultures of firms ☐ Legal and political support ☐ Active participation and commitment Please comment on the success factors: ……………………………….
C. RESULTS & PROSPECTS	
What were the main benefits created by the deployment/operation of the industrial eco-system? *(select all that apply)*	☐ Contribution to the regional GDP ☐ Cost reduction / Annual savings ☐ Increased productivity for the participating companies ☐ Increase in job opportunities (employment) ☐ Enhanced research and innovation capacity ☐ Reduce in greenhouse gas emissions ☐ Improved resource efficiency ☐ Other (please specify): *Please briefly discuss about the degree of impact on the selected categories of benefits*
How would you describe the industrial eco-system deployed?	☐ Very successful ☐ Quite successful ☐ Somewhat successful ☐ A little successful

	☐ Not at all successful ☐ Do not know / Do not wish to answer
Has the industrial eco-system (or aspects of it) been replicated / transferred in other areas and settings?	☐ Yes ☐ No *Please briefly discuss about practice's potential for transferability / replicability*
What are the most significant features of the industrial eco-system that make it transferable?	☐ Use of standardised technology solutions and processes ☐ Needs addressed are common among industries, organisations and different regions/countries. ☐ Demonstrated achieved benefits outweigh investment costs by far ☐ Low implementation risks ☐ Small change in daily operations, low risk of organizational resistance ☐ Legal requirements ☐ Other (please specify)
Main lessons learned	
Further information (URL, sources)	