PROCEEDINGS

Methods and tools for the implementation of industrial symbiosis

Best practices and business cases in Italy

Symbiosis User Network - SUN

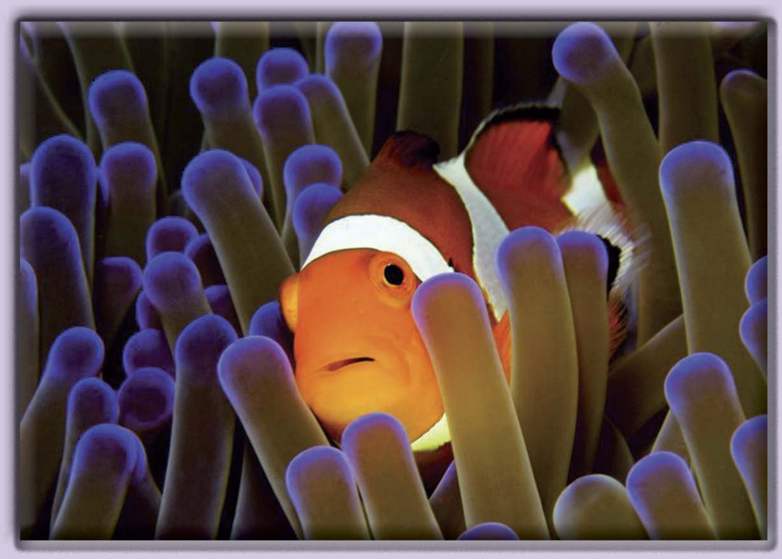
Proceedings of the first SUN Conference

Rome

25th October 2017

Edited by Erika Mancuso and Valentina Fantin

SYMBIOSIS USERS NETWORK



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

METHODS AND TOOLS FOR THE IMPLEMENTATION OF INDUSTRIAL SYMBIOSIS

BEST PRACTICES AND BUSINESS CASES IN ITALY

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2017 ENEA
National Agency for New Technologies, Energy and
Sustainable Economic Development

ISBN: 978-88-8286-358-6

Editorial review: Giuliano Ghisu

Cover design: Cristina Lanari

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INTRODUZIONE

Secondo la Commissione Europea, l'economia circolare è un sistema economico in cui:

"*il valore dei prodotti e dei materiali si mantiene il più a lungo possibile; i rifiuti e l'uso delle risorse sono minimizzati e le risorse mantenute nell'economia quando un prodotto ha raggiunto la fine del suo ciclo vitale, al fine di riutilizzarlo più volte e creare ulteriore valore*".

L'economia circolare rappresenta un cambiamento radicale di paradigma rispetto al modello di economia lineare, nell'ambito del quale sviluppare nuovi modelli di business sostenibili, in grado di accrescere il potenziale di chiusura dei cicli produttivi e di uso efficiente delle risorse sul territorio.
La simbiosi industriale, ossia il trasferimento e la condivisione di risorse (materie prime, acqua, rifiuti, cascami energetici, servizi, competenze, strumenti, banche dati) tra imprese e/o altri operatori presenti sul territorio, è una strategia operativa di economia circolare espressamente citata nel Piano d'Azione sull'Economia Circolare, emanato dalla Commissione Europea nel 2015 (COM/2015/0614 final) e nella sua revisione del 14 marzo 2017.

A seguito delle esperienze maturate negli anni, ENEA si propone di mettere a sistema tutte le competenze relative alla simbiosi industriale in Italia, attraverso il coinvolgimento di stakeholder che a vario titolo e con diversi ruoli hanno avuto ed hanno un ruolo per l'implementazione operativa della simbiosi industriale in Italia.
Per questo motivo, ENEA si è fatta promotrice della costituzione della prima rete italiana di simbiosi industriale, SUN - Symbiosis Users Network, che nasce per valorizzare le esperienze maturate da anni in queste tematiche, condividerle e collaborare per favorire un'applicazione sistematica della simbiosi industriale. SUN promuove modelli di economia circolare attraverso la simbiosi industriale, approfondendo tematiche di carattere operativo che possono riguardare, ad esempio, normative, standard tecnici, buone pratiche.
Le attività di consultazione e di acquisizione delle adesioni delle parti interessate si sono concluse nel settembre 2017 e la rete SUN è pertanto operativa.

SUN si è adoperata per realizzare un primo momento di confronto sui temi dell'economia circolare e l'uso efficiente delle risorse in Italia ed a livello internazionale. Allo stato attuale SUN vede la partecipazione di diciannove aderenti tra cui istituzioni di rilievo nazionale (Ministero dell'Ambiente e Ministero dello Sviluppo Economico), Confindustria, Università (Univ. degli Studi di Bari Aldo Moro, Univ. di Bologna, Univ. degli Studi "G. D'Annunzio" di Chieti-Pescara, Univ. degli Studi di Messina, Univ. degli Studi di Roma Tre, Univ. degli Studi della Tuscia, Politecnico di Bari), ONLUS (Amici della Terra ed EnergoClub), organizzazioni territoriali (LazioInnova, Sviluppumbria, ASTER, DINTEC), il Centro Tessile Cotoniero e Abbigliamento SpA ed il Consorzio LEAP-Laboratorio Energia e Ambiente Piacenza.
SUN è aperta all'adesione di altri interessati (imprese, istituzioni, associazioni, mondo della formazione e della ricerca) che vogliano contribuire ad arricchire il patrimonio di competenze e a farsi promotori di iniziative comuni per facilitare l'applicazione della simbiosi industriale in Italia.

Con grande piacere ENEA ospita il primo convegno della rete SUN, i cui atti sono raccolti nel presente volume, ed augura alla neocostituita rete di poter efficacemente contribuire al confronto ed allo sviluppo dell'economia circolare e della simbiosi industriale in Italia.

Roberto Morabito
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In ordine da sinistra: Valentina Fantin, Roberto Morabito, Erika Mancuso

Dicembre 2016

INTRODUCTION

According to the European Commission, circular economy is an economic system where:

"*the value of products and materials is maintained for as long as possible; waste and resource use are minimised, and resources are kept within the economy when a product has reached the end of its life, to be used again and again to create further value*".

Circular economy represents a radical paradigm shift from the linear economy model, within which new sustainable business models can be developed, in order to increase the potential for closed-loop productive systems and for the efficient use of resources on the territory.
Industrial symbiosis, i.e. the transfer and sharing of resources (raw materials, water, waste, scraps, services, skills, tools, databases) among companies and / or other local operators, is an operational circular economy strategy mentioned in the Action Plan for the Circular Economy, issued by the European Commission in 2015 (COM / 2015/0614 final) and its revision of 14 March 2017.

Following the experience gained over the years, ENEA aims to systematize all the skills and expertise on the application of industrial symbiosis in Italy by means of stakeholders involvement who, in various ways and with different roles, have had and have a role for the operational implementation of industrial symbiosis in Italy.
Because of these reasons, ENEA has been the promoter of the constitution of the first Italian network on industrial symbiosis, SUN - Symbiosis Users Network, which aims to both enhance the experiences gained over the years in these topics and share them as well as to cooperate for promoting a systematic application of industrial symbiosis. SUN fosters circular economy models by means of industrial symbiosis, deepening operational issues which may concern, for example, regulations, technical standards and good practices.
Consultation and acquisition activities of stakeholder memberships were concluded in September 2017 and the SUN network is therefore operative.

SUN has worked to create a first moment for the exchange of views on the circular economy and the efficient use of resources in Italy and at international level. To date, nineteen participants have joined SUN, including national institutions (Ministry of the Environment and Ministry of Economic Development), Confindustria, Universities (University of Bari Aldo Moro, University of Bologna, Univ. "G. d'Annunzio" of Chieti-Pescara, Univ. of Messina, Roma Tre University, University of Tuscia, Polytechnic of Bari), ONLUS (Amici della Terra and EnergoClub), territorial organizations (LazioInnova, Sviluppumbria, ASTER, DINTEC), Centro Tessile Cotoniero e Abbigliamento Spa and the LEAP Consortium - Laboratory of Energy and Environment Piacenza.
SUN is open to the participation of other stakeholders (companies, institutions, associations, actors from education and research world as well) who wish to contribute to increase the professional skills as well as to promote common initiatives for facilitating the application of industrial symbiosis in Italy.

With great pleasure ENEA hosts the first SUN network conference, whose proceedings are collected in this volume, and wishes to the newly established network to effectively contribute to the comparison and development of the circular economy and industrial symbiosis in Italy.

Roberto Morabito
ENEA, Director of Department for Sustainability (SSPT)

INDUSTRIAL SYMBIOSIS AND ENERGY EXCHANGES.WHAT IS THE EFFECTIVE AND EFFICIENT EXCHANGE MODEL?

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Abstract

Industrial symbiosis is a cornerstone of industrial ecology and, more generally, the new paradigm of a circular economy, which generates mutual benefits among the actors of a production system through the exchange of matter and energy. Within the research activities of the FIR project - "Industrial Symbiosis in a Wide Area: Ionian Territory", we are studying how to manage the energy variable in symbiotic exchanges. The Taranto industrial area is very close to the urban area and, for this, the incidence of industrial activities on the city has caused strong urban environmental impacts.
In this presentation, we will present the current results of the project, including the symbiotic waste exchange scenario and the development of an energy symbiosis model.

Keywords: Circular Economy, Energy exchange, General Framework, Waste Exchange Scenario, Wide Areas

Introduction

The concept of a circular economy was proposed in China in 1998 [1] and universally accepted in 2002 when the central government adopted it as a new development strategy with the scope to alleviate the contradiction between rapid economic growth and the rational use of raw materials and energy [2]. The Ellen MacArthur Foundation [3] looks at the economy in the perspective of self-regeneration where exchanges of raw materials, waste of processing, but also water and energy, are designed to create the so-called "closed loop" according to an approach "Green economy", as an alternative to the classic linear model of production systems. In 2000, Chertow in one of her studies considered the theoretical basis of the subject, by defining Industrial Symbiosis as "the involvement of traditionally separated industries with an integrated approach aimed at promoting competitive advantages through the exchange of matter, energy, water and/or by-products " [4]. In her "Industrial Symbiosis: Literature and Taxonomy", she also explains the various ways in which symbiosis (utility-sharing or resource sharing) can be created and how to start material transfer. For this reason, in the FIR Project - "Industrial Symbiosis in a Wide Area: Ionian Territory", the research group carried out a study on the recovery procedure through industrial symbiosis of energy.

Methods

An analysis of the literature highlighted a gap relating to studies on Symbiotic exchange. In fact there are a lot of case studies and applications in term of waste exchanges but less example for the energy exchanges and there isn't a theoretical model for symbiosis energy exchange implementations [5]. Following the cataloging of the scientific papers, 646 articles from Scopus database were collected. After that, a bibliometric analysis integrated with the Automatic Text Analysis was carried out, consisting of a skimming and an analysis of the texts relating to energy (29% of the total database). Analyzed nodes and sub-nodes, together with the Taranto Area data, were used to identify the key variables for the creation of the theoretical model for energy treatment in symbiotic exchanges.

Results and discussion

The themes directly related to energy that were found into the papers are: energy consumption, energy flows, energy inputs, energy exchanges, energy use, energy efficiency, energy savings, energy recovery. Furthermore, the analysis tools used to assess the energy key factor were found and classified as energy analysis, emergy analysis and exergy analysis.
Finally, the studies in which the energy variable was characterized were extracted and classifed in terms of various energy sources, for example in Taranto Area we found thermoelectric power plants, refinery and heat produced by steel plants.
Therefore, the model was created taking into account: 1. Parameter: Process Input and/or Output; 2. Object of exchange: Energy characterization; 3. Localisation: Within the individual enterprise; Between groups of firms located in adjacent geographic areas (eco-industrial parks); Between groups of firms located in wide geographic areas (eco-industrial network); 4. Economic sectors: exchanges between firms in the same productive sector or different economic sectors.
The result is the drafting of a general model for the symbiotic exchange of energy waste, which highlights the key variables for its correct application and the reasons for the current limited exploitation of the practice.

Conclusion

In Taranto Area the energy waste production amounts to 1064 Ktoe respect to the energy consumption which amounts to 3974 ktoe [5]. The residential thermal energy demand is lower than the waste heat production. If compared to the total energy used in the provincial residential sector (169 ktoe/year for a population of 578,000 inhabitants), the above quoted transformation energy loss represents a massive amount of energy that is currently wasted but that could be usefully recovered and recycled [6]. Hence, for the present study, this data on waste energy and energy use in the district, was used for the development of a generalised theoretical model for symbiotic energy exchanges considering the energy mapping, the real and potential exchanges and the parameters and indicators for effective and efficient exchanges [7].

References

1. Zhu, Q., Geng, Y., & Lai, K. H. (2010). Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. Journal of Environmental Management, 91(6), 1324-1331.
2. Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: moving from rhetoric to implementation. Journal of Cleaner Production, 42, 215-227.
3. Ellen MacArthur Foundation, (2016). www.ellenmacarthurfoundation.org.
4. Chertow, M. R. (2000). Industrial symbiosis: literature and taxonomy. Annual review of energy and the environment, 25(1), 313-337.
5. Notarnicola B., Tassielli G., Renzulli A.P., Arcese G., Di Capua R., (2016b). Simbiosi industriale in Italia: stato dell’arte e prospettive di sviluppo future in Italia, Annali del Dipartimento Jonico, in: Annali del Dipartimento Jonico. ISNB: 978-88-909569-6-6.
6. Notarnicola B., Tassielli G., Renzulli A.P., Arcese G., Di Capua R., (2017). Gli Scambi energetici nella Simbiosi industriale. Risultati preliminari di un riesame della letteratura attraverso l’integrazione tra analisi bibliometrica e analisi automatica dei testi. Forthcoming.
7. Notarnicola, B., Tassielli, G., & Renzulli, A.P. (2016a). Industrial symbiosis in the Taranto industrial district: current level, constraints and potential new synergies. Journal of Cleaner Production, 122, 133-143.

STEELMAKING PROCESS GASES UTILIZATION

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Abstract

Steel production in the ILVA Taranto plant, basing on integrated route, also involves the generation of by-products such as process gases as production residues for coking, blast furnaces and steelworks. These gases, being equipped with calorific value, are burned in the CET2 and CET3 thermoelectric power plants of Taranto Energia SRL, giving rise to electricity and steam for steelmaking plant users. In this way, environmental and economic benefits are achieved, as the aim is to reuse a production residue, to limit the consumption of natural gas in the full view of sustainable development. Industrial symbiosis is therefore profitable between the manufacturing and energy sectors, meeting the requirements of the circular economy.

Keywords: Steelmaking process gases, electricity, heating, resource efficiency.

Introduction

Coke oven gas (COG), blast furnace gas (BF gas) and basic oxygen furnace gas (BOF gas) constitute the basis of the energy system in an integrated steelworks. Most of the energy demand is satisfied by these gases; the remaining part must be balanced with purchased energy, normally electrical power and natural gas. The steelmaking process gases can be used by power plants, consisting in gas fired boilers or combined cycle gas turbines, for electricity and steam production [1, 2]. There are many plants in Europe of this type while, in Italy, there is only the case ILVA-Taranto Energia in relation to the combustion of COG, BF gas and BOF gas in the same mix of fuels. The net electrical efficiency for existing plants is defined by the range 30%-40% for gas fired boilers and by the range 40%-48% for combined cycle gas turbines. ILVA's process gases contribute to the constitution of mix of fuels, together with natural gas, conventional fuel with higher calorific value, which is burnt in the thermoelectric power plants (CET2 and CET3) of Taranto Energia Srl, located inside the perimeter of ILVA Taranto plant for the production of steam and electricity. The power plants of Taranto Energia Srl, in the past belonging to Edison SpA, use by-products of ILVA plant in order to produce energy. In this way we have a clear case of industrial symbiosis with exchange between two Companies of two different sectors (manufacturing and power).

Methods

The CET2 plant is a traditional multi-fuel thermoelectric type with a total electrical power of approximately 480 MW. It is composed of three identical units consisting of a boiler, a steam turbine, a seawater condenser, an alternator and a power transformer. The CET3 plant is a combined cycle in a cogeneration system with a total electrical power of about 564 MW. This also is composed of three identical units each consisting of a compression system for steel gases, three closed-circuit sealed water coolers and for compressor cooling, a gas turbine, an alternator and a gas turbine elevator transformer, a steam recovery generator, a steam turbine, an alternator and an elevator transformer for the steam turbine. These plants have the function of producing steam and electrical energy for the steel plant's networks. The methods of implementing industrial symbiosis include the use of production residues (coke oven gas, blast furnace gas, basic oxygen furnace gas) in order to generate thermal and electrical energy by their combustion in the CET2 and CET3 plants.

Environmental and economic benefits

Electricity, produced in this way, satisfies much of the steel plant's needs. Likewise, the generated steam is used by the thermal utilities of the steelworks. The savings of conventional fuel, that is natural gas, is remarkable (Tables 1 and 2).

Table 1. Fuels consumption

Fuels consumption	2014	2015	2016	U.M.
Natural gas (PCI = 34541 kJ/Sm^3 equivalent to 8250 kcal/Sm^3)	3,373,499,799	2,480,296,340	3,007,397,864	Mcal
Coke oven gas (PCI = 17794 kJ/Nm^3 equivalent to 4250 kcal/Nm^3)	1,369,615,880	1,023,316,810	1,274,425,107	Mcal
Blast Furnace Gas (PCI = 3768 kJ/Nm^3 equivalent to 900 kcal/Nm^3)	2,320,121,590	1,190,311,690	1,872,910,467	Mcal
Blast furnace Gas + Basic Oxygen Furnace Gas (PCI = 3768 kJ/Nm^3 equivalent to 900 kcal/Nm^3)	3,125,603,657	2,503,831,782	2,762,574,536	Mcal
Basic Oxygen Furnace Gas (PCI = 7955 kJ/Nm^3 equivalent to 1900 kcal/Nm^3)	15,893,290	22,859,420	18,318,510	Mcal
Total steelmaking process gases	6,831,234,417	4,740,319,702	5,928,228,620	Mcal
Natural gas	33.1	34.4	33.7	%
Steelmaking process gases	66.9	65.6	66.3	%

Table 2. Energy production

ENERGY PRODUCED	2014	2015	2016	U.M.
Electricity	4,205,977	3,035,264	3,739,702	MWh
Steam	489,593	554,973	619,594	MWh
Total	4,695,570	3,590,237	4,359,296	MWh

Results

Combustion of iron and steel gases for the production of energy has generated considerable natural gas savings (Table 3).

Table 3. Energy saving and CO_2 emissions reduction

Natural gas saving	6,831,234,417	4,740,319,702	5,928,228,620	Mcal
Natural gas saving referred to 34,5 MJ/Sm^3	828,028	574,584	718,573	kSm^3
CO_2 emissions saving referred to 55,82 t/TJ (ETS directive parameter)	1,596,509	1,107,847	1,385,470	t CO_2

Discussion and conclusion

In the viewpoint of the circular economy, the generation of thermal and electrical energy through the use of process residues has saved large quantities of a natural resource, re-using sub-products that, if not burned in thermoelectric power plants, could only be burnt by flaring, resulting, in this way, in significant environmental impact.

References

1. Large Combustion Plants BREF – Joint Research Center, European Commission.
2. Iron & Steel Production BREF – Joint Research Center, European Commission.

ZERO WASTE PROJECT: AN EXAMPLE OF CIRCULAR ECONOMY IN FERRIERE NORD

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Abstract

Ferriere Nord S.p.A., a steel producer from ferrous scrap, in 1998 decided to start the "Zero Waste" project to transform the main process wastes into products to be re-used in a logic of circular economy. 20 years later, since "Zero Waste" project started, the main secondary materials of the EAF (Electric Arc Furnace) process have been reviewed and re-evaluated: the slag from EAF, the slag from ladle furnace, the EAF dust, the iron scale and the refractories. Many companies are now involved in dealing with these materials and established important and stable relations of symbiosis to prepare, transform and finally use them. A company network trusts on regular availability and quality of the new products: scrap dealers, lime producers, zinc producers, aggregates and asphalt producers, highway companies… Finally, reuse of these materials allows saving equivalent quantities of natural resources: iron ore, basalt, porphyry, limestone, zinc and lead minerals.

Keywords: EAF, Scrap, Slag, Dust, Granella®

Introduction

Ferriere Nord S.p.A. is a company based in Osoppo that produces steel bars and wire rod with a process route with Electric Arc Furnace (EAF) for ferrous scrap melting, ladle furnace (LF) for chemical refinement, continuous casting for solidification and hot rolling mill for getting final shape and properties of steel products. In 1998 the company decided to implement the "Zero Waste" project[1,2]. The underlying idea was to study and transform the main wastes into products to be re-used in the same or in other industrial processes. The project lasted for many years and today is still going on: now it focuses on increasing quality of new products and optimizing transformation processes taking in consideration economic and environmental aspects. At a distance of 20 years since "Zero Waste" project started, we can state that all secondary materials have now been reviewed and re-evaluated in a circular economy perspective. The new developed materials replace natural ones that otherwise should be extracted from mines or quarries: basalt, porphyry, limestone, iron ore, zinc and lead minerals. We dealt with slags from EAF and LF, with EAF dust, with iron scale and refractories. We established an important and stable relation with many users of these new products, creating a network that now trusts on regular availability and quality of them. At European level all these materials and their reuse are now considered in Best Available Technologies[3]. The situation is nowadays changed respect to 1998 when started Zero Waste project, but still not all residues are reused in Europe and in Italy: most of Lf slag is landfilled, 30% of EAF slag is landfilled, while EAF dust and iron scale are mostly reused.

Methods

The report deals with the following materials and describes their origin, characteristics, and transformation from a linear economy to a circular one: EAF slag, EAF Dust, LF slag and refractories, iron scale.

EAF Slag

In EAF process, the addition of lime and the flotation of oxides from scrap creates a second liquid phase above liquid steel: the slag that mainly consists of oxides of iron, calcium, silicon. The quantity is remarkable: 15% by weight of the steel product and a comparable quantity in volume (in our plant 200,000 tpy).

The analysis and the technological tests on the EAF slag showed that we were facing a very "hard" material that could be interesting for road pavements because of a potential prolongation of service life of the asphalt layer attainable with it. Together with the regional highway network operator (Autovie Venete) we started a research and testing program (laboratory 1995, pilot scale 1998) that led to the development of a pilot plant for the production of asphalt aggregates[4,5]. We named it Granella®. This is the trade mark that Ferriere Nord registered for the new product. The pilot plant (1998) allowed consolidation of the use on the market: since that date, most of the motorway draining asphalt pavements of the regional network is made with this material, replacing basalt or porphyry of natural origin. In 2004, we built the final plant to handle the whole EAF slag produced by Ferriere Nord. In 2005, the material was certified and sold under CE marking according to the CPR (European Construction Products Regulation). Since then all EAF slag production is devoted to the new product instead of wasting and land filling it. In this new activity we are the producers of the new synthetic aggregate, Autovie Venete is the end user, but many other companies are involved in preparation of asphalts, testing, certifying, and using the new products. The experience gained with Granella® was “exported” in Basilicata Region where Ferriere Nord S.p.A. owns another steel plant based in Potenza. With this new product, also in that area, we established an industrial symbiosis experience based on circular economy concept.

EAF Dust

Analysis of dust collected by dedusting system in EAF process showed that dust is a zinc and lead rich mineral (Zn 20-30%, Pb 5%), richer than natural ores. A collaboration with an engineering company gave us the opportunity for laboratory testing, pilot plant and, in 1998, the first industrial plant for the production of zinc cathodes from steel powders with an electrowinning process was settled. The Ezinex® process[6] was active at Ferriere Nord for two years, and was able to handle the complete production of EAF powders at that time, with a final zinc production of about 2,000 tpy. We designed the process with the "Zero Waste" philosophy: all the materials must be tackled without leaving parts to landfill. Ezinex® alone was not the definitive solution because the installed plant was too small for the whole EAF dust production of Ferriere Nord, in the meanwhile increased, it was small if compared to standard zinc production facilities, and because ferrous residue was recycled in EAF and this was not the appropriate way to handle it; pyrometallurgical processes as Indutec®[6] would have been necessary to complete the treatment line. In the meantime, zinc producers have become competitive in the production of zinc from EAF powders and therefore Ferriere Nord decided to deliver EAF dust to that chain. In this way we closed a circular economy loop saving zinc and lead minerals: from that time roughly 25.000 tpy of zinc with 25% Zn content are saved instead of wasting and land filling it.

LF Slag and Refractories

LF slag and refractories are often heterogeneous materials, they are difficult to handle, especially because they quickly transform into a very fine powder with a high content of CaO and MgO. After an initial study of a possible re-use in EAF in partial substitution of lime, some pilot tests demonstrated the feasibility of the hypothesis. The process[7] was developed and installed: material solidification, cooling and following transformation in powder, magnetic separation of metal parts, refractory grinding, storage and pneumatic transport to EAF and subsequent re-injection. The plant was built in 2001, since then it allows reuse of all LF slag and all refractories directly in the EAF: about 30,000 tpy. This saves the equivalent of the lime content. In this case, our plant is the destination of the re-use process in a circular economy loop.

Iron Scale

It is known that metal iron is not stable: it combines with oxygen to return to the form of oxide. All surfaces of steel products are covered with a layer of oxide that is more consistent if formed at high temperatures. These oxides seemed particularly interesting materials, as they are very rich in iron.
In our case iron oxide >98%: no mineral is so rich! The job was to standardize the product to re-use it. We improved separation processes from cooling fluids. Now it is an interesting material with high iron content and new customers are interested in it: from chemical to cement industry. Also in this case about 30,000 tpy are reused instead of wasting it.

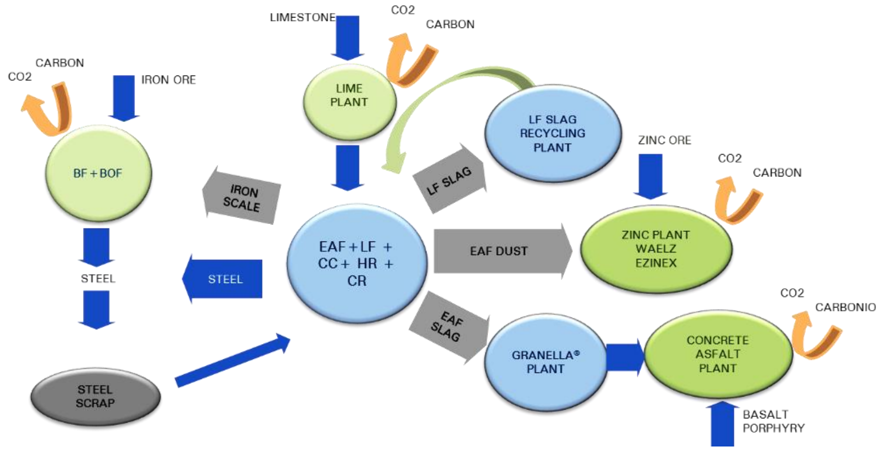

Figure 1. Ferriere Nord Process in a logic of circular economy after Zero Waste project

Results

The Table 2 summarizes the quantities of materials handled by Ferriere Nord in Osoppo Plant with a logic of circular economy after Zero Waste project started and equivalent materials saved. In the table also it is reported an estimation of these EAF process route residues at European level.

Table 2

Material	K tons per year	K tons in Ferriere Nord 1998-2016	Natural material substituted	M tons per year at European level[7]
Steel scrap	1500	25000	Iron ore	
EAF slag	200	3500	Basalt, porphyry	1300
LF slag and refractories	30	460	Lime	130
EAF dust	25	380	Zinc ore	100 (20 % Zn)
Iron scale	30	450	Iron ore	130

The Zero Waste project allowed to overcome the waste disposal of big quantities of material: particularly at the starting of the project not always were available landfilling facilities for all that quantities and at reasonable distances or costs. At the beginning this was an important driving force. After first results, sustainability of the process was appreciated by many stake holders, authorities, local communities, environmental actors, workers etc.; this new consensus replaced partially the first driving force.

Conclusion

If we have a look to Ferriere Nord S.p.A. case, after "Zero Waste" project, we can see that many loops of circular economy have been closed dealing with materials that in a logic of linear economy should be disposed: scrap, EAF Slag, LF Slag, spent refractories, EAF Dust, Iron Scale. Many other companies have been involved in a logic of industrial symbiosis to deal with these materials to prepare, transform or finally use them: scrap dealers, lime and zinc producers, aggregates and asphalt producers, highway companies…

Finally reuse of these materials allows saving of equivalent quantities of natural resources: iron ore, basalt, porphyry, limestone, zinc and lead minerals. Moreover saving these natural resources allows reducing energy consumption and consequently CO_2 emissions.

References

1. L. Bianco, S. Porisiensi "From Linear to Circular Economy in Ferriere Nord: ladle Slag and Biomass case studies" -La metallurgia italiana" n. 10 – 2016.
2. 2 L. Bianco "Zero waste esperienza di un'acciaieria elettrica", Enco Journal n° 38-39 2007.
3. BREF, Iron and Steel production, 2012 pag 419-479: http://eippcb.jrc.ec.europa.eu/reference/BREF/IS_Adopted_03_2012.pdf
4. S. Porisiensi, M Maschietto, P Grandesso "Scorie di acciaieria: un nuovo aggregato ad elevate caratteristiche per conglomerati bituminosi speciali", www.buildup.it (tecnologie stradali) 2005.
5. M. Del Fabbro, M. Stefanutti, C. Ceschia, "Impiego di derivati delle scorie di forno ad arco elettrico come materiale eco-compatibile nella sovrastruttura stradale", www.buildup.it (tecnologie stradali) 2005.
6. Processo Ezinex and Indutec: www.engitec.com
7. S. Porisiensi – "Recycling of ladle slag and spent refractories by injection into an EAF" – Iron & Steel Technology June 2004.

PROPOSING INDUSTRIAL SYMBIOSIS FOR MASS-RETAIL COMPANIES: AN EVALUTION THROUGH LIFE CYCLE ASSESSMENT

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Abstract

The environmetal impacts related to a hypothetical Industrial Symbiosis system in which the food waste (FW) produced by a mass retail company (MRC) is treated in an anaerobic digestion (AD) plant in order to produce electricity that may be used into the MRC's stores are assessed through the Life Cycle Assessment. Three main phases are considered: 1) collection (transport of the FW); 2) pre-treatment (unpacking process); and 3) treatment (processing in the AD plant). Global Warming results underscores that the main contribution to the environmental impacts are related to the unpacking processes, followed by the treatment phase, while the lowest contribution is related to the transport of FW from the stores to the plants. The replacement of the conventional electricty used in the MRC's stores with the electricity produced from the treatment of FW allows a reduction of the Global Warming impatcs for -11,153.4 kg CO_2 eq.

Keywords: Industrial symbiosis, Life Cycle Assessment, Food waste, Retail, Biogas

Introduction

Food waste (FW) is a problem that is receiving growing attention by the European Union and the international scientific community in recent years. The household sector showed the highest contribution to the FW production in EU-28 accounting for about 46.5 million tonnes in 2012, while the wholesale and retail sector produced the lowest amount of FW accounting for 4.6 million [1]. Nevertheless, the retail sector shows the highest contribution in terms of edible food wasted (about 83%) and a high economic loss equivalent to 2,768 Euro per tonne [1]. Due to this, it is necessary to define strategies for retail-oriented sustainable FW management. In this context, the Industrial Symbiosis (IS) can help the MRCs to achieve a high FW management's level by adopting sustainable systems that would allow an exchange between materials (FW) and energy sources (electricity). The application of the IS concept could allow economic advantages for the MRCs as well as the reduction of the environmental impacts. The aim of this study is to assess the environmental impacts, through the application of the Life Cycle Assessment (LCA), related to a hypothetical IS system in which a MRC operating in Messina (Sicily) treats its FW by means of an anaerobic digestion (AD) plant, in order to produce electricity and to use it into the stores.

Methods

Figure 1 shows the hypothetical IS system under investigation.

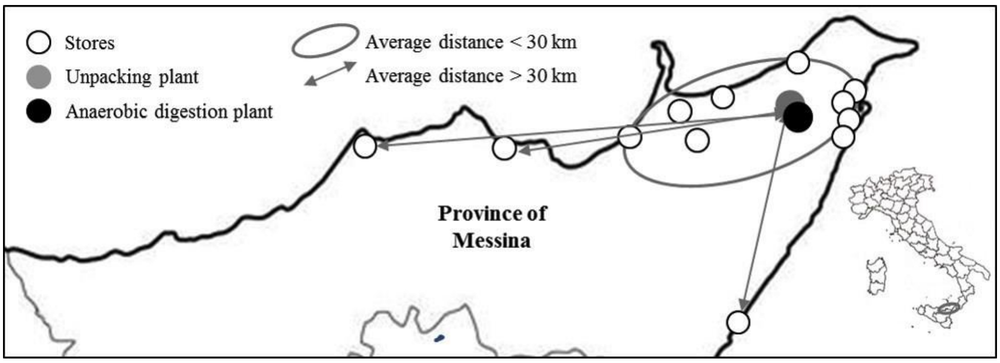

Figure 1. Localization of the MRC' stores and the hypotetical plants involved in the IS system

LCA is a standardized tool that allows to analyse the potential environmental impacts of a product, process or service throughout its whole life cycle, from raw material extraction and processing, through manufacturing, transport, use, reuse, recycling and final disposal [2].

The functional unit (FU) selected to carry out the analysis is related to the amount of FW produced by 12 MRC's stores in 2015 (111.3 tonnes). System boundaries include all the activities from FW collection at supermarkets to its unpacking and final treatment, including the production of electricity from biogas and the replacement of conventional electricity consumed in the stores. The treatment of the packaging materials is not included in the system boundaries, as well as the avoided production of fertilizers that may be replaced by the compost produced during the AD of the FW, because these were outside the scope of the analysis.

Three main phases were selected to carry out the analysis: 1) collection; 2) pre-treatment; and 3) treatment. In accordance with Mondello et al., 2017 [3], the localisation for the unpacking and AD plants was supposed at an average distance (about 30 km) among the MRC's supermarkets. Data related to the amount and transport of FW were collected through specific questionnaires and direct interviews, while the data related to the AD plant (annual capacity of 3000 tonnes) were obtained from Righi et al., 2013 [4]. The treatment of 111.3 tonnes of FW (FU) allows to produce 9,460.5 Nm^3 of biogas which is combusted in a Combined Heat and Power (CHP) unit in order to obtain electricity (19,477.5 kWh per annum). Furthermore, the amount of conventional electricity consumed in the 12 MRC's supermarkets was estimated considering the average consumption related to three of the most assorted MRC's stores (about 545,720.33 kWh per annum). The Life Cycle Impact Assessment (LCIA) has been carried out by means of CML 2 baseline 2000 method in order to obtain a higher level of detail by analysing ten different impact categories.

Results

Characterisation results (Figure 2) underscores that the electricity consumption during the unpacking phase causes the main contribution to the environmental impacts in all the impact categories, followed by the treatment phase. Instead, the lowest contribution is related to the transport of FW from the stores to the plants which contributes less than 14.4% in all the impact categories.

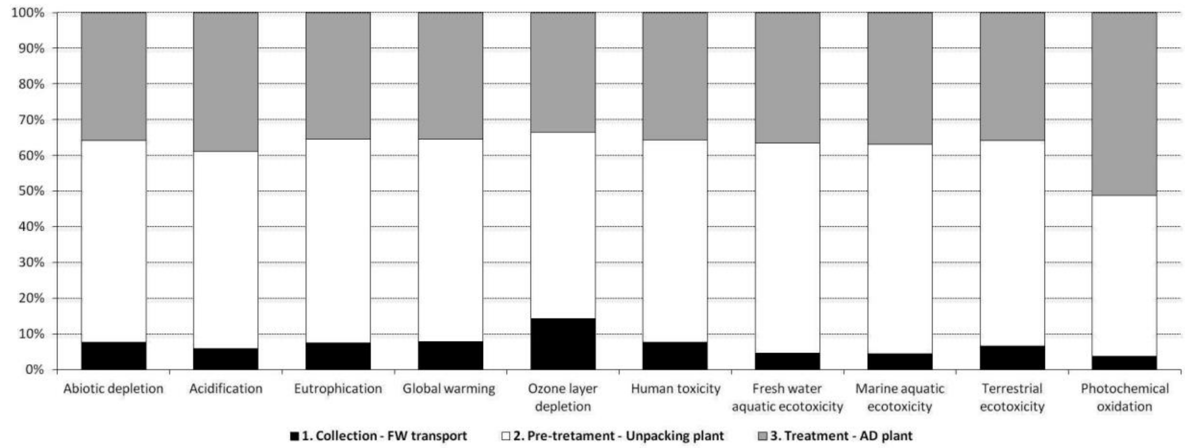

Figure 2. Contribution analysis related to the FU of 111.3 tonnes of FW (characterisation results)

A depth analysis of Global Warming (GWP) underscores that the investigated scenario causes 6,190.2 kg CO_2 eq per FU. In particular, the percentage contribution to the GWP related to the three phases is 7.9% (phase 1), 56.6% (phase 2), and 35.7% (phase 3), respectively. Regarding the AD plant the results shows that the highest contribution to the GWP is due to the electricity production which contributes for about 35% to the total impacts.

Analysing the avoided production of conventional electricty used in the 12 MRC's stores, the results highlightes that the adoption of the electricity produced by the biogas allows a reduction of the impacts for about 3.6% in all the impact categories. The substitution causes an environmental benefit related to the GWP for -11,153.4 kg CO_2 eq.

Discussion and conclusion

The results underscore that considering the FW as a resource can allow environmental benifits and it can help the MRCs to achieve higher efficiency in FW management in an IS context. Furthermore, because of the higher annual capacity of the proposed AD plant in relation to the amount of FW produced by the company per year, the IS system can also involve the agricultural companies among the area by processing the biomass in order to produce electricity and compost. Future analysis will focus on the assessment of the environmental impacts or benefits related to the treatment of the biomass through the AD plant as well as the comparison between the current situation for waste disposal adopeted in the province of Messina (landfill) and the proposed IS scenario.

References

1. Å. Stenmarck, C. Jensen, T. Quested, G. Moates, M. Buksti, B. Cseh, S. Juul, A. Parry, A. Politano, B. Redlingshofer (2016). FUSIONS—Food waste data set for EU-28. New estimates and environmental impact.
2. J.B. Guinée (2002). Handbook on life cycle assessment, operational guide to the ISO standards. International Journal of Life Cycle Assessment, 7, 311–313.
3. G. Mondello, R. Salomone, G. Ioppolo, G. Saija, S. Sparacia, M.C. Lucchetti (2017). Comparative LCA of Alternative Scenarios for Waste Treatment: The Case of Food Waste Production by the Mass Retail Sector. Sustainability, 9, 827.
4. S. Righi, L. Oliviero, M. Pedrini, A. Buscaroli, C. Della Casa (2013). Life cycle assessment of management systems for sewage sludge and food waste: Centralized and decentralized approaches. Journal of Cleaner Production, 44, 8–17.

INDUSTRIAL SYMBIOSIS FOR THE SUSTAINABLE MANAGEMENT OF RAW MATERIALS: THE EXPERIENCE OF THE STORM PROJECT

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Abstract

STORM (Industrial Symbiosis for the Sustainable Management of Raw Materials) is a network of infrastructures project funded in the frame of the EIT Raw Materials programme. The objective is to implement a long term self-sustainable excellence network dedicated to provide services to external customers for the implementation of innovative, sustainable business and cooperation models of circular economy aligned with the concepts of industrial symbiosis for recycling and exploitation of raw materials. To such an aim the STORM partners will develop a common industrial symbiosis methodology, based on the ENEA's one. Two industrial symbiosis pilot applications with companies were held in Ljubljana and in Assisi with two different methodologies. The third pilot will be in Bilbao; during this event the common methodology will be tested in order to evaluate its effectiveness.

Keywords: Circular economy, Matchmaking, Resources sharing

Introduction

In the framework of the strategies and tools for closing cycles of resources and circular economy, a growing interest towards "industrial symbiosis" (IS) stands out, addressed at making the residues of one productive sector available for another one. This approach is not only a potential factor of competitiveness for industrial activities, but also a factor of enrichment, since all resources are valorised locally and not dissipated, delegated or given away to third parties. The European Commission assigned to IS a strategic role in the efficient use of resources, clearly identified in various planning and funding documents ("European Resource Efficiency Platform" (EREP), "Roadmap to a Resource Efficient Europe" [1], Communication COM (2014) 398 "Towards a circular economy: A zero waste programme for Europe" [2], Circular Economy Package [3]).

Within the frame of the European Initiative on Raw Materials, the STORM Project objective is to implement an excellence network dedicated to provide services and tools to external customers for the implementation of innovative, sustainable business and cooperation models of circular economy for the all-round recycling. The purpose of the network is to facilitate the exploitation of European secondary resources via the integration and strengthening of already existing competences and infrastructures, as well as new forms of collaboration between companies. In addition, the project will offer guidance to local and regional authorities when planning new industrial parks or revitalizing existing areas in order to achieve a higher level of resource efficiency and greater harmonization of national waste strategies.

STORM consortium is based on 12 partners, led by ENEA, characterized by complementary competences and infrastructures for exploration and evaluation of secondary resources, waste management, waste recycling, eco-innovation, industrial ecology: ENEA (Italy), AGH Akademia Górniczo-Hutnicza im. Stanisława Staszica (Poland), Bay Zoltan Nonprofit Ltd. for Applied Research (Hungary), IVL Svenska Miljöinstitutet (Sweden), Fundación Tecnalia Research & Innovation (Spain), Università degli Studi di Milano Bicocca (Italy), ASTER S. Cons. P.A. (Italy), DMT GmbH & Co. KG(Germany), Slovenian National Building and Civil Engineering Institute – ZAG (Slovenia), TU Bergakademie Freiberg (Germany), and Mineral and Energy Economy Research Institute of The Polish Academy of Sciences, MEERI (Poland).

In this paper the activities and the results of the first 18 months (January 2016 – July 2017) are presented.

Methods

In the first year of activity we developed a matrix of competences and a database with the services offered by partners (STORM toolbox) along with the communication plan to promote the network.
In the specific field of industrial symbiosis, we performed two pilot applications with the involvement of the companies: in Ljubljana (11th of April) and in Assisi (9th of June). The Ljubljana pilot was held in the frame of KIC RM event "Utilisation of secondary raw materials - Boosting transition to Circular Economy with Industrial Symbiosis", 10th and 11th April 2017 (2nd day). It was a joint event with the collaboration of the Slovenian Chamber of Commerce and Industry (CCIS). The Assisi pilot application was organized with the collaboration and support of Sviluppumbria, the Multi-functional Agency of the Umbria Regional Authority, who sent the invitations to the event.
In both cases the personal contact with companies was of great relevance for their involvement in the project.
In Ljubljana and in Assisi we adopted 2 different methodologies and formats for collecting the resource data. ENEA has already tested both the methodologies in other projects at national level [4]. The differences in the methodology used concern only the pre-event activity and the forms used during the event. The procedures adopted during the events were the same.
Concerning the pre-event activity, few days before the Assisi pilot application the registered companies were requested to fill in an Excel file and to send it back. The file had sheets for company records and for input-output data collection.
In Ljubljana input and output forms were printed on different coloured papers and delegates wrote one resource per form. In Assisi input and output data were reported on the same form.
Few days after the Assisi event, ENEA sent to each delegate a summary report showing in brief the first results of the event. In addition, ENEA analysed the data, searched for additional matches, created a single company report in which the matches of each company are reported and sent it to the interested company. ENEA will also develop operative handbooks for the main synergies with the cooperation of the companies involved.

Results

During the working tables companies had the possibility to face each other in order to individuate possible resource sharing.
39 delegates participated at the Ljubljana pilot application, coming from 23 industries (mainly from the construction sector, industry and mining) and 16 other organisations (e.g. Universities). The first results of the event are shown in Table 1: 24 input resources and 48 output resources were shared during the working tables, creating more than 100 potential matches.
In Assisi we had 26 companies, coming from different productive sectors (agroindustry, metal industry, construction, electronics, textile/clothing, zootechnical, paper, food industry, etc.). Companies expressed the will to share around 90 resources in output and requested 35 resources in input, creating about 100 potential matches (Table 1). Other synergies complemented the process as a result of the elaboration of the data by ENEA.

Table 1. First results of the Ljubljana and Assisi pilot applications

Location	N. of delegates	N. input resources	N. output resources	Matches
Ljubljana	39	24	48	103
Assisi	26	35	90	99

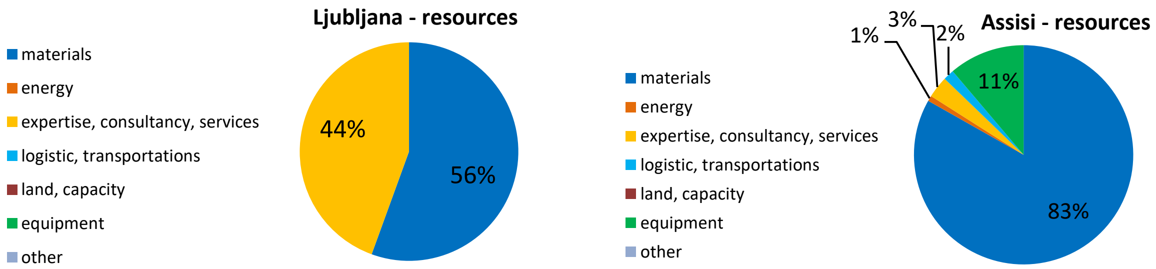

Figure 1. Categories of the resources shared during the Ljubljana and the Assisi pilot applications

The resources shared were mainly "materials": 56% and 83% of the total resources in Ljubljana and Assisi, respectively, as reported in Figure 1. In Assisi almost the totality of the matches involved materials, in particular paper and cardboard, metals and metallic product, wood and wood products, construction/demolition materials and agricultural waste. The synergies will be examined aiming at assessing the technical - operative feasibility also through the collaboration of the involved companies and eventual interested stakeholders. The complete results will be available by the end of September 2017.

Conclusions

The common STORM methodology will be created by mixing the ones used in Ljubljana and in Assisi. In particular, for the third pilot application to be held in Bilbao (Basque Country, Oarsoaldea region in Spain) in November 2017 we will:

- adopt the pre-event activity as in Assisi (Excel file to be sent to registered companies), in order to inform and to train companies before the working tables;
- use the forms as the ones used in Ljubljana (one resource per form), which proved to be more user friendly.

The procedures adopted during the pilot applications will not be changed.
After developing and testing the common methodology, a specific industrial symbiosis case will be carried out during 2018, managed by using the common/tailored methodology and selected shared tools. The industrial symbiosis event will be held in Budapest by the end of March 2018; it will be discussed the possibility to organize one industrial symbiosis event in Germany and/or in Sweden.
The STORM activity will enhance the awareness of the companies on industrial symbiosis and on the benefits which can derive in terms of competitiveness, reduction of costs and environmental impacts.

References

1. European Commission (2011). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Roadmap to a Resource Efficient Europe - COM(2011) 571.
2. European Commission (2014). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Towards a circular economy: A zero waste programme for Europe - COM(2014) 398.
3. European Commission (2015). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy - COM(2015) 614.
4. L. Cutaia, A. Luciano, G. Barberio, S. Sbaffoni, E. Mancuso, C. Scagliarino, M. La Monica (2015). The Experience of the First Industrial Symbiosis Platform in Italy. Environmental Engineering and Management Journal, 14, 7, 1521-1533.

INDUSTRIAL SYMBIOSIS NETWORK IN UMBRIA, ITALY

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Abstract

This paper reports the activity developed by Sviluppumbria (Multi-functional Agency of the Umbria Regional Authority) and ENEA (Italian Agency for New technologies, Energy and Sustainable Economic Development) in the framework of the project to support SME's to individuate symbiosis opportunities at regional level. The project for an Industrial Symbiosis (IS) network in Umbria is currently in progress and at this stage includes: analysis of the productive sector in Umbria; local network activation with public and private actors; and collection and processing data. Two workshops have been held in Terni and Assisi, where more than 50 SME participated, sharing 200 resources in output and about 80 resources in input. More than 200 potential matches were found among the participating companies which will be processed by ENEA. The resource streams and synergies will be studied to realise technical dossiers

Keywords: Circular economy, Resource efficiency, By-products, Synergies

Introduction

Industrial symbiosis (IS) studies the physical flows of resources (e.g. materials and energy) through the local industrial system using a systematic approach. IS approach is in line with the recent European strategies of decoupling economic growth from natural resource consumption through the promotion of a more sustainable business models. IS is actually identified as a tool to implement circular economy in the last circular economy package of European Commission [1]. According to the internationally recognized waste hierarchy [2] IS application at local scale can contribute to the systematic reuse of waste and by-products minimizing in this way the need to extract natural resources and the depletion of environment. For this reason the project in Umbria aims at support the SME's to individuate symbiosis opportunities in this region. ENEA and Sviluppumbria shared a common interest to develop a network model among the companies in the Umbria territory for the implementation of industrial symbiosis and for evaluating the response of the territory to this new business model. Sviluppumbria contacted about 100 companies in order to involve them in the IS working tables. 51 companies participated at the two Terni and Assisi workshops. They shared 200 output resources and about 80 input resources. More than 200 potential synergies were identified. ENEA processed all the resources data in order to carry out the single company reports. These reports include the input and output resources, the matches occurred during the two workshops and eventually other matches proposed by ENEA.

Methods

The methodology followed to support companies and to enhance the implementation of industrial symbiosis pathways has been developed by ENEA [3] and consists of the following steps:

- Analysis of productive sectors in the region;
- Companies involvement;
- Network activation and promotion activities through stakeholders involvement at regional level;
- Workshop finalized to have input-output related information;
- Development of a draft of the technical dossiers for the main synergies;
- Consultation with companies and other stakeholders (e.g. public authorities, decision makers, institutions and associations of category);

- Revision of the dossiers and development of their final version;
- Delivery of the final dossiers to the companies involved.

According to the ENEA methodology, prior to the workshop companies have been asked to fill in input-output tables with resources to be shared within the project. Those resources could be eventually be updated and improved both during and after the workshop. ENEA is now working on the analysis of all the data in order to individuate potential additional synergies. Also the first version of the dossiers is in progress. These dossiers are operative handbooks including European, Italian and regional regulations, guidelines, technical standards, logistic and economical aspects useful for supporting companies in synergies implementation. Many technical solutions for waste and by-product materials, water, and energy reuse between neighboring industries will be studied as well .

Results

At this stage of project it is possible to show the first results of the workshops. At the workshop held in Terni, on 7th of April, the distribution of companies by production sector appears balanced, as they came from the manufacturing sector, energy , chemistry, agriculture and construction. Instead, at the Assisi workshop, held on 9th of June, most companies came from agricultural sector (about half of participants), followed by manufacturing sector and with a small contribution of energy, paper construction sectors. More than 250 resources were shared and about 200 potential synergies were identified, as reported in Table 1.

Table 1. Resources shared and matches during the Terni and Assisi workshops

	Terni s Workshop	Assisi s Workshop
Resources Input	32	35
Resources Output	95	90
Matches	95	90

After the workshop ENEA and Sviluppumbria carried out and sent to the companies a summary report with the first results coming from the workshops. In addition, all data collected on resources and matches were merged into a single file, called “master report”. This master report includes also the potential additional matches proposed by ENEA. The company report for each company have been extracted from the master report and have been sent to the companies involved. The company report is the first step for implementing an IS pathway. After this stage, ENEA will process the data for specific resource in order to carry out the final dossiers.

Conclusion

The industrial symbiosis project in the Umbria region is currently in progress. At this stage the companies are actively involved and received the reports on resource shared and potential synergies. The collaboration between ENEA and Sviluppumbria is really advantageous in order to receive a good response from the local productive actors. Currently, ENEA is working on the identification of the main resource streams which will be studied for the dossier. The next steps will be the involvement of the interested companies to focus on specific solutions for waste valorization and a consultation with other stakeholders, in order to analyse the feasibility of the synergy and the potential barriers.

References

1. European Commission (2015). Communıcatıon Closing the loop - An EU action plan for the Circular Economy.
2. European Commission (2008). Directive of the European Parlıament and of the Council on waste and repealing certain Directives
3. L. Cutaia et al. (2015). The Experience of the First Industrial Symbiosis Platform in Italy. Environmental Engineering and Management Journal, 14, 7, 1521-1533.

USE OF ANALYTICAL TOOLS TO SIMULATE AND OPTIMIZE INDUSTRIAL SYMBIOSIS IN A SUSTAINABILITY PERSPECTIVE: THE SYMBIOPTIMA CASE

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Abstract

The United Nations´ Sustainable Development Goals requires industrial infrastructures to provide a positive impact on society by reducing waste generation and resource consumption. The enhancement and optimization of symbiotic aspects in industry clusters can support the achievement of such goals. The present paper illustrates a new quantification methodology to foster the implementation of a circular economy within existing industry clusters. A Java tool has been developed to track and optimize material and energy flows within different symbiosis scenarios. The quantitative assessment is focused on identifying environmental, social and cost gains for specific Key Performance Indicators. Furthermore, multi-criteria optimization allows to identify heuristic solutions for symbiosis scenarios. The tool has been implemented with reference to a preliminary symbiosis case for an industrial Sector. Preliminary results evidence that industrial symbiosis and industrial sustainability are complementary but different areas. Moreover, concurrent applications of such paradigms introduce a number of new challenges and operational managerial issues to be addressed.

Keywords: LCA; Industrial Symbiosis; Circular Economy; Optimization.

Introduction

The concept of industrial symbiosis understood as material and energy flows sequestration within the technosphere is a concept that has progressively begun since the 1970s. This paradigm constitutes a preliminary basis for circular economy implementation. Such paradigm has recently re-set as focus area due to European Circular Economy Action Plan and the Sustainable Goal agenda by United Nations [1]. In the last decade, symbiosis practices have spread to several industrial parks in Europe and in the Far East, nevertheless there significant barriers to the effective sustainability of recovery and reuse processes still persist. In particular, the substantial decoupling of instruments for optimizing symbiosis and those for assessing sustainability seem to represents a significant barrier. As matter of the fact, the industrial symbiosis mainly aims to maximize the flows circularization and cooperation between entities. Differently, Sustainable Production paradigm focuses on minimizing long-term impacts. As a result, LCA analysis or other types of analysis commonly support industrial parks once infrastructures and cooperation activities have already been created. In the "*open symbiosis*" scenario, each company can flexibly negotiate resources and output flows in the recovery perspective. In this regard, companies are not necessarily close (e.g. industrial parks) and can manage different symbiosis options by assessing different cost-benefits within flexible industry networks.

Methods

A sustainability assessment is applied to design Symbiosis activities of a company. Such assessment is performed in presence of: A) Business processes of a Production Unit (PU in Figure 1) consuming virgin resources and producing emissions towards boundaries to the ecosphere; B) A potential substitution of flows from/to ecosphere with other flows from/to another company within technosphere. Each time potential symbiosis can be performed, incremental impact is represented by the equation system (1). The assessment is considered as incremental assessment respect to a benchmark condition in which the production unit do not perform any symbiosis activity.

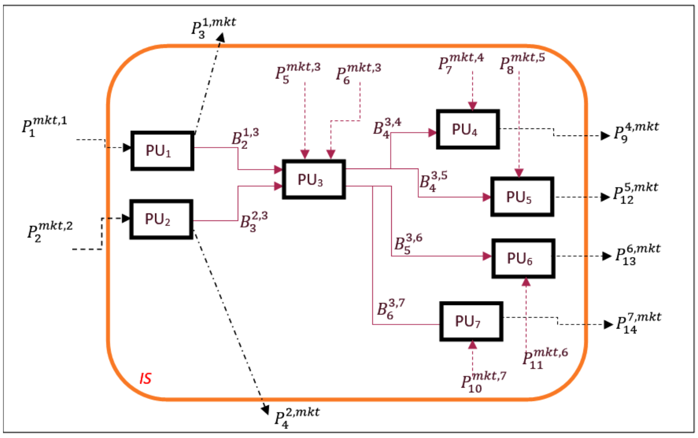

Figure 1. Modelling of industrial symbiosis in an *open symbiosis* scenario

Such methodology has been implemented in a Java tool. Once the different options and constrains are defined through data entry mask, optimization methodologies are applied to identify optimal symbiosis scenarios (e.g. optimal allocation of flows among a certain company cluster) under specific Hierarchical criteria.

$$\boldsymbol{S_{PU}}(T) = \sum_{t=1}^{T}\sum_{i=1}^{I}[S_i] * m_{t,i} - \sum_{t=1}^{T}\sum_{j=1}^{J}[S_j] * m_{t,j} \qquad (1)$$

Table 1. Values in equation 1

$\boldsymbol{S_{PU}(T)}$	Sustainability profile for the symbiosis activities of production unit U (PU) in the time horizon T: vectoral representation of impact for a certain scenario of symbiosis for production unit PU
$[\boldsymbol{S}]$	Sustainability Impact matrix collecting social, economic and environmental effects for single unit (e.g. 1 grams or kg) of entering and outgoing flows from/to production unit
i	Flows in the benchmark conditions without symbiosis
j	Replacing or replaced flow for a reference flow i iof the benchmark condition
T	Time horizon in which symbiosis is considered

Results and conclusions

The tool has been applied to model a power plant producing different by-products. In particular allocation problem of fly ashes among four different end-users has been modelled and solved by such tool. Four optimization criteria have been identified with reference to six quantitative Key Performance Indicators for social impact . Optimization criteria range from economic efficiency to resource conservation, occupational health, up to stakeholders community safeguard. According to these criteria four allocation scenarios have been identified. In general terms symbiosis seem to represent a remarkable field for further methodological developments in the use of integrated mathematical modelling. Relevant issues in further research seem regard the proper definition of substitution coefficient among different symbiotic flows as well as the definition of constrains for material reuse within traditional process. As preliminary remark, multiobjective optimization could provide effective support both by providing a range of heuristic solutions to managers and by properly representing "emerging effects" due to the complexity of symbiosis network.

References

1. Sala, S., Farioli, F., Zamagni, A., 2013. Life cycle sustainability assessment in the context of sustainability science progress (part 2). Int. J. Life Cycle Assess. 18, 1686–1697. doi:10.1007/s11367-012-0509-5.
2. Bellantuono, N., Carbonara, N., Pontrandolfo, P., 2017. The organization of eco-industrial parks and their sustainable practices. J. Clean. Prod. 161, 362–375. doi:10.1016/j.jclepro.2017.05.082.
3. Brondi, C., Carpanzano, E., 2011. A modular framework for the LCA-based simulation of production systems. CIRP J. Manuf. Sci. Technol. 4. doi:10.1016/j.cirpj.2011.06.006.
4. Daddi, T., Nucci, B., Iraldo, F., 2017. Using Life Cycle Assessment (LCA) to measure the environmental benefits of industrial symbiosis in an industrial cluster of SMEs. Doi:10.1016/j.jclepro.2017.01.090.

NEW PERFORMANCE INDICATORS FOR INDUSTRIAL SYMBIOSIS: AN ECOSYSTEM APPROACH

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Abstract

This paper proposes new performance indicators for industrial symbiosis networks (ISNs) based on the ecosystem approach. ISNs are framed as ecosystems where the firms correspond to the organisms and perform specific functions, i.e., recovering wastes and saving inputs. Two kinds of indicators are designed: 1) indicators assessing the performance of each waste exchange; 2) indicators assessing how each firm is contributing to these exchanges. The designed indicators can be useful in backing up decision-making tools for ISNs.

Keywords: Industrial Symbiosis Networks, Performance Indicators, Input-Output, Ecosystem approach.

Introduction

Industrial symbiosis (IS) is recognized a key practice to support the sustainable development since it can generate economic benefits for firms and environmental benefits for the collectivity. Despite policymakers in many countries have introduced IS into their agenda, the IS practice appears to be underdeveloped compared to its theoretical opportunities. Therefore, IS needs decision-making tools suggesting policy makers with strategies to support the evolution of IS networks (ISNs). To do this, it is required to analyze the performance of the ISNs through appropriate performance indicators [1]. The literature proposes performance measurements mainly based on three categories: life-cycle assessment (LCA), eco-efficiency indicators, and material flow analysis (MFA). LCA indicators focus on the environmental impact of products during all their life-cycle, which is a different point of view than the waste exchanges within ISNs. Eco-efficiency indicators are aimed at assessing the individual performance of firms, but without considering how firms are connected among them [2]. MFA focuses on each waste flow separately, hence considering how firms are connected among them. However, since each flow has a different metric and compare indicators concerning different flows is a difficult task, MFA indicators cannot be used to measure the overall contribution of each firm to the ISN [3]. Moreover, all the above-mentioned indicators are unable to highlight the extent to which the current performance of the ISN could be further increased, because they do not provide a reference point. Based on the above, we recognize that there is a lack of indicators able to measure both the performance of each waste exchange within ISNs and the extent to which each firm contributes to these exchanges. This paper is aimed at filling this gap by designing performance indicators for ISNs based on the ecosystem approach.

Methods

We frame the ISN as an ecosystem where the firms correspond to the organisms and perform specific functions [4]. Two kinds of functions are performed: recovering the produced wastes and replacing the required inputs. Firms contribute to these functions by producing, requiring, and exchanging wastes. Through these functions, the ISN generates two services: 1) creating economic benefits for firms; and 2) creating environmental benefits for the collectivity. All the waste flows among firms are modeled by adopting the Enterprise Input-Output approach [5]. Two kinds of performance indicators are designed: 1) indicators assessing the performance of each function; 2) indicators assessing the extent to which each firm contributes to the ISN functions.

Results

For the generic function f_{w_i} "recovering waste *i*", the following performance indicator is defined:

$$p^W(f_{w_i}) = \frac{w_i^S}{E_i^W} \times \frac{E_i^W}{w_i} \tag{1}$$

where w_i^S is the amount of waste *i* saved, i.e., not disposed of in the landfill thanks to the IS practice, w_i is the amount of waste *i* produced by firms belonging to the ISN, and E_i^W is the highest amount of waste *i* which is possible to save through waste exchanges. $E_i^W = \min\{w_i; \sum_j s_{ij} \times r_j\}$, where *j* is the generic input which can be replaced by waste *i*, s_{ij} is the amount of waste *i* replacing one unit of input *j*, and r_j is the amount of input *j* required by firms belonging to the ISN. Similarly, for the generic function f_{r_j} "saving input *j*", the following performance indicator is defined:

$$p^I\left(f_{r_j}\right) = \frac{r_j^S}{E_j^I} \times \frac{E_j^I}{r_j} \tag{2}$$

where r_j^S is the amount of input *j* saved, i.e., not purchased from conventional suppliers thanks to the IS practice and E_j^I is the highest amount of input *j* which is possible to save through waste exchanges. $E_j^I = \min\left\{r_j; \sum_i \frac{w_i}{s_{ij}}\right\}$, where *i* is the generic waste which can replace input *j*. The first factor in Equation 1 (Equation 2) stands for the amount of waste *i* recovered (input *j* saved) compared to the highest possible quantity, being representative of the operational performance of the function. The second factor stands for an ISN structural factor, being representative of the match between waste demand and supply. $p^W(f_{w_i})$ and $p^I\left(f_{r_j}\right)$ range between 0 and 1. They are equal to one when $w_i^S = E_i^W = w_i$ and $r_j^S = E_j^I = r_j$, respectively, otherwise they are lower than one. For the generic firm *K*, the following performance indicator is defined:

$$p(K) = \frac{1}{f^W}\sum_i \frac{w_{iK}^S}{w_i^S} + \frac{1}{f^I}\sum_j \frac{r_{jK}^S}{r_j^S} \tag{3}$$

where f^W is the number of wastes exchanged within the ISN, f^I is the number of input saved within the ISN, w_{iK}^S is the amount of waste *i* saved by firm *K*, and r_{jK}^S is the amount of input *j* saved by firm *K*. The value of $p(K)$ depends on: 1) how many functions the firm *K* performs within the ISN; 2) the contribution of firm *K* to each function. $p(K)$ ranges between 0 and 1: the higher the value, the higher the contribution of the firm *K* for the ISN. When $p(K) = 1$, the overall ISN will disappear if *K* leaves the network.

Discussion and conclusion

The proposed indicators are able to assess the performance of each ISN function and how each firm is contributing to these functions. We apply them to several ISNs with different topology and test their application and usefulness. Furthermore, we highlight how the proposed indicators can be used to back up decision-making tools for ISNs, since they highlight: 1) which ISN functions are currently underdeveloped respect to their potential; 2) which firms are providing the strongest contribution to the ISN.

References

1. A.S. Chiu, G. Yong (2004). On the industrial ecology potential in Asian Developing Countries. Journal of Cleaner Production, 12, 1037–1045.
2. H.-S. Park, S.K. Behera (2014). Methodological aspects of applying eco-efficiency indicators to industrial symbiosis networks. Journal of Cleaner Production, 64, 478–485.
3. Y. Geng, P. Zhang, R.P. Côté, T. Fujita (2009). Assessment of the National Eco-Industrial Park Standard for Promoting Industrial Symbiosis in China. Journal of Industrial Ecology, 13, 15–26.
4. J. Korhonen (2001). Four ecosystem principles for an industrial ecosystem. Journal of Cleaner Production, 9, 253–259.
5. L. Fraccascia, V. Albino, C.A. Garavelli (2017). Technical efficiency measures of industrial symbiosis networks using enterprise input-output analysis. International Journal of Production Economics, 183, 273–286.

INDUSTRIAL SYMBIOSIS IN EMILIA-ROMAGNA'S COOPERATIVE ENTERPRISES

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Abstract

The Business Associations of the Emilia Romagna Region have proposed to the Region to create a permanent working group to identify what kind of treatments on by-product can be considered "normal industrial practice". For each by – product, the Region makes a tab which contains an official regional list of by – products. Confcooperative Emilia Romagna has proposed into the working group the use of apricot's and peach's kernels to produce sweets, spirits, cosmetics and energy and the use of corn residues to produce biogas. The joint work between business representatives and the Emilia Romagna Region has produced formal acts identifying some qualified by-products chains and describing their uses. Another achievement is the establishment of the "regional list of by-products" that we hope will help companies to feel safer in the use of by-products, because they cannot be condemned for having used tomato skins or peach's kernels to produce energy.

Keywords: Cooperative enterprises, By-product, Circular economy, Working group

Introduction

Confcooperative Emilia Romagna is a Cooperatives Business Association that supports cooperative enterprises in their business development. It helps also enterprises to understand the environmental laws and makes lobbying actions to central and local governments to apply the new waste European Directive and the prevention principle, through the correct application of "by-product" concept. The best and first environmental option must be the use of by–products compared to recovering wastes. Cooperative companies works in different areas, from agro – industries to social, and they produce big quantities of by – products which can be used to make others products or goods.

In last decades, laws had prevented to manage the by–products in a safe, clear and simple way. This is because the border between a recoverable waste and a re-usable by-product is legally subtle. We need a change of mentality to move from linear economy to circular economy.

Entrepreneurs, on the other hand, know well, for example, the value of a reusable wood chip as litter in animal husbandry, but, until today, many sentences have condemned the entrepreneurs for using waste as a substrate for animal breeding.

Therefore, legislation as always been the biggest obstacle in the use of productive residues and just today we begin shyly working peaceful on by-products, thanks new principles of circular economy. To use by–products means doing prevention and fulfill the first target in hierarchy of waste reduction.

A video (https://www.youtube.com/watch?v=8hVnp_qgG40) shows some examples how cooperative companies have applied industrial symbiosis in Emilia Romagna Region.

Methods

The Business Associations of the Emilia Romagna Region (among which Confcooperative) have proposed to the Region to create a permanent working group to identify what kind of treatments on by-product can be considered "normal industrial practice". This group, which is composed by industrial represents and regional officers, has been officialized from the recent Circular Economy Regional Act (L.R. 16/2015). For each by – product, the group make an investigation. If the method of use is considered a "normal industrial practice" the Region makes a tab and this by – product come in an official regional list of by – products.

Companies which have an equal method of using this by – product can entry in this list and get an enrollment certificate. This certificate can represent a good legal evidence that the by – product holder does not want to discard it but they want to use it. This certificate can follow the by – products – transport and the holder can feel more sure.

Confcooperative Emilia Romagna, until this moment, has proposed into the working group the use of apricot's and peach's kernels to produce sweets, spirits, cosmetics and energy and the use of corn residues to produce biogas.
Currently the "by – products 's regional list", which is steadily updated by Emilia Romagna Region, includes the by – products included in Table 1.

Table 1. Types and use of by-products included in the regional list

By - product	Use
Apricot's kernels	Sweets, spirits, cosmetics, energy
Peach Kernels	Sweets, spirits, cosmetics, energy
Corn's residues	Biogas
Black liquor	Biogas
Salty salt meats	Ice road use

The working progress is available on web page:
http://ambiente.regione.emilia-romagna.it/rifiuti/temi/economia-circolare/sottoprodotti
For subscribing to the by-product list, companies have a dedicated portal:
https://www.ermesservizi.it/sottoprodotti/

Figure 1. Apricot's kernels usable in sweet's industry

Results

The joint work between business representatives and the Emilia Romagna Region has produced formal acts identifying some qualified by-products chains and describing their uses. Another achievement is the establishment of the "regional list of by-products" that we hope will help companies to feel safer in the use of by-products, because they cannot be condemned for having used tomato skins or peach's kernels to produce energy.

Discussion and conclusion

Industrial symbiosis is, therefore, a term that must be get in practice. For co-operative companies we represent, the first option is not just the recovery of waste but it is, above all, the use of by-products, because there is no reason why a material that can be re-used must become a waste.
Our Association, therefore, will work to support the public authorities so that they can see and touch with their hands the good practise in the use of by – products. Companies expect only more certain and courageous regulations so that residuals of their production can be used without bureaucracy linked to waste management.

References

http://ambiente.regione.emilia-romagna.it/rifiuti/temi/economia-circolare/sottoprodotti
https://www.ermesservizi.it/sottoprodotti/

REGIONAL POLICIES SUPPORTING A SYSTEMIC UPTAKE OF INDUSTRIAL SYMBIOSIS: THE INTERREG TRIS PROJECT

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Abstract

Industrial Symbiosis (IS) is a building block of the Circular Economy, a means to sustainable growth by increasing resource efficiency, competitiveness and resilience in industry. Despite the acknowledged advantages, IS is not yet fully widespread, but a dedicated policy could support its diffusion. The Interreg TRIS project aims at supporting five European regional policy makers to develop local action plans facilitating local IS practices. TRIS will therefore identify drivers/obstacles and embed/remove them from relevant policy instruments, and engage stakeholders in structured local networks including SMEs and policy actors to build a cooperation culture. TRIS is determined to accomplish the following results: raise awareness on the concepts of IS and its economic and environmental benefits; embed IS practices into regional policy instruments, launch tangible initiatives in the involved regions and test new governance models. The final output of TRIS shall bring IS to a higher position in the European political agenda.

Keywords: industrial symbiosis, governance models, regional policy, SME, cooperation culture

Introduction

Inefficient resource use by Europe's SMEs has been identified by the European Commission as a clear market failure creating additional and unnecessary costs that constrain growth, contribute to greenhouse gas (GHG) emissions, and further exploit scarce natural resources [1].
Successful industrial symbiosis keeps resources circulating in the economy for longer but the product, process, technology and procurement changes necessary are often complex for SMEs, which represent up to 99% of the EU entrepreneurial fabric. The barriers and key success factors in the development of regional industrial symbiosis networks are often of a political or economic nature rather than technological [2]. The European Resource Efficiency Platform calls Europe to double its resource productivity by 2030 – at least – in order to boost competitiveness of our industry and maintain a high quality of life for citizens [1]. Pan European industrial symbiosis, Resource efficiency and SME competitiveness are fundamental to the European agenda to create the conditions for smart, sustainable and inclusive growth. This includes assessing the economic, social and environmental effects of technical efficiency improvements from both single technical options and more system wide changes.
Interreg Europe programme helps regional and local governments across Europe to develop and deliver better policy, offering an excellent framework to mainstream the "transition thinking" approach towards IS.

Governance framework

The TRIS project involves five European regions with a common interest on IS: West Midlands, Central Hungary, Comunidad Valenciana, Emilia-Romagna, and South Sweden. TRIS vision is to connect European regions to optimise regional development policies by sharing best practice in industrial symbiosis, driving forward resource efficiency, competitiveness and growth in European industry.

The overall objective of TRIS is to support the partnering public authorities and related bodies to increase resource efficiency and the competitiveness of their SMEs, by introducing industrial symbiosis practices. To this end, the regional policies targeted (Table 1) are those related to:

- Production and management of industrial waste;
- Efficient production processes;
- Access to innovative technologies and production techniques;
- Penetration of new markets.

In order to achieve these goals, a favourable and stable environment needs to be created at the local level. TRIS reaches out and engages with the actors that can drive the change, encouraging them to be involved in a structured network by building Local Industrial Symbiosis Labs in each of the partner regions.

Table 1. Local Policy instruments addressed by Interreg TRIS project

Region	TRIS Partner	Policy Instrument
West Midlands	Birmingham City Council (lead partner) Industrial Symbiosis	Greater Birmingham and Solihull Local Enterprise Partnership European Structural and Investment Funds (ESIF)
Central Hungary	IFKA Herman Otto Institute	Economic Development and Innovation Operational Programme (EDIOP)
Comunidad Valenciana	IVACE AIDIMME	Programa Operativo del fondo de desarrollo regional de la Comunidad Valenciana 2014-2020 (ROP)
Emilia-Romagna	Emilia-Romagna Region ASTER	Regional Waste Management Plan
South Sweden	Energi Kontor	Regional Structural Fund Program for Smaland och Oarna 2014-2020

Source: www.interregeurope.eu/TRIS

TRIS Approach and expected results

The TRIS project is based on the sharing of best practices in industrial symbiosis between European regions thanks to Interregional workshops, peer reviews and staff exchanges. These activities will provide learning and knowledge exchange for policy makers to help identify appropriate incentives to accelerate the uptake of industrial symbiosis contributing to a more circular economy.

A shared base of Good Practices has been collected by each region and will be then shortlisted and clustered through a self ranking process producing a catalogue of best practices which will be published on the project website. The Local IS Labs created in each region, gave contribution to the good practice identification and receive inputs from the interregional learning activities. The good practices and the Local IS Lab outcomes provide content for the 5 Interregional Thematic Workshops addressing the following themes:

- Awareness raising (Information & Communications);
- Policy and regulation;
- Financial schemes & business models;
- Tools to improve the capacity of SMEs to use industrial symbiosis (e.g. by products database, matching tools, setting up industrial symbiosis facilitated networks etc.). Coupled with the Interregional Workshops are Site Study visits related to examples on the ground. To further enhance the learning at the project organisation level, Peer Review visits are carried out: a delegation of senior staff from one organisation visits an organisation of another region. Additionally, individual learning is at the core of the Five Staff Exchanges. These involve staff in an internship of up to 5 working days in a partner organisations of a different region. Since the start of the project, in April 2016, three international workshops have been held and the Local IS Lab activities were initiated in each region, two peer reviews and one staff exchange have taken place. The outcomes of TRIS first phase of activities (2016-2019) will be:

- A set of focused practices and operations whose potential for replicability have been assessed by each region's Industrial Symbiosis Lab;
- 5 Regional Action Plans developed through a common methodology agreed at project level.

In the second phase of the project (2019-2021), each Action Plan will be applied and iteratively reviewed and monitored by the Local IS Lab.

Discussion and conclusion

Facilitated industrial symbiosis brings together producers and users of underutilised resources (including materials, water, energy, logistics) with technological innovators to foster innovation that responds to the needs of the market. Measures that support industrial symbiosis aim to enable the sharing among industries of services, utility and by-products/resources (including reuse of waste from one industry by another industry) in order to add value, reduce costs and make environmental improvements. Regional policy makers are involved by TRIS project activities and maintain an open dialogue with the Local IS labs stakeholders, ensuring in this way commitment towards the outcome of the defined Regional Action Plans. In this way, by supporting a systemic uptake of IS at regional level though policy instruments, the Interreg TRIS project will collect evidences to bring IS to a higher position in the European political agenda.

References

1. European Parliament European Resource Efficiency Platform, Manifesto and Policy Recommendations [Rapporto]. 2014.
2. Iacondini A. Mencherini U., Passarini F., Cibotti P. 2015 Feasibility of Industrial Symbiosis in Italy as an Opportunity for Economic Development: Critical Success Factor Analysis, Impact and Constrains of the Specific Italian Regulations [Rivista] // Waste and Biomass Valorization.

THE FOOD CROSSING DISTRICT PROJECT: INDUSTRIAL SYMBIOSIS FOR THE AGROFOOD SECTOR IN THE EMILIA-ROMAGNA REGION IN ITALY

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Abstract

The agro-food sector is responsible for the production of considerable amounts of by-products and waste, consequently of negative environmental impacts and inefficient economic management. Industrial Symbiosis (IS), through transfer and sharing of resources among companies, can help mitigate environmental losses and enhance resource efficiency. The Food Crossıng District project aims to detect IS paths within the agro-food sector, which can be replicable in the Emilia-Romagna region and at national level. The Interdepartmental Centre for Industrial Agrofood Research and the ENEA Laboratory for the Environment are working together exploiting their specific expertise and involving agro-food companies. The method adopted to foster IS consists of: i) contacting companies to involve in IS paths; ii) mapping companies of the territory for viable solutions; iii) developing operative manuals for selected IS paths; iv) updating and improving the IS platform for data elaboration. The found synergies will boost the territory transition to circular economy.

Keywords: Agro-food, Tomato skins, Durum Wheat Bran, Circular Economy.

Introduction

The agro-food sector produces relevant amounts of by-products and waste whose disposal generates environmental and economic negative impacts. In line with the objectives of the “Circular Economy Package” [1], which has recently been adopted by the European Commission, an Industrial Symbiosis (IS) approach can help valorising materials, energy, spaces and competences of the agro-food chain. The IS foresees the transfer and sharing of resources among different production industries contributing to decoupling economic growth from environmental impacts [2]. In this context, the Food Crossing District project, co-financed by the POR FESR Emilia-Romagna 2014-2020 (ROP ERDF Emilia-Romagna 2014-2020), aims at detecting technological and system solutions that can help activating symbiosis paths among regional enterprises in order to valorise by-products and waste, and obtain new products using low environmental impact technologies. The project particularly focuses on selected typologies of agro-food by-products, such as tomato skins and seeds, and durum wheat bran, coming from two industrial chains that are well developed in Emilia-Romagna and have a great strategic relevance at national level. The project will end by March 2018 and gathers two different industrial research labs: the Interdepartmental Centre for Industrial Agrofood Research, whose expertise is focused on agro-food products and processes; and ENEA Laboratory for the Environment, whose expertise is focused on IS and environmental impact evaluation, mainly through Life Cycle Assessment. The labs work in synergy with two important agro-food companies of the Emilia-Romagna territory, Consorzio Casalasco del Pomodoro and Barilla. This collaboration is aimed at detecting solutions for the valorisation of some by-products.

In the following sections are described some of the activities carried out to foster the realization of IS paths in the two selected chains and their replicability in the territory.

Methods

The identification of actors that may be brought together in synergies is done through a constant involvement of regional companies by email sending, telephone calls and organization of interested companies meetings. Operative manuals for the realization of individuated symbiosis paths are developed as a support to companies. The IS platform is the tool for supporting territorial analysis and to exploit the replicability potential of the method. The platform can be accessed through a website and can be used by companies to upload information about their by-products, which could be shared with others companies, and their requests for resources, which could be fulfilled with by-products of other industries. The platform also allows its administrators to highlight potentials for interactions on the territory which are not explored yet, also in relation to new technologies and inter sectoral collaborations.

Results

A database with contacts of about 120 different companies from the Emilia-Romagna region in diverse industrial sectors has been created. The companies have been invited via email to participate to a resource mapping. The mapping has been done by preparing a module where companies had to fill in information about inputs and outputs of their productive process, in order to identify possible exchanges of materials, energy, spaces and competences, thus possible IS paths, among companies in the region. This activity has seen in the first phase the direct involvement of a sample of companies through individual meetings and collective tech tables. It has allowed detecting some interesting synergies such as shared management of some resources common to all met companies.
Currently, the activities are focused on the mapping of the companies of the agro-food sector which are the object of the present project (olive oil mills, tomato production/storage companies, milling industries). This will allow understanding the quantity of by-products that are present in the region as well as the average dimension of the related companies. The aim is to design and size the final plants (after the experiment) coherently with the quantity of the available by-products, as well as the capacity of the single companies to individually implement the technology. In parallel, the operative manuals related to some detected symbiosis paths are developed. These documents have the objective to collect indications useful to the companies that intend to get involved in the valorisation of the analysed by-product. They include the description of the context and conditions that make the specific symbiosis interesting. In particular, the documents contain different aspects concerning regulation, technology, logistics, economic and environmental issues that have to be considered during the implementation of detected synergies. Actors who have to be involved are also defined. A brief introduction is also given to the use of the platform, where companies can verify the presence and the location of other enterprises in the territory which could be partners to implement symbiosis initiatives. The symbiosis platform, which is now being updated, wants to extend and improve functions and stability of the existing ENEA platform which is available on-line at web page http://www.simbiosiindustriale.it [3].
The objective of the platform is to create a network of users who can geo-localize their location, upload their resources (input/output) in the database and detect symbiosis paths by using this information. The current development activity aims in particular to improve the usability of the tool and wants to enhance some functions related to the management and implementation of the database. It also aims to further elaborate the input/output relation tables with the objective to detect the symbiosis synergies.

Conclusion

The activity of creating preliminary relations with companies allows enhancing the awareness of the enterprises of the region regarding the possibilities provided by the IS approach. The collected input/output data, organized thanks to the use of the platform, are useful for the assessment of the replicability of the IS paths detected during the project, and also for the identification of other potentially interesting paths. The implementation of the IS paths detected during the project allows promoting industrial collaboration activities that can significantly contribute to the enhancement of the enterprise competitiveness and to improve territorial synergies and inter-company communication. The final objective is to reduce the environmental impacts connected to the agro-food production in the Emilia-Romagna region and to facilitate the transition towards a circular economy.

References

1. European Commission (2015). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Closing the loop - An EU action plan for the Circular Economy.

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

3. L. Cutaia, A. Luciano, G. Barberio, S. Sbaffoni, E. Mancuso, C. Scagliarino, M. La Monica (2015). The Experience of the First Industrial Symbiosis Platform in Italy. Environmental Engineering and Management Journal, 14, 7, 1521-1533.

STATE OF PROGRESS OF THE INDUSTRIAL SYMBIOSIS PROJECT IN THE TARANTO PROVINCE

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Abstract

The aim of this paper is to describe the state of progress of the research project, started in 2012, on the application of industrial symbiosis to the Taranto Productive District. Starting from the update of the economic and environmental study of the productive district, it was possible to identify the main economic sectors involved in this district and its main non-hazardous industrial waste flows. Considering the environmental impact of the ILVA steel plant in Taranto, the research then focused on Industrial Symbiosis practices in the iron and steel industry in the European Union, in order to identify the most efficient waste recovery activities. The economic crisis of the steel industry has led to a reduction of more than half of the waste produced and managed in the studied area, nonetheless, LD slag is the main stream of special waste within the industrial district.

Keywords: Industrial Symbiosis, Productive District, Non-hazardous industrial waste, Iron and Steel Industry, LD slag

Introduction

One of the Industrial Symbiosis projects under development in Italy concerns the Taranto Province Productive District characterized by highly diversified economic sectors [1]. This research project, which regards a wide area within the Puglia Region, was launched in 2012 by the Ionian Department of the University of Bari, thanks to the funding of the Caripuglia Foundation and it is currently in progress thanks to the Puglia Region Future in Research Project funding sources with the aim of proposing industrial symbiosis scenarios among the firms located in the district.

Method

The Industrial Symbiosis application to a wide area requires the need for an economic and environmental mapping of the productive system. The latest economic data, referring to 2014, used to frame the Taranto production system, were provided by the Taranto Chamber of Commerce. A detailed analysis of the production, re-use and disposal of industrial waste within the province was carried out for the year 2014 using data contained in the M.U.D (Unique Model of Environmental Declaration – Italian national law n. 0/94) models provided by the Taranto Chamber of Commerce. From the economic and environmental analysis of the industrial district, it emerges that the most impacting industry, in terms of waste flows, is the ILVA steel plant. The next research step involved the analysis of the actual industrial symbiosis practices among the integrated steelworks in the European Union considering data from environmental reports and official statements on the web of each EU steel mill [2].

Results and discussion

The Taranto production system consists of 47,551 firms, including active firms and subsidiary firms. The most important industrial sectors in Taranto are the building sector (55% of active industrial firms) and the manufacturing sector (40% of active industrial firms). The analysis of the manufacturing firms, which considers the number of active and subsidiary firms, the overall value of revenue, share capital and employees of active firms, shows that the most relevant sectors are the construction of metal products, the clothing and leather industry, the food industry, the production of non-classifiable machinery, machine repair and installation, production of non-metallic minerals, waste management, the drinks industry and the production of electrical equipment. Regarding the industrial waste flows in the Taranto Province for the year 2014, it emerges that the waste managed in the ionian territory amounts to 3,245,369 tons of which more than one million tonnes are incoming external waste flow from outside the province. In detail, 52% of the managed waste is used for material recovery and refuse derived fuel production in compliance with Italian law, while 37% of waste is disposed in landfills. The remaining percentage of managed waste is subjected to treatment, incineration and storage processes (Figure 1).

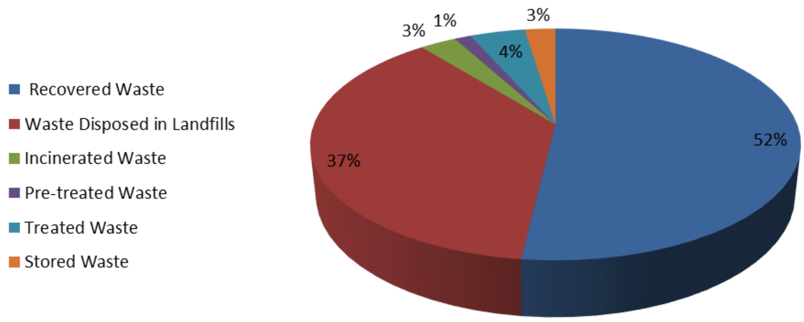

Figure 1. Waste Managed in Taranto Province (%), Taranto Chamber of Commerce, 2014

The main waste types produced, recovered and disposed in the Taranto Province in the year 2014 are those of the integrated steel industry due to the presence of ILVA steel plant. This waste flow includes: LD slag (630 kt compared to 1.5 Mt produced in 2008), blast furnace slag (600 kt compared to 1.5 Mt produced in 2008), refractory materials (60 kt compared to 78 kt produced in 2008) and mill scales (15 kt compared to 75 kt produced in 2008). Considering these waste flows, the research work entailed the analysis of the actual reuses of the integrated steel industry waste flows in the EU, in terms of industrial symbiosis activities that could potentially also be implemented in the Taranto district. The twenty-nine analysed EU integrated steel mills generate annually more than 32 Mt of waste that represent 28% of the overall EU crude steel production. Seven integrated steel mills that declare waste recovery, located in six EU nations, recover a total of 1.84 Mt/year of waste as secondary raw materials. LD slag is the most reused waste as a secondary raw material in different economic sectors such as civil engineering, road construction, cement and agriculture production. Six of the above-mentioned steel mills recover 1.67 Mt/year of LD slag which represents an 8.7% recovery of the overall EU LD slag production. ArcelorMittal is the steel company that recovers the most LD slag (especially in Spain and Belgium) in the construction industry. Other recovery activities of LD slag are carried out by the U.S. Steel Košice in Slovakia and the Raahe steel works in Finland.

Conclusions

The study shows that the environmental crisis of the steel industry in Taranto has led to a reduction of more than half of the main waste produced and managed. Despite this, LD slag is the main industrial waste within the industrial district. The EU overview of the Industrial Symbiosis activities, mainly related to this waste category, highlights that these waste recovery activities are not yet widespread and they have to be encouraged among the firms and extended to the other main waste categories.

References

1. Notarnicola B. et al. (2016), "Simbiosi industriale in Italia: stato dell'arte e prospettive di sviluppo future in Italia". In: Annali 2016 Anno IV, Ionian Department of Law, Economics and Environment, University of Bari Aldo Moro, p. 349-359.
2. Notarnicola B. At al. (2016), Waste Recovery in Steelmaking Sector: An EU Overview, 20th IGWT Symposium Commodity Science in a Changing World, Proceedings Scientific Works, Publishing house, "Science and economics" University of Economics – Varna, Bulgaria, p. 307-314.

INDUSTRIAL SYMBIOSIS (IS) IN THE ENERGETIC VALORIZATION OF DIFFERENT ORGANIC FRACTIONS THROUGH THE AD PROCESS

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Abstract

A sustainable model for integrateing waste and wastewater management, through a symbiotic approach based on anaerobic co-digestion of activated sludge with organic wastes is proposed for the Metropolitan Area of Catania. Biogas yield was assessed and considered for biomethane production while the scraps from wastes' separation processes were considered as a fuel for the waste to energy (WtE) plant. Part of the thermal energy from WtE was also considered for heating the digester in a completely holistic and circular approach. Different operating scenarios were evaluated for the anaerobic co-digestion process considering different temperatures and suspended solids concentrations. The thermophilic semi-dry condition resulted as the best option for sludge/biowaste treatment, obtaining the best performances in terms of biogas yields and digestate production reduction.

Keywords:anaerobic co-digestion,industrial symbiosis, waste, WWTP, WtEplant

Introduction

The treatment of municipal solid organic waste fraction is of paramount importance, giving a great contribution to the energy and material recovery. Anaerobic digestion (AD) has been shown to be the most environmentally sustainable technology for treating the organic fraction of municipal solid waste (OF-MSW), as it allows for the recovery of energy and nutrients from the waste [1]. AD technologies have been shown to yield additional benefits when placed within an integrated waste management system for treating OF-MSW associated with a Waste Water Treatment Plant (WWTP), so that the OF-MSW can undergo the treatment together with the wastewater sludge [2,3]. As a result energy production increases while reactor volume requirements, water usage, and excess leachate generation can be reduced. The aim of this study is to evaluate a holistic and integrated waste management scheme as applied to the Metropolitan Area of Catania based on a symbiotic approach of anaerobic co-digestion of activated sludge with other organic wastes from the same community. The use of the thermal energy produced by the combustion of the scraps deriving from separate wastes selection in a WtE plant for heating the digester is also considered to close the loop. The proposed scheme creates a synergy between different industrial plants (WWTP, AD, WtE) achieving a strong industrial symbiosis which would lead to an increase in the overall sustainability of the waste and wastewater management system.

Methods

An analysis of the waste fluxes is performed in order to identify and optimize the best configuration of the integrated system. The analysis is subdivided according to the following interconnected sections: 1) Separate Collection; 2) WtE process of the residual waste; 3) WWTP; 4) AD of sludge and separate waste organic fraction. For the application to the Metropolitan Area of Catania a 65% mean value of separate collection was considered according to the goals set by the current regulation. However a sensitivity analysis was also performed considering different overall waste productions and targets of separate collection. Consequently the residual waste as well as the scraps from separate waste selection were evaluated for energy recovery. The chance to partially address the residual waste to a prior Mechanical Biological Treatment (MTB) was also considered in the analysis.

TheWWTP of “Pantano D’Arci” located in Catania, with a capacity of about 500000 p.e. was considered within the symbiosis approach. For the anaerobic co-digestion process four different scenarios were evaluated: 1) Wet AD with a TS 9% and Mesophilic conditions; 2) Wet AD with a TS 9% and thermophilic conditions; 3) Semi-Dry AD with a TS 13% and mesophilic conditions; 4) Semi-Dry AD with a TS 13% and thermophilic conditions. Four parameters are obtained as a result: Digester Volume, Biogas Flow Rate, Digestate Flow Rate, AD Heat Requirement.

Results

The mass balances for the different scenarios and parameters of interest are reported in Figure 1. The Thermophilic Semi-Dry condition resulted as the best option in the co-digestion process for sludge/biowaste mixtures treatment, obtaining the best performances in terms of biogas yields and digestate production reduction, due to the lower water content and the higher applied temperature.

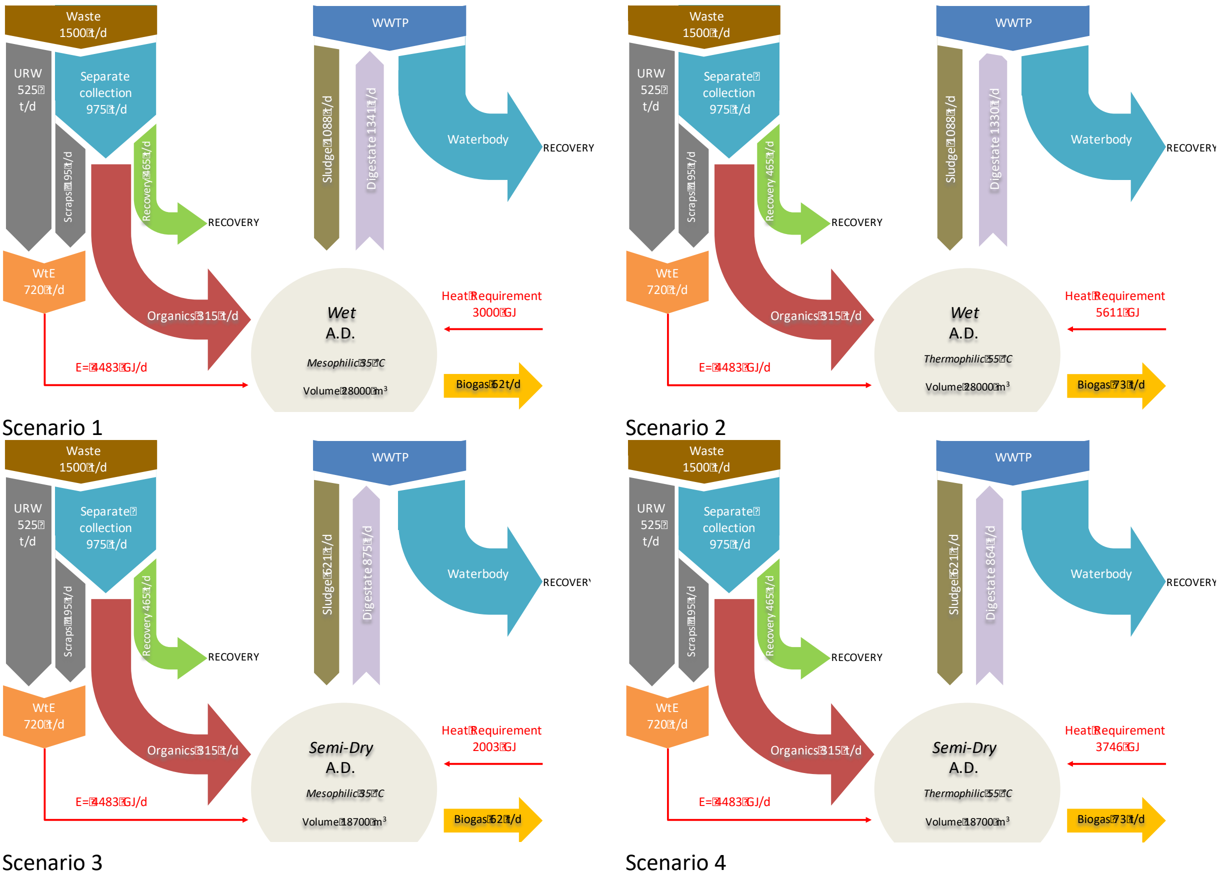

Figure 1. Result of the industrial simbiotic and integrated model for waste management

Discussion and conclusion

The proposed model, based on the IS approach, can be considered an interesting and promising solution for the integrated management of organic wastes and sludges and constitutes a prospective sustainable solution especially in regions of Southern Italy where these organic fractions are still mainly landfilled. The energy balance of the thermophilic process, although demanding a higher heat capacity compared to a mesophilic process, can be easily supported through the heat produced by the WtE plant. A simple aerobic and less energy demanding post stabilization step allows finally allows the production of quality compost so completely satisfying the circular economy principles.

References

1. De la Rubia et al. (2005).Temperature Conversion (Mesophilic to Thermophilic) of Municipal Sludge Digestion, Environmental and Energy Engineering, Vol. 51, No. 9.
2. Cabbai et al.(2016). Pilot plant experience on anaerobic codigestion of source selected OF-MSW and sewage sludge, Waste Management, 49 47–54.
3. Bolzonella et al. (2012). High rate mesophilic, thermophilic, and temperature phased anaerobic digestion of waste activated sludge: A pilot scale study, Waste Management, 32, 1196–1201.

THE SUSTAINABLE REGENERATION OF AN INDUSTRIAL AREA AS URBAN LABORATORY OF CIRCULAR ECONOMY AND INDUSTRIAL SYMBIOSIS

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Abstract

The industrial symbiosis is a really useful tool model which is widely spreading and validated in Europe. By an integration of different activities, production and resources supply can be reviewed with the aim to extend the cycle of utilization and consumption of natural resources encouraging an efficient eco-design, the reuse and recycling of many residual outputs. Many industrial areas, closely inserted in our urban contexts, can be renovated and refurbished using this innovative symbiotic approach. An added value could be also achieved by the creation of a sort of "urban laboratory" involving all stakeholders, as research centers, local authorities and entrepreneurs, producing a virtuous circle of sustainability. In this issue, an important research has been planned in order to re-thinking an industrial area on the outskirts of the city of Bologna, starting from industrial building energy consumption and supply, waste management and services sharing including a general area's mobility reassessment. The paper shows a possible working method for the first step of the research.

Keywords: Industrial district, Sustainable regeneration, Industrial symbiosis, Living lab, Waste.

Introduction

In the context of the strategies and technical tools for the management of natural and industrial resources, the closure of resource cycles according with a circular economy approach has become a fundamental objective both at a scientific and industrial level: any waste should not be considered as waste to be disposed, but a resource to be valorized in different integrated activities. Industrial symbiosis approach could be a useful tool to achieve that goal, promoting the innovative collaboration between companies and also increasing the competitiveness of local business and enterprises [1]. The contextual levels of an industrial symbiosis strategy can be applied at a territorial scale between companies, operators and organizations (networks for industrial symbiosis) and at industrial districts level, inside industrial areas. The present case study is referred to an industrial area, named Roveri, adjacent to Bologna and born in the 80's by an assembly of small and medium-sized industrial and artisan enterprises. Over the years, the local authorities, Municipality of Bologna and Emilia Romagna Region, have allowed the construction of residential buildings, to constitute an integrated and mixed (industrial, artisanal and residential) village. The economic crisis has led to a decline in production activities, but, in recent years, a dynamic and spontaneous renovation seems to be possible. The Think Tank planned an archetypal of business-resilient ecosystem with the goal of maximizing the use of material, energy and services assets focusing the attention on energy efficiency, by-product recovery and regeneration, and sharing welfare, services, mobility in order to rethink the area as a sustainable industrial district. It is also possible thanks to the regional law on circular economy [2] and the recent specific regulation on by-products [3] thus facilitating and supporting the strengthening of existing productive activities, encouraging the community in moving from a traditional - linear to an innovative - circular approach. Even if, this predisposition is led by specific local stakeholders, the trend involve all the local community thus creating a urban living laboratory of sustainability in which ENEA and University of Bologna cover the role of facilitators for the multi-layered skill set.

Methods

The lack of an updated picture of activities inside this area has kicked off to the first step of the project, the method of which is shortly reported below. It is an approach that could be applied as study method in any similar context.

Table 1. A starting project methodology

Step 1	Activity	Actors	Tools	Results
Phase 1	Indirect collection of primary data (type of activities)	Emilia Romagna region - UNIBO	PARIX database	Updated mapping of industrial and commercial activities in Roveri area
Phase 2	Georeferencing of companies operating in Roveri area	Municipality of Bologna - Metropolitan city of Bologna - ENEA - UNIBO	Geographic informatic system (GIS), Territorial information system (SIT) of Municipality of Bologna	Geo-localized mapping of industrial and commercial activities in Roveri area
Phase 3	On-the-spot control	UNIBO	/	Data validation
Phase 4	Historical reconstruction of industrial heritage of Roveri area	Confindustria - ENEA - UNIBO	/	Story of transformation and evolution of Roveri area from 80's to today
Phase 5	Direct collection of secondary data (type of waste, by-products, services and spaces)	Confindustria - ENEA - UNIBO	Workshop and One-to-one meeting with company executives	Mapping of available resources

Results

The primary data are collected thanks to PARIX database, a Company Register platform, maintained by the Italian Chambers of Commerce that gives update information daily about master data, balance sheet and type of manufacturing activities. This has allowed to define the current picture of the area that shows a completely different conformation than the original one: a lot of industrial buildings have changed their purpose of use, many commercial activities and residential facilities are born and new brands have decided to invest here.

Conclusion

The knowledge of the transformation of the area over the years and the current conformation mapping will help to plan all following steps of the research in order to implement actions in line with the identity of the area and the needs of the community. Particularly, the goal of this first step of activities is to outline the current framework of the industrial and commercial activities and its available resources (in terms of substances, energy, spaces, services) that on the one hand, will feed, at first, a new database and then, the industrial symbiosis platforms (as ENEA's Symbiosis) [4] allowing to define the symbiotic scenarios and in another hand, will increase the relationship between industrialists and residents, thus creating a proactive sustainable industrial community.
Energy audit, waste management design, sharing mobility planning will represent the following steps of the plan. Finally, a match-making of resources will be tested, with the support of public and private bodies, in order to facilitate the implementation of a sustainable industrial system [5].

References

1. N.M.P. Bocken et al. (2013). A literature and practice review to develop sustainable business model archetypes. Journal of Cleaner Production 65 (2014).
2. L.R.16/2015. Disposizioni a sostegno dell'economia circolare, della riduzione della produzione dei rifiuti urbani, del riuso dei beni a fine vita, della raccolta differenziata e modifiche alla L.R.19/08/1996 n. 31.
3. Deliberazione Giunta regionale 2260/2016 http://ambiente.regione.emilia-romagna.it
4. L. Cutaia et al. (2015). The experıence of the fırst ındustrıal symbıosıs platform ın Italy. Environmental Engineering and Management Journal Vol.14, No. 7, 1521-1533.
5. M. La Monica, L. Cutaıa, S. Franco (2014). La simbiosi industriale come modello per lo sviluppo sostenibile dei sistemi economici territoriali. ISBN 978-88-907394-4-6.

IMPACT ASSESSMENT OF URBAN SCENARIOS - AN OVERVIEW

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Abstract

As widely recognized, urban sustainability approaches, as well as other place-based approaches to Industrial Ecology (IE), should incorporate methods for measuring the environmental impacts caused by the activities established in such contexts. Urban Metabolism (UM) studies traditionally stop at the identification and quantification of mass or energy flows. Scholars have recently affirmed that the more promising way to fill this gap is that of integrating UM and life-cycle-based approaches to develop a multi-scale framework for the environmental impact assessment of urban scenarios. This article proposes a literature overview on these issues highligthing potential and limitations of such a perspective.

Keywords: Urban Metabolism; Life Cycle Assessment; Scenario; Literature Overview.

Introduction

To measure the potential environmental performances of a complex system it is necessary to start from a baseline, defined as the situation in which the system is currently, and compare it with and at least one future scenario [1] in which improvement solutions are implemented. At present, the main methodologies for representing and quantifying the flows of anthropic systems are essentially Material Flow Analysis (MFA) and Life Cycle Assessment (LCA) [2; 3]. Their potential remains partly unexplored in the case of urban contexts [4]. Urban Metabolism (UM) has gradually affirmed as the Industrial Ecology (IE) approach focused on urban contexts [5]; it traditionally stops at the quantification of mass or energy flows through MFA-based tools. The integration of UM and LCA approaches is able to develop an integrated multi-scale framework for environmental impact assessment also in a UM perspective. In the last years, efforts have been made in this direction; this article, moving from a literature overview, seeks to highlight the most significant ones.

Methods

The authors defined a combined search for the two key-concepts of UM and LCA and refined the results obtained through a qualitative analysis. Sources were retrieved from the Scopus database.

Results

In this section, the results of the literature overview are summarized (Table 1).

Table 1. Main results of the literature overview

Author(s)	Contribution
Mahmoud et al. [6]	Use scenarios to plan *long-term decisions* and *short-term decisions* that have long-term effects. They highlight two types of scenarios found in literature: exploratory and anticipatory scenarios. The former is related to the extrapolation of trends from the past, projections, and patterns. The latter, that is closer to our UM scenarios, is related to desired or feared different visions - policy-responsive scenarios - of the future that may be achievable or avoidable if certain events or actions take place (e.g. decision-maker policies).
Baynes and Wiedmann [7]	Consider three categories of direct or indirect material and energy flows accounting in the urban context: the consumption-based accounting (CBA), the metabolism-based accounting (MBA) and the complex systems approach. They suggest different kind of tools to assess the environmental sustainability for the CBA and MBA, such as *extended input–output analysis* (IOA) and, more recently, *hybrid input–output life-cycle analysis* (IO-LCA). They point out that to simulate future scenarios

Author(s)	Contribution
	dynamic cause-effect relationships needs to be described, and that IO-LCA is better to assess existing scenarios. They also recognize that complex systems include features such as system interactions, feedbacks, network relationships and agency. The disadvantage of such contexts is uncertainty.
Goldstein at al. [8]	Applied a *hybrid model approach integrating UM and LCA* to five global cities. The results of this study show that the UM-LCA helps to identify which parts of the city's supply chain have the higher environmental impact and it can be successfully applied to cities for which the data exists. However, according to the authors, UM-LCA is methodologically immature.
Tseng and Chiueh [9]	Proposed a study, regarding food waste, in which the analysis of UM is integrated to the LCA method (the so-called UM 2.0) to evaluate 4 different scenarios with different technologies of food waste treatment. Data was collected from the literature, statistics and databases. The authors state that applying simultaneously UM and LCA can provide information on the environmental impacts, as well as about the interactions of flows inside the black box, i.e. the interaction between components.
Junqua et al. [10]	Propose two valid tools for the assessment of the different options of land planning of a territory: *Eurostat Material Flow Accounts* and *Territorial LCA*. The authors state that these tools are able to propose scenarios integrating global initiatives of circular economy, regulations changes and local action as industrial ecology. They highlight the role of *consequential LCA* in territories with strong interactions between many activities.

Discussion and conclusion

The results obtained highlight that the joint use of UM and LCA may: i) improve the understanding of how cities consume resources and discharge waste by incorporating flows beyond city geopolitical boundaries; ii) provide a framework for connecting urban flows with resource depletion, human health damage, and ecosystem quality damages; iii) provide rigorous understanding of infrastructure role (e.g. for utilities, water, and wastes management). However, as also recognized by Chester et al. [11], the full achievement of these goals implies to reconsider the boundaries of the urban system intended as a residential system, because it predominantly focuses on use and consumption activities and this limits the perspective characterizing life-cycle-based methodologies, which should also include the extraction, production, and end of life stages.

References

1. Pesonen et al ., 2000. Framework for scenario development in LCA. International Journal of Life Cycle Assessment 5, 21–30.
2. Holmes, T., Pincetl, S., 2012. Urban Metabolism Literature Review, Center for Sustainable Urban Systems, UCLA Institute of the Environment.
3. Clift, R., Druckman, A., Christie, I., Kennedy, C., Keirstead, J. 2015. Urban metabolism: a review in the UK context, Foresight – Future of Cities Project, Government Office for Science, UK.
4. Padovan, D., 2015. Assembling societal metabolism and societal practices: the dynamics of sustainable and (un)sustainable reproduction. Strandbakken, P., Gronow, J. (Eds), The Consumer in Society. A tribute to Eivind Sto, Abstrakt Forlag AS, Oslo, pp. 335-362.
5. Kennedy C, Cuddihy J, Engel-Yan J (2007) The Changing Metabolism of Cities. J Ind Ecol 11:43-59
6. Mahmoud M. Et al., 2009. A formal framework for scenario development in support of environmental decision-making. Environmental Modelling & Software 24, 798–808.
7. Baynes, T. M., Wiedmann, T., 2012. General approaches for assessing urban environmental sustainability. Environmental Sustainability 4, 458–464.
8. Goldstein, B., Birkved, M., Quitzau, M.-B., Hauschild, M., 2013. Quantification of urban metabolism through coupling with the life cycle assessment framework: concept development and case study. Environmental Research Letters 8, 1-15.
9. Tseng, W.-L., Chiueh, P.-T., 2015. Urban metabolism of recycling and reusing food waste: A case study in Taipei City. Procedia Engineering 118, 992-999.
10. Junqua, G., Forcier, U., Gonzalez-Roof, A., Lopez-Ferber, M., 2016. Comparison and complementarities between Eurostat and Territorial LCA methods for land planning based on a Mediterranean case study. Proceedings of 22nd SETAC Europe LCA Case Study Symposium, Nantes, 2016.
11. Chester, M., Pincetl, S., Allenby, B., 2012. Avoiding unintended tradeoffs by ıntegrating life-cycle ımpact assessment with urban metabolism. Current Opinion in Environmental Sustainability 4, 451-457.

INDUSTRIAL SYMBIOSIS: A LITERATURE OVERVIEW

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Abstract

As known industrial symbiosis (IS), could be defined as "the involvement of industries operating in different sectors, with an integrated approach, to promote competitive advantages through the exchange of energy, water, by-products, best practices, Know how and information". Aim of present study is to identify the critical aspects that limit the adoption of good IS practices through a literature analysis highlighting the key role that IS assumes in the transition to the Circular Economy by implementing the so-called "closure of production cycles".

Keywords: Industrial Ecology, Circular Economy, Industrial Symbiosis, Literature Review

Introduction

In industrial ecology, industrial symbiosis (IS) is a strategic driver for the transition to circular economy, spreading in many regions of the world as a good practice in reducing environmental impacts of production processes, thus enabling the so-called "Closure of Cycles" [1]. Industrial Symbiosis has been defined as the involvement of "traditionally separated industries with an integrated approach aimed at promoting competitive advantages through the exchange of matter, energy, water and / or by-products". This definition has been expanded during the latest years, including intangible goods trade as knowledge, experience, information etc.[2] .

Methods

The theme of the interaction between production systems and exchange of material was first studied by Ayres, who introduced the concept of "industrial metabolism" highlighting similarities between production systems and biosphere. This aspect was further deepened by Erkman who clearly distinguished the "industrial metabolism" from "Industrial Ecology" by defining the first one as the total flows of materials and energy circulating within the industrial system and that are related to the antropic activity along the whole life cycle and highlighting its three key elements: a) systematic and integrated approach of all components of the industrial economy and their relation to the biosphere; b)relevance of human activity; c) technological dynamics which are the essential tool for transition to a sustainable system from a not-sustainable one. The most important contribution in the literature was given by M.R. Chertow, who between 1997 and 1999 investigated the collective exchanges of 18 different eco-industrial parks, which allowed to identify 5 types of material exchanges to be activated between Enterprises, pointing out that the Industrial Symbiosis occurs when the collaboration start within a well-defined geographical area by exchanging energy, materials and water and sharing information and services such as transportation functions and marketing activities. Many researchers investigated the well-known case of Kalundborg where IS was born in a completely natural and spontaneous way through intensifying collaboration between local businesses in order to achieve economic, environmental and social benefits, the literature focused on the study of many other Industrial Symbiosis experiences highlighting opportunities , strengths and future research projects of eco-industrial parks (EIPs), systems specially designed and realized through economic policy measures in order to recreate the conditions for the development of the IS. EIP planning and development depends to a large extent on institutional provisions and regulatory directives, while the IS is born spontaneously. Enterprises that act in such a context needs the presence of human resources with specific skills supporting choices and achieving the goals set. The analysis of the symbiotic realities present in Rio de Janeiro, Brazil, put in evidence that companies supported by State help can better deal with difficult situations. Another important aspect is given by geographic proximity, particularly when clusters of businesses around a "vital" plant are generated, by-product exchanges, energy, water and heat are more profitable [3]. It should also be considered that an increase in the degree of heterogeneity of the actors involved in the symbiosis process extends the scope for co-operation, despite the increase in the number of involved parties that may lead to conflicting interests. The IS stimulates the development of new environmental innovations that promote collaborations between multiple organizations, enabling coordinated environmental challenges. Thanks to eco-innovation, firms reach a competitive advantage in business management and achieve a win- win status in the supply chain networks through the IS [4]. By analyzing the case studies in literature, it is possible to combine the production of heavy industry with the conservation of the territory and the environment, as evidenced by the areas of Kwinana and Gladstone in Australia, where IS processes are integrated (metal processing, chemicals and fertilizer production, petroleum refineries and lime and cement production), as well as water treatment and cogeneration plants and two power plants [5]. It is possible to make the mineral processing processes more sustainable by trying to eliminate progressively and systematically emissions and waste by ensuring that the same business performance is respected by companies while respecting the interests of the communities involved. In fact, Industrial Symbiosis is able to reduce the existing gap between technical and sociocultural aspects of industrial development. Recently, in some areas of the USA affected by a significant loss of heavy industry, there has been an increase in co-localized small-scale enterprises (such as fabrication labs or co-working spaces) with the intent of revitalize the local economies. These new types of structures not only well reflect the underlying principles of the circular economy, but represent an opportunity for the development of IS [6].

Results and discussion

Industrial Symbiosis, as an instrument of Industrial Ecology, is able to create the conditions necessary for new opportunities for economic growth. The constant increase in scientific work and analysis of case studies on IS and in particular on EIBs in different parts of the world have shown the economic, environmental and social benefits that a well-integrated system can reproduce. From the preliminary study of literature review in this paper, it turned out that IS is a topic widely analyzed in the Circular Economy, but some critical issues have to be overcome. Among critical points emerged from this work the lack of information and communication tools to support actors acting within networks that can facilitate cooperation activities and sharing best practices and know-how seems to be relevant. Moreover support of local authorities is very important to enterprises both from the regulatory standpoint and through any funding mechanisms, by encouraging the adoption of technological innovations for the modernization of production systems that enable the effective implementation of Industrial Symbiosis models. The relationships between IS and eco-innovation remains unclear due to the lack of detailed description of this item. Thanks to eco-innovation, firms reach a competitive advantage in business management and achieve a win- win status in the supply chain networks through the IS. However, future studies could analyze the role of eco-innovation in the development of IS.

References

1. F. Boons, M. Chertow, J. Park, W. Spekkink, H. Shi, (2016). Industrial Symbiosis Dynamics and the Problem of Equivalence Proposal for a Comparative Framework, Journal of Industrial Ecology. DOI:10.1111/jiec.12468.
2. D. R Lombardi, P. Laybourn, (2012). Redefining industrial symbiosis. Journal of Industrial Ecology,16, 28-37.
3. H. Shi, M. Chertow, Y. Song, (2010). Developing country experience with eco-industrial parks: a case study of the Tianjin economic-technical development in China. Journal of Cleaner Production 18, 191e199.
4. Ming-Lang Tseng, Tat-Dat Bui, (2017). Identifying eco-innovation in industrial symbiosis under linguistic preferences: A novel hierarchical approach. Journal of Cleaner Production 140 (2017) 1376e1389.
5. D. van Beers, G. Corder, A. Bossilkov, R. van Berkel, (2007), Industrial Symbiosis in the Australian Minerals Industry The Cases of Kwinana and Gladstone, Journal of Industrial Ecology 11 (1), 55–72.
6. J. Mulrow, S.Derrible, W. S. Ashton,S. S. Chopra, (2017). Industrial Symbiosis at the Facility Scale, Journal of Industrial Ecology, DOI: 10.1111/jiec.12592.

LEARNING FAIR PLAY IN INDUSTRIAL SYMBIOTIC RELATIONS

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Abstract

In this paper, we provide practical decision support to managers in firms involved in Industrial Symbiotic Relations (ISRs) in terms of strategy development and test the hypothesis that in the long-term, playing a fair strategy for sharing obtainable ISR-related benefits is dominant. We employ multi-agent-based simulations and model industrial decision-makers as interacting agents that observe their history of cooperation decisions in ISRs. The agents are able to: learn from their past, deviate from relations in which their partner plays unfair, and change their strategy to reach higher long-term benefits. Results show that in a long-run, industrial decision makers learn to play fair in ISRs. In addition to managerial support for developing long-lasting ISRs, our work introduces the concept of learning as a notion that links the micromotives in ISRs to their macrobehavior.

Keywords: Industrial Symbiotic Relations, Strategy Management, Learning in Industrial Relations, Industrial Symbiosis Evolution, Multiagent-Based Simulation

Introduction

To improve the implementability of Circular Economy (CE) in the industrial context, providing practical insights about Industrial Symbiotic Relations (ISRs) and their evolution fosters the shift from CE in theory to practice as it supports industrial decision-makers while getting engaged in ISRs. For such a purpose, understanding the long-term behavior of ISRs aids the decision makers learn about the effects of different strategies applicable for sharing obtainable ISR-related benefits. Accordingly, this work is focused on the long-term behavior of industrial agents and the evolution of cooperation decisions in ISRs. In such relations, two possible fair and unfair benefit-sharing strategies are taken into account. Applying a fair strategy implies that the firm is available to obtain a minimum acceptable benefit value while an unfair firm takes the major part of ISR-related obtainable benefits, which might be triggered by several reasons such as power asymmetry between companies, market image or existence of governmental regulations. Considering these strategies, we test the hypothesis that in the long-term, firms learn to implement the fair strategy. The rationale is that in case a firm A applies the unfair strategy, in the long-term other firms that are in relation with A learn that they can benefit more by defecting the relation (and joining other relations). Such collapses of relations are costly for A as it has to establish new ISRs and pay corresponding costs. This approach captures the *path dependence* phenomena and organizational learning processes in the context of industrial symbiosis [1,2].

Methods

We test our hypothesis using multi-agent-based simulations. In particular, we simulate multi-round games among industrial agents. The generic i^{th} agent is provided with the following three parameters: 1) $\pi(i)$ represents the probability that i plays the fair strategy when starting a new game; 2) $\psi(i)$ represents the probability that, if at time $t-1$ the agent i and its partner were cooperating, both of them playing the fair strategy, at time t the agent i changes its strategy and plays the unfair strategy; 3) $\chi(i)$ represents the probability that agent i interrupts its current relationship because it is playing the fair strategy and its partner is playing the unfair strategy. We consider 100 resource-provider firms and 100 resource-receiver firms interacting with each other for 600 runs. At the end of the simulation, we collect: 1) the average value of π. The higher this value, the more firms learned the fair play in ISRs; 2) the average value of χ which is about agents learning that they can gain greater economic benefits by breaking the relationship with unfair partners; and 3) the average value of ψ. The higher this value, the more firms learned that opportunistic behaviors stemming from changing from fair to unfair strategy when the partner is playing the fair strategy is detrimental for long-term ISRs. Simulations are replicated 10000 times to give statistically significant results. All values are averaged across the replications.

Results

Simulation results are shown in Figure 1. In particular, Figure 1-Left shows the values of π, ψ, and χ for resource-provider firms whereas Figure 1-Right shows the values for resource-receiver firms.

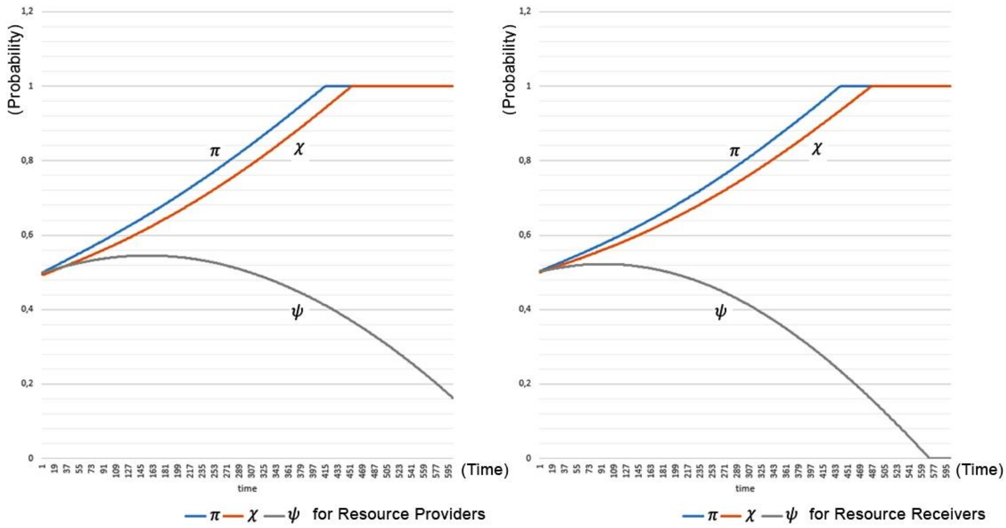

Figure 1: Evolution of ISR parameters π, ψ, and χ for resource-providers (Left) and resource-receivers (Right)

Discussion and conclusions

First, we can note similarities between corresponding values for resource receivers and providers (e.g. $\pi(A)$ and $\pi(B)$). These similarities are because we have considered the ISRs as a form of symmetric relations and mainly focused on the temporal behavior of ISRs. Our results show that in the long-term, playing fair strategies increases the probability that an ISR arises. Moreover, firms learn that the opportunistic behavior (i.e. aiming to take more advantage from existing ISRs) is detrimental for their economic results. These results are in line with the literature highlighting the key role of collaboration for the success of the IS practice [3]. In addition to managerial decision support to industrial firms and suggesting the implementation of fair strategies in ISRs, we contribute to theoretical understanding of the relation between motives of individual industrial agents and the failure/establishment of long-term relations. We show that the macro-level behavior of ISRs (e.g., simultaneous emergence of multiple ISRs and their evolution) is not simply the aggregation of micro-level motives, e.g., to maximize the benefits regardless of the opponent's benefits (see [4]). Our results show that the ability of industrial decision-makers to learn, from their past experiences, bridges ISR micromotives to macrobehaviors and explains the dominance of fair ISRs in the long-term. This is, in a long-run, agents learn to play fair in ISRs.

References

1. Boons, Frank, and Jennifer A. Howard-Grenville, eds. 2009. The social embeddedness of industrial ecology. Edward Elgar Publishing.
2. M.R. Chertow, 2007 "Uncovering" industrial symbiosis. Journal of Industrial Ecology 11(1) :11-30.
3. M.R. Chertow, 2000 Industrial symbiosis: literature and taxonomy. Annual review of energy and the environment 25(1) 313-337.
4. Schelling, Thomas C. 2006 Micromotives and macrobehavior. WW Norton & Company.

RESOURCE INVENTORY FOR FOSTERING INDUSTRIAL SYMBIOSIS PRACTICES

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Abstract

In this paper, we investigate the potential environmental benefits obtainable in Industrial Symbiotic Networks (ISNs) in case firms stock wastes when the demand is lower than supply. We design multiagent-based simulations to model the spontaneous emergence and operations of ISNs over time where firms are involved in substitution-based symbiotic relationships. In each simulation, we compute: 1) the amount of resources saved with respect to the amount of produced wastes; and 2) the amount of resources not saved because of the lack of inventory compared to the produced amounts. Results show that waste stocking could be a useful strategy to reduce the negative effects of the waste market dynamicity on the match between demand and supply.

Keywords: Industrial Symbiotic Networks, Inventories, Multiagent-Based Simulations.

Introduction

From the technical perspective, the most relevant condition for the development of Industrial Symbiotic Networks (ISNs) is the match between supply and demand of reusable resources, e.g., wastes [1]. However, ISNs' vulnerability to perturbations in the amount of both produced resources and required inputs negatively affects such a match [2]. When the produced amount (or required input) is reduced, the firm requiring the corresponding input (or producing the corresponding resource) is forced to buy additional amount of input from external suppliers (or to dispose additional amount of reusable resource in the landfill). Hence, since the economic benefit stemming from the industrial symbiotic relation (ISR) is reduced, the firm may decide to defect from the cooperative relation [3]. In order to deal with this problem, when demand is lower than supply, providers can stock the reusable resource rather than disposing. These stocked resources could be exchanged when the demand (potentially) becomes higher than supply. Whilst in some cases such a practice is hampered by the normative framework or because of technical issues [4], in other cases firms prefer not to stock because they are not willing to pay inventory costs. However, resource inventory can increase the amount of exchanged resources in the long period, hence providing firms with additional economic advantages, which could be higher than the inventory cost. To the best of our knowledge, this paper is the first attempt to investigate the strategy of resource stocking in ISNs. In particular, this paper is aimed at assessing the environmental benefits obtainable in case ISN firms adopt such a strategy.

Methods

ISNs are studied in the complex systems perspective, i.e., as emergent networks arising from the spontaneous decisions of independent but interconnected firms [3]. This study adopts a multiagent-based simulation approach: we design a model where agents are the firms within the ISN and links among agents are ISRs. The model simulates the spontaneous creation and operation of an ISN over time in different environmental scenarios, defined by two parameters: 1) waste market dynamicity (WMD), modeled as the standard deviation of demand and supply of wastes compared to the mean value (see [3] for details); 2) ISN topology, modeled as the average firms' degree of centrality (DOC) in the ISN normalized by the total number of firms in the ISN. Whilst the former parameter is considered to have a negative impact on the match between demand and supply, the latter is considered to have a positive effect [3,5].

All the physical and monetary flows among firms are modeled by adopting the Enterprise Input-Output (EIO) approach [1]. The model is applied to a case study involving marble producers and concrete producers [5]. Simulations are run for 40 time periods and replicated 200 times. At the end of each simulation, we compute: 1) the amount of resources exchanged in absence of stocking strategies in comparison to the amount of produced reusable resources; 2) the amount of not-exchanged (but disposed) resources as a result of lacking inventories in comparison to the amount of produced reusable resources.

Results

Table 1 shows the percentage of resources saved in absence of resource stocking strategies (in black) and the percentage of not-exchanged resources as a result of lacking inventory (in italic red) for each ISN simulation scenario. For instance, imagine an ISN with average DOC equal to 1 and WMD equal to 0.4. In absence of resource stocking strategies, 42.59% of produced wastes is saved while an additional 11.71% could be saved if firms would adopt waste stocking strategies.

Table 1. Percentage of resources saved in absence of resource stocking strategies (in black) and percentage of not-exchanged resources as a result of lacking inventories for each ISN simulation scenario (in italic red)

		WASTE MARKET DYNAMICITY							
		0.1		0.2		0.3		0.4	
AVERAGE FIRMS' DEGREE OF CENTRALITY	0.02	14.24 %	*0.80 %*	13.24 %	*1.60 %*	12.23 %	*2.33 %*	11.33 %	*2.99 %*
	0.04	22.43 %	*1.30 %*	20.49 %	*2.50 %*	18.82 %	*3.70 %*	17.59 %	*4.75 %*
	0.1	37.43 %	*2.20 %*	35.00 %	*4.29 %*	31.44 %	*6.24 %*	28.68 %	*7.82 %*
	0.2	48.00 %	*2.80 %*	44.66 %	*5.59 %*	40.85 %	*8.15 %*	35.55 %	*9.78 %*
	0.4	54.56 %	*3.21 %*	50.44 %	*6.29 %*	47.06 %	*9.33 %*	40.94 %	*11.23 %*
	1	58.71 %	*3.46 %*	54.69 %	*6.81 %*	49.98 %	*10.00 %*	42.59 %	*11.71 %*

Discussion and conclusion

The percentage of not-exchanged resources because of missing inventory strategies in ISNs ranges between 0.8% and 11.71% and it is much higher when the WMD and the DOC are high. This illustrates that the practice of stocking wastes in ISNs can significantly reduce the negative effects of the WMD, which is recognized as an important barrier to the development of new ISRs [3]. However, this practice appears to be barely useful when the ISN is characterized by low DOC. In such a case, firms should concentrate on building social relationships and trust among them instead of dealing with technical issues [6]. Further developments will address the economic implications of resource inventory for firms, in order to assess the extent to which such a practice could enhance the economic benefits for firms.

References

1. D.M. Yazan, V.A. Romano, V. Albino (2016). The design of industrial symbiosis: an input–output approach. Journal of Cleaner Production, 129, 537–547.
2. L. Fraccascia, I. Giannoccaro, V. Albino (2017). Rethinking Resilience in Industrial Symbiosis: Conceptualization and Measurements. Ecological Economics, 137, 148–162.
3. L. Fraccascia, I. Giannoccaro, V. Albino (2016). Exploring the role of contracts to support the emergence of self-organized industrial symbiosis networks: An agent-based simulation study. Journal of Cleaner Production, 112, 4353–4366.
4. A. Golev, G.D. Corder, D.P. Giurco (2015). Barriers to Industrial Symbiosis: Insights from the Use of a Maturity Grid. Journal of Industrial Ecology, 19, 141-153
5. L. Fraccascia, D.M. Yazan (2017). The role of information for the emergence of self-organized industrial symbiosis networks: an agent-based simulation approach. In ISIE-ISSST Conference 2017: Science in Support of Sustainable and Resilient Communities, 25th-28th June 2017, Chicago (USA).
6. A.K. Hewes, D.I. Lyons (2008). The Humanistic Side of Eco-Industrial Parks: Champions and the Role of Trust. Regional Studies, 42, 1329–1342.

STANDARDIZED AND MACHINE READABLE DATA FOR IMPROVING TRANSFER OF RESOURCES AND INDUSTRIAL COLLABORATION

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Abstract

The construction sector process is characterized by an intensive production of information due to the high number of requirements derived from building codes, standards and regulations. The proposed paper aims to present a standardized data structure and related uses for collecting, sharing and exchanging information between stakeholders involved along the building process. The research is focused on the Italian context and has been developed defining a structured methodology that includes the collection of requirements from several actors reached thank to the development of a linked UNI standard. The alignment to international product information requirements and the study of practical applications. The final result is the definition of criteria for the unification of terminology, organization, collection and exchange of information for the Architecture, Engineering and Construction (AEC) sector structured in a web-based portal where all the information is machine readable. This allows better collaboration along the process promoting the diffusion of industrial symbiosis between stakeholders.

Keywords: Information management, Data structure, BIM, Sustainability.

Introduction

The construction sector process is characterized by an intensive production of information due to the high number of requirements derived from building codes, standards and regulations, clients' and users' needs. Hence, an ordered structure for information is needed to store and use all the required data. This is even truer nowadays, when data and information tend to dissolve in a digital ecosystem more and more volatile. In fact, for enhancing visibility and traceability of information, it is essential to manage requirements from the Strategic Definition stage to the In use stage [1]. A lack of transparency in the information management and of communication between stakeholders often brings to the adoption of solutions in the design process that do not meet the original requirements [2, 3]. Therefore, the process results in design iterations, rework, and, consequently, low efficiency [4]. Furthermore, the operational islands between different disciplines cause ineffective coordination (Schade, J., Olofsson, T., and Schreyer, M. 2011). These issues lead to final products (buildings and infrastructures) that are inefficient in terms of both performances and available information. This last point creates a great barrier in the transfer of resources between different actors hindering the creation of industrial symbiosis. Hence, another fundamental dimension of the information management is the usability and re-usability of data and information in order to create value in the process. The paper focuses on some preliminary efforts within the Italian building sector for proposing a standardized structure for collecting, sharing and exchanging information between stakeholders along different stages of the building process. Some possible uses with reference to the inclusion of different industries along the life cycle are presented, proposing dedicated applications for automating the process of information fruition.

Methods

An analysis of the Italian building sector has been considered essential for identifying main criticalities to be solved and essential information to be collected, shared and exchanged. Therefore, several stakeholders have been involved during the research for identifying informational requirements and information technologies to be adopted for the definition of a standardized structure and for the fruition of information through a web-portal. The points of view of different actors have been collected through the establishment of working groups at the Italian standardization organization (UNI) and through the participation at a national research project (INNOVance). These stages have been followed by an application phase that highlighted the critical role of the proposed methodological approach in the use of information.

Results

The collaboration between several stakeholders through UNI and the involvement of different teams in a national research project result in the definition of criteria for the unification of terminology, organization, collection and exchange of information for the AEC sector. Two main results have been achieved: an unambiguous classification system and models for performance-based computational digital technical datasheets. Both the classification system and the models for technical datasheets have been proposed for different technical solutions adopted in the building process including technical information about construction products and technological solutions. Particularly, standard criteria have been identified to describe construction products, in identificative, qualitative and quantitative terms. The structure has been defined in accordance with harmonized standards for CE marked products or in agreement with other relevant reference standards (if available and/or applicable) for non-CE marked products. Once defined the models for construction products, a comparable structure has been developed also for technological solutions, providing datasheets for layers and technological systems. As demonstrated through the proposed exploration of use, such structure is critical to provide an easily accessible source of data, directly usable from machines. This feature improves effective communication between industries with different information needs widening the opportunity of industrial symbiosis.

Conclusions

The whole supply chain can take advantages of the availability of a defined data structure and of its implementation in a BIM-based platform to support web-based collaborative design and construction. Particularly, different manufacturers have the possibility to upload complete information of their products, designers can easily compare characteristics and performances of similar products, construction companies have access to information concerning the installation and the maintenance of selected products. Moreover, such structure can promote the development of dedicated applications able to use and re-use the information in order to automate the process. These applications can be developed thanks to the data structure proposed that makes data accessible in an electronic way. The proposed structure applies to the information flow of the construction process and affects all subjects and phases related to it. The development of a classification system and computational technical datasheets accessible through a BIM-based platform aims to improve actual building processes through a standardized structure for collecting building-related information that is still lacking in the Italian constructions sector. Therefore, the results of the project support collaborative design and construction, providing a shared database and promoting the usability of data and information through dedicated applications.

References

1. Royal Institute of British Architect (2013), RIBA Plan of work 2013, United Kingdom.
2. Jallow et al. (2008). Life cycle approach to requirements information management in construction projects: state-of-the-art and future trends. Proceedings of the 24th Annual Conference of Association of Researchers in Construction Management ARCOM, Cardiff, Wales, Vol.2, pp 769-778.
3. Kiviniemi, A. (2005). Requirements management interface to building product models. CIFE Technical Report 161, Stanford University.
4. Jansson, G., Schade, J., and Olofsson, T. (2013). Requirements management for the design of energy efficient buildings. Journal of information technology in construction, Vol. 18, pp. 321-337.

SURPLUS TRADING NETWORK: A NEW MODEL OF CIRCULAR ECONOMY

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Abstract

A new business feasibility and model, based on a e-commerce platform addressed to support the trading of industrial surpluses, is exposed. The model promotes the reuse and valuation of "waste" materials, reintroducing them as secondary materials in the productive value chains, boosting the symbiosis between industries. Its aim is contributing to reduce the consumption of raw materials and the generation of waste, thus resulting in the reduction of the environmental impact associated with the life-cycle of materials and in a direct reduction of GHG emissions focused on the concepts of "zero carbon value chains" and "zero waste systems". The exposed model has been developed in the context of a project funded by the European Union Climate KIC and addressed to the metals and chemicals sectors.

Keywords: Waste materials, e-commerce, Industry, Metals, Chemicals

Introduction

Reducing the environmental impact associated to productive chains is one of the main challenges faced by climate change mitigation strategies. Within this line, plans addressed to circular economy have been developed with the aim of obtaining carbon-neutral value chains and reducing residual waste generation by promoting the reuse and the revaluation of materials and energy, thus reducing the needs of raw materials. Among the priorities of the "circular economy package" of the EU [1], there are strategies aiming to promote the industrial symbiosis - turning one industry's by-product into another industry's raw material- under which our proposal has been developed.
A project executed by a consortium composed by Italian, Spanish and Swiss partners has been developed centered on the concept of sustainable production as a strategy for facilitating the reintroduction of residual or surplus materials in the value chains through an industrial surplus trade e-commerce platform, being an innovation concept oriented to promote cross-industry connections and to improve socio-economic and environmental balances. As a result, a business model has been developed demonstrating that the concept is suitable to be moved to production, generating both a CO_2 reduction together with economic revenues to both the platforms users and owners.

Methods

During eight months, two different sectors (metal and chemicals) in two different countries (Italy and Spain) have been studied by submitting more than 1500 polls to sectorial industries. The surveys were translated in Italian and Spanish, in order to facilitate the understanding by the local companies. The survey document includes questionnaires for 3 different "profiles" according the different kind of users of the platform: Profile 1 - Surplus generating company; Profile 2 - Surplus Applicant Company; Profile 3: Intermediary agents).The information requested was of quantitative (amount of waste generated, percentage of waste re-used, percentage of raw material that could be replaced by secondary materials, management costs, etc.) and qualitative (typology of materials, frequency of generation, interest in using Surplus Mall platform, risk, barriers, suggestion, etc.) nature.

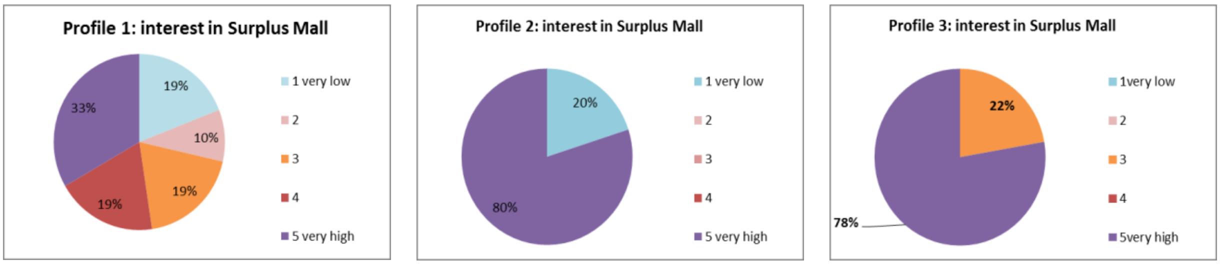

Figure 1. Survey results respect to the interest in Surplus Mall platform

Legal, functional and economical barriers have been identified taking as base, among others, the experience with similar platforms deployed by one of the partners (WBCSD) in the United States market. Finally, actors suitable to be present in the platform (logistics, recycling, legal services companies, etc.) have been identified (Figure 2).

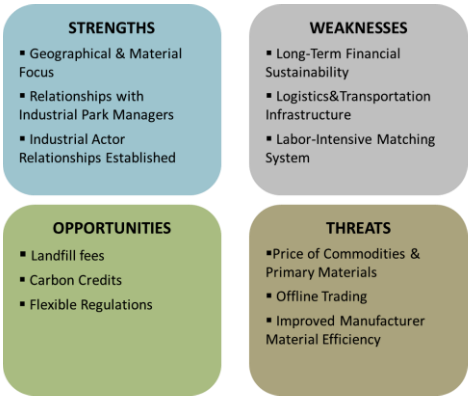

Figure 2. SWOT analysis

With the obtained information, a business model has been developed by defining three different e-commerce operational rules, each one in three different scenarios (optimistic, neutral and pessimistic). For each of these scenarios, the economic feasibility has been studied in a five-years horizon.
Finally, taking into account the previous results the initial specifications of the platform were defined. The functionalities and design of Surplus Mall were adapted to the identified requirements and needs (Figure 3).

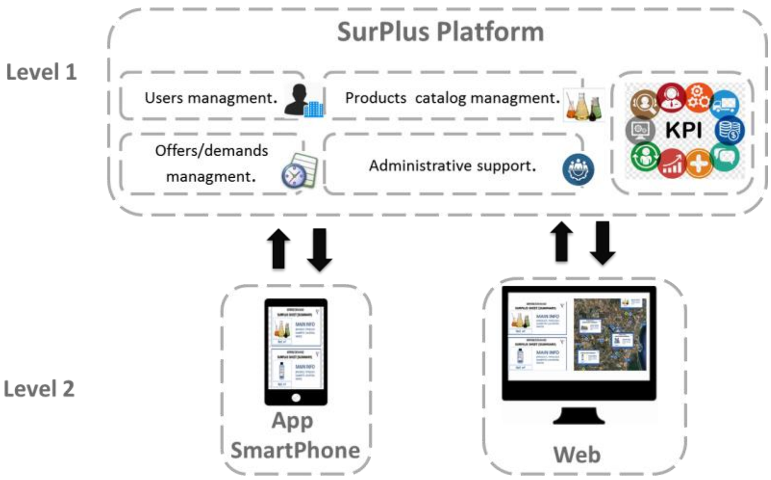

Figure 3. Platform architecture diagram

In this business model, the offer/request management is in charge of the users; the platform will be as most self-managed as possible, in order to reduce the management costs, with a management model similar to popular online shopping and auction websites.

Results

The project was aimed at testing the feasibility of a new business model aligned with European strategies of circular economy, based on a community cloud platform addressed to support the trading of industrial surpluses. Currently the project is finished, with the development of nine business-case scenarios, five of them showing a *Return Of Investment* in a five-years horizon (Table 1). The next step will be the practical realization of the proposed platform.

Table 1. Surplus Mall IRR of 9 business-case scenarios

IRR for each scenarios/situations	Probable	Optimistic	Pessimistic
Case 1	1,53%	84,38%	-
Case 2	30,42%	107,53%	-
Case 3	-22,99%	75,45%	-

Regarding the first phase (the consulting process), if from one side the overall opinion on the project is positive, from the other side there are still some uncertainties and doubts to clarify. The participants showed the willingness to be part of the platform and participate in the trade of raw and secondary material and by-products and the inclination towards more practices aligned with a circular economy philosophy. But they still hesitate because the uncertainty of the economic benefits compared with the actual management of these type of materials. Moreover, there are concerns about the technical barriers, regarding the transformation from waste to raw materials, and about the national legislation, which is very fragmented and complex on the waste theme. The results of the second project phase has regarded the assessment of the environmental impact, based on key performance indicators (KPI) calculated applying Life Cycle Assessment (LCA) techniques (Figure 4) and socio-economic benefits.

Copper:

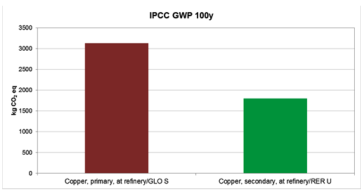

Figure 2: CO_2 equivalent emissions for the production of 1 t of primary copper (in red) versus secondary copper (in green)

Aluminum:

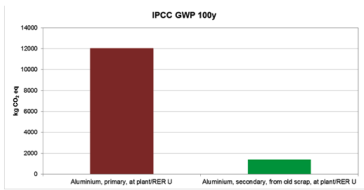

Figure 4: CO_2 equivalent emissions for the production of 1 t of Al from primary sources (in red) and secondary sources (in green).

Iron:

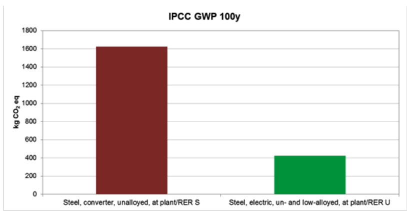

Figure 6: CO_2 equivalent emissions for the production of 1 t of Fe from primary (in red) and secondary sources (in green).

Solvents:

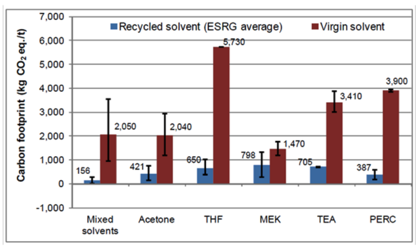

Figure: Comparison of the carbon footprints of recycled and virgin solvents.

Figure 4. CO_2 emissions of some of the main materials that could be interchanged through Surplus Mall platform, calculated applying LCA techniques

In particular, the following key conclusions can be drawn from this study:
- Due to the amount of companies of the interested sectors, the high availability of recoverable wastes, the growing awareness of companies, the needs that could be covered by the platform and the intended use drawn from the consultation process, we could estimate a high potential demand of the proposed platform.
- Based on data collection results, intermediary agents could play a more active role in the business model centralizing the purchases of surpluses.
- The results derived from the feasibility analysis are quite good for all the study cases. To reach the objective number of users and transactions and to guarantee their loyalty are the key aspects to ensure the success of the platform and its profitability.

Discussion and conclusion

The project results show that circular economy, far from being just a philosophy, represents a new business opportunity. By studying two different industrial sectors (metals and chemicals) in two different European countries (Italy and Spain) the project demonstrates that an e-commerce platform addressed to allow companies to exchange production surpluses is economically viable in the most of the studied cases.

References

1. European Commission (2015). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Closing the loop - An EU action plan for the Circular Economy.

THE BEBOP PROJECT - BIOMASS EXCHANGE: BYPRODUCT OPTIMIZER PORTAL THE NETWORK OF RESIDUAL BIOMASS FOR A CIRCULAR ECONOMY

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Abstract

In 2016 an E.S.CO. began a project, called BeBOP, whose aim is to create an ICT (Information and Communication Technologies) service, to connect producers, consumers and logistics agencies of residual biomass in a new network. This digital platform is an excellent tool for developing local value chains that represent industrial symbiosis. Ligno-cellulosic residual biomass is the core business of BeBOP's trade. Now this byproduct is considered a waste in many context, at the other hand it becomes a raw material for productive and energy processes. Currently, residual biomasses are not efficiently exploited due to some problems related to non-optimal distribution during the year of each by-product, in addition to specific energy conversion process, logistics, economic and authorization problems. BeBOP wants to overcome this condition thank to a digital Platform where all user can join in a community and their work can be planned and optimized.

Keywords:residual biomass, circular economy, short supply chain, biomass exchange, eco-innovation

Introduction

In this project, residual biomass means wood-cellulosic by-product of plant origin, commonly produced by agriculture (orchards, vineyards, cereal crops,...) and forest utilizations (e.g. treetop and branches) and from landscape conservation and maintenance work. Symbiosis involves several actors from different sectors supported by BeBOP to obtain a local and certifiable market, that improves circular economy and eco-innovation. Users are Companies, Public entity and Private. Each kind of biomass and use is different, a detailed analysis of chemical and technological processes is essential to achieve an optimal employ. Nowadays, Italy depends on imports for more than 75.9% of its primary energy consumption [1]. There are both environmental and social opportunities due to a better exploitation of residual biomass, with direct and indirect benefits on local communities.

Methods

Current problems can be overcome thanks to services and tools in BeBOP Platform:
- BeBOP geo-referencing tool and new models designed allow to know the real availability of biomass in the neighborhood and consequently to set market prices. Thanks to our algorithms we can estimate, from digital data collecting, available residual biomass in area and simplify the operations. A focus on market transparency and sustainable development is represented by optimizing logistics.
- BeBOP Biomass Exchange is an innovation that allows to plan operation for harvesting residual biomass and guarantees of being able to proceed if there is an economic return. This service on Platform achieve the industrial symbiosis, combining more types of production and consumption.
- Ease of use of the platform and the open source database makes possible to overcome the current market barriers, occasional actors including (BeBOP hub is their own community).

Results

Thanks to its services & tools, BeBOP Platform:
- Promotes local economies: develop local chains for an integrated land management, where industrial symbiosis are going to be the core of circular economies.

- Matches supply with demand through Internet and Mobile services for a transparent trade.
- Optimizes logistics (collection, transport and transformation) of supply chains (spatial, time and economic assessment) in order to a sustainable development.
- Promotes new policies: the information collected will provide decision makers with a very valuable resource of information for planning actions and other tools for an improved society.

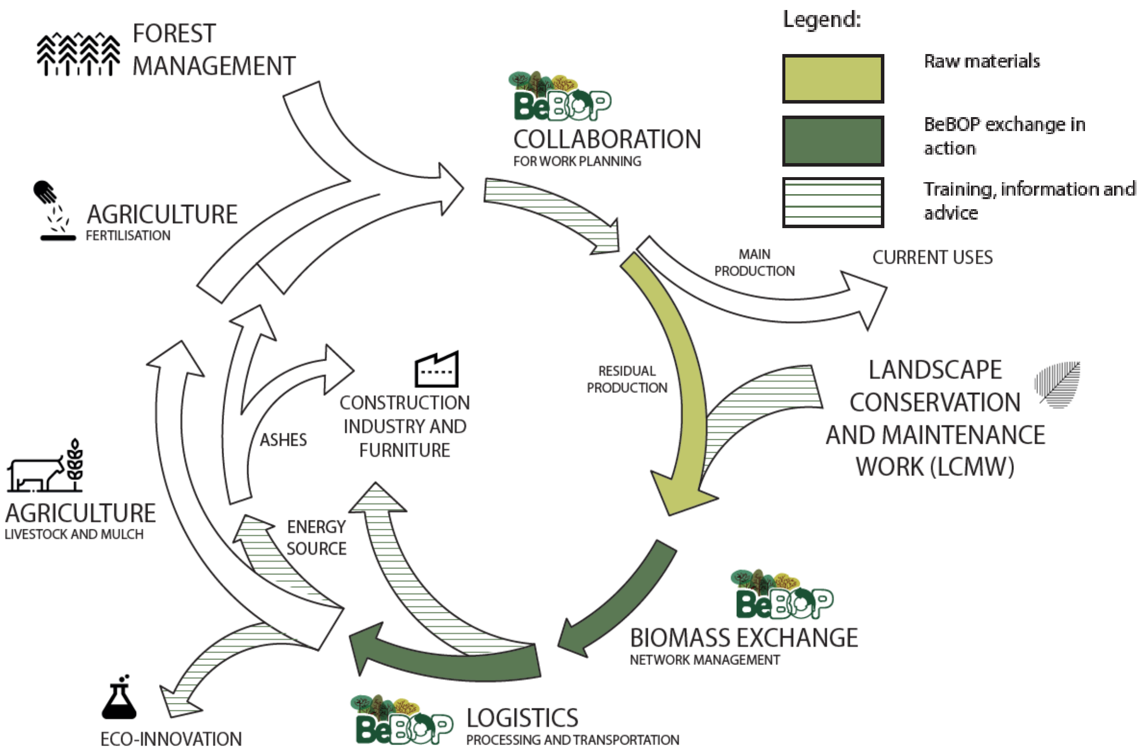

Figure 1. A Circular enomomy whit BEBOP. An industrial symbiosis in view of integrated land management

Discussion and conclusion

Nowadays, technological progress is not as fast as it could be, instead we must focus on logistics improvements, based on a better process control as a whole. The Project gives an answer to present-day challenges of the EU fundamental pillars, such as sustainable development, efficient utilization of resources and adaptation to Climate Change avoiding to allocate large areas dedicated to energy crops, decreasing import of fossil fuels, and reducing the energy embedded in construction materials. EU specific challenge is also to identify opportunities for introducing of ICT tools (like BeBOP) to increase the efficiency and sustainability of biomass supply chains for bio-based industry. We want to spread BeBOP toward several market segments, not only energy, where using residual biomass, as raw materials, can contribute of eco-innovation such as animal litters, as biorefineries or green building raw materials how the 2016 Legambiente Report "100 materials for a new construction industry" shown. Moreover we are going to improve BeBOP over the time to give constantly answers for ongoing EU challenges, for example ashes produced by RES (Renewable Energy Source) users can be employed as cement addictive (fluidifier).

References

1. Eurostat - European Commission (2016). "Energy, transport and environment indicators" Publications Office of the European Union. Available at http://ec.europa.eu/eurostat/

SUSTAINABILITY AND BUSINESS FOR RESIDUAL MATERIAL: THE PROPOSAL OF ERMAT PROJECT

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Abstract

The paper summarises the aim and the main activities of ERMAT (**E**fficient use of **R**esidual **Mat**erials) project, a network of infrastructures project funded in the frame of the EIT Raw Materials programme. The scope of ERMAT is to create business of residual materials with the aim to reach zero deposits. The focus is the metallurgical sector, that needs to optimize the material usage in industrial symbiosis. ERMAT proposes to the whole KİC-RM community a platform as solution for residues valorisation and exchange with the scope to increase European industrial competitiveness and environmental and social sustainability with new products based on secondary raw material.

Keywords: industrial symbiosis, circular economy, web tool, metallurgical sector

Introduction

EIT Raw Materials was designated as an EIT Knowledge and Innovation Community (KIC) addressed in the field of raw materials (sustainable exploration, extraction, processing, recycling and substitution) and the impact it will generate.The aim of EIT RawMaterials is to develop technologies and processes that establish new primary and secondary sources of CRM reducing the dependency on imports to EU. Matchmaking and networking activities are key to building the EIT RawMaterials community for connecting people and stimulating the generation and exchange of knowledge between people from all fields of expertise and from all corners of the Knowledge Triangle.

ERMAT (Efficient use of Residual Materials) project is a network of infrastructure (NoI) project with the scope to create business of residual materials with the aim to reach zero deposits. It lasts 36 months and started in January 2016 This is in line with EU Council directive 1999/31/EC of 26 April 1999 on landfill of waste and in line with EU raw material strategy and plan. Circular economy means re-using, repairing, refurbishing and recycling existing materials and products. What used to be regarded as 'waste' can be turned into a resource in order to look beyond waste and to close the loop. All resources need to be managed more efficiently throughout their life cycle.

The focus sector in ERMAT is the metallurgical sector in which the need is to optimize the material usage in industrial symbiosis. The optimization of material usage gives the possibility to reduce the energy consumption by minimum processing of residual materials. In general utilizing secondary resources instead of primary resources has a positive impact for industrial strength on a cost-efficient, secure, sustainable supply and use of RM.

The ERMAT community has a broad representation with different expertise located in different European regions and different organisation types including:

- industrial sector, as the coordinator comes from a large industry in Sweden, the world's largest manufacturer of metal powders;
- higher education as two University are represented (Tallin University of Technology and University of Oulu);

- research centres, represented by ENEA, the Italian National agency for energy, new technologies and sustainable economic development; VTT, the Technical Research Centre of Finland and VITO, the Flemish Institute for Technological.

Methods

The efforts of ERMAT are voted to stimulate the use of side streams and other types of residual materials by offering a platform including both a web-based register of by-product suppliers and needs, a web store providing expertise of process routes for processing residuals and offer expertise in residual materials, in modelling and in infrastructure.
The objectives are to create:

- hubs of demonstrators for process routes of residual utilization
- a register of by-product suppliers
- a register of needs

Target audience includes industrial players with potential side-streams and a potential to utilize residue products, SMEs for residue processing and utilization, and circular economy start-ups.
Main impact and added value is that industry and organizations in need gets an easy access to find information about useful contacts and process routes.
The data has been collected form the project partners. The work to map different types of residuals, possible applications and industries of interest has been distributed according to geographical position.

The web solution

A “prototype” of the web page is done in Excel with different sheets for “Residuals”, “User needs” and “Technologies” for external use. “Companies of interest” and “Platform” represent sections for internal use for the project. The data in the collected and documented Excel in the project has been used as a start and as an example to be put into the final web-tool. The tool will be firstly tested within the ERMAT consortium/project to check it and then will be tested within the KIC EIT RM community. Finally, it will be launched to larger scale by making it open.
The solution for the web page is a multi-level solution: Level 1, public with basic information and Level 2, permission needed to get more comprehensive information. To get access to Level 2 a membership fee is suggested. Simple online contract for accepting terms for level 2 is also required. The targeted end-customers and key beneficiaries of the project are residue owners, residue processers and business sectors in need of new materials and products and circular products with the simultaneous need of decreasing waste.

Discussion and conclusion

ERMAT (Efficient use of Residual Materials) project is a NoI project of the KIC-RM with the scope to create business of residual materials with the aim to reach zero deposits. The project, currently underway, is developing a tool for the residues valorization and their exchange by using an easily accessed web platform with the ambition to cover all the European regions. Indeed this NoI advertises itself through the KIC network, other European and national networks and functions through an internet base application in order to reach the optimum coverage of customers. The expected amount of users will be growing yearly gradually.
In the raw-material-based industry in Europe today the key benefiters of the ERMAT industrial actors are providing the residual materials, and the companies refining the residual materials into new products and/or new raw materials. End-users of the various business sectors are for instance companies producing and using different concrete applications, road constructions, plastic fillers, industrial refractories, consumer products etc., benefitting the project and related activities, achieving circular products.

The expected contribution of this project (and others of the KIC-RM) is to increase European industrial competitiveness and environmental and social sustainability with new products based on secondary raw material. The human capital related issues such as new jobs based on new application opportunities is possible. The project lays ground to the upscaling innovations on residues valorisation.

Published by ENEA

Promotion and Communication Service

www.enea.it

October 2017