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Industrial symbiosis efficiency parameters in context of Regional sustainable development

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Abstract. Regional sustainable development demands detailed structured efficiency counting methods overview, which allow to analyse industrial symbiosis effects. Currently industrial symbiosis is defined as mutual commercial and managerial co-habitat of business entities, which mainly in scientific literature are analysed in terms of legislative procedures and management rules. Regional sustainable development depends on Industrial symbiosis efficiency and synergy, which also can be counted by using methods of applied efficiency parameters. The article analyses the main efficiency counting parameters, used to evaluate industrial symbiosis in terms of regional sustainable development systems.

1 Introduction

Since 2000, industrial symbiosis has been increasingly seen as a strategic tool for economic development, green growth, innovation and resource efficiency at all policy levels in Europe - local, regional, national and international. At the European level, industrial symbiosis has been recognized for its potential contribution to the sustainable production and competitiveness of the EU industry through the flagship Resource-Saving Europe initiative.

Key to industrial symbiosis is collaboration between companies and the synergistic possibilities [2] offered by geographical proximity. Industrial symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchanges of materials, energy, water and/or by-products [1, 8].

Taken into the overall approach, industrial symbiosis is defined as the synergistic exchange of waste, by-products, water and energy between individual companies in an area, region, or even in a virtual community. This helps preserve the value chains within the EU-28 and helps generate value within the EU-28 for global value chains [7, 10]. Although the generally accepted approach will be delocalization towards more favourable regions of the world - for various reasons, ranging from labor costs to environmental protection and

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healthcare rules - industrial symbiosis helps create new opportunities for generating value around existing industrial activities, contributing to the modernization and transformation of the European Union industrial fabric.

The essential conditions for Industrial Symbiosis are [4, 7, 8]: (1) Waste exchange or by-product reuse - the exchange of firm-specific materials between two or more parties for use as substitutes for commercial products or raw materials. (2) Utility/infrastructure sharing - the pooled use and management of commonly used resources such as energy, water, and wastewater. (3) Joint provision of services - meeting common needs across firms for support activities such as fire suppression, transportation and food provision. To be counted as a basic type of industrial symbiosis at least three different entities must be involved in exchanging at least two different resources [1, 6].

The main purpose of this paper - to investigate Industrial symbiosis (IS) economic efficiency parameters in context of regional sustainable development.

2 Materials and methods

In June 2014, the EC adopted the message “Towards a Circular Economy: A Waste-Free Program for Europe” with the aim of creating a common and coherent EU structure [2,7] to promote a circular economy. The ultimate goal is to get a more resource-efficient Europe, while at the same time making EU enterprises more competitive. Another document, the Waste Framework Directive (latest version: 2008/98 / EC), sets out basic concepts and definitions related to waste management, such as waste definition, recycling, disposal [3].

The main sources for statistics data analysis were: (1) Eurostat: the Eurostat database compiling waste generation statistics based on the bi-annual reports submitted by Member States in compliance with the Waste Statistics Regulation (EU) N° 2150/2002. (2) Eurostat: the Eurostat database compiling trade statistics on the value and the quantity of goods exchanged between the Member States of the EU (intra-EU) and between the Member States and third countries (extra-EU), based on customs records and Intrastat monthly data declarations. (3) Eurostat: the Eurostat database compiling waste treatment statistics based on the bi-annual reports submitted by Member States in compliance with the Waste Statistics Regulation (EU) N° 2150/2002.

Table 1. Summary Table of Industry Data Source Utility

Industry sector	Waste generation	Trade	Waste treatment
Food industry	√	±	√
Paper and pulp	√	√	√
Chemicals rubber and plastics	√	√	√
Pharmaceutical	X	√	X
Cement	X	X	X
High tech	X	X	√
Automotive	X	√	√
Construction	√	X	√
Wood processing	√	√	√

For the assessment, 6 waste streams were selected for the significant potential of industrial symbiosis - to use the waste as a resource: (1) Metal waste: slag, foundry sand and abrasives for ferrous and / or non-ferrous metals, excluding scrap. Scrap is excluded because a lot of recycling and recovery already exists. (2) Mixed food waste and vegetable waste: production waste before the consumer in the food industry. The pre-consumer phase includes the processing and distribution of food. (3) Mineral waste associated with construction and demolition. This waste stream is very important in terms of volumes. It also has a close relationship with local industry and the economy [13]. (4) Chemical waste: plastics. Rubber tires are also important, but this waste stream has been studied in Waste as a resource study [11]. Plastic itself is a relatively broad category, and there is also a link to bioplastics as an alternative [12]. (5) Wood waste: there is already a lot of recycling and recovery for the multiplex card, but there is still untapped potential for other sub streams. Of particular interest is the link with bio-industry [3, 6]. (6) Agricultural waste and residues are excluded, as well as manure (without appropriate statistics, this waste stream was excluded from further ongoing assessment in the framework of this study).

Evaluation of the economic benefits of using industrial symbiosis was done by statistical modelling - E3ME. The E3ME model is a detailed industry disaggregation using a scenario-based approach [1, 3]. This model includes 69 sectors of the economy based on the current two-digit classification of Eurostat in NACE with an additional breakdown of the energy sector [10]. These sectors are connected to each other through input-output coefficients that affect the supply chain [11]. However, for IS modelling, this industry disaggregation can also be considered a limitation, since many of the more detailed sectors discussed in the report are not explicitly covered in the model.

The main assumptions for the study: a) The results show the macroeconomic costs and benefits of increasing IS indicators without identifying the reasons why IS will increase; b) In all cases, we assume that the intermediary is involved in the processing of the waste stream.

Given the local dimension of industrial symbiosis, it would also be very useful to have data on material flow at the regional level [9]. Both access to more detailed data on waste streams and by region will provide an opportunity to depict a more accurate picture of the economic significance [12] of industrial symbiosis in the EU28 and its contribution to the sustainable transformation of industry with corresponding growth and job opportunities.

3 Results and discussion

Platforms of industrial symbiosis help to bridge the information gap and the problem of coordination between suppliers of production residues, suppliers of know-how and technology and potential customers.

The classification of the various categories of resource exchange is focused on the following main types: through waste exchange (IS1); in an institution, company or organization (IS2); among firms located in a particular eco-industrial park (IS3); among local firms that are not located in the same place (IS4); among firms organized “virtually” in a wider region (IS5) [3, 9, 14].

For industrial symbiosis, material flows are industrial waste, not product waste. In addition, materials are most often exchanged directly, without a preliminary processing stage. Three configurations of industrial symbiosis are distinguished: within a company, between companies on a bilateral basis, or through any interaction on the market.

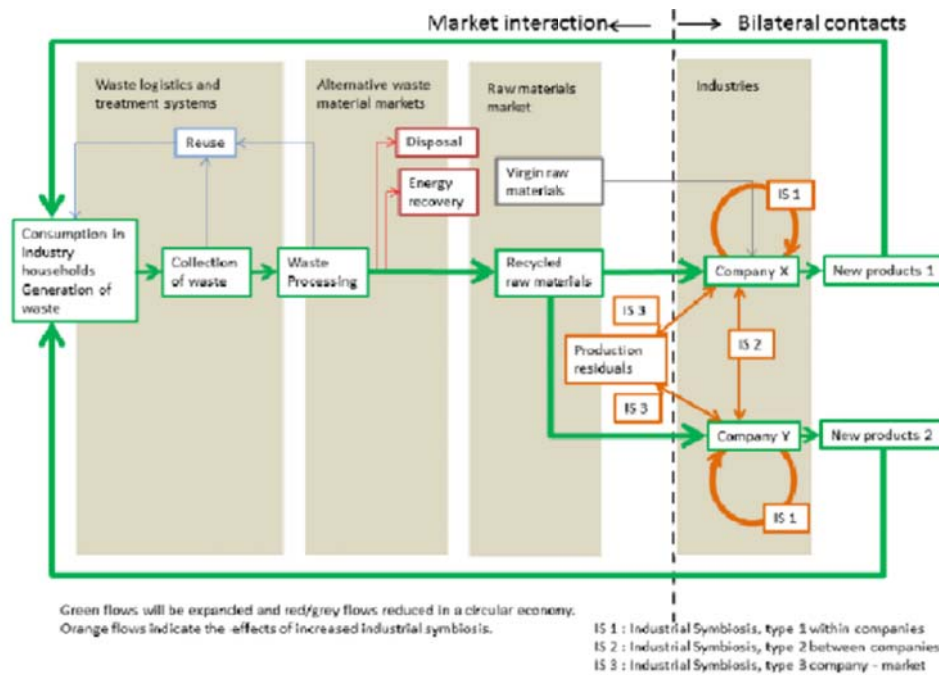


Fig. 1. Analytical framework: industrial symbiosis in the circular flow of materials

In this paper the presented results are focused on IS1-IS2-IS3 levels. IS4 and IS5 evaluation results are excluded not having sufficient statistics data for comprehensive analysis and confirmation of results significance.

For all waste streams, it can be stated that the involvement of technology and R&D providers is an important element in successfully matching supply and demand, leading to the introduction of new high value-added applications. The table below shows the main impacts if IS rates are increased [4, 14].

Table 2. Industrial symbiosis scenarios for the main waste streams impact on regional economics

Indicators →											
Waste streams ↓	GDP	Employment	Consumption	Exports	Imports	Inflation	Social responsibility	Wages	Consumer price index	Sectors that gain	Sectors that loose
Pre-consumer mixed food waste and vegetal wastes	+	0	+	0	-	0	+	+	0	Waste management; Food, drink, tobacco; Construction	Chemicals
Construction and demolition related mineral wastes	+	0	+	0	-	+	+	+	0	Construction; Waste management	Non-metallic minerals; Chemicals; Non-energy mining
Plastic waste	+	0	+	0	-	0	+	+	0	Waste management; Construction	Chemicals
Wood waste	0	0	0	0	0	0	+	+	0	Paper and pulp; Waste management	Forestry
Non-scrap metallic waste	+	0	+	0	-	0	+	+	0	Basic metals; Waste management; Construction	Non-metallic minerals; Non-energy mining

Food waste has perhaps the widest range of potential uses. Sectors that purchase from waste streams include chemicals, pharmaceuticals, and rubber / plastics. There is little information about the prices of products coming from waste streams, so in this analysis we assume that prices do not change overall (that is, products from a waste stream have a cost similar to the products that they displace) [3, 6].

The shift between sectors in the case of construction and demolition again affects the structure of trade. In particular, there is a decrease in imports of non-metallic mineral products, which is replaced by domestic costs, mainly aimed at waste management services. This leads to a small net profit in general to GDP [4, 5].

For plastic waste, our scenario is defined as a reduction in industrial and post-consumer waste coming to landfill, and an increase in the share collected, processed and recycled. Our scenario is defined as the rubber and plastics sector, which increases purchases in the waste management sector [3] and reduces purchases of chemicals. It is assumed that the proportion of plastic waste used for energy recovery will remain unchanged, so we are not making any changes to the model in this scenario. The study shows that the cost of recycled plastic is often higher than the cost of primary materials, and that there may be an increase in costs for the plastics sector [5].

The case study for wood waste stream finds several different applications for wood waste, but, from the point of view of modelling, they are equivalent to purchases from the waste stream by the paper and pulp sectors, replacing purchases from the forest sector [14]. In the scenario, we assume that the use of wood waste for energy production remains unchanged, and simply focus on the shift in the pulp and paper sector [3].

By-products of the production of metals (both ferrous and non-ferrous) have many potential applications, but in modelling scenarios we focus on the chemical sector, buying recycled residual waste, and reducing the amount of primary resources acquired in the non-energy sector.

Summing up, the main driving forces of industrial symbiosis are the following main factors [2, 3, 8, 14-16]: increased financial return on investment by increasing economic efficiency and / or increasing income; developing a market niche and improving the environmental performance of the company and the company's environmental image.

Nevertheless, the main categories of obstacles are noticeable in these categories [3, 4, 7, 9]: problems of coordination; the potentially low economic value of waste streams and by-products compared to substitute products and primary materials; relatively high transportation costs, dispersed production sites and suboptimal economies of scale, as well as subsidies for bioenergy and the lack of equal conditions between energy recovery and material valorisation.

4 Conclusions

Macroeconomic impacts are likely to be negligible, as the scenarios cover small parts of small sectors. This conclusion does not mean that there may be larger local impacts and a possible increase in competitiveness in specific sectors, but if we consider them in the context of the entire economy, the impacts will be relatively insignificant. This affects very specific sectors, and these effects are often associated with changes that are made at the plant level. The macroeconomic consequences of an increase in IS rates will be quite small.

Opportunities for waste companies or for the waste management sector to gain value. Who exactly gets the benefit depends on the specific cases and the type of IS (i.e. IS2 or IS3) that

takes place. Companies that provide services to the waste management sector can also benefit.

The sectors that may lose are either basic production sectors or primary production sectors. These sectors see their products being replaced. As a rule, they have fairly short supply chains, so the consequences of lower consumption of their goods are limited to a few specific cases.

A key factor that can lead to an increase in GDP is a reduction in the cost of imported goods, which leads to an increase in the level of domestic production, while higher food prices can reduce the overall GDP. Since the effect on employment is close to zero, these results suggest that the net impact of cost-effective measures will at least be positive.

Key recommendations: improving statistics on material flows of industrial symbiosis, promoting platforms and initiatives for industrial symbiosis, supporting and increasing the value of R&D, developing the sales market through green public procurements, streamlining regulation and adjustments.

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