

Legal Barriers and Policy Gaps in Industrial Symbiosis: a Pathway to Regulatory Innovation

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Abstract— The latest report on the Circularity gap reveals that the circularity ratio in 2022 has dropped by 21%. Simultaneously, in just the past six years alone, global consumption reached over half a trillion tonnes of materials - nearly as much as the entirety of the 20th century. This paper explores the key legal and policy facilitators and barriers that prevent businesses from fully engaging in Industrial Symbiosis, focusing on EU waste legislation and national regulatory constraints, applying methodologies such as literature review and analysis of secondary data. This research aims to analyse policy planning documents and identify key strategies for implementing Industrial Symbiosis. The paper highlights practical solutions to support the expansion of Industrial Symbiosis by addressing the legal and policy roadblocks. Overcoming these barriers will help businesses operate more sustainably, foster cross-sector collaboration, and accelerate the shift toward a circular and resource-efficient economy. In addition, the implementation of Industrial Symbiosis will also lead to the country's ability to i) account for credible and verifiable data for waste prevention, ii) increase resource productivity rate (which is currently a significant issue for countries such as Latvia), iii) increase material circularity rate. The main findings and conclusions will outline the strategies required at the policy and regulatory levels to foster industrial symbiosis. The paper provides practical recommendations to policy planners on how to apply Industrial Symbiosis for an efficient country's economy's transition to a circular economy.

Keywords — *circular economy, industrial symbiosis, material circularity rate, resource productivity.*

I. INTRODUCTION

According to the Circularity Gap 2024 report, global statistics show that despite the circular economy reaching 'megatrend' status, ambitious goals are yet to translate into action and measurable impact. While the total amount of materials consumed by the global economy continues to

rise: in the last six years alone, we have consumed more than half a trillion tonnes of materials – almost as much as in the entire 20th century – the global circularity rate fell from 9.1% in 2018 to 7.2% in 2023 [1]. Without bold, urgent action to move towards a circular economy, the world will not achieve its broader social and environmental goals, from reducing emissions to promoting secondary materials. However, the per capita material footprint remained stable from 2010 to 2022 and dropped by 4.5% in 2023. Raw material extraction was 14.1 tons per capita in 2023, which is considered unsustainable and above the global average [2]. In addition, Richardson et al. have emphasised that six of the nine boundaries are transgressed, suggesting that Earth is now well outside of the safe operating space for humanity [3]. In response to this global devastation, companies must develop business and management practices to answer new and emerging challenges and speed economies' recovery, create new jobs and prosperity, boost resource efficiency, and achieve sustainable growth. Here is where Circular Economy (CE) is required, as one of its core principles is designing out waste. It strongly emphasises closing the loops and eliminating waste or leftovers within the systems. IS supports this approach, being one of the CE business models and representing a critical business process for transforming waste into a valuable resource [5-7].

Industrial Symbiosis (IS) is an efficient Circular Economy business model that encourages industries to share resources or production leftovers, minimise waste, and reduce their reliance on primary resources. While Industrial Symbiosis has the potential to contribute to the European Green Deal goals significantly, its large-scale adoption is often blocked by complex legal frameworks and outdated regulations. IS is seen as a strong facilitator for implementing the Green Deal concepts by significantly cutting primary resource consumption, strengthening intersectoral cooperation, retrieving vast amounts of

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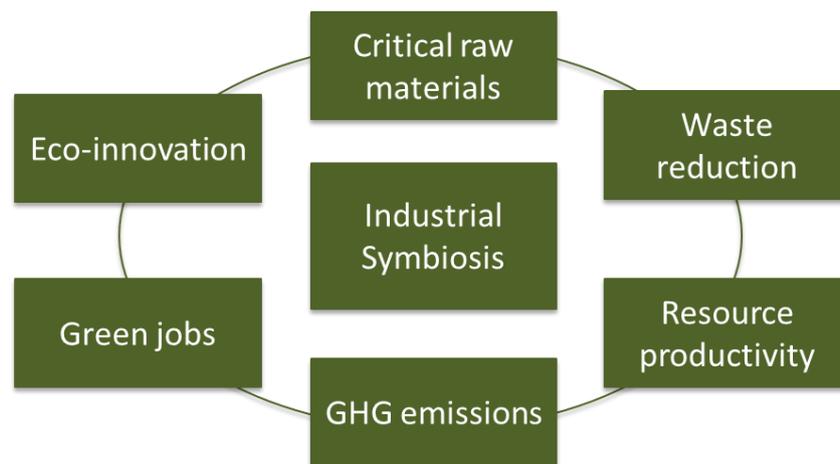


Fig. 2. Topics, fostering IS in the EU-level policy planning documents.
 Source: developed by the author, based on [15-19].

III. RESULTS AND DISCUSSION

When assessing the grey literature alongside scientific research undertaken up to date, the author has identified a range of regulatory and policy barriers to implementing IS in real economies. Below, the author provides an insight into the most significant obstacles.

A. Regulatory complexity and lack of unification

A 1. Waste and by-product definitions

The legislative framework of the EU frequently faces challenges when differentiating between waste and by-products. Due to concerns about non-compliance, these ambiguities may discourage businesses from implementing IS. Often, it has been emphasised that the regulation of waste leaves little opportunity for product reuse as feedstocks, highlighting how constrictive the categories of waste currently in use are [20].

A 2. Differences in EU Waste Framework Directive (WFD) implementation

Various approaches to implementing EU WFD into national legislation result in a disjointed regulatory landscape. Entities operating on a cross-country level face difficulties due to this inconsistency, which might obstruct the growth of IS networks. The report on the SCALER project (2020) states that "the main barrier concerning the existing legislative framework is a lack of cohesion and alignment between rules and laws at the national level and policies at the regional level" [21].

B. Legislative aspects

B 1. Waste Classification

Strict classifications may significantly limit possibilities for material reuse since some byproducts may be classified as waste and must be managed according to strict guidelines. This aspect substantially reduces the potential for symbiotic interactions, as it discourages industries with the potential to enter the waste management sector. It is

identified that legislation focuses on the end of pipe solutions, such as waste treatment and disposal, instead of prioritising prevention and re-use [21, 22].

B 2. Bureaucratic Procedures

Entities may be discouraged from pursuing IS projects due to the complicated process of obtaining the required permits for waste management. Adoption of IS practices may be reluctant if the administrative strain of compliance exceeds the alleged advantages. According to a UK government report from 2023, one of the high-importance barriers to IS is a lack of knowledge about IS and general IS setup and capital costs [23]. In addition, it is essential that, at its core, IS deals with resources diverted from the waste stream. As such, the waste permits can be even redundant and become a significant barrier, for instance, when an entity is dealing with food processing. Still, its involvement in IS would require a specific waste management permit, and the entity would not want its stakeholders to associate it with waste management activities.

B 3. End-of-waste (EOW) criteria issues

Currently, EOW is being applied in the EU only for a limited type of resources:

- iron, steel, and aluminium scrap;
- glass cullet;
- copper scrap.

Although the Joint Research Centre has published a methodology to develop the EOW, the real-time activities are still limited and require much time. JRC has started creating new scientific proposals for end-of-waste criteria for plastics and plans to do the same for textiles. These criteria had to be developed in 2023 but are still unavailable [24]. Without precise and uniform EOWs across the EU, determining when a material ceases to be classified as waste, the whole process becomes challenging unless waste and by-product definitions are tackled. Of course,

implementing EOW for a broader number of resources would be a step towards fostering IS, but currently, this is not the case. Another option is for the EU to continually review the feasibility of subsidies, taxes, grant schemes, carbon prices, etc., and either enhance or constrain them to support IS.

C. *Issues with Liability and Compliance*

C 1. *Legal Uncertainties*

Considering the range of responsibilities involved in managing and transferring waste products, entities may be reserved to participate in IS. Entities are hesitant to join symbiotic agreements due to unclear legislation on one hand side and the other. If maintaining current legislation, an entity receiving specific waste/production residues would require a waste management permit, and in case the same company is operating in, i.e., the food processing industry, such a permit would not be well-seen from the client or Stakeholder perspective. Addressing accountability for environmental damage can result in legal conflicts. In addition, uncertainties in the legislative framework pose a serious obstacle to advancing IS [25, 26].

C 2. *The Impact of Extended Producer Responsibility (EPR)*

In a particular manner, IS activities may also be impacted by the existing EPR regulations. The regulations make manufacturers responsible for the end-of-life handling of their products placed on the market. EPR may add extra duties to manufacturers, which, as a result, could impact their willingness to participate in IS, even though EPR's

initial goal is to encourage recycling and waste minimisation [27, 28].

IV. ASSESSMENT OF IS BENEFITS

However, to overcome the barriers, it is essential to comprehend the benefits of establishing IS and how they can impact both country, region, and entity levels. IS lacks a standard solid definition, and it varies across economies. Still, in principle, the same message is conveyed. It is a process that promotes cooperation between companies and the efficient use of resources, reduces waste and environmental impact, and is closely related to the improvement of the circular economy in the country. IS is influenced by internal and external factors, as depicted in Fig. 3.

The IS ecosystem depicted is a compilation of the latest trends and developments on how IS interacts both internally within an entity and on the internal level. Three layers are assessed: environmental, economic, business development, and social. First, to implement efficient IS, it is necessary to secure the fulfilment of internal factors or consider them during the IS planning and implementation phase. Secondly, it is vital to consider the External factors; as per the assessment above, a range of these External factors also overlap with barriers to IS, so if not addressed in the initiation phase, the External factors may become quite significant obstacles to successful IS implementation. One more essential layer depicted in Fig.3 is the IS ecosystem – which shows how IS impacts the achievement of the United Nations Sustainable Development Goals (SDGs).

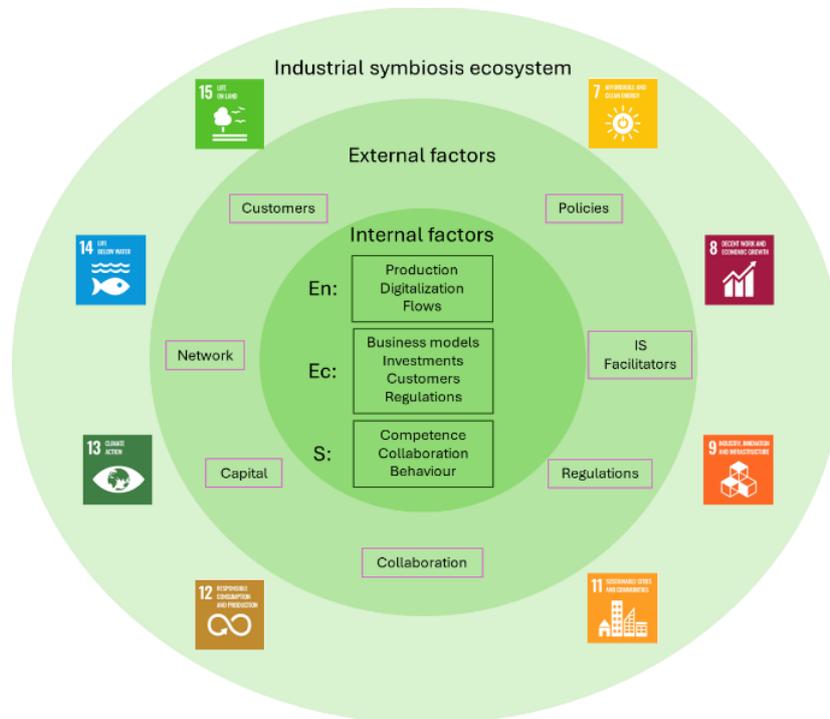


Fig. 3. IS ecosystem. Source: developed by the author.

IS has a positive impact by promoting resource efficiency, waste reduction, and cross-sectoral collaboration. The main SDGs positively impacted by IS are listed in the Table 1, which is provided below. Considering this impact assessment on the SDGs, IS is an economically beneficial CE business model and a powerful tool for achieving sustainability by promoting resource efficiency, innovation, and cross-sector collaboration. It directly supports policies and strategies such as the Green

Deal and contributes to a more sustainable and resource-efficient future.

One of the most critical points in promoting and implementing IS is the sustainability of the system and the benefits it provides.

TABLE 1 POSITIVE IMPACT OF IS ON SDGS

SDG	Positive impact
SDG 7 - Affordable and Clean Energy	IS improves energy efficiency by reusing heat and energy from industrial processes and promotes the integration of renewable energy sources.
SDG 8 - Decent Work and Economic Growth	IS promotes sustainable industrial practices and enables economic growth through resource efficiency and material flow optimisation; it also fosters new business opportunities and green jobs in the CE.
SDG 9 - Industry, Innovation, and Infrastructure	IS supports sustainable industrialisation and innovation through resource-sharing networks and strengthens industrial infrastructure by optimising resource use.
SDG 11 - Sustainable Cities and Communities	IS reduces industrial waste and pollution by promoting cleaner urban environments; it supports CE initiatives that benefit local communities.
SDG 12 - Responsible Consumption and Production	IS reduces waste by transforming by-products and waste materials into new valuable resources; it also encourages entities to adopt sustainable production methods and fosters cross-sectoral cooperation.
SDG 13 - Climate Action	IS reduces greenhouse gas emissions by optimising resource use and reducing energy consumption, and it also promotes low-carbon technologies alongside industrial processes.
SDG 14 - Life Below Water	IS reduces industrial waste and pollution that could contaminate marine ecosystems, thus stopping long-term pollution possibilities.
SDG 15 - Life on Land	IS reduces land degradation and deforestation by reducing the extraction of raw materials and supports sustainable land use practices in the long term.

After extensive literature research, three main areas of benefits were defined: economic, environmental, and social.

A. Economic benefits

A 1. Cost reduction

Sharing resources, thus reducing waste management costs, can significantly reduce the company's operating costs. For example, a company that obtains heat in production can sell it to its neighbour for process heating [29, 30].

A 2. Reduction in raw material imports

Limited resource availability in EU member states (especially regarding critical raw materials) makes the latter dependent on third countries. Eurostat data show that around half of the resources used in the European Union are imported [31]. Trade in raw materials between the EU and the rest of the world has skyrocketed over the past 20 years. Although the volume of raw materials exported is growing faster than that of imported raw materials, the EU still imports more than it exports. 2023, this imbalance resulted in a trade deficit of €29 billion. Between 2013 and 2023, the total EU trade in raw materials grew by 37%, equivalent to an average annual growth of 3.2%. In this period, exports grew faster (3.8%) than imports (2.8%). Recycling materials is one way to mitigate this risk, as it helps to stabilise prices, ensure the availability of raw materials, and reduce import dependency [32].

A 3. Job creation

An apparent increase in the number of people employed in the CE has been observed during the past decades. A steady growth between 2005 and 2021 shows the number of people employed in 2005 was 3,345,348 (1.7% of total EU employment) and in 2021, 4,284,745 (2.1%) [33]. According to a proposal published by the European Parliament for a new circular economy action plan, 700,000 new jobs could be created across the European Union by 2030, and EU GDP growth could increase by 0.5% [34].

B. Environmental benefits

The amount of waste is increasing with the increasing consumption of resources. Many valuable materials are still being disposed of as waste across the globe and also within the EU. However, efforts to recycle waste are starting to pay off, and a generally positive trend can be observed for municipal waste (which represents around 10% of the total waste stream, but simultaneously, due to its non-homogeneous compound, results are the most challenging to manage). Annual municipal waste generation is around 660 million tons; the per capita generation has decreased by 5% (to 530 kilograms per person compared to 560 kilograms in 2000), but is still high compared to other countries in the world and is still higher than in the early 1990s [35]. The introduction of the IS model will also allow for the diversion of certain waste types from landfills. In addition to effective waste management, abandoning the traditional production and consumption flow and

converting waste into new resources will reduce CO2 emissions. By reducing the emission of harmful substances into the environment, IS can improve air, water, and soil quality.

C. Social benefits

With the introduction of the IS model, cooperation between companies, municipalities, and other stakeholders will increase. Neighbouring regions and cities and their residents would benefit from greener ecosystems, reducing the burden on local resources. This would contribute to territorial conservation and waste reduction in surrounding areas.

V. BEST PRACTICE ASSESSMENT

IS involves entities operating in different sectors of activity or industries that engage in mutually beneficial cooperation activities to reuse waste and to use by-products properly, finding innovative ways to source inputs and optimising the value of the residues of their processes [25]. One of the main goals of IS is to avoid waste by identifying valuable resources and diverting them from the waste stream. Best practice from a sample of EU member states with regards to IS fostering is summarised in Table 2:

TABLE 2. ASSESSMENT OF EXAMPLES IS INTEGRATION INTO THE COUNTRY'S ECONOMY

Country	Action description	Method
Denmark	Kalundborg Eco-Industrial Park: A pioneering IS network for decades, where multiple stakeholders exchange materials, energy, and water to boost resource efficiency, cut raw material consumption, and obtain environmental benefits.	Initiative
Finland	Finnish Industrial Symbiosis System: Facilitates resource exchange between companies to promote circular economy practices.	Initiative
France	Regional initiatives are being implemented to encourage industrial collaboration to optimise resource use and reduce waste generation.	Initiatives
Germany	Resource Efficiency Program: Encourages industries to engage in resource-sharing practices to foster sustainability.	Legislation
Italy	A range of policies are in place to support sustainable industrial practices and efficient resource use.	Policies
Netherlands	Integrating IS into CE policies by promoting material and energy exchanges between industries to reduce waste generation.	Policies
Poland	A range of initiatives are based on developing strategies to incorporate IS into industrial sectors, thus aiming to improve resource efficiency and environmental performance.	Strategies
Spain	Regional programs facilitate IS and encourage collaboration in resource optimisation and waste prevention.	Programs
Sweden	Promotion of IS through regional networks that facilitate resource exchange between entities.	Networks
United Kingdom	National Industrial Symbiosis Programme: Facilitates resource exchanges between entities to promote IS.	Program

From the table above, the lack of specific legislation promoting IS is not a primary obstacle to fostering and developing IS projects and cross-sectoral cooperation. However, many countries and their regulatory bodies still consider that to avoid certain illegal activities that IS can unintentionally stimulate, it is vital to have a strict and

transparent set of regulations, fostering the implementation of IS. Considering this, the author proposes a first set of recommendations (covering only part of the barriers identified in section III of the paper) for policymakers on supporting IS through regulatory adjustments. The key recommendations are summarised in Table 3 below.

TABLE 3. RECOMMENDATIONS FOR POLICYMAKERS

Policy Barrier	Recommended Action
Waste Classification Rigidity	Broaden EOW criteria to include more materials or revise the by-product criteria.
Fragmented Regulations EU	Harmonise national waste policies with EU directives.
Lengthy Permit Processes	Develop fast-track approval processes for IS projects.
Legal Liability Uncertainty	Establish clear accountability frameworks to protect entities and ensure transparency within IS monitoring and accountability.

VI. CONCLUSIONS

From the author's point of view, one of the most essential CE business models - IS, offers a comprehensive strategy for waste prevention, resource efficiency, and sustainable industrial practices. This research has identified key legislative and policy obstacles that prevent IS from being widely adopted throughout the EU. The obstacles

include bulky permitting procedures, complex waste classification, regulatory fragmentation, and a lack of standardised end-of-waste standards for broader resource types. Liability issues and a lack of institutional support make IS deployment more difficult. One more vital aspect to be pointed out is that legislation often focuses on the "end of pipe" solutions like waste treatment and disposal

instead of prioritising waste prevention and different reuse strategies.

Despite the barriers identified, the study also points out several possibilities for policy changes and regulatory innovation that may speed up the adoption of IS and shift to a CE-offered business model.

The study's conclusions highlight that IS is a profitable and win-win business model for all stakeholders and an effective instrument for accomplishing sustainability objectives and supporting resource efficiency, innovation, and environmental preservation. By integrating IS into national and regional policies, EU member states can accelerate the transition toward a more resilient CE.

Future research will focus on exploring empirical case studies and assessment of the economic impact of IS initiatives to strengthen further the case for regulatory reforms supporting industrial symbiosis. Notwithstanding these obstacles, the study identifies significant chances for policy changes and regulatory innovation that can speed up the implementation of IS.

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