Glossary of Terms for Industrial Symbiosis

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RISERS

A Roadmap for Industrial Symbiosis Standardisation for Efficient Resource Sharing

Literature Review: The Evolution and Conceptualisation of Industrial Symbiosis

The concept of *industrial symbiosis* (IS) has emerged at the intersection of systems thinking, industrial ecology, and sustainability science, drawing explicitly on biological metaphors to describe mutually beneficial reuse of materials, energy, water, and services among industrial actors. While the metaphor of symbiosis originates in biology (de Bary, 1879), its application to industrial systems reflects a broader intellectual movement that sought to reconceptualise industry as an ecosystem-like system governed by flows, interdependencies, and feedback loops (Ayres, 1989; Frosch & Gallopoulos, 1989).

Early uses of ecological metaphors in economic geography and industrial organisation predate the sustainability framing of industrial symbiosis, but it was not until the late 1980s and early 1990s that the concept gained a coherent analytical identity. The empirical development of the Kalundborg industrial network in Denmark played a pivotal role in this process. Documented by Ehrenfeld and Gertler (1997), Kalundborg demonstrated how independently operating firms could, through incremental and largely unplanned cooperation, develop a network of synergies that reduced waste, lowered costs, and generated environmental benefits. Importantly, Kalundborg was not initially designed as an "eco-industrial park", but rather evolved organically, a feature that strongly influenced subsequent academic discourse of industrial symbiosis.

The consolidation of industrial symbiosis as a distinct research domain situated IS as a subfield of industrial ecology. Chertow (2000) proposed that industrial symbiosis involves "traditionally separate industries engaging in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products." Her work postulated boundary conditions, distinguishing industrial symbiosis from bilateral recycling, waste management, or mere co-location. The emphasis on multiple actors and multiple resource synergies became a widely adopted heuristic for identifying symbiotic systems and remains influential in contemporary scholarship. The 2018 CEN Workshop Agreement on industrial symbiosis, however, has since redefined these postulated boundary conditions as they were not realistic in practice.

During the 2000s, the concept expanded beyond isolated case studies toward broader regional and national applications. Implementation at national scale was led by the UK's National Industrial Symbiosis Programme (NISP®, 2010) whose impressive impacts were cited as best practice by the Commission from 2009. The NISP® model of facilitation has since been replicated in over 20 countries around the world. Academic research increasingly addressed the mechanisms enabling symbiosis, including trust, institutional support, regulatory frameworks, and intermediary organisations (Mirata, 2004; Domenech & Davies, 2011). This period also saw growing interest in quantifying the economic and environmental benefits of symbiotic exchanges (Chertow & Lombardi, 2005), reinforcing the argument that industrial symbiosis could align environmental improvement with industrial competitiveness.

A major conceptual advance occurred with Lombardi and Laybourn (2012), who reframed industrial symbiosis as a process-oriented and network-based phenomenon rather than a static configuration of transactions. Drawing on empirical evidence from the UK National Industrial Symbiosis Programme (NISP®), they argued (in line with Chertow & Ehrenfeld, 2012)that industrial symbiosis should be understood as a "business opportunity process" facilitated by active brokerage, shared learning, and systemic coordination. This contribution marked an important shift away from the earlier emphasis on geographic proximity and spontaneous emergence, demonstrating that symbiosis could be deliberately enabled at regional and national scales. Lombardi and Laybourn's work thus redefined Chertow's foundational taxonomy by foregrounding facilitation, governance, and intermediary roles, helping to explain how symbiosis can be replicated beyond exceptional cases such as Kalundborg.

The increasing institutionalisation of industrial symbiosis is further reflected in the development of formal standards and guidance documents, most notably the CEN Workshop Agreement – CWA 17354:2018. This industry-led agreement represents a significant step in adapting academic concepts for operational and policy-relevant frameworks. CWA 17354:2018 outlines implementation approaches for industrial symbiosis, including guidance on stakeholder engagement, data sharing, legal considerations, and performance monitoring. In contrast to earlier descriptive and analytical studies, the CWA formalises industrial symbiosis as a repeatable and scalable practice, aligning it explicitly with European circular economy objectives.

The CWA builds directly on insights from the industrial ecology and industrial symbiosis literature, particularly the recognition—articulated by Lombardi and Laybourn (2012)—that successful symbiosis requires active coordination, facilitation, and supportive institutional environments. By codifying these insights into a pre-standard, CWA 17354:2018 bridges the gap between theory, practice, and policy, reinforcing the role of industrial symbiosis as an implementation mechanism for delivering on circular economy strategies rather than merely an analytical concept.

In recent years, industrial symbiosis has increasingly been positioned as a core operational component of the circular economy (Neves et al., 2020). While circular economy discourse often remains abstract and normative, industrial symbiosis provides concrete mechanisms for closing resource loops within and across organisational boundaries. Nevertheless, ongoing debates persist regarding conceptual overlap, definitional clarity, and measurement, particularly concerning whether industrial symbiosis should be treated as a subset of the circular economy or as a parallel but distinct systems approach (Boons et al., 2017).

Overall, the evolution of industrial symbiosis reflects a trajectory from metaphor and empirical observation toward implementation and institutional uptake. Foundational ecological metaphors and early case studies established the conceptual basis; analytical work in industrial symbiosis clarified definitions and boundaries; and more recent contributions—exemplified by Lombardi and Laybourn (2012) and CWA 17354:2018—have shifted the focus toward governance, facilitation, and implementation. This progression underscores industrial symbiosis as a practical tool for advancing resource efficiency and systemic sustainability transitions.

TERMS TO USE

There has been much debate regarding the terminology associated with industrial symbiosis, including debate on what the term itself means and how it should be addressed (industrial symbiosis vs industrial urban-symbiosis being just one example).

This glossary seeks to provide clarity for the RISERS project, so there is consistency of language and terms used in communications both inside the project and from the project to our audience.

INDUSTRIAL SYMBIOSIS

Industrial symbiosis is the use by one company or sector of underutilised resources broadly defined (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials) from another, with the result of keeping resources in productive use for longer. Core elements of industrial symbiosis are the aspects that enable its identification.

CWA 17354:2018

When we define IS within the RISERS project, we should use this wording to provide a consistent message from the project.

TRANSACTION

Definition:
A mutually profitable link or flow between two (or more) organisations in which one organisation obtains novel sourcing of required inputs and another obtains value-added destinations for non-product outputs (or under-utilised resources).

Explanation:
Lombardi & Laybourn suggest "transaction" is a better term than "exchange", because transactions emphasise the business/competitive advantage and value creation (not simply material moving).

Why important:
By using "transaction", one acknowledges that IS is not just about waste materials being moved around, but about creating new business value, innovation, knowledge flows, and non-material resources.

UNDER-UTILISED RESOURCE

Definition:
A resource which is available but not fully used in its current state — for example by-products, residues, waste, excess capacity, expertise, logistics, or water/energy flows.

Explanation:
The focus in IS is on keeping under-utilised resources in productive use for longer. Lombardi & Laybourn emphasise broadening beyond just waste/by-products.

Why:
Using this term helps shift the mindset from "waste management" to "resource utilisation" and opens up new possibilities (e.g., knowledge, capacity). Resources should be viewed in their widest sense, and can even include human resources that can be seconded between companies.

NETWORK

Definition:
A set of diverse organisations, typically separate, collaborating (through transactions) in a system-oriented way to foster eco-innovation and long-term culture change.

Explanation:
Lombardi & Laybourn emphasise that IS involves networks, not just isolated bilateral exchanges; the network perspective helps capture knowledge flows, shared infrastructure, relationships and trust.

Why:
Helps avoid overly narrow characterisations of IS (e.g., only material flows between two firms) and supports understanding of systemic change.

ECO-INNOVATION

Definition:
Innovation that results in a reduction of environmental impact, improved resource productivity, or creation of new value streams by altering processes, products or business models.

Explanation:
IS is framed by Lombardi & Laybourn as more than resource flows—it is a tool for "innovative green growth".

Why:
Emphasises that IS is not just "doing what we already do but with less" but "doing new things" or "re-thinking things".

CULTURE CHANGE (LONG-TERM)

Definition:
The shift in organisational or industrial behaviour and mind-set over time, towards resource intelligence, collaboration, and system thinking.

Explanation:
They highlight that IS involves long-term cultural change (trust, relationships, knowledge sharing) beyond just implementing one resource-flow project.

Why:
Recognises that the durable benefits of IS often depend on relational and organisational factors, not just technical transactions.

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SHARED INFRASTRUCTURE / UTILITIES / SERVICES/KNOWLEDGE

Definition:
Instances where organisations collaborate to share assets, infrastructure, utilities (e.g., steam, water, waste-heat networks), services (e.g., logistics) that enable resource efficiency and IS transactions.

Explanation:
Such sharing often supports the transactions of under-utilised resources and builds network capacity. It is referenced in the broader literature and is aligned with the updated IS framing.

Why:
Signifies that IS may involve more than just material flows—it can involve infrastructure and services that facilitate resource circulation.

RESOURCE PROCESSING

Definition:
The processing of resources to a form where they can be used in a subsequent production process. The same resource could undergo a variety of different process methods, depending on the end use of the processed resource.

Explanation:
The main aim for processing a resource is to transform it into a usable input into a production process. Waste management, on the other hand, may have a different aim, often to make the waste stable, or suitable for disposal/destruction.

Why:
Maintains the emphasis on retaining resources as productive inputs to production cycles.

SYNERGY/SYNERGIES/MATCHES

Definition:
The outcome of transactions in IS where the combined effect of organisations collaborating is greater than the sum of what they could achieve individually (in terms of resource efficiency, cost savings, innovation).

Explanation:
The term appears in IS literature and also in the CWA 17354 which refers to "Industrial symbiosis 'synergies' are transactions..."

Use:
Useful as a descriptor of benefits when framing IS opportunities.

RESOURCE MATCHING PLATFORM

Definition:
ICT system that allows inputs of resources and the ability to find partner companies to create synergies. A range of functionalities associated with this main aim can be present, but are not essential to this main aim.

Explanation:
Emphasizes resources and finding a solution whereby they are maintained in production processes.

Why:
Signifies that resources will be matched to beneficial use rather than treated to become non-polluting (although this remains an important aspect).

TERMS NOT RECOMMENDED (OR REQUIRING CAUTION)

EXCHANGE

Why to avoid: The term "exchange" is used widely in IS literature (e.g., material/ energy exchange) but Lombardi & Laybourn argue it is too narrow and misleading. It can reinforce the idea of simple swapping of waste and inputs, without capturing the business/innovation dimension, knowledge flows, non-material resources, or networks.

Explanation: They propose "transaction" instead, because "transaction" signals value creation, business logic, and the possibility of non-material flows (e.g., knowledge) as well as material flows.

BY-PRODUCT (USED WITHOUT CARE)

Why to use caution: While "by-product" is a valid term, using it alone may hide the fact that the output may currently be under-utilised and can become a resource. Also, focusing only on by-products may miss other under-utilised resources (capacity, expertise, logistics) highlighted by Lombardi & Laybourn.

Explanation: Use "under-utilised resource" (see above) to be broader and more inclusive of different resource types.

GEOGRAPHIC PROXIMITY

Why to avoid: Although geographic proximity (i.e., being co-located) has often been assumed as necessary for IS, it is neither sufficient nor always necessary.

Explanation: Value determines distance. Different resources have different economic value, along with other factors. Aggregates may have a short travel distance, while aluminium, due to its value, may travel upwards of 200 miles.

WASTE MANAGEMENT (WHEN USED AS THE PRIMARY LENS)

Why caution: If IS is framed primarily as waste management, it risks missing the broader opportunities for resource flows, value creation, innovation and business model transformation. Lombardi & Laybourn emphasise that IS is not just about waste. ResearchGate

Explanation: When you talk about IS, shift the language toward "resource utilisation", "novel sourcing", "value-added destinations" rather than just "managing/disposing waste".

Use caution: Ensure the dialogue emphasises positive resource flows, not solely cost of waste disposal.

WASTE EXCHANGE PLATFORM

Why to avoid: As with the term "exchange", the term 'waste exchange platform' does not accurately reflect the ICT. It can reinforce the idea of simple swapping of waste and inputs, without capturing the business/innovation dimension, knowledge flows, non-material resources, or networks.

Explanation: Use the term 'Resource matching platform' instead as in general, ICT systems operate in connecting companies that have a resource with companies that can make use of those resources. The resources are then transacted, rather than exchanged.

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About the RISERS project

RISERS is a Horizon Europe project aimed at developing an Industrial Symbiosis Standardisation Roadmap supporting the uptake of high impact synergies and resources considering:

- identification of the needs, gaps and opportunities,
- revision of current standards and standardisation efforts relevant for CE and the priority synergies and resources,
- initiating the process of new standards development (especially for newer technologies and pilot-scale synergies).

The RISERS project was launched in January 2024 with a duration of 3 years.

For more information visit: https://risers-project.eu

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