LIAISE

Cooperation, development
and cross-border transfer
of industrial symbiosis

D1.2 Identification of existing databases and other IT tools for monitoring Industrial Symbiosis streams

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Created 26/10/2025 Rev 0

Publisher
Technological Centre of Furniture and Wood of the Region of Murcia (CETEM), Yecla, Spain

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This report is part of the LIAISE COST Action. Concretely, it is D1.2. Identification of existing databases and other IT tools for monitoring Industrial Symbiosis streams. LIAISE COST Action (CA22110) is a project funded by the COST Action Programme in 2023, whose objective is to ensure an inclusive and holistic Industrial Symbiosis approach by generating relevant synergies among different actors from the q-helix stakeholder model and by setting the groundwork for increased and robust development of knowledge, apart from promoting future results-oriented R&D.

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CEIS	Circular Economy Indicator Set
DCCAE	Department of Communications, Climate Action and Environment
EIP	Eco-Industrial Park
EME	Excess Materials Exchange
EPA	Environmental Protection Agency
EWC	European Waste Catalogue
GHG	Green House Gas
ICESP	Italian Circular Economy Stakeholder Platform
ICT	Information and communication technologies
IoT	Internet of Things
IS	Industrial Symbiosis
KPI	Key Performance Indicators
LCA	Life Cycle Assessment
RECP	Resource Efficient and Cleaner Production
SDG	Sustainable Development Goals
SNA	Social network analysis
SUN	Symbiosis Users Network
UCFL	Urban Climate Future Lab
WG	Working Groups

Project Action Context

In the context of addressing climate change, the industrial sectors play a significant role as major contributors to carbon dioxide emissions, energy consumption, and waste generation. To combat these challenges, adopting a Circular Economy (CE) strategy is imperative. The CE model diverges from the traditional linear approach by promoting sustainable production and consumption practices while considering societal, environmental, and economic factors in a balanced manner.

Industrial Symbiosis (IS) emerges as a practical solution within this framework. In IS, waste or by-products generated by one industry are repurposed as resources for another, presenting opportunities for environmental sustainability and economic efficiency. Despite its potential, many companies and industrial actors lack awareness of IS, and its development is hindered by various barriers, including environmental, economic, technical, regulatory, organizational, social, and cultural challenges.

To address these issues, the LIAISE COST Action seeks to foster an inclusive and holistic approach to IS. By fostering synergies between stakeholders from diverse sectors and laying the groundwork for knowledge enhancement, LIAISE COST Action aims to bridge the gap between theory and practice. This initiative will involve developing a participatory approach to support cross-sector collaborations and establishing Key Performance Indicators (KPIs) to assess the effectiveness of IS business models in industry.

The LIAISE COST Action represents a collective effort to make Industrial Symbiosis a reality across Europe, fostering collaboration between researchers, practitioners, and policy makers. To achieve these objectives, LIAISE COST Action will leverage the expertise of four interdisciplinary Working Groups (WGs) and integrate their findings through a reference framework. This holistic approach aims to drive meaningful progress towards sustainable industrial practices and contribute to a more Circular Economy.

1. Introduction

1.1. IS & ICT tools - background and definition

Traditionally, the most frequently used definition of IS is the one used by Chertow (2000), which defines IS as a part of industrial ecology that engages traditionally separate entities in a collective approach to competitive advantage, involving the physical exchange of materials, energy, water, and by-products. The keys to Industrial Symbiosis are collaboration and the synergistic possibilities [often] offered by geographic proximity. Lombardi and Laybourn (2012) presented a renewed definition of Industrial Symbiosis, which the Journal of Industrial Ecology accepted. This definition was summarized by Domenech et al. (2019) as follows: IS is a systems approach to a more sustainable and integrated industrial system, which identifies business opportunities that leverage underutilized resources (such as materials, energy, water, capacity, expertise, assets, etc.). Explaining this definition further, Domenech et al. (2019) state that "Industrial Symbiosis involves organizations operating in different sectors of activity that engage in mutually beneficial transactions to reuse waste and by-products, finding innovative ways to source inputs and optimize the value of the residues of their processes, for instance by using waste or by-products from one activity as an input for another activity".

IS utilizes a cross-organizational approach to create synergies by matching one company's waste output with another's input through cooperation and resource sharing (Yeo et al., 2018). However, managing these relationships is complex, leading to various qualitative and quantitative tools in the literature that address IS creation opportunities and performance evaluation (Yeo et al., 2018). The digitalization of industry offers new opportunities to achieve a Circular Economy through IS (Antikainen et al., 2018; Tseng et al., 2018). Information and communication technologies (ICT) enable monitoring and tracking of the availability, quality, and location of material and energy flows in manufacturing processes (Antikainen et al., 2018). Based on these data, digital platforms can facilitate the identification of potential synergies and interaction between companies by supporting the exchange of (real-time) information and bringing resource buyers and suppliers together (Benedict et al., 2018; Kosmol & Leyh, 2020). Despite the benefits of using digital platforms to enable IS, their application in industry has not been very successful to date. Existing platforms lack crucial IS-related services or have not managed to reach a critical mass of users (Benedict et al., 2018). However, there is little research addressing the question of how IS platforms can be designed to overcome existing barriers to IS (Benedict et al., 2018; Kosmol & Leyh, 2020).

Over the past two decades, research on IS has expanded significantly, and its potential economic (e.g., cost reduction), social (e.g., employment generation), and environmental (e.g., waste and emissions reduction) benefits are well documented. Despite the potential of IS to increase companies' efficiency and profitability, the primary research focus has been on Environmental Sciences, Green Sustainable Science Technology, Environmental Engineering, and Environmental Studies. At the same time, scholars in the fields of Economics, Management, and Business, or Business Finance, have conducted significantly less research in this area, focusing more on CE (Pavlović et al., 2025).

Nevertheless, practical implementation of IS remains limited (Benedict et al., 2018; Fraccascia & Yazan, 2018; Maqbool et al., 2018). Golev et al. (2014) categorized the main barriers and enablers to IS into seven broad areas: organizational commitment to sustainability, environmental regulatory frameworks, limited community engagement and inter-industry collaboration, inadequate information sharing (particularly data on waste streams and local resource needs), and both technical and economic viability of symbiotic exchanges.

Although numerous case studies worldwide have demonstrated the environmental and economic benefits of IS, its large-scale adoption is hindered by a variety of technical and non-technical barriers (Krzeminski et al., 2025). In particular, the absence of reliable and comprehensive monitoring systems limits the identification of potential synergies and the optimization of existing exchanges (Krzeminski et al., 2025).

More recent literature reviews have expanded and refined these lists of barriers, drivers, and enablers, often organizing them into overarching technical and non-technical categories akin to those identified by Golev et al. (Krzeminski et al., 2025; Domenech et al., 2019; Henriques et al., 2021; Neves et al., 2019; Södergren & Palm, 2021). Facilitating inter-organizational collaboration in IS remains a complex endeavour, increasingly supported by ICT (Grant et al., 2010; Maqbool et al., 2018; Yeo et al., 2019). Various digital tools—such as online platforms, databases, social networking applications, and knowledge repositories—are now available to aid IS development in different phases: identifying synergies, evaluating symbiotic opportunities, overcoming barriers, executing exchanges, and managing subsequent documentation and review (Bonnet et al., 2016; Grant et al., 2010; Maqbool et al., 2018).

The evolution of IS tools reflects a shift from simple data-gathering systems to multifunctional digital platforms that act as enablers of broader ecosystem collaboration (Benedict et al., 2018). In support of the CE, such platforms facilitate the sharing of surplus capacity (e.g., access, resale, or trade of products and materials), support product-service systems for maintenance and repair, and enable user participation in knowledge exchange and co-creation (e.g., through crowd-sourced solutions) (Konietzko et al., 2019). Within the IS context, digital platforms primarily aim to enhance information exchange, host open e-marketplaces, and deliver supportive services that promote cooperation, stakeholder engagement, and community awareness (Benedict et al., 2018; van Capelleveen et al., 2018; Kosmol & Leyh, 2020).

Robust tools, databases, and digital platforms, some of which are international, while some are locally oriented, are essential to support IS by enabling secure information sharing, automating resource matching, and providing decision-support capabilities for stakeholders (Erceg et al, 2024). Such systems not only facilitate the creation of new synergies but also help track and evaluate the performance of ongoing exchanges (Erceg et al., 2024; Krom et al., 2022).

Effective IS implementation relies on a clear understanding of resource flows and the ability to identify, quantify, and match available resources with potential users (Erceg et al., 2024). Monitoring is vital for IS sustainability, enabling efficient resource use, regulatory compliance, reducing environmental impact, and fostering innovation and trust within the network. IS requires ongoing monitoring of the professionals involved. The collaborating companies are monitoring and monetizing waste and creating value from their by-products (Gonçalves et al., 2021). The development of tools and strategies to monitor resources and waste flows at different scales would allow better resource planning and more sustainable management of the territory (Piemonti et al., 2023). Controlling the development and progress of an IS system, an indicator system must be set up to standardize and assess IS (sustainability) performance (Lütje & Wohlgemuth, 2020). Although various performance indicators for measuring IS had been proposed in the literature, currently there is no widely accepted consolidated indicator in practice (Mantese et al., 2016). Monitoring and tracking the benefits of IS is also critical to Eco-industrial park performance evaluation (Dong et al., 2022).

Resource mapping involves identifying, analysing, and visualising the flow of resources between companies or industrial sites (Erceg et al., 2024). Resource mapping identifies collaboration opportunities for businesses to exchange discarded resources, improving efficiency and reducing waste. It begins by mapping operational processes to understand resource flows and identify areas for collaboration. Quantifying available resources helps assess potential exchanges and highlight inefficiencies. This process is crucial for effective mapping and identification of synergies. After mapping, a further analysis of the connections between sites reveals IS opportunities. Enhanced data collection through specialized databases categorizes resources by materials, energy, water, and waste, while a geographical map of participating businesses aids in assessing transportation logistics and prioritizing collaboration opportunities (Erceg et al., 2024).

1.2. Report Objectives

The primary aim of this report is to map the existing tools, databases, and platforms that support the implementation of IS. More specifically, it seeks to:

1. Review and classify the currently available IS monitoring and facilitation systems on the local, national, and international scales.
2. Evaluate their functionalities in resource mapping, resource matching, and operational analysis.
3. Identify gaps, strengths, and opportunities to improve IS monitoring practices.

By consolidating this knowledge, the report aims to address persistent challenges in IS implementation and strengthen the evidence base necessary to advance resource-sharing strategies across industries. The selected tools (24 examples) will be available in an interactive, searchable table at the LIAISE webpage under the following link.

1.3. Scope and Limitations

The literature has identified a wide range of different ICT tools, platforms, and software. However, these platforms are still underdeveloped and not very well recognized in the worldwide environment.

The main limitation of the report is that, despite thorough research by contributors, some ICT tools, platforms, and software available in certain countries may have been overlooked. Although there is a high number of identified examples of ICT tools, platforms, and software, these findings have limitations in the research team members' citizenship, as most of the identified examples are from Europe.

2. Methodology

This work has been carried out as part of the LIASE COST Action CA22110 - Cooperation, development and cross-border transfer of Industrial Symbiosis among industry and stakeholders. With almost 350 members from 39 countries, LIAISE COST Action aims to create synergies between stakeholders to promote IS implementation by identifying barriers relevant to various countries, sectors, and stakeholders and designing guidelines to mitigate these barriers. When creating the report on IS and relevant IT tools, databases and platforms, a multi-layered approach to data collection and evaluation was used. Based on the classification by van Capelleveen et al. (2018) and Akrivou et al. (2023), which divided IT tools into six different categories, WG1 have adapted their division into the following four categories: platforms, toolkits, marketplaces, and software. Platforms, as the highest category, offer all services connected to IS (functionality, covers phases of IS, all sectors of industry, all materials, offer software for IS, etc.); toolkits present collection of resources designed to perform a specific function or solve a particular problem in IS; marketplaces are defined by the possibility for companies to offer or buy waste and byproducts; and software which present programs intended for user-specific tasks regarding the IS.

First, WG1 made a systematic review of the literature, focusing on publications and professional papers published in the last ten years. The search included databases such as Scopus, Web of Science, Google Scholar, institutional repositories, and thematic journals in the field of industrial ecology, entrepreneurship, and sustainable development. Publications were further selected if they described the use of digital tools, platforms, and databases in the context of IS or were methodologically relevant for its implementation.

In addition to the literature, key European and international projects, such as SYNERGIE, SHAREBOX, EIT Circular Economy, FISSAC, and CIRCULAR IMPACTS, which developed or used digital tools for IS, were analysed. For this purpose, data was collected from project platforms, official websites, and project reports, with special emphasis on the analysis of the functionality of the developed tools, geographical representation, and accessibility to users.

Additionally, a structured web search was conducted to identify available platforms, digital solutions, and databases that enable the implementation of IS, primarily in the European but also on the global market. The search was carried out using relevant keywords, with additional combinations according to individual industry sectors.

To make the results transparent and comparable, WG1 used the following criteria when selecting and evaluating tools, databases and platforms: type of solution (whether it is a solution that provides support, facilitates direct exchange of resources or enables online 'matchmaking'), type of action that the tool allows for (informing, connecting participants, logistic support, analytics, facilitating exchange), then types of resources it covers (e.g., material, water, energy, by-products, information or capacities), representation by country or region, billing or availability model, industry sectors to which it applies, and the activity status of each solution (active, inactive, withdrawn). All collected data was additionally validated by comparing information from multiple sources, as soon as possible, to ensure the reliability and up-to-datedness of the results presented. To ensure analytical consistency in comparing diverse IS platforms, a classification scheme was applied based on selected attributes extracted from the shared data collection. Specifically, tools were grouped by their primary function as reported under "Functionality / Type of action provided" and "Platform", distinguishing between (i) supportive tools that offer information and guidance, (ii) physical/direct exchange-enabling tools that facilitate logistical operations or infrastructure sharing, and (iii) online tools that provide digital matchmaking services. Additionally, complementary attributes such as "Phases of IS implementation covered", "Type of resource covered", and "Accessibility (open source/paid)" were integrated to enrich the classification and provide contextual nuance. This allowed categorization to reflect not only what a tool does, but also when and how it contributes to the IS process.

With the applied methodology, WG1 enabled broad but selective coverage of the most essential IT tools and platforms relevant to IS. Clearly defined criteria contribute to objectivity and can be easily applied when developing similar analytical reports. Data on IT tools, databases, platforms, and toolkits were collected by members of COST LIAISE WG1, who conducted research and added details about their findings based on several essential characteristics.

3. Overview of Industrial Symbiosis Monitoring Needs

Monitoring the performance of IS systems is crucial to concompany environmental and economic benefits and to ensure transparency for all stakeholders. Practical KPIs are needed for tracking operations. Life Cycle Assessment (LCA) provides a scientific way to evaluate the real environmental impacts of symbiotic exchanges. These two methods work well together: KPIs allow for regular and scalable monitoring across networks, while LCA offers depth, credibility, and context for important decisions. This section includes recent literature and EU frameworks (FISSAC, 2018; UNIDO, 2017), simulation-driven KPI evaluations (Yu et al., 2018), and LCA-focused environmental monitoring guidelines (Kerdlap et al., 2020; Daddi et al., 2017; Capucha et al., 2023).

Based on a thorough review of the scientific literature and policy frameworks, several leading international initiatives have created strong methods for monitoring and evaluating the performance of IS. The most important frameworks include those developed by the SCALER project (2019), the UNIDO Eco-Industrial Park (EIP) Framework (2017), the Resource Efficient and Cleaner Production (RECP) monitoring approach, the Ellen MacArthur Foundation's Circularity Indicators (2015), and the EU's Circular Economy Indicator Set (CEIS).

The SCALER project (2019), funded by the European Commission, offered a practical and scalable framework for IS by focusing on simplified but scientifically supported indicators. It highlighted pre-calculated environmental metrics from LCA, enabling quick assessments of common symbiosis types like heat recovery and by-product substitution. The key feature of SCALER is its tiered structure, which provides rapid estimation tools for early-stage opportunities and more detailed LCA tools for established symbiotic systems. This makes it especially suitable for small industrial parks and regional clusters that want to adopt IS.

In addition, the UNIDO International Framework for EIPs (2017) presents a globally accepted standard for monitoring environmental, social, and economic performance in IS settings. Developed with the World Bank and GIZ, this framework includes 32 key indicators across four performance areas. These cover environmental KPIs, such as water reuse rates and GHG emissions reductions, economic metrics like cost savings or investment mobilization, and social indicators, including jobs created or workforce training. Its structure is particularly relevant for parks that want to be recognized as EIPs or aligned with the UN Sustainable Development Goals (SDGs).

At the business level, the RECP methodology provides a proper monitoring approach to prepare companies for symbiosis. Created jointly by UNIDO and UNEP, RECP focuses on improving internal operations before engaging in symbiosis, monitoring resource use intensity, waste reduction, and cost savings. This framework is beneficial for pinpointing internal inefficiencies in companies and connecting them with IS opportunities. Each of these frameworks plays a unique role in understanding IS performance. Together, they create a multi-level monitoring system.

Monitoring the performance of IS systems requires a complete set of indicators that reflect the environmental, economic, and social aspects of resource exchanges. To ensure comparability and practical use across sectors and ecosystems, the indicators are grouped into five categories, aligned with the international frameworks like the UNIDO EIP Framework (UNIDO, 2017), the SCALER Project (2019), the FISSAC project (2013), and LCA standards ISO 14040/44 (ISO 2006; European Commission, 2023). The five groups of relevant indicators and examples are presented in Table 1.

Table 1. Relevant indicators examples

CATEGORY	KEY INDICATOR	PURPOSE	SOURCE(S)
MATERIAL & RESOURCE EFFICIENCY	Material exchange rate (%)	Measures the share of materials diverted from waste to reuse pathways	UNIDO, 2017 SCALER, 2019
	Secondary raw material utilization (tons/year)	Quantities of industrial by-products reused in other operations	SCALER, 2019; FISSAC, 2018
	Circular material use rate (%)	Secondary raw materials are used to make new products	EU Commission Communication 306 (2023) [4]
	Waste reduction (tons/year)	Waste reduction in landfills can be achieved through IS practices	OECD, 2020
	Water reused or cascaded (m^3/year)	Tracks water efficiency through reuse and cascading flows	UNIDO, 2017; World Business Council for Sustainable Development, 2018
	Energy exchanged or recovered (kWh/year)	Measures energy sharing across facilities	UNIDO, 2017; FISSAC, 2018
ENVIRONMENTAL PERFORMANCE	GHG emissions avoided (CO_2e/year)	Quantifies CO_2 savings due to symbiotic substitutions	Zhang et al., 2017; SCALER, 2019
	Reduction in resource footprint	Tracks the overall reduction in primary resource demand	Ellen MacArthur Foundation, 2015, 2019
	Reduction in hazardous waste generation	Assesses the impact of IS on reducing toxic waste	UNIDO, 2017
	Pollutant load reduction (NOx, SOx, COD)	Measures of environmental benefits from shared treatment facilities	UNIDO, 2017
ECONOMICS	Cost savings from IS (€/year)	Calculates the financial benefits of waste valorization or utility sharing	SCALER, 2019
	Revenue from by-product sales (€/year)	Measures added value from trading reusable materials	FISSAC, 2018; SCALER, 2019
	OPEX	Material, energy, etc. costs,	FISSAC,2018
	CAPEX	Capital cost invested in IS measures	FISSAC, 2018
	Cost of avoided emissions (€ per ton CO_2e)	Links GHG benefits to carbon pricing	European Parliament & Council, 2003, 2018
NETWORK MATURITY & PARTICIPATION	Number of active synergies	Tracks the implementation depth of the IS system	UNIDO, 2017; SCALER, 2019
	Creation of IS	Number of liaisons (connections between companies) and extent of shared facilities	FISSAC, 2018

	Firm collaboration rate (%)	Measuring organizational and operational collaboration among companies	Herczeg et al. 2018
	Time to implement new synergy (months)	Evaluates the maturity and agility of facilitation mechanisms. Agility is highlighted through the adaptability of tools to different contexts and stages of IS implementation.	SCALER, 2019
SOCIAL & INSTITUTIONAL	Jobs created through IS initiatives	Reflects employment impacts of circular business models	UNIDO, 2017
	Participation rates of beneficiaries	Assesses inclusivity and cross-sector cooperation	UNIDO, 2017
	Number of programs and capacity-building workshops launched	Indicates the level and intensity of capacity-building activities	UNIDO, 2017
	Number of laws/regulations improved and/or created.	Identifies policy and governance infrastructure supporting IS	UNIDO, 2017; OECD, 2020
CROSS-CUTTING	Carbon footprint per synergy	Composite LCA metric quantifying emissions reductions per exchange	ISO 14040/44, 2006; OpenLCA, 2020

Source: LIAISE WG1

IS initiatives require robust environmental monitoring methodologies to verify that resource exchanges indeed yield net sustainability benefits. LCA has emerged as the most frequently cited technique for appraising the environmental performance of IS systems (Kerdlap et al., 2020). LCA allows for the quantification of environmental impacts, such as greenhouse gas emissions, eutrophication, resource depletion, and toxicity potentials, associated with the entire life cycle of resource exchanges within and between facilities. This includes upstream processes (e.g., raw material extraction), on-site production (e.g., process emissions), and downstream processes (e.g., waste handling or reuse of by-products in partner industries). For example, the famed Kalundborg symbiosis reports annual savings of thousands of tons of CO_2, as well as significant reductions in water and oil consumption. Still, to validate such claims rigorously, LCA methodologies were employed – indeed, a commissioned LCA in 2015 for Kalundborg quantified how each exchange contributed to emissions reductions and resource conservation (EU SCALER Project, 2015). The European Commission has explicitly highlighted the need for "*assessment methodologies and KPIs to measure the performance of symbiosis, including environmental, economic and social impacts*," recommending that life cycle-based methods (LCA for environmental, life cycle costing for economic) be used in IS monitoring and aligned with ISO 14040 and 14044 standards. In practice, this means IS monitoring tools should incorporate LCA-derived indicators (e.g., carbon footprint per synergy, acidification potential, etc.) alongside simpler metrics.

The ability to consider multiple impact categories and timeframes makes LCA particularly suitable for monitoring IS systems, which are often complex, heterogeneous, and dynamic (Zhang et al., 2017). Moreover, at the core of LCA-based monitoring lies the need to track key resource flows, including material and energy exchanges, water and raw material reuse, and waste valorisation pathways. As highlighted in Kerdlap et al. (2020), effective environmental monitoring in IS requires disaggregated data across three tiers: the network level, where aggregate environmental performance of the IS system is assessed (e.g., total CO_2 emissions savings across an EIP); the entity level, providing facility-specific insights for individual companies participating in symbiotic exchanges; the resource flow level, where individual synergies (e.g., a specific material or energy stream) are evaluated for their marginal impact. Multi-level LCA approaches ensure that each stakeholder receives tailored impact indicators for decision-making. Such disaggregated analysis ensures that different stakeholder groups, including facility operators, IS facilitators, and policymakers, can access relevant metrics aligned with their decision-making needs (Zhang et al., 2017; Daddi et al., 2017).

Infrastructural synergies, such as shared wastewater treatment and by-product recovery plants, demand specific monitoring parameters, both in quantity (mass or volume of shared resources) and quality (e.g., pollutant concentrations, embodied emissions). Recent studies have demonstrated the applicability of LCA in real-world IS implementations. For instance, the comparative LCA by Daddi et al. (2017) on a tannery SME cluster demonstrated how infrastructure sharing initiatives (e.g., wastewater and chromium recovery) contributed to up to a 22% reduction in climate change impacts per m² of leather. Similarly, Capucha et al. (2023) analyzed the implementation of IS in the European cement sector. They reported significant reductions (up to 12% GHG emission reduction) in primary resource use and emissions, demonstrating how sector-specific monitoring can be achieved through tailored life cycle models. Moreover, the selection of reference scenarios is critical for monitoring the real benefit of IS versus baseline systems. From a methodological perspective, reference scenario selection is a crucial component of environmental monitoring via LCA. Aissani et al. (2019) emphasize the importance of appropriate baseline design and sensitivity analysis in LCA to avoid overestimating the advantages of by-product exchanges. Monitoring tools, therefore, must not only collect raw environmental data but also contextualize it within well-constructed system boundaries. Accordingly, monitoring frameworks must include clear guidance on how to construct credible counterfactuals to evaluate “what would have happened” in the absence of symbiosis. This is particularly important when evaluating avoided burdens, such as the displacement of virgin material production or landfill emissions through by-product utilization (Wang et al., 2019). In advanced cases, like that of Pechsiri et al. (2023), integrating novel production systems (e.g., algae-based CO_2 utilization) into urban-Industrial Symbiosis required life cycle modelling of both avoided and added impacts, illustrating the depth of environmental monitoring required for innovative IS configurations. Their findings indicated that while CO_2 valorisation and nutrient recycling led to substantial environmental benefits, upstream impacts related to energy use in cultivation and harvesting required careful monitoring to avoid burden shifting. These insights underscore the need for LCA-based monitoring tools that can account for both innovations and unintended consequences in novel IS arrangements.

The types of data required for LCA-based monitoring include quantitative flows of materials, energy, water, and emissions; characteristics of by-products and residues; transport distances; and information on substituted or avoided processes. In many cases, LCA studies depend on primary data collected from the facilities involved, which need to be complemented with secondary datasets (e.g., Ecoinvent, Switzerland) and sensitivity analysis to ensure robustness and transparency (Aissani et al., 2019; Capucha et al., 2023). Geographically, Zhang et al. (2017) and Wang et al. (2019) have shown the feasibility of applying LCA in IS settings across different cultural and industrial contexts, including China's energy-intensive chemical parks, highlighting the transferability and adaptability of LCA as a monitoring tool. In each case, significant environmental gains were verified through LCA modelling, supporting its role in long-term monitoring and decision-support. As mentioned, the quantified benefits would not be detectable without systematic LCA-based monitoring integrated into the symbiotic infrastructure. Another important fact is that integrating environmental monitoring into IS platforms through automation, real-time data feeds, and API-based LCA tools could substantially enhance the functionality of IS digital tools. While current IS platforms primarily focus on resource matchmaking, the future of IS facilitation must involve embedded LCA capabilities to provide transparent environmental metrics directly to users and stakeholders.

Given these systems, how do standard LCA tools (SimaPro, GaBi, openLCA) fare in supporting monitoring needs? In direct physical or hybrid programs, experts often conduct dedicated LCA studies using these tools to evaluate symbiosis projects. SimaPro and GaBi are frequently used in case studies of IS to calculate, for example, the net CO_2 reduction of using one company's by-product in another's process. Both tools have extensive databases. GaBi encourages industry-specific data (necessary for accurate modelling of industrial processes), while SimaPro offers transparent methodology customization and links to impact assessment methods (e.g., ReCiPe). They produce reliable results but require significant expertise and data input. Historically, this meant that embedding SimaPro or GaBi into an online platform was unrealistic; instead, practitioners would manually run LCA models offline. However, as noted, new cloud-based offerings (e.g., SimaPro's API) signal that these tools can be used for other applications. For example, a platform could use SimaPro's calculation engine on a server to compute impacts when a user selects a synergy. openLCA, being open source, has already been experimented with in research for integration. Its advantage is that it can be customized to include specialized impact metrics relevant to industrial ecosystems (e.g., regional impact factors, toxicity of industrial by-products) and can run in batch mode. Researchers have developed openLCA-based scripts to automate scenario analyses for symbiosis options through GitHub. For instance, an IS platform prototype could use openLCA to evaluate each match option overnight and provide a dashboard of which exchanges yield the highest environmental benefit. However, challenges, including data availability and user effort, are still present. Full LCA requires detailed data (material compositions, energy use for processing, transportation distances, etc.), which typical platform users may not readily provide for each waste listing. If a platform requires users to input extensive technical data to obtain an LCA result, it may discourage participation. Some projects have attempted to address this issue by utilizing default scenarios and data (e.g., the EU SCALER project), which developed a set of generic symbiosis cases with pre-estimated LCA impacts to integrate into evaluations. Another approach is using simplified metrics as proxies: e.g., carbon footprint per ton of waste reused can be a single indicator pre-calculated for common waste types, which the platform then multiplies by tonnage. This is less accurate than a complete LCA model, but it is far more practical for real-time monitoring.

In this context, fully embedding detailed LCA into operational IS matchmaking platforms that cater to broad use needs is still emerging, with easy-to-use interfaces. Moreover, LCA results themselves carry uncertainty and can be misinterpreted without expert guidance. Truly automated, high-fidelity LCA integration is still rare. Thus, the realistic approach for now is to use LCA in the background for developing symbiosis opportunity datasets and impact benchmarks, and to use simpler derived metrics online. Experts can then perform detailed LCAs on promising synergies as a follow-up service. Ideally, the tools should not only find matches but also help manage and monitor them, which is where tailored LCA-based evaluations come in at the right stage. Overall, LCA-based monitoring provides a scientifically grounded, versatile, and scalable method for evaluating the environmental performance of IS systems. By identifying both positive and negative environmental trade-offs, it enables informed decision-making, supports transparency, and fosters the continuous improvement of symbiotic networks across industrial sectors and geographies.

4. Digital Platforms

4.1. Digital Platform Types

Recently, many tools have been offered to support IS through identification and matchmaking. Developed tools enable the identification of potential partners and assist decision makers by recommending potential synergies. Some of these tools are even expected to manage potential flows/ transactions between IS collaborators. The IS facilitator tools can be classified into six different types of information systems (van Capelleveen et al., 2018; Akrivou et al., 2023): open online waste markets, facilitated synergy identification systems, industry sector identification systems, social network platforms, IS knowledge repository, and region identification systems. The objectives, types of input and output required by these platforms and the potential members/users of these platforms are summarized in Table 2.

Table 2. Classification of the digital platforms

TYPE OF PLATFORM	THE AIM IS TO	TYPE OF INFLOW-OUTFLOW DATA SHARED	WHO CAN USE THE SYSTEM
OPEN ONLINE WASTE MARKETS	Enable exchange of waste and material to match demand and supply	Detailed information about the type of flow and its quality	Openly accessible to businesses
FACILITATED SYNERGY IDENTIFICATION SYSTEMS	Support intermediaries in identifying and managing synergies		Only accessible to the members of the program or the EIP
INDUSTRY SECTOR IDENTIFICATION SYSTEMS	Enhance partnerships between and within industrial clusters, not individual IS collaborators	The end user offers sector-specific data and informs the platform about potential synergies, average quality of the flow and its properties	
IS KNOWLEDGE REPOSITORIES	Store information to provide knowledge and help companies to reveal their potential synergies		Open to the public
SOCIAL NETWORK SYNERGY IDENTIFICATION	Foster collaboration by expanding the professional networks of companies to enable them to create or join an IS network	Supplied or demanded resources, availability, quantity and quality	Open to the public
REGION IDENTIFICATION SYSTEMS	Identify districts/ regions with high IS potential that offer abundant synergies for potential matchmaking	.	Openly accessible to businesses

Source: Adapted from van Capelleveen et al., 2018; Akrivou et al., 2023

Examples of different digital platforms based on the types outlined in Table 2 will be presented in the following sub-chapters.

4.2. Examples of Different Digital Platforms Connected with IS

Online waste markets are platforms where data about the quality, quantity, and price of waste or by-products are shared to enable exchange between collaborators who supply or demand these synergies. These platforms enable companies to share data about the contact person, company size, and location. Another crucial piece of data required for online waste marketplaces is the company's role in the supply chain (Bakogianni et al., 2019; Akrivou et al., 2023). Some of the online waste markets are introduced in Table 3.

Table 3. Examples of the online waste marketplaces

PLATFORM	AIM	DATA NEEDS
EVREKA 360	Optimize waste collection and exchange	Waste types, logistics data, sensor data
SFRIDOO	Marketplace for industrial by-products	Material types, availability, pricing
HGK WASTE EXCHANGE	Facilitate waste exchange among companies	Material types, location, pricing
H4C PLATFORM/ MARKETPLACE	Marketplace for IS	Material types, availability, pricing
EXCESS MATERIALS EXCHANGE (EME)	Exchange excess materials	Material types, quality, pricing
WALNUT PLATFORM	Marketplace for circular materials	Material types, availability, pricing

Source: LIAISE WG1

Facilitated synergy identification systems aim to support intermediaries in identifying and managing synergies. These systems align with the facilitated IS approach (Paquin & Howard-Grenville, 2012), where intermediaries help companies to exchange resources. These platforms enable not only material flow data but also process data and stakeholder profiles, as seen in Table 4.

Table 4. Examples of facilitated synergy identification systems

TOOL	AIM	DATA NEEDS
SYNERGie®	Support intermediaries in identifying and managing synergies	Process data, compatibility metrics, stakeholder profiles
Ecocycle	Identify and manage industrial synergies	Material flow data, stakeholder profiles
iNEX circular	Identify Circular Economy synergies	Process data, material flows

SYMBIOTPTIMA	Support IS implementation and monitoring	Process data, KPIs, stakeholder roles
MAESTRI	Manage energy and resource efficiency	Energy data, material flows
UNIDO IS Identification Tool (V2)	Support IS identification globally	Process data, stakeholder profiles
Finnish Industrial Symbiosis System	Support IS in Finland	Process data, stakeholder roles
SÍMBIOSY Platform and Tools	Identify and manage IS synergies	Material flows, stakeholder data
Platform for Industrial Symbiosis	Support IS implementation	Process data, stakeholder profiles
AquaSPICE Platform	Water reuse and symbiosis	Water flow data, stakeholder roles
CORALIS Platform for IS development	Development of IS in industrial clusters	Cluster data, stakeholder roles

Source: LIAISE WG1

Industry sector identification systems allow an examination of possible synergies between industries. By considering the production processes and features of production in each sector, these platforms enable the evaluation of sectoral by-products and waste. Some of the industry sector identification systems are summarized below in Table 5.

Table 5. Examples of Industry sector identification systems

PLATFORM	AIM	INDUSTRY SECTOR FOCUS	TYPE OF DATA REQUIRED
OPENLCA	Life Cycle Assessment and Impact Analysis	All sectors	Process data, emissions, material flows
CAMBRIDGE VALUE MAPPING TOOL	Identify value types across business models	Manufacturing, services	Business model data, stakeholder roles
EPOS	Cross-sectoral IS facilitation	Energy, chemicals, metals	Resource flows, sectoral profiles
CIRCLEAN NETWORK	EU-wide IS data collection and analysis	Multi-sector	Waste/resource data, company profiles
M3P	Match waste materials with potential users	Manufacturing, construction	Material types, volumes, and sector classification
EME	Marketplace for excess materials	Multi-sector	Material taxonomy, company sector info
SYMBIOSIS/ SYMBIOTPTIMA	EU IS a platform for regional development	Industrial clusters	Resource data, sectoral classification

CORALIS PLATFORM	IS development in industrial clusters	Steel, chemicals, energy	Sector readiness, resource flows
FISSAC	Circular economy in construction and demolition	Construction, demolition	Waste types, sector-specific data
SHAREBOX	Real-time resource sharing	Manufacturing, industrial parks	Resource availability, sectoral profiles
DSPOSAL	Waste tracking and compliance	Waste management	Waste types, company info
RECIRCULAR	Match waste with reuse opportunities	Multi-sector	Waste/resource data, sector info
RECONOMY	Circular economy implementation	SMEs, manufacturing	Business data, resource flows
RHEAPLY	Asset exchange and reuse	Education, healthcare, and corporate	Asset data, organizational sector info

Source: LIAISE WG1

While some of the tools focus on specific sectors like Construction (FISSAC, M3P), Manufacturing (Cambridge Value Mapping Tool), Steel (CORALIS), chemicals (EPOS, CORALIS), metals (EPOS, CORALIS), energy (CORALIS) and waste (DSposal), WG1 also observed those that also offer a multi-sectoral perspective.

The Regional Identification Systems aim to detect promising districts or regions for potential IS. These systems aim to identify regions with abundant synergies, making potential IS applications economically viable. Various types of data are required to evaluate the regions, including the availability and density of regional infrastructure, the types of industries available, their potential waste and by-products, the availability of energy plants, and water or waste treatment facilities. Considering these data, indices such as the suitability index of symbiosis (Jensen et al. 2012; van Capelleveen et al. 2018) can be generated to attract companies to initiate symbiotic exchanges in these regions. A list of some relevant tools is listed in Table 6.

Table 6. Example tools that might be classified as Regional Identification Systems

PLATFORM	DESCRIPTION
IWMM TOOL (INDUSTRIAL WASTES MATCHMAKING TOOL)	This tool uses data on waste streams, material concentrations, and market prices to identify profitable IS opportunities across regions.
CIRCLEAN NETWORK	An EU initiative standardizing IS identification methodologies and supporting regional IS mapping and policy development. It focuses on systemic facilitation.
METHOD BY CHALMERS UNIVERSITY	A top-down IS identification method using statistical datasets and IS databases to match inputs and outputs across sectors. It supports regional IS planning.
ISDATA	A data-driven tool for regional IS analysis, using aggregated industrial data to identify symbiotic opportunities across sectors and geographies.
EPOS	Focuses on integrating IS into energy-intensive sectors at a regional level, using systemic modeling and planning tools.

CORALIS PLATFORM	Supports regional IS demonstrators and planning, especially in industrial clusters. It emphasizes long-term systemic development.
CIRCULAR FLANDERS	A regional initiative in Belgium that facilitates IS through policy, mapping, and cluster-level coordination.
CICULEIRE	Ireland's national platform for the Circular Economy and IS, supporting regional opportunity identification and stakeholder engagement.
INCUBIS	An EU project that develops regional IS incubators and supports the identification of systemic opportunities.
URBAN-INDUSTRIAL SYMBIOSIS RECOMMENDATION PLATFORM	Utilizes AI and spatial data to identify and recommend IS opportunities across urban-industrial regions.
EUROPEAN CLUSTER COLLABORATION PLATFORM – IS TOOLKIT	Provides tools and guidance for regional clusters to identify and implement IS opportunities.
SYMBA PROJECT DATABASE	A repository of IS projects used for benchmarking and regional opportunity identification.
CAMBRIDGE VALUE MAPPING TOOL	Although not exclusively for IS, it supports regional value flow analysis to inform IS planning.

Source: LIAISE WG1

Knowledge repositories store information to provide knowledge and help companies to reveal their potential synergies. These tools enable a platform where organizations can share their IS experiences and access databases. For example, ISDATA offers access to the Composition dataset, which provides data on the physical and chemical composition of materials, as well as Facility Databases and LCA databases. GitHub also enables access to a relatively higher number of Composition, Facility, and LCA databases. It also acts as a gateway to many related platforms (EPOS, e-sumbiosis, Inex Circular, Life M£P, LOWaste, MAESTRI, The Near-Zero European Waste Innovation Network, Materials Innovation Exchange, US BCSD Materials Marketplace, Sharebox, simbiosiindustriale.it, SymbioSyS, Synergie Quebec). Some of these platforms are presented in Table 7.

Table 7. Example tools that might be classified as knowledge repositories

PLATFORM	SCOPE	TYPES OF DATA STORED
ISDATA	Regional	Case studies, material flow data, technology applications, market and environmental analysis
IWMM TOOL	Company-level and Regional	Waste stream volumes, material concentrations, market prices, industry profiles, geographic coordinates
CIRCLEAN NETWORK	Regional	IS transaction records, material types, flow volumes, impact metrics, facilitation documentation
SHAREBOX	Company-level	Real-time resource availability, transaction history, synergy records, and environmental impact metrics

EXCESS MATERIALS EXCHANGE (EME)	Company-level	Material passports, lifecycle data, transaction history, environmental and economic value metrics
OPENLCA	Company-level	Life cycle inventory data, environmental impact assessments, process and product-level material flows.
SYMBA PROJECT DATABASE	Regional	Project metadata, types of exchanges, outcomes, performance indicators, policy context
EPOS PLATFORM	Regional and Sectoral	Sector-specific resource flows, exchange opportunities, and environmental and economic impact metrics

Source: LIAISE WG1

The list includes some tools that are also classified as Regional Identification Systems. As shown in Table 7, tools such as ISDATA, CircLean Network, and SYBMA project store information at the regional level, whereas SHAREBOX, EME, and OpenCLA consider only company-level information.

Social Network Synergy Identification Tools aims to foster collaboration by expanding professional networks and enabling companies to create or join IS networks. These tools may be observed in independent or existing social network platforms (van Capelleveen et al. 2018). Companies could disseminate best practices through these platforms; however, they might be hesitant to share data. An example of this tool is the Green Social Network offered by Ghali et al. (2016). This web-based tool, based on social network functionality, enables companies to communicate and build symbiotic relations. On the other hand, IS platforms might have some social networking features that facilitate "interaction spaces" (Yeo et al, 2019) for companies to enable information exchange on needs and wants while identifying possible collaboration opportunities.

5. Identification of Existing Databases, Platforms and IT Tools for IS Facilitation

5.1. Research Results

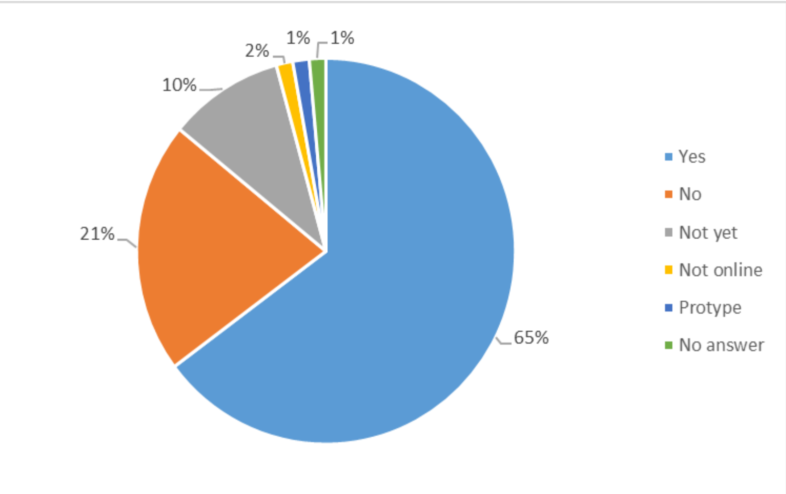
During preparation for this report, members of COST LIAISE Action WG1 conducted i) a systematic review of the literature, focusing on publications and professional papers published in the last ten years. ii) analysis of the key projects, and iii) structured web search to find ICT tools, databases, and platforms that are connected to IS. The study was conducted from April to October 2025. Although the research group identified 69 different examples, it is necessary to state that the research did not find all of them, and this is one of the limitations of the study.

Numerous platforms have been identified, such as: SYNERGie®, ASPIRE, openLCA, Ecocycle, Evreka 360, Waste dashboard, Sfridoo, HGK Waste Exchange, iNEX circular, SYMBIOSIS, SYMBIOTPTIMA, MAESTRI, FISSAC, Circular Flanders, IWMM tool, UNIDO IS Identification Tool (V2), H4C platform/Marketplace, Excess Materials Exchange (EME), Material Match Making Platform (M3P), CircLean Network, Finnish, Industrial Symbiosis System (FISS), SÍMBIOSY Platform and Tools, Platform for Industrial Symbiosis, AquaSPICE Platform, Walnut Platform, CORALIS Platform for IS development, MAESTRI 4TIS, SHAREBOX, BIS screeneing tool, Cambridge Value Mapping Tool, EPOS, European Cluster Collaboration Platform - IS Toolkit, United Circle Digital toolkit, ISDATA, Urban-Industrial Symbiosis Recommendation Platform, GitHub - Awesome IS, Circle Lab - Industrial Symbiosis Platform, SYMBA Project Database, Looplocal, modeFRONTIER, Symbiosis Users Network (SUN), Resource audit tool, Synerplatform, Waste Marketplace, Recycler's Exchange, Co-Recyclage Pro, Water Smart, FISAC Platform, Screening Tool for Industrial Symbiosis, eSymbiosis, Reconomy, DSposal, Recircular, SYNER, INCUBIS, Sowhat, CiculEIRE and Rheaply. Some identified platforms were never launched, highlighting the complexity of IS in practice.

Tools can be applied at various levels, including global, regional, national, or local. The identified tools cover the following areas: Global, USA, Australia, Europe, EU Member States, UK, Ireland, Spain, Portugal, Italy, Netherlands, Switzerland, Belgium, Denmark, Sweden, Germany, France, Hungary, Slovenia, Czech Republic, Romania, Croatia, Turkey, and specific urban areas such as Braunschweig in Germany and Sicily in Italy.

The following figures present the statistical data that was extrapolated from research.

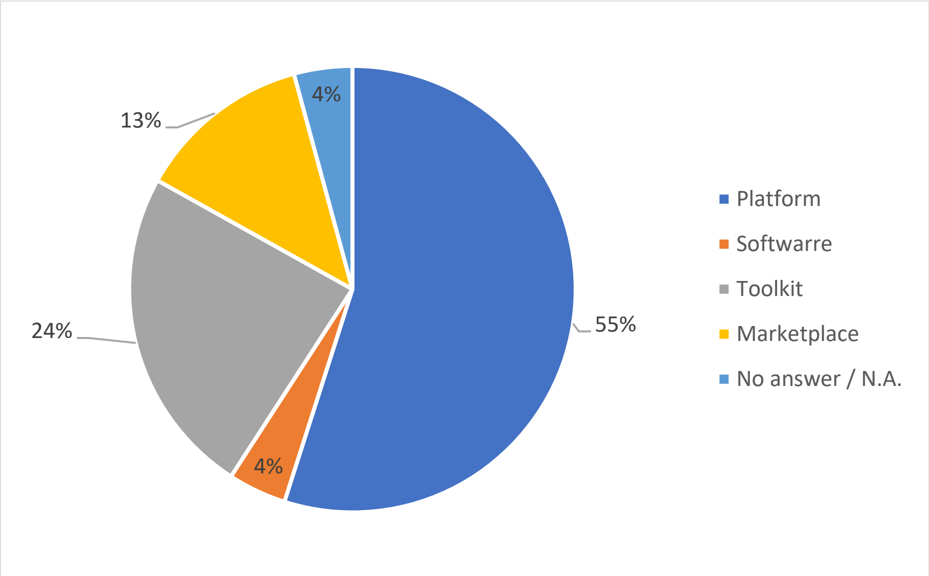
Figure 1. LIAISE COST WG1 IS platforms overview (n=69) - working



Source: LIAISE WG1

Out of 71 identified ICT tools connected to IS, 65% are operational, while 21% are no longer functioning. Some of the tools are still offline and may not be operational. Some of the identified ICT tools were connected to a different EU project, and when the financing was over, they stopped working.

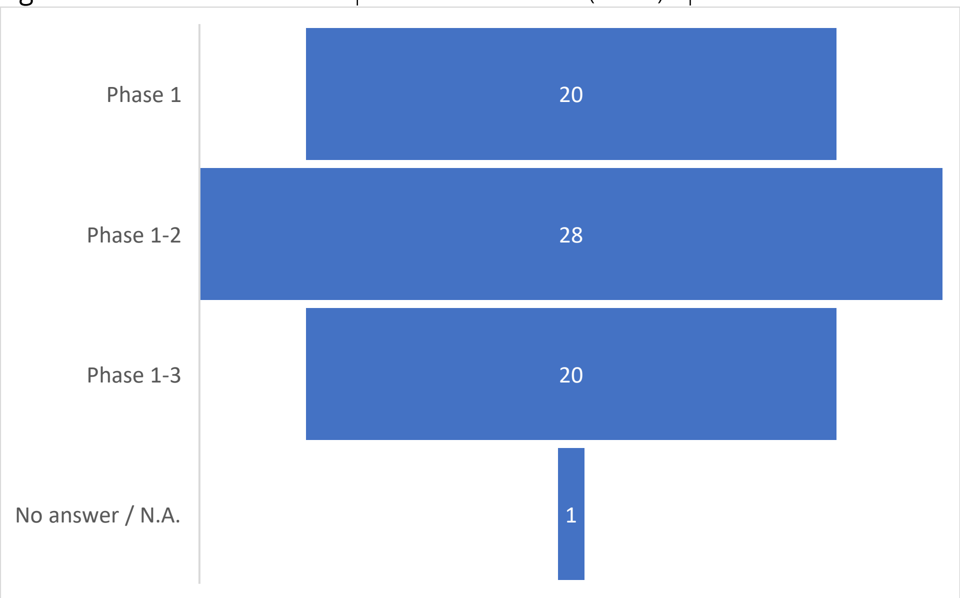
Figure 2. LIAISE COST WG1 IS platforms overview (n=69) - types



Source: LIAISE WG1

Out of the identified 69 different ICT tools connected to IS, research showed that 55% are platforms (with the broadest definition of what a platform is), 23% are different toolkits for IS, and 13% are online waste marketplaces (which do not represent IS in the whole meaning of the definition). For the three identified ICT tools, researchers could not define their type (purpose).

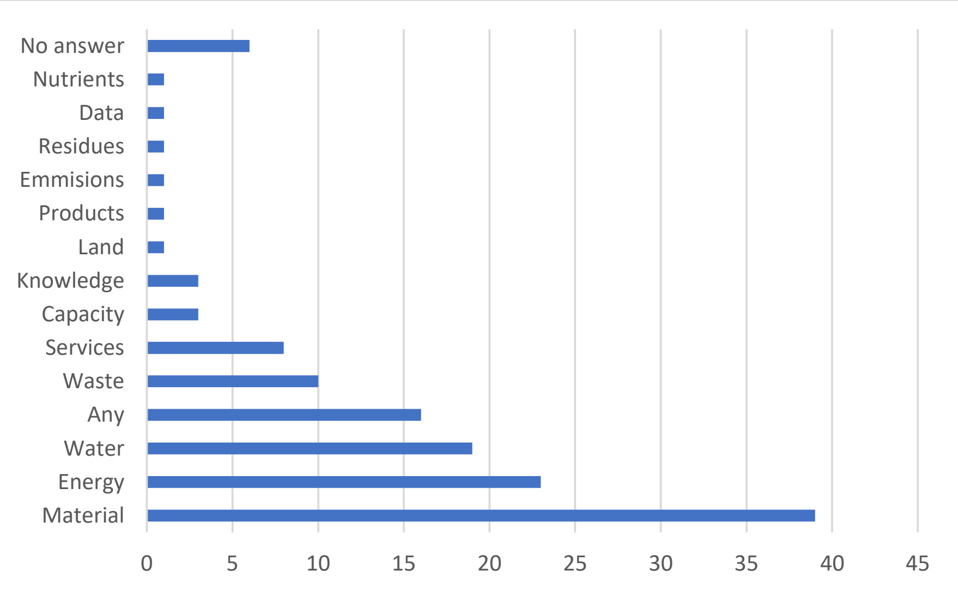
Figure 3. LIAISE COST WG1 IS platforms overview (n=69) - phases



Source: LIAISE WG1

Based on previous reports D1.1 State-of-the-art report on Industrial Symbiosis topic and its different sub-areas (settling the basis for further improvements and their introduction in the industry) (Erceg et al., 2024) and D1.4 Identification of technical and non-technical barriers related to the implementation of Industrial Symbiosis (Krzeminski et al., 2025), researchers have identified 3 IS phases (mapping, assessment, realization). Based on the phase's definition, research has found that most of the identified ICT tools are connected to the first two phases of IS implementation (28 of them), followed by 20 tools that cover phase 1 and 20 tools covering all three phases. For the one identified ICT tool, it was not possible to determine which phases it covers.

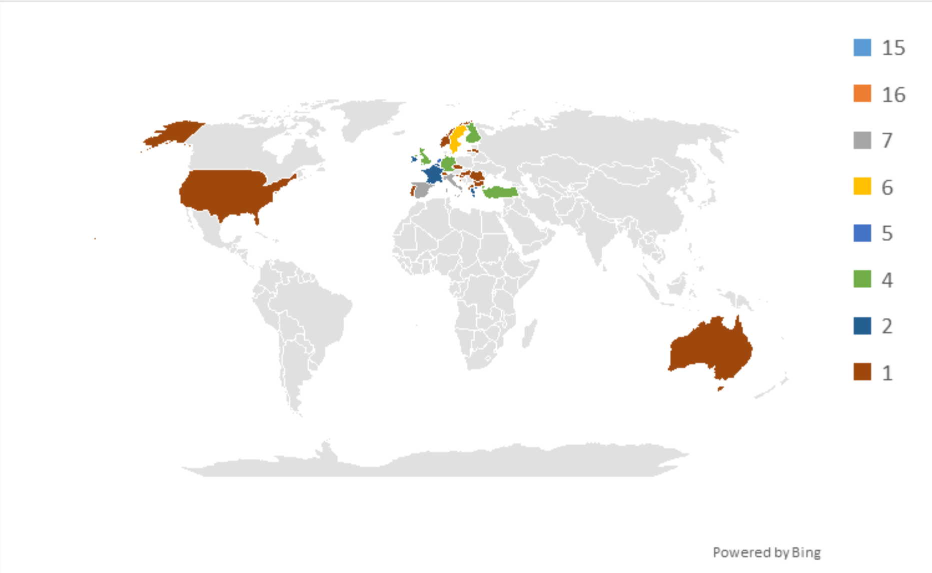
Figure 4. LIAISE COST WG1 IS platforms overview – type of resources



Source: LIAISE WG1

Based on the identified resources, it can be concluded that most ICT tools cover general materials, while some are specifically focused on energy and water. Additionally, some tools are connected to services, knowledge, and data.

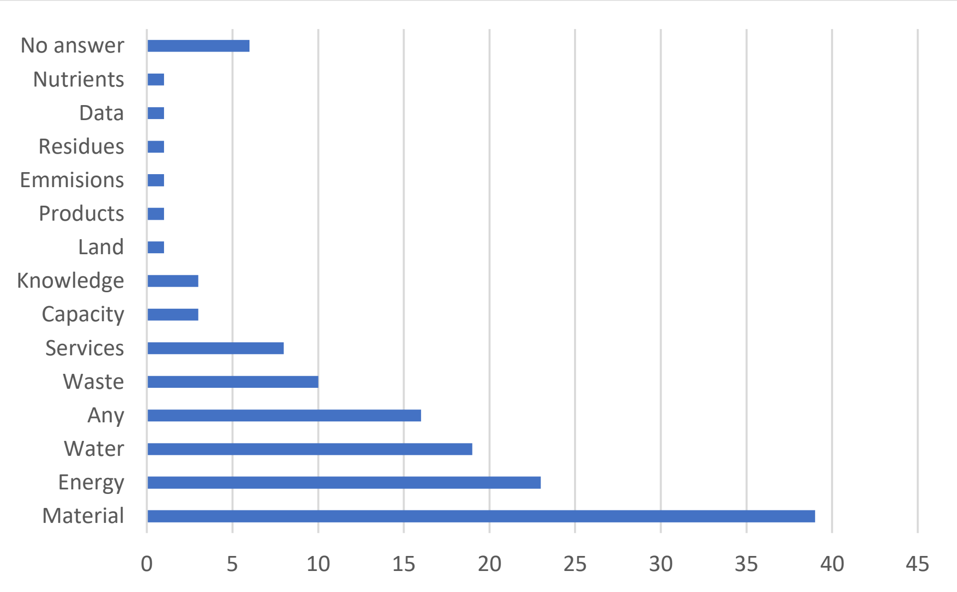
Figure 5. LIAISE COST WG1 IS platforms overview – countries of coverage



Source: LIAISE WG1

When examining the countries they cover, nearly 50% are international (15 international and 16 specifically EU/Europe), whereas there are tools that cover only the countries of origin. Again, coverage shown is mostly European with two "extremes" – the USA and Australia. This is due to research limitations, as WG1 research team members, who are from Europe, were looking for examples of ICT tools in Europe.

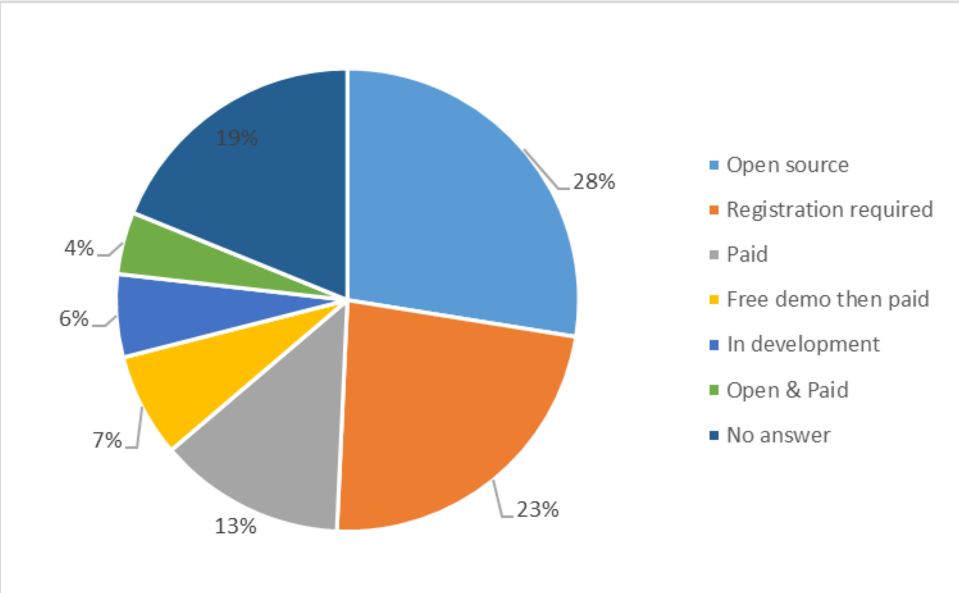
Figure 6. LIAISE COST WG1 IS platforms overview – industrial sectors



Source: LIAISE WG1

When examining the industrial sectors covered by the identified ICT tools within the research, the majority (39 tools) cover all sectors, while 16 are cross-sectoral. All other ICT tools are specific to certain sectors (i.e., metal, wood, construction, etc.). In contrast, six identified tools could not be assigned to specific sectors due to their non-operational status at the time of research.

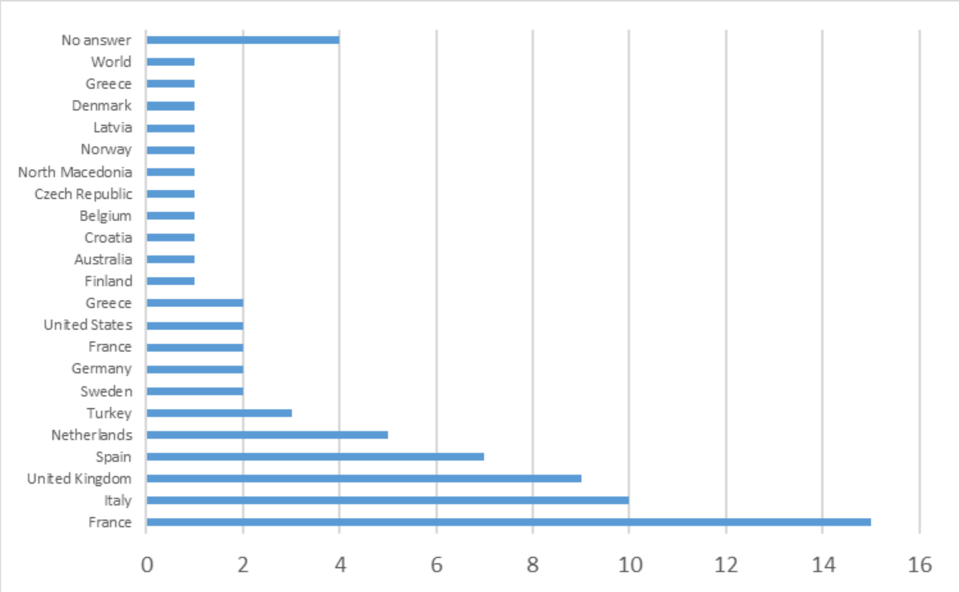
Figure 7. LIAISE COST WG1 IS platforms overview – accessibility



Source: LIAISE WG1

One of the most important characteristics of the identified ICT tools is accessibility. This was measured by asking whether the tool requires payment or is freely accessible. Most of the tools (28%) are open for unrestricted use, followed by the tools for which registration is required (23%). With these tools, it is unclear whether registration requires payment or if they remain open access. For 13% of the tools, payment is required, followed by 7% that offer a free demo, but then necessitate payment for further use. For 13 ICT tools, researchers found no information on accessibility because some tools were not functional at the time of the research.

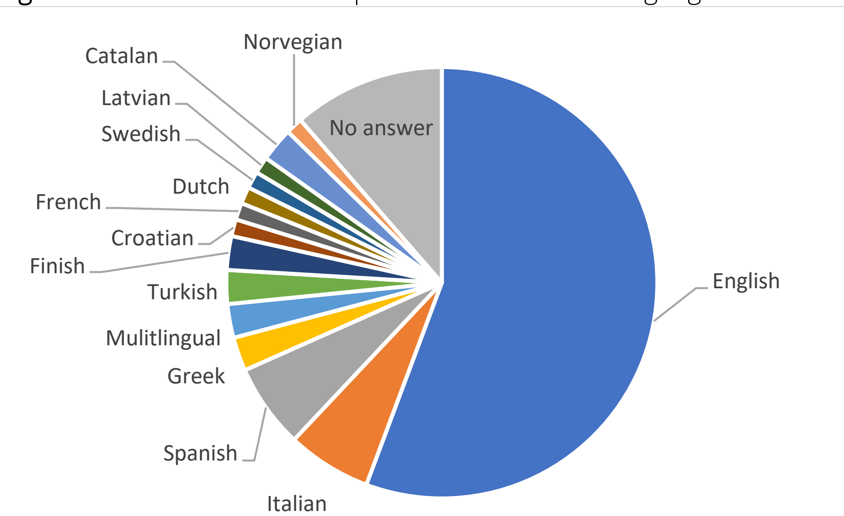
Figure 8. LIAISE COST WG1 IS platforms overview – country of origin



Source: LIAISE WG1

Results for the country of origin are like the coverage results, as the identified ICT tools originate mainly from the EU/Europe and then from specific European countries. For several ICT (4) tools, it was not possible to determine the country of origin.

Figure 9. LIAISE COST WG1 IS platforms overview – languages



Source: LIAISE WG1

The final question in ICT tools research was about the language in which the ICT tool operates. As is the case with countries of coverage where most of the tools cover international areas, here the primary language of ICT tools operations is English (56%). Italian, Spanish, Greek, Turkish, Finnish, etc., follow this. Some ICT tools are multilingual, and WG1 have identified specific regional ICT tools that operate in Catalan. For the 9 ICT tools, there was no answer about the operating language, as they were not functional at the time of research.

5.2. ICT Tools, Platforms and Databases: Selected Examples

During the preparation of the report, the research group has been evaluating identified examples of the IS ICT tools connected to IS (platforms, toolkits, waste marketplaces and software).

A total of 38 IS tools were analysed. Half of them are platforms, accompanying this as the dominant format for IS facilitation, while 23% are toolkits, 15% marketplaces, and the remaining 12% software or hybrid solutions. Nearly 45% of the tools target both facilitators and companies, indicating an overlap in intended users. However, only 15% focus solely on company access, and 21% are exclusively facilitation-oriented, suggesting a gap in tools designed for autonomous company use.

In terms of functionality, 52% of the tools enable the identification of available resources, while 44% facilitate the identification of resource needs. However, only 8% enable selling resources online, and just one marketplace includes a buying function. This reveals a critical gap in transactional capacity; most tools support the identification of synergies but not their operational realization or material exchange. Matchmaking functions, essential for IS implementation, are found in 47% of tools, led by 58% of platforms, whereas only one of the nine toolkits offers this option. Intermediary services, such as logistics or IS facilitation, appear in 58% of tools, again concentrated in platforms.

Self-assessment functions are present in 47% of tools, more common in marketplaces (66%) and software (50%), while reporting capabilities appear in 42%, dominated by software (100%) and platforms (47%). Toolkits consistently underperform across nearly all operational functions, although they remain useful for capacity building, guidance, and awareness-raising on IS.

Overall, platforms stand out as the most balanced solutions for IS implementation, combining facilitation, matchmaking, and reporting, although they still lack strong transactional features. Marketplaces show potential for IS operation thanks to higher self-assessment and transaction functionality but remain limited in facilitation. Toolkits are better suited for capacity building rather than implementation, and software tools excel in data management and reporting, but are less accessible to SMEs.

The analysis reveals that current ICT tools for IS are fragmented and often limited to the connection stage, failing to facilitate actual exchanges between companies. Most still depend on human facilitation and operate in isolation, without the ability to share or integrate data with other systems. As a result, many replicates similar functions, such as resource identification or matchmaking, without building on each other, which limits the creation of a cohesive and interoperable digital ecosystem.

While the digital landscape has advanced in identification and matchmaking, it remains weak in execution, integration, and user engagement. On-the-ground experience further shows that companies are reluctant to use online platforms for transactions, as exchange resources must meet specific quality requirements and negotiations typically occur in person. Consequently, tools that combine facilitation with direct company access and actively support the implementation of synergies can offer a real advantage by bridging the current gap between digital interaction and practical execution in IS.

Table 8. Heatmap of ICT examples from LIAISE action research

NAME OF A TOOL	TYPE OF TOOL (PLATFORM, TOOLKIT, MARKETPLACE)	HOW IS USED (1 FACILITATION, 2 DIRECT COMPANY ACCESS, 3 BOTH, 0 UNKNOWN)	FUNCTIONALITY (1 BUY OR SELL, 2 SUPPLY AND DEMAND, 0 NONE)	FUNCTIONALITY - INTERMEDIARY SERVICES (LOGISTICS/TRAINING/ASSISTED SEARCH) 1 YES 0 NO	FUNCTIONALITY - SELF-ASSESSMENT 1 YES 0 NO	FUNCTIONALITY - REPORTING - 1 YES / 0 NO
AquaSPICE Platform	Platform	1	2	1	1	0
ASPIRE	Marketplace	2	2	0	1	1
BIS screening tool	Toolkit	3	0	0	1	1
CiculEIRE	Platform	0	2	1	0	0
Circular Flanders	Platform	0	0	1	1	1
CYRKL	Platform	3	2	1	1	1
DSposal	Software	3	2	1	0	1
Ecosym	Platform	3	2	0	1	1
Evreka 360	Platform	3	1	1	1	1
Excess Materials Exchange (EME)	Platform	3	2	1	1	1
FLOOW2	Platform	3	2	1	0	1
GitHub - Awesome Industrial Symbiosis	Database/Repository	1	0	0	0	0
INCUBIS	Toolkit	1	2	0	1	0
Industrial Symbiosis Data	Database /Platform	1	0	1	1	0

Repository (ISDATA)						
iNEX circular	Platform	2	2	0	0	0
IWMM tool	Toolkit	0	0	0	0	0
MAESTRI 4TIS	Toolkit	3	0	1	0	0
Material Match Making Platform (M3P)	Platform	3	2	1	0	0
Materialtorget	Platform	3	1	1	0	0
modeFRONTIER	Software	2	1	1	1	1
openLCA	Platform	3	0	0	1	1
Platform for Industrial Symbiosis	Platform	3	2	1	0	1
Recircular	Marketplace	3	2	1	1	0
Resource audit tool	Toolkit	0	0	0	0	0
Rheaply	Marketplace	1	1	1	0	0
Screening Tool for Industrial Symbiosis	Toolkit	0	0	0	0	0
Sfridoo	Platform	2	2	1	0	0
Sidestream database	Platform	0	1	0	0	0
SINERGIA	Platform	3	1	0	0	0
Sowhat web page with a waste heat/cooling toolkit	Toolkit	1	0	1	1	1
SYMBIOSIS	Platform	2	2	1	0	0

Symbiosis Users Network (SUN)	Platform	0	0	0	0	0
Symtrack	Toolkit	1	0	1	0	0
SYNER (SÍMBIOSY Platform and Tools)	Marketplace	3	2	1	1	1
SYNERGie®	Marketplace	3	2	1	1	1
UNIDO Industrial Symbiosis Identification Tool (V2)	Toolkit	1	0	0	1	0
Waste dashboard	Platform	3	1	0	1	1
WasteTrade	Marketplace	2	2	0	0	0

Source: LIAISE WG1

Heatmap legend

Strong functionality Moderate functionality Limited functionality Data not available

Based on the heatmap (Table 8), 24 examples (of the identified 69) have been selected, and they are described in more detail in alphabetical order (Tables 9-32). In the tables, the most important characteristics were presented to provide a better understanding of the ICT tools. Other identified examples are presented in an excel file (link).

Table 9. AquaSPICE

NAME	AQUASPICE PLATFORM
Logotype	AquaSPICE
Provider	AquaSPICE project & University of Huddersfield
Link	https://aquaspice.hud.ac.uk/
Short description of the tool	The AquaSPICE Symbiosis Enabling Platform aims to facilitate the identification and development of one-to-one waste reuse value chains through the collaboration of an industrial waste source and a potential waste user. These proposed symbiotic schemes can be based on liquid, solid, or gaseous waste streams
Country of coverage (current / past)	Europe
Resources covered	Materials, water, energy (solid, liquid, gaseous)
Accessibility (open / registration / paid)	Registration required
How is used	Facilitation, Have/Sell/Supply, Matchmaking (Supply and Demand)
IS phase	Identification, selection, and implementation
Language of application	English
Additional information	N/A

Source: AquaSPICE project & University of Huddersfield, N/A

Table 10. ASPIRE - Empowering Businesses to Exchange Waste as a Resource

NAME	ASPIRE
Logotype	ASPIRE
Provider	CSIRO, Data61
Link	https://aspiresme.com/
Short description of the tool	It functions as a marketplace and matchmaking tool. Track total waste diverted and send notifications when specific types of waste are available
Country of coverage (current / past)	Australia
Resources covered	Material
Accessibility (open / registration / paid)	Open and paid
How is used	Direct company access, Resource marketplace, Report impacts, Have/Sell/Supply, Matchmaking (Supply and Demand), Reporting

IS phase	Identification, selection, establishing connections, and impacts
Language of application	English
Additional information	Data are based on information provided on their website

Source: Aspire

Table 11. BIS Screening Tool

NAME	BIS SCREENING TOOL
Logotype	
Provider	Baltic Industrial Symbiosis Project & Symbiosis Centre Denmark
Link	https://symbiosecenter.dk/screening-tool-for-industrial-symbiosis-facilitators/
Short description of the tool	A screening tool, checklist, or questionnaire that guides IS facilitators through the screening process. The screening sets the scene for business matchmaking by providing potential symbiotic partners with an overview of their internal resource flows and insights into optimizing these flows and their value in future production
Country of coverage (current / past)	Europe
Resources covered	Energy, water, and materials
Accessibility (open / registration / paid)	Open access
How is used	Facilitation and Direct Company access, screening for opportunities, and reporting
IS phase	Identification
Language of application	English
Additional information	N/A

Source: Dansk SymbioseCenter, N/A

Table 12. Circular Flanders

NAME	CIRCULAR FLANDERS – VLAANDEREN CIRCULAIR
Logotype	
Provider	Flemish Government
Link	https://www.vlaanderen-circulair.be/en
Short description of the tool	Circular Flanders is the hub and the inspiration for the Flemish Circular Economy. It is a partnership of governments, companies, civil society, and the knowledge community that will take action together
Country of coverage (current / past)	Belgium
Resources covered	Any resource

Accessibility (open / registration / paid)	Open access
How is used	Circular Flanders brings all these parties together, ensures connections, and offers inspiration and guidance to accelerate the transition to a Circular Economy. Developing and implementing work agendas is no guarantee of success. We need to address the rules, barriers, and habits of the linear economy, and support is needed in various areas. Therefore, in parallel with the work agendas, Circular Flanders focuses on seven levers. Levers are "accelerators" that advance work agendas. They address shared challenges and opportunities through a single, centralized approach. They are led by key players (both government and private), supported by a core group. Partners come from various sectors – from civil society and businesses to investors and government
IS phase	Identification, mapping, and establishing connections
Language of application	English
Additional information	More information is available on the Flemish version of the site than on the English version

Source: Vlaanderen Circulair, N/A

Table 13. Cyrkl

NAME	CYRKL
Logotype	
Provider	CYRKL Zdrojová platforma, s.r.o.
Link	https://www.cyrkl.com/en
Short description of the tool	Cyrkl is an international technology and consulting company specializing in circular waste management. Thanks to advanced technological solutions, Cyrkl helps companies turn waste into resources and thus into revenue with Europe's largest digital marketplace for waste and residuals. In the area of consulting, they rely on our team of waste management experts. With our Circular Waste Scans, they analyze your company's waste streams and identify potential for CO_2 and cost savings. Cyrkl provides market analyses and facilitates the transfer of recycling technologies and legislation. With these activities, Cyrkl brings innovation and circular economic principles to the world of waste management
Country of coverage (current / past)	Worldwide
Resources covered	Waste
Accessibility (open / registration / paid)	Registration needed - Free

How is used	The tools provide consulting services and facilitate connections with waste management partners. Cyrkl offers optimization of waste management with tailored consulting services—from Circular Waste Scans to Green Sourcing. They offer to help in cutting costs, boosting resource efficiency, and achieving full regulatory compliance. Make waste management one less thing to worry about with Cyrkl Waste Copilot. Their service ensures significant cost savings, transparent partnerships, and innovative improvements for your waste strategy, from waste logistics and compliance with the latest regulations to cost-cutting, waste prevention and alignment with your ESG goals. Cyrkl will help the company meet high standards every step of the way
IS phase	Identification, mapping, and establishing connections
Language of application	English
Additional information	N/A

Source: Cyrkl, N/A

Table 14. Dsposal

NAME	DSPOSAL
Logotype	
Provider	Disposal is a UK-based technology company
Link	https://dsposal.uk/
Short description of the tool	Commercial software to match and transact resources
Country of coverage (current / past)	International
Resources covered	Materials
Accessibility (open / registration/ paid)	Paid
How is used	Facilitation and Direct Company access, Waste management, Have/Sell/Supply, Matchmaking (Supply and Demand), Reporting.
IS phase	Identification, mapping, and establishing connections
Language of application	English
Additional information	N/A

Source: Dsposal, N/A

Table 15. Ecosymbiosis

NAME	ECOSYM
Logotype	
Provider	Ecosymglobal
Link	https://www.ecosymglobal.com/
Short description of the tool	An AI-powered platform that creates matches between waste generators and potential users, establishing IS networks that benefit both businesses and the environment
Country of coverage (current / past)	Türkiye
Resources covered	Any
Accessibility (open / registration/ paid)	Paid
How is used	Facilitation and Direct Company access, matching (Supply and Demand), Reporting
IS phase	Identification, mapping, and establishing connections
Language of application	English, Turkish
Additional information	N/A

Source: Ecosymbiosis, N/A

Table 16. Evreka360 Platform

NAME	EVREKA 360
Logotype	
Provider	The founders of Evreka are Mehmet Pancaroglu, Berkay Akcora, Mert Barutcu, and Umutcan Duman.
Link	www.evreka.co/evreka360
Short description of the tool	Evreka is a Turkish-based smart waste management company that provides comprehensive software and hardware solutions. Their platform, Evreka360, is designed to digitize and optimize the entire waste management process for companies, municipalities, and local authorities.
Country of coverage (current / past)	Anywhere is integrated
Resources covered	Any
Accessibility (open / registration/ paid)	Free demo / then purchase

How is used	Operations & Fleet Management: Optimizing routes, tracking vehicles, and supervising daily tasks. Asset Management: Using smart sensors to monitor waste containers and prevent overflows. Data & Finance: Providing data-driven insights and financial management tools for better decision-making. Customer Engagement: Facilitating communication with citizens via a mobile app. Have/Sell/Supply, Reporting
IS phase	Identification, selection, and environmental impact quantification
Language of application	English
Additional information	N/A

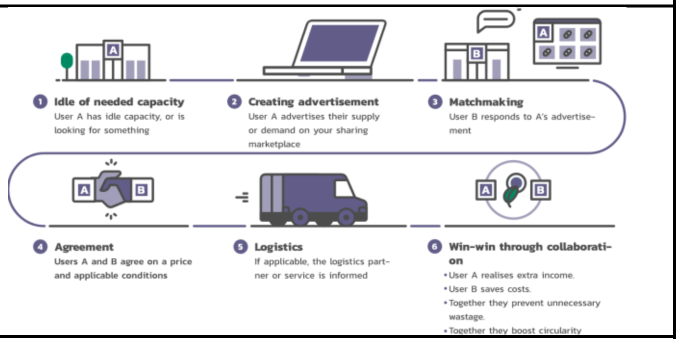
Source: Evreka, N/A

Table 17. Excess Materials Exchange

NAME	EME (EXCESS MATERIALS EXCHANGE)
Logotype	
Provider	Excess Materials Exchange B.V.
Link	https://excessmaterialsexchange.com/
Short description of the tool	EME is a pioneering digital platform designed to accelerate the transition to a Circular Economy by facilitating the efficient reuse of materials and products. The EME is an online, facilitated marketplace where companies can exchange any excess material B2B. They match supply and demand, and they match materials with their highest reuse opportunities. It is a matchmaking site for materials. They match supply and demand with materials that have their highest reuse opportunities. It is a matchmaking site for materials
Country of coverage (current / past)	The Netherlands and the EU
Resources covered	Material
Accessibility (open / registration / paid)	Paid
How is used	Facilitation, Resource marketplace, Have/Sell/Supply, Matchmaking (Supply and Demand), Reporting
IS phase	Identification, selection
Language of application	English
Additional information	N/A

Source: Excess Materials Exchange, N/A

Table 18. FLOOW2

NAME	FLOOW2
Logotype	FLOOW2 COMMUNITY
Provider	FLOOW2, Nijverheidsweg 32, 5061KL Oisterwijk, The Netherlands
Link	https://www.floow2.community/community-en.html
Short description of the tool	FLOOW2 has specialized in developing sharing marketplaces since 2012. They bring all this experience together in one low-threshold tool for every organization, network, or region. With a FLOOW2.Community: companies can create a professional sharing marketplace for employees, partners, or colleagues to make supply and demand transparent. Equipment, consumables, furniture, services, facilities and knowledge; by optimizing usage of available capacity, you enhance efficiency, collaboration and sustainability. FLOOW2.Community is perfect for: Universities, Cities, Area management, Business networks, large organizations for internal usage, Market sectors
Country of coverage (current / past)	Netherlands
Resources covered	All
Accessibility (open / registration / paid)	Paid
How is used	
IS phases	Identification, mapping and establishing connections
Language of application	Dutch, English
Additional information	N/A

Source: Floow2, N/A

Table 19. Incubis

NAME	INCUBIS
Logotype	INCUBIS ENERGY SYMBIOSIS INCUBATOR
Provider	Simbiosy Created in the Incubis Project, which received funding from the European Union\'s Horizon 2020 research and innovation program under Grant Agreement No. 894800
Link	https://incubis.org/auth/incubis-login
Short description of the tool	A toolbox for delivering the IS Incubator Services (via energy use)
Country of coverage (current / past)	Europe
Resources covered	Energy
Accessibility (open / registration / paid)	Registration required (free)
How is used	Facilitation, Matchmaking features, Ranking tools, Feasibility tools, Best practices, Guidelines, Training materials, Funding opportunities The platform facilitates three crucial steps for Energy IS: IDENTIFY, ASSESS, and REMOVE BARRIERS. Services, Matchmaking (Supply and Demand)
IS phase	Matchmaking features, Ranking tools, Feasibility tools, best practices, Guidelines, Training materials, Funding opportunities
Language of application	English
Additional information	A toolbox for delivering the Industrial Symbiosis incubator services. Matchmaking features, Ranking tools, Feasibility tools, best practices, Guidelines, Training materials, Funding opportunities Benefits to: IS facilitators, Industrial parks, Factories that manage heat residues, SMEs, and Investors. Public stakeholders promoting symbiosis schemes. A virtual incubator for IS projects (based on energy)

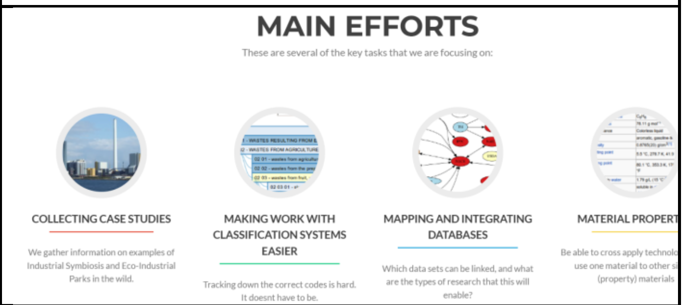
Source: Incubis, N/A

Table 20. iNEX circular

NAME	INEX CIRCULAR
Logotype	iNex ECO SYSTEM EXCHANGE
Provider	iNex, Eco System Exchange 80 rue la Condamine 75017 Paris, France
Link	https://www.inex-circular.com/en/resources-and-wastes https://www.inex-circular.com/en/inex-plateform
Short description of the tool	iNex instantly shows local potential synergies for your wastes or resources. It allows direct collaboration between « givers » and « takers ». As a "third-party trustee," iNex remains neutral and facilitates cooperation; it is not a broker and does not interfere with logistics. The iNex platform instantly shows synergy potential and simulates savings. It uses big data techniques and a comprehensive knowledge base on waste reuse
Country of coverage (current / past)	International
Resources covered	Materials, services, energy
Accessibility (open / registration / paid)	Demo request, then registration
How is used	Workshops and project definition - iNex experts provide services to organize workshops with companies from your ecosystem, and to evaluate projects in terms of logistics, technique, environment and economy. Synergies platform - The iNex platform identifies synergistic opportunities, simulates them, and offers the necessary tools to establish a community, facilitate follow-up exchange projects, monetize them, and manage legal documents. 
IS phase	Identification, monitoring
Language of application	French, English
Additional information	N/A

Source: iNex, N/A

Table 21. Industrial Symbiosis Data Repository (ISDATA)

NAME	INDUSTRIAL SYMBIOSIS DATA REPOSITORY (ISDATA)
Logotype	IS DATA
Provider	Industrial Symbiosis DATA
Link	https://isdata.org/
Short description of the tool	Online repository of IS projects and input-output matching resources. The Industrial Symbiosis DATA repository is an open platform for collecting and supplying structured information on IS. In addition to providing a source of best practice activities, the platform has been established to enable various user segments to utilize this data on Industrial Symbiosis in conjunction with other open or proprietary data sets. A collection of tools has been created to support the utilization of various data sources, assisting platform users according to their interests and goals. Example Applications: - Symbiosis input-output matching websites - Market and technology analysis in conjunction with internal data - Automatic suggestions for classification codes
Country of coverage (current / past)	Finland / Sweden
Resources covered	All
Accessibility (open / registration / paid)	Open source
How is used	
IS phase	Identification, selection, monitoring
Language of application	English
Additional information	N/A

Source: IS Data, N/A

Table 22. Kiertotalouden Markkinapaikka Yrityksille

NAME	MATERIALTORGET
Logotype	Materiaalitori
Provider	Ministry of Environment & Motiva
Link	https://www.materiaalitori.fi/
Short description of the tool	The Materialitori is intended for the professional exchange of waste and side streams of companies and organizations. The Materialitori can also be used to search for and offer services related to these materials, such as waste management and expert services
Country of coverage (current / past)	Finland, Sweden
Resources covered	Materials, energy, water
Accessibility (open / registration / paid)	Free, Registration required
How is used	Facilitation and Direct Company Access Companies can showcase their unused waste and surplus on the Material Market, as they can find a use for it Have/Sell/Supply goods (waste)
IS phase	Identification, selection
Language of application	Finish, Swedish
Additional information	N/A

Source: Materiaalitori, N/A

Table 23. Symbiosis Space – MAESTRI – Energy and Resource Management Systems for Improved Efficiency in the Process Industries

NAME	MAESTRI 4TIS
Logotype	MAESTRI RESOURCE AND ENERGY EFFICIENCY FOR PROCESS INDUSTRIES
Provider	H2020 MAESTRI project
Link	https://maestri-spire.eu/symbiosis-space/
Short description of the tool	The MAESTRI Toolkit for Industrial Symbiosis (T4IS) is a self-guided process that helps companies identify potentially exploitable waste and develop value creation strategies
Country of coverage (current / past)	Europe
Resources covered	Energy, water, residues and recycled materials
Accessibility (open / registration / paid)	Open access

How is used	Facilitation and Direct Company Access Provides support in identifying new ideas for alternative waste reuse, as well as the process to implement them
IS phase	Identification
Language of application	English
Additional information	https://ee-ip.org/en/article/demystifying-industrial-symbiosis-a-comprehensive-guide-to-opportunity-identification-7803

Source: MAESTRI, N/A

Table 24. Recircular - Platform for Buying and Selling Waste and Company Assets

NAME	RECIRCULAR
Logotype	recircular
Provider	Spanish Ministry of transformation in ecology and demography in Collaboration with the EU
Link	https://recircular.net/
Short description of the tool	Matching software charges 10% of the transaction value
Country of coverage (current / past)	Spain, but visible in the international range
Resources covered	Wastes, by-products, equipment
Accessibility (open / registration / paid)	Open
How is used	Facilitation and Direct Company access, Resource marketplace, Sell/Supply/Demand goods
IS phase	Identification/Assessment/Selection/ Selling extra Environmental Impact
Language of application	Spanish/English /Basque
Additional information	Selling wastes and by-products from the agrifood industry, chemicals, computers and office equipment, Construction and demolition material, Containers and storage, Electrical and electronic equipment, Glass and fibreglass, Industrial tools and equipment, Metals and cables, Oils and fuels, Paper and cardboard, Plastics, rubber and foam, Sludge and soil, Textiles and leather, Vehicles and parts, Wood

Source: Recircular, N/A

Table 25. The Rheaply Platform for Efficiency at Scale

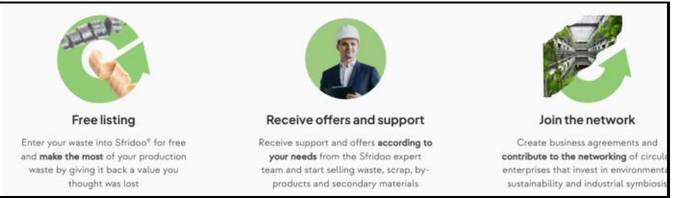
NAME	RHEAPLY
Logotype	Rheaply
Provider	*Dr. Garry Cooper, founder*
Link	https://rheaply.com/

Short description of the tool	Although focused on circular asset management (such as furniture or equipment), Rheaply is a digital platform that enables reuse within and between organizations. I believe it presents a valid case for industrial resource sharing
Country of coverage (current / past)	USA
Resources covered	Material resources
Accessibility (open / registration / paid)	Paid
How is used	Facilitation, Consultation, and a resource/reuse marketplace in US cities. Rheaply is a website for selling used objects. In the manufacturing section, waste from various facilities, used equipment, and old materials are sold for further use or reuse
IS phase	Identification, establishing connections
Language of application	English
Additional information	https://app.rheaply.com/s/listings

Source: Reaply, N/A

Table 26. Sfridoo

NAME	SFRIDOO
Logotype	sfridoo
Provider	Sfridoo S.r.l. Bologna – REA 534620
Link	https://www.sfridoo.com/en/
Short description of the tool	Sfridoo is a platform that enables companies to buy and sell industrial waste, by-products, and secondary materials, aligning with Circular Economy principles. Sfridoo promotes Industrial Symbiosis by fostering collaboration among businesses to exchange functional materials, ultimately seeking to redefine waste as a resource instead of a discarded product
Country of coverage (current / past)	Italy
Resources covered	Materials
Accessibility (open / registration / paid)	Free registration
How is used	Sfridoo is the platform where companies meet to buy industrial waste, by-products, secondary raw material and leftovers, gaining economic and environmental benefits. The platform provides economic and environmental benefits, helping companies to earn or save money through waste transactions, gain a competitive edge and find partners to meet sustainability goals. • Earn or save from buying and selling waste • Gain a strong competitive advantage over your competitors • Find partners to achieve your sustainability goals

	
IS phase	identification, selection, and establishing connections
Language of application	Italian, English
Additional information	Sfridoo is a project co-funded by the European Regional Development Fund POR-FESR 2014-2020 and Climate-KIC Accelerator.

Source: Sfridoo, N/A

Table 27. Symbiosis

NAME	SYMBIOSIS
Logotype	SYMBIOSIS Platform
Provider	AENEAS, Lungotevere Thaon di Revel, 76, 00196 ROME – Italy
Link	http://www.industrialsymbiosis.it/piattaforma
Short description of the tool	The platform is a tool aimed at businesses and other operators in the area. It aims to match supply and demand for resources, including materials, energy by-products, water, services, and skills, and facilitate their transfer between businesses. The goal is to identify and connect local businesses and operators, according to the principles of Industrial Symbiosis.
Country of coverage (current / past)	Italy
Resources covered	Materials, energy, water
Accessibility (open / registration / paid)	Registration required
How is used	The Resource Diagnosis application allows registered companies to enter, through a dedicated interface (with selectable fields that can vary by technology/process/product) and with the support of guidelines and "modular" process layouts specific to the type of plants analyzed in the VALUE CE-IN project (wastewater treatment in municipal and industrial settings provided by the Platform Manager), quantitative information regarding the inputs and outputs of the processes themselves (e.g. identification code, type, quantity, technical characteristics, etc.) and therefore reproduces a schematic representation of the production process, also divided into main phases
IS phase	Identification
Language of application	Italian, English

Additional information	N/A

Source: AENEAS, N/A

Table 28. SYNER - Plataforma de Detección de Sinergias Entre Empresas a Través de Los Recursos Sobrantes

NAME	SYNER (SÍMBIOSY PLATFORM AND TOOLS)
Logotype	syner | Plataforma de Sinergias
Provider	SÍMBIOSY
Link	https://synerplatform.com/
Short description of the tool	Digital tools for resource mapping and facilitation of IS projects. Automatically identify potential collaborations between companies based on surplus materials. Identify and define waste streams in the area with potential for reuse and determine their producers. Explore innovative methods for converting waste into valuable raw materials and identify suitable partners for exchange. Analyse the territory with detailed data and visualized resource flows to better understand the agro-industrial potential of the ecosystem. Access a curated library of cutting-edge solutions and real-world success stories in waste recovery. Seamlessly integrate with existing systems through API technology to uncover new synergies and accelerate IS projects
Country of coverage (current / past)	Spain, Europe
Resources covered	Materials, waste (energy, water)
Accessibility (open / registration / paid)	Paid
How is used	Facilitation and Direct Company access, Resource marketplace, Resource flow mapping, self-assessment, training, facilitation, have/sell/supply goods, Matchmaking (Supply and Demand), reporting.
IS phase	Identification, mapping, and establishing connections
Language of application	ES / Catalan
Additional information	Screenprint of the tool: https://synerplatform.com/que-es-syner/wp-content/uploads/2021/07/PANTALLASINER3.png https://simbiosy.com/wp-content/uploads/2024/02/Poster-SYNER_w1.jpg Advanced marketplace with flow mapping, training, and API integration. Offers a library of success stories and regional analyses

Source: Symbiosi, N/A

Table 29. SYNERGie® - International Synergies

NAME	SYNERGIE®
Logotype	International Synergies
Provider	*International Synergies (ISL)*
Link	https://international-synergies.com/
Short description of the tool	Users enter resources they have and want to identify cross-sector reuse opportunities. Match records can be made and progressed through a series of stages. Outcomes can be recorded against each match, and various reports can be produced and exported. Algorithms enable both manual and system-generated analysis to identify potential match partners. Users can also set up alerts to receive automatic notifications when resources of interest are added to the system. Operates in two modes, facilitator and direct company access, both using the same information but with different levels of access to the data and functionality
Country of coverage (current / past)	UK (any) 20+ countries worldwide
Resources covered	All - material, energy, water, services, land, capacity and beyond
Accessibility (open / registration / paid)	Open and Paid
How is used	Facilitation and Direct Company access, Resource matching with reporting of impacts, Analysis of data, have/sell/supply goods, Matchmaking (Supply and Demand), and reporting
IS phase	identification, selection, progression to live, impact recording, reporting
Language of application	English, French, Hebrew (plus others, including Mandarin)
Additional information	Based on the NISP model, it is globally replicated. Data based on system usage

Source: International Synergies, N/A

Table 30. Industrial Wastes Matchmaking Tool

NAME	INDUSTRIAL WASTES MATCHMAKING TOOL
Logotype	ULTIMATE
Provider	Horizon 2020 project ULTIMATE: industry water-utility symbiosis for a sMarter wATer society
Link	https://iwmmt.uwmh.eu/account/login/?next

Short description of the tool	The “Industrial Wastes Matchmaking Tool” is a digital tool designed to alleviate the information barrier between business-as-usual practices and the Industrial Symbiosis paradigm, emphasizing financial benefits as a key driver for Industrial Symbiosis
Country of coverage (current / past)	International
Resources covered	materials, water, energy
Accessibility (open / registration / paid)	Paid
How is used	The tool provides an abundance of results, valuable to multiple stakeholders/occasions. On the “Global” scale, it provides a very concise picture of financial performance, transaction mass flows, and environmental benefits, effectively providing the user with a much more tangible “rendering” of IS’s impact, clearly motivating towards its implementation. Putting proportional emphasis on the “Individual” set of results—since it is the decision-making on the individual level that can eventually create a symbiotic network—similar financial, mass flow and environmental information are provided, illustrating a compelling case in favour of implementing IS. Strategic emphasis is placed on the “waste stream” level, as any intervention (e.g., adding a material recovery apparatus) will realistically be performed at this level. Therefore, providing a decision-maker of an industrial unit with such detailed and relevant information facilitates the implementation of the corresponding intervention
IS phase	identification, selection
Language of application	English
Additional information	Result of the Horizon 2020 project ULTIMATE: industry water-utility symbiosis for a sMarter wATer society

Source: Ultimate, N/A

Table 31. UNIDO Industrial Symbiosis Identification tool

NAME	UNIDO INDUSTRIAL SYMBIOSIS IDENTIFICATION TOOL (V2)
Logotype	UNIDO
Provider	UNIDO
Link	https://hub.unido.org/sites/default/files/publications/UNIDO%20Industrial%20Symbiosis%20Identification%20Tool%20V2.xlsx

Short description of the tool	The objective of the tool is to support the identification of IS opportunities (by-product and waste exchanges) between companies. This tool can be used in existing industrial parks (brownfields) to provide stakeholders with an indication of the symbiosis opportunities related to companies operating in the park. Alternatively, the tool can be used for new industrial parks (greenfields) to highlight possible IS between companies locating in the park and thereby assist in the planning of infrastructures and utilities to enable these connections.
Country of coverage (current / past)	Any
Resources covered	Any
Accessibility (open / registration / paid)	Open
How is used	Facilitation UNIDO toolbox for creating a database for possible matching
IS phase	Identification, selection
Language of application	English
Additional information	MS Excel files

Source: UNIDO Knowledge Hub, N/A

Table 32. WasteTrade

NAME	WASTETRADE
Logotype	
Provider	Bevin Tumulty (founder), John McKenna (co-founder)
Link	https://www.wastetrade.com/
Short description of the tool	WasteTrade is the pioneering online marketplace that connects waste generators, such as manufacturers, with recyclers and end users of waste commodities around the world.
Country of coverage (current / past)	Worldwide
Resources covered	Wastes
Accessibility (open / registration / paid)	Registration needed (Free)
How is used	Direct access to the company's resource marketplace. Have/Sell/Supply goods, Matchmaking (Supply and Demand)
IS phase	Identification, mapping and establishing connections
Language of application	English, Arabic, Belarusian, Bulgarian, Chinese (China), Chinese (Hong Kong), Chinese (Taiwan), Chech, Dutch, French, German, Greek, Hungarian, Italian, Japanese, Lithuanian, Polish, Portuguese, Romanian, Slovak, Spanish, Swedish, Turkish, Russian, Ukrainian
Additional information	N/A

Source: WasteTrade, N/A

6. Recommendations

The successful implementation of IS hinges on the effective use of appropriate tools and databases throughout various stages of the process, from opportunity identification to monitoring, compliance, and impact assessment (Yazan et al., 2022). Research indicates that most platforms focus primarily on identifying opportunities. Input-output matching is used to connect waste providers to users; however, this process encounters significant challenges due to data barriers. A major obstacle is the difficulty of obtaining reliable input-output data, as companies are often reluctant to disclose confidential production information, and the data collection process can be costly and time-consuming (Neves et al., 2019). Additionally, inconsistent waste classifications and the absence of standardized frameworks compromise data quality (Zhao et al., 2025). Existing methods typically rely on either sector-based data, which is broad yet imprecise, or process-based data, which is more accurate but often incomplete. Different stakeholder groups — including IS facilitators, industries, policymakers, and IT developers — have distinct needs and therefore benefit from customized sets of tools. The following recommendations suggest some tools suited for specific purposes and guide their practical application.

6.1. Tools for Opportunity Identification and Matchmaking

The identification of potential synergies among companies is a fundamental aspect of IS. A variety of platforms, including InduSym, SYNER, eSymbiosis, and the Materials Marketplace, have been developed specifically to facilitate this process. These platforms enable companies to register their waste streams and resource requirements, while automated matching algorithms recommend possible exchanges. Such tools are especially beneficial for IS facilitators who are tasked with coordinating networks of companies, as they provide a structured methodology to discover opportunities. Furthermore, geospatial analysis tools like ArcGIS, QGIS, and CircularityGIS offer regional and national perspectives by mapping the geographical distribution of waste and by-product flows. This capability is particularly advantageous for local, regional and national authorities engaged in the planning of regional Circular Economy strategies. Machine Learning (ML)-based approaches offer a novel and promising avenue for data acquisition in IS. Rather than requiring companies to disclose intricate details about their production processes, ML techniques can forecast relationships between companies and their waste based solely on textual descriptions of their activities and waste streams. This predictive methodology significantly reduces the need for direct input from companies, effectively addressing confidentiality concerns and reducing data collection costs.

Furthermore, ML-based systems are scalable and adaptable, capable of analyzing large datasets across various industries and regions. For IT developers, facilitators, and policymakers, these tools present a robust means to automate opportunity identification and facilitate the transition towards Circular Economy models. Although the approach does face limitations—such as its reliance on high-quality training data and the need for ongoing updates to ensure accuracy — the potential benefits far outweigh these challenges

6.2. Tools for Waste and By-Product Classification and Compliance

Ensuring compliance with regulatory requirements for waste and by-product exchanges is critical in the implementation of IS. Tools such as the European Waste Catalogue (EWC), the ECHA database, and the Basel Convention portal provide standardized classification systems and legal guidance relevant to waste management practices. These resources are indispensable for industries needing to verify the legal permissibility of their exchanges, as well as for policymakers responsible for monitoring and regulating industrial activities. By providing harmonized terminology and classifications, these tools minimize inconsistencies and foster cross-border collaboration.

6.3. Tools for Environmental and Economic Impact Assessment

In addition to identifying opportunities, stakeholders must assess the environmental and economic implications of IS initiatives. LCA tools, such as SimaPro, GaBi, and OpenLCA, are particularly well-suited for this evaluation. These tools facilitate the quantification of reductions in greenhouse gas emissions, enhancements in resource efficiency, and potential cost savings arising from symbiotic exchanges. They are highly recommended for companies looking to illustrate the sustainability impacts of their IS activities to clients, investors, and regulatory bodies. Policymakers can also take advantage of LCA results to evaluate the overall contribution of IS to national or regional sustainability objectives.

6.4. Tools for Real-Time Monitoring of Resource Flows

For industries involved in IS, access to reliable real-time data on resource flows is essential. Internet of Things (IoT)-enabled monitoring platforms, such as Eco-Track, Senseye, and ThingWorx, are particularly valuable in this context. These tools facilitate the tracking of energy, water, and material flows within production processes, delivering accurate and timely data that can be integrated into IS databases. Real-time monitoring not only helps companies to optimize their resources efficiently but also ensures that data shared with IS platforms is current and reliable, thus improving the accuracy of synergy identification.

6.5. Tools for Data Integration and Interoperability

Given that IS encompasses diverse stakeholders and multiple datasets, the ability to integrate and share information across platforms is paramount. Tools such as FIWARE, Apache Kafka, and CKAN are recommended for IT developers and policymakers aiming to create or manage interoperable IS systems. These tools enable the aggregation of data from various sources, ensure secure sharing, and facilitate the development of open data portals. By promoting interoperability, these tools mitigate redundancy and enhance the accessibility of IS-related information for a broader community of stakeholders.

6.6. Tools for Traceability and Secure Transactions

In contexts where sensitive or high-value by-products are exchanged, issues of trust and data security become significantly important. Blockchain-based frameworks, including Hyperledger and Ethereum-based systems, offer robust solutions to ensure traceability and transparency in IS exchanges. These tools allow for secure, immutable recording of transactions, thus fostering trust among participants and ensuring accountability. They are particularly relevant in sectors where compliance with regulations, protecting intellectual property, or ensuring product quality is crucial.

6.7. How It Can Be in the Future

Different tools can play an important role in IS. Table 33 provides an overview of how current technologies and applications can have future potential in IS implementation, management, and control.

Table 33. Proposal for the future use of ICT in IS

TECHNOLOGY CATEGORY	CURRENT APPLICATIONS	FUTURE POTENTIAL	IMPLEMENTATION CHALLENGES
ARTIFICIAL INTELLIGENCE & MACHINE LEARNING	Resource matching algorithms; Pattern recognition; Predictive analytics	Advanced synergy prediction; Automated negotiation; Adaptive learning systems	Data quality requirements; Algorithm bias; High computational costs
BLOCKCHAIN & SMART CONTRACTS	Transaction transparency; Supply chain traceability; Automated contracts	Decentralized governance; Automated payments; Immutable audit trails	Scalability issues; Energy consumption; Regulatory uncertainty
INTERNET OF THINGS (IOT) & SENSORS	Real-time monitoring; Asset tracking; Environmental sensing	Autonomous resource monitoring; Predictive quality control; Smart logistics	Device management; Data privacy; Network connectivity
DIGITAL TWINS	Virtual asset modelling; Predictive maintenance; Scenario simulation	Comprehensive ecosystem modelling; Real-time optimization; Risk simulation	Model complexity; Real-time synchronization; High implementation costs
BIG DATA ANALYTICS	Material flow analysis; Market trend analysis; Performance optimization	Advanced pattern recognition; Predictive market dynamics; Circular KPI tracking	Data governance; Privacy concerns; Storage requirements
CLOUD & EDGE COMPUTING	Platform hosting; Real-time processing; Distributed computing	Edge-enabled processing; Hybrid cloud solutions; Improved latency	Security concerns, Vendor dependency, Network reliability
MOBILE & USER INTERFACE	Mobile access; User-friendly interfaces; Notification systems	AR/VR interfaces; Voice interaction; Personalized dashboards	User adoption; Device compatibility; Design complexity
INTEGRATION & INTEROPERABILITY	ERP integration; Data standardization; API connectivity	Seamless data exchange; Universal standards; Cross-platform compatibility	Legacy system compatibility; Standard development; Technical complexity

Different tools serve distinct purposes within Industrial Symbiosis and should be selected according to stakeholder needs. Facilitators benefit most from matchmaking and geospatial tools to connect companies and map synergies. Industries rely on compliance databases, IoT monitoring platforms, and LCA tools to ensure legal, operational, and sustainability performance. Policymakers require standardized classification systems, open data platforms, and impact assessment tools to monitor progress and guide regulatory frameworks. Finally, IT developers play a critical role in ensuring interoperability and security by implementing integration frameworks and blockchain solutions. By aligning the right tools with the right purposes, the barriers to IS can be reduced, enabling greater adoption and measurable benefits in terms of both resource efficiency and sustainability.

7. Conclusions

The identification and analysis of existing databases, digital platforms, and IT tools for monitoring IS streams company that digitalization plays an essential role in facilitating the transition towards a Circular Economy. However, despite notable progress, the current landscape remains fragmented and uneven in terms of functionality, accessibility, and interoperability.

Findings highlight the role of ICT tools in fostering IS by enabling improved resource matching, knowledge exchange, and collaboration between diverse industrial actors. These digital platforms support the identification of potential synergies, facilitate the tracking and management of material and energy flows, and strengthen the implementation of Circular Economy principles within industrial networks.

The mapping performed within this report demonstrates that most existing tools focus primarily on the early phases of IS—resource mapping and opportunity identification—while far fewer support the realization and monitoring of symbiotic exchanges. While this is understandable as synergy facilitation is primarily needed at the early stages of IS realization, this is also likely a reflection of the maturity of the IS, which is generally in the early phase of development. Moreover, many platforms still rely heavily on human facilitation, lacking automated matchmaking and transactional features. Integration with environmental monitoring systems, such as LCA-based indicators, is still rare but represents a critical direction for future development.

ICT-enabled solutions are shown to enhance operational efficiency, reduce waste, and promote sustainable practices by integrating real-time data analytics with resource sharing mechanisms. The report emphasizes that successful IS depends both on technological innovation and the commitment of stakeholders to share information and actively participate in symbiotic exchanges.

The analysis highlights that most active platforms are European in origin and scope, showing strong alignment with EU Circular Economy and Green Deal policies. Nevertheless, regional disparities persist, and many tools become inactive once project funding ends, indicating the need for sustainable business models for the digitization of IS.

Policymakers should also consider the development of a system connecting or expanding existing reporting systems for emissions and by-products/waste streams that industries use currently (e.g., European Industrial Emissions Portal), with a new system allowing them to identify the available resources and their key characteristics. Such a system would reduce the need to input the site-specific data, and thus reduce the effort needed for industrial actors to explore IS concepts, as the data typically needed for matchmaking platforms would already be available. To strengthen future IS monitoring and implementation, the development of interoperable, user-friendly, and data-secure digital ecosystems is recommended. These should combine matchmaking functions with real-time monitoring, traceability, and performance assessment based on environmental, economic, and social KPIs. The findings recommend further development of user-friendly and interoperable ICT platforms tailored to the specific needs of IS practitioners. It suggests ongoing investment in training and awareness-building to ensure effective adoption of these tools in different sectors and regions.

Overall, this report provides a foundation for understanding the current digital landscape of Industrial Symbiosis tools. It supports the broader objective of the LIAISE COST Action to build a holistic and inclusive framework for IS implementation by connecting technical innovation with collaborative multi-stakeholder engagement. Continued cooperation between researchers, policymakers, and industry stakeholders will be essential to ensure that digital tools not only enable but also sustain Industrial Symbiosis practices across Europe and beyond.

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