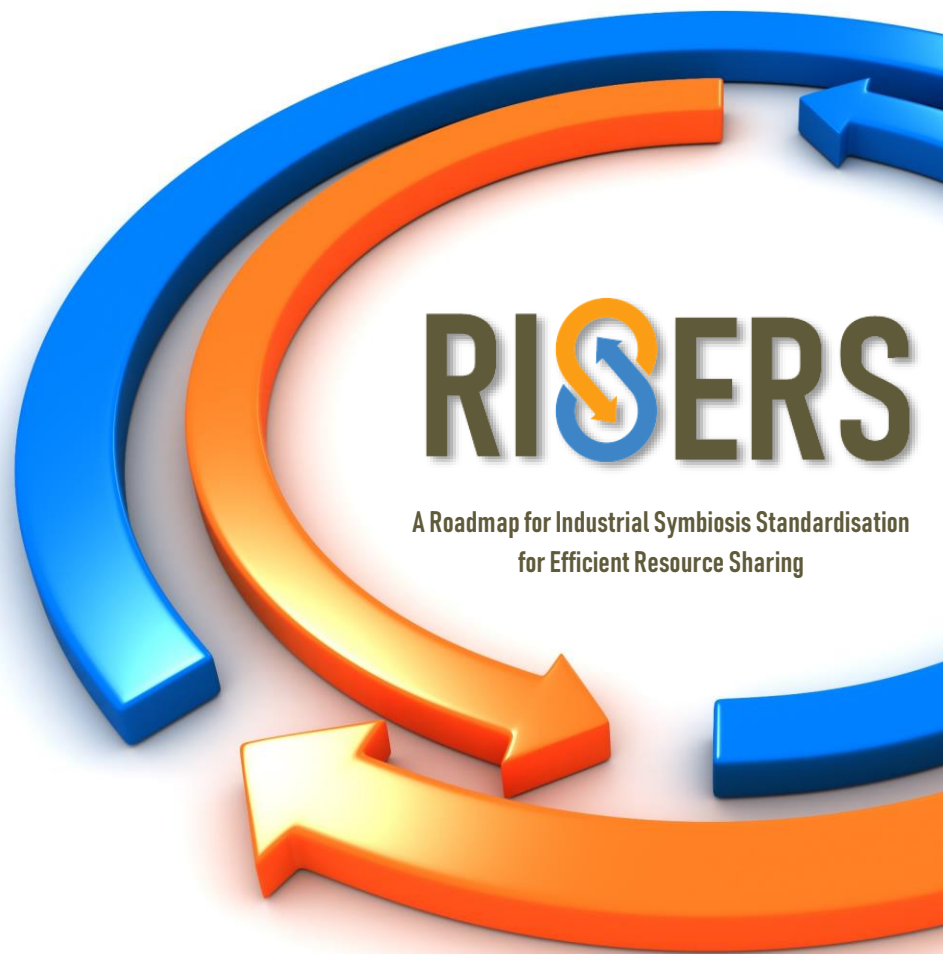




D4.3 MAP OF STANDARDISATION RELATED R&I NEEDS

THIS DELIVERABLE IS AWAITING FORMAL REVIEW BY THE EUROPEAN COMMISSION
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*) **R** — Document, report; **DMP** — Data Management Plan; **DATA** — datasets, microdata, etc; **DEC** — Websites, patent filings, videos, etc

) **Public — fully open (automatically posted online); **Sensitive** — limited under the conditions of the Grant Agreement; **EU classified** — restreint-ue/eu-restricted, confidentiel-ue/eu-confidential, secret-ue/eu-secret under decision 2015/444

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List of Acronyms

Abbreviation	Explanation of abbreviation
CE	Circular Economy
CWA	CEN Workshop Agreement
DPP	Digital Product Passport
EoL	End of Life
EoW	End of Waste
ESG	Environmental, Social, and Governance
IPCC	Intergovernmental Panel on Climate Change
IS	Industrial symbiosis
ISO	International Organization for Standardisation
JRC	Joint Research Centre
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCSA	Life Cycle Sustainability Assessment
PE	Polyethylene
PVC	Polyvinyl chloride
R&I	Research and Innovation
SME	Small and medium enterprise
SRIA	Strategic Research and Innovation Agenda
TC	Technical Committee
WG	Working Group
WP	Work Package

Executive summary

Industrial symbiosis (IS) is a cornerstone of the European Union's transition to a circular and resource-efficient economy. However, its large-scale implementation remains constrained by fragmented, incomplete, and often inconsistent standardisation frameworks.

Deliverable D4.3 – **Map of Standardisation related R&I needs**, provides a comprehensive and evidence-based assessment of the key standardisation gaps that currently limit the operationalisation of IS across Europe. Building on the analysis of over 150 research and innovation projects—of which 21 were identified as highly relevant—this report defines

priority Resource and Innovation (R&I) actions required to align innovation efforts with standardisation processes.

Purpose and Scope

The objective of this deliverable is twofold:

- To identify critical deficiencies in existing standardisation frameworks that hinder the deployment of industrial symbiosis;
- To define targeted R&I priorities that can directly support the development, harmonisation, and uptake of standards.

The analysis is structured across **13 strategic topic areas**, encompassing three cross-cutting domains—Industrial Symbiosis in general, End-of-Waste (EoW), and Digitalisation & Data—and ten theme-specific areas including steel, batteries, packaging, waste heat, textiles, energy data, biomass, construction, finance & market, and Life Cycle Assessment (LCA).

Key Findings

The assessment reveals that **standardisation is the critical enabling mechanism for scaling IS**, yet current frameworks are insufficient to support its widespread implementation. The main findings include:

- **Absence of a unified European framework for Industrial symbiosis**
There is no dedicated European standard defining IS, resulting in inconsistent terminology, methodologies, and implementation practices across sectors and Member States.
- **Fragmented End-of-Waste (EoW) criteria**
The lack of harmonised criteria creates legal and commercial uncertainty, limiting the uptake of secondary raw materials and cross-sector resource exchange.
- **Insufficient digital and data interoperability standards**
Critical gaps persist in areas such as Digital Product Passports (DPPs), data exchange, traceability, and system interoperability, hindering the development of data-driven industrial ecosystems.
- **Sector-specific barriers to circular implementation**
Key sectors face targeted challenges, including:
 - Lack of standards for waste heat contracts and infrastructure;
 - Inconsistent classification and testing frameworks in textiles and packaging;
 - Outdated mandates and lack of performance-based standards in construction;
 - Limited frameworks for circularity assessment in LCA methodologies.
- **Disconnect between strategic agendas and standardisation processes**
Strategic Research and Innovation Agendas (SRIAs) rarely integrate standardisation

as an operational tool, leading to a gap between policy ambitions and practical implementation pathways.

Strategic Insights

The findings confirm that **standardisation is not merely a supporting activity, but a prerequisite for the large-scale adoption of industrial symbiosis in Europe**. Current approaches remain overly sector-specific and product-centric, while IS requires **horizontal, cross-sectoral frameworks** supported by harmonised metrics, indicators, and methodologies.

Furthermore, the report highlights the need to **embed standardisation within the R&I lifecycle**, ensuring that research outputs are aligned with standard development processes and contribute directly to market uptake and regulatory implementation.

Priority Actions for R&I

To address the identified gaps, future R&I initiatives should:

- **Engage early with standardisation bodies (CEN, ISO, TCs (Technical Committees))** to align research outputs with future standards;
- **Leverage flexible instruments such as CEN Workshop Agreements (CWAs)** for rapid standardisation of emerging technologies;
- **Develop robust data, metrics, and Key Performance Indicators (KPIs)** to support standardisation evidence requirements;
- **Synchronise research timelines with standard revision cycles** to maximise impact;
- **Invest in standardisation training and capacity building** within project consortia;
- **Prioritise horizontal standardisation approaches**, particularly for circular economy (CE) indicators and environmental performance metrics.

Expected Impact

The outcomes of this deliverable provide a **strategic foundation for aligning research, standardisation, and policy development**, enabling:

- **Faster market uptake of innovative IS solutions;**
- **Reduced regulatory uncertainty for circular business models;**
- **Improved interoperability and data-driven decision-making;**
- **Stronger integration between European R&I programmes and standardisation systems.**

Ultimately, this report supports the development of a **coherent European roadmap for industrial symbiosis standardisation**, accelerating the transition towards a competitive, resilient, and sustainable CE.

1 [Introduction](#)

Deliverable D4.3, **Map of Standardisation Related R&I Needs**, is linked to Task 4.2, **Identify Research and Innovation Priorities for Industrial Symbiosis**. Its purpose is to translate the findings from previous RISERS activities into a structured analysis of standardisation needs, R&I priorities, and recommendations for future research and innovation actions.

The deliverable has three main objectives. First, it identifies standardisation needs emerging from the analysis of R&I projects, particularly in areas where standards are missing, outdated, fragmented, or insufficient. Second, it proposes recommendations for R&I funding calls and projects to address these gaps and strengthen future standardisation activities. Third, it analyses existing SRIAs to assess how IS standardisation is currently reflected in European R&I planning.

This work builds directly on Deliverable D4.1, **Map of Current R&I Activities Related to Industrial Symbiosis Standardisation**, which screened more than 150 R&I projects and identified 21 highly relevant projects, including 17 finalised and four ongoing projects. These projects were analysed across standards, technologies, and policies to understand their contribution to S standardisation in Europe.

The structure of D4.3 is aligned with the priority synergies identified in RISERS' WP3 (Gaps and opportunities analysis for priority synergies) and with the topic areas considered in the roadmap developed under WP7. The initial framework included three horizontal areas, **Industrial Symbiosis in General, End-of-Waste, and Digitalisation & Data**, and seven vertical areas, **Steel, Batteries, Packaging, Waste Heat, Textiles, Energy Data, and Biomass**.

During the analysis, three additional strategic areas were identified as highly relevant to IS standardisation: **Construction, Finance & Market, and Life Cycle Assessment**. These areas were therefore incorporated into the final structure, bringing the total scope of the deliverable to 13 topic areas.

The deliverable synthesises evidence from publicly available reports, official websites, project outputs, and other authoritative sources. It provides a structured overview of the main gaps, needs, and recommendations required to better connect R&I activities with the development and uptake of IS standards.

2 Standardisation needs

This chapter analyses R&I project outputs to identify where existing standardisation frameworks do not yet adequately support Industrial Symbiosis. It highlights incomplete, fragmented, or emerging areas where harmonised standards are needed to improve implementation, interoperability, market confidence, and regulatory clarity.

The analysis is structured around 13 strategic topic areas. These combine horizontal themes and sector-specific domains, reflecting the cross-sectoral and interdisciplinary nature of IS.

2.1 Industrial Symbiosis in General

IS is a collaborative approach in which traditionally separate industries exchange materials, energy, water, and by-products to improve resource efficiency and reduce environmental impact. By transforming waste streams into valuable resources and fostering cooperation across sectors, IS supports the transition from linear production models to a CE.

One of the gaps identified in R&I projects is the absence of European standards directly addressing the concept of IS. In addition, there is no universally standardised sustainability definition either [1]. It is recommended to introduce new standards to harmonise vocabulary, share best practices, tools, and processes related to the topic [2]. This emphasises the crucial strategy in having a common language to support effective adoption by both the public and private sectors [3]. Current inconsistencies in terminology and methodologies are confusing and hamper the practical implementation of CE and IS. [4]

Standardised indicators are also needed to evaluate environmental performance and CE outcomes. Examples include material circularity indicators, resource productivity, recycling rates, and KPIs for monitoring the performance and impact of IS practices. [5]. These metrics would help benchmark initiatives, identify opportunities, and support evidence-based decision-making. [2].

In addition to conceptual and methodological gaps, administrative, regulatory, technical, social, and accessibility barriers continue to limit implementation. Table 1 summarises the main bottlenecks, including excessive bureaucracy, rigid policy frameworks, insufficient data on waste streams, limited European focus in technical documents, low levels of trust, and poor accessibility of standardisation information [6]:

Table 1 shows that IS standardisation is constrained not only by technical gaps, but also by institutional and organisational barriers. The most urgent needs concern clearer regulatory pathways, better access to data, and a more visible entry point for companies seeking guidance on relevant standards.

The industry requires better alignment between regulation and standardisation, specifically a faster release of harmonised standards from EU standardisation bodies. There is an insufficient ability for industry to determine the objectives of harmonised standards, which contributes to stagnating participation [7]. The primary driver for standardisation is the increasing integration of IS into European Commission policies, reports, and recommendations across multiple Directorates-General and member states [8].

Table 1: Main bottlenecks for IS standardisation implementation

Bottleneck	Description
Bureaucracy	Excessive bureaucracy and prolonged approval timelines for environmental permits are major hurdles.
Policy	Existing policy frameworks are often too rigid to accommodate the innovative, adaptive practices required for IS.
Data	A lack of accessible, up-to-date data regarding the types, location, and availability of waste streams makes identifying symbiosis opportunities difficult.
Technical	Currently, only 15% of technical documents on IS have a dedicated European focus, with most being global or national in scope.
Social	Low levels of trust between communities and administrative bodies, coupled with the "Not in My Back Yard" sentiment, create social bottlenecks to adopting new technologies.
Accessibility	The information available is described as widespread and unintuitive to access (no first-point-of-entry for standardisation), with poor search engine visibility for newcomers.

To ensure efficacy and proportionality, European legislation requires a more coherent methodology. This indicates that current regulatory frameworks may lack the "Innovation Principle" required to support industrial advancement without creating unnecessary friction [9]. Many schemes are product-centric, optimising recovery or design without evaluating symbiotic strategies as a whole or quantitatively, leading to a privileged path for some materials while penalising overall symbiosis management strategies [4].

There is a lack of specific IS focus on company management schemes, when they often embed symbiosis within other requirements. This makes it difficult to define customised environmental targets or allow for homologation and comparisons within specific sectors [4]. The creation of standards that stimulate IS facilitation and synergies help to match the concept of IS cooperation, provides guidance on its facilitation, and promotes supply chain approaches that recognise the value of IS and collective solutions like eco-industrial parks [2].

Current standards often focus on specific waste streams, materials, or product categories rather than on IS as a system of cooperation across companies and value chains. This product-centric approach limits the capacity of standards to support network-based resource exchanges, eco-industrial parks, and collective CE strategies. [4]. Currently, there is no specific standard that refers directly to IS. Existing TCs are just starting the development of this task [10].

2.2 End-of-Waste

EoW refers to the point at which a material, previously classified as waste becomes a product or secondary raw material after meeting defined regulatory criteria. This transition is critical

for IS because it enables recovered materials to re-enter the economy safely, legally, and commercially.

Current standards still tend to focus on treatment and disposal rather than on higher levels of the waste hierarchy, such as prevention, reuse, recycling, and EoW application. R&I projects therefore highlight the need for standards that strengthen extended producer responsibility, promote sustainable product design, reduce material use at source, and support product longevity, repairability, and recyclability [2].

Passive online waste exchanges have seen limited success because they fail to meet specific standardised information requirements for industrial users, such as classification, contamination, distribution, and timing issues [8]. Standards are identified as a necessary tool to help change the "waste condition" of certain outputs, which is a requirement for these materials to be legally and commercially treated as products in the market [5].

Ambiguity and technical barriers also prevent transactions of secondary materials and by-products. There is a need to design standards which harmonise the application and define specific minimum requirements or allow flexibility for using secondary materials and by-products, promoting optimal resource use and guaranteeing material purity [2].

Some existing product standards demand more than is necessary for performance, which can inadvertently exclude the use of recycled materials [11]. There is a specific need for standardisation in recycled content declarations and the "chain of custody" to prove sustainability claims [12]. Fragmented rules across Member States, different permitting procedures, inconsistent waste classifications, and uneven operational practices make it difficult to create reliable markets for secondary raw materials [11].

Standards are also needed to clarify the distinction between waste, by-products, secondary products, and secondary raw materials. This distinction is essential for market confidence, regulatory compliance, and the wider uptake of IS exchanges [1].

2.3 Digitalisation & Data

Digitalisation and data are essential enablers of IS. Sensors, data platforms, analytics, digital twins, and interoperable information systems can improve transparency, resource management, decision-making, and cross-sectoral collaboration.

The main standardisation needs in this area concern scalability, interoperability, reliability, and trust. Digital twins and simulations require verification and validation standards to assess accuracy and uncertainty [9] while SMEs need guidance on selecting and implementing digital tools in a cost-efficient way [1].

Existing manufacturing standards are not yet sufficient to fully support smart manufacturing, Industry 4.0, and circular data exchange. R&I projects point to the need for standards supporting distributed manufacturing services, impact assessment methodologies, and publicly accessible information exchange platforms [2].

Data users and producers face interoperability challenges when combining information from different sectors and systems. Standards are therefore needed for data processing services

[13], product use documentation, repair history, maintenance records, and product lifetime information [12].

DPPs represent a particularly important standardisation area. Interfaces, access rights, data security, traceability tools, data exchange formats, and authentication mechanisms are required to ensure that different actors can interact with product data consistently and reliably across sectors[12]. Eco-design and Product Specifications must include new standards for the durability, reparability, and recyclability of products to ensure they fit into a circular lifecycle [4]. There is also a requirement for standards defining traceability tools and methods, as well as an international format for data exchange (aligned with DPP) to detect anomalies like counterfeits or pollution [14].

To support implementation of the DPP, the European Commission has requested CEN/CENELEC to develop seven harmonised standards by the end of 2025, as described in Table 2. [12]:

Table 2: Seven priority standards to be developed in the DPP are

Standard	Topic
1	Unique identifiers and their global uniqueness across different products, operators, and facilities.
2	Data carriers and the links between physical products and their digital representations.
3	Access rights management, system security, and protection of business confidentiality.
4	Interoperability at technical, semantic, and organisational levels.
5	Data processing, including exchange protocols and data formats.
6	Data storage, archiving, and data persistence throughout the product's life cycle.
7	Data authentication, reliability, and integrity to ensure the truthfulness of provided information.

Table 2 demonstrates that the Digital Product Passport is not only a product-data tool, but also a standardisation infrastructure. Its successful implementation depends on harmonised approaches to identifiers, data carriers, security, interoperability, data processing, storage, and authentication.

2.4 Steel, Slag & Refractories

The steel sector is highly relevant to IS due to the volume and value of its by-products, including slag and refractory materials. These streams can support circularity through reuse in construction, recycling into new materials, and cross-sectoral resource exchanges.

Most existing standards still address steel processes in a linear manner and do not provide a comprehensive framework for steel recycling management. Recycling, reuse, and

reprocessing are generally covered within specific industries or product groups rather than through a cross-sectoral IS perspective [1].

Additional gaps concern the definition, classification, testing, analysis, and technical delivery requirements for metallurgical products. [14].

Standards are also lacking in obsolete vehicle management, which is necessary to manage these valuable waste streams correctly (e.g. steel). There are currently no standardised methods to evaluate the level of demonstrability or the repairability specifically for automotive products [15].

Steel wire characterisation for additive manufacturing is currently guided by welding standards, but most specialists believe these are not applicable [16]. Differences in chemical composition ranges, contaminants, mechanical properties, and the transition from 2D to 3D processes make welding standards insufficient for additive manufacturing [16]. To guarantee quality, measurements must be comparable and reliable worldwide, which requires the use of *Reference Materials and Certified Reference Materials* to achieve metrological traceability [14].

Many of CEN's TCs for metals (e.g. steel) were established decades ago, and there has been a lack of new committee creation for many years [14]. Europe needs to increase its influence within the International Organization for Standardisation (ISO) system, as many recent international committees (e.g. rare earths, lithium) were created at the request of China [14].

The analysis did not identify specific R&I information related to IS standardisation in the refractories sector. The topic title is retained to maintain consistency with the wider RISERS structure, but this gap should be considered a potential area for future investigation.

2.5 Batteries

The battery sector enables IS through the recovery, reuse, and circulation of critical raw materials such as lithium, cobalt, and nickel. By integrating recycling processes, second-life applications, and cross-sectoral material exchanges, battery value chains support resource efficiency and reduce environmental impacts. These practices contribute to closing material loops and advancing CE objectives.

A key standardisation need concerns interoperability between swappable battery systems, vehicles, and stations. This is essential for a sustainable free market and to give consumers freedom of choice [17]. Standards are also requested in battery swapping stations, by including minimum requirements for network density and transparent pricing to avoid unfair competition and ensure user accessibility [17].

Beyond technical interoperability, standardisation is also required to support EU regulations, such as the Battery Regulation and Regulation (EU) 168/2013 (L-category vehicles), by providing technical specifications that ensure compliance with essential legal requirements [17].

Standardisation is also needed for battery-swapping infrastructure across different European vehicle manufacturers. Standardisation is needed to harmonize all interfaces of

vehicle battery systems while still allowing internal battery design to remain manufacturer specific [17].

2.6 Packaging

The packaging sector plays a pivotal role in IS by enabling the reuse, recycling, and valorisation of materials across value chains. Improved design for recyclability, integration of secondary raw materials, and cross-sectoral use of packaging waste can support more circular packaging systems.

The main standardisation needs concern shapes, formats, and materials, which should be harmonised to simplify reuse, sorting, and recycling [5]. While a mandate related to the CE exists, it primarily covers energy-using products, suggesting a gap in broad CE mandates for the plastics sector [18].

Packaging waste has also emerged as a valuable feedstock for additive manufacturing, but standards are still lacking. As a result, projects often rely on practical experience and material characterisation rather than harmonised procedures [16]. Therefore, it is vital to create standardised procedures as it is already happening with regular plastics (e.g. Polyethylene/PE or Polyvinyl chloride/PVC). Standards are needed for diverse packaging waste flows, as different sources may be subject to different regulatory requirements [19].

To facilitate market acceptance and utilisation of developed solutions within the plastic packaging value chain, **Table 3** demonstrates relevant primary standardisation gaps [5] [19]:

Table 3: Standardisation gaps in the plastic packaging sector

Gaps	Description
1	Standards are needed to provide a baseline for interoperability with existing industry recognized state-of-the-art solutions.
2	While stakeholders are initially “users” of standards, there is a need for them to become contributors or project leaders to influence future standardisation.
3	New biopolymers often lack specific application standards because they have not yet reached a significant market share or been assigned to a specific TC.
4	There is a lack of established widely accepted protocols for testing disintegration and biodegradation of plastics in marine environments.
5	Adopt uniform measures related to the plastic life cycle. These measures vary significantly, leading to a lack of uniform European-wide standardisation for certain aspects of packaging treatment.

Table 3 highlights that packaging standardisation must address both material quality and market integration. Gaps in interoperability, biodegradation testing, recycle quality, and stakeholder participation limit the ability of circular packaging innovations to gain wider acceptance.

The use of plastic recyclates also requires standards addressing:

- New applications ensuring recyclability at end-of-life (EoL) establishing quality requirements, performance criteria, and material traceability frameworks [1].
- Definition of impurity and contaminant (such as plastics from packaging) limits according to intended applications [1].
- Assessment methods for evaluating the quality of secondary raw materials [20].
- The absence of dedicated resin identification codes also creates barriers for sorting, classification, and recycling [21].

The analysed R&I sources did not provide information on other packaging materials such as steel, wood, or aluminium. This section therefore focuses specifically on plastics.

2.7 Waste Heat

Waste heat is a valuable IS resource because it enables excess thermal energy from industrial processes to be reused in district heating, neighbouring facilities, or other productive applications. This improves energy efficiency and supports more integrated circular energy systems.

A major barrier is the absence of EU-level legislation specifically targeting waste heat recovery. This creates uncertainty for investors and limits confidence in the long-term classification and sustainability of waste heat projects.

There are currently no harmonised norms or standard contracts governing relationships between waste heat suppliers and network operators [22]. Industrial waste heat is highly site-specific, depending on product mix, technology type, temperature levels, and local demand, creating significant challenges for standardisation [23].

Standardisation is also notably fragmented in permitting procedures for large-scale heat pumps or solar thermal plants, which significantly delay project deployment [24]. Most existing heat pump standards were originally developed for space heating and air conditioning, which operate at lower temperatures and typically use closed-cycle compression.

Existing standards fail to adequately address industrial operating conditions, particularly higher temperatures and process-specific requirements [25].

There is an urgent need for standardised *Heat Purchase Agreements* and rules for third-party access. Currently, the sector presents no consistent guidelines or clear protocols for metering, dispatch, or tariff structures for decentralised sources [26].

2.8 Textiles

The textile sector contributes to IS the recovery, reuse, and recycling of fibres, fabrics, and production residues. Cross-sectoral exchanges and the use of secondary raw materials can reduce waste, lower resource consumption, and support more circular and sustainable textile value chains.

A central barrier is the lack of consistent classification and sorting systems. Standardisation is needed for tags, QR codes and other data carriers that can support high-speed automated sorting. Without standardised classification systems, the automation and interoperability required for a DPP in textile materials are nearly impossible [27].

Basic characteristics, such as colour, are recorded inconsistently across the textile industry. There is also a lack of clear standards for complex terms like "multilayer" and related concepts such as fabric construction [27].

Testing methods are needed to determine the actual recycled content in both synthetic and natural fibres to verify product claims. Current standards cannot distinguish between various types of man-made cellulosic fibres. Specifically, there are no methods to differentiate wood-based cellulose from plant-based versions (such as banana, pineapple, hemp, or nettle) or biological waste [28]. Standards for determining the biodegradability of textiles do not cover all environments. While some methods exist, areas like sea water, fresh water, landfill, and soil are not fully addressed, and "biodegradation" is not always considered [28].

Terminology for environmental aspects remains inconsistent across the textile industry, leading to confusion and hindering sustainable practices. A common language and shared criteria are needed to support circular transformation, improve trust, and enable reliable data sharing across the value chain. [27]. Standardised terminology is required for the transition of EoL material to EoW material (feedstock for recycling), including methods for assessing the quality of the textile material [28].

2.9 Energy Data & Grids

Energy data and grids support IS by enabling the monitoring, optimisation, and exchange of energy flows between industrial actors. Smart grids, real-time data monitoring, and digital platforms can help identify synergies, improve energy efficiency, and strengthen resilience.

Existing energy efficiency standards, such as ISO 50001, need to be expanded or adapted to address inter-plant energy data exchange within industrial clusters. This includes defining system boundaries for groups of companies and measuring shared energy balances [10].

Standards are also required to support remote energy data exchange on an extended scale (remote rather than just local) and systematise the properties of symbiosis to reduce the cost of managing that information [4].

There is also a need for standardised methodologies to measure and report the exchange energy data. Such methodologies would increase transparency, demonstrate environmental and economic value, and support wider industrial adoption of energy-sharing practices [10].

2.10 Biomass & Waste Wood

Biomass and waste wood support IS through cascading use, valorisation of organic and lignocellulosic resources, and the conversion of residual streams from forestry, agriculture, and wood-processing industries into energy, bio-based materials, and chemical applications. Through cross-sectoral exchanges and efficient resource utilisation, these practices reduce waste, optimise material value, and support broader circular bioeconomy objectives.

Current methods do not fully account for different parameters of biomass availability, such as socio-economic factors and anthropogenic stocks [29]. Subsequently, there are insufficient standards governing the general and specific requirements of biomass resources, such as quality, variability, and material property measurement. Additionally, there is a lack of standards for specifying product lifetime or appraising the value of natural generative resources like biodiversity [10].

Bio-based products require standards demonstrating that their physical and technical performance is comparable to fossil-based alternatives [30]. Existing sustainability criteria (e.g. EN 16751) only address the bio-based part of a product. They do not cover fossil or mineral parts, making it impossible to make a sustainability claim for the whole product without additional standards [30]. A systemic bottleneck is the confusion between bio-based content and biodegradability. Bio-based carbon content is not an indication of biodegradability, as bio-based compounds can be either biodegradable or non-biodegradable [30]. This leads to the lack of harmonised rules for allocating by-products across different sectors.

Standardisation is needed for biogenic carbon and land use change assessment, conducting to inconsistent results in bio-based product assessments [29].

Standardisation must also be applied as an instrument to validate the use of urban-managed wastes (solid waste, heat, and wastewater) as a valuable industrial input [6].

The other emergent gap is the absence of standards related to the production of advanced renewable fuels and other products using CO₂/CO as feedstock [21]. Standardisation needs to expand into the area of CO₂ utilisation and avoidance, establishing references for comparable solutions [1].

2.11 Construction

The construction sector offers major opportunities for IS because of its high material consumption and significant waste generation. Reusing construction and demolition materials, integrating secondary raw materials, and valorising industrial by-products can significantly improve resource efficiency and circularity in the built environment.

A key challenge is that many construction product mandates were developed during the 1990s and early 2000s and no longer fully reflect current market realities or Member State needs. Projects should therefore be prepared for standardisation to be a multi-year process that may require the revision of outdated mandates from the 1990s and early 2000s [3].

The uptake of secondary raw materials is limited by uncertainty regarding source, composition, quantity, and quality. Standards and EoW rules to build trust and enable these materials to benefit from the internal market [31]. One possible approach would be the development of standards for measuring material retention and harmonising the legal status of secondary materials across the construction sector. This measure could encourage businesses to choose secondary materials over primary resources. Existing standards and regulations tend to focus on waste treatment and disposal rather than higher-tier priorities like waste minimisation and reuse [10].

Another gap is the absence of horizontal standardised assessment methods to quantify the release of regulated dangerous substances from construction products during their working life. Many existing product standards lack these clauses, though they are expected to be included in future revisions [31]. Standards should shift focus from the operation phase to the production phase, considering resource consumption and emissions during manufacturing. There is also a need for standards that facilitate the simple disassembly of construction materials [1].

A clear place for future standardisation work has been detected for new cement types to ensure they are recognised by the standardization system. Currently, no dedicated standards have been identified for the raw materials incorporated into the kiln for clinker production, as producers currently manage these proportions internally [31]. **Table 4** reveals core needs for the integration of this type of material.

Table 4 shows that low-carbon and innovative cement types face both technical and institutional standardisation barriers. Progress depends on performance-based standards, long-term durability evidence, and stronger coordination between TCs covering cement, concrete, and buildings.

Beyond cement formulations, additional standardisation gaps have been identified in concrete applications and emerging construction materials. A key challenge for eco concrete is the development of criteria and testing plans for non-traditional performance characteristics that are not covered by current standardised testing methods [32].

Existing core standards like EN 206 must be considered alongside national technical rules [3]. It is also essential to define the characteristics of recycled and secondary aggregates through standardisation to address regulatory questions and restricted extraction of natural resources [31].

Some wood plastic composites are standardized only for certain uses or test methods, while new applications and design values may still require further standardization. For example, there are existing standards for decking, guardrails, cladding, and material testing, but the field is still under development for broader or newer construction uses.

There is a need for adequate and economical test methods to assess the mechanical and environmental performance of new plastic-based composites, particularly those with a lower carbon footprint [31]. Furthermore, wood plastic composites can be developed by using secondary raw materials (like tyre rubber and waste plastic) to ensure they meet performance requirements and benefit from revised standards. There is a specific need to convert voluntary standards into harmonized standards under the *Construction Product Regulation* to support CE implementation and broader market uptake. [3].

Table 4: Core standardisation needs for new cement types

Reference	Core Needs
EN 14647	Eco cement composition range differs substantially from ordinary cements and standardised specialty cements like aluminat cements [32].

EN 197-1	There is a lack of adapted harmonized testing methods to prove conformity of green cements, which creates challenges for their commercialization [32].
EN 197-6	Innovative cements currently fall out of the existing standardisation scope, which set strict limits on constituent rates to "performance-based" standards [33].
CEN TC 104	Standardisation work is currently split between different TCs (cements, concrete, and buildings), leading to a lack of a harmonised approach. It is necessary to ensure that concrete-related standards and building codes appropriately reference and account for low-carbon cement standards [33].
Other TCs	TCs require evidence of long-term performance and behaviour (durability) of the new cements in real-world applications over time before they can be standardised [3].
Other References	Facilitate the use of a wider variety of supplementary cementitious materials, such as biomass ash, calcined clay, or recycled concrete fines [33].

2.12 Finance & Market

Finance and market mechanisms are essential for scaling IS because they create the economic conditions for cross-sectoral resource exchanges, shared infrastructure, and secondary-material markets. Through innovative financing instruments, market frameworks, and value chain integration, IS initiatives can become economically viable and scalable. These mechanisms facilitate investment in infrastructure, technologies, and partnerships, thereby accelerating the transition towards a circular and resource-efficient economy.

There is a systemic market failure of information regarding resource efficiency. Decision-makers often operate within one industry and lack standardised information flows that would allow them to identify opportunities in other sectors [8]. The rapid issuance and revision of standards to keep pace with technology can also create disincentives for investment, as companies fear adopting frameworks that may soon be withdrawn or outdated [10].

Standardisation and certification can also create administrative and financial burdens, particularly for SMEs. Furthermore, there is a significant lack of awareness and involvement in standardisation bodies [16]. Additionally, SMEs perceive higher bottlenecks than large enterprises, particularly regarding limited access to standards and the resources needed to manage standardisation processes [34].

One of the most significant needs is to decrease the long time for implementing standards in the market. The current decision-making process is viewed as too complex, necessitating simpler access for stakeholders [7]. Existing approaches (such as those in CEN Workshop Agreement/CWA 17354) are often relevant only for businesses and fail to cover the breadth of governance principles (like planning, controlling, and self-governing) that public actors invoke [6].

Discrepancies between European and American standardisation systems also represent a strong trade barrier [34]. The absence of standards/instruments focused on sustainable finance (specifically for green bonds) requires the development of a coherent framework for the bond market to reflect the transition towards a low-carbon transformation. This is supported by voluntary and compulsory instruments and standards should harmonise terminology and procedures for assessing the sustainability of the bonds [2].

A further challenge is the shortage of professionals with the knowledge required to manage complex standardisation documentation [34]. Professionals familiar with the complex language and structure of the standardisation process are rare. Training programmes are needed to help companies, associations, and project consortia engage effectively with standardisation processes. [7]. Another challenge is the gap between technical innovation managers and regulatory experts within companies to ensure that standardisation impacts are properly understood and managed [34].

2.13 Life Cycle Assessment

LCA is a central methodological tool for IS because it enables the environmental impacts of material and energy exchanges to be assessed across value chains. By assessing impacts from a life cycle perspective, LCA supports informed decision-making, identifies efficiency gains, and ensures that IS practices deliver net environmental benefits. This contributes to more transparent, evidence-based, and sustainable implementation of CE strategies.

Although environmental LCA is relatively mature, there is no unified standardised framework linking CE principles, eco-design, and LCA. Standardised methodologies methodologies are still needed to incorporate waste analysis and circularity. [1]. There is a specific need for harmonised LCA methodologies cross-sectoral comparability [34].

While environmental LCA is relatively mature, the broader framework of Life Cycle Sustainability Assessment (LCSA) is hindered by significant gaps. LCSA and Life Cycle Costing (LCC) also currently lack mature impact assessment methods, fully developed databases, and the same level of standardisation as environmental LCA [29].

Rules for calculating material and energy intensities from a life-cycle perspective are not yet fully defined, which hampers standardised reporting [29]. While these models are widely used in process industries, the report notes that there are no specific standards or recommendations dedicated solely to this type of model. Beyond sustainability assessment methodologies, additional standardisation gaps affect process-based modelling approaches used in industrial systems [9].

3 Recommendations for Future R&I Projects

The current chapter provides targeted recommendations for R&I funding calls and projects aimed at addressing identified standardisation gaps and guiding future research and innovation efforts in the field of IS. Building upon the findings of the previous chapter, these recommendations are designed to support the development, harmonisation, and

implementation of standards that can facilitate cross-sectoral collaboration and enhance the scalability of IS practices.

The aim is to strengthen the connection between research results, standardisation processes, and practical market uptake.

The recommendations follow the same 13-topic structure used in the standardisation needs analysis. This ensures traceability between identified gaps and proposed actions.

3.1 Industrial Symbiosis in General

Future R&I projects should engage early with relevant TCs, Working Groups (WGs) and Standardisation Bodies to ensure alignment between research outputs and future standardisation requirements. Early interaction can help projects identify necessary evidence, data requirements, and procedural expectations while increasing the likelihood of translating research results into recognised standards. Table 5 displays IS recommendations for future R&I projects.

It is also recommended that innovation projects conduct two to three best-practice examples with rigorous scientific backing. These pilots should demonstrate safety and effectiveness to address public fears and support the transition for EU regulations [6]. Research should explore how local governments can act as enablers rather than just facilitators, incorporating principles of planning, controlling, and self-governing into the standardisation process [6]. The inclusion of "Innovation Deals" is highly mentioned too. This ensures that as legislation is adjusted to support innovation, standards are updated simultaneously to avoid regulatory uncertainty [1].

In the human resources sector, the creation of new professional roles is supported specifically to manage complex energy flows between different industries and research areas [10]. Technical teams (who use standards for product characterisation) and administrative teams (who handle exploitation and surveys) must be aligned to accurately report and utilize standardisation activities [5]. Thus, R&I projects should perform standardisation training at the beginning of the project to ensure the consortium understands how standards are developed and how they can support the uptake of project outputs [15]. Standardization workshops should be performed with other projects funded under similar calls too. This would help to identify overlapping needs (e.g., interoperability, terminologies, or KPIs), initiate shared standardisation activities, and increase the weight and likelihood of adoption for their proposed solutions [15].

For cross-cutting topics such as CE, research should move away from industry silos and consider standardisation horizontally to avoid duplication of effort [1]. R&I projects should include specific references to involve standardisation bodies whenever concrete needs for standards are identified. This approach is intended to increase awareness and accelerate the application of new knowledge within industrial and commercial environments [7]. Therefore, research results should be timed to coincide with the revision cycles of major standards to ensure that the project influences the next generation of industry requirements [18].

Table 5: Recommendations for future R&I projects

Dossiers	Recommendations
Industry	Projects should involve a wide range of stakeholders to ensure that future standards reflect industrial reality rather than theoretical models [16].
Terminology	Terminology should be harmonised through common vocabulary and shared definitions provided by the CWA to unify understanding across public and private stakeholders [8].
Committees	Appoint delegates with high social competence and the authority to make internal decisions for their organizations. At least one project partner should collaborate early with a standards committee to understand procedures and identify influential members [17].
CWA	Utilise the CWA process because it is designed to be compatible with research projects and offers a suitable route for standardisation when no specific TC exists for a topic [8].
Tangible Standards	Develop tangible standards via CWAs, which are specifically recommended for their speed and flexibility in handling innovative solutions. If no standards exist for a new technology, a CWA is recommended to implement a technical framework for compliance with changed regulations [1].
KPIs	Define KPIs to monitor the uptake and effectiveness of standards and CWAs generated through project activities [7].
Research	Identify where pre-normative research is needed to fill data gaps that prevent the TC from reaching a consensus on new standards [32].
Market	Allow project results to be shared with market stakeholders and technical experts nominated by businesses, consumers, and environmental groups, building a consensus around the new technologies. Standardisation should be viewed not just as a technical requirement but as a tool for dissemination [18].

Future research should also prioritise areas where standardisation is currently lacking or evolving rather than focusing on traditional properties. Traditional mechanical and physical-chemical properties already have hundreds of well-known standards. The real added value lies in properties related to the CE and environmental indicators. Research should target these emerging fields to ensure new solutions are market-ready and recognised [18].

Formal standards (ISO, EN) often take more than two years to develop, which is often too slow for the fast-paced nature of R&D projects. For that reason, innovation projects should focus on developing specifications rather than formal standards [15].

3.2 End-of-Waste

Future R&I projects should support the development of uniform European criteria for determining when a material ceases to be waste. This would reduce uncertainty created by regional disparities, inconsistent interpretations, and case-by-case decisions [10].

Projects should clarify definitions such as waste, by-product, secondary raw material, and secondary product. They should also identify responsibilities and incentives that enable companies to participate in IS [8].

Research should support standards that prioritise material reduction at source, product longevity, repairability, and reuse [2]. The use of waste as raw materials is a major bottleneck for the non-ferrous, fertilizer, and iron and steel sectors. Research actions should develop policies that facilitate the use of different sources of circular materials (such as nitrogen, phosphorus and sulphur compounds in the fertiliser sector) without creating disproportionate administrative burdens [9].

Future projects should build on the Joint Research Centre (JRC) report (e.g. towards a better definition and calculation of recycling) to develop standardised calculation rules for recycled content that follow physical material flows rather than mass balance approaches [11]. To overcome the bottleneck of market hesitation, research projects should demonstrate the successful use of recyclates in market-ready products using defined performance standards.

3.3 Digitalisation & Data

Future R&I projects should develop standards for digital platforms that ensure data privacy, security, and interoperability, and reliable information sharing between competing companies [10].

DPPs should be used to track product life cycles and material composition, supporting transparency within symbiotic networks [10].

Data Spaces and Data Contracts should be explored as tools for sharing sensitive circularity information while maintaining control over access and use conditions [12]. Privacy-by-design solutions should also be investigated to improve transparency for authorities while protecting business confidentiality [12].

3.4 Steel, Slag & Refractories

Investigation on standards are needed for the chemical analysis of primary and secondary critical metals to ensure they meet expected performance, quality, and purity levels. For example, the characterisation and performance of recycling steel [14]. The refractories materials also lack research parameters to assess performance, durability, reusability, and repairability, alongside technical specifications for safe disassembly and clear labelling of content [14].

It is also a priority to establish a research group to track all activities concerning the circularity of products and components containing valuable metals (e.g. steel) to ensure coherence among material and product specific standards [14]. The link between

Standardisation Bodies and the JRC should be defined to assess the environmental impact and carbon footprint of minerals and metals recycling processes [14].

3.5 Batteries

The transition towards energy flexibility relies heavily on battery energy storage systems. R&I projects should address standardisation gaps related to battery energy storage systems, including performance assessment after site operation and safety requirements. Second-life batteries should be explored as demonstration cases due to the lack of established normative guidance for their industrial reuse [35].

R&I projects should also focus on standardising data formats, metrics, and protocols for tracking materials and components across the battery value chain [17].

Safety and transport standards for EoL batteries should be prioritised, particularly for safe handling, storage, and transportation of used batteries, particularly in the context of cross-border IS activities [35].

3.6 Packaging

Future research should establish clear EU-wide criteria for assessing recycling quality. This addresses the bottleneck of long-term sustainability by ensuring that policies account for how different technologies impact packaging waste across multiple cycles [11].

Research projects should define standardised methodologies for assessing health and safety risks associated with plastic chemical, thermal and mechanical recycling. This includes evaluating different grinding configurations and waste streams against exposure limit values [21].

R&I activities should address gaps identified by the Circular Plastics Alliance and the European Commission regarding recycle quality, design for recyclability, and recycled content definition [20].

Projects should systematically map and assess existing standards and legislation governing the use of packaging residues in plastic recycling systems [19].

3.7 Waste Heat

Systemic bottlenecks in the waste heat sector are exacerbated by inconsistent metrics. R&I funding should support the standardisation of data models for waste heat exchanges. This would improve transparency and comparability across sectors [36], [37].

Research should address the lack of common standards for industrial high-temperature heat pump deployment, including the safe management of hydrocarbon refrigerants and high-temperature steam systems. Furthermore, research activities should support these types of initiatives within industrial manufacturing processes [38].

In terms of materials, two innovation actions involving standardisation in the waste heat topic are suggested [39]:

- Support the creation of standards in high-pressure components related to steam pipes and vessels.
- Standards for insulation material durability and performance. The current procedures (ISO/DIS 22975-5) are still under development.

3.8 Textiles

Research should develop a unified international system for grading the condition of second-hand clothing. Current grading standards vary by organization, and a shared system is essential for scaling reuse and repair businesses [27].

Projects should refine circular design guidelines and standards, such as limiting fibre blends to no more than three types and reducing the use of elastane to improve EoL recyclability [27]. There is also a recommendation to develop generally accepted quality standards for recycled fibres or textile products to ensure they meet industry requirements and foster market acceptance [40].

While LCA standards exist, there is a lack of consensus regarding indicators and assessment methods for the textile industry. Research actions about this topic would prevent environmental impacts from being evaluated through comparable methodologies across all products [28].

Concerning new certifications for smart and high-performance textile products, innovation projects should develop standardised test methods to evaluate durability and advanced functionalities, ensuring reliability and consistency in technical applications [40].

3.9 Energy Data & Grids

Future R&I projects should systematise energy data exchange according to industry 4.0 principles. This includes enabling remote exchange between companies that are not geographically close, thereby supporting more flexible and distributed symbiotic networks [4].

3.10 Biomass & Waste Wood

Research is needed to establish methods for determining total biomass content (total biogenic raw materials by mass percentage), as existing standards (like EN 16295:2012) mainly address bio-based carbon content [30].

The use of tools like the Material Circularity Index is encouraged to assess the transition from linear to circular models, particularly once specific data for bio-based products becomes available [30].

Future work should investigate the applicability of standards for initial feedstocks and to add standards regarding sustainability reporting to the current provided lists [30]. Future projects should focus on standardising the re-use of different grades of wastewater for industrial

purposes and the use of various waste types as feedstock for bioproducts production or energy generation [34].

3.11 Construction

Innovation projects should prioritise data collection that directly supports future standardisation. Extensive testing should be carried out to demonstrate the fitness for intended use of new construction materials [31].

Projects should investigate both the recyclability of materials at EoL and the use of recycled materials in new construction products through horizontal standards [31].

R&I projects should use sustainability standards for construction works, including “Environmental Product Declarations”, to promote sustainable materials in the market [31]. Also relevant here is the design of standards that define minimum quality and performance requirements for secondary materials and by-products to improve market confidence and create viable alternatives to primary raw materials [10].

A critical research gap in the construction sector is how recycled metal properties can affect additive manufacturing quality. Future projects should investigate how the surface and internal conditions of recycled metal influence final part defects [16].

For new cements, research should develop mechanisms for verifying long-term performance (10 to 100 years). Current practice typically relies on 28-day tests, which may be insufficient to identify long-term behaviour and potential pathologies in new cement constituents. There is a need in research for a mechanism to verify performance and durability specifically for concrete using these new cements [33]. In addition, performance-based standards should also be explored to allow any standardised constituents to be used without specific rate limits, provided that final cement products meet required concrete performance levels. This is expected to accelerate the market launch of cements with lower carbon footprints and cover a wider variety of binders [33].

3.12 Finance & Market

A major bottleneck is that roughly half of the relevant standards are currently national level only, leading to duplicates and inconsistencies. Future R&I projects should support the adoption of relevant national standards at European level through CEN-CENELEC to reduce duplication and improve consistency across the single market [4].

Standards should be treated as a primary tool for dissemination, exploitation of results, and market acceptance. Educational initiatives should be used to close knowledge gaps on how standardisation works [17].

Another research action could be the implementation of standardisation as a tool to help market acceptance. Standards can act as both a barrier and a lever for new materials and products. Developing new standards for specific products or processes, or fulfilling existing requirements, can help change the waste condition of materials and promote market acceptance [5]. Given the current legal and bureaucratic blockages in the European

standardization system, research projects should consider alternative routes to market. This allows for CE marking and commercialisation even when a harmonized standard is unavailable or blocked [3].

The incorporation of standards requirements in the obligatory projects deliverables is also necessary to bridge the gap between R&I results and real market implementation, in order to sustain the funded research for the future [13]. Research and innovation should prioritise the harmonisation of methodologies for measuring the ecological footprint of businesses and their value chains [8].

In the finance sector, R&I projects should investigate economic mechanisms such as tax incentives and EU grants, for the design and construction of shared infrastructures, including district heating networks [10]. Further study is recommended to understand the technical and economic limits of distance for different types of exchanges (e.g. heat is limited to local opportunities, while materials can often travel further) [10].

Projects should also align IS standards with green financing mechanisms (ESG goals) to attract investment for energy-efficient symbiotic projects [10]. Innovation projects should define standardised methods for roles and pricing in symbiotic exchanges (e.g. "who pays for what") [6].

3.13 Life Cycle Assessment

Innovation projects should work on expanding LCA logic to include broader social effects (e.g. employment prospects) and environmental impacts across the entire supply chain resulting from resource substitution [4]. Table 6 identifies key metrics that can support more comprehensive sustainability monitoring, including cumulative energy demand, total material consumption, global warming potential, and big-data methods for early-stage assessment.

Future research should prioritise the standardisation of LCC and social-LCA. Further work is also needed on "Safe and Sustainable by Design", particularly for nanoscale materials [16].

Sustainability tools should be integrated with engineering software so that engineers can optimise material and energy flows while accounting for life-cycle impacts within standard design workflows. [29].

Table 6: Measures to monitor life cycle metrics

Indicators	Measures
Cumulative Energy Demand	Broken down into renewable and non-renewable.
Total Material Consumption	Categorised as critical/non-critical and fossil/non-fossil.
Global Warming Potential	Calculated based on Intergovernmental Panel on Climate Change (IPCC) data.

Big-data methods	Support early-stage R&I with simplified assessments.
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4 Strategic Research and Innovation Agendas (SRIA) Analysis

The analysis of existing SRIAs was carried out to understand how IS standardisation represented in European and sectoral R&I strategies. The review covered initiatives including Processes4Planet (ASPIRE) SRIA 2050, Built4People Partnership, Batteries European Partnership, Clean Steel Partnership, Water4All, Sustainable Blue Economy Partnership, EIT Raw Materials, Forest Technology Platform, Clean Energy Transition Partnership and Clean Hydrogen Partnership. These initiatives were selected due to their relevance in shaping strategic priorities across key industrial ecosystems and their potential contribution to IS-related developments.

The findings of this analysis highlight several structural limitations with respect to IS standardisation. Firstly, there is a general absence of explicit references to IS standardisation activities across the reviewed SRIAs. While these documents frequently address IS from a broader perspective (e.g. policy frameworks and regulatory aspects), they do not provide concrete or systematic consideration of standardisation as a supporting mechanism. This indicates a gap between high-level strategic priorities and the operational instruments required for their implementation.

Secondly, the analysis revealed significant challenges in establishing clear linkages between the content of the SRIAs and the vertical and horizontal topic areas mentioned in this deliverable. The information identified is often fragmented, general in scope, or not directly associated with standardisation processes. This is particularly evident in sector-specific domains, where strategic priorities are discussed without corresponding consideration of standardisation needs, frameworks, or ongoing activities. As a result, the integration of SRIA insights into a structured IS standardisation context remains limited.

Although hydrogen and water emerged as strategic themes across several SRIAs, their connection to IS standardisation remains insufficiently developed within the reviewed documents. While these sectors may hold potential for future exploration, their current treatment in the analysed SRIAs does not provide a robust basis for inclusion in the present assessment.

Overall, the SRIA analysis confirms a disconnect between strategic R&I agendas and the practical development of IS standardisation frameworks. This highlights the need for a more explicit integration of standardisation considerations within future SRIAs, as well as stronger alignment between policy-driven research priorities and the technical and methodological requirements necessary to operationalise industrial symbiosis at scale.

5 Conclusions

The comprehensive analysis conducted in this deliverable highlights the **pivotal role of standardisation in operationalising IS and advancing the CE across European industrial ecosystems**. The following section synthesises the primary findings and strategic conclusions derived from the assessment of standardisation needs, R&I recommendations, and the current landscape of SRIAs.

The investigation reveals that the current standardisation landscape for IS is characterised by **significant fragmentation and critical gaps**. Key technical and regulatory challenges identified include:

- Absence of **universal European standards** to define core concepts such as IS, leading to inconsistent terminology and methodologies that hamper practical implementation.
- Existing frameworks often adopt a **product-centric or "end-of-pipe" approach**, failing to provide the holistic, cross-sectoral perspective required for symbiotic resource sharing.
- Excessive **bureaucracy and rigid policy frameworks** often fail to accommodate the innovative, adaptive nature of IS practices.
- The lack of **clear, harmonised criteria** for when waste transitions to **secondary raw material** status creates legal and commercial uncertainty.
- An urgent **need exists for standards** ensuring interoperability, data security, and reliable Digital Twin verification in **DPP and Industry 4.0**.
- **LCA tools currently lack mature and standardised impact assessment methods** specifically tailored for circularity and sustainability metrics.

To address these gaps, future R&I initiatives must move beyond technical development and explicitly integrate standardisation as a core dissemination and exploitation tool. Core recommendations for future R&I projects include:

- Research results should be timed to align with the revision cycles of major standards to maximise impact.
- Consortia should establish **early communication with TCs and utilise CWAs** as a flexible route for rapid standardisation of innovative solutions.
- **Fill data gaps** (e.g. recycled content verification and long-term performance data for new materials) to **enable TCs to reach consensus on new standards**.
- Future projects should incorporate standardisation training within research teams and the creation of new professional roles capable of navigating complex regulatory and technical documentation.
- R&I must transition away from industry silos, **prioritising horizontal standardisation** for cross-cutting topics like CE and environmental indicators.

The SRIA analysis demonstrates that high-level strategic agendas do not yet sufficiently address standardisation as an implementation tool for IS. Future SRIAs should therefore embed standardisation frameworks more explicitly to ensure that R&I priorities can be translated into market, industrial, and regulatory environments.

6 [Next Steps](#)

The outcomes of this deliverable provide a **strategic foundation for the next phases of the RISERS project**. The identified standardisation gaps and R&I priorities will inform training, market-entry analysis, and the development of the RISERS roadmap for IS standardisation.

First, the analysis will support the continuation of Task 4.2 by defining technical content for training and awareness-raising activities to be implemented under Work Package 9.

Second, the bottlenecks identified in D4.3 will contribute to Task 4.3, **Mapping Barriers and Enablers to Market Entry for Innovative Circular Economy and Industrial Symbiosis Solutions**. This will help identify common barriers and enabling factors across different contexts, including administrative, social, technical, and market-related dimensions.

Third, this deliverable will directly support **Work Package 7 (Roadmap for industrial symbiosis standardisation)**, by providing relevant evidence for guidelines that can help standardisation TCs address IS and circularity of resources in future European Standardisation deliverables.

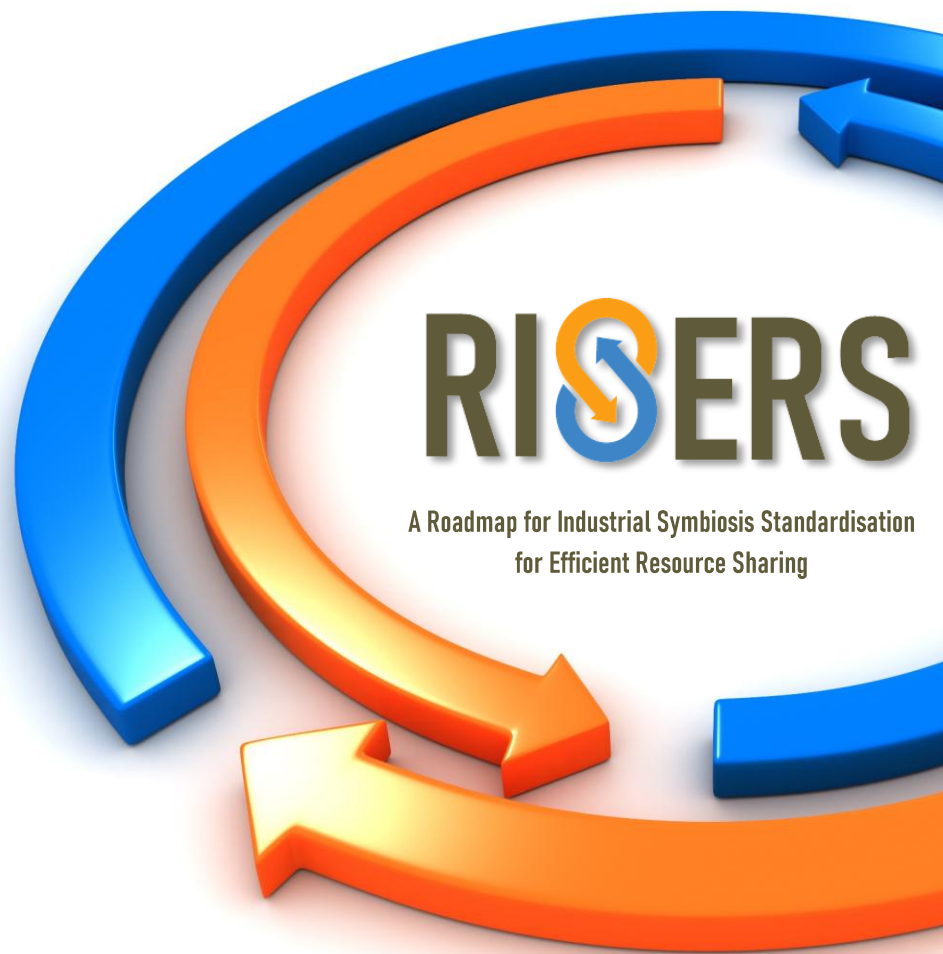
Through these interconnected activities, RISERS will ensure that the **research needs** identified in this deliverable are not only documented, but actively translated into the **regulatory and technical architecture of the European Research area**.

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D4.3 ANNEX 1

SUMMARISED TABLE OF MAIN IS STANDARDISATION NEEDS

DUE DATE: **31.07.2026**

RESPONSIBLE PARTNER: ISQ



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INTRODUCTION

This document serves as an Annex 1 to the RISERS project Deliverable 4.3 ‘Map of Standardisation Related R&I needs’, providing a summarised table related to standardisation needs in areas where existing frameworks are either lacking, fragmented, or insufficiently developed.

The following table is organised between the 13 strategic topic areas described in D4.3 and considered critical for the advancement of IS standardisation.

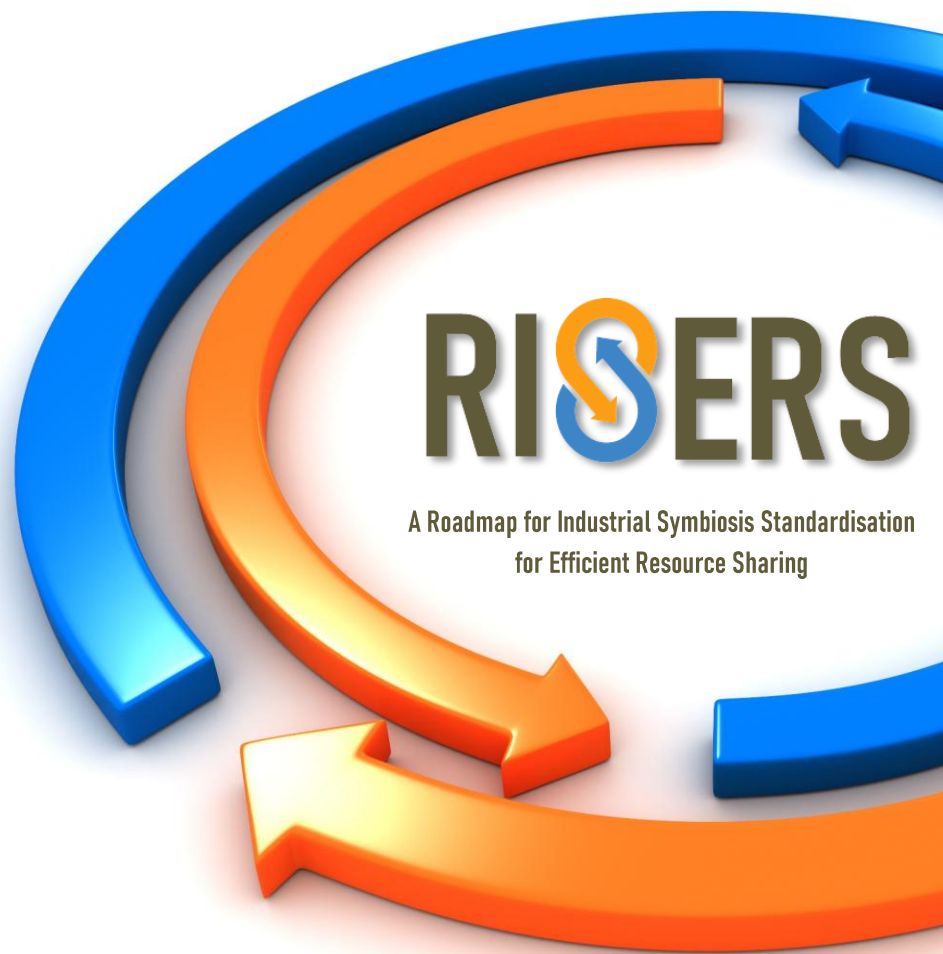
SUMMARISED TABLE OF MAIN IS STANDARDISATION NEEDS

Table 1 details the main standardisation need and gaps collected from R&I projects and initiatives present in D4.3.

Table 1: Summarised table of main IS Standardisation needs

TOPIC AREAS	MAIN IS STANDARDISATION NEEDS
<u>1. IS in General</u>	- Absence of universal standards for core terms like "IS" leading to inconsistent vocabulary. - Lack of coordinated KPIs for monitoring circularity and resource productivity. - Existing frameworks are often "product-centric" rather than holistic.
<u>2. EoW</u>	- Current standards focus on "end-of-pipe" solutions (treatment/disposal) rather than reuse and recycling. - There is a critical need for harmonised criteria to distinguish waste from secondary raw materials and for standardised "chain of custody" to prove sustainability claims.
<u>3. Digitalisation & Data</u>	- Lack of interoperability and scalability across diverse energy-intensive industries. - Urgent need for priority harmonised standards to make DPP operational (e.g., unique identifiers, data carriers, and security protocols).
<u>4. Steel, Slag & Refractories</u>	- Absence of formal standards for cross-sectoral steel recycling management and technical delivery requirements for metallurgical industry products. - Existing welding standards are insufficient for steel wire characterisation in additive manufacturing.
<u>5. Batteries</u>	- Critical need for interoperability standards for swappable battery systems across different vehicles and manufacturers. - Lack of normative guidance for the industrial re-use and performance assessment of second-life batteries.
<u>6. Packaging</u>	- Need to standardise shapes, formats, and materials to simplify sorting and recycling. - Gaps include a lack of protocols for disintegration in marine environments and uniform European-wide measures for the plastic life cycle.
<u>7. Waste Heat</u>	- Absence of EU-level legislation and standardised contracts, such as Heat Purchase Agreements, between suppliers and network operators. - Existing heat pump standards are geared toward space heating and do not account for industrial processes.
<u>8. Textiles</u>	- Need for industry alignment on tags and QR codes for high-speed automated sorting. - Testing methods are lacking to verify actual recycled content in man-made cellulosic fibers.

<u>9. Energy Data & Grids</u>	- Existing energy efficiency standards (like ISO 50001) need adaptation for inter-plant energy exchanges. - Standardised methodologies are required to measure and report energy data exchange to provide transparency.
<u>10. Biomass & Waste Wood</u>	- Lack of consensus on defining "biomass" and assessing natural resources like biodiversity. - There is significant confusion between bio-based content and biodegradability, with a need for rules on biogenic carbon assessment.
<u>11. Construction</u>	- Outdated mandates from the 1990s/2000s do not meet current needs. - There is a lack of horizontal assessment methods for dangerous substance release and a critical need for performance-based standards for new cement types.
<u>12. Finance & Market</u>	- Market failure of information regarding cross-sectoral resource efficiency. - Gaps include the absence of instruments for sustainable finance (e.g. green bonds) and a severe deficiency of qualified personnel to manage standardisation documentation.
<u>13. LCA</u>	- Gaps in mature impact assessment methods for Life Cycle Sustainability Assessment (LCSA) and Life Cycle Costing (LCC). - Lack of specific standards for calculating material and energy intensities from a life-cycle perspective.



D4.3 ANNEX 2

LIST OF RECOMMENDATIONS FOR R&I PROJECTS AND FUNDING CALLS

DUE DATE: **31.07.2026**

RESPONSIBLE PARTNER: ISQ



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INTRODUCTION

This document serves as an Annex 2 to the RISERS project Deliverable 4.3 ‘Map of Standardisation Related R&I needs’, delivering a brief list covering recommendations for R&I funding calls and projects to address standardisation gaps and guide future research and innovation efforts.

The following table is organised between the 13 strategic topic areas described in D4.3 and considered critical for the advancement of IS standardisation.

LIST OF RECOMMENDATIONS FOR R&I PROJECTS AND FUNDING CALLS

Table 1 describes the key recommendations for future research projects and calls based on the R&I projects and initiatives present in D4.3.

Table 1: List of Recommendations for R&I projects and funding calls

TOPIC AREAS	KEY RECOMMENDATIONS
<u>1. IS in General</u>	- Establish early communication with TCs and utilise CWAs for rapid standardisation of innovative solutions. - Move away from industry silos to think about standardisation horizontally. - Perform standardisation training at project start and align technical and administrative teams.
<u>2. EoW</u>	- Establish uniform European criteria for when material ceases to be waste to reduce regional uncertainty. - Prioritise source reduction and products designed for longevity. - Develop standardised calculation rules for recycled content based on physical material flows rather than mass balance.
<u>3. Digitalisation & Data</u>	- Develop standards for digital platforms ensuring data privacy, security, and interoperability. - Utilise "Data Spaces" and "privacy by design" solutions to overcome bottlenecks regarding data sovereignty and trust. - Leverage DPPs for lifecycle transparency.
<u>4. Steel, Slag & Refractories</u>	- Investigate standards for chemical analysis of critical metals and establish research parameters for the durability and reusability of refractories - Define the link between Standardisation Bodies and the Joint Research Centre to assess environmental impacts of metal recycling.
<u>5. Batteries</u>	- Focus on normative guidance for the industrial re-use and performance assessment of second-life batteries. - Standardise data formats, metrics, and protocols for tracking components across the value chain. - Address gaps in safety and transport standards for end-of-life batteries.
<u>6. Packaging</u>	- Establish EU-wide definitions for recycling quality based on scientific evidence. - Define standardised methodologies for health and safety risks associated with plastic grinding. - Address Circular Plastics Alliance gaps regarding recyclate quality and design for recyclability.
<u>7. Waste Heat</u>	- Standardise data models to allow transparency in heat exchange across sectors.

	- Develop standards for high-temperature heat pump deployment, safe management of hydrocarbon refrigerants, and high-pressure steam components.
<u>8. Textiles</u>	- Develop a unified international grading system for second-hand clothing to scale reuse businesses. - Refine circular design standards (e.g., limiting fiber blends) and seek consensus on LCA indicators specifically for the textile industry.
<u>9. Energy Data & Grids</u>	- Systematise information according to Industry 4.0 perspectives. - Enable high degrees of remote energy data exchange between companies that are not geographically proximate to allow flexibility and less local symbiotic networks.
<u>10. Biomass & Waste Wood</u>	- Establish methods for determining total biomass content by mass percentage rather than just carbon content. - Standardise the re-use of different grades of wastewater and the use of various waste types as feedstock for energy or bioproducts.
<u>11. Construction</u>	- Carry out extensive tests on new materials to demonstrate fitness for intended use and support future standardisation. - Develop horizontal standards for recycling ability and performance-based standards for new cements that verify long-term durability (10–100 years).
<u>12. Finance & Market</u>	- Prioritise the adoption of national standards by CEN-CENELEC to ensure a uniform single market. - Align IS standards with green financing (ESG goals) and define standardised methods for determining roles and pricing in symbiotic exchanges.
<u>13. LCA</u>	- Expand LCA logic to include remote social effects and standardise Life Cycle Costing (LCC) and social LCA. - Link sustainability assessment tools directly with process simulation and engineering software.