



Comprehensive overview of the project

Valentina Colla, Alice Petrucciani (SSSA)

March 2025



Project co-funded by the Research Fund for Coal and Steel (RFCS)
G.A. 101156509

The information and views set out in this document do not necessarily reflect the official opinion of the European Commission. The European Commission does not guarantee the accuracy of the data included in this document. Neither the European Commission nor any person acting on the European Commission's behalf may be held responsible for the use which may be made of the information contained therein.



Table of contents

1.	Introduction and purpose of the document	4
2.	Motivations	6
3.	Objectives	9
4.	State-of-the-art	12
5.	Symbio-Steel contribution to advance the state-of-the-art	15
6.	Developed Methodology	17
6.1	Overall methodology, including concepts, models and assumptions....	17
6.2	Dissemination and communication including comprehensive stakeholder engagement.	18
6.3	Screening of industrial symbiosis initiatives with accompanied impact assessment	19
6.4	Enhance synergies for industrial symbiosis linked to the steel industry.....	21
6.5	Exploitation and update of policy initiatives to push industrial symbiosis.	21
	List of acronyms and abbreviations	23
	List of Figures	23
	References	24



1. Introduction and purpose of the document

The European Green Deal foresees a new binding climate law to achieve the climate neutrality by 2050. Among the many possible strategies available to achieve this goal, a more sustainable management of materials and resources according to circular economy and industrial symbiosis concepts is also included. Industrial symbiosis activities aim at reducing dependence on critical materials and replacing virgin materials thus resulting in CO₂ emissions mitigation and innovative technologies development to transform existing waste resources in the value chain into a usable form.

In the last few decades, the steel industry has been committed to minimize waste production by re-using waste and by-products as resources thus reaching significant results in the industrial symbiosis implementation. The Symbio-Steel project aims at analysing the results achieved in the steel sector thanks to industrial symbiosis implementation, encouraging new opportunities and creating new synergies and networks with other sectors. In addition, the main drivers and specific barriers as well as impacts on companies, environment, and society will be identified, considering aspects and features of existing and new networks for new decision-making approaches. Research outcomes will be analysed, and dissemination measures will be designed to implement new synergies addressing economic, environmental, and societal drivers. Symbio-Steel will use the obtained results, further extending and disseminating them to promote a fruitful knowledge exchange and new synergies thus contributing to achieve more fastly higher TRLs levels of proposed technologies. In this sense, the dissemination of the projects' results will be more effective to implement novel solutions and strategies for reducing raw materials and energy uses and the related environmental impacts and investment needs. In addition, Symbio-Steel aims at attracting relevant stakeholders to implement new measure, leading to new decision-making approaches and supporting final strategic decisions.



The present document provides a comprehensive overview of the Symbio-steel project, by describing its background and scope as well as the pursued methodological approach. In particular, the document is organised as follows:

- Section 2 describes the background and motivations which led to conceiving the project idea.
- Section 3 describes the objectives of the project.
- Section 4 briefly overviews the state of the art of industrial symbiosis in the steel sector.
- Section 5 discusses the envisaged contribution of the project to advance the state of the art.
- Section 6 describes the developed methodological approach.



2. Motivations

Industrial symbiosis generally concerns transactions between different industry sectors, also involving technological and non-technological challenges. According to the recent CEN Workshop Agreement on industrial symbiosis [1], this strategy entails the use by one company or sector of underutilized resources, e.g., waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials, from another, making those resources last for longer. Industrial symbiosis provides alternatives to the traditional supply chain by reducing dependence on critical materials and, consequently, mitigating supply risks. Replacing virgin materials also results in reducing CO₂ emissions and encourages innovation through the development of new technologies to transform existing waste resources in the value chain into a usable form.

The motivation for exploring industrial symbiosis between the steel sector and other industries arises from the desire to redefine inter-industry collaboration, enhance resource efficiency, and foster sustainability. In the steel sector, industrial symbiosis is not a new concept, and over the past few decades, significant progress has been made toward its implementation. At the same time, all energy intensive industries are committed in this regard. In light of this, it is necessary to investigate further, by collecting results that have already been achieved in the steel sector to create new opportunities for encouraging further synergies. On the other hand, it is necessary to make other sectors and the public authority aware of what has already been done by the steel industry and what has hindered cooperation.

In this context, a deeper analysis of different approaches to implementing industrial symbiosis in the steel sector can pave the way for the creation of new symbiosis networks. In addition, the identification of specific barriers, including impacts on companies, the environment, and society, as well as different issues affecting networks, can provide tools for new decision-making approaches aiming to achieve strategic objectives.

The pursued approach for analysing research outcomes and designing dissemination measures that promote societal awareness and implementation of synergies with other sectors addresses economic, environmental, and societal drivers, necessitating research disclosure for the Symbio-Steel project's upcoming efforts.



Symbio-Steel aligns with steel research scopes of RFCS 2023 (Council Decision 2008/376/EC amended by Council Decision EU 2021/1094), particularly Article 10 ("Conservation of resources, protection of the environment and circular economy") and Article 8 ("New, sustainable and low-carbon steelmaking and finishing processes"), as schematically depicted in Figure 1.

Industrial symbiosis transforms resource challenges into solutions for industries like steel production. By repurposing waste into assets, industries embrace circular principles, easing pressure on finite resources and benefiting diverse sectors. For the steel sector, embracing industrial symbiosis demonstrates a proactive commitment to resource conservation, environmental protection, and circular economy values. Collaborations with other industries minimize resource depletion and environmental impact thus reflecting Article 10, e.g., the valorization and utilization of BF (blast furnace), BOF (basic oxygen furnace), EAF (electric arc furnace) slags, plastic and polymer wastes for iron- and steelmaking processes, etc.

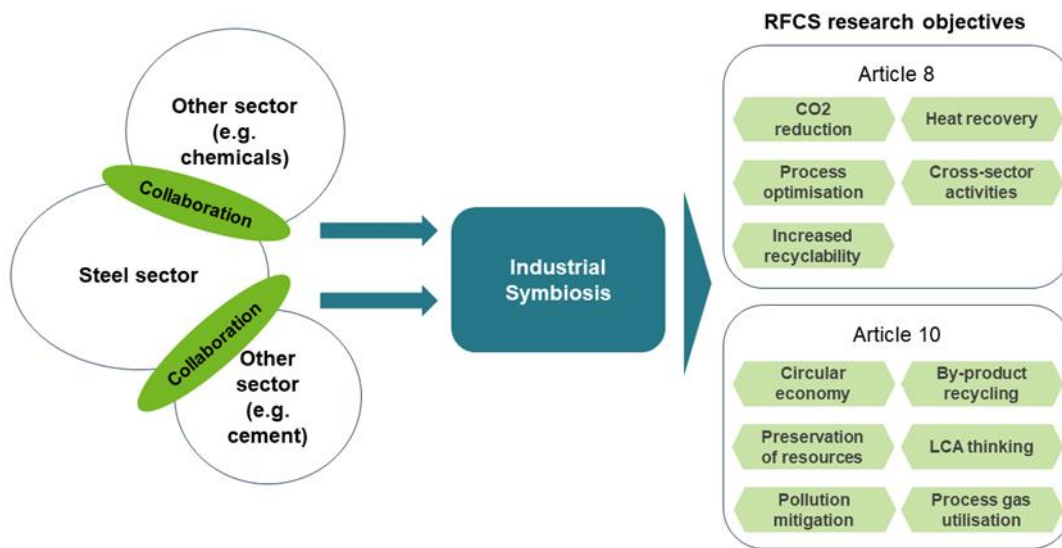


Figure 1. Impact of Industrial Symbiosis research on RFCS research objectives, showing related research areas from Article 8 and Article 10 of Council Decision on RFCS scope.

This collaboration also supports innovative, sustainable, and low-carbon steelmaking. Partnering with complementary sectors provides access to new technologies and supply sources, aligning with greener production, as seen in Article 8. e.g., carbon capture and conversion, hydrogen steelmaking technologies, etc. Policy-wise, industrial symbiosis aligns with circular and green

initiatives. In the era of low-carbon economies, these alliances fulfil environmental goals and enhance economic resilience.

Moreover, this motivation resonates with global sustainability goals (UN SDGs) [2] and circular economy principles. Participants contribute to climate mitigation, emission reduction, and regenerative economic models. Recently, viable lessons are designed to assist stakeholders, investors, managers, and practitioners in the implementation of industrial symbiosis networks, by consider political, technological, and social dimensions. They aim to promote collaborations and formulate incentive policies, paving the way for future research and practical implementations within industrial symbiotic networks [3].

In summary, the drive behind steel-industry symbiosis reshapes norms by conserving resources, protecting the environment, and embracing sustainable practices. This pursuit enriches stakeholders and harmonizes economic growth with ecological equilibrium. Industrial symbiosis guides industries toward balanced, responsible development, fostering a fusion of growth and environmental stewardship.



3. Objectives

The overall objective of the project is to pave the way to a wider uptake of industrial symbiosis solutions involving the steel sector by exploiting and spreading knowledge on most promising results that are already available and by supporting the generation of further opportunities of advancements through synergies with other industrial sectors. To this aim, the project targets the following main objectives:

- Obj 1: Monitoring and assessing impact of industrial symbiosis initiatives on steel sector through suitably selected and/or defined relevant Key Performance Indicators (KPIs).
- Obj 2: Assessment of industrial symbiosis with respect to the transformation of steel industry to decarbonized next generation steelmaking.
- Obj 3: Development of guidelines on how to enhance industrial symbiosis in the steel industry through intersectoral cooperation activities.
- Obj 4: Meeting skills demands and attracting young talents to support development and deployment of innovative technologies for industrial symbiosis in the steel sector.

Obj 1: Monitoring and assessing impact of industrial symbiosis initiatives on steel sector

Relevant Key Performance Indicators (KPIs) will be used to monitor the progress of projects from different EU and national funding programs dealing with industrial symbiosis approaches, in which the steel sector is involved. Final KPI definition will be done within the first 3 months of the project. Among them, KPIs will include (i) decrease of Scope I-II CO₂ emissions, (ii) replacement rate of fossil carbon in specific processes, (iii) recycling rate of iron-rich residue streams, and (iv) share of carbon content in specific process gas (CO₂/CO) provided to be transformed into products.

Relation to the call: Obj 1 is aligned to the RFCS objectives for steel “new, sustainable and low-carbon steelmaking and finishing processes” as KPIs, used to monitor and assess industrial symbiosis initiatives, will include: decrease of CO₂ emissions, the replacement of fossil carbon, recycling rate of iron-rich residue streams, or share of carbon content in specific process gas (CO₂/CO).



These KPIs are measurable, verifiable, and realistic to be achieved before the end of the project.

Obj 2: Assessment of industrial symbiosis with respect to the transformation of steel industry to decarbonized next generation steelmaking

The steel sector is embracing the decarbonization challenge through important efforts devoted towards modernization of the whole sector. The transition is ongoing, and it is foreseen that it will have major impact on current symbiosis activities as well as provide new opportunities. However, major challenges still remain to reach the ambitious target of CO₂-lean steelmaking by 2030, according to the European Green Deal objectives.

Coordinated activities in cooperation with other sectors, such as energy, chemicals, raw materials and transport will be analysed. In particular, results on innovative solutions for transitioning from current processes towards carbon-lean production achieved in projects from different EU and national funding programs will be assessed. The dissemination and sharing of knowledge are crucial for smooth transition that does not disrupt current markets.

Relation to the call: The Symbio-Steel project aims at analysing projects related to the decarbonization of the steelmaking industry by implementing and increasing industrial symbiosis activities. On one hand, Obj. #2 addresses the RFCS objective for steel “new, sustainable and low-carbon steelmaking and finishing processes” as the implementation of synergies in terms of industrial symbiosis will reduce the energy consumption and resources depletion by increasing energy efficiency and decreasing CO₂ emissions. This will result in low-carbon steelmaking processes. Moreover, Obj #2 addresses the RFCS objective “conservation of resources, protection of the environment and circular economy” as industrial symbiosis activities aim at preserving resources by promoting circular economy.

Obj 3: Development of guidelines on how to enhance industrial symbiosis in the steel industry.

Improving industrial symbiosis activities among energy intensive industries, including the steel sector, through newly established synergies will be analysed. Guidelines will be developed to further encourage the development of future scenarios considering material scarcity, decarbonization of industrial processes, and stricter environmental policies. These guidelines aim at supporting the steel industry in the transferability of solutions across sectors, particularly in horizontal areas with high potential, at identifying barriers, such as lack of awareness or perceived technology risk, and at developing strategies to help overcome these barriers, by promoting solutions utilized



successfully by others. This will allow for new decision-making approaches and will support strategic decisions.

Relation to the call: Obj. #3 is in line with the RFCS objectives for steel “new, sustainable and low-carbon steelmaking and finishing processes” as well as “conservation of resources, protection of the environment and circular economy”, as the guidelines that will be developed in the project will support deployment of technologies and solutions related to industrial symbiosis, considering the achieved results also in terms of reduction of emissions, energy consumption, the carbon footprint and environmental impacts, as well as of conservation of resources and increase in circular economy activities.

Obj 4: Meeting skills demands and attracting young talents.

Analysing the outcomes of project funded by various EU and national programs can reveal how transactions of energy and material flows can increase competitiveness in the steel sector, through a cross-sectorial cooperative approach in the industrial symbiosis implementation. Symbio-Steel also contribute to meet the skill demands for industrial symbiosis by developing dissemination actions especially targeting undergraduate, graduate and PhD students, young professional, etc. to attract young talents, also considering the gender balance by recruiting and retaining female scientists. These activities will be developed to improve the attractiveness of the steel sector and careers related to industrial symbiosis for talented people. In this regard, the most relevant past and ongoing EU projects will be analysed, including SPIRE-SAIS (“Skills Alliance for Industrial Symbiosis (SAIS)-A Cross-sectorial Blueprint for a Sustainable Process Industry (SPIRE)”) and ESSA (“New Skills Agenda Steel: Industry-driven sustainable European Steel Skills Agenda and Strategy”) projects. In this sense, the collaboration with SPIRE-SAIS and ESSA projects will be developed, by also exploiting tools developed in these projects for the dissemination activities (e.g., SKILLS4Planet and steelHub).

Relation to the call: Obj. #4 is in line with the RFCS objectives for steel “management of work force and working conditions”, as attention is paid not only to working conditions, including health, safety in the workplace, but also to skill requirements in different aspects related to the industrial symbiosis activities and technological innovation in the steel sector. In this context, dissemination activities are also developed to attract young talents.



4. State-of-the-art

In the context of industrial symbiosis implementation in energy intensive industries [4], the steel sector plays a key role, currently involving synergies with other sectors through transaction activities involving by-products and energy [5]. In particular, the implementation of industrial symbiosis aims at exploiting by products to produce final products with the same properties achievable by using virgin primary raw materials. These activities contribute to reduce raw materials consumption as well as the disposal of materials to landfills. Furthermore, the utilization of secondary materials increases their economic potential. In the context of the foreseen digital and green transition, the improvement of cross-sectorial cooperation will lead to increased energy and resource efficiency. Furthermore, industrial symbiosis and circular economy practices not only support sustainable development and resource efficiency goals but also enhance the overall resilience of the economy. In addition, the investment on innovative technologies for industrial symbiosis activities should include measures for adjusting the related skills, competences, and experiences of the workforce to increase competitiveness, by also considering effects in terms of new skills requirements [6]. Furthermore, collaborative approaches will lead to a higher resource efficiency and the expertise of institutions will facilitate and support these goals. In this context, policy frameworks and incentives represent a support to adopt circular practices. On the other hand, it addresses the challenges of industrial symbiosis implementation, such as the need for innovative technologies, industry collaboration, and supportive regulatory environments [7]. In addition, the role of policy instruments promoting innovation is crucial in relation to industrial symbiosis in the process industries. Innovation policy instruments aim at supporting collaboration among partners according to the principles of industrial symbiosis. In particular, the policy instruments supporting collaboration and networking are crucial and, therefore, they potentially influence positively industrial symbiosis formation. The instruments aimed at knowledge sharing and dissemination, i.e., technical services and advice, clusters, collaboration policies and innovation networks, show a particular potential to foster industrial symbiosis in the process industries both in the formation phases and in the industrial symbiosis dimensions [8].

In this context, policies and regulations can facilitate or can limit industrial symbiosis implementation. In the long-term, the European Union is committed



to minimise the waste production, and to re-use generated waste, by exploiting them as a resource. In this regard, different European directives, communications, and funded programs are related to industrial symbiosis. In particular, the sustainable management of resources based on economic growth is the topic of the communication “Roadmap to a Resource Efficient Europe” [9], which introduced industrial symbiosis to the agenda of some countries. On the other hand, “Closing the loop - An EU action plan for the Circular Economy” focuses on the cooperation with EU member states’ promotion [10], while the Directive 2018/851 on waste aims at improving the efficiency of waste management and implementing industrial symbiosis [11]. Refs. [12] and [13] underline the importance of industrial symbiosis implementation. The “Circular Economy Action Plan” [14] represents one of the main building blocks of the European Green Deal, the new agenda of Europe for a sustainable growth [15], supported by the previous European strategy “Europe 2020” on the rational resource management [16], the recent 2050 Climate and Energy Policy [17] and the Energy Union initiative [18]. The European Green Deal for the EU and its citizens was launched to prevent climate change through better natural resource management to achieve a complete reduction in net emissions of greenhouse gases (GHGs) by 2050, following the previous actions and policies [19] [20]. In addition, Climate Law [21] aims at managing material and resources in a more sustainable way to achieve climate neutrality by 2050. This implies finding novel solutions based on industrial symbiosis, considering the environmental, economic, and social dimensions.

Achieving carbon-neutral goal by 2050 requires the decarbonization of the whole steel sector, guided by recent analyses of technology pathways, industrial structure adjustments, and short- or long-term policies for greenhouse gas emission reduction. In particular, existing energy-saving technologies in the steel industry present limited carbon reduction capacity. Consequently, significant further reductions need coordinated efforts by optimizing collaborative CO₂ emission reductions pathways across industries, by integrating advanced industrial symbiosis practices, especially with hydrogen and power sectors. In this context, financial support, low-carbon policies as well as further research are essential to avoid additional carbon emissions [22].

The analysis to be carried out in Symbio-Steel will focus on the current state, upcoming techniques, and developments of industrial symbiosis implementation, based on the main levers of the circular economy transformation, to reach proactive cross-sectorial cooperation and integrations.



Results of the analysis performed in the Symbio-Steel project will aim at identifying future research activities and directions in the field of industrial symbiosis of the steel sector, taking into consideration all sustainability dimensions, i.e., environmental, economic, and social aspects [23]. On one hand, technological aspects including the reduction of related environmental impacts as well as their economic viability will be investigated. On the other hand, the upskilling and reskilling process and recruitment of new talents should be promoted by considering the current skills and gaps for new professional profiles requirements as well as the gender balance. Attracting talents to the EU steel industry is crucial for the future of this sector. In this context, companies must be committed to the personnel development and to retain existing talents. On the other hand, it is important for steel companies to be attractive for future talents in the future labour market [24].



5. Symbio-Steel contribution to advance the state- of-the-art

Symbio-Steel goes beyond the state-of-the-art by analysing industrial symbiosis existing synergies and by fostering the creation of new symbiosis networks. Past and ongoing industrial symbiosis projects, mainly based on promoting residues and resource transactions, will be considered. In this regard, the status of the creation of networks and synergies among companies operating in different sectors by developing projects, solutions and integrated approaches will be analysed. Symbio-Steel will make use of the results already obtained, further extending and disseminating them to promote a fruitful knowledge exchange and new synergies. Through the approach developed, Symbio-Steel will contribute raising TRLs of proposed technologies related to the industrial symbiosis topic faster. In this regard, the knowledge exchange, the dissemination of the projects' results and the collaboration among steel producers is expected to be more effective by promoting cross-sectoral cooperation and novel solutions and strategies for reducing resource and energy uses and related environmental impacts and investment needs. In addition, the main drivers and specific barriers will be identified during the project as well as impacts on companies, environment, and society, by considering various aspects and features of existing and new networks. Results will also lead to new decision-making approaches and will support final strategic decisions.

Symbio-Steel, going beyond the state-of-the-art, will attract all relevant stakeholders to participate in the broad framework by implementing various measures, e.g., workshops, dedicated online seminars, and thematic and networking events. In the last few years ESTEP has already organised Focus Group (Circular Economy, Low-Carbon & Energy Efficiency, Transport & mobility, Construction & Infrastructure, People, Energy Market Applications &



Engineering, Smart Factory), workshops on low carbon and energy efficiency, and the circular economy. Results already obtained by the Focus Groups will be used by Symbio-Steel, further extending and disseminating them to promote a fruitful knowledge exchange.

In addition, the support actions carried out by the partnership will include the creation of synergies with EU and national programmes that enable the upskilling of the steel workforce and attract and retain young talents, also considering gender balance. Knowledge exchange, awareness of research projects results as well as collaboration among steel producers and stakeholders inside and outside the sector is expected to increase and to be more effective thanks to Symbio-Steel.

Compared to previous dissemination activities, Symbio-Steel will provide further information on transactions of energy and material flows that can enhance the steel industry competitiveness by exploiting a more proactive cross-sectorial cooperative approach. This can encourage further developments in a context including material scarcity, decarbonization of industrial processes, and stricter environmental policies.



6. Developed Methodology

6.1 Overall methodology, including concepts, models and assumptions

Decarbonising the EU steel industry is an extremely challenging task. Carbon plays a key role in the steelmaking process as both energy source, and metallurgical reactant. Therefore, the close to complete decarbonisation of the steel industry, needs a transition process that could be compared to a fully-fledged industrial revolution. Industrial symbiosis is one supporter and accelerator of the transformation for the steel sector and other process industries to reach a circular and climate neutral society. To foster the green revolution, three key pillars must be considered, which are policies, technologies, and industrial applications (Fig. 2.a).

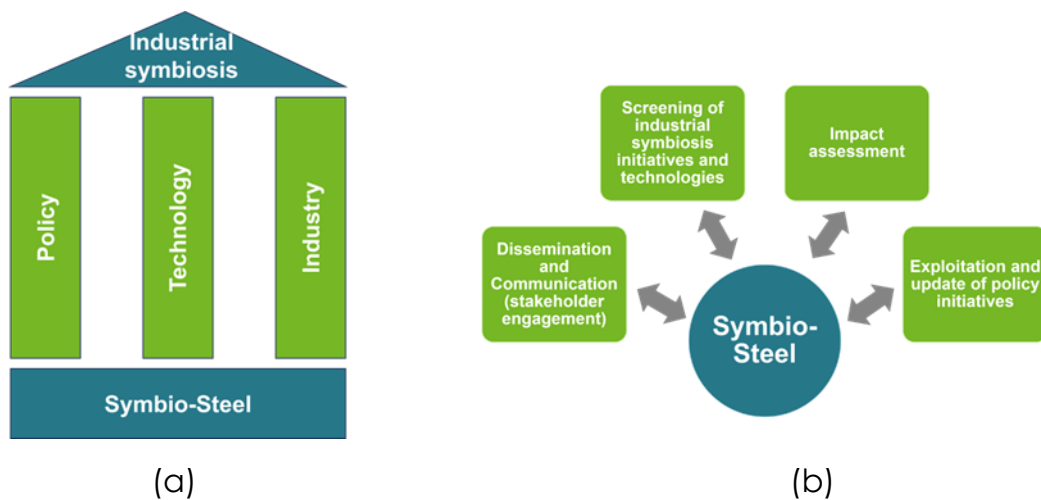


Figure 2. (a) Concept of Symbio-Steel; (b) Approach of Symbio-Steel

In this context, the innovative concept proposed by Symbio-Steel mainly consists of performing a cross-cutting analysis of technologies, industrial transformation and enabling financial and non-financial policy measures. The combined and multi-disciplinary analysis of these three pillars can effectively



support the sustainable decarbonisation and circular economy of the EU steel industry thus promoting a similar process in other European industries. Fig. 2.b illustrates the approach proposed by Symbio-Steel to implement this innovative concept.

Symbio-Steel is an ambitious Accompanying Measures Project, comprising 14 Tasks across 5 Work Packages (WPs), which will:

- Ensure the highest level of stakeholders' engagement, at the EU and national level, and the effective dissemination and uptake of the project's results.
- Identify the most promising technology routes and national/EU initiatives to push forward industrial symbiosis closely linked to the steel sector to support decarbonization of the steel industry, to detect financial and non-financial barriers and devise pathways for industrial deployments of such technologies.
- Detect relevant investment needs mentioned in relevant projects/initiatives and possibly identify EU and national public funding opportunities to meet such needs and propose blending and sequencing solutions to maximize the impact of existing and forthcoming funding opportunities.

6.2 Dissemination and communication including comprehensive stakeholder engagement.

Comprehensive dissemination and communication activities to be done in WP2 will guarantee that the findings of the Symbio-Steel project are widely shared with scientists, researchers, engineers, policy makers, and the public. An open and transparent participatory approach is planned, relying on stakeholder interaction with relevant parties to gather data and information, collect feedback, validate key findings, and ensure industrial commitment and the uptake of the project findings. Symbio-Steel will network with national and international projects, initiatives, and networks. This ensures that project results are efficiently disseminated. Some measures planned during the project comprise a website, peer-reviewed (open-access) journal publications, conference participations, organization of workshops, periodic newsletters, and broad social media activities, e.g., LinkedIn.

An eminently qualified consortium featuring all the required skills and expertise to work on the proposed approach is supported by ESTEP (subcontractor) as steel related stakeholder organisation. ESTEP will support the project by enabling interaction with relevant players of the steel value chain, e.g.,



steelmakers, technology providers, steel users, also within the frame the co-programmed Clean Steel Partnership of Horizon Europe. ESTEP also ensures a cross-cutting communication towards other European partnerships under the frame of Horizon Europe, such as Processes4Planet (P4P), which has industrial symbiosis as one main element in its Strategic Research and Innovation Agenda [25].

6.3 Screening of industrial symbiosis initiatives with accompanied impact assessment

Relevant activities and initiatives, in which the EU steel sector is involved to push forward industrial symbiosis, will be screened in WP3 with the approach shown in Fig. 3.

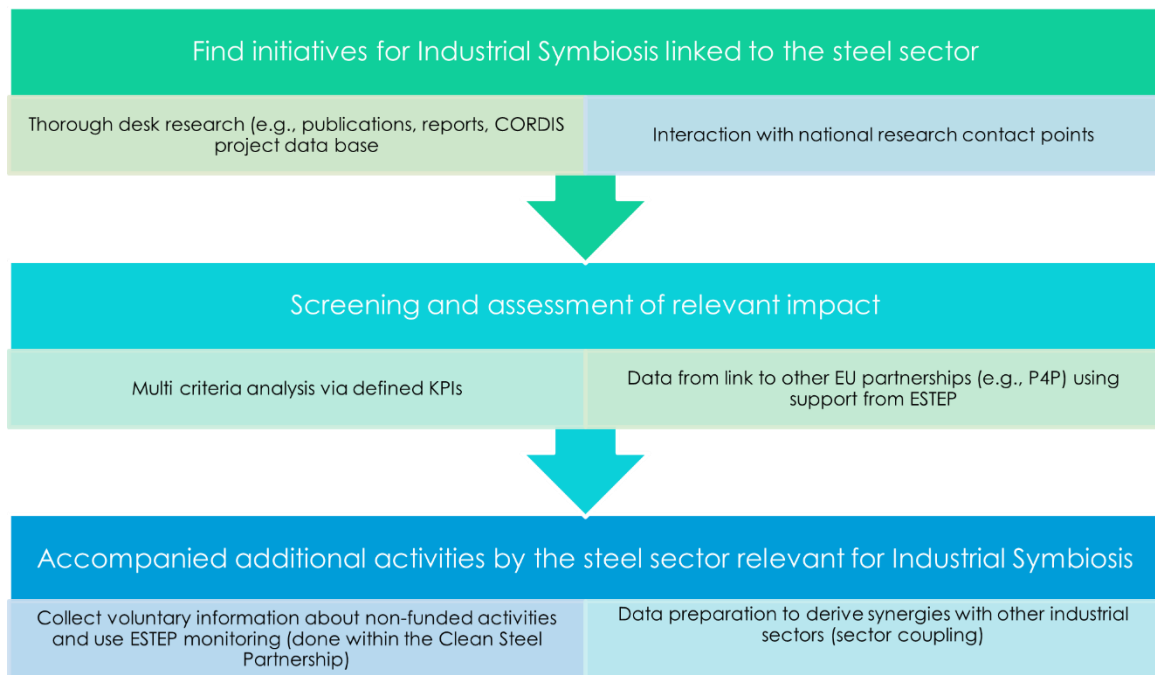


Figure 3. Symbio-Steel methods for technology screening and impact assessment

Desk research will comprise the screening of different data bases and publicly available documents such as publications, conference proceedings, project reports/deliverables, whereas funded regional and EU projects from different funding programs and connected best practice solutions should be included. An extensive list will offer a wide portfolio of technical solutions driven by the steel sector for other process industries applications. Connecting the main actors involved in R&D&I within steel industry and coupled industrial sectors



provide the technical basis for further impact and cross-sectorial synergies and to draw guidelines and policies for the future. By KPIs definition which will be finalized during the first 3 months of the projects, economic, social, and technological impact of R&I activities on national and EU levels on steel sector's competitiveness and sustainability will be monitored. Among others, the EUROFER map of low-CO₂ projects [26] will be used as one starting point to define the most relevant initiatives for industrial symbiosis.

Special attention will be given to decarbonisation pathways such as smart carbon usage, e.g., CO₂ from steel sector as raw material for other energy intensive industries, and circular economy, e.g., metal and mineral fractions from steelmaking slags as secondary raw material. It is guaranteed that no relevant initiative is left out thanks to the homepage from the SPIRE Association (A.SPIRE) about relevant projects, EU databases, such as CORDIS or the RFCs synopsis documents containing information about funded projects, and the interaction with national research contact points via the consortium partners. The analysis of the current R&D strategies on industrial symbiosis will cover smaller scale as well as pilots and demonstration scale activities with a TRL range from 3-9 since there are also promising industrial symbiosis initiatives ongoing with a current smaller development range, e.g., carbonisation projects to use metallurgical residues for sequestering CO₂ from other industrial processes, such as cement.

Monitoring of additional activities and/or investments will also be part of this methodological part. It is known that deployment of low carbon iron and steelmaking technologies in industrial scale will induce the combination of public funding with additional private investments to support such sizable projects. 1 billion € CAPEX per every million ton of crude steel produced via the route hydrogen-based direct reduction and electric arc furnace is estimated [27] (2020 level before gas price increased). Apart from funded project activities, non-funded investments into technology scale-up, and efforts to retrofit existing steelmaking sites, steelmakers will also execute other additional activities related to the decarbonization of their processes. Such additional efforts can include non-funded dissemination and communication activities, workers training and skills development to prepare the steel plant workforce on the new technologies for low CO₂ steelmaking. Other examples are high-level automation with sector coupling approaches, or contributions to the development of new standards, regulations, and policies to give recommendations for regulatory measures for new low CO₂ emission technologies at national and EU levels or regarding the certification of new "green" steel qualities.



6.4 Enhance synergies for industrial symbiosis linked to the steel industry.

This activity within the frame of WP4 represents the starting point of exploitation activities dedicated to the definition of new and further development of existing synergy scenarios between the steel and other industrial sectors. Connection with actors relevant for steel-related industrial symbiosis will be done, e.g., via workshops/seminars planned during the project. This includes different European partnerships beyond the CSP, e.g., Process4Planet or Clean Energy Transition. To transform the steel industry towards decarbonized processes, a consistent progress with all connected supply chains is necessary, necessitating a continuous and intensive cross-industrial coordination of all relevant roll-out scenarios. The activity of defining synergy scenarios aims to support the required connections with respect to the most relevant actors across and along the complete supply chains for closing material and energy cycles via sector coupling approaches. Implementation scenarios will be developed, and first data patterns will be derived to initiate the data exchange for cross-industrial cooperation. To develop these scenarios, the latest publications relevant for implementation of industrial symbiosis technologies will be collected and analysed. Relevant KPI categories defined in WP3 will be used, such as the CO₂ mitigation potential. Based on scenarios defined, the main links to other partnerships respectively industries and suppliers beyond steel industry as well as the corresponding stakeholders will be identified. Contacts to the relevant actors are established to initiate the exchange of procedures, information, and data within common events. Finally, the scenarios are evaluated with respect to consistent impact assessment and will serve to provide input for EU policy initiatives e.g., Roadmap to a Resource Efficient Europe [9] or the EU Action Plan for the Circular Economy [10].

6.5 Exploitation and update of policy initiatives to push industrial symbiosis.

The economic boundary conditions for industry became increasingly mobile in recent years and the future boundary conditions cannot be predicted in a reliable fashion. However, each large investment as well as the overall transformation towards a resource efficient and decarbonised steel industry must be adapted flexibly to these boundary conditions. This is a complicated task in the highly integrated steel industry, and it gets even more complicated if cross-industrial links must be considered.



Symbio-Steel is fully in line with the idea of an RFCS Accompanying Measures project as it will provide suggestions on possible policy initiatives to contribute to the digital, greening, and circular transformation of the Coal and Steel communities, according to the European Green Deal, the “Fit for 55” package, the Just Transition Mechanism, or the Sustainable Development Goals. The results of Symbio-Steel, e.g., industrial symbiosis scenarios and corresponding data pattern, as well as the procedures and networks for cross-industrial communication will provide a solid groundwork for this existential and continuous task of the overall European industry development. Thus, Symbio-Steel can provide a unique level of exploitation potential compared to any other Accompanying Measure approach. The Symbio-Steel activities related to industrial symbiosis implementation will assess not only resources and technologies but also the impacts (WP3), synergies with other industries (WP4) and policy recommendations (WP5) to achieve an effective industrial roll-out of sector coupling technologies, in which the EU steel sector plays a central role. ESTEP as subcontractor will have a relevant function in communication towards the European Commission. ESTEP’s connection to the relevant units within the Commission allows the Symbio-Steel consortium to present recommendations on how to update existing policy initiatives to push forward industrial symbiosis.



List of acronyms and abbreviations

Acronym	Full name
BF	Blast Furnace
BOF	Basic Oxygen Furnace
CORDIS	Community Research and Development Information Service
CSP	Clean Steel Partnership
EAF	Electric Arc Furnace
ESTEP	European Steel Technology Platform
EU	European Union
KPI	Key Performance Indicator
P4P	Processes4Planet
R&D&I	Research and Development and Innovation
RFCS	Research Fund for Coal and Steel
SDGs	Sustainable Development Goals
SPIRE	Sustainable Process Industry through Resource and Energy Efficiency
TRLs	Technology readiness levels
UN	United Nations
WP	Work Package

List of Figures

Figure 1. Impact of Industrial Symbiosis research on RFCS research objectives, showing related research areas from Article 8 and Article 10 of Council Decision on RFCS scope..... 7

Figure 2. (a) Concept of Symbio-Steel; (b) Approach of Symbio-Steel 17

Figure 3. Symbio-Steel methods for technology screening and impact assessment 19



References

1. European Committee for Standardization. Industrial Symbiosis: Core Elements and Implementation Approaches. Available online: <https://www.cencenelec.eu/research/CWA/Pages/default.aspx>
2. <https://sdgs.un.org/goals>
3. Sellitto, M.A., de Lima, M.S., Ackermann, A.E.F., Kadel Jr, N. and Butturi, M.A., 2025. Exploring Industrial Symbiotic Networks: Challenges, Opportunities, and Lessons for Future Implementations. *Sustainability*, 17(4), p.1509
4. Branca, T.A., Fornai, B., Colla, V., Pistelli, M.I., Faraci, E.L., Cirilli, F. and Schröder, A.J., 2021. Industrial symbiosis and energy efficiency in European process Industries: A review. *Sustainability*, 13(16), p.9159
5. Branca, T.A., Colla, V., Algermissen, D., Granbom, H., Martini, U., Morillon, A., Pietruck, R. and Rosendahl, S., 2020. Reuse and recycling of by-products in the steel sector: Recent achievements paving the way to circular economy and industrial symbiosis in Europe. *Metals*, 10(3), p.345.
6. Branca, T.A., Fornai, B., Colla, V., Pistelli, M.I., Faraci, E.L., Cirilli, F. and Schröder, A.J., 2022. Skills Demand in Energy Intensive Industries Targeting Industrial Symbiosis and Energy Efficiency. *Sustainability*, 14(23), p.15615.
7. Abbas, Muhammad Faizan, Zaheer Abbas, and Joanna Godlewska. "Potential of industrial symbiosis towards circular economy—a case of Poland." *Akademia Zarządzania* 8, no. 3 (2024).
8. Laatsit, Mart, and Glenn Johansson. "Fostering industrial symbiosis in process industries: An innovation policy perspective." *Environmental Technology & Innovation* 37 (2025): 104027.
9. European Commission. Roadmap to a Resource Efficient Europe COM (2011) 571 Final; European Commission: Brussels, Belgium, 2011
10. European Commission. Closing the Loop—An EU Action Plan for the Circular Economy—COM(2015) 614 Final; European Commission: Brussels, Belgium, 2015.
11. European Commission. Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 Amending Directive 2008/98/EC on Waste. 2018.
12. European Commission. Measuring Progress towards Circular Economy in the European Union e Key Indicators for a Monitoring Framework 16.1.2018. SWD(2018) 17 Final; European Commission: Brussels, Belgium, 2018.



13. European Commission. Proposal for a Decision of the European Parliament and of the Council on Establishing the Specific Programme Implementing Horizon Europe e the Framework Programme for Research and Innovation; European Commission: Brussels, Belgium, 2018.
14. European Commission. Circular Economy Action Plan. For a Cleaner and More Competitive Europe; European Commission: Brussels, Belgium, 2020.
15. European Commission. Communication No. 640, 2019. The European Green Deal; (COM no. 640, 2019); Commission of European Communities: Brussels, Belgium, 2019.
16. European Commission. Communication No. 2020, 2010. Europe 2020—A Strategy for Smart, Sustainable and Inclusive Growth; (COM No. 2020, 2010); Commission of European Communities: Brussels, Belgium, 2010.
17. European Commission. Roadmap for Moving to a Competitive Low-Carbon Economy in 2050. 2011.
18. European Commission. A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy; COM/2015/080 Final, February 25; European Commission: Brussels, Belgium, 2015.
19. European Commission. The Road from Paris: Assessing the Implications of the Paris Agreement and Accompanying the Proposal for a Council Decision on the Signing, on Behalf of the European Union, of the Paris Agreement Adopted under the United Nations Framework Convention on Climate Change (Communication from the Commission to the European Parliament and the Council); European Commission: Brussels, Belgium, 2016.
20. Intergovernmental Panel on Climate Change. Global warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty; Intergovernmental Panel on Climate Change: Geneva, Switzerland, 2018.
21. European Commission. Regulation of the European Parliament and of the Council Establishing the Framework for Achieving Climate Neutrality and Amending Regulation (EU) 2018/1999 (European Climate Law); (Proposal No. COM(2020) 80 Final); European Commission: Brussels, Belgium, 2020.
22. Sun, Jingchao, Hongming Na, Yuxing Yuan, Ziyang Qiu, Tao Du, Yingnan Li, Lei Zhang, and Weichen Wang. "A systematic review of decarbonization pathway and modeling conception in iron and steel



- industry at micro-, meso-, and macro-levels." Environmental Science and Pollution Research (2024): 1-29.
23. Colla, V., Branca, T.A., Pietruck, R., Wölfelschneider, S., Morillon, A., Algermissen, D., Rosendahl, S., Granbom, H., Martini, U. and Snaet, D., 2023. Future Research and Developments on Reuse and Recycling of Steelmaking By-Products. *Metals*, 13(4), p.676.
 24. Echterhoff, V., Schelkle, P. and Cassel, S., 2024. Attracting Talents to the Steel Industry. In *Industry 4.0 and the Road to Sustainable Steelmaking in Europe: Recasting the Future* (pp. 155-163). Cham: Springer International Publishing.
 25. A.SPIRE. Processes4Planet Strategic Research and Innovation Agenda, 2021
 26. <https://www.eurofer.eu/assets/Maps/eurofer-low-carbon-projects-map.pdf>
 27. Roland Berger: The future of steelmaking-how European steel industry can achieve carbon neutrality, 2020

