

D 2.2. SME SYMBIOTECH TRAINING NEEDS MAPPING REPORT AND LEARNING PATHWAY'S STRUCTURE

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INTRODUCTION

In recent years, industrial symbiosis (IS) has gained recognition as an effective concept for improving environmental performance and resource efficiency at the regional level. In 2018, it was formally incorporated into European Union (EU) policy and regulations. Since then, Member States have been required to support and promote solutions in this field, particularly practices that can be replicated and implemented across different sectors and regions. Industrial symbiosis is also a key element of the EU's new Circular Economy Action Plan, aimed at building a cleaner and more competitive Europe.

Industrial symbiosis is based on collaboration between different sectors and organizations that make mutual use of each other's waste, by-products, energy, and water. This approach reduces the negative environmental impact of industrial activity while generating economic benefits. In practice, waste produced by one company becomes a valuable resource for another, fostering synergies, reducing landfill disposal, and lowering the demand for primary raw materials.

The development of IS in EU Member States, however, has been uneven and depends on multiple organizational, institutional, and economic factors. Experience from Scandinavian countries shows that successful implementation requires long-term strategies, expert support, and public investment. In contrast, countries with less developed industrial sectors or economic constraints have tended not to prioritize IS, often directing funding toward industries with short-term returns rather than those requiring strategic cooperation. As a result, symbiotic mechanisms rarely emerge spontaneously without the assistance of experts acting as facilitators and coordinators of this complex process.

Additional challenges arise from legal, organizational, and technological barriers that limit the full potential of IS. The growing complexity of industrial processes and the urgent need for sustainable resource management now call for a shift toward a new paradigm **Digital Industrial Symbiosis**. Leveraging digital technologies such as artificial intelligence and advanced monitoring and analytics tools makes it possible to optimize material and energy flows between industries, enabling more effective and scalable symbiosis.

The European Union actively supports the implementation of IS through various legal and policy instruments. Key examples include:

- the **Waste Framework Directive** ¹, which establishes the legal basis for recycling and reuse,
- the **Circular Economy Action Plan** ², which promotes resource circulation across industries,
- the **Industrial Emissions Directive** ³, which encourages integration of processes and emission reductions,
- regulations on **alternative fuels, eco-design, renewable energy, and specific waste streams** (e.g. waste electrical and electronic equipment, batteries, and accumulators).

Although EU legislation does not provide a precise legal definition of “industrial symbiosis,” the concept is consistently framed within the broader context of the circular economy, sustainable development, and resource efficiency.

In summary, industrial symbiosis represents an innovative approach to resource management that aligns closely with the EU’s sustainable development agenda. However, its effective implementation requires overcoming regulatory and organizational barriers, strengthening expert support, and harnessing digital technologies. Only such a holistic approach will enable lasting environmental, economic, and social benefits, supporting Europe’s transition toward a truly circular economy.

The purpose of this report is to present the results of research on educational and competence needs in the field of industrial symbiosis, with particular emphasis on its digital dimension (Digital Industrial Symbiosis – DIS). The starting point for the analyses was the growing importance of the circular economy in European Union policies and the need to prepare specialists capable of supporting enterprises – especially small and medium-sized enterprises (SMEs), in transitioning from traditional business models to modern, technologically supported symbiotic solutions.

In this context, the necessity of educating a new generation of experts, the so-called **SymbioTech Managers**, was identified. Their role will be to initiate, design, and oversee mechanisms of inter-firm cooperation within industrial symbiosis, as well as to support their implementation through the use of advanced digital tools such as artificial intelligence, machine learning, blockchain technologies, environmental management systems, and Internet of Things

¹ Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance).

² The European Commission adopted the circular economy action plan (CEAP) in March 2020. It is one of the main building blocks of the European Green Deal, Europe’s agenda for sustainable growth. The EU’s transition to a circular economy will reduce pressure on natural resources and will create sustainable growth and jobs. It is also a prerequisite to achieve the EU’s 2050 climate neutrality target and to halt biodiversity loss.

³ The revised Industrial and Livestock Rearing Emissions Directive (**Directive 2010/75/EU** or ‘IED 2.0’) as amended by Directive 2024/1785, is the main EU instrument to reduce these emissions into air, water and land, and to prevent waste generation from large industrial installations and intensive livestock farms (pig and poultry).

(IoT)-based solutions. SymbioTech Managers are expected to play a pivotal role in the economic transformation process, combining technical and analytical expertise with managerial skills.

The report is the outcome of research conducted across all partner countries of the project, aimed at identifying training needs, competence gaps, and expectations associated with emerging professional roles in the field of digital industrial symbiosis. The research covered both an analysis of the existing educational offer at the level of higher education institutions (HEI) and vocational education and training (VET), as well as an assessment of market practices employed by enterprises implementing elements of IS. An important component of the study was also the consideration of equality and inclusion, particularly in the context of the educational needs and expectations of women engaged in the development of the circular economy.

The research process employed a **mixed-method approach**, combining quantitative and qualitative techniques. Interviews were conducted with representatives of companies practicing industrial symbiosis as well as with academic experts, trainers, and consultants involved in disseminating knowledge on IS. At the same time, survey research was carried out in nine partner countries.

The data collected in the course of the research enabled the formulation of a number of important conclusions concerning the conditions for the development of industrial symbiosis. Specifically, they allowed to:

- **identify and analyze the understanding of industrial symbiosis in sectoral discourse**, which is crucial for ensuring consistency of communication among enterprises and for the proper implementation of symbiotic practices,
- **determine the main drivers of symbiotic cooperation**, such as economic benefits, reduction of operational costs, process innovation, and increased market competitiveness,
- **indicate barriers and challenges hindering the implementation of IS**, including lack of trust among partners, insufficient knowledge and technical competences, regulatory constraints, and difficulties in accessing modern technologies,
- **define criteria for assessing the readiness of enterprises to participate in symbiotic processes**, encompassing organizational, financial, technological, and cultural factors,
- **characterize the conditions enabling the transition from traditional industrial symbiosis to its digital equivalent (DIS)**, including the application of artificial intelligence, blockchain technologies, material flow monitoring systems, and integrated data exchange platforms.

The findings revealed significant disparities in the level of knowledge and practices across different regions, with the most substantial competence gaps identified in Central and South-Eastern Europe. At the same time, the research confirmed a clear demand for new forms of

education that could effectively support the development of competences related to digital industrial symbiosis.

Based on the research results, **14 training module syllabuses** were developed, seven dedicated to the VET level and seven to the HEI level. Each syllabus includes a detailed description of learning objectives, intended learning outcomes (knowledge, skills, competences), timeframes, substantive content, teaching methods, and assessment forms. The syllabuses are aligned with the European Qualifications Framework (EQF) and assigned ECTS points, ensuring consistency with the European education system. An important element of the program is the introduction of **micro-credentials**, which allow for flexible documentation and validation of acquired qualifications.

The structure of the report reflects the logic of the research process and consists of three main parts:

- **Chapter One** presents the methodological foundations of the research, including its scope, stages, and applied statistical tools (e.g. descriptive statistics, correlation analysis). This section also includes the results of quantitative and qualitative analyses.
- **Chapter Two** outlines the developed educational pathway for the SymbioTech Manager. It provides a detailed discussion of the syllabuses prepared for both the VET and HEI levels and presents the methodology used in their design. The subsequent sections of the report include references, a list of tables, a list of charts and figures, and an appendix.

As a result, this report not only documents the research process and its outcomes but also indicates possible directions for the development of education and professional training in the field of Digital IS. It thus represents an important step towards building modern, knowledge- and technology-based mechanisms to support the transition towards a circular economy.

CHAPTER I

1. Research methodology and results

1.1. Research methodology description

Methodology of the research process carried out as part of WP2 of the SymbioTech project

The starting point for the research process was a review of scientific literature on Industrial Symbiosis (IS) and the circular economy. Systematising the state of knowledge in this area, analysing existing examples of industrial symbiosis, and identifying the benefits of applying solutions that fit into the IS concept helped to build research tools and develop procedures for their use.

Industrial symbiosis presents a systems approach to a more sustainable and integrated industrial economy, which identifies business opportunities to improve resource utilisation. Industrial Symbiosis' synergies are transactions where one organisation acquires underutilised resources (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials that are not the primary output of the production process) from the organisation generating them and integrates them as inputs into its production process.

Core elements of industrial symbiosis are the aspects that enable its identification. Elements considered core to industrial symbiosis are:

- Returning underutilised resources (often called waste) to productive use. Transactions (synergies) involving material, energy and water tend to be at the core of industrial symbiosis, but non-material resources such as expertise, capacity and logistics can be equally valuable.
- Information about opportunities (e.g. data on other organisations' resources or new technologies) is required to advance synergy.
- Business conditions incentivising industrial symbiosis, which may be through market conditions (cost reduction, risk reduction, improved competitiveness) or through policies and regulations that specify definitions (for example, waste versus by-product) and responsibilities.

Optional dimensions that may occur in some synergies and not in others:

- Collaboration through networks: A diverse network of organisations of all sectors and sizes contributes to success, as most opportunities lie outside one's sector. Sectors including Government, third sector, research, and the community can all contribute to industrial symbiosis, bringing new ideas and stimulating further activity. A formal network is not required for an actor to pursue industrial symbiosis (e.g. in the self-organised approach).
- Innovation: Often, an industrial symbiosis opportunity entails innovative diversification of the business-as-usual supply chain.

Shared services: Sharing may reduce the environmental impact of the services, which is in line with the goal of industrial symbiosis, but if those services are not derived from previously underutilised resources (such as another organisation's wastewater being converted to input), then it may not be aligned with the core elements of industrial symbiosis described above.⁴

To obtain a comprehensive overview of the subject matter (IS), a mixed approach was employed, comprising three complementary methods: individual interviews, an online survey, and focus group interviews (FGI). This triangulation approach enabled both quantitative and qualitative coverage of the topic.

Data from interviews and FGIs were subjected to qualitative analysis (e.g. thematic coding, content analysis). At the same time, survey results were analysed quantitatively using basic descriptive statistics (e.g. percentage distribution of responses, averages). The results from different sources were collated to identify areas of consistency and divergence and to indicate practical recommendations for the implementation of industrial symbiosis.

Hoover's business information database was used in the sample selection process. Based on a review of the literature, the following keywords were identified in preparation for the selection of entities for the study: industrial symbiosis, cooperation, certificate, enterprise and companies. The selected words were used to select the initial databases of companies in all partner countries, from which respondents were invited to participate in the study (Austria - 435, Bulgaria - 30, Czech Republic - 116, Denmark - 450, Greece - 46, Italy - 443, Netherlands - 909, Norway - 86, Poland - 370, Slovakia - 74, Slovenia - 265). The differences in the number of potential respondents identified are due to the activity of enterprises in the area of IS and the popularity of the Hoover's database in individual countries.

Individual in-depth interviews (IDI)

The following individuals were invited to participate in in-depth interviews: different groups of stakeholders representing the circular economy sector, business support

⁴ Domenech et al. (2018). Cooperation fostering Industrial Symbiosis, Report prepared for DG Grow, available at: <https://publications.europa.eu/en/publication-detail/-/publication/174996c9-3947-11e8-b5fe-01aa75ed71a1/language-en>

organisations, specialised research institutes, policy makers' institutions, trainers, and training providers. The following respondent selection scheme was used in each country:

- Trainers: 5 VET providers and 5 HEIs in each partner country (min. 10 trainers of both categories will be participating in the procedure in each country), and CE sector employees: 10 men and 10 women working in the field of circular economy practices (min. number of interviews 10 in total),
- 5 business support organisations, five specialised research institutes, (min. number of interviews 10 in total),
- 10 firms actively involved in circular economy practices (min. number of interviews 10).

The complete interview questionnaire consisted of the following parts: Opening questions (sect. 1), Industrial symbiosis – definitions, identification, meaning (sec. 2), Practices within the IS (sect. 3), Determinants of the IS (sect. 4), Environmental policy (sect. 5), IS barriers (sect. 6), Digital Industrial Symbiosis (sect. 7), Training needs in DIS modules (sect. 8), Collaboration and integration (sect. 9). Each of the sections listed contained a list of questions that could be asked to participants. This was an initial proposal, the implementation of which depended on the individual knowledge and experience of the respondent. It was assumed that some parts could be omitted or developed further depending on the course of the interview. The interviews were semi-structured.

Table 1. Individual in-depth interview procedure (with questions).

Sect.	Topics	Specific topics
1.	Opening questions	What is your job? Please describe your daily duties.
2.	Industrial symbiosis – definitions, identification, meaning	• How do you understand the term industrial symbiosis (IS)? • Do you know companies/organisations where IS is carried out? • What motivates organisations to adopt Industrial Symbiosis practices? • What are the main barriers or challenges faced when implementing IS practices?
3.	Practices within the IS	• Could you provide examples of how it influences daily operations or employee engagement? • Please give examples of supportive actions taken at the organisational level and policies/priorities/activities/strategy elements in your company to support and develop IS. • Are your direct superiors supportive of efforts to establish relationships and initiate IS? [if YES - ask for specific examples, if NO - ask for an explanation why].
4.	Determinants of the IS	• What factors influence an organisation's ability to form partnerships? • What role does trust play in the process of developing a relationship within IS? • What is the role of sharing information with partners and obtaining information from partners in IS cooperation? • What is the importance of access to funds in creating exchange networks? • Do environmental policies and regulations in your country encourage IS? • What is the role of infrastructure (e.g. digital platform, networks, industry associations) in supporting IS? • What is (could be) the role of consulting in IS development? • How does the lack of organisations representing entrepreneurs or coordinating different industries (chambers) affect the development of IS?

		What could make more entities interested in IS?
5.	Environmental policy	- What are the main regulations and laws that may hinder the development of Industrial Symbiosis in your country? - How does current legislation limit the possibilities of cooperation between companies within IS? - What legislative changes do you consider crucial for facilitating the implementation of Industrial Symbiosis? - How can governments and companies be encouraged to commit long-term to the development of IS?
6.	IS barriers	- What factors cause some companies not to engage in IS? - What do you think is a barrier to IS engagement in your company? - Are there people in the company who are against such solutions? - How would you characterise such people? - What are the main concerns of companies regarding the economic viability and risks associated with waste exchange within IS? - How can companies be encouraged to engage in IS practices, considering their need for profitability? What business models or innovative financial solutions could help overcome these barriers? (e.g. circular business model, B2B business model)?
7.	Digital Industrial Symbiosis	- What is the relevance of digitalisation to the development of IS? - What specific supports or resources do assist organisations in this digital transition? - How can digital platforms contribute to reducing IS barriers? (The term DIS should be introduced.) - Could you describe your experience or thoughts regarding the transition from traditional Industrial Symbiosis to Digital Industrial Symbiosis? - What are the main technological challenges related to monitoring and managing waste and resource flows within IS? - How can modern digital technologies (e.g. digital twins, big data analytics, blockchains, artificial intelligence, additive manufacturing, internet of things, 5G/6G network communications, cloud computing) help overcome these challenges? - What do you think DIS consists of in relation to the traditional approach to IS? - What long-term benefits do you see from the implementation of Digital Industrial Symbiosis in your country? - What initiatives or projects do you consider key for the future development of Digital Industrial Symbiosis in your country?
8.	Training needs in DIS modules	1. Introduction to the SymbioTech curriculum: - What are the current educational offerings related to Circular Economy and Industrial Symbiosis in your country? - Could you describe the most prominent training programs or courses available? - Who provides these educational offerings (HEI, VET providers, private organisations)? - Are there specific gaps or areas lacking in current educational programs? - How well are these programs aligned with industry needs and expectations? - How do you assess the need to integrate new topics related to Digital Industrial Symbiosis into existing educational programmes? - Which of the sub-topics do you consider most important for the development of Digital Industrial Symbiosis competencies? - Marketplaces for trading industrial waste and by-products; - AI and machine learning to predict material flows and optimise supply chain/process; - Blockchain technologies, to create transparent and secure tracking and certification systems for material and energy flows; - Symbiotic energy efficiency/management technologies and models; - Life Cycle Assessment principles for assessing the environmental benefits and drawbacks of sharing resources;

		- Environmental Management Systems; - Human aspects related to Industrial Symbiosis; 2. Innovative technologies and methods: • What applications do you see for marketplaces for trading industrial waste and by-products? • How can AI and machine learning help optimise material and process flows? If necessary, give an example of AI and ML. • What are the challenges and benefits of implementing blockchain technology in systems for tracking and certifying material and energy flows? If necessary, explain blockchain. 3. Energy efficiency and management: • What technologies and energy efficiency models do you see as key to the development of Digital Industrial Symbiosis? 4. Role of Life Cycle Assessment in Digital Industrial Symbiosis: If necessary, explain LCA meaning. • How do life cycle assessment principles contribute to understanding the environmental benefits and drawbacks of resource sharing in the context of Digital Industrial Symbiosis? 5. Training needs of the DIS manager: • What specific human aspects need to be considered when implementing DIS practices? • What essential qualifications should possess a professional responsible for facilitating and managing IS and CE in an organisation? Please specify knowledge skills, social competencies. • Which are the most important (ask for a hierarchy of importance)? • What areas of knowledge and skills do you consider most important to be trained? • How can the training program help overcome technological and organisational barriers? • What are your expectations regarding the practical application of knowledge acquired during training? • Could you describe the existing qualifications and competencies among women currently involved in the circular economy sector? • What specific training needs may be identified among women working or aiming to work as professionals responsible for facilitating and managing IS and CE in an organisation? • Are there known skill deficits currently impacting women's effectiveness in such roles? • How could training and support systems better accommodate women's learning preferences and career development needs in this field especially in leadership roles? • How can the curriculum promote gender equality and diversity in the DIS workforce? • What are the anticipated future skills required for effective performance in such roles?
9.	Collaboration and integration	• What opportunities do you see for collaboration among universities, companies, and other stakeholders in initiatives related to Digital Industrial Symbiosis? • How can such initiatives foster the integration of different disciplines and specialisations within the context of Digital Industrial Symbiosis? • What do you consider as the long-term benefits of implementing structured educational and industry-focused initiatives for Digital Industrial Symbiosis?

The purpose of the interviews was to gain a deeper understanding of IS and identify key topics that could be developed in further stages of the research. Duration of one interview: maximum 90 minutes (depending on the respondents' knowledge, experience and involvement). The form of the interview depended on the respondent's choice and availability (online/telephone/face-to-face).

To supplement the knowledge gathered during the interviews, an online survey was conducted using Google Forms, which enabled the efficient consolidation of the results obtained.

The selection of respondents was multi-channel and largely deliberate. It used a database of companies prepared for in-depth interviews, social media, and individual contacts of project team members. In the next stage, the snowball method was used and existing study participants were invited to expand the group of respondents. A research agency was also used to assist with the quantitative research. The online surveys were conducted between 15 April and 15 May 2025.

A total of 187 companies actively participated in this comprehensive survey, all of which were already implementing various IS practices. These contributing companies were geographically distributed across nine distinct European countries, providing a broad and insightful cross-section of the European industrial landscape. The country-specific breakdown of participation (presented in alphabetical order) is as follows. Austria (11 respondents), Bulgaria (15), Czech Republic (11), Denmark (25), Greece (15), Netherlands (10), Norway (14), Poland (79) and Slovenia (7).

The data underpinning this analysis were collected through a structured survey instrument comprising 56 distinct questions. These questions were designed to capture a broad spectrum of information pertinent to industrial symbiosis, ranging from fundamental operational aspects and collaborative structures to subjective perceptions of benefits, trust dynamics, and internal organisational integration. The various question formats employed were as follows: Binary Questions (Yes/No), 5-point Likert Scale Questions, Categorical and Open-Ended Questions and Numerical Data.

The analytical backbone of this report is based on descriptive statistics, which serve to summarise the fundamental characteristics of the data set comprehensively. Beyond simple summation, this includes the calculation and interpretation of means, medians, and standard deviations to articulate central tendencies and dispersion.

Furthermore, to investigate the potential interrelationships and underlying dynamics within the collected data, a correlation analysis was systematically performed. Specifically, Pearson's correlation coefficients (r) were calculated. Pearson's correlation is a parametric statistical measure that quantifies the strength and direction of a linear relationship between two continuous variables. Its values range from -1 (indicating a perfect inverse linear relationship) to +1 (denoting a perfect direct linear relationship), with 0 signifying no linear correlation. For instances involving one binary variable and one continuous/Likert-scale variable, the Pearson

coefficient effectively functions as a point-biserial correlation, providing a measure of association between a dichotomous variable and a continuous one. This rigorous analytical approach helps to identify which specific factors could be significantly influenced or consistently associated with the successful implementation, perceived benefits, and overall trajectory of industrial symbiosis. To ensure the robustness and practical relevance of our findings, only those correlations identified as statistically significant (with a p-value less than 0.05) and simultaneously demonstrating at least moderate strength (an absolute Pearson's r-value of 0.3 or higher) are highlighted and extensively discussed within the report. This dual criterion helps to focus on relationships that are unlikely to be due to random chance and possess meaningful practical implications.

The third type of primary research used to analyse the phenomenon of industrial symbiosis was focus group interviews (FGIs). Qualitative focus group interviews (FGIs) were conducted remotely, with the participation of representatives of companies operating in the IS model (both women and men).

The study aimed to gather in-depth knowledge about the experiences of micro, small and medium-sized enterprises (SMEs) actively participating (or capable of participating) in industrial symbiosis (IS). The analysis covered barriers, motivators, managerial competencies, the role of women, and educational and digital needs related to IS.

The group interview scenario (semi-structured) included, among others, the following topics:

- knowledge and the beginnings of IS implementation,
- role and competences of an IS manager,
- educational needs and evaluation of training modules,
- participation of women in IS,
- digitisation and automation in IS.

The interview used in-depth techniques aimed at identifying specific insights and practical examples of activities.

Two FGI sessions were conducted with a total of 16 representatives of SMEs operating in the IS area, divided into women (8) and men (8). Each FGI session lasted approximately 120 minutes. Completion date: 10 and 15 July 2025.

Qualitative analysis according to a thematic approach: identification of recurring patterns, opinions, attitudes and barriers. Key analytical areas were identified: competences, educational needs, digitisation, the role of women, and barriers to IS implementation. The analysis was practical, focused on drawing recommendations for the development of the SymbioTech programme.

1.2. Qualitative research results

Understanding, Challenges, and Enablers of Industrial Symbiosis

1. Understanding of the Industrial Symbiosis (IS) Concept

Participants in the study primarily perceive industrial symbiosis as a form of cooperation between companies, aimed at the reuse of waste and by-products in the production processes of other entities. They emphasized tangible economic benefits (such as cost reduction and production optimization), as well as environmental effects (waste minimization, resource conservation, and closing material loops). IS was functionally defined as a mechanism for resource sharing and the reduction of material and energy losses.

“What becomes waste in our plant is a valuable product in another.”
“It’s about reducing what we throw away so others can use it.”

▪ Limited Awareness of the Term “Industrial Symbiosis”

Despite an intuitive understanding of the principles behind IS, the term itself proved to be little known or rarely used in professional practice. Both managerial staff and operational specialists admitted unfamiliarity with the concept. Instead, they more frequently employed terms such as: circular economy, material, efficiency, recycling, waste management or simply sustainability.

“No one here says ‘industrial symbiosis. If I said that, people would laugh.”
“We tend to use terms like ‘circular economy’ or just ‘waste.’”

▪ Conceptualizing IS through Familiar Frameworks and Strategies

Although IS-related practices are present in the operations of many companies such as: material exchange, energy optimization, or cooperation with industry partners, they are rarely identified as part of industrial symbiosis. Instead, participants interpret these activities within more widely recognized categories, such as circular economy, industrial clusters, ESG (Environmental, Social, and Governance) strategies, or EU climate policy requirements. In this context, IS is often viewed through the lens of compliance with environmental regulations and broader sustainability strategies.

▪ Ambivalent Attitudes Toward EU Policies and Regulations

Respondents also discussed IS in the context of European Union environmental and climate policy, pointing to both enabling and limiting aspects. On the one hand, EU frameworks were seen as supportive of innovation, providing access to funding, and promoting resource efficiency. On the other hand, they were also viewed as burdensome, with complex regulatory requirements and excessive bureaucracy. Such factors may influence how IS is perceived and the willingness of companies to engage in its implementation.

2. Barriers and Challenges to Industrial Symbiosis Implementation

Despite growing recognition of industrial symbiosis (IS) as a critical component of the circular economy transition, multiple systemic barriers and challenges continue to hinder its wider adoption across Europe. Drawing from qualitative data collected in Austria, Bulgaria, Czech Republic, Denmark, Greece, Italy, Netherlands, Norway, Poland, Slovakia, and Slovenia, the following key themes emerge:

▪ Limited Awareness and Conceptual Clarity

A recurrent barrier across all countries is the low level of awareness and understanding of industrial symbiosis, particularly among small and medium-sized enterprises (SMEs). In many cases, the IS concept is either unknown or conflated with general waste management or circular economy practices. This cognitive gap impedes strategic planning and integration of IS principles into business models.

- *Austria, Slovakia, and Slovenia* highlight a significant lack of IS-specific knowledge, especially in SMEs.
- *Poland and Italy* report limited environmental awareness and insufficient internal competencies related to circular business models.

▪ Trust Deficit and Reluctance to Share Information

A critical socio-organisational barrier observed across all countries is the **low level of inter-organisational trust**. Companies are frequently reluctant to engage in collaborative resource sharing due to concerns over **confidentiality, loss of competitive advantage, and misuse of proprietary information**.

- *Austria, Bulgaria, Poland, and Slovakia* explicitly cite unwillingness to share operational data or material flow information.
- *Denmark and Italy* indicate that finding trusted partners outside existing networks is difficult without facilitation mechanisms.

▪ Legal and Regulatory Complexity

Regulatory frameworks often **lack clarity, consistency, or flexibility**, particularly regarding **waste classification, permitting procedures, and cross-sectoral resource flows**. These complexities hinder the establishment of IS partnerships and material exchange systems.

- *Italy and Norway* note that rigid or outdated waste regulations act as a major constraint.
- *Poland* highlights the fragmentation and opacity of environmental legislation and ESG integration at the EU level.
- *Slovenia* emphasizes regulatory uncertainty and institutional inertia.

▪ Financial and Economic Constraints

A widespread barrier is the **lack of financial resources and incentives** to initiate or scale IS projects, especially for SMEs. The high **initial investment costs**, absence of clear return-on-investment models, and limited public funding mechanisms deter companies from engaging in IS initiatives.

- *Austria, Bulgaria, Greece, Poland, and Slovenia* report that IS is often economically unfeasible without targeted support.
- *Greece* further identifies market-related barriers such as limited demand for secondary materials.

▪ Organisational and Human Resource Limitations

Many companies face **internal organisational constraints**, including **short-term strategic focus, lack of staff with relevant expertise, and limited managerial commitment**. Human capital deficits are especially pronounced in regions where IS facilitation or advisory services are not well developed.

- *Slovakia, Poland, and Greece* identify a shortage of qualified personnel and environmental management skills.
- *Norway* reports a lack of trained facilitators for flow mapping and inter-company collaboration.

▪ Inadequate Digital and Physical Infrastructure

The absence of **digital platforms for matchmaking, resource flow visibility, and material tracking** is another key impediment. In many regions, there is no centralized database or technical tool to facilitate resource exchanges across sectors.

- *Denmark, Slovakia, Slovenia, Poland, and Norway* all emphasize the need for digital infrastructure to enable effective IS networking.
- *Slovakia and Greece* also cite weak physical infrastructure and underdeveloped support systems.

▪ Cultural and Psychological Barriers

Resistance to change, **short-term economic thinking, and institutional conservatism** frequently prevent companies from embracing IS. In many cases, cultural attitudes toward innovation and risk-sharing act as invisible yet powerful deterrents.

- *Italy and Poland* identify deep-rooted cultural resistance, especially among managers and decision-makers.
- *Austria* points to a “negative mindset” and general scepticism towards collaborative models.

3. Drivers for IS

In the countries studied, both common and national context-specific drivers supporting the development of industrial symbiosis are perceived. Country-specific factors are described first, followed by an attempt to identify meta-drivers for the populations interviewed.

In Austria, respondents attribute key importance to policies that support IS and funding systems that enable the implementation of business-to-business cooperation. Also important are trust and good relationships between partners, supported by geographical proximity and digital platforms that bring participants together. Transparency and knowledge sharing promote the sustainability of relationships.

In Bulgaria, the main motivators for informants are economic benefits in the form of cost savings and improved resource efficiency, as well as the need to comply with EU regulations.

Denmark as indicated by informants is an example of a country where the drivers of IS are particularly extensive. These include economic incentives and stringent environmental regulation, as well as strong government support. Denmark's culture of trust and consensus, together with its drive for green transformation, creates a favorable environment for collaboration. The high level of innovation, the technological potential of the economy and a well-educated workforce further strengthen the IS dynamic.

In the Czech Republic, according to Informants, companies focus on cost reduction opportunities, regulatory pressures and offers to use EU funds. Managers see IS as a pathway to a circular economy, but emphasise the need for clearer guidelines and practical implementation tools.

In Greece, informants indicate that the driving factors are multidimensional and include legal, political, financial, market, organisational and information considerations, as well as technical, geographical, social and environmental aspects. This shows that IS is seen as a process dependent on a broad ecosystem of stakeholders.

In Italy, according to informants, not only the organisational drivers of IS are analysed, but also the criteria for companies' willingness to cooperate. Digitalisation is of great importance - both in the context of the Digital Industrial Symbiosis and in the broader dimension of IS development. Regulatory and financial barriers are also key, which can be mitigated through appropriate policies, legislative instruments and financial support.

In Norway, according to informants, a culture of trust is particularly important to foster the early stages of cooperation. Risks are mitigated through public financial support mechanisms, such as the Enova or Longship project.

In Slovenia, informants indicate that trust, transparency and frequent communication between partners are key factors. Geographical proximity and common sustainability goals are

also important. Motivation is strengthened by economic savings and support from institutions and advisors. Digital tools that make it easier to match partners and track material flows play an important role.

Meta-drivers of Industrial Symbiosis Development in Partner Countries

A qualitative cross-country analysis reveals a set of shared drivers that facilitate the adoption and diffusion of Industrial Symbiosis (IS). Despite context-specific differences, it is possible to identify meta-categories of drivers that constitute the foundation for building integrated frameworks to support IS at both regional and European levels.

First, **economic benefits and resource efficiency** remain the primary motivation for enterprises to engage in IS. The potential to reduce operational costs, increase efficiency in resource use, and achieve long-term savings acts as a strong incentive for industrial collaboration.

Second, **regulatory frameworks and policy support** serve as important catalysts for IS uptake. Strict environmental regulations, clear definitions of waste and by-products, and access to European and national funding significantly accelerate adoption. In countries where public policies provide stable and predictable institutional settings, firms demonstrate a higher willingness to participate in symbiotic initiatives.

Third, a **culture of trust and cooperation** plays a crucial role in ensuring the durability of symbiotic linkages. Transparent communication, openness to knowledge sharing, and traditions of consensus-building and cooperation, particularly strong in Nordic countries, help overcome cognitive and organizational barriers.

Fourth, **geographical and organizational proximity** facilitates partnerships by lowering logistical costs and fostering more frequent interactions. Regional networks and industrial clusters function as key hubs for initiating and scaling IS practices.

Fifth, **digitalisation and technological platforms** are increasingly perceived as strategic enablers of IS. Digital tools support resource mapping, partner identification, and material flow monitoring, thereby enhancing transparency and efficiency of exchanges. Digital Industrial Symbiosis (DIS) emerges as a forward-looking trajectory, leveraging data and technology to unlock the full potential of symbiotic practices.

Sixth, **institutional support and facilitation** structures act as mediators and catalysts of IS. Cluster organisations, government agencies, and specialised consultants reduce transaction costs, build trust, and enhance the capacities of firms, especially SMEs, to engage in IS projects.

Seventh, **environmental and societal factors** further strengthen the momentum for IS through the pressure of green transition agendas, climate policy commitments, and rising societal expectations regarding sustainability. In certain contexts, such as Greece or Slovenia,

community-based and cultural dimensions reinforce local responsibility and collaborative engagement in IS.

Educational challenges of Industrial Symbiosis

1. Characteristics of educational offers in partner countries

Educational offers in the field of the circular economy (CE) and industrial symbiosis (IS) vary significantly across European countries, reflecting national priorities, institutional capacities, and policy frameworks. While many universities and training providers integrate CE elements into their curricula, IS is most often treated as a complementary or sector-specific component rather than a standalone discipline. The following overview presents country-specific approaches, highlighting both strengths and gaps in the provision of CE and IS education.

- **Austria**

In Austria, the educational offer in the field of the circular economy (CE) and industrial symbiosis (IS) is primarily based on courses and training related to sustainability, the CSRD (Corporate Sustainability Reporting Directive)⁵, and recycling systems. Universities integrate CE elements into study programs, while annual conferences, workshops, and webinars targeted at local coordinators serve as an additional channel for knowledge transfer. However, IS does not function as a separate subject but rather as a complementary module.

- **Bulgaria**

In Bulgaria, available educational programs are fragmented and unsystematic. They are delivered by universities, VET providers, and private centers. Most of them focus on environmental management and general sustainability issues. There is a lack of specialized training in Digital Industrial Symbiosis (DIS), as well as practical courses related to IS implementation in industry. Gaps in digital technologies (AI, blockchain, IoT) are particularly evident.

- **Denmark**

Denmark stands out with a well-developed and diverse offer. Four universities and two university colleges provide courses on CE, including elements of IS. Industry organizations and the Symbiosis Center Denmark (<https://symbiosecenter.dk>) deliver more practical and tailored training for companies. University programs focus mainly on theory, while practical aspects of IS are developed by non-academic institutions.

- **Czech-Republic**

⁵ The Corporate Sustainability Reporting Directive (CSRD) is an EU legislation aimed at enhancing transparency in corporate sustainability reporting, requiring companies to disclose their environmental and social impacts.

In the Czech Republic, there are no dedicated IS education programs, though respondents emphasized a broader need for education. Managerial competencies are particularly important: information selection, critical thinking, communication, knowledge of CE and waste management law, as well as adaptability and problem-solving skills. IS is seen more as part of the wider CE agenda and EU regulatory framework.

- **Greece**

In Greece, education in CE and IS is developing dynamically. Universities (through continuing education centers such as KEDIVIM, (<https://kedivim.uoc.gr>) and private institutions increasingly offer online courses and training for employees. At the master's level, many specialized programs on sustainability and circular economy strategies have emerged. The offer is broad and accessible, but IS is usually taught as a component of CE education rather than a standalone subject.

- **Italy**

In Italy, CE is well integrated into university programs, especially at the master's and postgraduate levels, where strong links are made to the Sustainable Development Goals (SDGs). IS does not exist as a separate subject but as a module within sustainability courses. Research groups and ENEA, (<https://www.enea.it>) play an important role in promoting IS and have developed a dedicated training pathway. Sectoral programs also exist, for example in agribusiness and waste reuse.

- **Netherlands**

The Netherlands offers a wide range of academic and online CE courses, provided by TU Delft, the University of Amsterdam, Vrije Universiteit Amsterdam (VUA), Leiden University, and Maastricht University. Massive Open Online Courses (MOOCs)⁶ and masterclasses are popular, increasing accessibility, though most require registration and fees. IS continues to appear mainly as a component of CE courses rather than as an independent topic.

- **Norway**

The educational offer in Norway includes both higher education (CE and IS courses at **Norwegian University of Life Sciences** (NMBU), Høgskulen på Vestlandet (HVL), Norwegian University of Science and Technology (NTNU) and vocational schools (e.g. CE courses in the wood and plastics sectors). In addition, online courses (NKI, <https://www.nki.no/>) and business programs (Innovation Norway, regional business associations) are available. Despite this broad offer, there are no accredited programs for IS facilitators, and DIS-related content is scarce.

- **Poland**

⁶ A massive open online course (MOOC) or an open online course is an online course aimed at unlimited participation and open access via the Web.

In Poland, CE is well represented both in higher education (bachelor's, master's, doctoral, and postgraduate studies) and in courses provided by private training companies. Numerous CE-related subjects appear in curricula, ranging from urban ecology to LCA and environmental design. IS does not exist as a separate discipline but is included as part of broader thematic blocks.

- **Slovakia**

In Slovakia, there is no standalone program dedicated to CE, but selected universities, like University of Economics in Bratislava, Slovak University of Technology in Bratislava, Slovak University of Agriculture in Nitra include CE topics in individual subjects. Educational projects and associations, such as INCIEŇ, (<https://incien.org/>), play an important role, offering workshops, discussions, and practical activities in secondary schools. International projects also contribute to developing digital tools e.g. the CIRCLES project, (<https://circlesproject.eu/>).

- **Slovenia**

Slovenia has a relatively well-developed offer in CE and bioeconomy, though IS-related content remains limited. Several institutions (FUDŠ, Ptuj College, Institute of Occupational Safety and Health) run programs and training that partly cover IS. However, most universities focus on general sustainability and waste management. Many trainings are informal, short-term, or project-based. There is a recognized need to complement the offer with digital (DIS) content, as well as soft, systemic, and legal competencies.

Comparative summary of CE and IS education in partner countries

The analysis of interviewees' statements regarding educational offerings in each country shows variation in the degree of development and specialisation of programmers related to the circular economy (CE) and industrial symbiosis (IS).

Systemic Approach to IS/CE Education-Denmark, Norway, Netherlands, Italy

In these countries, the educational offer is well developed, covering higher education institutions, vocational training, professional courses, and postgraduate programmes. Industrial Symbiosis is addressed, though often as a module within broader Circular Economy programmes.

- **Denmark** - combines academic knowledge (universities) with practical training (industry organisations, symbiosis centres).
- **Norway** - academic and VET programmes are available, though there is no accredited IS facilitator programme yet; limited integration of Digital Industry Symbiosis (DIS) content.
- **The Netherlands** - strong presence of online courses (MOOCs, masterclasses), mainly at the academic level.

- **Italy** - well-developed university programmes and sectoral projects; IS is promoted mainly by research institutions (e.g. ENEA).

Integrated Thematic Approach to IS/CE Education- Austria, Greece, Poland, Slovenia

These countries demonstrate a relatively broad offer in the field of Circular Economy, with IS-related content included as a complementary element within wider sustainability frameworks.

- **Austria** - courses, study programmes, and conferences on CE and sustainability are available, with IS present to a limited extent.
- **Greece** - rapid development in recent years, with many postgraduate and online programmes; IS is still positioned as a secondary theme.
- **Poland** - a rich academic and private offer in CE, ESG, and waste policy; IS appears indirectly within selected modules.
- **Slovenia** - HEI and VET programmes include IS components (e.g. FUDŠ, Ptuj College), though the emphasis remains on general sustainability and bioeconomy.

Contextual Approach to IS/CE Education- Bulgaria, Czech Republic, Slovakia

In these countries, education in the field of CE and IS is at the stage of early formation and dynamic growth. The current offer is mainly initiative- and project-based, but this creates significant potential for expanding towards more comprehensive educational pathways in the future.

- **Bulgaria** - courses are offered by universities, VET schools, and private training centers. The educational offer is gradually evolving towards broader inclusion of DIS and more practice-oriented modules for industry.
- **Czech Republic** - although there is no dedicated IS offer yet, respondents clearly indicate the need for programmers developing managerial competences such as analysis, critical thinking, and knowledge of environmental law.
- **Slovakia** - CE topics appear mainly within projects (e.g. CIRCLES, INCIEN) and selected university courses. This forms a good starting point for building specializations and formal IS learning pathways.

The research, based on qualitative research in all partner countries, covered the following topics: the understanding of the concept of industrial symbiosis, the barriers and drivers of its development, also the benefits of digitalising industrial symbiosis as perceived by informants. In addition, they addressed the current training offerings in the partner countries, the training needs of industrial symbiosis managers and the curricular content needed to professionalise the

SymbioTech management profession. They also focused on the specific training needs of women working or considering working in industrial symbiosis and the reasons for the underrepresentation of women in this profession.

Training Needs Analysis for the Industrial Symbiosis Manager

The insights provided by respondents from different countries highlight that the current educational offer in the field of Industrial Symbiosis (IS) remains fragmented. IS is most frequently embedded within broader Circular Economy (CE) programmes and only rarely developed as a dedicated managerial pathway. This fragmentation underscores the necessity for an Industrial Symbiosis Manager to acquire a holistic competence framework that extends beyond sector-specific expertise. The required skill set should encompass managerial and leadership capacities, regulatory and policy literacy, technological proficiency, and cross-cutting soft skills that facilitate collaboration, negotiation, and stakeholder engagement.

Based on the conducted interviews, eight categories of training needs for industrial symbiosis managers were identified:

1. **Technical Competences** – Understanding of industrial processes, material and energy flows, and sector-specific technologies, including LCA.
2. **Digital Competences** – Proficiency in digital tools (AI, IoT, blockchain, GIS, ERP, digital material passports), supporting data-driven IS design and monitoring.
3. **Legal and Regulatory Competences** – Ability to interpret and apply EU and national regulations on waste, resources, ESG, CSRD, and taxonomy.
4. **Business and Economic Competences** – Skills in project and financial management, cost–benefit analysis, risk management, and aligning IS with long-term strategies.
5. **Strategic and Analytical Competences** – Systems thinking, critical and adaptive decision-making, and the ability to analyse complex industrial ecosystems.
6. **Soft and Leadership Skills** – Communication, facilitation, negotiation, trust-building, change management, and inspiring leadership.
7. **Sector-Specific Competences** – In-depth knowledge of industry-specific resource flows and opportunities (agrifood, energy, tourism, chemicals, waste).
8. **Inclusive and Social Competences** – Promoting diversity, gender equality, mentoring, stakeholder engagement, and cross-sector collaboration.

Table 2. Competency Matrix of the IS Manager.

	Description	Priority (based on respondents)	Countries highlighting particular importance
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Technical Competences	Knowledge of industrial processes, material and energy flows, LCA, and sector-specific technologies.	High	Poland, Greece, Italy, Slovenia, Slovakia
Digital Competences	Ability to use digital tools (AI, IoT, blockchain, GIS, ERP, digital material passports).	Medium–High (growing)	Bulgaria, Norway, Slovenia, Slovakia, Poland
Legal and Regulatory Competences	Interpretation and implementation of EU and national law (waste, resources, ESG, CSRD, taxonomy).	Very High	Czech Republic, Denmark, Poland, Greece, Italy
Business and Economic Competences	Project and financial management, cost–benefit modeling, risk analysis, and business strategy.	High	Italy, Denmark, Norway, Poland
Strategic and Analytical Competences	Systems thinking, critical and adaptive decision-making, flexibility, and analysing industrial ecosystems.	High	Austria, Czech Republic, Greece, Poland
Soft and Leadership Skills	Negotiation, mediation, facilitation, communication, trust-building, change management, leadership.	Very High	Netherlands, Poland, Denmark, Slovenia, Czech Republic
Sector-Specific Competences	Specialist knowledge of sectors (agrifood, energy, tourism, chemical industry, waste management).	Medium–High	Italy, Poland, Greece
Inclusive and Social Competences	Promotion of gender equality, mentoring, stakeholder engagement, and cross-sectoral collaboration.	Medium (critical in some countries)	Norway, Slovenia

The analysis of competence needs and available educational offerings in partner countries indicates that training Industrial Symbiosis (IS) Managers requires an integrated and modular approach, tailored to diverse market and regulatory expectations. Training programmes should cover all eight key competence areas.

For effective IS implementation, it is essential to combine sector-specific knowledge with managerial and digital competences. Microcredentials play a significant role in this process, as they enable the certification of acquired competences on a modular basis. Each module (e.g. “*IS Law and Regulations*”, “*Digital Tools for IS*”, “*Leadership and Facilitation*”) should conclude with a digital badge confirming specific skills.

Microcredentials also allow the personalization of learning pathways, support international recognition and transferability, and can be integrated into qualification systems (e.g. postgraduate studies). They facilitate lifelong learning, enabling specialists to update knowledge in areas undergoing rapid transformation (e.g. digitalisation, ESG regulations, AI). Training programmes should combine online courses, practical workshops, case studies, and projects carried out in cooperation with enterprises. This approach connects theory with practice, which is particularly important in IS, where cross-sectoral collaboration is crucial.

Analysis of Conditions and Opportunities for Increasing Women’s Participation in the IS Manager Profession

The role of women in the circular economy (CE) and industrial symbiosis (IS) is gaining increasing importance in the context of building sustainable and innovative development models. Across the partner countries, the situation differs significantly, with diverse barriers and training needs identified depending on local social, cultural, and institutional conditions. The following overview presents key country-specific observations and recommendations for supporting women in developing competencies and taking leadership roles in CE and IS.

Austria

- Women are present in IS/CE management roles, though representation in the waste management sector remains limited.

Bulgaria

- High demand for training in leadership, negotiation, and digital tools.
- Recommended inclusive learning environments, mentoring, and promotion of women’s participation.

Denmark

- Women are strongly represented in the labour market, but less so in IS management.
- Barriers are linked to managerial culture in technical business sectors.

- Suggested measures: mentoring, role model programmes, scholarships, and initiatives addressing stereotypes.

Czech Republic

- No specific training needs identified for women.
- Women are more often engaged in HR, ESG, and NGO-related areas.
- IS manager roles are typically integrated into existing structures.

Greece

- Broad range of identified training needs (technical, managerial, regulatory, soft skills).
- Suggested measures include partnerships with women-in-STEM organisations, peer groups, mentoring, and female-focused case studies.

Italy

- No distinct training needs for women identified.
- Equal access to opportunities highlighted as a priority.

Netherlands

- Strong focus on soft skills training (communication, leadership).
- Emphasis on increasing women's representation and tackling discrimination.

Norway

- Women make up the majority of CE/IS graduates but remain underrepresented in technical professions.
- Targeted training in technical competences (e.g. digital twins, retrofit) is needed.
- Retention of women in the sector is as important as recruitment.

Poland

- Strong presence of cultural stereotypes limiting women's access to technical professions.
- Recommended actions: promotional and educational campaigns at school and university level, mentoring, development programmes, media campaigns featuring female IS leaders, and early-interest programmes for girls.

Slovakia

- Emphasis on inclusiveness and flexible education formats.
- Need for mentoring and support networks.
- Encouragement of women to enter technical IS fields.

Slovenia

- Need to combine technical competences (digital tools, law, systems thinking) with soft skills (leadership).
- Recommended actions: mentoring, women's networks, awareness campaigns, and flexible learning opportunities.

Based on the insights provided by the informants, the research findings made it possible to develop a table that presents a concise description of country-specific challenges in this area,

together with corresponding recommendations. The table serves as a structured summary, highlighting key issues identified in each national context and offering tailored guidance on how these challenges could be effectively addressed.

Table 3. Specific Training Needs and Support Strategies for Women in IS and CE.

Country	Diagnosis	Recommendations
Austria	Women seen as well-prepared for IS/CE managerial roles; underrepresentation in waste management sector.	Promote visibility of women in technical fields; encourage participation in waste management.
Bulgaria	Need for stronger leadership, negotiation, digital skills; importance of inclusive environments.	Leadership and digital tools training; gender-inclusive education; mentoring and outreach.
Denmark	Low female presence in IS management despite high labour market participation; cultural/structural barriers.	Role model programs; women's mentoring; scholarships; awareness on gender bias in sciences.
Czech Republic	No specific gender-based needs; women often in ESG/HR roles; limited standalone IS manager positions.	Ensure equal access to training; promote women in technical IS fields; strengthen NGO leadership.
Greece	Broad spectrum of needs – technical, managerial, regulatory, soft skills; women often underrepresented.	Partnerships with women-in-STEM; scholarships; women-only peer groups; female mentors in IS.
Italy	No gender-specific training needs; women aligned with green and social values.	Equal access; support for inclusion and leadership opportunities.
Netherlands	Need for more representation; women underexposed in leadership; discrimination persists.	Workshops on communication/leadership; more female role models; normalize women's participation.
Norway	Women majority of graduates but minority in STEM workforce; retention issues in CE/IS sectors.	Focus on technical upskilling (digital twins, retrofit); scholarships/mentoring; inclusive networks.
Poland	Strong stereotypes and cultural barriers; male-dominated technical sectors.	Promote IS manager as attractive for women; mentoring & coaching; campaigns; early engagement programs.
Slovakia	Need for gender-inclusive training; women	Flexible training; mentoring; networking;

	underrepresented in technical IS fields.	encourage female participation in material flow management.
Slovenia	Complex set of needs (technical, legal, leadership, communication).	Mentorship, women's networks, flexible formats; awareness campaigns; visibility of women leaders.

Survey responses from various countries show that women's participation in the field of Circular Economy (CE) and Industrial Symbiosis (IS) varies depending on the country and sector. While women are often associated with strong communication, organisational, and collaborative competences, structural barriers remain, including:

- underrepresentation in technical and industrial sectors,
- gender stereotypes and traditional job segmentation,
- limited availability of visible role models and mentoring,
- insufficient training opportunities tailored to women's needs.

In some countries (e.g. Italy, Czech Republic), respondents emphasise the importance of equal access policies rather than separate training programmes for women.

Fundamental areas for improvement:

1. Strengthening technical and digital competences – particularly in areas with lower female participation (e.g. digital twins, blockchain, material flow management).
2. Self - confidence building and breaking stereotypes – campaigns promoting the IS Manager profession as attractive for women, framed in interdisciplinary and socially valuable terms.
3. Mentoring and role models – programmes connecting young professionals with experienced female leaders in IS/CE.
4. Flexible learning formats – enabling the combination of professional and personal responsibilities.
5. Networks and support groups – creation of women's platforms for knowledge exchange, peer-to-peer learning, and matchmaking for future IS managers.
6. Integrating gender perspectives into education – embedding equality and anti-discrimination approaches into HEI and VET curricula.
7. Scholarships and grants – supporting women's participation in CE/IS projects.

Digital Industrial Symbiosis (DIS): Definitions, Significance, and the Need for Digitalization

Digital Industrial Symbiosis (DIS) is perceived by the informants as the natural evolution of traditional industrial symbiosis, enabling the expansion and improvement of collaboration between companies through the use of digital technologies. In this context, DIS refers not only to the use of digital platforms and tools but, above all, to a new way of organizing and coordinating material, energy, and information flows, based on data and automated processes.

Digitalization is considered essential because it allows:

- Overcoming physical and geographical barriers, enabling collaboration among companies from different industries and regions;
- Increasing transparency and trust through technologies such as blockchain or digital product passports;
- Enhancing information exchange and partner matching, for example, through artificial intelligence algorithms or resource databases;
- Optimizing processes and forecasting needs using IoT, sensors, big data analytics, and digital twins;
- Supporting small and medium-sized enterprises, which often lack access to advanced tools, through simple and user-friendly platforms;
- Reducing bureaucracy and transaction costs while simultaneously increasing the scale and efficiency of industrial symbiosis.

In a broader sense, DIS is not regarded merely as a technology but as strategic cooperation infrastructure that integrates technical, business, and institutional aspects. Its development therefore requires not only appropriate digital tools but also managerial competencies, legislative support, and new educational and training models (e.g. programs for SymbioTech Managers).

The conducted analysis of the research results made it possible to capture the specific ways in which DIS is perceived across the partner countries. Below, examples are presented that illustrate the diverse interpretations of this concept. These understandings are not contradictory but rather complementary, reflecting the multifaceted nature of DIS and its context-dependent applications.

In **Austria**, digital industrial symbiosis is primarily perceived as a tool for fostering collaboration and knowledge transfer. A key focus is placed on developing training and practical programs (curricula, vocational training, living labs) that respond to real market needs. Digitalization is considered essential to facilitate communication between IS partners, provide platforms for experiential learning, and support the growth of interdisciplinary centers and professional development programs.

In **Bulgaria**, DIS is understood as a practical tool that supports partner-matching processes and resource monitoring. Digitalization is expected to help companies more quickly identify opportunities for collaboration, track material flows, and improve transparency. The need for digitalization arises from the necessity to overcome barriers, such as lack of information, limited competencies, or transaction costs, that hinder the development of traditional industrial symbiosis.

In the **Czech Republic**, digitalization and the use of digital tools are regarded as a natural element of doing business and strategic planning. DIS is understood here as an evolutionary stage in enterprise development. Companies take a pragmatic approach, investments in digital platforms are subject to cost-benefit analysis. The need for digitalization stems from the demand to streamline collaboration and reduce bureaucracy, while managers expect legislative and institutional support in the form of unified, user-friendly platforms (at either EU or national level).

In **Greece**, the understanding of DIS is linked to the readiness of companies to engage in industrial symbiosis. Digitalization is expected to support both the “hard” side (access to resources such as water, energy, by-products, waste) and the “soft” side (the ability to exchange information, build trust, ensure access conditions, provide infrastructure). Digitalization is seen as essential, as it increases transparency, facilitates data exchange, and enables real-time process monitoring conditions necessary for effective collaboration.

In **Italy**, DIS is understood as a means of overcoming fragmentation and geographical limitations. Digital tools make it possible to connect enterprises from different industries and regions, thereby creating IS linkages where physical proximity is not possible. The need for digitalization thus arises from the necessity to build networks and collaboration platforms, improve information flows, and ensure transparency and traceability of material streams (e.g. blockchain, digital material passports). Although adoption is still limited, digitalization is considered a prerequisite for the development of IS.

In **Poland**, digital industrial symbiosis is perceived as a tool for supporting waste data analysis, process optimization, and automated partner matching. Particular importance is assigned to artificial intelligence, which could automatically connect enterprises based on location, waste codes, or resource demand. The need for digitalization also arises from the necessity to create simple and intuitive systems for SMEs, which are unable to handle complex corporate platforms. The implementation of AI and automation is expected to significantly improve IS operations and scale-up in Poland.

Perceptions of the Conditions Enabling the Transition towards Digital Industrial Symbiosis (DIS) Across Partner Countries

Transitioning from traditional forms of Industrial Symbiosis (IS) to its digital version (DIS) is a complex process, dependent both on the level of technological maturity and on institutional and cultural conditions in individual countries. In general, the main determinants include: the availability of relevant technologies (IoT, blockchain, artificial intelligence, digital material passports), a developed digital infrastructure, legislative and financial support, as well as the competencies of managers capable of utilizing the potential of data and digital tools in business practice. Below are the perspectives of informants regarding the conditions for the transition towards Digital Industrial Symbiosis (DIS).

- **Austria**

In Austria, the transformation towards DIS is supported strongly at the institutional level – government funds (e.g. FFG) are available to help companies implement digital and AI solutions in IS. An important factor is also the use of communication platforms and digital marketplaces (Teams, LinkedIn, Slack). For managers, this implies the need to combine technological and soft skills in order to effectively foster collaboration between companies.

- **Bulgaria**

In Bulgaria, digitalization is mainly perceived as a tool to increase efficiency and transparency. The most important determinants are the development of digital infrastructure, access to financing, and the improvement of digital skills. At the same time, barriers include lack of expertise, costs, and cybersecurity risks. In this context, a SymbioTech Manager must possess knowledge in digital platform operation, data processing, and information security, while also being prepared to implement advanced technologies (AI, IoT, blockchain).

- **Denmark**

In Denmark, the transformation to DIS is approached pragmatically – digital tools are applied when they demonstrably increase efficiency rather than as a universal solution. Key importance is given to platforms that facilitate partner matching and to tools based on AI and blockchain. Another important aspect is the integration of digital solutions with existing management processes and supply chains, while simultaneously emphasizing the role of the “human factor.”

- **Czech Republic**

In the Czech Republic, digitalization is treated as a natural element of enterprise development, with every investment in digital tools subject to cost–benefit analysis. Respondents highlight the need for institutional and legislative support – preferably unified European or national platforms that would facilitate cooperation and reduce bureaucracy.

- **Greece**

In Greece, particular emphasis is placed on developing open and low-cost digital infrastructure supported by intelligent algorithms (ML, multi-agent systems, GIS). Key prerequisites include the development of digital material passports, databases, and collaboration

platforms. The transformation to DIS therefore requires not only access to technology but also managers capable of data management and relationship-building among partners.

- **Italy**

In Italy, the adaptation of DIS is still limited and concerns mainly large, well-organized enterprises. Barriers include low digital maturity and the lack of widely accessible platforms, especially for SMEs. The main motivators are cost reduction, efficiency improvement, and overcoming geographical barriers. Managers should be able to combine technological expertise with change management skills in companies of varying levels of development.

- **Netherlands**

In the Netherlands, emphasis is placed on the functionality of digital tools, the ease of access to data, and the role of big data in fostering inter-company cooperation. Also crucial are managerial competencies in communication and in using digital platforms that enable more effective relationship-building.

- **Norway**

In Norway, the level of IS digitalization remains low – companies still rely primarily on spreadsheets. A major problem is the lack of integration between ERP systems across firms. The development of DIS depends on strengthening managerial competencies in strategically selecting digital tools and embedding them into business processes. A SymbioTech Manager must be able to diagnose companies' real needs and match them with appropriate technologies.

- **Poland**

In Poland, the transformation to DIS requires systemic measures: education, dissemination of best practices, and active lobbying for the development of digital platforms. Particularly important are tools using AI, blockchain, and IoT, which can ensure transparency and data security. However, it is also necessary to provide financing for SMEs and to promote the benefits of industrial symbiosis through efficiency calculators and awareness campaigns.

- **Slovakia**

In Slovakia, respondents emphasize the importance of accessible digital tools and infrastructure that allows for secure data sharing. Legislative support for digital forms of IS is also considered crucial.

- **Slovenia**

In Slovenia, particular importance is attached to transparency and trust between partners – tools such as blockchain and digital platforms enhance the security of cooperation and enable better real-time monitoring of material flows. A SymbioTech Manager should not only be knowledgeable about technologies but also be capable of embedding them into daily practice, ensuring regulatory compliance and effective use of data.

The development and **effective implementation of Digital Industrial Symbiosis (DIS)** depend on a wide range of interrelated factors. These determinants shape both the opportunities and the challenges associated with digitalization processes in industrial ecosystems. They can be grouped into several key categories:

- **Technological:** availability of digital platforms, IoT, blockchain, AI, digital twins, predictive tools, and material flow databases.
- **Organizational:** readiness of enterprises to adopt digitalization (maturity level), integration of DIS with management processes and supply chains.
- **Economic:** access to financing (grants, public support), cost-effectiveness of implementations, cost-benefit analyses.
- **Institutional and regulatory:** political support, legal frameworks and standards (e.g. material passports, ESG requirements).
- **Social and cultural:** openness to cross-sector collaboration, willingness to share data, overcoming mental barriers.
- **Security and trust:** cybersecurity, data protection, process transparency (blockchain).

Based on the results of research conducted in the partner countries, a number of criteria can be identified that determine the readiness of enterprises to move from traditional industrial symbiosis (IS) to its digital equivalent (DIS). Analyses indicate that the foundation of this transformation lies in the combination of technical, organizational, regulatory, and cultural factors. The first and key criterion is the possession of resources and the ability to exchange them. Companies must have an adequate material base (e.g. water, energy, waste, by-products) and infrastructure enabling the logistics and circulation of these resources. However, the mere availability of resources is not sufficient – mechanisms that build trust and cooperation between partners are also necessary. Research emphasizes that transparent communication, openness to data sharing, and clear conditions of cooperation are becoming the cornerstone of implementing digital IS tools. The second area conditioning readiness for digitalization is digital maturity and organizational culture. Enterprises that have internal systems for monitoring material flows and an open culture of cooperation and information sharing are better prepared to use technologies such as IoT, blockchain, or digital exchange platforms. In countries with low digital maturity, reliance on simple tools (e.g. spreadsheets) often remains a barrier, limiting the possibilities of data integration.

Another criterion is access to data and digital tools. Readiness to transition to DIS depends on whether companies can not only collect data from their own processes but also exchange it with partners in a secure and transparent manner. In this context, regulatory and institutional issues are of great importance – managers point out that the transition to DIS requires coherent legal frameworks, reduced bureaucracy, and the establishment of central, user-friendly

platforms supported by national or EU institutions. Financial and organizational factors are also significant. Studies highlight that companies conduct cost-benefit analyses before implementing digital solutions, and access to public funding or EU grants can significantly accelerate investment decisions. Financial support is particularly important for small and medium-sized enterprises, which often lack the resources to develop their own systems. Finally, human capital and managerial competencies play an equally important role. Readiness to implement DIS requires the awareness and knowledge of employees, as well as the ability of management to use digital tools effectively. Managers must be able to identify potential barriers, adapt technological solutions to real needs, and integrate them into everyday business processes. In summary, readiness to move from IS to DIS depends on a combination of technical (data, infrastructure, digital tools), organizational (trust, cooperation culture), regulatory (legal frameworks, institutional support), financial (access to funds), and competency-related (knowledge and managerial skills) elements. The shared experiences of the partner countries show that only the simultaneous fulfillment of these criteria enables the full potential of digitalization to be realized in the development of industrial symbiosis.

Conclusion

The findings reveal a significant gap between the practical implementation of industrial symbiosis (IS) principles and the awareness of the concept itself. Many enterprises are already engaging in IS-compatible activities such as resource sharing, waste valorization, or cross-sector collaboration without explicitly identifying them as industrial symbiosis. This discrepancy highlights the importance of communication strategies that align the terminology of IS with business realities, for instance by embedding it within the more familiar frameworks of the circular economy or ESG agendas.

Barriers to IS adoption are multidimensional, spanning regulatory, economic, cognitive, organisational, infrastructural, and cultural domains. Addressing these challenges requires an integrated approach. Priority actions include targeted awareness-raising campaigns, education and training programs, and the development of practical case studies that demonstrate IS in action. Equally critical are supportive instruments ranging from simplified and harmonized legal frameworks, through financial incentives for SMEs, to digital tools and matchmaking platforms that facilitate resource mapping and partner identification. Moreover, the establishment of public–private facilitation structures is essential to building trust, fostering collaboration, and ensuring long-term sustainability of IS networks.

At a systemic level, the meta-drivers of IS can be clustered into seven categories: **economic benefits, regulatory and policy support, culture of trust, geographical proximity, digitalisation, institutional facilitation, and environmental–societal factors**. Their interplay varies across national contexts, reflecting different levels of maturity, institutional support, and

cultural readiness. Effective implementation of industrial symbiosis therefore requires a **multi-level and context-sensitive strategy** that combines both market and non-market instruments. Such an approach not only enhances the competitiveness of firms but also contributes to broader sustainability and resilience objectives at regional, national, and European scales.

Digital Industrial Symbiosis (DIS) is perceived as the natural evolution of traditional industrial symbiosis, enabling the expansion and improvement of cooperation between enterprises through the use of digital technologies. In this context, DIS refers not only to the use of digital platforms and tools, but above all to a new way of organizing and coordinating material, energy, and information flows, based on data and automated processes.

Digitalization is considered essential because it allows to:

- overcome physical and geographical barriers, enabling cooperation between companies from different sectors and regions;
- increase transparency and trust through technologies such as blockchain or digital product passports;
- streamline information exchange and partner matching, e.g. through artificial intelligence algorithms or resource databases;
- optimize processes and forecast needs by using IoT, sensors, big data analytics, and digital twins;
- support small and medium-sized enterprises, which often lack access to advanced tools, through simple and intuitive platforms;
- reduce bureaucracy and transaction costs, while at the same time increasing the scale and efficiency of industrial symbiosis.

Conclusions and Recommendations for Designing VET and HEI Training in Industrial Symbiosis (IS)

The data obtained during the interviews made it possible to formulate recommendations for the development of training programs dedicated to industrial symbiosis managers. These recommendations address both the content and the structure of such programs, emphasizing the need to equip managers with the necessary knowledge, skills, and competences to effectively foster and coordinate industrial symbiosis initiatives. They also highlight the importance of integrating practical case studies, digital tools, and cross-sectoral perspectives into the training process, ensuring that the programs are aligned with real-world challenges and the evolving demands of sustainable development.

1. A systemic approach to education – complementarity of VET and HEI

Training at HEI and VET levels should be designed as interconnected vessels: academic programs prepare strategists and change leaders, while vocational education (VET) equips practitioners and coordinators of implementation activities. The key link between both levels should be **dual learning** mechanisms (combining study with practice in enterprises) as well as joint implementation projects.

2. Balance between theory and practice

- **HEI:** emphasis on in-depth analytical and strategic knowledge (systems thinking, interdisciplinarity, economics, public policy, EU regulations, modeling of material and energy flows).
- **VET:** strong emphasis on hands-on practice – flow mapping, use of digital platforms, pilot implementations in SMEs, project assignments carried out in close cooperation with enterprises.

3. Strengthening the digital and technological component

Industrial symbiosis increasingly relies on digitalization. Both levels of education should address the existing skills gap in this area:

- **HEI:** courses on AI, blockchain, IoT, data analytics, and digital product passports; development of simulation laboratories for analyzing material and energy flows.
- **VET:** modular operational training in the use of specific digital tools and matchmaking platforms; practical skills development for applying technology in everyday business processes.

4. Legal and regulatory component

- **HEI:** in-depth analysis of EU regulations (taxonomy, CSRD, waste directives, water law, climate policy) to prepare experts capable of interpreting and implementing regulations from a strategic perspective.
- **VET:** practical application of law – ESG reporting in SMEs, compliance with local waste and energy regulations.

5. Soft and facilitation skills

The effectiveness of IS depends on the ability to coordinate and build trust among stakeholders:

- **HEI:** training in process facilitation, mediation, change management, and leadership in cross-sectoral networks.
- **VET:** workshops on communication, negotiation simulations, and case studies in local and industrial contexts.

6. Sectoral and industry specializations

Training should reflect the specificities of sectors with the highest IS potential:

- **HEI:** interdisciplinary specializations in sectors such as agri-food, energy, chemicals, construction, waste management.
- **VET:** short sector-based courses tailored to specific material flows and technologies.

7. Integration of technical and social competences

- **HEI:** interdisciplinary programs combining engineering, economics, and social sciences – preparing managers capable of steering complex IS systems.
- **VET:** dual programs that teach both technology use and teamwork in project contexts.

8. Inclusiveness and sustainable leadership

Programs should promote gender equality, mentoring, and ethical and sustainable leadership. In particular:

- supporting women in leadership roles in countries where barriers are cultural and structural,
- providing mentoring programs, scholarships, and technical training in countries where barriers are institutional and systemic.

9. Modular programs and microcredentials

The most adequate solution is a flexible, modular training system based on microcredentials. This model:

- enables step-by-step acquisition and certification of competences,
- increases accessibility of education for students, practitioners, and policymakers,
- allows rapid adaptation to evolving market and technology needs.

The analysis indicates that both academic (HE) and vocational (VET) training face an urgent need to strengthen **facilitation and digital competences** in the field of industrial symbiosis (IS). Course participants – whether as internal managers or external consultants/facilitators –

must be prepared to lead change processes, engage diverse stakeholder groups, overcome resistance, and foster cross-silo collaboration.

Circular economy (CE) and environmental management issues, although relatively well represented in existing training programs, require stronger orientation toward **practical IS applications**.

A significant educational gap has been identified: the lack of accredited programs for IS facilitators, limited inclusion of digitalization (AI, blockchain, IoT in the IS context), and weak integration of training with actual labor market needs.

The research highlights the need to reinforce training modules focused on:

- facilitation of change processes and resistance management,
- building dialogue and cooperation within and across organizations,
- foundations of digital transformation in IS (AI, blockchain, IoT),
- and aligning learning outcomes with competences sought by the labor market.

Such structured content will better prepare future IS managers and practitioners to act as leaders and facilitators of change in the context of the circular economy and digital transformation.

1.3. Quantitative research results

Comprehensive analysis of data collected from a survey focused on the current state and practices of Industrial Symbiosis (IS) was prepared. The survey gathered valuable information from companies in nine European countries: Austria, Bulgaria, Czech Republic, Denmark, Greece, Netherlands, Norway, Poland and Slovenia. The primary objective of this analysis is to identify and thoroughly explore the dominant trends, recurring challenges, and significant benefits associated with the implementation of IS in these diverse European contexts.

A total of 187 companies actively participated in this comprehensive survey, all of which, as stipulated by the methodology, were already implementing various IS practices. These contributing companies were geographically distributed across nine distinct European countries, providing a broad and insightful cross section of the European industrial landscape. The country-specific breakdown of participation (presented in alphabetical order) is as follows. Austria (11 respondents), Bulgaria (15), Czech Republic (11), Denmark (25), Greece (15), Netherlands (10), Norway (14), Poland (79) and Slovenia (7). The 187 responding companies confirmed that IS is currently carried out within their operational frameworks.

The analysis shows clear indication that waste management and valorization of waste (engaged by a substantial 76.5% of companies) stands out as the most widely used resource targeted within IS initiatives. This prominent focus unequivocally highlights a primary organizational drive toward comprehensive waste valorization, strategic reduction, and effective diversion of materials from traditional disposal pathways. The high level of

engagement with waste management undeniably underscores its perceived critical importance in achieving circular economy objectives, while simultaneously promising notable potential for direct cost savings. Following closely, by-products (actively concerned by 54.5% of companies) represent the second most frequently addressed resource. This significant figure unequivocally demonstrates a strong collective effort to transform various industrial outputs that might otherwise be considered discarded materials into valuable new inputs for other, often entirely different, industrial processes. While participation in by-product valorization is substantial, this figure also implies that there remains considerable scope for broader adoption and innovation in this area across the industrial landscape. Energy (43.9%) and water (30.5%) are also recognized as important resources within the overarching frameworks of IS; however, their integration into symbiotic practices is notably less universal when compared directly with the predominant focus on waste and by-products.

An in-depth analysis reveals that the two most dominant and frequently employed forms of cooperation within IS initiatives are intricately linked to the fundamental objectives of resource circulation: the exchange of energy, by-products, and secondary raw materials (engaged by a significant 56.1% of companies) and the collective gathering and removal of waste materials (practiced by 55.1% of companies). These compelling figures unequivocally demonstrate that more than half of the surveyed companies are actively and collaboratively engaged in sophisticated efforts to manage, valorize, and strategically circulate waste and various industrial by-products throughout their networks. Furthermore, these statistics highlight a strong commitment to facilitating the efficient exchange of essential industrial resources, including critical energy streams and valuable secondary raw materials. Beyond these core material flows, other substantial forms of cooperation observed include the joint use of utilities and shared firm functions (41.2%) and the leveraging of public utilities with demonstrably highly useful effects (41.2%). These figures collectively suggest a broader and more integrated scope of collaborative engagement that extends beyond mere transactional material exchange to encompass shared infrastructure, specialized services, and communal resources. Such expanded collaborative efforts inherently promise to yield more comprehensive efficiencies and foster deeper mutual benefits among participating entities. However, certain other types of cooperation, such as strategic combining of transport for goods and personnel (34.2%), the promotion of more intensive and efficient use of industrial space (35.8%), and the establishment of joint commercial firm facilities (23.5%), appear to be considerably less common.

The analysis provides compelling evidence that SME enterprises, with a commanding 73.8% participation, are overwhelmingly identified as the most frequently engaged actors in IS initiatives. This statistically significant and highly prevalent participation fundamentally highlights their critical and widespread role in driving, sustaining, and expanding IS efforts throughout the industrial ecosystem. This is probably attributable to their inherent organizational flexibility, often pronounced need for improved resource efficiency to remain

competitive, and a natural propensity to foster and thriving within local or regional collaborative networks. Their high level of engagement emphatically suggests that contemporary IS models are remarkably well suited to the operational dynamics, resource constraints, and innovative spirit characteristic of smaller and medium-sized businesses. Following SMEs, large enterprises demonstrate substantial participation, with 51.9% reporting participation. These larger entities frequently serve as foundational partners within symbiotic networks, often providing significant resource flows (both as waste producers and as consumers of secondary raw materials) or offering critical infrastructure and expertise that underpin complex symbiotic relationships. Their notable involvement underscores the strategic imperative of engaging major industrial players to achieve meaningful scale, systemic impact, and broader market adoption within IS. Furthermore, local governments and municipalities play a significant and active role, with 43.9% participation. This robust figure emphatically indicates that direct public sector support, the provision of conducive regulatory frameworks, and proactive local planning are often not just beneficial but, indeed, integral to effectively facilitating, nurturing, and strategically expanding IS ecosystems within specific geographical areas. On the contrary, other crucial actors, such as specialized research institutions (28.9%), industry associations (23.5%) and dedicated facilitators (21.3%), demonstrate less frequent direct involvement in the day-to-day operations of IS initiatives across the overall sample. This pattern suggests that while these entities are undeniably vital to the broader enabling ecosystem of IS (e.g. providing knowledge, networking platforms, or coordination services), their role might be more predominantly supportive, advisory, or indirect rather than direct operational participation in the majority of reported IS projects. Farmers (18.2%) represent a distinct, though currently smaller, segment of involvement in IS, particularly relevant in biobased and agricultural waste valorization streams.

Companies overwhelmingly perceive environmental benefits (mean 3.69, median 4) as the most significant and tangible outcome derived from their participation in IS. This strong perception is in direct alignment with the core objectives of promoting a circular economy and advancing sustainable waste management practices, clearly indicating that the ecological advantages of IS are not only widely recognized but also highly valued by participating firms. Following closely, both operational benefits (mean 3.47, median 3) and social benefits (mean 3.51, median 3) are also highly regarded by companies. Operational improvements suggest improved efficiency, resource optimization, and streamlined processes, while perceived social benefits indicate positive impacts on communities, employment, or stakeholder relations resulting from symbiotic activities. Financial benefits (mean 3.41, median 3) and technological benefits (mean 3.18, median 3), while certainly acknowledged as positive outcomes, are rated slightly lower on average compared to their environmental and broader societal counterparts.

The companies most strongly agree that formal provisions for IS exist within their company policy (mean 3.17, median 3), suggesting a foundational high-level endorsement of IS

principles within organizational governance frameworks. However, a noticeable gradient exists as we move from policy towards deeper integration. The perceived integration into the company's strategy (mean 3.07, median 3) and its specific priorities (mean 2.94, median 3) is less pronounced on average. This critical distinction indicates that while IS is a recognized element within the company's guiding principles, it may not yet be fully embedded as a core, actionable component of long-term strategic planning and daily operational decision-making processes. Furthermore, the lowest average ratings are observed for the degree to which IS is recognized by employees (mean 3.03, median 3) and actively discussed among employees (mean 2.76, median 3).

Companies generally report a moderate level of access to fundamental information and general production data from geographically close industries with mean 2.31 and median 2. This indicates a foundational, albeit sometimes limited, level of information exchange that is essential for identifying initial symbiotic opportunities. However, a significant and concerning trend emerges as the specificity and strategic importance of the data increase: perceived access notably decreases for more detailed and sensitive information types. The reception of long-term planning data (mean 2.19, median 2), access to granular operational details (mean 2.14, median 2), and the acquisition of daily metrics (mean 1.90, median 1) are all rated considerably lower.

The companies involved in IS report varied and, in several key areas, notably limited access to crucial external support resources that could significantly facilitate and scale up their IS efforts. Analyzing the data from questions 19-23, which are rated on a 1-5 scale, allows for a nuanced understanding of perceived accessibility. For access to external funding sources, companies rate their access moderately (mean 2.86, median 3, SD 1.22), suggesting that, although some financial support mechanisms are available, their accessibility might not be universally high. However, perceived access to more specific financial instruments like the Ability to access grants is rated lower (mean 2.65, median 3, SD 1.25), indicating a potential bottleneck in securing targeted financial incentives explicitly designed for creating or expanding symbiotic exchange networks. Similarly, access to digital platforms specifically designed to facilitate resource sharing is perceived as the lowest among these categories (mean 2.47, median 2, SD 1.24), suggesting a significant digital gap in IS facilitation. Access to networking and industry associations (mean 2.82, median 3, SD 1.19) and specialized IS consulting services (mean 2.80, median 3, SD 1.28) is rated moderately, yet still indicates that a considerable portion of companies may not have readily available access to, or do not effectively utilize, these critical nonfinancial supporting resources. The mean ratings for all categories hovering below 3 (the neutral point on the Likert scale) and medians often at 2 or 3, collectively indicate that a substantial number of surveyed companies perceive their access to these critical external support mechanisms as moderate to low.

Companies involved in IS consistently express a generally high and robust level of trust in their partners, a crucial foundation for any collaborative effort. The highest mean ratings are

observed for beliefs in effective joint dispute resolution (mean 3.93, median 4), the partner's strong dedication to shared goals (mean 3.89, median 4), and the fundamental perception of partners as honest (mean 3.87, median 4). Partners are also widely and consistently considered to be predictable (mean 3.66, median 4) and possess the necessary competence (mean 3.65, median 4), and there is a strong collective conviction that cooperation will yield benefits exceeding costs (mean 3.52, median 4). This high level of foundational trust across multiple dimensions is a critical and enabling factor for the successful initiation, execution, and long-term sustainability of collaborative IS projects. Interestingly, despite the inherent risks in new ventures, scepticism towards cooperating with a new partner is relatively low (mean 2.52, median 2), suggesting an openness to expanding IS networks. However, a notable and important area of potential improvement is highlighted by the moderate agreement that partners often cannot *fully* utilize their competencies at all stages of cooperation (mean 2.98, median 3).

A consistently strong and widely held belief among the surveyed companies is the belief that together with their partners, they can collectively achieve more than they could on their own (mean 4.17, median 4). This profound belief in the power of synergy and collaborative advantage serves as a fundamental and powerful motivator for engaging in IS. Companies generally report a good understanding of partner expectations (mean 3.67, median 4), suggesting effective communication channels and a shared vision within collaborations. Furthermore, the overall level of organizational preparedness for IS (mean 3.41, median 4) is rated moderately high, indicating that many firms have taken initial steps to prepare themselves for symbiotic activities. Similarly, the consistent practice of defining clear goals for cooperation (mean 3.44, median 4) and strategically considering partner needs within their own corporate strategy (mean 3.41, median 4) also receives positive average ratings.

The survey findings indicate a subtle yet discernible preference in the perceived nature of cooperation within IS, with collaborations leaning slightly more towards a relational approach (mean 3.49, median 3) compared to a purely transactional one (mean 3.43, median 3). Although the difference in means is marginal, this slight inclination toward relationality suggests that companies involved in IS implicitly or explicitly value the cultivation of long-term, enduring partnerships that are fundamentally built upon foundations of trust, mutual understanding, and shared strategic objectives.

The data unequivocally highlight that environmental concern (mean 3.73, median 4) serves as the main and consistent driving force behind the development and adoption of IS among the surveyed companies. This finding strongly underscores a clear and fundamental commitment to broader sustainability objectives, including critically important goals such as improving resource efficiency, reducing waste generation, and mitigating carbon dioxide emissions. Follow closely, the search for direct financial benefits (mean 3.47, median 4) emerges as the second most significant motivator for engaging in IS. This dual emphasis indicates that economic viability, which encompasses crucial aspects such as risk sharing, operational cost

reduction, and potential revenue generation from waste valorization, is a vital consideration that complements environmental drivers. This suggests a pragmatic approach where ecological responsibility is underpinned by sound economic rationale. Other factors, such as administrative constraints or regulatory pressures (mean 3.07, median 3), play a more moderate and secondary role.

Companies generally express a moderate level of agreement (mean 3.33, median 3) with the statement that IS effectively meets the needs of both small and large organizations in terms of crucial aspects like resource efficiency and the exchange of energy and by-products. This finding suggests that while IS acknowledged as a beneficial strategy, there could still be considerable room for optimization or a perceived need for more highly tailored and adaptable solutions to fully address the diverse and evolving operational requirements and resource management challenges faced by companies of different sizes and sectors.

The survey data consistently indicates that companies are generally not actively engaged in extensive or deep information sharing with geographically close industries. The mean ratings for both the frequency/extent of sharing (mean 2.55, median 3) and the level of detail provided (mean 2.05, median 2) are notably low. This overall pattern strongly suggests that current intercompany information exchange practices are either infrequent or primarily limited to very basic, superficial levels, and rarely delve into granular operational or strategic insights.

The following is presented below Company and Respondent Demographics.

Industrial Sector: The open text responses provided by surveyed companies revealed a remarkably diverse array of industrial sectors involved in IS. This includes, but is not limited to, traditional heavy industries such as Petrochemical, Chemical/Process Industry, and Metallurgy (including steel processing and automotive manufacturing) alongside sectors focused on resource recovery like Waste management and Plastic Recycling. Other represented industries span Food / Agriculture (including poultry and meat production, as well as food retail and gastronomy), Energy (including city heating, new energy and hydrogen), Construction (including cement and building materials), Education (including higher education and schooling), Consulting, IT, Public sector (including local governments, municipal utilities, and water/sewage services), as well as more specialized areas such as Mattress Manufacturing and Furniture Manufacturing.

Geographical Level of IS: The data indicates a distinct bimodal distribution in the perceived geographical level of IS implementation. IS is most frequently reported to be practiced at the international level (71 mentions) and, concurrently, at the local level (44 mentions). This intriguing pattern suggests a dual strategic approach to IS: involving both broad, often complex, cross-border collaborations (perhaps embedded within the supply chains of large multinational corporations, intricate international industrial networks, or extended value chains) and simultaneously highly focused, geographically proximate industrial clusters where direct, tangible resource exchanges can be easily facilitated. The national (33 mentions)

and regional (27 mentions) levels of implementation appear to be comparatively less common within this specific sample.

Company's Size: The analysis of the company size within the surveyed sample reveals a predominant involvement of medium-sized enterprises accounting for 77 respondents. This finding is particularly insightful as it suggests that companies of this scale are key players in the landscape of IS, possibly due to a balance between resource needs, operational flexibility, and sufficient organizational capacity to engage in complex collaborations. Following medium companies, small enterprises (59 respondents) constitute the next largest group, indicating their active participation, likely driven by acute needs for resource efficiency and local network engagements. Large companies (50 respondents), while fewer in number compared to medium or small firms in this specific sample, still represent a significant portion of the participants.

Form of Ownership: Analysis of ownership within the surveyed companies reveals a striking prevalence of state-owned companies accounting for a substantial 151 respondents. This finding significantly reshapes the understanding of the driving forces behind IS in this specific European context. Contrary to common assumptions that private sector initiatives might dominate, these data suggest that state-owned entities are overwhelmingly leading the charge in implementing IS practices. This could be due to various factors, such as stronger mandates for environmental performance, direct governmental directives for resource efficiency, or greater access to public funding for sustainability projects within state-controlled operations.

Respondent's Position in the Company: The analysis of the respondent's position within the companies offers insightful perspectives on who is involved in responding to surveys about IS and, by extension, potentially who is engaged in IS initiatives. The largest group of respondents comes from Middle Management (57 mentions), highlighting their central role in operationalizing and overseeing IS activities. This is closely followed by Top Management (55 mentions), indicating strong strategic oversight and high-level engagement with IS within the surveyed organizations. Specialists (33 mentions) also represent a significant portion, underscoring the technical and expert input required for IS. Nonproduction employees (18 mentions), who typically handle administrative, HR, marketing, or finance roles, show moderate involvement. On the contrary, Experts (18 mentions) and Production employees (5 mentions) constitute the smallest groups of respondents.

Gender: The survey sample is predominantly composed of male respondents (122 mentions), significantly outnumbering female respondents (59 mentions) and a smaller group of individuals identifying as "other" or preferring not to disclose (6 mentions). This gender distribution in the survey could reflect the broader demographic composition of the industries and roles typically associated with the activities of IS within these European countries, which traditionally have been male-dominated. Alternatively, it could indicate a degree of gender bias in the survey's reach or response rates.

Duration and Financial Results of IS: On average, the cooperation of IS among the surveyed companies has been remarkably consistent, with an average duration of approximately 8.94 years. This figure suggests a substantial long-term commitment to symbiotic practices within a portion of the firms surveyed. However, a closer examination reveals that the median duration of IS cooperation is notably shorter at 5 years. This significant disparity between the mean and median (coupled with a relatively high standard deviation of 9.62 years) is indicative of a positively skewed distribution.

Next, **correlation analysis** was carried out to unravel the complex web of interrelationships within the IS ecosystem, moving beyond descriptive statistics to identify statistically significant associations between various factors. All the correlations highlighted in this section are considered statistically significant (with a p-value less than 0.05), indicating a high probability that these relationships are not due to random chance. Furthermore, only correlations demonstrating at least a moderate strength (an absolute Pearson's r value of 0.3 or higher) are discussed, ensuring their practical relevance and meaningfulness.

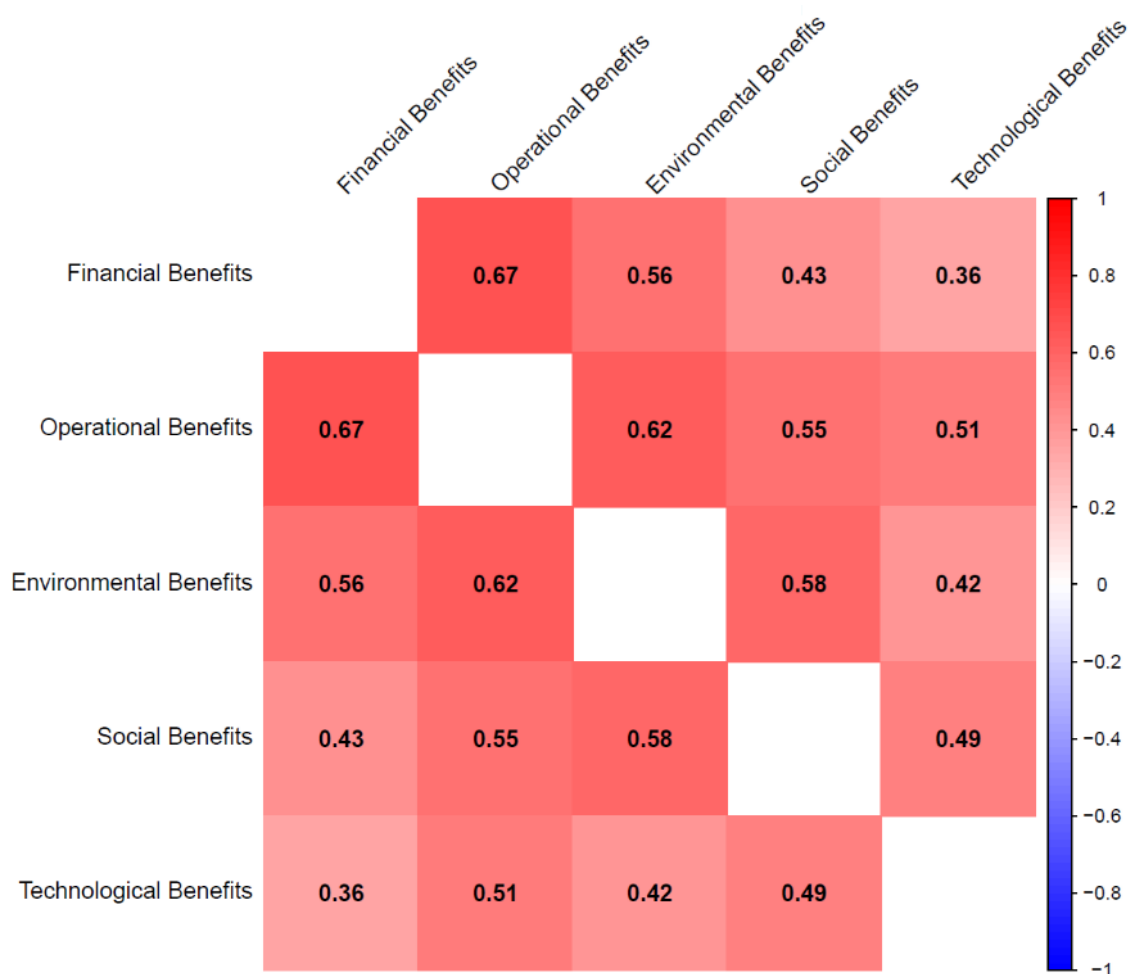


Figure 1. Pearson correlation heatmap. Inter-Correlations of Benefits.

Inter-Correlations of Benefits: A profoundly significant finding is the widespread presence of strong positive correlations between the different types of benefit perceived by companies (Figure 1). This critical insight unequivocally suggests that firms experiencing positive outcomes in one dimension of IS are highly likely to simultaneously realize advantages across other benefit categories. This reinforces the concept of IS as a holistic strategy, yielding multifaceted positive impacts rather than isolated gains.

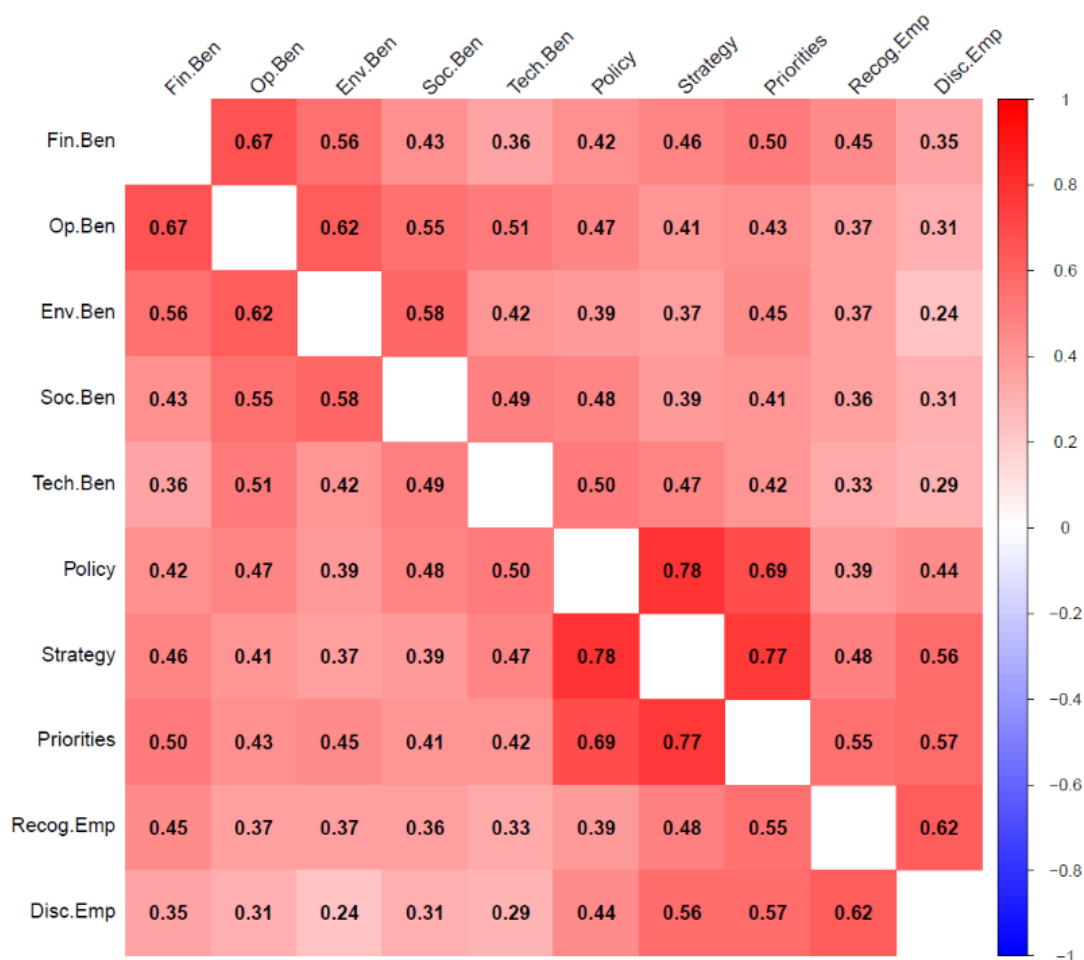


Figure 2. Pearson correlation heatmap. Benefits vs. IS Integration.

Benefits vs. IS Integration: The degree to which IS integrated within the company's internal structures and culture shows consistent and meaningful positive correlations with the spectrum of perceived benefits, emphasizing the importance of internal alignment (Figure 2). These correlations collectively demonstrate that embedding IS not merely as an external initiative but as an integral part of organizational structures, from high-level formal policies to pervasive employee awareness and active internal discussions, is crucial for realizing diverse and tangible benefits.

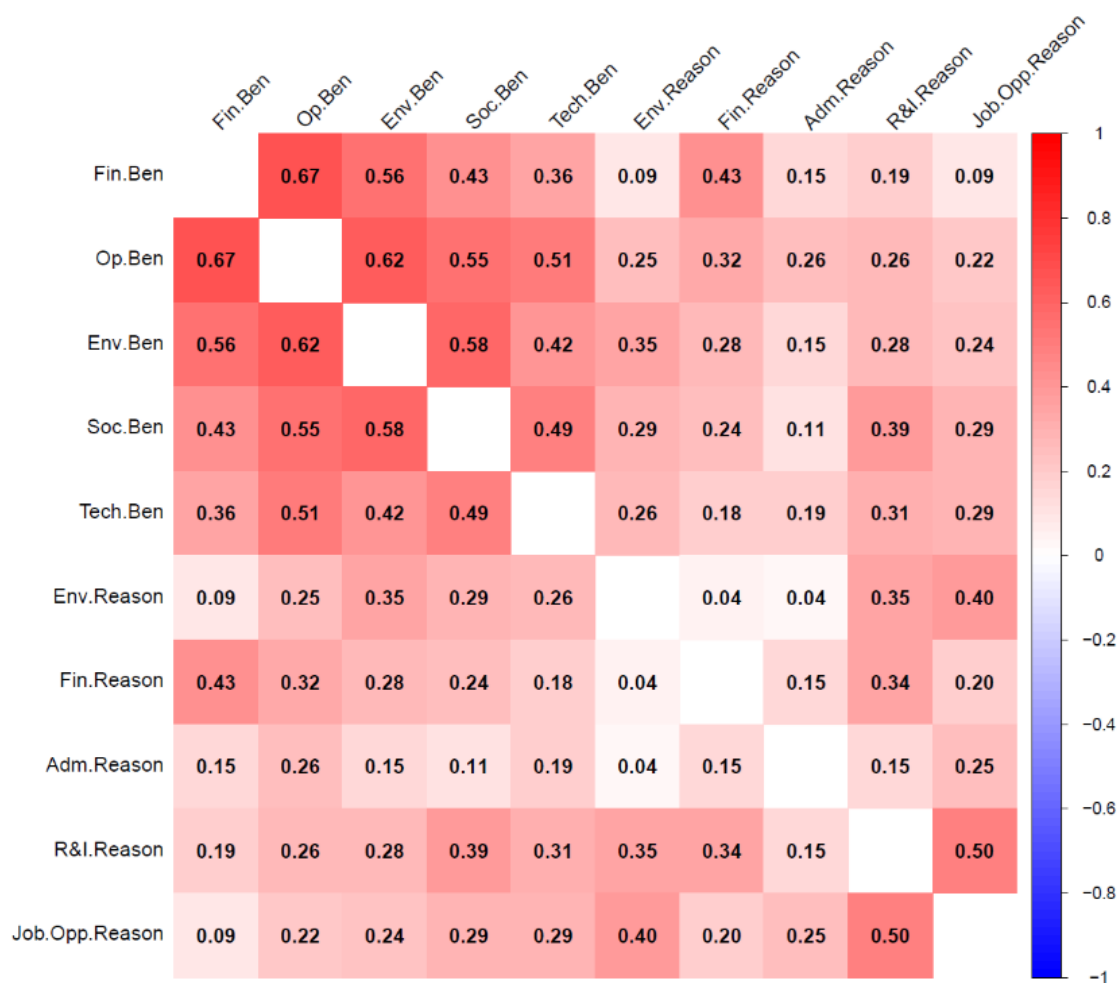


Figure 3. Pearson correlation heatmap. Benefits vs. Reasons for IS.

Benefits vs. Reasons for IS: The primary motivations that drive companies to develop IS also show insightful moderate positive correlations with the actual benefits they subsequently perceive and achieve (Figure 3). These correlations suggest that while environmental and direct financial motivations are strong, other drivers like research and innovation can also contribute to achieving a spectrum of benefits, highlighting the multifaceted nature of IS value.



Figure 4. Pearson correlation heatmap. Benefits & Overall Results vs. Trust.

Benefits & Overall Results vs. Trust: A critical set of findings is related to the positive association between perceived levels of trust in partners and the degree of information sharing, with greater benefits and better overall results from IS (Figure 4).

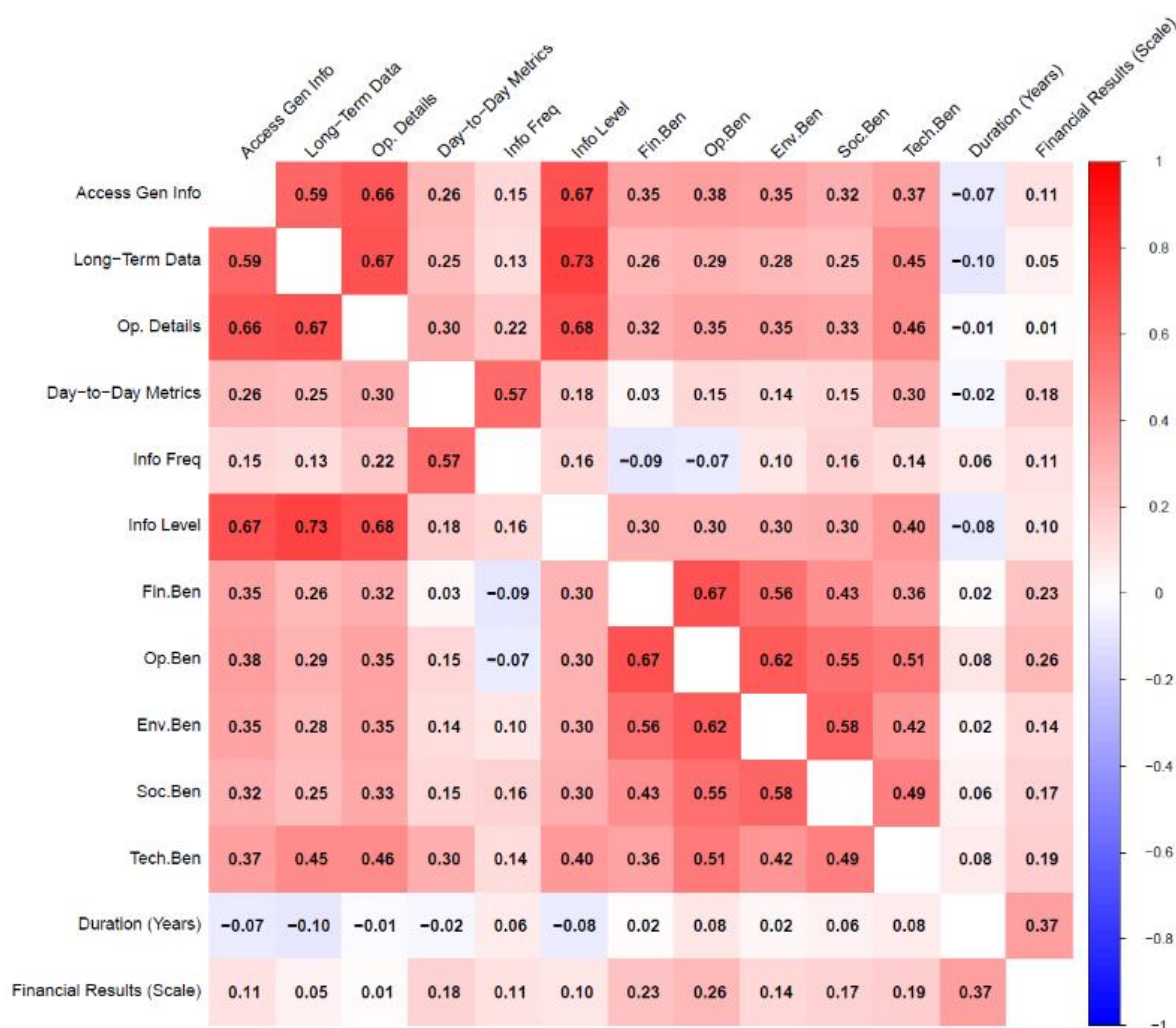


Figure 5. Pearson correlation heatmap. Information Sharing vs. Benefits vs. Overall Results.

Information Sharing vs. Benefits vs. Overall Results: A critical set of findings is related to the positive association between information sharing and overall greater benefits and better results from IS (Figure 5). These extensive correlations collectively underscore the absolutely critical role of trust and transparency in fostering successful and mutually beneficial symbiotic relationships. They demonstrate that active information sharing, supported by a foundation of trust, can unlock significant operational efficiencies, environmental improvements, and broader positive outcomes for all participants in an IS network.



Figure 6. Pearson correlation heatmap. Actor Involvement vs. Benefits.

Actor Involvement vs. Benefits: No significant correlations ($r \geq 0.3$, $p < 0.05$) found in this group (Figure 6).

Conclusions and Recommendations

Industrial symbiosis, while unequivocally driven by a strong commitment to environmental concerns (waste and by-product management), consistently delivers a wide array of interconnected benefits. Experiencing positive outcomes in one dimension (e.g. environmental) is significantly correlated with achieving advantages across other crucial benefit categories (operational efficiencies, social contributions, technological advancements, and even financial gains), underscoring IS as a truly holistic and synergistic strategy, yielding multifaceted positive impacts rather than merely isolated gains. This integrated benefit profile makes a highly

compelling case for its widespread adoption, moving beyond a singular focus on ecological impact to embrace a broader value proposition.

Small and medium-sized enterprises (SMEs) are identified as highly critical and deeply involved actors within the IS ecosystem. Their active involvement is further supported by a notable positive correlation with the financial benefits derived from IS, highlighting their agility and ability to translate symbiotic engagement into tangible economic value. Concurrently, large enterprises also play a significant and strategic role, often serving as foundational anchors within symbiotic networks by providing substantial resource flows or crucial infrastructure. This dual participation underscores the need to design customized support mechanisms that cater to both the agility of SMEs and the strategic weight of larger firms.

High levels of interpersonal and interorganizational trust in partners – encompassing beliefs in honesty, commitment to shared goals, and collaborative dispute resolution – are fundamental for successful IS. These vital relational factors are strongly correlated with perceived benefits, indicating that robust and transparent interorganizational bonds are crucial. Furthermore, embedding of IS within a company's internal policy and strategic frameworks, coupled with active employee recognition and discussion, is strongly associated with achieving greater benefits. This highlights that IS success hinges not only on external partnerships but also on internal organizational alignment and cultural acceptance.

Although current levels of information sharing (especially detailed operational and long-term planning data) are relatively low, it shows positive correlations with perceived operational and environmental benefits. This suggests that increasing data transparency could unlock significant value and improve the efficiency and value of existing collaborations.

While overall financial results from IS are moderately positive, there is country-specific variation. Similarly, the duration of IS cooperation varies significantly, with some countries (such as Poland and Denmark) showing more established and long-standing initiatives. These longer engagements are positively correlated with higher perceived financial returns, suggesting that sustained collaboration is the key to maximizing economic benefits.

Encourage and facilitate more open and systematic sharing of operational and production data among potential IS partners. Policies and digital platforms should prioritize secure data exchange, emphasizing the proven correlation between information sharing and increased benefits. This transparency will enable for more precise matchmaking and optimization of resource flows.

Actively promote the comprehensive and interconnected benefits of IS. Move beyond only environmental messaging to emphasize quantifiable operational efficiencies, social contributions, and technological advancements, all of which are correlated with overall success. Showcase compelling case studies that demonstrate these multifaceted returns, particularly featuring companies that have achieved strong financial results, to broaden appeal and justify investment.

Implement targeted initiatives that explicitly foster and solidify trust among potential and existing IS partners. This can involve structured matchmaking events, clear and consistent communication protocols, establishing shared governance models for joint projects, and developing transparent mechanisms for collaborative problem solving. Policies must actively recognize and incentivize the relational aspects of IS, as trust is a critical foundation for sustained cooperation.

Encourage companies to go beyond superficial policy statements by embedding IS principles directly into their core business strategies, long-term priorities, and daily operational performance metrics. Promote comprehensive internal awareness campaigns and training programs at all organizational levels to significantly increase employee recognition, understanding, and active discussion of IS. This will transform IS from an external initiative into an ingrained organizational culture, using internal champions to drive bottom-up innovation and ensure that internal alignment strongly correlates with external success.

Design and fund IS support programs that are meticulously tailored to meet the specific needs of businesses across the entire size spectrum. This includes providing accessible financial instruments and streamlined matchmaking services for agile SMEs to capitalize on niche opportunities, as well as offering regulatory guidance and frameworks for larger enterprises to manage complex resource streams and champion internal IS initiatives. Public bodies should proactively enhance their role as strategic facilitators and essential enablers for IS development, adapting support to national contexts.

Support ongoing research and innovation initiatives aimed at identifying new symbiotic pathways, developing cutting-edge technologies, and overcoming persistent challenges in IS implementation. Furthermore, cultivate adaptive policy and regulatory frameworks that are sufficiently flexible to respond effectively to emerging needs within IS ecosystems and capable of integrating lessons learned from diverse national and regional experiences, thereby accelerating the broader adoption and optimization of IS across European industries. This adaptive approach ensures that IS remains dynamic and relevant in a changing economic and environmental landscape.

CHAPTER II

2. Curriculum for SymbioTech Managers

2.1. The methodology of preparing syllabuses

The process of formulating syllabuses was preceded by the identification of training needs.

Qualitative and quantitative research were conducted in all partner countries, just like consultations were held with educational institutions to diagnose the needs of both HEI students and VET representatives. Based on the research results, the main competence gaps were defined (e.g. lack of knowledge about IS, lack of skills in mapping material flows, lack of practices in managing inter-organizational cooperation). As a result, new professional roles were defined (e.g. *SymbioTech Manager*, *IS Operator*).

Based on the defined learning outcomes, two curricula have been developed:

a. one for university students (EQF level 6) with the appropriate knowledge to complete it (preferably in economics and environmental engineering).

b. one for vocational education and training (EQF level 5), designed for implementation in vocational education and training, as well as for experts/specialists in the field of circular economy who do not have higher education.

The curriculum takes into account the learning outcomes and training and education needs of higher education and vocational students so that they can act as symbiotic technology managers after graduation. Finally, syllabuses for seven modules for HEIs and seven modules for VET were developed. For each syllabus, learning outcomes were formulated in three categories:

- Knowledge (e.g. knowledge of CE/IS terminology).
- Skills (e.g. use of flow mapping tools).
- Competences/Autonomy and responsibility (e.g. independent observation and reporting).

The learning outcomes were linked to **EQF 5 and EQF 6** (compliance with the qualification framework).

Each module was assigned: EQF level and ECVET/ECTS, total number of hours (workload), form of education (blended learning: bootcamp + e-learning + workplace assignment), link to future qualifications and micro-certificates. The content and teaching activities have been designed and tools have been selected (e.g. Sankey MATIC, CE Canvas). Weekly schedules were established (e.g. Bootcamp in week 1, practical task in weeks 2–3, final assessment in week 4). Active learning methods were included: case studies, workshops, practical exercises in production plants, e-learning with quizzes and mentoring. Assessment

methods (e.g. Sankey diagram, oral exam recording) and passing requirements were proposed for each training module.

Each module ends with the issuance of a micro-certificate (digital badge). The badge includes: title, EQF level, workload, description of competences, evidence of assessment. In order to ensure the highest quality, EQAVET principles have been implemented, which guarantee quality in vocational education and training. This means that each module and the entire program should be planned and implemented in accordance with the quality cycle: planning (defining objectives, learning outcomes, assessment methods, and success criteria), implementation (actual delivery of the course (bootcamp, e-learning, work tasks)), evaluation (checking whether the objectives and learning outcomes have been achieved (e.g. analysis), review (evidence archived for continuous improvement and quality assurance), recognition: (digital badge awarded upon successful performance across all tasks). Scientific sources were proposed (*Journal of Cleaner Production*, *Resources, Conservation & Recycling*, Ellen MacArthur Foundation reports). Archiving of assessment evidence (Sankey, exam recordings, rubrics) was proposed and the possibility of feedback was presented: students → mentors → institution → business partners.

First, the syllabuses were evaluated by partner teams. They will then be consulted with stakeholders (HEIs, VETs, CE companies). In order to ensure the highest standard of teaching, after translation into the national languages of the partners, they will also be evaluated by local Knowledge Committees before final approval. Only after this multi-stage evaluation process will the final version be published in the form of a standardized syllabus (including: overview, learning outcomes, schedule, tools, assessment methods, bibliography, metadata badge).

Curriculum structure

Each curriculum consists of 7 modules.

1. The IS framework

This is highly relevant as it provides the key principles of IS, origin and evolution in the context of circular economy, benefits and challenges, case studies, practical steps to engage in IS.

2. Life Cycle Assessment principles for assessing the environmental benefits and drawbacks of sharing resources

This module delves deeper into Life Cycle Assessment (LCA) as a comprehensive method for assessing the environmental impacts of products and services throughout their entire life cycle including production, distribution, use, and end-of-life stages alongside the associated upstream and downstream processes. It extends to evaluating inputs from and emissions into the environment, underlining the importance of Life Cycle Impact Assessment (LCIA) in capturing all relevant environmental interactions. Tailored for SymbioTech Managers, this

module empowers them to guide SMEs through making informed, environmentally responsible decisions regarding resource sharing and repurposing, leveraging guidelines from ISO 14040 and 14044 to ensure sustainability in business practices within the Industrial Symbiosis (IS) framework.

3. Inter-organisational relations

This module deals with the strategic creation of inter-organisational relationships, which are the basis for beneficial partnerships between independent actors. Diverse factors influencing collaboration within an industrial symbiosis will be presented, with the aim of eliminating inefficiencies and ensuring the sustainability of established relationships. Emphasis will also be placed on interpersonal aspects of collaborations such as building credibility and trust in relationships. The role and pressures of individual stakeholders in IS will also be outlined.

4. AI and machine learning to predict material flows and optimize supply chain/process

This is crucial to finally start the switch from typical IS to Digital IS. The module will explore how to Incorporate AI and machine learning into material flow management to drastically improve the efficiency of supply chains, to predict supply and demand trends, optimize logistics, and reduce waste.

5. Blockchain technologies, to create transparent and secure tracking and certification systems for material and energy flows

This module covers Blockchain's application and value in industrial symbiosis to provide transparency and traceability. The focus will be on the integrity of data related to the lifecycle of materials and energy, and compliance with environmental standards.

6. Symbiotic energy efficiency/management technologies and models

This module covers the integration of renewable energy sources and the optimization of energy consumption within industrial networks. The focus will be on technologies and models integration, for businesses to enhance their energy efficiency, reduce costs, and minimize their environmental footprint.

7. Environmental Management Systems (EMS)

The module equips students with the skills to develop, implement and maintain an EMS. Focus will be on ISO 14001, EMAS and other relevant EMS standards, and how to conduct an initial environmental review, set objectives, and implement policies. We will make use of real-world examples of EMS implementation.

In addition, a central part of creating the learning pathways is how the micro-credentials are implemented. They need to refer to learning outcomes (knowledge, skills, and competences), course content, training (knowledge, skills, and competences), course content, training method, gamification elements, duration, and number of ECTS. To fit the purpose, they need to be delivered through the establishment of partnerships between the HEIs with VET providers and private enterprises from the circular economy sector.

2.2. The curriculum for HEI level

Below the syllabuses for the seven training modules for HEI are presented.

Module 1. Industrial Symbiosis Framework (Syllabus: 4 ECTS)

Course Description

This module provides an in-depth understanding of Industrial Symbiosis (IS) as a key enabler for circular economy transition. Students will study the theoretical foundations, historical development, business models, and practical implementation of IS. The course also emphasizes analysing real-world case studies and using digital tools for symbiotic mapping and opportunity identification.

General Learning Outcomes	
Upon successful completion of this micro-credential, the learner will be able to:	
	– Define and explain the principles and history of Industrial Symbiosis within the Circular Economy framework. – Analyse the role of EU policies (e.g. Fit for 55, taxonomy regulation) in shaping IS strategies. – Identify symbiotic opportunities in industrial clusters using mapping and digital tools (e.g. QGIS*, Sankey diagrams). – Apply business model typologies to design sustainable industrial symbiosis projects. – Evaluate barriers, benefits, and success factors for IS implementation and stakeholder collaboration. – Communicate IS project proposals effectively through written reports and oral presentations.
* QGIS is a <u>geographic information system</u> (GIS) software that is free and open-source. QGIS supports Windows, macOS, and Linux. It is the most popular tool for handling spatial data, used by both professionals and beginners around the world. ** Sankey diagrams are flow visualizations that represent the movement of values between different stages or categories, with the width of the arrows indicating the magnitude of the flow.	
Expanded Student Competencies	
By the end of this module, students will develop the following competencies aligned with EQF Level 6:	
Knowledge:	

	– Comprehensive understanding of Industrial Symbiosis principles, including its role within Circular Economy frameworks and policy contexts such as EU Fit for 55 and taxonomy regulations. – Familiarity with historical development and evolution from traditional IS practices to digital symbiosis approaches.		
Skills:			
	– Ability to critically analyse industrial clusters to identify symbiotic opportunities using tools such as QGIS and Sankey diagrams. – Competence in applying business model typologies and stakeholder analysis to design viable IS partnerships. – Proficiency in data collection, mapping material and energy flows, and using this data for decision-making. – Communication skills to present IS opportunities effectively in written and oral formats.		
Competences:			
	– Capacity to design and evaluate IS projects considering technical, economic, and environmental aspects. – Ability to work collaboratively in multidisciplinary teams, engaging stakeholders and managing project workflows. – Ethical and sustainability-oriented mind-set, integrating EU policies and international standards in project proposals. – Self-directed learning and reflective practice to continuously improve IS knowledge and practical skills.		
Weekly Topics and Activities			
Week	Topic	Activities	Learning Outcomes
1.	Introduction to IS: definitions, scope, and linkages with circular economy and eco-industrial parks	Lecture	Understand IS fundamentals and its systemic role.
2.	Historical evolution and worldwide applicability: from Kalundborg 1960s to Digital IS of the 2020s	Lecture	Trace IS development in historical and modern contexts.
3.	EU policy context: Fit for 55, taxonomy alignment, and regulatory frameworks	Seminar + Document analysis	Interpret how EU policies influence IS strategies.
4.	Industrial symbiosis business models and typologies	Lecture + Case Studies	Differentiate and apply IS business models.
5.	Symbiotic matching algorithms and digital tools	Lecture + Case Studies (QGIS*, SankeyMATIC**)	Use digital tools for identifying synergies.
6.	Mapping material and energy flows in clusters	Lecture + Case Studies	Visualize and quantify resource exchanges.
7.	Stakeholder analysis and engagement strategies	Lecture + Case Studies	Identify and prioritize stakeholders in IS projects.
8.	Design of symbiotic networks and value chains	Lecture + Case Studies	Create actionable IS network designs.

9.	Measuring IS effectiveness: KPIs, monitoring, and reporting	Lecture + Case Studies	Apply metrics to evaluate IS performance.
10.	Benefits: operational, economic, marketing, environmental and social	Lecture + Case Studies	Evaluate the multi-dimensional positive impacts of IS.
11.	Barriers and risk management	Lecture + Case Studies	Analyse and mitigate risks in IS projects.
12.	Factors influencing IS	Lecture	Analyse factors influencing IS implementation
13.	Practical project: IS opportunity assessment for a local cluster	Case Study	Conduct a full IS opportunity study.
14.	Exam preparation clinic	Review session	Prepare for final exam and assessments.

* QGIS is a geographic information system (GIS) software that is free and open-source. QGIS supports Windows, macOS, and Linux. It is the most popular tool for handling spatial data, used by both professionals and beginners around the world.

** SankeyMATIC is a web-based tool that lets you create and customize beautiful flow diagrams.

Teaching Methods

	– Interactive lectures integrating recent research and policy updates. – Open-source and commercial digital tools. – Case study analyses focusing on European and global IS projects. – Projects encouraging collaboration and practical application. – Guest lectures from industry experts and policy makers (optional).
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Assessment

Component	Weight	Description
IS Opportunity Study Report	30%	A 3,000-word analytical report evaluating a real or simulated local IS opportunity, including cluster analysis, flow mapping, and business model recommendations.
Participation & Engagement	10%	Active participation in lectures and case studies
Final Written Exam	60%	Exam testing theoretical knowledge, policy understanding, and practical tools competence.

Bibliography

	– Albino V., Fraccascia L. (2015). The industrial symbiosis approach: A classification of business models. <i>Business, Environmental Science. Procedia Environmental Science, Engineering and Management</i> 2 (2015) (3) 217-223. – Baas L.W., Boons F.A. (2004). An industrial ecology project in practice: exploring the boundaries of decision-making levels in regional industrial systems. <i>J Clean Prod</i> 12(8–10):1073–1085
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	– Bassi F., José G. Dias. (2019). The use of circular economy practices in SMEs across the EU, Resources, Conservation and Recycling, Volume 146, 523-53. – Bocken N.M., De Pauw I., Bakker C., Van der Grinten B. (2016). Product design and business model strategies for a circular economy. J Ind Prod Eng 33(5):308–320. – Chowdhury S., Dey P.K., Rodríguez-Espíndola O., Parkes G., Anh Tuyet N.T., Long D.D., Phuong Ha T. (2022). Impact of Organisational Factors on the Circular Economy Practices and Sustainable Performance of Small and Medium-sized Enterprises in Vietnam. Journal of Business Research, Volume 147, 362–378. – Domenech T., Bleischwitz R., Doranova A., Panayotopoulos D., Roman L. (2019). Mapping industrial symbiosis development in Europe_ typologies of networks, characteristics, performance and contribution to the circular economy. Resour Conserv Recycl 141:76–98. – Godina R., Azevedo S., Matias J. (2020). A comprehensive review of industrial symbiosis, Journal of Cleaner Production, Volume 247, 119113. – Mallawaarachchi H., Sandanayake Y., Karunasena G., Liu C (2020). Unveiling the conceptual development of industrial symbiosis: Bibliometric analysis. J Clean Prod 120618. – Salomone R., Cecchin A., Deutz P., Raggi A., Cutaia L. (2020). Industrial Symbiosis for the Circular Economy: Operational Experiences, Best Practices and Obstacles to a Collaborative Business Approach, Springer Nature. – Stahel, W. R., & MacArthur, E. (2019). The Circular Economy. Routledge. https://doi.org/10.4324/9780429259203
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Proposal for Micro-credential: Industrial Symbiosis Framework (IS Foundations badge) (4 ECTS)

Micro-credential Title: **Industrial Symbiosis Framework (IS Foundations badge)**

Qualification Level: **EQF Level 6 (Bachelor's / Early Master's level)**

Learning Outcomes

Upon successful completion of this micro-credential, the learner will be able to:

1.	Define and explain the principles and history of Industrial Symbiosis within the Circular Economy framework.
2.	Analyse the role of EU policies (e.g. Fit for 55, taxonomy regulation) in shaping IS strategies.
3.	Identify symbiotic opportunities in industrial clusters using mapping and digital tools (e.g. QGIS, Sankey diagrams).
4.	Apply business model typologies to design sustainable industrial symbiosis projects.
5.	Evaluate barriers, benefits, and success factors for IS implementation and stakeholder collaboration.
6.	Communicate IS project proposals effectively through written reports and oral presentations.
Workload	
Total workload: 100 hours (equivalent to 4 ECTS)	
	– Contact hours (lectures, labs, workshops): 42 hours – Guided self-study: 20 hours – Independent study and project work: 38 hours
Assessment Methods	
	– Written analytical report (3,000 words) on an IS opportunity study – Participation in lectures and case studies – Final written exam testing theoretical and practical knowledge
Metadata (for digital credential)	
	– Issuer: [University / Consortium Name] – Credential type: Micro-credential (badge) – Credit value: 4 ECTS – Date of issue: [date] – Expiry: None (lifelong learning credit) – Verification: JSON-LD data format with verifiable signature – URL to module syllabus and assessment details
Summary	
	This micro-credential certifies that the holder possesses the theoretical knowledge, analytical skills, and practical abilities to develop and evaluate industrial symbiosis projects within the framework of the Circular Economy and EU climate policies. It forms a building block towards the full SymbioTech Manager Advanced Certificate.
Micro-Credential Specification	
Field	Content
Title	Foundations of Industrial Symbiosis (IS Framework)

EQF Level	6
Workload	100–120 hours ($\approx$ 4 ECTS)
Mode	Blended / hybrid (lectures)
Skills Tag	Circular Economy, IS principles, case analysis, engagement strategies
Assessment Evidence	IS engagement strategy, annotated case study, concept map
Issuer	SymbioTech Alliance
Format	Verifiable JSON-LD badge with metadata & assessment evidence links

Module 2. Life-Cycle Assessment Principles (Syllabus: 4 ECTS)

Course Description

This module covers Life Cycle Assessment (LCA) as a systematic method to evaluate environmental impacts of products and services across their entire life cycle from raw material extraction to disposal or recycling. It empowers students to assess the environmental benefits and trade-offs of sharing resources and industrial symbiosis projects, based on ISO 14040 and 14044 standards. Special focus is on applying LCA within the Industrial Symbiosis framework to support sustainable decision-making in SMEs.

General Learning Outcomes	
Upon successful completion of this micro-credential, the learner will be able to:	
	– Define and explain the key principles of Life Cycle Assessment (LCA) methodology in line with ISO 14040 and 14044 standards. – Conduct basic LCA studies using standard software tools (e.g. OpenLCA). – Interpret and communicate LCA results, especially in the context of industrial symbiosis (IS). – Apply LCA insights to improve sustainability performance and decision-making in resource-sharing systems and circular economy models.
Expanded Student Competencies	
By the end of this module, students will develop the following competencies aligned with EQF Level 6:	
Knowledge:	
	– Understand LCA methodology, including goal and scope definition, inventory analysis, impact assessment, and interpretation. – Familiarity with ISO 14040 and 14044 standards and relevant guidelines. – Comprehend environmental impact categories and Life Cycle Impact Assessment (LCIA) approaches. – Awareness of challenges and limitations of LCA in industrial contexts.
Skills:	

	– Ability to conduct a basic LCA study using LCA software (e.g. OpenLCA). – Analyse and interpret LCA results for informed decision-making in resource sharing. – Critically evaluate existing LCA case studies, focusing on IS scenarios. – Communicate LCA findings effectively to technical and non-technical audiences.		
Competences:			
	– Integrate LCA insights into business strategies for SMEs engaging in IS. – Apply LCA results to optimize resource use, minimize emissions, and enhance sustainability. – Collaborate in interdisciplinary teams to address environmental impacts comprehensively. – Demonstrate ethical responsibility and transparency in environmental reporting		
Weekly Topics and Activities			
Week	Topic	Activities	Learning Outcomes
1.	Introduction to LCA: concepts and history	Lecture + Discussion	Understand LCA scope and relevance.
2.	ISO standards 14040 & 14044 overview	Seminar	Learn key requirements and framework.
3.	Goal and scope definition in LCA	Workshop	Define study boundaries and objectives.
4.	Life Cycle Inventory (LCI) data collection	Lab (OpenLCA)	Gather and manage LCI data.
5.	Life Cycle Impact Assessment (LCIA) methods	Lecture + Exercises	Apply impact category methods (e.g. ReCiPe) *.
6.	Interpretation and sensitivity analysis	Case Study	Evaluate robustness and significance of results.
7.	LCA software tools: OpenLCA practical	Hands-on lab	Perform LCA calculations.
8.	Case studies: LCA in industrial symbiosis	Group Discussion	Analyse published IS LCA examples.
9.	Resource sharing and circularity: LCA perspective	Lecture	Assess benefits of sharing vs. linear use.
10.	LCA challenges: data quality, uncertainty	Seminar	Understand limitations and data gaps.
11.	Integrating LCA in business decisions	Workshop	Use LCA to support sustainable business models.
12.	Reporting and communicating LCA results	Presentation skills	Prepare clear LCA summaries for stakeholders.
13.	Group project: LCA of an IS resource exchange	Project work	Conduct and present a mini-LCA study.
14.	Exam preparation clinic	Review session	Prepare for final assessment.

* ReCiPe is a method for life cycle impact assessment (LCIA). The primary objective of the method is to transform the long list of life cycle inventory results into a limited number of indicator scores.

Teaching Methods

This module employs a blended and practice-oriented teaching approach to foster both conceptual understanding and practical skills. The following methods will be used:

- **Lectures and Seminars:** To introduce core theoretical concepts and ISO standards.
- **Hands-on Labs:** Guided sessions using OpenLCA to provide practical experience with real-life datasets.
- **Workshops:** Interactive activities focused on problem-solving, group work, and application of LCA methods.
- **Case Studies:** In-depth analysis of industrial symbiosis scenarios to develop critical thinking.
- **Group Project Work:** Students collaborate to conduct a simplified LCA, enhancing teamwork and integration of knowledge.
- **Presentations and Discussions:** To strengthen communication skills and peer learning.

Assessment

Assessment is based on both individual and group performance, combining theoretical understanding with practical application. The breakdown is as follows:

Component	Weight	Description
Group Project (LCA Case Study)	30%	Students conduct and present an LCA of a resource exchange in an IS context.
Practical Lab Assignment	20%	OpenLCA-based analysis with interpretation of results.
Individual Written Report	20%	A critical review of an LCA study (case-based or literature-based).
Final Written Exam	20%	Assessment of knowledge on ISO standards, LCA phases, and key concepts.
Class Participation & Engagement	10%	Based on seminar contributions, group discussions, and workshop activities.

Bibliography

- Aissani L., Lacassagne A., Bahers J.B., Féon S.L. (2019). Life cycle assessment of industrial symbiosis: a critical review of relevant reference scenarios. *Journal of Industrial Ecology*, 23(4):972–985.
- Daddi T., Nucci B., Iraldo F. (2017). Using Life Cycle Assessment (LCA) to measure the environmental benefits of industrial symbiosis in an industrial cluster of SMEs, *Journal of Cleaner Production*, Volume 147, 157–164.
- Kerdlap P., Low J., Zong Loong Tan D., Yeo Z., Ramakrishna S. (2020). M3-IS-LCA: A Methodology for Multi-level Life Cycle Environmental Performance Evaluation of Industrial Symbiosis Networks, *Resources Conservation and Recycling*.
- Valdivia S., Jana Gerta Backes, Traverso M., Sonnemann G., Cucurachi S., Guinée J., Schaubroeck T., Finkbeiner M., Noémie Leroy-Parmentier, Ugaya C., Peña C., Zamagni A., Inaba A., Amaral M., Berger M., Dvarionienė V., Vakhitova T., Benoît-Norris C., Prox M., Foolmaun R., Goedkoop M. (2021). Principles for the application of life cycle sustainability assessment, *The International Journal of Life Cycle Assessment*. Volume 26, 1900–1905.

Proposal for Micro-credential: 2. Life Cycle Assessment Principles (Certified LCA Analyst Badge) (4 ECTS)

Micro-credential Title: **Life-Cycle Assessment Principles (Certified LCA Analyst badge)**

Qualification Level: **EQF Level 6 (Bachelor's / Early Master's level)**

Learning Outcomes	
Upon successful completion of this micro-credential, the learner will be able to:	
1.	Define and explain the key principles of Life Cycle Assessment (LCA) methodology in line with ISO 14040 and 14044 standards.
2.	Conduct basic LCA studies using standard software tools (e.g. OpenLCA).
3.	Interpret and communicate LCA results , especially in the context of industrial symbiosis (IS).
4.	Apply LCA insights to improve sustainability performance and decision-making in resource-sharing systems and circular economy models.
Workload	
Total workload: 100 hours (equivalent to 4 ECTS)	

	– Contact hours (lectures, labs, workshops): 42 hours – Guided self-study: 20 hours – Independent study and project work: 38 hours
Assessment Methods	
	– Written analytical report (3,000 words) on an IS opportunity study – Group oral presentation of project findings – Participation in labs, discussions, and peer assessments – Final written exam testing theoretical and practical knowledge
Metadata (for digital credential)	
	– Issuer: [University / Consortium Name] – Credential type: Micro-credential (badge) – Credit value: 4 ECTS – Date of issue: [date] – Expiry: None (lifelong learning credit) – Verification: JSON-LD data format with verifiable signature – URL to module syllabus and assessment details
Summary	
	Holders of the Life Cycle Assessment Principles micro-credential have demonstrated the ability to carry out structured environmental assessments across the entire life cycle of a product, process, or system. They are equipped to identify environmental trade-offs, prioritize sustainability improvements, and support circular economy initiatives through life cycle thinking. Learners have gained practical experience in using LCA software tools and interpreting complex data, enabling them to inform sustainability strategies in small and medium-sized enterprises (SMEs) and industrial symbiosis (IS) contexts. They are also prepared to communicate LCA findings effectively to a range of stakeholders, bridging technical insights with actionable recommendations. Moreover, this micro-credential validates strong collaborative and analytical competencies, including the ability to work in interdisciplinary teams and apply LCA knowledge to real-world resource sharing scenarios in line with ISO 14040 and 14044 standards.
Micro-Credential Specification	
Field	Content
Title	Life Cycle Assessment Principles
EQF Level	6
Workload	100–120 hours ($\approx$ 4 ECTS)
Mode	Blended / hybrid (lectures, workshops, software labs)
Skills Tag	LCA, LCIA, ISO 14040, ISO 14044, environmental footprint, resource efficiency
Assessment Evidence	LCA case report, impact interpretation presentation, LCA data model using software (e.g. OpenLCA)
Issuer	SymbioTech Alliance
Format	Verifiable JSON-LD badge with metadata & direct links to student assessment portfolio

Module 3. Inter-organisational Relations (Syllabus: 4 ECTS)

Course Description

This module explores the strategic foundations of building and maintaining effective inter-organisational relations in industrial symbiosis (IS). Students will study collaboration dynamics, trust-building, stakeholder alignment, and governance models. Special attention is given to communication, negotiation, persuasion, managing resistance to change, conflict resolution, and building long-term trust across diverse actors in circular economy systems. Practical tools and real-world examples will equip future SymbioTech Managers to navigate partnerships, mitigate risks, and foster long-term cooperation across networks.

General Learning Outcomes

Upon successful completion of this micro-credential, the learner will be able to:

- Analyse complex stakeholder landscapes within industrial symbiosis networks.
- Design and implement governance frameworks that foster effective collaboration among diverse organisations.
- Develop and apply strategies to build trust, communicate persuasively, and negotiate shared goals.
- Manage and resolve conflicts arising from differing stakeholder interests.
- Recognise and address resistance to change in multi-actor partnerships.
- Facilitate workshops and meetings that promote co-creation and shared decision-making.
- Present ideas clearly and respond effectively to difficult questions.
- Build rapport and trust with diverse stakeholders

Expanded Student Competencies

By the end of this module, students will develop the following competencies aligned with EQF Level 6:

Knowledge:

- Understand key theories of inter-organisational collaboration (resource dependency, transaction cost economics, network theory).
- Identify enablers and barriers to cooperation in IS partnerships.
- Recognise stakeholder motivations and institutional pressures.
- Understand governance models, trust-building mechanisms, and engagement processes.
- Distinguish between sources of resistance to change and types of organisational conflict.

Skills:

- Map and analyse stakeholder ecosystems.
- Design stakeholder engagement strategies and governance frameworks.
- Use clear and persuasive communication to present ideas and proposals.
- Apply negotiation tactics and facilitate consensus-building.
- Respond effectively to difficult questions and critical feedback.
- Resolve interpersonal and inter-organisational conflicts using structured approaches.
- Identify, anticipate, and manage resistance to change through empathy and evidence.
- Facilitate co-creation workshops among diverse stakeholders.

Competences:

	– Lead multi-actor industrial symbiosis (IS) partnerships through effective collaboration. – Promote transparency, credibility, and ethical standards in cross-sectoral cooperation. – Build trust and gain stakeholder support even in conflict-prone or uncertain environments. – Adapt communication and persuasion strategies to different organisational cultures and power dynamics. – Act as a mediator and facilitator in situations of interpersonal or inter-organisational conflict. – Recognise early signs of resistance to change and apply targeted interventions to address it. – Present ideas clearly and convincingly, answer difficult questions under pressure, and build empathy. – Negotiate shared goals and align diverse stakeholder interests toward circular economy objectives. – Foster a cooperative atmosphere by creating mutual understanding and trust across sectors		
Weekly Topics and Activities			
Week	Topic	Activities	Learning Outcomes
1.	Introduction to inter-organisational theory	Lecture + Discussion	Understand collaboration foundations
2.	Drivers and barriers to collaboration	Case analysis	Identify enablers and obstacles to IS relations
3.	Stakeholder analysis and mapping	Lab (PowerMap* /QGIS**)	Map stakeholder ecosystems
4.	Governance models for partnerships	Seminar	Compare coordination structures
5.	Trust, credibility, and reciprocity	Workshop	Build long-term relational credibility
6.	Communication and negotiation	Simulation	Present ideas and persuade effectively
7.	Conflict resolution strategies	Roleplay + guided reflection	Apply techniques to resolve disputes
8.	Managing resistance to change	Case workshop + coaching	Recognise and address resistance proactively
9.	Designing stakeholder engagement processes	Lab	Plan co-creation workshops
10.	Metrics for monitoring collaboration	Seminar	Define KPIs and relational indicators
11.	Multi-level collaboration (regional/EU)	Lecture	Understand vertical coordination in IS
12.	Ethics, inclusion, and power in partnerships	Debate + reflection	Evaluate fairness and representation
13.	Group project: design an IS partnership	Group work + mentoring	Apply course tools in a real scenario
14.	Final review and exam clinic	Q&A, mock oral exams	Prepare for final assessment
* QGIS is a <u>geographic information system</u> (GIS) software that is free and open-source. QGIS supports Windows, macOS, and Linux. It is the most popular tool for handling spatial data, used by both professionals and beginners around the world.			
** Microsoft Power Map for Excel is a three-dimensional (3-D) data visualization tool that lets you look at information in new ways. A power map lets you discover insights you might not see in traditional two-dimensional (2-D) tables and charts.			

Teaching Methods

This module employs a blended and practice-oriented teaching approach to foster both conceptual understanding and practical skills. The following methods will be used:

- **Interactive Lectures:** concepts integrated with IS case examples live polling, Q&A, collaborative activities.
- **Case Studies & Simulations** Kalundborg IS, SYMBI*, NISP**, and emerging clusters, conflict resolution simulations and trust-building games.
- **Stakeholder Mapping Labs:** using PowerMap and QGIS to visualise engagement strategies
- **Role Plays & Communication Labs;** exercises in pitching ideas, answering critical questions, and negotiating under pressure.
- **Co-creation Workshops:** group activities to design multi-stakeholder forums.
- **Reflection and Coaching;** individual coaching sessions to enhance personal communication, confidence, and credibility.

* SYMBI - Industrial Symbiosis for Regional Sustainable Growth and a Resource Efficient Circular Economy Green. Project contributed to improve the implementation of regional development policies and programmes related to the promotion and dissemination of IS and CE from 7 participating countries faced to policies alignment with the CE strategy of the European Commission to transform Europe into a more competitive resource-efficient economy.

**National Industrial Symbiosis Programme - the world's first national industrial symbiosis programme. NISP provides a platform to INSPIRE businesses to implement resource optimisation and efficiency practices, keeping materials and other resources in productive use for longer through 'industrial symbiosis'.

Assessment

Assessment is based on both individual and group performance, combining theoretical understanding with practical application. The breakdown is as follows:

Component	Weight	Description
Group Project (LCA Case Study)	30%	Students conduct and present an LCA of a resource exchange in an IS context.
Practical Lab Assignment	20%	OpenLCA-based analysis with interpretation of results.
Individual Written Report	20%	A critical review of an LCA study (case-based or literature-based).
Final Written Exam	20%	Assessment of knowledge on ISO standards, LCA phases, and key concepts.
Class Participation & Engagement	10%	Based on seminar contributions, group discussions, and workshop activities.

Bibliography

- Alosi A., Katana K., Annunziata E., Mirata M., Rizzi F., Frey M. (2025). Management of paradoxical tensions in industrial symbiosis: An exploration at the inter-organizational level, *Industry Ecology*, 29(2), 602–616.
- Cecchin A., Salomone R., Deutz P., Raggi A., Cutaia L. (2020). Industrial Symbiosis for the Circular Economy. Operational Experiences, Best Practices and Obstacles to a Collaborative Business Approach.
- Saha P. (2020). The process of building inter organizational collaboration for Industrial Symbiosis Two cases from Finland: ECO3 & Envitech, Master of Science Thesis Tampere University Degree Programme in Industrial Engineering and Management.
- Shi L. (2019). Industrial Symbiosis: Context and Relevance to the Sustainable Development Goals (SDGs), *Responsible consumption and production*, 1–12.

	– Walls J., Pa R. (2015). Organizational Perspectives of Industrial Symbiosis, Organization & Environment, Volume 28, Issue 1.
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Proposal for Micro-credential: 3. Inter-Organisational Relations (Collaboration Architect Badge) (4 ECTS)

Micro-credential Title: **Industrial Symbiosis Partnership Design (Collaboration Architect Badge)**

Qualification Level: **EQF Level 6 (Bachelor's / Early Master's level)**

Learning Outcomes	
Upon successful completion of this micro-credential, the learner will be able to:	
1.	Analyse complex stakeholder landscapes within industrial symbiosis networks.
2.	Design and implement governance frameworks that foster effective collaboration among diverse organisations.
3.	Develop and apply strategies to build trust, communicate persuasively, and negotiate shared goals.
4.	Manage and resolve conflicts arising from differing stakeholder interests.
5.	Recognise and address resistance to change in multi-actor partnerships.
6.	Facilitate workshops and meetings that promote co-creation and shared decision-making
7.	Present ideas clearly and respond effectively to difficult questions.
8.	Build rapport and trust with diverse stakeholders.
Facilitate workshops and meetings that promote co-creation and shared decision-making	
Workload	
Total workload: 100 hours (equivalent to 4 ECTS)	

	– Contact hours (lectures, labs, workshops): 42 hours – Guided self-study: 20 hours – Independent study and project work: 38 hours
Assessment Methods	
	– Written analytical report (3,000 words) on an IS opportunity study – Group oral presentation of project findings – Participation in labs, discussions, and peer assessments – Final written exam testing theoretical and practical knowledge
Metadata (for digital credential)	
	– Issuer: [University / Consortium Name] – Credential type: Micro-credential (badge) – Credit value: 4 ECTS – Date of issue: [date] – Expiry: None (lifelong learning credit) – Verification: JSON-LD data format with verifiable signature – URL to module syllabus and assessment details
Summary	
	Holders of the Inter-Organisational Relations micro-credential have demonstrated the ability to deal with the strategic creation of inter-organisational relationships, which are the basis for beneficial partnerships between independent actors. They are equipped to identify diverse factors influencing collaboration within an industrial symbiosis, with the aim of eliminating inefficiencies and ensuring the sustainability of established relationships. Learners have gained interpersonal skills such as collaborations, building credibility and trust in relationships. Moreover, the role and pressures of individual stakeholders in IS will also be outlined.
Micro-Credential Specification	
Field	Content
Title	Inter-organisational Collaboration for Industrial Symbiosis
EQF Level	6
Workload	100–120 hours ($\approx$ 4 ECTS)
Mode	Blended / hybrid (interactive seminars, stakeholder simulations, group projects)
Skills Tag	stakeholder mapping, trust-building, negotiation, conflict resolution, partnership governance
Assessment Evidence	Stakeholder engagement strategy, group partnership plan, peer-reviewed simulation outcomes
Issuer	SymbioTech Alliance
Format	Verifiable JSON-LD badge with metadata & portfolio evidence

Module 4. AI & Machine-Learning for Material-Flow Forecasting in IS (Syllabus: 4 ECTS)

Course Description

This course equips future SymbioTech Managers with applied knowledge of artificial intelligence (AI) and machine learning (ML) methods to accelerate the digital transformation of Industrial Symbiosis (IS) ecosystems. Students will explore how data-driven algorithms can predict material and energy flows, detect inefficiencies, and support real-time decision-making in circular supply chains. Through hands-on labs, simulations, and case studies, students will develop competencies in selecting and applying suitable ML models to solve real-world industrial problems such as forecasting secondary resource availability, identifying symbiotic matches, and optimizing logistics. The course emphasizes practical integration with IS platforms and the ethical use of data in circular economy contexts.

General Learning Outcomes

Upon successful completion of this micro-credential, the learner will be able to:

- **Apply** basic machine learning (ML) models to industrial symbiosis (IS) scenarios.
- **Analyse** time-series and historical material flow data to detect trends and inefficiencies.
- **Evaluate** the suitability of AI/ML tools for forecasting supply-demand imbalances and logistics bottlenecks.
- **Create** data-informed process optimization plans using supervised and unsupervised learning techniques.
- **Communicate** findings and insights from AI-supported analysis to IS stakeholders in business-friendly terms.

Expanded Student Competencies

By the end of this module, students will develop the following competencies aligned with EQF Level 6:

Knowledge

Students will demonstrate advanced, specialized knowledge in the following areas:

- The role of Artificial Intelligence (AI) and Machine Learning (ML) in the context of Industrial Symbiosis (IS) and Circular Economy.
- Key ML concepts, including supervised and unsupervised learning, time-series forecasting, clustering, and predictive modeling.
- Types, structures, and quality dimensions of industrial material flow and process data.
- Digital tools and platforms used in IS for data integration, visualization, and decision support.
- Ethical, legal, and societal implications of using AI in industrial systems, including issues of bias, data privacy, and interpretability.

Skills

Students will acquire the ability to:

	– Collect, clean, and pre-process real-world industrial and environmental datasets using appropriate tools (e.g. Python, Pandas). – Develop and evaluate ML models (e.g. ARIMA (autoregressive integrated moving average), LSTM (long short - term memory), k-means) for material flow forecasting, anomaly detection, and resource optimization. – Interpret model outputs and derive actionable insights relevant to supply chain performance, waste valorisation, or process redesign. – Use visualization tools (e.g. SankeyMATIC*, QGIS**, Power BI *(https://app.powerbi.com/home) to communicate results to technical and non-technical stakeholders. – Integrate AI tools with IS platforms and industrial decision-making processes, using open-source software or APIs.
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Competences

Upon completion, students will be able to:

	– Operate autonomously in selecting appropriate digital methods to analyse and optimize resource flows in a multi-stakeholder industrial setting. – Understand the strengths and limits of different AI approaches, and choose the most practical one for your IS context balancing performance, simplicity, cost, and sustainability - lighter and clearer description. – Contribute to the digital transformation of companies or public sector clusters by proposing data-driven improvements to current symbiotic practices. – Work collaboratively in interdisciplinary teams and communicate AI-supported insights clearly to varied audiences. – Act in an ethically responsible manner regarding data usage, model transparency, and the societal impact of automation in sustainability contexts
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* SankeyMATIC is a web-based tool that lets you create and customize beautiful flow diagrams.

** QGIS is a geographic information system (GIS) software that is free and open-source. QGIS supports Windows, macOS, and Linux. It is the most popular tool for handling spatial data, used by both professionals and beginners around the world.

*** Microsoft Power BI – A leading BI tool for building visual dashboards, exploring time-series data, and performing simple analyses and forecasts.

Weekly Topics and Activities

Pre-course “Python/AI Crash Kit” (optional prep module)

Peer-pairing or mentor support in first 3 weeks

Week	Topic	Lab / Practice	Independent Study Focus
1.	Introduction to Digital IS	Case: transition from traditional to Digital IS	Reading: Ellen MacArthur Foundation (2023)
2.	Fundamentals of AI/ML	Python notebook: classification vs regression	Review: supervised learning basics
3.	Material Flow Data: Sources and Structures	Dataset wrangling in Pandas	Data cleaning in industrial datasets
4.	Time Series Forecasting I	ARIMA and Prophet (hands-on)	Tutorial: Demand prediction
5.	Time Series Forecasting II	LSTM for process prediction	Reflection: neural nets in IS
6.	Clustering & Unsupervised Learning	K-means for flow grouping	Use cases: material type clusters

7.	AI in Supply Chain Management	Tool demo: AnyLogistix* or Digital Twin viewer (https://flair3d.com/)	Case study analysis
8.	Optimizing Logistics Flows	Routing algorithms and constraints	Warehouse & transport scenarios
9.	Predictive Maintenance via ML	Anomaly detection (sensor logs)	Downtime cost modeling
10.	Integrating ML with IS platforms	APIs and decision-support dashboards	Reading: Circularise, EcoTrack
11.	Limitations and Bias in AI	Audit tools and ethics discussion	Read: “AI Ethics in Industry” (OECD, 2022)
12.	Group Project Work	Coaching session	Literature and tool review
13.	Group Presentations	Peer review and feedback	Project write-up
14.	Exam & Wrap-up	Written exam + project submission	Final reflections

* **anyLogistix** - software combines supply chain optimization and simulation for logistics network design, inventory, and production capacity planning.

Teaching Methods

This module employs a blended and practice-oriented teaching approach to foster both conceptual understanding and practical skills. The following methods will be used:

- **Interactive lectures** with demos (Jupyter, Excel ML, PowerBI)
- **Hands-on lab sessions** with datasets (industrial waste, transport logs)
- **Mini-hackathons** with toolkits like scikit-learn, TensorFlow Lite
- **Expert webinars** (e.g. AI in waste valorisation)
- **Flipped classroom**: video tutorials & ML model walkthroughs before class
- **Group projects**: industrial process optimization challenge

Assessment

Assessment is based on both individual and group performance, combining theoretical understanding with practical application. The breakdown is as follows:

Component	Weight	Description
Group AI Project	35%	Develop a predictive material flow model for an IS network (report + code + visualization dashboard)
Lab Portfolio	25%	4 selected Jupyter Notebooks or tool-based exercises
Final Exam	30%	Short-answer and applied scenario questions
Class Participation	10%	

Bibliography

	– Lütje A., Willenbacher M., Engelmann M., Kunisch C., Wohlgemuth V. (2019). Exploring the System Dynamics of Industrial Symbiosis (IS) with Machine Learning (ML) Techniques—A Framework for a Hybrid-Approach, Conference paper, 117–130. – Davis C., Graham A. (2022). Machine learning-assisted industrial symbiosis Testing the ability of word vectors to estimate similarity for material substitutions, Volume 26, Issue1, Data Innovation in Industrial Ecology, 27–43. – Cutaia L., Luciano A., Barberio G., Scaffoni S., Mancuso E., Scagliarino C., & La Monica M. (2015). The experience of the first industrial symbiosis platform in Italy. Environmental Engineering and Management Journal, 14(7), 1521–1533. – Matino I., Dettori S., Castellano A. (2021). Machine learning based models for supporting optimal exploitation of process off-gases in integrated steelworks, in: Advances in Intelligent Systems and Computing, 1338, Springer.
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Proposal for Micro-credential: 4. AI & Machine-Learning for Material-Flow Forecasting in IS (Data-Driven Symbiosis Badge) (4 ECTS)

Micro-credential Title: **AI & Machine-Learning for Material-Flow Forecasting in IS (Data-Driven Symbiosis Badge)**

Qualification Level: **EQF Level 6 (Bachelor's / Early Master's level)**

Learning Outcomes	
Upon successful completion of this micro-credential, the learner will be able to:	
1.	Apply basic machine learning (ML) models to industrial symbiosis (IS) scenarios.
2.	Analyse time-series and historical material flow data to detect trends and inefficiencies.
3.	Evaluate the suitability of AI/ML tools for forecasting supply-demand imbalances and logistics bottlenecks.
4.	Create data-informed process optimization plans using supervised and unsupervised learning techniques.
5.	Communicate findings and insights from AI-supported analysis to IS stakeholders in business-friendly terms.
Workload	
Total workload: 100 hours (equivalent to 4 ECTS)	

	– Contact hours (lectures, labs, workshops): 42 hours – Guided self-study: 58 hours
Assessment Methods	
	– Project (group-based predictive model & report; group oral presentation of project findings) – 35% – Lab Assignments (2 individual applied ML tasks) – 25% – Participation in labs, discussions, and peer assessments (active engagement in workshops; problem-solving, teamwork, AI ethics discussions) – 10% – Final Quiz testing theoretical and practical knowledge - 30%
Metadata (for digital credential)	
	– Issuer: [University / Consortium Name] – Credential type: Micro-credential (badge) – Credit value: 4 ECTS – Date of issue: [date] – Expiry: None (lifelong learning credit) – Verification: JSON-LD data format with verifiable signature – URL to module syllabus and assessment details
Summary	
	Holders of the AI & Machine-Learning for Material-Flow Forecasting in IS micro-credential will be able to: Confidently design and implement AI and machine learning strategies to optimize supply chains and material flow systems in industrial symbiosis settings. They can evaluate data sources, train and test models for forecasting demand and supply trends, and recommend logistics or process adjustments based on predictive insights. They also demonstrate fluency in data ethics, stakeholder communication, and the use of AI tools such as regression, clustering, and classification in resource-sharing networks.
Micro-Credential Specification	
Field	Content
Title	AI & Machine-Learning for Material-Flow Forecasting in IS
EQF Level	6
Workload	100–120 hours ($\approx$ 4 ECTS)
Mode	Blended / hybrid (labs, simulations, projects, peer collaboration)
Skills Tag	AI, machine learning, predictive analytics, material flow optimization, supply chain intelligence
Assessment Evidence	Predictive model prototype, logistics optimization case, dashboard design, group project report
Issuer	SymbioTech Alliance
Format	Verifiable JSON-LD badge with metadata, code snippets, visuals, and assessment criteria

Module 5. Blockchain for Transparent Traceability (Syllabus: 4 ECTS)

Course Description

This course introduces the fundamentals and applied use of blockchain technologies in the context of **industrial symbiosis (IS)** and **circular economy**. Students will explore how blockchain can be leveraged to create secure, immutable, and transparent systems for tracking material and energy flows across complex industrial networks. The module focuses on enhancing **data integrity**, **real-time traceability**, and **compliance** with environmental and sustainability standards (e.g. CSRD, EFRAG, ISO 14000). Through a combination of theoretical input, case study analysis, and applied labs, students will gain practical insights into blockchain-based **product passports**, **digital twins**, and **certification systems** that support low-carbon transitions and inter-organisational accountability. The course is especially relevant for future SymbioTech Managers aiming to digitise resource management in multi-actor industrial ecosystems.

General Learning Outcomes

By the end of this module, students will be able to:

- **Apply** blockchain principles to trace material and energy flows in Industrial Symbiosis (IS) ecosystems.
- **Analyse** the benefits, risks, and limitations of distributed ledger technologies in sustainable value chains.
- **Evaluate** different blockchain platforms for use in IS-related traceability.
- **Design** a basic blockchain-based certification system for tracking resources or emissions.
- **Explain** how blockchain contributes to ESG compliance, anti-greenwashing, and secure data governance.

Expanded Student Competencies

By the end of this module, students will develop the following competencies aligned with EQF Level 6:

Knowledge

Students will demonstrate advanced, specialised knowledge in the following areas:

- **Understanding of blockchain architecture, including distributed ledgers, consensus algorithms, and smart contracts.**
- **Familiarity with tokenisation, oracles, traceability protocols, and compliance frameworks**
- **In-depth awareness of ethical, legal, and governance issues in blockchain-based sustainability systems.**

Skills

Students will acquire the ability to:

	- Design smart contract logic. - Map and model traceability flows for raw materials, recycled inputs, or renewable energy. - Utilise evaluation frameworks to compare blockchain solutions for traceability, auditing, or reporting purposes. - Draft Digital Product Passport templates for IS applications.		
Competences			
Upon completion, students will be able to:			
	- Independently assess the suitability of blockchain solutions in real-world sustainability scenarios. - Exercise judgment in managing transparency vs confidentiality conflicts in industrial data. - Collaborate across technical and business teams to advocate for trust-based innovation in circular systems. - Communicate the potential and limitations of blockchain-based traceability to multiple stakeholders (technical, legal, managerial).		
Weekly Topics and Activities			
Week	Topic	Lab / Activity	Independent Study Focus
1.	Introduction to Blockchain and DLT	Interactive demo: how blocks link in a ledger	Reading: EU Blockchain Observatory report (2024)
2.	Blockchain and Circular Economy	Case analysis: Circularise, Everledger	Reading: Role of traceability in CE and IS
3.	Blockchain Architecture	Hands-on: Block structure, consensus models	Reading: Hash functions and key management
4.	Smart Contracts for IS	Smart contract logic	Case study: Smart-contract in IS
5.	Tokenisation of Resources	Design token for material streams	Study: Utility vs security tokens
6.	Traceability in Supply Chains	Chain-of-custody mapping	Practice: Transparent steel or textile supply
7.	Energy Certificates and Blockchain	Simulate renewable energy tracking	EU Guarantees of Origin (GoO) systems
8.	IoT & Oracles Integration	Designing sensor dashboard	Digital twins for production monitoring
9.	Privacy, Security & Compliance	Ethics case: Traceability vs confidentiality	Study: Zero-knowledge proofs, GDPR*
10.	Digital Product Passports	Create a basic DPP template	Use case: Battery Regulation, textiles
11.	Blockchain Evaluation for IS	Tool: Multi-criteria decision matrix	Compare Tezos**, Hyperledger***, and Ethereum****
12.	Group Design Sprint	Ideation workshop: resource trace project	Develop system sketch & stakeholder map
13.	Final Presentations	Group project pitches	Peer feedback and adjustment
14.	Exam + Wrap-Up	Written exam + oral exam	Module reflection

* GDPR General Data Protection Regulation is a comprehensive data protection law in the European Union that came into effect on May 25, 2018. It aims to enhance individuals' control and rights over their personal data and to unify data protection laws across Europe. **Tezos is an open-source blockchain that can execute peer-to-peer transactions and serve as a platform for deploying smart contracts. ***Hyperledger Composer is an open-source development framework designed to simplify the process of building blockchain applications on top of Hyperledger Fabric. ****Ethereum is a global, decentralized platform for money and new kinds of applications.

Teaching Methods

This module employs a blended and practice-oriented teaching approach to foster both conceptual understanding and practical skills. The following methods will be used:

- **Lectures** with real-world case integration
- **Hands-on labs** using RETScreen*, HOMER**, SankeyMATIC***
- **Simulation & planning workshops** for energy integration
- **Flipped classroom** and expert videos
- **Design studio approach** (Weeks 12–13)
- **Guest contributions** from energy auditors or local grid operators.

*RETScreen is a tool for energy planning, implementation, monitoring and reporting. ** HOMER (Hybrid Optimization of Multiple Energy Resources) software navigates the complexities of building cost effective and reliable hybrid microgrid and grid-connected systems that combine traditionally generated and renewable power, storage, and load management. *** SankeyMATIC is a web-based tool that lets you create and customize beautiful flow diagrams.

Assessment

Assessment is based on both individual and group performance, combining theoretical understanding with practical application. The breakdown is as follows:

Component	Weight	Description
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Group Project	40%	Design a symbiotic energy efficiency concept for a cluster, including flow analysis, tech options, and policy fit deliverables: presentation, technical model, risk map.
Lab Report Portfolio	30%	Exercises in Sankey flow mapping, storage scenario simulation, and audit KPIs
Final Exam	30%	Technical and scenario-based questions, energy modeling and regulatory alignment
Bibliography		
		- Bahga, Arshdeep, Vijay K. Madiseti. (2016). Blockchain platform for industrial internet of things. Journal of Software Engineering and Applications 9.10, 533–546. - Silvestri L., Forcina A., Introna V., Santolamazza A., Cesarotti, V. (2020). Maintenance transformation through Industry 4.0 technologies: A systematic literature review. Computers in industry, 123, 103335. - Ventura V., La Monica M., Bortolini M., Cutaia L. & Mora C. (2024). Blockchain and industrial symbiosis: a preliminary two-step framework to green circular supply chains, Volume 22, pages 17–30. - Wang Q., Zhu X., Ni Y., Gu L., Zhu H. (2020). Blockchain for the IoT and industrial IoT: A review. Internet of Things 10 (2020): 100081.

Proposal for Micro-credential: 5. Blockchain for Transparent Traceability (Blockchain Steward Badge) (4 ECTS)

Micro-credential Title: **Blockchain for Transparent Traceability (Blockchain Steward Badge)**

Qualification Level: **EQF Level 6 (Bachelor's / Early Master's level)**

Learning Outcomes	
Upon successful completion of this micro-credential, the learner will be able to:	
1.	Apply blockchain principles to trace material and energy flows in Industrial Symbiosis (IS) ecosystems.
2.	Analyse the benefits, risks, and limitations of distributed ledger technologies in sustainable value chains.
3.	Evaluate different blockchain platforms (e.g. Ethereum, Hyperledger, Circularise) for use in IS-related traceability.
4.	Design a basic blockchain-based certification system for resource or emissions tracking.
5.	Explain how blockchain contributes to ESG compliance, anti-greenwashing, and secure data governance.
Workload	
Total workload: 100 hours (equivalent to 4 ECTS)	

	- Contact hours (lectures, labs, workshops): 42 hours - Guided self-study and project work: 58 hours
Assessment Methods	
	- Project (group-based predictive model & report; data analysis, system modeling) – 35% - Lab Assignments (2 individual applied ML tasks; material flow prediction, algorithm testing, visualisation) – 25% - Class Participation (active engagement in workshops, discussions, and peer assessments (active engagement in workshops; problem-solving, teamwork, AI ethics discussions) – 10% - Final Quiz (Short-form questions & practical cases; knowledge, ML terminology, system architecture) - 30%
Metadata (for digital credential)	
	- Issuer: [University / Consortium Name] - Credential type: Micro-credential (badge) - Credit value: 4 ECTS - Date of issue: [date] - Expiry: None (lifelong learning credit) - Verification: JSON-LD data format with verifiable signature - URL to module syllabus and assessment details
Summary	
	Holders of the <i>Blockchain</i> Steward micro-credential will be equipped with the ability to apply blockchain and distributed ledger technologies to enhance transparency, trust, and accountability in industrial symbiosis systems. They will understand how to design blockchain-based tools such as digital product passports and smart contracts that enable the secure tracking of material and energy flows across organisational boundaries. With a strong grasp of regulatory requirements and environmental standards, they will be able to support compliance processes (e.g. under CSRD (Corporate Sustainability Reporting Directive) or EUDR (EU Deforestation Regulation)), while ensuring data integrity and stakeholder confidence. These professionals will also be capable of evaluating the ethical, technical, and operational implications of blockchain adoption in multi-actor sustainability networks.
Micro-Credential Specification	
Field	Content
Title	Blockchain for Transparent Traceability (Blockchain Steward Badge)
EQF Level	6
Workload	100–120 hours ($\approx$ 4 ECTS)
Mode	Blended / hybrid
Skills Tag	Traceability, smart contracts, digital product passports
Assessment Evidence	Traceability prototype (repo + slides), individual reflections
Issuer	SymbioTech Alliance
Format	JSON-LD verifiable micro-credential, registered on public blockchain

Learner Readiness Rubric: Blockchain for Transparent Traceability

(Knowledge/skills already included in the Module 4 readiness rubric are omitted below; see Module 4 pack for those.)

Domain	Basic	Developing	Ready
1. Blockchain Literacy	Never heard of blockchain	Knows about crypto but not industrial uses	Can explain what blockchain is and why it's used in sustainability or business contexts
2. Systems Mapping	Struggles with data flow logic	Understands introduction-to tracing (e.g. chain of custody)	Can diagram a blockchain network for tracking material or energy flows
3. Smart Contract Logic	No exposure to conditional logic	Familiar with "if-then" from formulas or pseudo-code	Can interpret a simple contract written in plain logic (coding not required)
4. Traceability & ESG Awareness	Unaware of traceability concepts	Knows what product passports are but not applied in practice	Can describe accountability, digital product passports, and ESG traceability needs
5. Evaluation Reasoning	Doesn't grasp trade-offs	Notices pros/cons but can't structure them	Can compare platforms and justify selection using transparent criteria

Interpretation:

Total Score (number of "Ready" ratings)	Readiness Level	Suggested Action
5–6 "Ready" ratings	High	Learner is likely to thrive at standard course pace; no intervention needed
3–4 "Ready" ratings	Medium	Learner may need light scaffolding such as peer support, prep videos, or guided tools
<3 "Ready" ratings	Low	Recommend completing the Pre-Course Resource Pack or attend additional course

Module 6. Symbiotic Energy-Efficiency Technologies (Syllabus: 4 ECTS)

Course Description

This module explores the integration of renewable energy sources and advanced energy management systems within the context of industrial symbiosis. It focuses on how businesses can collaboratively optimise energy consumption, reduce costs, and minimise environmental impact by sharing and managing energy resources more intelligently across industrial networks. Students will examine the principles and technologies that underpin symbiotic energy models, including industrial heat recovery, energy cascading, local energy communities, and intelligent grid systems. Through practical tools, real-world case studies, and system modeling exercises, students will learn to identify energy synergies, assess technical and economic feasibility, and design collaborative solutions that align with the goals of a circular economy and climate neutrality. The module prepares future SymbioTech Managers to lead energy integration projects, work with multiple stakeholders, and contribute to resilient, low-carbon industrial ecosystems.

General Learning Outcomes

By the end of this module, students will be able to:

- Apply energy efficiency models and renewable integration techniques in the context of Industrial Symbiosis (IS).
- Analyse energy flows and synergies within and between companies to reduce waste and improve environmental performance.
- Evaluate economic feasibility of energy-sharing systems (e.g. heat exchange, storage, peer-to-peer trading).
- Design scenarios for integrating symbiotic energy management into industrial networks using simulation tools.
- Communicate viable energy efficiency strategies to technical and managerial stakeholders.

Expanded Student Competencies

By the end of this module, students will develop the following competencies aligned with EQF Level 6:

Knowledge

Students will demonstrate advanced, specialised knowledge in the following areas:

- In-depth understanding of energy flows, heat recovery, cogeneration, renewable integration, and smart grid concepts within industrial networks.
- Familiarity with Energy Efficiency Directive and the related EU policies.
- Knowledge of key energy modeling tools and methodologies for scenario simulation and cost-benefit analysis - all from the economic/business perspective.

Skills

Students will acquire the ability to:

	- Conduct energy audits, analyse thermal and electrical flows, and identify opportunities for recovery or sharing. - Simulate energy system scenarios using tools like RETScreen*, SankeyMATIC**, or HOMER***. - Evaluate the technical, economic, and regulatory viability of symbiotic energy projects. - Communicate solutions through technical reports and visual tools for diverse audiences. - Calculate carbon footprint based on heat exchange between two or more entities. (or: Assess carbon footprint associated with inter-entity heat exchange)
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Competences

Upon completion, students will be able to:

	- Make independent judgements on energy-saving strategies and system integration opportunities. - Lead or support energy management initiatives within a multi-stakeholder IS setting. - Interpret and apply EU energy regulations to company-level decisions. - Act ethically and responsibly in energy data management, system optimisation, and balancing environmental risks.
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*RETScreen is a tool for energy planning, implementation, monitoring and reporting. ** SankeyMATIC is a web-based tool that lets you create and customize beautiful flow diagrams. *** HOMER (Hybrid Optimization of Multiple Energy Resources) software navigates the complexities of building cost effective and reliable hybrid microgrid and grid-connected systems that combine traditionally generated and renewable power, storage, and load management.

Weekly Topics and Activities

Week	Topic	Lab / Activity	Independent Study Focus
1.	Energy in the Circular Economy	Review: Energy hierarchy, exergy	Literature: IEA Circular Energy 2024
2.	Industrial Energy Flows	Mapping: Steam, heat, cooling	Reading: Pinch analysis basics
3.	Symbiotic Energy Synergies	Case: e.g. Ulsan Eco-Industrial Park	Identify synergy opportunities
4.	Heat Recovery and Exchange	Tool: Sankey diagrams (SankeyMATIC)	Heat network case study
5.	Renewable Energy Integration	Explore: PV, wind, biogas in IS	Tech brief: Hybrid energy systems
6.	Smart Grids & Demand Response	Smart meters, AI load balancing	ENTSO-E demand flexibility reports
7.	Energy Storage Systems	Lab: Battery modeling, hydrogen storage	Cost-benefit of storage solutions
8.	Energy Management Standards	Focus: ISO 50001, audits, KPIs	Tools: EnPI Lite (Energy Performance Indicator), energy audit steps
9.	Energy Contracting and Business Models	ESCOs (Energy Service Companies), PPA*, shared ownership	Exercise: Energy service agreement
10.	Simulation Tools for Energy Planning	Lab: RETScreen or HOMER software (who will take care of this?)	Develop a symbiotic energy model
11.	Regulatory Landscape	EU policies and regulations for energy efficiency	Compliance checklist

12.	Group Project Workshop	Co-design of IS energy concept	Draft business and tech pitch
13.	Group Presentations	Peer critique and refinement	Final reflection & alignment
14.	Written exam + oral exam	Final project oral and written test	Module wrap-up

* PPA - power purchase agreement or electricity power agreement, is a long-term contract between an electricity generator and a customer, usually a utility, government or company.

Teaching Methods

This module employs a blended and practice-oriented teaching approach to foster both conceptual understanding and practical skills. The following methods will be used:

- Interactive Lectures (present key concepts on renewable energy technologies, energy efficiency strategies, and symbiotic energy management models within industrial networks; incorporate the latest research findings and case studies).
- Technical Workshops and Labs (hands-on sessions using energy simulation software, optimisation tools, and real-world data to analyse energy flows and identify efficiency improvements in industrial clusters).
- Case Study Analysis (explore successful implementations of energy symbiosis projects, focusing on renewable integration, demand-side management, and cost reduction strategies).
- Group Problem-Solving Sessions (collaborative exercises where students develop and propose energy management solutions tailored to specific industrial contexts).
- Guest Lectures and Industry Talks (sessions led by experts from the energy sector, highlighting cutting-edge technologies, policies, and market trends related to sustainable energy use).
- Field Visits/Virtual Tours (optional visits or virtual tours of industrial sites practising energy symbiosis to observe technology applications and management practices firsthand).

Assessment

Assessment is based on both individual and group performance, combining theoretical understanding with practical application. The breakdown is as follows:

Component	Weight	Description	Assessed Competencies
Energy Optimisation Project	50%	Group project analysing energy flows in an industrial cluster and proposing efficiency measures, with analysis of symbiosis effects (technical) Cost-benefit analysis for the energy optimisation project: financial efficiency measures of symbiosis	Application of selected models, Application of cost-benefit analysis, teamwork, and analytical thinking
Class Participation	20%	Engagement in discussions, labs, and problem-solving workshops	Communication, collaboration, and critical thinking
Final Exam	30%	Written exam with theoretical questions and case-based problem solving	Conceptual understanding, problem-solving skills

Bibliography

	– Branca T., Colla V., Fornai B., Petrucciani A., Pistelli M., Faraci E., Cirilli F., Schröder A. (2022). Current state of Industrial Symbiosis and Energy Efficiency in the European energy intensive sectors, <i>Matériaux & Techniques</i> 109 (5-6). – Cervo H., Ferrasse J.-H., Descales B. (2020). Blueprint: A methodology facilitating data exchanges to enhance the detection of industrial symbiosis opportunities–Application to a refinery, <i>Chem. Eng. Sci.</i> 211. – Fraccascia L., Yazdanpanah V., van Capelleveen G. & Yazan D.M. (2020). Energy-based industrial symbiosis: a literature review for circular energy transition, <i>Volume 23</i>, 4791–4825. – He K., Wang L. (2017). A review of energy use and energy-efficient technologies for the iron and steel industry, <i>Renew. Sustain. Energy Rev.</i> 70, 1022-1039. – Malinauskaite J., Jouhara H., Ahmad L., Milani M., Montorsi L., Venturelli M. (2020). Optimizing the Efficiency of Resource Exchange in Industrial Symbiosis (IS). <i>Responsible Consumption and Production</i>, 1–12, <i>Energy</i>, <i>Volume 172</i>, 255–269.
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Proposal for Micro-credential: 6. Symbiotic Energy-Efficiency Technologies (Energy-Loop Designer Badge) (4 ECTS)

Micro-credential Title: **Symbiotic Energy-Efficiency Technologies (Energy-Loop Designer Badge)**

Qualification Level: **EQF Level 6 (Bachelor's / Early Master's level)**

Learning Outcomes	
Upon successful completion of this micro-credential, the learner will be able to:	
1.	Apply energy efficiency models and renewable integration techniques in the context of Industrial Symbiosis (IS).
2.	Analyse energy flows and synergies within and between companies to reduce waste and improve environmental performance.
3.	Evaluate technical and economic feasibility of energy-sharing systems (e.g. heat exchange, storage, peer-to-peer trading).
4.	Design scenarios for integrating symbiotic energy management into industrial networks using simulation tools.
5.	Communicate viable energy efficiency strategies to technical and managerial stakeholders.
Workload	
Total workload: 100 hours (equivalent to 4 ECTS)	

	- Contact hours (lectures, labs, workshops): 42 hours - Guided self-study and project work: 58 hours
Assessment Methods	
	- Group Energy Optimization Project: (50%) Students collaborate to analyse energy consumption patterns within an industrial network and develop integrated solutions that enhance energy efficiency and incorporate renewable sources. Assessment focuses on problem-solving, application of energy management models, and teamwork. Students collaborate while running cost-benefit analysis for the energy optimisation project: financial efficiency measures of symbiosis. Assessment focuses on: Application of cost-benefit analysis, teamwork, and analytical thinking - Class Participation and Engagement (20%) Active involvement in workshops, labs, discussions, and problem-solving sessions, demonstrating critical thinking, communication skills, and collaboration. - Final Written Exam (30%) The exam assesses the conceptual understanding of symbiotic energy management principles, renewable energy technologies, and the application of models to real-world industrial contexts.
Metadata (for digital credential)	
	- Issuer: [University / Consortium Name] - Credential type: Micro-credential (badge) - Credit value: 4 ECTS - Date of issue: [date] - Expiry: None (lifelong learning credit) - Verification: JSON-LD data format with verifiable signature - URL to module syllabus and assessment details
Summary	
	Holders of the Symbiotic Energy-Efficiency Technologies micro-credential will be able to critically assess and optimise energy consumption within complex industrial networks by integrating renewable energy sources and advanced management models. They will demonstrate the ability to analyse energy flows, identify inefficiencies, and design practical solutions that reduce environmental impact and operational costs. Graduates will communicate technical findings effectively, collaborate across disciplines, and apply contemporary energy technologies to support sustainable industrial symbiosis, thereby contributing to the achievement of circular economy goals.
Micro-Credential Specification	
Field	Content
Title	Symbiotic Energy-Efficiency Technologies (Energy-Loop Designer Badge)
EQF Level	6
Workload	100–120 hours ($\approx$ 4 ECTS)
Mode	Blended / hybrid
Skills Tag	Energy mapping, industrial symbiosis, simulation, energy policy
Assessment Evidence	Energy concept pitch + simulation + audit report

Issuer	SymbioTech Alliance
Format	Verifiable JSON-LD micro-credential on blockchain or digital wallet

Module 7. Environmental-Management Systems (Syllabus: 4 ECTS)

Course Description

This module introduces students to the structure, implementation, and evaluation of Environmental Management Systems (EMS), with a focus EMAS frameworks. Through hands-on activities, case analysis, and simulated audits, students will learn how to conduct environmental reviews, set objectives and indicators, implement operational controls, and ensure compliance with regulations. The module aims to develop applied EMS capabilities for industrial symbiosis settings, preparing students to guide SMEs or clusters toward improved environmental performance, regulatory alignment, and long-term sustainability strategies.

General Learning Outcomes	
By the end of this module, students will be able to:	
	– Apply core EMS principles, tools, and standards (e.g. EMAS*). – Design EMS elements, including policies, objectives, and operational control procedures. – Evaluate compliance and performance using KPIs and internal audits. – Communicate EMS strategies and documentation to external stakeholders, including regulators and partners.
* EMAS - Eco-Management and Audit Scheme is an environmental management tool established by the European Commission to help organisations improve their environmental performance.	
Expanded Student Competencies	
By the end of this module, students will develop the following competencies aligned with EQF Level 6:	
Knowledge	
Students will demonstrate advanced, specialised knowledge in the following areas:	
	– Comprehensive understanding of EMS frameworks. – Insight into environmental risk management, aspect identification, and compliance strategies. – Understanding of core environmental performance indicators – Knowledge of how EMS links to European Sustainability Reporting Standards
Skills	
Students will acquire the ability to:	

	- Ability to conduct Initial Environmental Reviews and identify legal & operational risks. - Design EMS documentation: environmental policy, objectives, KPIs, and procedures. - Develop and interpret EMS audits and performance dashboards to inform decision-making. - Draft effective EMS communications for internal and external stakeholders		
Competences			
Upon completion, students will be able to:			
	- Independently lead EMS implementation projects within SMEs or clusters. - Manage continuous improvement processes and audit cycles to ensure effective implementation. - Ensure cross-compliance with EU environmental law and sustainability targets. - Engage with regulators, auditors, and partners to maintain system integrity.		
Weekly Topics and Activities			
Week	Topic	Lab / Activity	Independent Work
1.	Introduction to EMS	EMS landscape & standards	Compare ISO 14001 vs. EMAS vs the new standards
2.	Principles of EMAS standards (1)	Analyse of EMAS clauses and requirements	Policy writing practice
3.	Principles of EMAS standards (2)	Analyse of EMAS clauses and requirements	Identify legal & environmental aspects
4.	Environmental Aspects (EA) and Impacts (EI)	Correlation matrix between EAs and Eis and Risk prioritisation matrix.	Research: LCA links to EMS
5.	Legal and Other Requirements	Legal register creation	EU regulations case review
6.	Setting Objectives, Indicators & Targets	SMART KPI lab	Aligning EMS and SDGs
7.	Operational Control & Monitoring	SMART KPI lab	Case: Energy Control Systems
8.	Roles, Responsibilities & Training	EMS org chart simulation	Communication plans
9.	Emergency Preparedness & Response	EMS org chart simulation	EMS risk mitigation mapping
10.	Internal Audits & Corrective Actions	Conduct a mock audit	Gap analysis template
11.	Management Review Process	Performance dashboard building	Prepare a management review memo
12.	EMS Documentation	Prepare the EMS manual	Peer feedback & revision
13.	Final EMS Project	EMS for a real-world case	Q&A and troubleshooting
14.	Exam preparation	Prepare for final exam	Reflective report submission

Teaching Methods		
This module employs a blended and practice-oriented teaching approach to foster both conceptual understanding and practical skills. The following methods will be used:		
	- lectures with EMS reference materials - Practical exercises (e.g. policy design, aspect identification, mock audits) - Case-based learning (real EMSs from industry) - Flipped learning for technical standards - Simulation-based evaluation in the final weeks - Peer review and role play (Week 10, 14)	
Assessment		
Assessment is based on both individual and group performance, combining theoretical understanding with practical application. The breakdown is as follows:		
Component	Weight	Description
Project	40%	Development of a detailed EMS plan for a real or hypothetical organisation, including environmental review, objectives, policy, and compliance measures.
Participation and Practical Exercises	10%	Active participation
Written Exam	50%	Testing understanding of EMS standards, processes, and practical application scenarios.
Bibliography		
	- Brady J., Lunn R., Ebbage A. (2024). Environmental Management in Organizations: The IEMA Handbook. - Frey M. (2021), Environmental Management System and SMEs: EU Experience, Barriers and Perspectives, Journal: Environmental Management. - Joy-Camacho W., Thornhill I. (2025). Opportunities and limitations to environmental management system (EMS) implementation in UK small and medium enterprises (SMEs) – A systematic review, Journal of Environmental Management, Volume 367, 121749. - Hassanh., Mazhar T. (2025). Environmental management systems and eco-innovation in SMEs.	

Proposal for Micro-credential: 7. Environmental Management Systems (EMS Practitioner Badge) (4 ECTS)

Micro-credential Title: **Environmental Management Systems (EMS Practitioner Badge)**

Qualification Level: **EQF Level 6 (Bachelor's / Early Master's level)**

Learning Outcomes	
Upon successful completion of this micro-credential, the learner will be able to: • Apply core EMS principles, tools, and standards (e.g. EMAS). • Design EMS elements, including policies, objectives, and operational control procedures. • Evaluate compliance and performance using KPIs and internal audits. • Communicate EMS strategies and documentation to external stakeholders, including regulators and partners.	
Workload	
Total workload: 100 hours (equivalent to 4 ECTS)	
	- Contact hours (lectures, labs, workshops): 42 hours - Guided self-study and project work: 58 hours
Assessment Methods	
	- Project: EMS Implementation Plan (40%) Develop a detailed EMS plan for a real or hypothetical organisation, including environmental review, objectives, policy, and compliance measures. Presentation and written report required. - Participation & Engagement (10%) Active participation during the course - Final Written Exam (50%) Testing understanding of EMS standards, processes, and practical application scenarios.
Metadata (for digital credential)	
	- Issuer: [University / Consortium Name] - Credential type: Micro-credential (badge) - Credit value: 4 ECTS - Date of issue: [date] - Expiry: None (lifelong learning credit) - Verification: JSON-LD data format with verifiable signature - URL to the module syllabus and assessment details
Summary	
	Holders of the micro-credential EMS Practitioner will be equipped to effectively develop, implement, and maintain EMS frameworks in compliance with ISO and EMS standards. They will possess the skills to conduct thorough initial environmental reviews, set clear and measurable environmental objectives, and design policies that promote sustainable practices. Additionally, they will be able to engage with stakeholders, ensure regulatory compliance, and drive continuous improvement in environmental performance within diverse organisational and industrial contexts. This capability enables them to support businesses in minimising environmental impacts while enhancing operational efficiency and sustainability.

Micro-Credential Specification	
Field	Content
Title	Environmental Management Systems (EMS Practitioner Badge)
EQF Level	6
Workload	100–120 hours ($\approx$ 4 ECTS)
Mode	Blended / hybrid
Skills Tag	ISO 14001, EMS, audits, and EMS implementation, environmental reporting
Assessment Evidence	Group project, practical exercises, written exam
Issuer	SymbioTech Alliance
Format	Verifiable JSON-LD badge with metadata & assessment links

2.3. The curriculum for VET level

Below the syllabuses for the seven training modules for VET are presented.

Module 1: Industrial Symbiosis Framework (IS Operator)	
EQF Level:	5
ECVET Credit:	3
Total Workload:	75 hours
Delivering Institution:	...
Certificate Issuing Authority:	SymbioTech Alliance
Module Overview	
This module introduces learners to the foundational concepts and practical applications of the Circular Economy (CE) and Industrial Symbiosis (IS) within the context of production and manufacturing. It is designed specifically for managers and coordinators in circular economy and industrial symbiosis initiatives, equipping them with essential managerial competencies. The module adopts a blended learning model, combining an intensive on-site boot camp with guided e-learning and a practical workplace task. Assessment includes the development of a Sankey diagram representing resource flows and a structured oral examination to confirm understanding. Upon completion, SymbioTech Managers will be able to observe, document, and analyse material and energy flows within industrial facilities, while identifying opportunities for efficiency and circularity.	

Learning Outcomes	
Knowledge	
	- Understand core concepts of the circular economy and industrial symbiosis, including key terminology and classification of typical material, energy, and waste streams in industrial systems. - Identify the environmental, economic, and operational rationale for applying industrial symbiosis principles at the plant or network level.
Skills	
	- Accurately identify, quantify, and log resource flows (inputs, outputs, losses, by-products) in a manufacturing or processing environment. - Utilise basic mapping tools (e.g. SankeyMATIC*, https://sankeymatic.com/) to create clear visualisations of resource flows and identify inefficiencies or “hotspots” in the system.
Responsibility and Autonomy	
	- Operate with limited supervision when conducting workplace observations, data collection, and flow analysis while adhering to safety, health, and environmental (SHE) protocols. - Recognise anomalies or inefficiencies and escalate potential areas for improvement or investigation to supervisors as appropriate.
*SankeyMATIC is a web-based tool that lets you create and customize beautiful flow diagrams.	
Learning Activities and Delivery Schedule	
Week 1 – On-site Bootcamp (Face-to-Face):	
	- A five-day intensive workshop delivered at the training centre. - Interactive sessions cover the fundamentals of the circular economy, IS typologies, and mapping techniques. - Practical walkthroughs of a simulated or real production facility to trace and document material and energy flows. - Learner’s practice creating Sankey diagrams using SankeyMATIC with sample data.
Weeks 2–3 – Mentored E-learning and Workplace Task:	
	- Learners engage in self-paced online learning via Moodle, supported by weekly virtual mentoring check-ins. - The digital curriculum includes in-depth CE/IS concepts, industry case studies, and self-assessment quizzes. - Learners carry out a structured task: mapping resource flows in their workplace (or based on provided case scenarios), including the classification of streams and the identification of hotspots.
Week 4 – Final Assessment Clinic:	
	- Learners submit their completed resource flow diagram and present it to the assessors in a 10–15-minute oral exam. - The oral component assesses learners’ understanding of CE/IS principles, the logic behind their flow mapping, and their ability to reflect critically on the results.
Key Tools and Resources	
	SankeyMATIC – Free web-based software for building Sankey diagrams; used to visualise flow intensity and losses in systems.

	– Circular Economy Canvas Cheat Sheet – Visual reference for identifying loop-closing strategies relevant to SMEs and local production systems. – “Industrial Symbiosis for SMEs” Handbook (Ellen MacArthur Foundation, 2024) – Primary reading that explains key IS strategies, practical steps, and case studies tailored to small- and medium-sized enterprises.
*SankeyMATIC is a web-based tool that lets you create and customize beautiful flow diagrams.	
Summative Assessment	
Assessment Components:	
1.	Practical Artefact: Creation of a resource flow map (Sankey diagram) illustrating material and/or energy streams of a specific process or facility.
2.	Oral Examination - Short, structured interview where the learner presents and justifies their diagram, responds to clarifying questions, and demonstrates understanding of key CE/IS concepts.
Evaluation Methodology:	
	– The resource diagram is evaluated using a 20-point rubric that assesses data accuracy, clarity, visual effectiveness, and interpretation. – The oral exam tests conceptual understanding, communication, and the ability to apply principles to real-world contexts. – Both components must be completed satisfactorily to earn the module badge and ECVET credits.
Assessment Evidence Includes:	
	– Submitted Sankey diagram (PDF or image format) – Oral exam video/audio recording – Completed scoring rubric with mentor/assessor feedback (PDF)
Bibliography	
	– Baas L.W., Boons F.A. (2004). An industrial ecology project in practice: exploring the boundaries of decision-making levels in regional industrial systems. <i>J Clean Prod</i> 12(8–10):1073–1085. – Bassi F., José G. Dias. (2019). The use of circular economy practices in SMEs across the EU, <i>Resources, Conservation and Recycling</i>, Volume 146, 523–53. – Bocken N.M., De Pauw I., Bakker C., Van der Grinten B. (2016). Product design and business model strategies for a circular economy. <i>J Ind Prod Eng</i> 33(5):308–320. – Chowdhury S., Dey P.K., Rodríguez-Espíndola O., Parkes G., Anh Tuyet N.T., Long D.D., Phuong Ha T. (2022). Impact of Organisational Factors on the Circular Economy Practices and Sustainable Performance of Small and Medium-sized Enterprises in Vietnam. <i>Journal of Business Research</i>, Volume 147, 362–378. – Domenech T., Bleischwitz R., Doranova A., Panayotopoulos D., Roman L. (2019). Mapping industrial symbiosis development in Europe_ typologies of networks, characteristics, performance and contribution to the circular economy. <i>Resour Conserv Recycl</i> 141:76–98. – Godina R., Azevedo S., Matias J. (2020). A comprehensive review of industrial symbiosis, <i>Journal of Cleaner Production</i>, Volume 247, 119113. – Mallawaarachchi H., Sandanayake Y., Karunasena G., Liu C (2020). Unveiling the conceptual development of industrial symbiosis: Bibliometric analysis. <i>J Clean Prod</i> 120618. – Salomone R., Cecchin A., Deutz P., Raggi A., Cutaia L. (2020). <i>Industrial Symbiosis for the Circular Economy: Operational Experiences, Best Practices and Obstacles to a Collaborative Business Approach</i>, Springer Nature.

Digital Badge Metadata Summary	
Badge Title:	IS Operator
Issued by:	SymbioTech Alliance
EQF Level:	5
Credit Weighting:	3 ECVET ($\approx$ 75 learning hours)
Mode	Blended / hybrid (lectures, workshops, software labs)
Skills Tag	Circular Economy, IS principles, case analysis, engagement strategies
Badge Description:	
	This badge certifies that the holder can observe, classify, and record industrial material and energy flows, and present them visually using a Sankey diagram. They understand how circular economy principles can be applied to identify and reduce waste and inefficiencies in industrial settings.
Key Competences Demonstrated:	
	- Identify and categorise different resource streams (e.g. raw materials, energy inputs, water use, emissions, by-products). - Use a Sankey diagramming tool to create a clear visualisation of resource flow. - Explain fundamental CE/IS concepts and how they relate to real industrial processes.
Assessment Evidence Includes:	
	- Submitted Sankey diagram (PDF or image format) - Oral exam video/audio recording - Completed scoring rubric with mentor/assessor feedback (PDF)
EQAVET Alignment	
	Planning: Learning outcomes linked to EQF descriptors and ECVET standards. Implementation: Delivered via blended model with bootcamp, mentoring, and assessment. Evaluation: Structured rubric applied to digital and oral outputs. Review: Evidence archived for continuous improvement and quality assurance. Recognition: Digital badge awarded upon successful performance across all tasks.

Module 2: LCA Essentials (EcoFootprint Assessor)	
EQF Level:	5
ECVET Credit:	3
Total Workload:	75 hours
Delivering Institution:	...
Certificate Issuing Authority:	SymbioTech Alliance

Module Overview

This module equips learners particularly future SymbioTech Managers with the theoretical understanding and practical competencies needed to apply Life Cycle Assessment (LCA) as a decision-support tool within the context of the circular economy (CE) and industrial symbiosis (IS). Learners explore the four phases of LCA in accordance with ISO 14040/14044 and gain familiarity with environmental indicators such as Environmental Footprint (EF) 3.1, Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA).

Through a combination of guided case studies, software training, and applied projects, learners develop the ability to model environmental impacts using openLCA particularly within CE and IS scenarios and to evaluate these impacts from environmental, economic, and social perspectives. The course emphasizes the integration of Life Cycle Thinking (LCT) with broader sustainability goals, including the UN Sustainable Development Goals (SDGs) and the European Green Deal (https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en).

Participants are trained to interpret LCA findings critically and communicate them clearly to various stakeholders, while also developing ethical awareness, systems thinking, and the ability to navigate the trade-offs and stakeholder interests inherent in circular transitions. By the end of the module, learners will be able to independently lead simplified LCA projects, contribute to sustainability reporting, and support informed decision-making across production and policy environments.

Learning Outcomes

Knowledge

- Understand the four phases of Life Cycle Assessment (LCA) according to ISO 14040/14044: goal and scope definition, life cycle inventory (LCI), life cycle impact assessment (LCIA), and interpretation.
- Understand the structure and purpose of environmental indicators such as Environmental Footprint (EF) 3.1 and their role in managerial decision-making and sustainability reporting.
- Recognize how LCA functions as a methodological tool within broader sustainability strategies, including circular economy (CE) models and the Sustainable Development Goals (SDGs).
- Explain the interconnections between the frameworks of Circular Economy (CE), Sustainable Development Goals (SDGs), and Life Cycle Thinking (LCT).
- Interpret environmental, economic, and social performance indicators using LCA-based tools in the context of comparative sustainability analysis.
- Identify the policy relevance of LCA, particularly within the European Green Deal and the Circular Economy Action Plan (CEAP).

Skills

- Gather and organize the Bill of Materials (BoM) and process data necessary for LCA modeling.
- Operate openLCA software, including the use of the "Quick LCA" wizard, to carry out simplified life cycle impact assessments.

	– Apply openLCA to model circular economy (CE) and industrial symbiosis (IS) scenarios and assess their environmental impacts. – Analyse and interpret LCA results to support sustainable production and business decision-making. – Use Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA) to perform holistic sustainability evaluations that incorporate economic and social dimensions. – Translate technical LCA findings into clear, decision-oriented visual and verbal communications tailored to diverse stakeholder audiences.
Responsibility and Autonomy	
	– Work independently and methodically, ensuring high data quality and accurate interpretation of LCA results. – Take initiative to contextualize LCA findings within broader sustainability, business improvement, and environmental compliance objectives. – Communicate LCA findings responsibly, clearly acknowledging uncertainties, methodological limitations, and system boundaries. – Embrace systems thinking and ethical responsibility when addressing environmental, economic, and social impacts. – Critically reflect on trade-offs, stakeholder perspectives, and value conflicts inherent in circular economy transitions.
Learning Activities and Delivery Schedule	
Week 1 – On-site Bootcamp (Face-to-Face):	
	– Introduction to Circular Economy (CE) principles, Life Cycle Thinking (LCT), and sustainability challenges in product and systems design. – Orientation to the openLCA software, including user interface, project structure, and database management. – Step-by-step walkthrough of LCA methodology according to ISO 14040/14044: goal and scope definition, inventory, impact assessment, and interpretation. – Hands-on lab sessions using the "Quick LCA" wizard to model a guided case (e.g. packaging, electronics, or textile item). – Application of Environmental Footprint (EF) 3.1 indicators in impact interpretation. – Discussion on LCA in the context of EU Green Deal, CEAP, and SDGs. – Key outcome: Develop a preliminary LCA model of a circular system with clearly defined functional unit and system boundaries.
Weeks 2–3 – Mentored E-learning and Workplace Task:	
	Format: Asynchronous + synchronous mentor sessions – Online modules on: ○ Advanced LCA modeling (multi-process networks, allocation methods) ○ Introduction to Life Cycle Costing (LCC) and Social LCA (S-LCA) concepts ○ Case examples of LCA in CE and Industrial Symbiosis (IS) settings – Application of knowledge to a self-directed simplified LCA project (based on a real or provided case relevant to learners' sector or interest). – Integration of basic cost data and social hotspot analysis into the environmental model to move toward holistic sustainability assessment. Weekly mentor check-ins (online or hybrid) to provide guidance, review modeling progress, and troubleshoot data or software issues.

	Key outcome: Completion of a full LCA model with draft interpretation of environmental, economic, and social indicators.
Week 4 – Final Assessment Clinic:	
	Format: Hybrid or on-site presentations and review – Submission of the openLCA project file (.zolca or ZIP), including BoM (Bill of Material), inventory data, impact results, and documentation of methods. – Preparation and delivery of a concise 5-slide presentation covering: ○ Scope and functional unit ○ System model and key processes ○ Environmental, economic, and social findings ○ Interpretation and scenario insights ○ Improvement recommendations – Individual oral exam: Each learner explains their methodology, data sources, system boundaries, modeling decisions, and interpretation of EF 3.1 and/or additional LCC or S-LCA results. – Peer feedback session (optional): Presentations reviewed by fellow learners to foster critical reflection and communication skills. – Key outcome: Demonstration of applied understanding of LCA tools and principles in a sustainability decision-making context.
Key Tools and Resources	
	– openLCA Software – A free, open-source Life Cycle Assessment tool developed by GreenDelta (https://www.greendelta.com/software/); learners use the built-in "Quick LCA" wizard for simplified workflows and gain experience modeling full product systems. – EF 3.1 Impact Factor Card – A quick-reference tool that supports learners in interpreting environmental impact results, normalization values, and midpoint indicators according to the EU Environmental Footprint method. – openLCA Beginner's Guide (GreenDelta, 2023) – A step-by-step instruction manual that introduces key LCA concepts, openLCA functionality, and guidance for building, analyzing, and interpreting models. – BoM (Bill of Material) and LCI Templates (Life Cycle Inventory Template) – Structured Excel sheets provided to support learners in organizing raw material inputs, energy data, and life cycle inventory data before entering into openLCA. – Scenario Comparison Template – A guided worksheet to help learners evaluate "baseline vs improved" or "linear vs circular" product scenarios. – S-LCA & LCC Worksheets – Optional data collection tools to support integration of basic social and economic indicators into LCA models, including stakeholder and cost mapping templates. – Presentation & Pitch Checklist – A guide to help learners structure their 5-slide presentation and prepare for the oral exam or pitch (oral defense) session.
Summative Assessment	
Assessment Components:	
3.	LCA Project Submission – Learners submit a complete openLCA project file (.zolca or ZIP archive) that includes: – A clearly defined functional unit and system boundaries – A structured Bill of Materials (BoM) and linked LCI data – Selection and application of an appropriate impact assessment method (e.g. EF 3.1) – Model outputs (midpoint or endpoint indicators) and documentation of methods, assumptions, and limitations

	– Optional inclusion of Life Cycle Costing (LCC) and Social LCA (S-LCA) data to support holistic evaluation
4.	Presentation Deck (5 slides): Summarising the Scope and functional unit, System model and key processes, including circular economy considerations, Environmental, economic, and social findings based on model outputs, Interpretation and scenario comparison (e.g. baseline vs improvement options), Actionable recommendations for sustainability improvements.
5.	Oral Defense: Oral Defense (Pitch) In a 10-minute oral exam, learners explain their modeling choices, justify assumptions and data sources, and: – Defend their system boundary and method selections – Interpret impact results using EF 3.1 or other relevant methods – Discuss trade-offs, limitations, and stakeholder implications – Reflect on the integration of environmental, social, and economic insights in circular economy decision-making
6.	(Optional) Peer Feedback Session Learners present their projects to peers for structured critique using a shared rubric, helping them refine their communication and critical reflection skills.
Evaluation Methodology:	
	– Work is assessed using a structured 20-point rubric, which covers criteria including data accuracy, methodological alignment, clarity of presentation, and the ability to interpret results. – Both the digital artefact and oral defense must meet minimum quality thresholds for credit awarding and badge issuance.
Assessment Evidence Includes:	
	– The learner's openLCA project file (.zolca or exported ZIP), including system definition, BoM, LCI data, selected impact method(s), and documented assumptions. – A PDF version of the 5-slide presentation deck, summarising the project scope, key processes, results, interpretation, and recommendations. – A recorded oral defense session, where the learner explains their methodology, modeling decisions, and interpretation of environmental, economic, and social findings. – An annotated scoring rubric completed by the evaluator, with structured feedback and performance comments across defined criteria (e.g. technical accuracy, systems thinking, communication quality, critical reflection). – (Optional) Peer feedback forms or reflective notes if learners participate in the peer review session.
Bibliography	
	- Aissani L., Lacassagne A., Bahers J.B., Féon S.L. (2019). Life cycle assessment of industrial symbiosis: a critical review of relevant reference scenarios. <i>Journal of Industrial Ecology</i>, 23(4):972–985. - Daddi T., Nucci B., Iraldo F. (2017). Using Life Cycle Assessment (LCA) to measure the environmental benefits of industrial symbiosis in an industrial cluster of SMEs, <i>Journal of Cleaner Production</i>, Volume 147, 157–164. - Kerdlap P., Low J., Zong Loong Tan D., Yeo Z., Ramakrishna S. (2020). M3-IS-LCA: A Methodology for Multi-level Life Cycle Environmental Performance Evaluation of Industrial Symbiosis Networks, <i>Resources Conservation and Recycling</i>. - Valdivia S., Jana Gerta Backes, Traverso M., Sonnemann G., Cucurachi S., Guinée J., Schaubroeck T., Finkbeiner M., Noémie Leroy-Parmentier, Ugaya C., Peña C., Zamagni A., Inaba A., Amaral M., Berger M., Dvarionienė V., Vakhitova T., Benoît-Norris C., Prox M.,

	Foolmaun R., Goedkoop M. (2021). Principles for the application of life cycle sustainability assessment, The International Journal of Life Cycle Assessment. Volume 26, 1900–1905.
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Digital Badge Metadata Summary	
Badge Title:	EcoFootprint Assessor
Issued by:	SymbioTech Alliance
EQF Level:	5
Credit Weighting:	3 ECVET (≈ 75 learning hours)
Mode	Blended / hybrid (lectures, workshops, software labs)
Skills Tag	LCA, LCIA, ISO 14040, ISO 14044, environmental footprint, resource efficiency
Badge Description:	
	This badge certifies that the holder, trained as a SymbioTech Manager, is capable of conducting simplified life cycle assessments using openLCA. They are proficient in applying ISO 14040/14044 methodology, structuring and managing Bill of Materials (BoM) and inventory data, and interpreting results using Environmental Footprint (EF 3.1) indicators. The badge holder can communicate environmental, economic, and social impacts in a decision-oriented format and support sustainability reporting and circular economy strategies.
Key Competences Demonstrated:	
	- Describe the four ISO 14040/14044 phases of Life Cycle Assessment (LCA) goal and scope definition, life cycle inventory, impact assessment, and interpretation and explain their role in evaluating environmental sustainability. - Use openLCA software to model product systems by inputting Bill of Materials (BoM) and process data, and to calculate and visualise environmental impacts using standardised methods such as EF 3.1. - Interpret and communicate LCA results clearly through concise visual and verbal formats, and relate findings to circular economy strategies, stakeholder decisions, and sustainability improvements.
Assessment Evidence Includes:	
	- The learner's openLCA project file (.zolca or exported ZIP), containing all relevant elements of the life cycle model including BoM, LCI data, system boundaries, impact assessment setup, and documentation. - A PDF version of the 5-slide presentation, summarising the scope, modeling approach, key findings across environmental, economic, and social dimensions, and proposed sustainability improvements. - A recorded oral defense session (pitch) in which the learner explains their modeling process, justifies assumptions, and interprets results in relation to circular economy strategies. - An annotated scoring rubric completed by the evaluator, including structured assessment criteria and personalised feedback. (Optional) Peer review reflections or feedback forms if a peer feedback session was conducted.
EQAVET Alignment	
	Planning: Learning outcomes linked to EQF descriptors and ECVET standards. Implementation: Delivered via blended model with bootcamp, mentoring, and assessment.

	– Evaluation: Structured rubric applied to digital and oral outputs. – Review: Evidence archived for continuous improvement and quality assurance. – Recognition: Digital badge awarded upon successful performance across all tasks.
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Module 3: Inter-organisational Relations

EQF Level:	5
ECVET Credit:	3
Total Workload:	75 hours
Delivering Institution:	...
Certificate Issuing Authority:	SymbioTech Alliance

Module Overview

This module equips vocational learners, particularly future SymbioTech Managers, with the skills to initiate and facilitate inter-organisational partnerships for industrial symbiosis. It develops essential interpersonal, negotiation, and influence-building competencies that enable learners to identify opportunities, build trust, and guide early collaboration efforts among diverse stakeholders. The course addresses how to manage resistance to change, align partner interests, and design simple cooperation agreements, including MoUs (A Memorandum of Understanding). By the end of this module, learners will be able to lead initial stakeholder engagement, manage outreach and communication, and facilitate early-stage discussions that lay the groundwork for resource-sharing collaborations.

Learning Outcomes

Knowledge

- Understand the dynamics of industrial symbiosis partnerships, including how to identify and profile partner types (e.g. SMEs, utilities, municipalities, waste management companies).
- Grasp the principles of trust-building, stakeholder alignment, and inter-organisational collaboration.
- Recognise common sources of resistance to change and strategies for addressing them in the context of resource exchange initiatives.
- Know the basic structure and function of a Memorandum of Understanding (MoU) for outlining collaboration terms.
- Understand core principles of negotiation, persuasive communication, and lobbying within business partnerships.

Skills

- Map and document stakeholders using appropriate tools, identifying their interests, influence, and potential contributions to a symbiosis project.
- Communicate clearly and professionally in written and verbal formats, including drafting outreach emails, conducting discovery calls, and preparing for meetings.

	- Facilitate early-stage collaboration activities, such as partner outreach, site visits, and introductory discussions. - Apply basic negotiation tactics to reach shared understanding and mitigate concerns. - Draft a simple MoU covering roles, expected resource flows, risks, benefits, and basic terms of collaboration. - Demonstrate effective techniques to influence, persuade, and gain buy-in from hesitant or sceptical partners.
Responsibility and Autonomy	
	- Take ownership of outreach, meeting planning, and follow-up with external partners under the supervision of a project lead. - Demonstrate proactive engagement, anticipating possible resistance or misunderstandings and responding constructively. - Escalate complex or legal matters to higher authority but show initiative in building momentum for partnerships through communication and persistence. - Represent their organisation with professionalism and diplomacy, ensuring transparent and respectful interactions.
Learning Activities and Delivery Schedule	
Week 1 – On-site Bootcamp (Face-to-Face):	
	- Five-day interactive workshop on stakeholder engagement and partnership facilitation. - Activities include: - Stakeholder mapping exercises using real or simulated industrial ecosystems. - Role-play scenarios to simulate partner outreach, resistance handling, and negotiation. - Peer-reviewed drafting of key MoU (Memorandum of Understanding) clauses (e.g. roles, expectations, dispute resolution). - Discussions on barriers to change and how to use persuasion, communication styles, and lobbying strategies to build consensus.
Weeks 2–3 – Mentored E-learning and Workplace Task:	
	- Online learning covers: - Case studies of successful symbiosis initiatives, communication breakdowns, and recovery strategies. - Micro-modules on non-verbal communication, email etiquette, and building influence across teams. - Learners select a potential partner (real or hypothetical) related to their workplace and complete: - A partner profile, including interest alignment and potential exchange. - A communication plan including an introductory email or script for a discovery call. - Mentors review and give feedback on the proposed plan and communication samples.
Week 4 – Final Assessment Clinic:	
	- Learners submit: - A partner engagement plan, outlining a realistic collaboration timeline, mutual benefits, and draft MoU terms. - A video-recorded role-play, where the learner simulates a call or meeting with a partner addressing concerns, pitching a symbiosis idea, and negotiating initial agreement points.

	– During a short oral Q&A, the learner reflects on trust-building approaches and explains how they managed resistance in their scenario.
Key Tools and Resources	
	– “Partnership and security risk management” – PDF used to support trust-building techniques and ethical partnership development. – Stakeholder Mapping Templates – Visual tools and worksheets to categorise actors by influence, interest, and relevance. – MoU Template Document – Editable outline including key components of a basic agreement. – Communication and Influence Toolkit – Includes tips on tone, timing, framing techniques, and persuasion principles adapted from business negotiation best practices. – Change Resistance Scenario Deck – A set of cards with typical objections and resistance cases used during role-play training.
Summative Assessment	
Assessment Components:	
1.	Partner Engagement Plan: description of targeted stakeholders, engagement strategy, expected benefits, timeline, and draft MoU terms.
2.	Role-Play Simulation Video of learner performing a simulated meeting or call with a hesitant partner. Must demonstrate persuasion, listening, and appropriate negotiation strategies.
3.	Oral Debrief/Q&A: live or recorded session to explain approach, reflect on trust-building and how resistance was addressed
Evaluation Methodology:	
	– Communication clarity and confidence – Relevance and feasibility of partner engagement plan – Appropriateness of negotiation/persuasion strategies – Application of trust-building principles
Assessment Evidence Includes:	
	– Partner engagement plan (document) – MoU (Memorandum of Understanding) draft excerpt (optional) – Role-play video file – Debrief audio/video – Scored evaluation rubric (PDF)
Bibliography	
	– Alosi A., Katana K., Annunziata E., Mirata M., Rizzi F., Frey M. (2025). Management of paradoxical tensions in industrial symbiosis: An exploration at the inter-organizational level, <i>Industry Ecology</i>, 29(2), 602–616. – Cecchin A., Salomone R., Deutz P., Raggi A., Cutaia L. (2020). Industrial Symbiosis for the Circular Economy. Operational Experiences, Best Practices and Obstacles to a Collaborative Business Approach.

	– Saha P. (2020). The process of building inter organizational collaboration for Industrial Symbiosis Two cases from Finland: ECO3 & Envitech, Master of Science Thesis Tampere University Degree Programme in Industrial Engineering and Management. – Shi L. (2019). Industrial Symbiosis: Context and Relevance to the Sustainable Development Goals (SDGs), Responsible consumption and production, 1–12. – Walls J., Pa R. (2015). Organizational Perspectives of Industrial Symbiosis, Organization & Environment, Volume 28, Issue 1.
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Digital Badge Metadata Summary	
Badge Title:	Symbiosis Facilitator
Issued by:	SymbioTech Alliance
EQF Level:	5
Credit Weighting:	3 ECVET (≈ 75 learning hours)
Mode	Blended / hybrid (interactive seminars, stakeholder simulations, group projects)
Skills Tag	stakeholder mapping, trust-building, negotiation, conflict resolution, partnership governance
Badge Description:	
	This badge certifies that the holder has the competencies to initiate and facilitate early-stage partnerships in industrial symbiosis. They can build trust, engage stakeholders, and manage communication and negotiation processes required to launch collaborative circular initiatives.
Key Competences Demonstrated:	
	– Identify and profile potential partners with aligned material/resource flows – Use structured communication techniques to build trust and handle resistance – Draft fundamental terms of a simple MoU (Memorandum of Understanding). – Navigate early-stage partner engagement with professionalism, empathy, and strategic influence.
Assessment Evidence Includes:	
	– Partner engagement plan (document) – MoU draft excerpt (optional) – Role-play video file – Debrief audio/video – Scored evaluation rubric (PDF)
EQAVET Alignment	
	– Planning: Learning outcomes linked to EQF descriptors and ECVET standards. – Implementation: Delivered via blended model with boot camp, mentoring, and assessment. – Evaluation: Structured rubric applied to digital and oral outputs. – Review: Evidence archived for continuous improvement and quality assurance. – Recognition: Digital badge awarded upon successful performance across all tasks.

Module 4: AI & Machine Learning Basics (Data Insights Assistant)	
EQF Level:	5
ECVET Credit:	3
Total Workload:	75 hours
Delivering Institution:	...
Certificate Issuing Authority:	SymbioTech Alliance
Module Overview	
This module introduces vocational learners particularly aspiring SymbioTech Managers—to core concepts in data analytics, forecasting, and machine learning (ML) with applications in industrial settings. Designed for those working in production, operations, or quality roles, the module shows how sensor-derived data can be turned into insights using Microsoft Power BI and basic forecasting models such as Prophet. Learners will clean, visualise, and analyse time-series datasets, generate predictive insights, and communicate trends effectively using dashboards. The course includes hands-on labs, mentored e-learning, and a practical workplace task. Ethical data handling, transparency, and model limitations are also addressed.	
Learning Outcomes	
Knowledge	
	- Understand the basic concepts of data analytics and machine learning in an industrial context, including definitions of sensor data, structured (“tidy”) data, and data integrity. - Comprehend the function of simple forecasting models (e.g. Prophet (a tool for forecasting time series data with seasonality, trends, and special events)), and the use of metrics like MAPE (Mean Absolute Percentage Error) to assess prediction accuracy.
Skills	
	- Use Microsoft Power BI to import and clean time-series data (e.g. from CSV files), apply visualisation techniques, and create interactive dashboards. - Apply a basic forecasting model using an automated forecasting tool (e.g. Prophet*), interpret prediction outputs, and evaluate forecast performance using accuracy indicators. - Communicate insights clearly via dashboards and brief reports or recordings, highlighting patterns, anomalies, and predicted trends.
* Prophet is a tool for forecasting time series data with seasonality, trends, and special events	
Responsibility and Autonomy	
	- Handle operational data responsibly, respecting data protection and integrity guidelines. - Work under supervision to validate analytical methods, check for anomalies, and flag questionable results for review. - Share findings with peers or supervisors in a clear, accessible manner, acknowledging uncertainty and limitations in the analysis.

Learning Activities and Delivery Schedule	
Week 1 – On-site Bootcamp (Face-to-Face):	
	– Five-day practical boot camp held in the computer lab. – Learners are introduced to the principles of “tidy data” and best practices in data handling. – Hands-on exercises include importing sensor data into Power BI**, cleaning and formatting datasets, and creating basic visuals (e.g. line charts, bar graphs). – Learners explore a basic time-series forecasting exercise using Prophet, and discuss prediction metrics such as MAPE.
**Microsoft Power BI – A leading BI tool for building visual dashboards, exploring time-series data, and performing simple analyses and forecasts.	
Weeks 2–3 – Mentored E-learning and Workplace Task:	
	– Online learning units cover foundational topics in AI/ML relevant to industrial settings (e.g. predictive maintenance, demand forecasting, and anomaly detection). – Learners complete interactive activities via Moodle and short quizzes to consolidate their understanding of data presentation and simple ML models. – Workplace task: Learners use either a provided dataset or real operational data (where possible) to create a Power BI report that includes meaningful visualisations and a basic forecast. – Weekly mentoring check-ins provide personalised feedback on data interpretation and dashboard clarity.
Week 4 – Final Assessment Clinic:	
	– Learners submit their final Power BI project file and a 3-minute screencast (video recording) explaining their dashboard, insights, and forecast. – During the assessment clinic, each learner participates in a brief oral Q&A, where they are asked to explain their approach, interpret the forecast, and demonstrate awareness of potential errors or limitations in the analysis.
Key Tools and Resources	
	– Microsoft Power BI – A leading BI tool for building visual dashboards, exploring time-series data, and performing simple analyses and forecasts. – Prophet Forecasting Library – An open-source time-series forecasting model developed by Meta; used for generating simple predictions with confidence intervals. – “Power BI for Shopfloor Workers” e-Book (2024) – A practical guide for beginners, explaining how to build and share Power BI dashboards; includes a “10 Common DAX Patterns” cheat sheet for basic calculations.
Summative Assessment	
Assessment Components:	
1.	Power BI Report Submission (.pbix file): A complete dashboard built using cleaned sensor data, with multiple visualisations and at least one forecast element.
2.	Screencast Video (3 minutes): A recorded walkthrough of the dashboard, highlighting key trends, prediction insights, and any issues or anomalies.
3.	Oral Q&A: A short interview with the assessors to verify understanding of data choices, forecasting interpretation, and communication of results.
Evaluation Methodology:	
	– Performance is evaluated using a 20-point rubric, including criteria such as data accuracy, quality of visualisations, logical interpretation of forecasts, and clarity of communication.

	– To receive the badge and credit, learners must demonstrate a minimum standard of competence across all three components.
Assessment Evidence Includes:	
	– Power BI (.pbix) file with all charts, filters, and forecast settings. – Screencast video file or hosted link (e.g. YouTube, Loom). – Oral Q&A session (recorded). – Completed scoring rubric with feedback (PDF).
Bibliography	
	– Lütje A., Willenbacher M., Engelmann M., Kunisch C., Wohlgemuth V. (2019). Exploring the System Dynamics of Industrial Symbiosis (IS) with Machine Learning (ML) Techniques—A Framework for a Hybrid-Approach, Conference paper, 117–130. – Davis C., Graham A. (2022). Machine learning-assisted industrial symbiosis Testing the ability of word vectors to estimate similarity for material substitutions, Volume 26, Issue1, Data Innovation in Industrial Ecology, 27-43. – Cutaia L., Luciano A., Barberio G., Sbaffoni S., Mancuso E., Scagliarino C., & La Monica M. (2015). The experience of the first industrial symbiosis platform in Italy. Environmental Engineering and Management Journal, 14(7), 1521-1533. – Matino I., Dettori S., Castellano A. (2021). Machine learning based models for supporting optimal exploitation of process off-gases in integrated steelworks, in: Advances in Intelligent Systems and Computing, 1338, Springer, Cham, 2021.

Digital Badge Metadata Summary	
Badge Title:	Data Insights Assistant
Issued by:	SymbioTech Alliance
EQF Level:	5
Credit Weighting:	3 ECVET (≈ 75 learning hours)
Mode	Blended / hybrid (labs, simulations, projects, peer collaboration)
Skills Tag	AI, machine learning, predictive analytics, material flow optimization, supply chain intelligence
Badge Description:	
	This badge certifies that the learner can transform raw sensor data into visual insights using Power BI, apply basic forecasting methods to predict future trends, and communicate results in a clear and understandable manner for informed operational decision-making.
Key Competences Demonstrated:	
	– Prepare and clean time-series sensor data for analysis (following tidy data principles). – Build interactive dashboards in Power BI that reflect real-world production data trends. – Use automated tools (e.g. Prophet) to forecast future outcomes and evaluate prediction quality (e.g. using MAPE).

Assessment Evidence Includes:	
	– Power BI (.pbix) file with all charts, filters, and forecast settings. – Screencast video file or hosted link (e.g. YouTube, Loom). – Oral Q&A session (recorded). – Completed scoring rubric with feedback (PDF).
EQAVET Alignment	
	– Planning: Learning outcomes linked to EQF descriptors and ECVET standards. – Implementation: Delivered via blended model with boot camp, mentoring, and assessment. – Evaluation: Structured rubric applied to digital and oral outputs. – Review: Evidence archived for continuous improvement and quality assurance. – Recognition: Digital badge awarded upon successful performance across all tasks.
Module 5: Blockchain Basics (Traceability Assistant)	
EQF Level:	5
ECVET Credit:	3
Total Workload:	75 hours
Delivering Institution:	...
Certificate Issuing Authority:	SymbioTech Alliance
Module Overview	
This module equips SymbioTech Managers with practical and conceptual knowledge of blockchain technology, focusing on its application in supply chain traceability and secure industrial recordkeeping. Participants learn to use a permissioned blockchain environment (Hyperledger Composer) to record, retrieve, and verify batch-level data securely and transparently. The module introduces the fundamentals of blockchain architecture (blocks, hashes, and smart contracts) and develops skills in blockchain usage to support sustainability and traceability. The delivery blends instructor-led labs, e-learning, and workplace tasks, tailored to those in manufacturing, logistics, or quality assurance roles.	
Learning Outcomes	
Knowledge	
	– Understand the core structure and function of blockchain networks, including differences between public and private (permissioned) blockchains. – Comprehend the purpose of distributed ledgers in recording and verifying transactions, particularly in industrial contexts involving batch traceability, documentation, and auditability.
Skills	
	– Use Hyperledger Composer to enter new records (batches) into a permissioned ledger, edit metadata fields, attach supporting documents (e.g. PDFs), and verify record addition.

	– Generate and link QR codes to ledger entries to enable easy retrieval and demonstration of traceability information. – Navigate command-line interfaces or low-code environments to deploy and test simple blockchain business networks.
Responsibility and Autonomy	
	– Adhere to ledger governance and data management protocols, ensuring data quality, proper version control, and record consistency. – Act responsibly when handling sensitive or confidential batch data, and verify ledger entries independently before submitting or sharing them. – Seek appropriate approval for modifications and demonstrate professional integrity in distributed recordkeeping.
Learning Activities and Delivery Schedule	
Week 1 – On-site Bootcamp (Face-to-Face):	
	– Five-day intensive training on blockchain fundamentals, delivered through a mix of short lectures, demos, and lab-based exercises. – Learners work in a controlled sandboxed environment (e.g. local Hyperledger Composer* deployment on Raspberry Pi** clusters or college servers). – Practical exercises include: adding batch records to the blockchain, generating QR codes, exploring how transaction hashes are created, and understanding data immutability.
*Hyperledger Composer is an open-source development framework designed to simplify the process of building blockchain applications on top of Hyperledger Fabric. ** Raspberry Pi is a series of small, affordable single-board computers designed for various applications, from education to industrial automation.	
Weeks 2–3 – Mentored E-learning and Workplace Task:	
	– Online modules delivered through Moodle explore real-world applications of blockchain in sustainable industries and materials traceability (e.g. recycled plastics, biofuels, and energy certificates). – Interactive tutorials and simulations guide learners through recording more complex entries and attaching documents to ledger blocks. – Where applicable, learners apply these skills in their workplace by recording a real or mock batch process onto the training ledger and testing QR code retrieval. Weekly mentoring sessions support troubleshooting and accuracy checking.
Week 4 – Final Assessment Clinic:	
	– Each learner completes a formal ledger entry task: adding a new batch record to the training blockchain environment, including structured metadata and a supporting file (e.g. delivery note). – They generate a QR code linked to the record and demonstrate retrieval. – Learners submit evidence including a screenshot of the ledger entry (with batch details and timestamp), a log extract or transaction ID hash, and the functioning QR code. – A brief oral examination follows, testing understanding of blockchain basics and the workflow executed.
Key Tools and Resources	
	– Hyperledger Composer – A low-code blockchain framework for modeling assets, participants, and transactions in permissioned networks.

	– Blockchain CLI Cheat Sheet – A reference guide for executing common ledger operations (e.g. deploying networks, retrieving records) using the Hyperledger Composer command-line interface. – “Blockchain Basics with Hyperledger Composer” (Linux Foundation, 2024) – Core learning resource with conceptual explanations and technical tutorials tailored for beginners.
Summative Assessment	
Assessment Components:	
4.	Practical Ledger Task: The learner must create and submit a complete blockchain ledger entry including: – Metadata fields (e.g. batch ID, date, location). – An attached document (PDF or similar). – A functioning QR code that links to the ledger record.
5.	Evidence Submission: – Screenshot of the ledger entry interface with visible metadata and timestamp. – Extract from the transaction log or unique hash identifier. – Working QR code and short explanation of its use.
6.	Oral Examination: – Learners explain the process they followed, justify their data input, and answer targeted questions on blockchain architecture, permissioned networks, and the practical implications of traceability.
Evaluation Methodology:	
	– A 20-point rubric is used to assess the task, covering technical accuracy, record completeness, QR functionality, and conceptual understanding during the oral component. – Learners must meet minimum thresholds in each area to be awarded the badge and full credit.
Assessment Evidence Includes:	
	– Ledger entry metadata screenshot. – Log extract or hash string (e.g. 0x3f9...). – QR code image or link. – Oral Q&A recording. – Scoring rubric with assessor feedback (PDF).
Bibliography	
	– Bahga, Arshdeep, and Vijay K. Madiseti. (2016). Blockchain platform for industrial internet of things. <i>Journal of Software Engineering and Applications</i> 9.10, 533–546. – Silvestri L., Forcina A., Introna V., Santolamazza A., Cesarotti, V. (2020). Maintenance transformation through Industry 4.0 technologies: A systematic literature review. <i>Computers in industry</i>, 123, 103335. – Ventura V., La Monica M., Bortolini M., Cutaia L. & Mora C. (2024). Blockchain and industrial symbiosis: a preliminary two-step framework to green circular supply chains, Volume 22, pages 17–30. – Wang Q., Zhu X., Ni Y., Gu L., Zhu H. (2020). Blockchain for the IoT and industrial IoT: A review. <i>Internet of Things</i> 10, 100081.

Digital Badge Metadata Summary	
Badge Title:	Traceability Assistant
Issued by:	SymbioTech Alliance
EQF Level:	5
Credit Weighting:	3 ECVET ($\approx$ 75 learning hours)
Mode	Blended / hybrid
Skills Tag	traceability, smart contracts, digital product passports
Badge Description:	
	This badge confirms that the learner can create and manage traceability records using blockchain technology in a permissioned environment. They understand how to input batch data, attach relevant documents, generate and use QR codes for verification, and maintain ledger integrity.
Key Competences Demonstrated:	
	– Explain the difference between public and private blockchain architectures. – Record and update traceable entries in a shared ledger using Hyperledger Composer. – Create QR codes that link to verifiable ledger records and demonstrate the ability to retrieve documents.
Assessment Evidence Includes:	
	– Ledger entry metadata screenshot. – Log extract or hash string (e.g. 0x3f9...). – QR code image or link. – Oral Q&A recording. – Scoring rubric with assessor feedback (PDF).
EQAVET Alignment	
	– Planning: Aligned with EQF and ECVET learning outcomes. – Implementation: Delivered via blended learning (boot camp + mentoring). – Evaluation: Rubric-based assessment of digital and oral evidence. – Review: Archived evidence supports continuous QA. – Recognition: A digital badge is awarded upon successful completion.

Module 6: Energy Efficiency Operations (EnergyLoop Assistant)	
EQF Level:	5
ECVET Credit:	3
Total Workload:	75 hours
Delivering Institution:	...
Certificate Issuing Authority:	SymbioTech Alliance
Module Overview	
This module provides SymbioTech Managers with hands-on and applied knowledge of environmental management systems (EMS) in industrial and manufacturing settings.	

Focusing on ISO 14001 and EMAS frameworks, learners will acquire the skills to implement, audit, and maintain EMS practices that align with circular economy principles and industrial symbiosis. Participants will explore EMS components such as policy development, impact assessment, compliance auditing, and continuous improvement. The blended delivery format combines workshops, simulations, and workplace-based implementation tasks to develop both operational and compliance capabilities.

Learning Outcomes

Knowledge

- Understand the core principles of energy efficiency and energy waste, including concepts such as waste heat recovery and system optimisation.
- Become familiar with Pinch Analysis fundamentals (hot/cold streams, pinch point) as a method for improving thermal energy integration.
- Recognise the key components of ISO 50001 standards that guide energy management systems in industrial settings

Skills

- Perform simple energy-related measurements (temperature, power readings) on industrial machinery using basic tools.
- Utilise devices such as thermal imaging cameras to identify heat loss zones and collect supporting data.
- Apply checklists and introductory Pinch Analysis tools to assess energy use patterns, locate inefficiencies, and propose appropriate technical adjustments (e.g. insulation, recovery systems, process improvements).
- Document findings clearly and structure recommendations in a corrective action plan.

Responsibility and Autonomy

- Work safely and attentively in industrial environments, adhering to established operational protocols, particularly when handling hot surfaces, working with electrical systems, or operating moving equipment.
- Take initiative in identifying energy loss points and drafting recommendations, while recognising the importance of deferring implementation decisions to supervisors or engineers.
- Maintain clear and systematic records of energy observations, ensuring traceability and reliability for follow-up or auditing purposes.

Learning Activities and Delivery Schedule

Week 1 – On-site Bootcamp (Face-to-Face):

- Five-day hands-on workshop introducing energy efficiency fundamentals, with a focus on practical applications.
- Learners explore real examples of energy savings in industry and simulate simplified Pinch Analysis exercises.
- Using thermal cameras and sensors, learners practice identifying heat losses from selected equipment and record temperature differentials.
- An introduction to energy flow mapping and the interpretation of energy data is included, along with a review of ISO 50001 principles.

Weeks 2–3 – Mentored E-learning and Workplace Task:	
	- Online modules cover energy management concepts, including energy balances, waste reduction techniques (e.g. process heat reuse), and calculations of energy usage in operational contexts. - Learners complete self-paced quizzes and guided tasks using real or simulated case studies. - Each participant conducts a mini energy audit, either in their actual workplace or using a virtual scenario provided by the instructor. - Tasks include selecting a process or machine, collecting data (such as temperatures and operating times), and identifying energy loss points using an audit checklist or a simple pinch analysis chart. - Mentors provide weekly check-ins and review interim data for consistency and accuracy.
Week 4 – Final Assessment Clinic:	
	- Learners finalise and submit: - An energy-waste map or diagram illustrating where energy losses occur in the process. - A corrective action plan listing targeted improvement measures (e.g. insulation, process optimisation, heat exchanger proposal). - During the assessment session, learners present their outputs and participate in a brief oral question-and-answer session, defending their analysis and demonstrating an understanding of energy management concepts.
Key Tools and Resources	
	Thermal Imaging Camera & Sensors – Used during bootcamp and project work to detect and document heat losses in equipment or processes. - Ian C. Kemp, Jeng Shiun Lim (2020). Pinch Analysis for Energy and Carbon Footprint Reduction. Energy Efficiency Checklists – Based on ISO 50001, these tools help learners systematically inspect processes and identify common causes of energy inefficiency (e.g. idle machinery, lack of insulation).
Summative Assessment	
Assessment Components:	
1.	Energy Audit Deliverables: Energy-waste map (e.g. diagram, table, or annotated thermal image) showing zones of energy loss. Corrective Action Plan outlining suggested improvements with justification (e.g. thermal insulation, heat exchanger, process shutdowns).
2.	Oral Defense (Q&A): Learners explain their energy findings, describe the tools used, and respond to questions about energy efficiency strategies and auditing methods.
3.	Evidence Submission: - Complete mini audit package including observation logs, diagrams, and action sheets. - Evaluation against a 20-point rubric, with feedback provided on technical accuracy, safety awareness, and quality of recommendations.
Evaluation Methodology:	

	This module employs a blended and practice-oriented teaching approach to foster both conceptual understanding and practical skills. The following methods will be used:
	– Interactive Lectures (present key concepts on renewable energy technologies, energy efficiency strategies, and symbiotic energy management models within industrial networks; incorporate the latest research findings and case studies). – Technical Workshops and Labs (hands-on sessions using energy simulation software, optimisation tools, and real-world data to analyse energy flows and identify efficiency improvements in industrial clusters). – Case Study Analysis (explore successful implementations of energy symbiosis projects, focusing on renewable integration, demand-side management, and cost reduction strategies). – Group Problem-Solving Sessions (collaborative exercises where students develop and propose energy management solutions tailored to specific industrial contexts). – Guest Lectures and Industry Talks (sessions led by experts from the energy sector, highlighting cutting-edge technologies, policies, and market trends related to sustainable energy use). – Field Visits/Virtual Tours (optional visits or virtual tours of industrial sites practising energy symbiosis to observe technology applications and management practices firsthand).
Assessment Evidence Includes:	
	– Ledger entry metadata screenshot. – Log extract or hash string (e.g. 0x3f9...). – QR code image or link. – Oral Q&A recording. – Scoring rubric with assessor feedback (PDF).
Bibliography	
	– Branca T., Colla V., Fornai B., Petrucciani A., Pistelli M., Faraci E., Cirilli F., Schröder A. (2022). Current state of Industrial Symbiosis and Energy Efficiency in the European energy intensive sectors, <i>Matériaux & Techniques</i> 109 (5-6). – Cervo H., Ferrasse J.-H., Descales B. (2020). Blueprint: A methodology facilitating data exchanges to enhance the detection of industrial symbiosis opportunities–Application to a refinery, <i>Chem. Eng. Sci.</i> 211. – Fraccascia L., Yazdanpanah V., van Capelleveen G. & Yazan D.M. (2020). Energy-based industrial symbiosis: a literature review for circular energy transition, <i>Volume 23</i>, 4791–4825. – He K., Wang L. (2017). A review of energy use and energy-efficient technologies for the iron and steel industry, <i>Renew. Sustain. Energy Rev.</i> 70, 1022-1039. – Malinauskaite J., Jouhara H., Ahmad L., Milani M., Montorsi L., Venturelli M. (2020). Optimizing the Efficiency of Resource Exchange in Industrial Symbiosis (IS). <i>Responsible Consumption and Production</i>, 1–12, <i>Energy</i>, Volume 172, 255–269. – Malinauskaite J., Jouhara H., Ahmad L. (2019). Energy efficiency in industry: EU and national policies in Italy and the UK, <i>Energy</i> 172, 255–269.

Digital Badge Metadata Summary	
Badge Title:	EnergyLoop Assistant
Issued by:	SymbioTech Alliance
EQF Level:	5
Credit Weighting:	3 ECVET (≈ 75 learning hours)

Mode	Blended / hybrid
Skills Tag	Energy mapping, industrial symbiosis, simulation, energy policy
Badge Description:	
	This badge certifies that the holder is able to evaluate simple industrial processes for energy inefficiencies using basic diagnostic tools. They can identify energy loss (e.g. waste heat), apply standard audit techniques to analyze the problem, and recommend targeted efficiency improvements in line with ISO 50001 guidance.
Key Competences Demonstrated:	
	– Use thermal cameras or basic sensors to measure energy losses. – Apply simple Pinch Analysis or checklist methods to locate inefficiencies in a process. – Develop and justify corrective measures for improved energy performance (e.g. insulation, heat recovery).
Assessment Evidence Includes:	
	– Ledger entry metadata screenshot. – Log extract or hash string (e.g. 0x3f9...). – QR code image or link. – Oral Q&A recording. – Scoring rubric with assessor feedback (PDF).
EQAVET Alignment	
	• Planning: Learning outcomes linked to EQF descriptors and ECVET standards. • Implementation: Delivered via blended model with bootcamp, mentoring, and assessment. • Evaluation: Structured rubric applied to digital and oral outputs. • Review: Evidence archived for continuous improvement and quality assurance. • Recognition: Digital badge awarded upon successful performance across all tasks.

Module 7: EMS Basics (EMS Implementer)

EQF Level:	5
ECVET Credit:	3
Total Workload:	75 hours
Delivering Institution:	...
Certificate Issuing Authority:	SymbioTech Alliance

Module Overview

This module trains SymbioTech Managers in the fundamentals of energy management and resource efficiency. It focuses on identifying and implementing low-cost and high-impact improvements in energy and material use across industrial operations. Learners will analyse energy and utility data, map consumption flows, and evaluate the impact of interventions such as equipment upgrades, process redesigns, and behavioural changes.

The blended course combines expert-led instruction, energy auditing simulations, and real workplace optimisation tasks, equipping participants with tools to reduce costs, emissions, and waste while boosting operational efficiency.	
Learning Outcomes	
Knowledge	
	– Understand the structure and fundamental requirements of ISO 14001, including the PDCA model* and its role in continuous environmental improvement. – Identify the typical environmental aspects and impacts associated with industrial or service processes. – Gain awareness of compliance mechanisms and internal audit processes, including the purpose and content of aspect-impact registers and Standard Operating Procedure (SOP)**.
* PDCA model, also known as the Plan-Do-Check-Act cycle, is a systematic approach for continuous improvement and problem-solving in various processes and industries. ** SOP Standard Operating Procedure (is a document consisting of step-by-step information on how to execute a task.	
Skills	
	– Conduct a basic environmental aspect-impact assessment using a structured matrix or register. – Evaluate and rank the significance of environmental impacts and suggest mitigation or control measures. – Draft a clear and concise Standard Operating Procedure (SOP) that addresses a specific environmental aspect (e.g. waste handling, emergency response). – Carry out basic internal EMS checks or audit sampling to assess procedural compliance.
Responsibility and Autonomy	
	– Contribute to EMS implementation and monitoring activities under the supervision of a designated authority. – Maintain accurate records such as logs, registers, and SOPs as part of routine EMS duties. – Act proactively by identifying potential environmental risks and improvement opportunities, and communicating them to the appropriate personnel. – Follow all organisational and legal procedures related to environmental protection and EMS maintenance.
Learning Activities and Delivery Schedule	
Week 1 – On-site Bootcamp (Face-to-Face):	
	– Intensive five-day training on the structure of ISO 14001 and EMS tools. – Learners review key ISO clauses and perform a practical aspect-impact assessment using a mock case scenario. – Learners practice using the aspect-impact matrix and explore the PDCA cycle* in group exercises. – Participants draft components of an SOP (e.g. policy statement, procedures) and receive peer feedback to improve clarity and structure.
*The PDCA cycle, also known as the Plan-Do-Check-Act cycle, is a four-step iterative process used for continuous improvement in various fields, including business, education, and healthcare.	
Weeks 2–3 – Mentored E-learning and Workplace Task:	

	- Online modules explain the steps for implementing EMS, including maintaining documentation, monitoring compliance, and preparing for audits. - Learners select either a real workplace activity or a provided case study to perform an aspect-impact assessment. - Using a template, they log at least one significant environmental aspect and draft an associated SOP addressing mitigation or control measures. - Mentors provide structured feedback during progress reviews and guide learners through the interpretation of ISO requirements.
Week 4 – Final Assessment Clinic:	
	- Learners submit a package containing: Completed aspect-impact matrix identifying and evaluating one significant environmental aspect. Draft SOP document addressing the control or improvement of the identified impact. - During assessment, learners explain their entries and defend their choices in a short oral Q&A or presentation. - Deliverables are evaluated using a 20-point rubric, assessing completeness, relevance, and alignment with ISO 14001 guidelines.
Key Tools and Resources	
	- Guide to the requirements of ISO 14001.-A plain English guide to the ISO 14001:2015 Environment Management System gsc-co.com Author: Karam Malkawi, or Pocket Guide to the Basics What every employee needs to know about the iso 14001:2015. A Pocket Guide to the Basics. Harold J. Steudel, P.E., Terry Mann of Steudel and Mann. Aspect-Impact Matrix Template – A structured spreadsheet or document for recording environmental aspects, associated impacts, significance, and existing controls. SOP (Standard Operating Procedures) Writing Guidelines – Instructional materials and templates for drafting effective procedures (including scope, responsibilities, steps, and emergency instructions).
Summative Assessment	
Assessment Components:	
1.	EMS Documentation Deliverables: Aspect-Impact Matrix identifying a significant environmental aspect and related evaluation. Draft SOP describing a procedure to manage or mitigate the impact (e.g. handling waste, preventing spills).
2.	Oral Q&A / Presentation: Learners explain and justify the environmental significance of their chosen aspect and how the SOP addresses it. Demonstrate understanding of ISO 14001 and EMS roles.
Evaluation Methodology:	
	- Clarity, completeness, and accuracy of documentation - Correct application of EMS concepts and tools - Ability to explain rationale during Q&A

Assessment Evidence Includes:	
	– Matrix and SOP files (PDF or editable format) – Rubric with feedback – Recorded Q&A or summary presentation
Bibliography	
	- Brady J., Lunn R., Ebbage A. (2024). Environmental Management in Organizations: The IEMA Handbook. - Frey M. (2021), Environmental Management System and SMEs: EU Experience, Barriers and Perspectives, Journal: Environmental Management. - Joy-Camacho W., Thornhill I. (2025). Opportunities and limitations to environmental management system (EMS) implementation in UK small and medium enterprises (SMEs) – A systematic review, Journal of Environmental Management, Volume 367, 121749. - Hassanh., Mazhar T. (2025). Environmental management systems and eco-innovation in SMEs.

Digital Badge Metadata Summary	
Badge Title:	EMS Implementer
Issued by:	SymbioTech Alliance
EQF Level:	5
Credit Weighting:	3 ECVET (≈ 75 learning hours)
Mode	Blended / hybrid
Skills Tag	ISO 14001, EMAS, audits, and EMS implementation
Assessment Evidence	EMS manual, policy, audit protocol, IER report
Badge Description:	
	This badge confirms that the learner can create and manage traceability records using blockchain technology in a permissioned environment. They understand how to input batch data, attach relevant documents, generate and use QR codes for verification, and maintain ledger integrity.
Key Competences Demonstrated:	
	– Explain the difference between public and private blockchain architectures. – Record and update traceable entries in a shared ledger using Hyperledger Composer. – Create QR codes that link to verifiable ledger records and demonstrate the ability to retrieve documents.
EQAVET Alignment	
	– Planning: Learning outcomes linked to EQF descriptors and ECVET standards. – Implementation: Delivered via blended model with boot camp, mentoring, and assessment. – Evaluation: Structured rubric applied to digital and oral outputs. – Review: Evidence archived for continuous improvement and quality assurance. – Recognition: Digital badge awarded upon successful performance across all tasks.

REFERENCES

1. Aissani L., Lacassagne A., Bahers J.B., Féon S.L. (2019). Life cycle assessment of industrial symbiosis: a critical review of relevant reference scenarios. *Journal of Industrial Ecology*, 23(4):972–985.
2. Alosi A., Katana K., Annunziata E., Mirata M., Rizzi F., Frey M. (2025). Management of paradoxical tensions in industrial symbiosis: An exploration at the inter-organizational level, *Industry Ecology*, 29(2), 602–616.
3. Baas L.W., Boons F.A. (2004). An industrial ecology project in practice: exploring the boundaries of decision-making levels in regional industrial systems. *J Clean Prod* 12(8–10):1073–1085.
4. Bahga, Arshdeep, and Vijay K. Madiseti. (2016). Blockchain platform for industrial internet of things. *Journal of Software Engineering and Applications* 9.10, 533–546.
5. Bassi F., José G. Dias. (2019). The use of circular economy practices in SMEs across the EU, *Resources, Conservation and Recycling*, Volume 146, 523–53.
6. Bocken N.M., De Pauw I., Bakker C., Van der Grinten B. (2016). Product design and business model strategies for a circular economy. *J Ind Prod Eng* 33(5):308–320.
7. Brady J., Lunn R., Ebbage A. (2024). *Environmental Management in Organizations: The IEMA Handbook*.
8. Branca T., Colla V., Fornai B., Petrucciani A., Pistelli M., Faraci E., Cirilli F., Schröder A. (2022). Current state of Industrial Symbiosis and Energy Efficiency in the European energy intensive sectors, *Matériaux & Techniques* 109 (5-6).
9. Cecchin A., Salomone R., Deutz P., Raggi A., Cutaia L. (2020). Industrial Symbiosis for the Circular Economy. Operational Experiences, Best Practices and Obstacles to a Collaborative Business Approach.
10. Cervo H., Ferrasse J.-H., Descales B. (2020). Blueprint: A methodology facilitating data exchanges to enhance the detection of industrial symbiosis opportunities—Application to a refinery, *Chem. Eng. Sci.* 211.
11. Chowdhury S., Dey P.K., Rodríguez-Espíndola O., Parkes G., Anh Tuyet N.T., Long D.D., Phuong Ha T. (2022). Impact of Organisational Factors on the Circular Economy Practices and Sustainable Performance of Small and Medium-sized Enterprises in Vietnam. *Journal of Business Research*, Volume 147, 362–378.
12. Cutaia L., Luciano A., Barberio G., Sbaffoni S., Mancuso E., Scagliarino C., & La Monica M. (2015). The experience of the first industrial symbiosis platform in Italy. *Environmental Engineering and Management Journal*, 14(7), 1521–1533.

13. Daddi T., Nucci B., Iraldo F. (2017). Using Life Cycle Assessment (LCA) to measure the environmental benefits of industrial symbiosis in an industrial cluster of SMEs, *Journal of Cleaner Production*, Volume 147, 157–164.
14. Davis C., Graham A. (2022). Machine learning-assisted industrial symbiosis Testing the ability of word vectors to estimate similarity for material substitutions, Volume 26, Issue 1, *Data Innovation in Industrial Ecology*, 27–43.
15. Domenech T., Bleischwitz R., Doranova A., Panayotopoulos D., Roman L. (2019). Mapping industrial symbiosis development in Europe_ typologies of networks, characteristics, performance and contribution to the circular economy. *Resour Conserv Recycl* 141:76–98.
16. Fraccascia L., Yazdanpanah V., van Capelleveen G. & Yazan D.M. (2020). Energy-based industrial symbiosis: a literature review for circular energy transition, Volume 23, 4791–4825.
17. Frey M. (2021), *Environmental Management System and SMEs: EU Experience, Barriers and Perspectives*, *Journal: Environmental Management*.
18. Godina R., Azevedo S., Matias J. (2020). A comprehensive review of industrial symbiosis, *Journal of Cleaner Production*, Volume 247, 119113.
19. Hassanh., Mazhar T. (2025). Environmental management systems and eco-innovation in SMEs.
20. He K., Wang L. (2017). A review of energy use and energy-efficient technologies for the iron and steel industry, *Renew. Sustain. Energy Rev.* 70, 1022–1039.
21. Joy-Camacho W., Thornhill I. (2025). Opportunities and limitations to environmental management system (EMS) implementation in UK small and medium enterprises (SMEs) – A systematic review, *Journal of Environmental Management*, Volume 367, 121749.
22. Kerdlap P., Low J., Zong Loong Tan D., Yeo Z., Ramakrishna S. (2020). M3-IS-LCA: A Methodology for Multi-level Life Cycle Environmental Performance Evaluation of Industrial Symbiosis Networks, *Resources Conservation and Recycling*.
23. Lütje A., Willenbacher M., Engelmann M., Kunisch C., Wohlgemuth V. (2019). Exploring the System Dynamics of Industrial Symbiosis (IS) with Machine Learning (ML) Techniques—A Framework for a Hybrid-Approach, *Conference paper*, 117–130.
24. Malinauskaite J., Jouhara H., Ahmad L. (2019). Energy efficiency in industry: EU and national policies in Italy and the UK, *Energy* 172, 255–269.
25. Malinauskaite J., Jouhara H., Ahmad L., Milani M., Montorsi L., Venturelli M. (2020). Optimizing the Efficiency of Resource Exchange in Industrial Symbiosis (IS). *Responsible Consumption and Production*, 1–12, *Energy*, Volume 172, 255–269.
26. Mallawaarachchi H., Sandanayake Y., Karunasena G., Liu C (2020). Unveiling the conceptual development of industrial symbiosis: Bibliometric analysis. *J Clean Prod* 120618.
27. Matino I., Dettori S., Castellano A. (2021). Machine learning based models for supporting optimal exploitation of process off-gases in integrated steelworks, in: *Advances in Intelligent Systems and Computing*, 1338, Springer, Cham, 2021.
28. Saha P. (2020). The process of building inter organizational collaboration for Industrial Symbiosis Two cases from Finland: ECO3 & Envitech, Master of Science Thesis Tampere University Degree Programme in Industrial Engineering and Management.
29. Salomone R., Cecchin A., Deutz P., Raggi A., Cutaia L. (2020). *Industrial Symbiosis for the Circular Economy: Operational Experiences, Best Practices and Obstacles to a Collaborative Business Approach*, Springer Nature.
30. Shi L. (2019). Industrial Symbiosis: Context and Relevance to the Sustainable Development Goals (SDGs), *Responsible consumption and production*, 1–12.

31. Silvestri L., Forcina A., Introna V., Santolamazza A., Cesarotti, V. (2020). Maintenance transformation through Industry 4.0 technologies: A systematic literature review. *Computers in industry*, 123, 103335.
32. Valdivia S., Jana Gerta Backes, Traverso M., Sonnemann G., Cucurachi S., Guinée J., Schaubroeck T., Finkbeiner M., Noémie Leroy-Parmentier, Ugaya C., Peña C., Zamagni A., Inaba A., Amaral M., Berger M., Dvarionienė V., Vakhitova T., Benoît-Norris C., Prox M., Foolmaun R., Goedkoop M. (2021). Principles for the application of life cycle sustainability assessment, *The International Journal of Life Cycle Assessment*. Volume 26, 1900–1905.
33. Ventura V., La Monica M., Bortolini M., Cutaia L. & Mora C. (2024). Blockchain and industrial symbiosis: a preliminary two-step framework to green circular supply chains, *Volume 22*, pages 17–30.
34. Walls J., Pa R. (2015). Organizational Perspectives of Industrial Symbiosis, *Organization & Environment*, Volume 28, Issue 1.
35. Wang Q., Zhu X., Ni Y., Gu L., Zhu H. (2020). Blockchain for the IoT and industrial IoT: A review. *Internet of Things* 10, 100081.

Internet sources

<https://symbiosecenter.dk>
<https://kedivim.uoc.gr>
<https://www.enea.it>
<https://www.nki.no/>
<https://incien.org/>
<https://circlesproject.eu/>

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Figure 5. Pearson correlation heatmap. Information Sharing vs. Benefits vs. Overall Results.

Figure 6. Pearson correlation heatmap. Actor Involvement vs. Benefits.

APPENDIX

Survey

The purpose of the survey is to collect data on the practices and importance of industrial symbiosis in the studied companies.

1.		Yes/No
2.		
	Water	Yes/No
	Energy	Yes/No
	Matter resources by-product	Yes/No
	Waste	Yes/No
3.		
	Exchange of energy, by products and secondary raw materials	Yes/No
	Joint use of utilities and firm functions	Yes/No
	Collective gathering and removal of waste materials	Yes/No
	Combining transport of goods and people	Yes/No
	More intensive use of space	Yes/No
	Public utilities with highly useful effects	Yes/No
	Joint commercial firm facilities	Yes/No
	Multimodal transport and high-quality public transport	Yes/No
	Others (please specify)	Yes/No
4.		
	Local governments/municipalities	Yes/No
	Large enterprises	Yes/No
	SME enterprises	Yes/No

	Associations	Yes/No				
	Facilitator (an actor supporting the collaboration)	Yes/No				
	Research institutions	Yes/No				
	Farmers	Yes/No				
	Others (please specify)					
		Strongly agree	I rather agree	Neither agree nor disagree	I rather disagree	Strongly disagree
5.	My company is gaining financial benefits from industrial symbiosis	5	4	3	2	1
6.	My company is gaining operational benefits from industrial symbiosis	5	4	3	2	1
7.	My company is gaining environmental benefits from industrial symbiosis	5	4	3	2	1
8.	My company is gaining social benefits from industrial symbiosis	5	4	3	2	1
9.	My company is gaining technological benefits from industrial symbiosis	5	4	3	2	1
10.	There are provisions for industrial symbiosis in the company's policy	5	4	3	2	1
11.	There are provisions for industrial symbiosis in the company's strategy	5	4	3	2	1
12.	There are provisions for industrial symbiosis in the company's priorities	5	4	3	2	1
13.	Industrial symbiosis is recognized among the employees of our company	5	4	3	2	1
14.	Industrial symbiosis is discussed among the employees of our company	5	4	3	2	1
15.	My company has access to information/production data of other geographically close industries	5	4	3	2	1
16.	My company receives long-term planning data of other industries close geographically	5	4	3	2	1
17.	My company receives operational details of other industries close geographically	5	4	3	2	1
18.	My company receives day-to-day metrics of other industries close geographically	5	4	3	2	1
19.	My company has access to external funding sources to convert its current manufacturing process to a more sustainable one	5	4	3	2	1
20.	My company has the ability to access grants to create symbiotic exchange networks.	5	4	3	2	1
21.	My company has access to digital platforms facilitating resource sharing	5	4	3	2	1
22.	My company has access to networking and industry associations facilitating resource sharing	5	4	3	2	1
23.	My company has an access to industrial symbiosis consulting	5	4	3	2	1
24.	We trust that the cooperation within the IS will yield benefits	5	4	3	2	1

	exceeding costs					
25.	We trust that, based on their competence, the partner may meet the terms of cooperation within the IS framework	5	4	3	2	1
26.	We perceive our key partners as predictable/acting based on specific principles	5	4	3	2	1
27.	We perceive our key partners as honest	5	4	3	2	1
28.	We trust that in the event of any dispute, we will find a solution together (with the partner)	5	4	3	2	1
29.	We trust that our partner is striving to achieve shared goals	5	4	3	2	1
30.	We are skeptical about cooperation with a new partner	5	4	3	2	1
31.	Despite the fact that the partner has the necessary competences, they cannot fully use them at each stage of cooperation	5	4	3	2	1
32.	Successful cooperation with a partner in the past will guarantee the same in new undertakings	5	4	3	2	1
33.	A proven partner will in each case try to meet the terms of cooperation with equal honesty	5	4	3	2	1
34.	My organization is prepared for Industrial Symbiosis	5	4	3	2	1
35.	We know the expectations of our partners with whom we work in industrial symbiosis	5	4	3	2	1
36.	Our strategy takes into account the needs of the market partners with whom we cooperate within industrial symbiosis	5	4	3	2	1
37.	Together with the partners within the IS, we can achieve more than we can on our own	5	4	3	2	1
38.	We have clearly defined goals for cooperation with partners within industrial symbiosis	5	4	3	2	1
39.	Our cooperation with partners in the industrial symbiosis is transactional in nature	5	4	3	2	1
40.	Our cooperation with partners in the industrial symbiosis is relational in nature	5	4	3	2	1
41.	Concern for the environment was our main reason for developing IS (e.g. improving natural resources efficiency, promoting use of sustainable bio-energy resources, reducing CO2 emissions)	5	4	3	2	1
42.	The search for financial benefits was the main reason for us to develop IS (e.g. sharing risk, increasing profitability, reducing cost)	5	4	3	2	1
43.	Administrative constraints (regulations) were the main reason for us to develop IS	5	4	3	2	1
44.	The enhanced research and innovation capacity was the main reason for us to develop IS	5	4	3	2	1
45.	The increase in job opportunities (employment) was the main reason for us to develop IS	5	4	3	2	1
46.	IS meets the needs of small and large companies/organizations in terms of resource efficiency and exchange of energy and by-products	5	4	3	2	1
47.	My company shares information (such as data/production metrics) with geographically close industries	☐ daily ☐ weekly ☐ monthly				

48.	My company shares information (such as data/production metrics) with geographically close industries at an operational level	☐ at an operational level ☐ at a tactical level ☐ at a strategic level
METRICS		
	Industrial sector	
	Geographical level of implementation	☐ international ☐ national ☐ regional ☐ Local ☐
	Company's size	☐ large company ☐ SME company ☐ micro company
	Form of ownership	☐ private ☐ state-owned
	Respondent's position in the company	☐ top management (e.g. CEO/COO/CTO/CIO) ☐ middle management ☐ production employee, ☐ non-production employee (finance, marketing, HR, administrative) ☐ specialist ☐ expert
	Gender	male ☐ female ☐ other/I do not want to answer
	Duration of IS cooperation in years	
	Financial results from IS	☐ none ☐ minimal ☐ not very visible ☐ significant ☐ very significant

The translated versions of D 2.2. can be found at: <https://symbiotech-project.eu/d22-sme-symbiotech-training-needs-mapping-report-and-learning-pathways-structure>