D10.1 User groups' skills gap report and training paths

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List of Acronyms

AI	Artificial Intelligence
CE	Circular Economy
DPP	Digital Product Passport
EoW	End-of-Waste Statute
EQF	European Qualifications Framework
GA	Grant Agreement
IoT	Internet of Things
IS	Industrial Symbiosis
KPI	Key Performance Indicator
LAR	Lithium Aluminosilicate Residue
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
ML	Machine Learning
SRM	Secondary Raw Materials
VET	Vocational Education and Training

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Keywords list

- European Qualifications Framework
- Industrial Symbiosis
- Skills Gaps
- Training Pathways
- Twin Transition

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1. Executive summary

Deliverable D10.1, developed under Work Package 10 (WP10) – Skills Development and Standardisation, provides the foundation for the ICARUS capacity-building strategy, aimed at supporting the green and digital transition of process industries. The document identifies user groups, maps their existing competences, and assesses skills gaps across different professional profiles, establishing a clear baseline for the design of modular and flexible training pathways.

The analysis focused on four key user profiles — blue-collar workers, engineers and managers, researchers and trainers, and policymakers — and mapped their skills against the European Qualifications Framework (EQF). The results highlight significant gaps in technical, digital, and regulatory competencies, particularly in the areas of sustainable product development, digitalisation and real-time optimisation, and compliance with environmental and circular economy regulations. These gaps represent critical barriers to the large-scale implementation of Industrial Symbiosis (IS) and Circular Economy (CE) models within the ICARUS demonstration sectors (steel, ceramics, and construction).

To address these gaps, D10.1 proposes a structured Learning Path composed of four modular Training Packs, each targeting a specific user group and aligned with their professional needs and qualification levels:

- TP1: Sustainable Operations and Efficiency in Circular Processes (EQF 3–5) – for plant operators and technicians.
- TP2: Integrated Resource Management and Process Digitalisation (EQF 6–7) – for engineers and technical managers.
- TP3: Standardisation, Certification and Systemic Innovation (EQF 7–8) – for researchers, trainers, and quality/innovation managers.
- TP4: Policy, Regulation and Communication for the Circular Economy (EQF 6–8) – for policymakers and association leaders.

Each Training Pack includes well-defined internal modules, learning outcomes, and teaching typologies (e-learning, workshops, and problem-based learning), ensuring an adaptable and practice-oriented approach. The structure supports progression from operational to strategic competencies, enabling professionals to act as agents of transformation in industrial ecosystems.

The outcomes of D10.1 establish the strategic and pedagogical framework that will guide the next steps of WP10. These include the development of detailed training materials, implementation of pilot sessions in the three demonstration cases, integration of evaluation feedback, and contribution to standardisation through the ICARUS Standardisation Watch/Observatory. Ultimately, the deliverable contributes to the long-term goal of creating a skilled, adaptive, and innovation-oriented workforce capable of advancing industrial upcycling and sustainability across Europe.

1.1. Purpose of this deliverable

Deliverable D10.1 aims to identify, characterise, and analyse the user groups that will benefit from and contribute to the ICARUS project. It also aims to design learning paths and training structures tailored to their current and future skills needs.

This deliverable forms the basis for the skills development and standardisation activities under Work Package 10 (WP10), which aims to support the twin green and digital transition in process industries through capacity building, education, and vocational training.

1.1.1. Specific objectives

Identification and Characterisation of User Groups

- Define and describe the different user groups relevant to ICARUS — including industrial operators, engineers, researchers, policymakers, trainers, and the general public.
- Classify these groups according to their industrial sector, role in the value chain, professional profile, qualification level (EQF), and type of activity (blue/White-Collar).

Assessment of Skills Gaps

- Assess the current competences in comparison with those required for each user group, within the context of ICARUS technologies and processes (upcycling, resource efficiency, carbon reduction, circular economy).
- Identify new and emerging skills necessary for supporting process industries' green and digital transition.

Design of Learning Paths

- Develop modular learning paths aligned with the needs of each user group and in accordance with the European Qualifications Framework (EQF).
- Define learning objectives, outcomes, and competencies to guide subsequent training activities.

Definition of Training Packs

- Structure a set of training packs, composed of smaller learning modules and resources, tailored to the different competence levels and professional profiles.
- Each training pack will serve as a building block for Task 10.2, which will focus on developing and implementing training materials and tools.

1.1.2. Expected results

Deliverable D10.1 will provide:

- A comprehensive mapping of ICARUS user and stakeholder groups, covering industrial, academic and political domains.
- A detailed analysis of skills gaps related to adopting ICARUS technologies.
- A set of learning paths and structured training packages, adapted to each group of users.
- A methodological framework to guide future training, certification and standardisation actions within the scope of WP10.

1.1.3. Role within the project

- WP10 Leader: ISQ
- Partners involved: All consortium partners (industry, academia, clusters, political authorities).
- Execution period: M19–M24 (delivery scheduled in M24).
- Dependencies: Builds on results from stakeholder mapping and demonstration cases.

1.1.4. In summary

Deliverable D10.1 constitutes the strategic link between ICARUS's technical results and the capacity-building and standardisation actions necessary for its large-scale adoption.

It ensures that all relevant user groups — from industrial operators to policy makers — are equipped with the necessary knowledge and skills to enable the implementation, replication and sustainability of the innovations developed by the ICARUS project.

2. Introduction

Deliverable D10.1 – User Groups' Skills Gap Report and Training Paths has been developed under Work Package 10 (WP10) – Skills Development and Standardisation, within the framework of the ICARUS project – Innovative Circular Solutions and Upcycling Routes. The main objective of this deliverable is to identify and analyse the skills gaps of the different user groups involved in the project, providing the foundation for the design of modular and flexible learning pathways that address emerging qualification needs across process industries.

The ICARUS project aims to accelerate the green and digital transition of the European industrial sector by promoting Industrial Symbiosis (IS) and Circular Economy (CE) practices that transform waste and by-products into High-Quality Secondary Raw Materials (SRMs). In this context, workforce upskilling represents a strategic pillar, as the successful adoption of innovative and sustainable solutions depends directly on the availability of a qualified, digitally skilled, and regulation-aware labour force aligned with European policy objectives.

The development of D10.1 involved the detailed characterisation of the main professional profiles operating within the industrial value chains addressed by the project — plant operators and technicians (blue-collar), engineers and managers, researchers and trainers, and policymakers. For each profile, existing competences, training gaps, and upskilling needs were mapped in accordance with the European Qualifications Framework (EQF). This analysis provided an integrated overview of the technical, digital, and regulatory capacities required to ensure the effective implementation of ICARUS demonstration cases and to support the replication of its results at a European scale.

The document also presents a structured proposal of Learning Paths and Training Packs, designed to provide targeted and adaptive responses to the identified gaps. These pathways will be implemented and validated in the subsequent phases of WP10 through pilot training sessions and standardisation activities, ensuring alignment between training outcomes, project objectives, and the broader requirements of Europe's green and digital transition.

2.1. Objectives and Scope

The primary objective of Deliverable D10.1 is to establish a comprehensive skills development framework to support the ICARUS capacity-building strategy. Specifically, this deliverable identifies, analyses, and categorises the competence gaps of the user groups targeted by the project, linking them to the required qualification levels and training priorities. This assessment provides the foundation for designing structured, modular, and flexible learning pathways that respond to the current and future needs of process industries engaged in Industrial Symbiosis (IS) and Circular Economy (CE) activities.

The scope of the document extends beyond a simple mapping exercise. It aims to:

- Characterise user groups involved in ICARUS demonstration activities, considering their functional roles, qualification levels, and relevance to industrial value chains.
- Identify skill shortages and training needs across technical, digital, and regulatory domains, using a multi-layered analysis aligned with the European Qualifications Framework (EQF).

- Define Learning Paths and Training Packs adapted to each user profile, ensuring coherence and complementarity between them.
- Support the design of training pilots and standardisation initiatives (Tasks 10.2 to 10.5) that will operationalise the proposed training structure.

In essence, this deliverable serves as both an analytical and strategic reference for the subsequent development of training materials and pilot activities under WP10. It ensures that the project's capacity-building efforts are evidence-based, targeted, and aligned with European priorities for digital and green transformation.

By clearly defining the training architecture, D10.1 lays the groundwork for the upcoming phases of ICARUS — transforming research outcomes into practical, scalable, and standardised training solutions capable of fostering innovation, sustainability, and workforce adaptability across Europe's process industries.

3. Methodology

The methodology applied in this study to identify and characterise the user groups of the ICARUS project followed a pragmatic approach, combining primary and secondary sources of information, participatory analysis and cross-validation between partners. The process began with collecting direct contributions from the consortium partners through an online questionnaire distributed to all members. It made it possible to map the main national and sectoral stakeholders based on existing collaboration networks and previous experiences in European projects. This information was consolidated by REVOLVE (leader of WP3) and complemented with specific inputs from partners, such as ISQ, ACCIONA, ARCELORMITTAL, KERABEN, CSIC and Université de Lorraine, who represent the different industrial and academic segments. At the same time, qualitative interviews and workshops were conducted with key stakeholders in several countries (Spain, Portugal, Germany, Belgium, Luxembourg, etc.), allowing for the validation of user categories, identifying barriers to technological adoption and skills gaps to be addressed in future training actions.

Additionally, the methodology integrated data from demonstration cases (WPs 4–8), which provided real examples of end users and made it possible to classify profiles according to EQF qualification level and type of activity (blue or White-Collar) — for example, plant operators and technicians in the ceramics and construction sectors (Blue-Collar; EQF 3–5), and engineers, managers and researchers in the steel and chemical sectors (White-Collar; EQF 6–8). A documentary analysis and secondary sources were added to this empirical component, including the ICARUS Grant Agreement, European skills for the twin transition, and references such as the EQF and ESCO, ensuring coherence with European guidelines for qualifications and professional profiles.

Finally, the mapping and validation process (D3.1) consolidated the information collected, grouping stakeholders into five major categories — researchers, policy makers, associations, companies and the public — and analysing the degree of relevance, influence and impact of each of them in the value chain of process industries. The triangulation between these sources allowed the construction of a robust and validated table of user groups, systematically characterised according to the industrial sector, role in the value chain, professional profile, EQF level and type of activity (blue/White-Collar), thus constituting the methodological basis of Deliverable D10.1, which, in addition to using sources produced by the ICARUS project, created from scratch an electronic questionnaire that was applied to project stakeholders to collect data and understand which professional skills are most relevant to the scope of the ICARUS project. The questionnaire applied in D10.1 was answered by 32 stakeholders and had its data analysed using quantitative methods, based on the professional skills and abilities most frequently indicated by respondents.

3.1. Deliverable 10.1: questionnaire characterisation

The ICARUS project's "Stakeholder Mapping and Professional Skills Survey" questionnaire (Annexe A) was designed as a structured data collection instrument to map and identify professional skills gaps in industrial symbiosis and the circular economy.

Its format is quantitative-qualitative, consisting of 24 questions distributed in three main sections, which are estimated to take 5 to 8 minutes to answer. The language is clear and accessible, focused on participants' self-perception and responses' voluntary and confidential nature, ensuring ethical compliance through informed consent.

- Section 1 - Characterisation of the Institution: Collects contextual information about the participating organisation, including the type of institution (public, private, university, VET provider, NGO, association), the sector of activity, the type of operation, the number of workers, the year of foundation and the country. This section aims to classify stakeholders by industrial sector, role in the value chain, professional profile and type of activity (blue/White-Collar), according to the D10.1 methodology.
- Section 2—Interest in collaboration with ICARUS: Assesses the level of involvement and availability of institutions to collaborate with the project, share knowledge, participate in training pilots, and contribute to good practices. This part distinguishes between active partners, potential users, and training entities, reinforcing the strategic mapping of the ICARUS ecosystem.
- Section 3 - Identification of skills gaps: It constitutes the analytical core of the questionnaire, allowing the identification of missing or lacking skills in institutions, grouped into nine domains:

1. Industrial Symbiosis Skills – concepts of industrial symbiosis, energy efficiency and circular economy.
2. Interpersonal and Management Skills – leadership, communication, problem solving and systemic thinking.
3. Technical and Operational Skills – technological application and operational efficiency.
4. Digital Skills – digital skills, AI, IoT and digital product passport (DPP).
5. Upcycling Processes Skills – treatment of waste and by-products, use of slag and cellulose.
6. Sustainable Product Development Skills – ecological design and formulation of sustainable products.
7. Quality, Process Optimisation and Standardisation Skills – laboratory evaluation, modelling and technical standardisation.
8. Process Optimisation - systematic improvement of industrial processes.
9. Standardisation and Normalisation - development, harmonisation, and application of technical standards and regulatory frameworks.

Each domain reflects training needs aligned with the levels of the EQF (European Qualifications Framework) and the distinction between blue-collar (technical and operational workers) and white-collar (engineering, management, and R&D professionals) workers.

In short, the questionnaire was designed as a central methodological tool in the stakeholder and skills mapping process (Tasks 3.1 and 10.1). It allows consistent data collection to characterise user groups, identify skills gaps, and design learning paths and training packages for the ICARUS project.

3.2. Identification and characterisation of user groups

The sources of information and the methods applied that allowed the generation of the table of stakeholders and user groups are described below:

1. Direct contributions from consortium partners - each ICARUS partner contributed national and sectoral information about relevant stakeholders in their contexts, through:

- Online questionnaire distributed to all partners (Annex A).
- Lists of existing contacts and collaboration networks, including clusters, universities, associations and authorities.
- Previous partners' experience in H2020/Horizon Europe projects (e.g. ISQ, ACCIONA, ARCELORMITTAL, KERABEN, CSIC, ULORRAINE, etc.).

2. Interviews and qualitative contributions, which complement the quantitative mapping, were carried out:

- Meetings and interviews with key stakeholders in partner countries (Spain, Portugal, Germany, Belgium, etc.).
- Internal workshops and consortium meetings to validate categories and subgroups.
- Discussions on barriers to adoption and skills gaps (relevant to Task 10.1 and D10.1).

3. Demonstration cases (Demo Cases in technical WPs 4–8) - ICARUS demonstration cases constituted a direct source of identification for end users:

- Demo 1 (Keraben, Spain): ceramic sector → plant operators and technicians (Blue-Collar).
- Demo 2 (ArcelorMittal, Luxembourg): steel sector → engineers and managers (White-Collar).
- Demo 3 (ACCIONA, Spain): construction sector → construction technicians, project managers.
- Demo 4 (Cales de Llierca, Spain / CSIC): chemistry and materials → researchers and laboratory technicians.

4. Document analysis and desk research - several secondary sources and European references were used:

- ICARUS proposal documents (Grant Agreement and Description of Action) — preliminary identification of target sectors.
- European policy reports on skills for the twin transition, Green Deal, SPIRE-SAIS and EIT RawMaterials.
- European qualifications frameworks (EQF and ESCO) to align professional profiles and skill levels.
- Scientific and sectoral publications on circular economy, recycling and revaluation of process materials.

5. Mapping and validation (Stakeholder Mapping Process – D3.1) - the mapping process itself was an analytical source:

- The results of the mapping questionnaire consolidated the stakeholder categories into five large groups (researchers, decision-makers, associations, companies and the public).
- Data was analysed to define each group's relevance, influence, and impact, allowing them to be related to functions in the value chain and EQF levels.
- This analysis served as the basis for the table of stakeholders by user group that you created (linking it directly to D10.1).

3.3. Characterisation of Blue-Collar and White-Collar

Definition of Blue-Collar workers (operational or technical workers): workers who perform practical, technical or manual activities, generally in industrial, production, maintenance or construction environments.

Blue-Collar - Features:

- Perform operational, technical or maintenance tasks.
- Professional or technical training (typically EQF 3–5).
- They work in factories, workshops, production lines, shipyards, treatment plants, etc.
- Examples: plant operators, laboratory technicians, industrial mechanics, process technicians, construction workers.
- In the ICARUS project: Blue-Collar workers are linked to upcycling activities, process operation, waste collection and transformation and implementation of demonstration technologies.

Definition of White-Collar workers (intellectual or administrative workers): workers who perform administrative, planning, management, design, research or development functions, generally in an office or academic context.

White-Collar - Features:

- Perform intellectual, analytical, management or supervisory tasks.
- Higher or advanced training (EQF 6–8).
- They work in technical, administrative, academic, or R&D departments.
- Examples: engineers, managers, researchers, architects, consultants, teachers.
- In the ICARUS project: White-Collar workers include process engineers, researchers, innovation managers, policy makers, and sustainability and standardisation experts.

3.4. Criteria for characterising user groups

The ICARUS project's user groups were characterised based on five fundamental criteria that allow mapping the role, professional context, and skills needs of each group. These criteria were defined in coherence with the European Qualification Framework (EQF), CEDEFOP recommendations on occupational profiles, and stakeholder mapping (D3.1).

Industrial Sector

Definition: identifies the economic and technological domain in which the user group operates, reflecting the application environment of ICARUS solutions and the type of industrial processes affected by the circular transition.

Objective: ensure that training and skills profiles are adjusted to the reality of each sector.

Reference categories:

- Cement, lime and ceramics industry.
- Steel and metallurgical industry.
- Chemical and materials industry.
- Construction and civil engineering.
- Management of waste and resources (water, effluents, slag, solid waste).
- Research, higher education and technological innovation.
- Public administration and environmental policies.

Role in the Value Chain

Definition: describes the role played by the user within the value chain of ICARUS technologies and processes — from knowledge generation to industrial application and regulation.

Objective: understand how each group contributes to developing, adopting and disseminating circular solutions.

Examples of roles:

- Research & Development: Creation and testing of new technologies and materials
- Industrial Production / Operation: Application and operation of upcycling and recycling processes
- Management and Planning: Strategic implementation, monitoring and decision-making
- Regulation & Standardisation: Creation of policies, legal frameworks and technical standards
- Training & Education: Dissemination of knowledge and training
- Communication & Awareness: Promoting social acceptance and sharing results

Professional Profile

Definition: refers to the nature and type of function the user performs, considering responsibilities, qualifications and work context.

Objective: relate roles to necessary skills (technical, transversal and behavioural).

Categories used:

- Technical / Operational – responsible for directly executing industrial or laboratory processes.
- Engineer / Technical Specialist – responsible for designing, controlling and optimising processes.
- Manager / Decision Maker – responsible for strategy, resources, policies and standardisation.
- Researcher / Teacher – responsible for generating and disseminating knowledge.
- Communicator / Citizen – involved in technology dissemination and social acceptance.

EQF level (European Qualification Framework)

Definition: corresponds to the level of qualification and autonomy expected in the European Qualifications Framework (EQF), from 1 to 8.

Objective: adapt learning paths to the depth and complexity of the skills required.

Some examples:

- EQF 3–4 - Professional and technical training: Operators, plant technicians (Blue-Collar).
- EQF 5–6 - Short higher education and degree: junior engineers, senior technicians.
- EQF 7 - Master's/Specialisation: Process engineers, middle managers.
- EQF 8 - Doctorate/Research: Researchers, strategic decision makers.

Activity Type (Blue/White-Collar)

Definition: traditional classification that distinguishes the type of work (manual or intellectual) and the environment in which it is carried out.

Objective: to allow aligning training programs with the context of professional activity.

Having posted this information below, the five user groups associated with the stakeholders and the respective countries where they are based are listed.

Table 1. Identification of user groups

Group Number	User Group	Country	Identified Stakeholders	Sector	Role in the Value Chain	Professional Profile	EQF Level	Type of Activity
1	Researchers & Scientific Community	Belgium France Germany Luxembourg Netherlands Portugal Spain	KU Leuven, Ghent University, BBRI Université de Lorraine, École Nationale Supérieure d'Ingénieurs TU Dresden, RWTH Aachen, Fraunhofer Building Innovation Alliance University of Luxembourg, LIST ISPT, Eindhoven University of Technology Universidade do Porto, Instituto Superior Técnico, Itecons, ISISE, CERIS CSIC, Universitat Politècnica de Catalunya, ITC, EURECAT, CETIM, ICRA	Research and Development	Generation of Knowledge and Technological Innovation	Researcher, Laboratory technician, University professor	7–8	White-Collar
2	Policy Makers & Public Authorities	Belgium France	ECSO, Construction 2050 Alliance Ministère de la Transition Écologique, OECD	Public Administration and Policies	Regulation, Policies and Standardisation	Public Manager, Policy	6–8	White-Collar

Group Number	User Group	Country	Identified Stakeholders	Sector	Role in the Value Chain	Professional Profile	EQF Level	Type of Activity
		Germany Italy Netherlands Portugal Spain	BMI, BBSR, Confederation of German Construction Industry MIMIT, Legambiente, COSMARI Rijkswaterstaat – Ministry of Infrastructure & Water Management Ministério da Habitação e Infraestruturas, AEP CEDEX, Consejerías de Fomento y Medio Ambiente, FEMP			Technician, Regulator		
3	Industrial Associations & Civil Society	Belgium Germany Italy Luxembourg Portugal Spain	FEAD, EuRIC, Eurometaux, FEDiEX, ACR+, Belgian Alliance for Sustainable Construction ZDB, GGBA, German Green Building Association, Federation of German Construction Industry Cluster Spring Bioeconomy, Legambiente FEDIL, Luxembourg Center for Circular Economy AICCOPN, AECOPS, ANI PLATEA, CEPCO, Green Building Council Spain	Industrial Associations and Civil Society	Dissemination, Representation and Sectoral Influence	Association Manager, Sector Technician, Sustainability Specialist	6–7	White-Collar
4	Companies, Entrepreneurs & Investors	Belgium Italy Luxembourg Netherlands Portugal Spain	KPMG, Ecopreneur.eu, Ramboll Group Hera, Acea, Iren, Italproget, Atzwanger BuildTec, Balthasar Constructions, Luxinnovation TNO, FCC Netherlands, RVO Eng. Adão da Fonseca, Consultores de Engenharia S.A. ACCIONA, Lafarge, Veolia, Aqualia, Ramboll	Industry, Construction, Energy and Environment	Production, Application and Technological Implementation	Engineer, Production Technician, Industrial Manager	4–7	Blue and White-Collar
5	General Public & Media	Belgium France Germany Luxembourg Portugal	POLITICO Pro Sustainability, Euractiv Construction21.org Euractiv, International Railway Journal Luxembourg Times, Chronicle.lu The Portugal News, Essential Business	Communication and Public Awareness	Dissemination and Social Acceptance of Project Results	Journalist, Scientific Communicator, Interested Citizen	3–7	White-Collar

Group Number	User Group	Country	Identified Stakeholders	Sector	Role in the Value Chain	Professional Profile	EQF Level	Type of Activity
		Spain	Agencia EFE Verde, El País, La Vanguardia, Construible.es					

3.5. Methodological link between the skills survey and the design of training activities

The skills needs survey conducted within the ICARUS project was a methodological foundation for developing the training structure, learning paths, and training packs proposed in this deliverable. The questionnaire, distributed among industrial, academic, and policy stakeholders, collected quantitative and qualitative data on ICARUS's current and required competences across the sectors and value chains.

The survey results were systematically analysed to identify skills gaps and to classify users according to their industrial sector, role in the value chain, professional profile, EQF level, and type of activity (blue/White-Collar). These dimensions formed the analytical framework that guided the design of the learning paths. Integrating survey results ensured that the proposed training activities are grounded in empirical evidence and respond directly to user needs, rather than solely on theoretical assumptions.

<u>The process followed five key steps:</u>

Identification of Skills Gaps - Data from Section 3 of the questionnaire was used to pinpoint areas where knowledge and competence were lacking (e.g., digitalisation, circular business models, process optimisation) (**1**).

User Group Classification - The information from Section 1 allowed the mapping of skills gaps to specific user profiles (industrial operators, engineers, researchers, policymakers, associations). (**2**)

Interpretation per Group - Cross-analysis between industrial sectors and skills needs enabled differentiation between technical, managerial, and research-oriented priorities. (**3**)

Design of Learning Paths - The identified needs were translated into modular training pathways aligned with EQF levels and professional contexts. (**4**)

Creation of Training Packs – The survey's most relevant and recurring topics were converted into thematic training packages with defined learning objectives and expected outcomes. (**5**)

<u>Examples of how survey results informed training design:</u>

Example 1_Plant Operators (Blue-Collar, EQF 3–5)Survey responses indicated significant skill gaps in Upcycling Processes and Industrial Symbiosis Concepts. This led to the development of Training Pack 1, "Sustainable Operations and Efficiency in Circular Processes," which covers energy efficiency, resource recovery, and digital tools for process monitoring.

Example 2_Engineers and Technical Managers (White-Collar, EQF 6–7)Participants highlighted needs in Circular Economy Business Models and Digital Competencies. These findings informed Training Pack 2, "Integrated Resource Management and Process Digitalisation," which includes modules on Digital Product Passport (DPP), data management, and process optimisation.

Example 3_Researchers and Trainers (White-Collar, EQF 6–8)The survey revealed gaps in Systemic Thinking and Standardisation Knowledge. Consequently, Training Pack 3, "Standardisation, Certification and Systemic Innovation," was designed to address the harmonisation of technical specifications and integrate certification procedures into R&D practices.

Example 4 – Policymakers and Associations (White-Collar, EQF 6–8)Respondents reported insufficient competence in Environmental Regulation and Stakeholder Communication. These results guided the creation of Training Pack 4, "Policy, Regulation and Communication for the Circular Economy," which focuses on regulatory frameworks, policy support tools, and communication strategies.

<u>Integration into the ICARUS Training Framework</u>

The analysis of survey results thus enabled the translation of stakeholder needs into practical, modular training actions. Each Training Pack integrates:

- Targeted learning objectives based on identified skills gaps.
- Alignment with EQF levels and user group profiles.
- Balance between blue- and white-collar competences.
- Cross-cutting emphasis on digital, circular, and green transition skills.

This methodological linkage ensures that the training activities proposed in Deliverable D10.1 are evidence-based, context-specific, and aligned with the real needs of the ICARUS user community, fostering effective capacity building across the European process industries.

4. Characterisation of respondents and survey results

The respondents of the ICARUS project survey — used to map competencies and collaboration intentions, based on up to 32 responses in the characterisation section — are predominantly from private companies (58%, 18 responses). Regarding institutional focus, the most frequently reported activity is Research, Development and Innovation (R&D&I), indicated by 52% of participants (17 responses). The most represented sectors include Research & Development (42%, 14 responses), Energy & Utilities (36%, 12 responses), and Industrial Manufacturing (27%, 9 responses), reflecting a strong participation from organisations closely aligned with process industries.

Geographically, most institutions are based in Spain (63%, 20 responses), followed by Italy and Portugal (9% each). A particularly relevant finding is that 79% of respondent institutions (23 out of 29 answers) have previously participated — or are currently involved — in Industrial Symbiosis projects, demonstrating a high level of experience in the field and reinforcing the value of the insights collected for the development of the ICARUS training framework.

Among the institutions that expressed an interest in collaborating with the ICARUS project, 86% (25 out of 30 responses) indicated that they are willing to share knowledge and good practices (Question 13). The areas mentioned predominantly relate to water management, waste treatment, and industry-specific operational challenges, which align directly with the technological and industrial focus of ICARUS.

The main areas of knowledge that institutions are prepared to share include:

- Ceramic manufacturing requirements and challenges: insights into technical requirements, constraints, and operational difficulties associated with ceramic production.
- Water analysis and recovery: expertise in water quality analysis and techniques for recovering compounds from industrial wastewater.
- Treatment technologies: experience with advanced treatment solutions, such as membrane technologies and encapsulation processes.

It is important to note that 79% of responding institutions (23 out of 29) have previously participated — or are currently involved — in Industrial Symbiosis (IS) projects. This background demonstrates not only strong technical capability but also a high level of maturity and willingness to contribute specialised knowledge to support the development of innovative solutions within the ICARUS project.

4.1. Assessment of skills gaps

The assessment of skills gaps was based on the responses of 19 participants[1] from Section 3 of the questionnaire, most of whom represent Private Companies (58%) with a strong focus on Research & Development (52%) and Wastewater Management. This institutional profile indicates a close connection to process industries and to the core themes of the ICARUS

[1] 32 respondents started the questionnaire and 19 completed it by answering all sections to the end.

project. Furthermore, nearly 80% of these organisations had previous involvement in Industrial Symbiosis (IS) projects, which strengthens the reliability of the insights gathered, as they originate from institutions with substantial technical maturity and practical experience in the field.

Based on the perceptions of these 19 respondents, it was possible to identify, across the nine thematic areas evaluated, the most significant skills gaps — that is, the areas where participants reported the greatest lack of knowledge or need for further development. The following sections present these priority gaps, highlighting the domains where capacity-building efforts are most urgently required to support the circular and digital transition promoted by ICARUS.

Table 2. Most significant gaps identified

Thematic Area	Most Needed Competence	Percentage (N=19)
Sustainable Product Development	Applications in Paving, Embankments and Hydraulics (Road Surfacing, Landfill and Hydraulic Applications). (Knowledge about how to adapt formulations to suit different applications).	74%
Normalisation and Standardisation	End-of-Waste Statute. (Knowledge of the European Commission's provisions on the end-of-waste status).	63%
Process Optimisation	Steel Slag – Use Value Modelling. (Knowledge of modelling to estimate the use value of the material as an alternative in sintering installations).	63%
Quality and Performance Assessment	Monitoring the Environmental Performance of Products. (Knowledge about performing leaching analyses to ensure that products do not release toxic elements into the environment).	63%
Digital Skills	Digital Product Passport (DPP). (Ability to identify DPP requirements and specifications, aiming for legal compliance, traceability and product sustainability).	53%
Upcycling Processes	Treatment and Transformation of Waste and By-products. (Detailed knowledge of the treatment processes and transformation of waste/by-products into new materials).	53%

The analysis indicates that the most significant training needs within the ICARUS project do not lie in basic interpersonal skills, but rather in the areas of regulatory application, technological optimisation, and validation of upcycled products. These domains represent essential pillars for enabling the Twin Transition (green and digital), particularly in process industries where the successful valorisation of secondary materials depends on strict standards of certification, environmental assessment, and technical performance.

<u>The Central Challenge: Application, Regulation, and Validation</u>

The three most prominent skills gaps — all exceeding 60% — highlight that the main barrier to successful upcycling is the ability to transform secondary materials into technically validated, environmentally safe, and legally compliant products.

- Application Barrier (74%): The most significant gap concerns knowledge on applications in road surfacing, landfill, and hydraulic uses. This deficit indicates a major limitation in the ability to adapt product formulations to match the technical and operational requirements of different end uses — a crucial step for market uptake of upcycled products.
- Regulatory Barrier (63%): A lack of understanding of the End-of-Waste (EoW) Statute represents a critical regulatory bottleneck. As ICARUS focuses on waste valorisation, the legal transition from by-product to commercial product hinges directly on demonstrating compliance with European EoW criteria.
- Optimisation and Safety Barrier (63%): Equally significant are the gaps in monitoring environmental performance (including leaching tests) and in modelling the use value of steel slag. These findings underscore the dual necessity of ensuring the environmental safety of the materials while possessing the modelling tools to optimise the technical use of complex industrial residues.

The Imperative of the Digital Transition: DPP, AI, and ML

Digital upskilling emerges as a clear requirement for ICARUS, with respondents demonstrating awareness of the new regulatory and operational demands of Industry 4.0.

- Traceability and Compliance (53%): The lack of knowledge regarding the Digital Product Passport (DPP) indicates that many institutions are not yet prepared to implement the digital tools needed to ensure traceability, transparency, and sustainability under the evolving European regulatory framework.
- Real-Time Optimisation (47%): Nearly half of respondents reported insufficient competencies in Artificial Intelligence, Machine Learning, and IoT. These technologies are essential for the real-time optimisation of upcycling processes in the ICARUS pilot plants, reinforcing the need for targeted, technically advanced training packages.

Foundational and Social Competencies: Strengths and Weaknesses

While the most critical gaps lie in technical and regulatory areas, the survey also reveals both strengths and persistent weaknesses in the management of Industrial Symbiosis itself.

- Areas of High Proficiency (0% Gap): Institutions reported strong capabilities in problem-solving and managing diverse tasks, suggesting a robust capacity for dealing with operational challenges and adapting to unexpected situations.
- Weakness in Collaboration (32%–37%): Despite the broad experience among respondents in IS projects, competencies related to communication, leadership across sectors, and raising awareness of Industrial Symbiosis remain underdeveloped. This indicates that implementing IS effectively requires not only technical expertise but also specialised soft skills to navigate complexity, overcome resistance, and facilitate cross-sectoral cooperation.

In summary, the analysis confirms that the ICARUS training pathways should focus on bridging the gap between operational know-how (where proficiency already exists) and the ability to apply, comply, and optimise (where the most significant gaps persist). Priority must therefore be given to strengthening technical, regulatory, and digital competencies, while also enhancing the social and collaborative skills that underpin effective Industrial Symbiosis.

Table 3. Other gaps identified (indicated by less than 50% of stakeholders)

Thematic Area	Specific Competency (Gap Description)	Percentage (N=19)
Digital Skills	Digital Skills (AI, ML, and IoT): Ability to use and apply digital technologies as enablers: artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT).	47%
Industrial Symbiosis	Environmental Regulation: Environmental laws, regulations, resource properties, and waste processing technologies.	37%
Interpersonal and Management	Importance of Industrial Symbiosis: Ability to manage and raise awareness among people about the importance of industrial symbiosis.	37%
Technical and Operational	Technology Implementation: Ability to integrate advanced technologies to improve operational efficiency, identify opportunities, and optimise resource flows.	37%
Industrial Symbiosis	Systems Thinking: Analyse complex systems and identify the interrelationships between different components.	32%
Interpersonal and Management	Management of the Complexity of Intersectoral Cooperation: Ability to manage the complexity of intersectoral cooperation.	32%
Technical and Operational	Product Composition and Development: Ability to compose and develop innovative products based on secondary raw materials.	32%
Technical and Operational	Application of Innovative Management Tools: Ability to apply creative tools to promote the transition to a circular economy.	32%

Thematic Area	Specific Competency (Gap Description)	Percentage (N=19)
Industrial Symbiosis	Circular Economy and Business Models: Circular business models, practical applications and understanding the economic implications of industrial symbiosis.	21%
Quality and Performance Assessment	Assessment in the Context of Civil Construction: Performance of products/materials, such as resistance, press time and expansion of mortars with upcycling.	21%
Interpersonal and Management	Multidisciplinary: Knowledge in engineering, environmental management, economics, social sciences and ability to integrate different areas through a holistic approach.	16%
Quality and Performance Assessment	Laboratory Tests and Quality Assessments: Knowledge of recovered materials and final products, including physical/chemical stability, density, hardness, colourimetry and water absorption of ceramic materials.	16%
Normalisation and Standardisation	Certification Methodologies and Legal Requirements: Knowledge of certification methodologies and legal requirements for products.	26%
Normalisation and Standardisation	Harmonisation of Technical Specifications: Knowledge in harmonising technical specifications.	11%
Industrial Symbiosis	Understanding Industrial Symbiosis and Energy Efficiency: Concepts, principles and energy efficiency.	5%
Upcycling Processes	Lithium Aluminosilicate Waste (LAR): Knowledge and mastery of techniques to purify, improve and package waste for reuse in construction and ceramics applications.	5%
Upcycling Processes	Cellulose from Urban and Industrial Waste: Knowledge of technologies for recovering cellulose from effluents from wastewater treatment plants and absorbent hygiene products.	5%
Interpersonal and Management	Entrepreneurial Mentality: Proactive and innovative approach in the search for solutions.	5%
Interpersonal and Management	Time and Change Management: Ability to effectively manage time and change.	5%
Interpersonal and Management	Problem Solving/Solutions.	0%
Interpersonal and Management	Task Diversity Management.	0%

The skills gap assessment carried out within the ICARUS project provides a clear and data-driven picture of the competencies that must be strengthened to support the successful deployment of circular and digital solutions in process industries. The profile of the 19 respondents — predominantly private companies with strong engagement in Research & Development and wastewater management, and with prior experience in Industrial Symbiosis (IS) — lends robustness to the findings. Their responses reveal a workforce that is technically mature but facing substantial challenges in areas that are fundamental for the valorisation of secondary raw materials and the implementation of advanced upcycling technologies.

The analysis demonstrates that the most critical gaps do not lie in soft or interpersonal skills but in regulatory compliance, technological optimisation, environmental validation, and digitalisation. Competencies such as knowledge of road surfacing and hydraulic applications (74%), compliance with the End-of-Waste Statute (63%), environmental performance monitoring (63%), and the ability to model the use value of steel slag (63%) highlight the central barriers to transforming waste streams into safe, market-ready products. In parallel, emerging digital requirements — particularly the Digital Product Passport (53%) and real-time optimisation using AI, ML, and IoT — underscore the importance of equipping professionals with the tools and knowledge necessary to operate effectively within Industry 4.0 environments. These findings confirm that the Twin Transition cannot be achieved without a workforce capable of combining regulatory, technical, and digital proficiency.

At the same time, the survey identifies areas of strength, such as problem-solving and task management (0% gap), alongside persistent weaknesses in collaboration, leadership, and systems thinking — competencies essential for enabling cross-sectoral cooperation and the wider adoption of Industrial Symbiosis. Taken together, these results indicate that ICARUS training pathways must prioritise closing the gap between operational capability and the ability to apply, validate, and optimise in real industrial contexts. Training efforts should therefore focus on enhancing advanced technical, regulatory, and digital skills, while also reinforcing the social and collaborative competencies needed to navigate the complexity of circular value chains and foster effective industrial collaboration.

4.2. Internal validation of results

As a second step to consolidate the data previously collected from stakeholders, an additional consultation was carried out through an electronic questionnaire addressed to ICARUS partners who are directly or indirectly involved in WP10. The purpose of this complementary stage was to validate the results obtained in the initial consultation, confirm the priorities identified, and gather further contributions that would strengthen the robustness of the skills gap analysis.

In total, ten representatives from nine partner institutions responded to the validation questionnaire. This sample includes organisations with central roles in the ICARUS project and with direct experience in technical demonstration, social innovation, research and training. The participating institutions were: Institute of Ceramics and Glass (Spanish National Research Council), ACCIONA Construcción, CARTIF, KERABEN GRUPO SAU, ArcelorMittal, Université de Lorraine, K-UTEC, SocialFare and ISQ. The diversity of these contributions enabled the integration of industrial, scientific and technological perspectives, ensuring that the conclusions of Task 10.1 accurately reflect the real needs of end users and of the industrial symbiosis ecosystem addressed by the project.

Below, all competences assessed by the ICARUS partners are listed, together with their respective weighted averages (on a scale from 1 to 10), where 10 represents "Total Agreement" and 1 represents "Total Disagreement":

Table 4. Level of internal agreement of the results of the questionnaire applied to stakeholders

Knowledge and skills indicated by stakeholders most frequently	Agreement levels of ICARUS partners (average)	Level of agreement
Transformation of waste/by-products into new materials.	9.1 / 10	Excellent
Importance of Industrial Symbiosis (ability to manage and raise awareness of the relevance of industrial symbiosis).	8.9 / 10	Excellent
Environmental Regulation (current environmental laws, regulations, resource properties and waste processing technologies).	8.7 / 10	Excellent
Composition and Development of products based on secondary raw materials.	8.7 / 10	Excellent
End-of-Waste (EoW) Statute (knowledge of the European Commission's provisions on end-of-waste status).	8.4 / 10	Excellent
Monitoring Environmental Performance of Products (knowledge of conducting leaching analyses).	8.4 / 10	Excellent
Digital Product Passport (DPP) (aimed at legal compliance, product traceability and sustainability).	8.4 / 10	Excellent
Innovative Ceramic Products (knowledge of replacing primary raw materials with aggregates using Lithium Aluminosilicate Waste).	8.3 / 10	Excellent
Technology Implementation (ability to integrate advanced technologies to optimise resource flows and operational efficiency).	8.2 / 10	Excellent
Application of Innovative Management Tools (ability to apply creative tools to promote the transition to a circular economy).	8.2 / 10	Excellent
Certification Methodologies and Legal Requirements (knowledge of certification methodologies and legal product requirements).	8.2 / 10	Excellent
Applications in Road Surfacing, Landfill and Hydraulic Uses (knowledge to adapt product formulations to meet the requirements of different applications).	8.0 / 10	Very Good
Assessment of upcycled mortars (resistance, pressing time and expansion of mortars containing upcycled materials).	8.0 / 10	Very Good
Systems Thinking (ability to analyse complex systems and the interrelationships among different components).	7.6 / 10	Very Good
Management of the complexity of intersectoral cooperation.	7.4 / 10	Very Good

Knowledge and skills indicated by stakeholders most frequently	Agreement levels of ICARUS partners (average)	Level of agreement
Steel Slag – Stabilisation (knowledge of slag stabilisation methods, including controlled hydration and carbonation).	7.4 / 10	Very Good
Digital Skills (ability to use and apply digital technologies such as AI, ML and IoT).	7.3 / 10	Very Good
Methodologies and Tools (knowledge of statistical methods and modelling tools to optimise production variables).	7.3 / 10	Very Good
Steel Slag – Modelling (knowledge of modelling to estimate the use value of slag as an alternative in sintering installations).	6.8 / 10	Good
Qualitative metric for analysing results: values equal to or less than **5** - Insufficient; **5.1-6.0** - Sufficient; **6.1-7.0** - Good; **7.1-8.0** - Very Good; **8.1-10** - Excellent.		

The table below reconstructs the relationship between the 19 competences assessed, using data from two questionnaires: the gap perceived by stakeholders (percentage of lack of knowledge) and the level of agreement among ICARUS partners regarding the development of training in these competences (Weighted Average, where 10 indicates “Total Agreement”). The competences listed below are ordered from the highest to the lowest perceived stakeholder gap (external training priority).

Table 5. Comparison between stakeholder and internal validation results

Competence/Skill	Percentage of Perceived Gap (External Priority) (N=19)	Weighted Average (Agreement to Develop Training – Internal)
Applications in Road Surfacing, Landfill and Hydraulic Uses (Adapting formulations)	74%	8.0 / 10
Steel Slag Modelling (Estimating use value in sintering)	63%	6.8 / 10
End-of-Waste (EoW) Statute (Knowledge of EC provisions)	63%	8.4 / 10
Monitoring Environmental Performance of Products (Leaching analyses)	63%	8.4 / 10
Digital Product Passport (DPP) (Identifying requirements and specifications)	53%	8.4 / 10
Treatment and Transformation of Waste/By-products	53%	9.1 / 10
Digital Skills (AI, ML and IoT)	47%	7.3 / 10
Environmental Regulation (Laws, regulations and processing technologies)	37%	8.7 / 10
Importance of Industrial Symbiosis (Managing and raising awareness)	37%	8.9 / 10
Technology Implementation (Optimising resource flows and efficiency)	37%	8.2 / 10
Steel Slag – Stabilisation (Controlled hydration and carbonation)	37%	7.4 / 10
Methodologies and Tools (Statistical methods and modelling tools)	37%	7.3 / 10
Composition and Development of Products (Secondary raw materials)	32%	8.7 / 10
Systems Thinking (Analysing complex systems)	32%	7.6 / 10
Management of Intersectoral Cooperation Complexity	32%	7.4 / 10
Application of Innovative Management Tools (Promoting the circular economy)	32%	8.2 / 10
Innovative Ceramic Products (Substitution with Lithium Aluminosilicate Waste)	26%	8.3 / 10
Certification Methodologies and Legal Requirements	26%	8.2 / 10
Assessment of Upcycled Mortar Parameters	21%	8.0 / 10

A combined reading of the two dimensions assessed — the percentage of perceived gaps among external stakeholders and the level of internal agreement among partners regarding the need to develop training — makes it possible to identify, with precision, the most critical competence areas for ICARUS and those requiring priority training interventions.

First, a group of competences emerges in which a high level of perceived external need (≥ 60%) aligns with equally high internal agreement, indicating strong convergence between stakeholder expectations and partner priorities. This is the case for competences related to applications in road surfacing, landfill and hydraulic uses (74%), the End-of-Waste Statute (63%), monitoring of environmental performance (63%), and treatment and transformation of waste and by-products (53%), all of which received weighted averages above 8.0. This correlation demonstrates that the consortium recognises these gaps as central barriers to the valorisation of upcycled materials and to the regulatory compliance required for the Green Transition.

A second group includes competences where external perceptions of gaps are high but internal agreement is more moderate, such as steel slag modelling (63% gap; 6.8/10 agreement). This disparity suggests that, while stakeholders identify this competence as important, some partners view it as a specialised area relevant to specific contexts (e.g., sintering in steelmaking), and therefore not requiring a broad training effort across the consortium.

Conversely, some competences display low external gap perception but high internal priority, indicating areas that, although less visible to stakeholders, are strategically important for ensuring the replicability and interdisciplinary coherence of ICARUS. This is particularly evident for competences linked to product composition and development (8.7/10) and innovative ceramic products (8.3/10), which hold significant relevance for the project's demonstrators.

Finally, competences such as systems thinking (7.6/10), management of intersectoral cooperation complexity (7.4/10) and digital skills (7.3/10) highlight an important trend: although these do not appear among the most critical external gaps, the partners recognise them as essential for enabling collaboration, digital integration and informed decision-making — all of which are foundational to industrial symbiosis and the Twin Transition.

In summary, the integrative analysis shows that training within ICARUS should prioritise three fundamental axes: technical valorisation of waste and application of upcycled materials, regulatory compliance and environmental assessment, and digital and transversal competencies. The alignment between internal and external priorities confirms these axes as central for the design of the Training Packs and Learning Paths under Task 10.1.

4.3. Current and future skills for the IS context

The comparative skills analysis, developed within the scope of Deliverable 10.1, aims to identify the differences between current skills and future skills required for the successful implementation of the innovative technologies and processes of the ICARUS project. Inserted in the context of Industrial Symbiosis (IS) and the Twin Transition (green and digital), the study is based on an integrated methodological approach, which combines a literature review, the analysis of European reference studies (such as SPIRE-SAIS), and the results obtained through the survey of training needs carried out with the project's partners and stakeholders. This systematic comparison allows us to understand the current state of workforce capabilities and the emerging requirements associated with adopting technological, digital and circular solutions in different industrial sectors.

The ICARUS project proposes a profound transformation in process industries by valorising secondary flows and waste — such as lithium aluminosilicate waste, cellulose from urban waste and steel slag — converting them into new materials and value-added products. This technological ambition requires a significant evolution of the technical, digital and transversal skills of the professionals involved to ensure the operation, optimisation and integration of upcycling technologies and digital monitoring and traceability tools. Therefore, this analysis aims to outline the skills development path that will allow professionals to raise their current level of knowledge to enable them to lead innovation, implement industrial symbiosis practices and support the green and digital transition promoted by ICARUS.

Current competencies are the starting point, but generally reveal lower proficiency in IS than in Energy Efficiency (EE). The existing context is characterised by a level of knowledge that, for some professional profiles, already reaches the level of "Specialist" (Level 3) in certain areas of IS, but needs to be deepened and complemented with digital skills.

Table 6. Current competencies in the field of industrial symbiosis

Competency category	Current competence (level)	Justification of the existing context
Basic Knowledge in IS	Basic understanding of IS - Level 3 - Expert, in operational profiles such as Waste Management Technician.	This level (Level 3) indicates that the individual can perform operations without assistance and deal with complicated circumstances. However, IS adoption has been hampered by a lack of mechanisms to educate potential stakeholders and sufficient awareness or understanding of IS terminology.
Methodological Skills	Field experience (in IS), assessment of product life cycle thinking and sustainable resource management (Level 3 - Expert).	Knowledge in Systems thinking is considered critical, but the focus has historically been on specific synergies, not a complete systemic vision of the Circular Economy (CE).
Regulatory Skills	Legislation on waste, energy management, and CO2 emissions (Level 4 - Master).	Familiarity with legislation and regulations is fundamental to regulatory compliance and is often the strongest area, reaching the highest level (Master).
Digital/Technological Skills	Generally insufficient.	The existing workforce in energy-intensive industries (EIIs) has demonstrated difficulty getting used to automated and digitised manufacturing processes.

Future competencies are determined by ICARUS innovation objectives, which include demonstrating new upcycling technologies (Demo-Cases 1, 2, and 3) and integrating advanced digital solutions. The goal is to raise the level of proficiency, typically to "Master" (Level 4), to allow professionals to take initiative, demonstrate adaptability, and lead the training of other professionals.

Table 7. Future competencies in the field of industrial symbiosis

Competency category	Required future competency (Level)	Justification in the ICARUS context
Mastery in IS and CE	Basic understanding of IS, Field experience (in IS), product life cycle thinking assessment, and Sustainable resource management (Level 4 - Master).	The increase to Level 4 is necessary so that the workforce can proactively build capabilities and establish new methods. The application of IS must be expanded and integrated with CE, requiring skills to perform Environmental Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) in ICARUS demo cases.
Advanced Technological and Digital Skills	Systems Optimisation and Process Analysis (Level 4 - Master).	ICARUS requires the development of a digital infrastructure to monitor data from pilot plants, send it to a cloud platform for advanced analytics, and deploy real-time optimisation algorithms on the edge computer. This requires personnel to be able to optimise the capabilities of the IS system.
Project-Specific Digitisation	Digital Product Passport (DPP) and Artificial Intelligence (AI).	ICARUS defines the DPP (O1.1) to monitor and facilitate compliance verification, requiring proficiency in data management and interoperability along the value chain. AI will be integrated to generate data-driven models that automatically optimise process parameters.
Transversal and Collaboration Skills	Project Planning and Management and Business Model Transformation.	The success of IS depends on collaboration and knowledge sharing between different companies and stakeholders. ICARUS includes tasks to define new

Competency category	Required future competency (Level)	Justification in the ICARUS context
		business models, stakeholder engagement, and co-creation strategies, requiring social and management skills.

The skills gap lies in the need to elevate IS skills from a knowledge level (Level 3), where operations are managed autonomously, to a mastery level (Level 4), where the workforce can innovate, lead and integrate new digital technologies (AI, Real-Time Optimisation) and complex methodologies (LCA, DPP) into ICARUS upcycling processes.

The comparison between current and future competencies in Industrial Symbiosis (IS) highlights a clear evolutionary trajectory from operational proficiency to strategic mastery, reflecting the increasing technical and digital demands introduced by the ICARUS project. Current competencies reveal that most professionals operate at a Level 3 – Specialist, particularly in methodological and regulatory skills, where practical experience and knowledge of legislation are relatively strong. However, these competencies remain largely reactive and task-oriented, focused on executing processes rather than optimising or innovating them. The lack of systemic thinking and limited familiarity with digital tools constrain the ability of the current workforce to fully apply IS principles across the broader Circular Economy (CE) framework. In short, while the workforce demonstrates solid foundations in environmental compliance and resource management, the existing skillset lacks integration with digitalisation and innovation-driven practices.

In contrast, the future competencies required under ICARUS shift towards Level 4 – Mastery, emphasising proactive learning, technological integration, and collaborative leadership. The focus expands beyond operational efficiency to include system optimisation, digitalisation, and life cycle thinking, with professionals expected to master advanced tools such as Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and digital systems like the Digital Product Passport (DPP) and Artificial Intelligence (AI). This evolution represents a quantitative increase in skill levels and a qualitative transformation — from understanding and applying industrial symbiosis to designing, leading, and innovating within interconnected industrial ecosystems. Furthermore, future competencies underline the importance of transversal and collaborative skills, which are essential for stakeholder engagement and the creation of new circular business models. The comparison therefore underscores the skills gap that ICARUS aims to address: advancing from a workforce that performs and complies to one that anticipates, optimises, and drives systemic change through digital and circular innovation.

5. Design of learning paths

5.1. Thematic domains of competencies assessed

The questionnaire used to identify skills gaps classified stakeholders' needs into seven main thematic domains. These domains served as the methodological basis for defining the Training Packs and designing the Learning Paths. Each domain is aligned with the European Qualifications Framework (EQF), ensuring coherence between the proficiency levels identified and the professional profiles assessed.

The seven domains analysed were:

- Industrial Symbiosis Skills.
- Interpersonal and Management Skills.
- Technical and Operational Skills.
- Digital Skills.
- Upcycling Processes Skills.
- Sustainable Product Development Skills.
- Quality, Process Optimisation and Standardisation Skills.

The following table presents the thematic domains of skills evaluated in the ICARUS project questionnaire, listed in descending order of perceived lack of knowledge (skills gaps), which reflects the order of priority of stakeholders for training.

Table 8. Mastery of priority skills identified by stakeholders

Domain of Competence	Biggest Perceived Knowledge Gap	Percentage (N=19)
Sustainable Product Development Skills	Knowledge of formulations adapted to Road Surfacing, Landfill and Hydraulic Applications.	74%
Quality, Process Optimisation and Standardisation Skills	Knowledge of: Environmental monitoring (leaching analyses); Modelling the value of steel slag utilisation; and End-of-Life Waste (EoW) statute.	63%
Digital Skills	Ability to identify Digital Product Passport (DPP) requirements and specifications.	53%
Upcycling Processes Skills	Detailed knowledge of the treatment and transformation of waste and by-products into new materials.	53%
Industrial Symbiosis Skills	Knowledge of environmental regulations (laws, resource properties, and waste processing technologies).	37%
Interpersonal and Management Skills	Ability to manage and raise awareness among people about the importance of industrial symbiosis.	37%
Technical and Operational Skills	Ability to implement advanced technologies to improve operational efficiency and optimise resource flows.	37%

The following sections detail the three domains most frequently indicated by stakeholders — Digital Skills, Upcycling Processes Skills, and Sustainable Product Development Skills — highlighting their content, the gaps identified, and their strategic relevance for the ICARUS project.

Sustainable Product Development Skills

This domain refers to the ability to design and optimise sustainable products using secondary raw materials. It encompasses knowledge of product composition, mix formulation, and the integration of recovered materials into real industrial applications.

- Domain content: Development of innovative products using materials derived from industrial waste, and the adaptation of formulations for different applications in construction and civil engineering.
- Critical gap identified: Applications in Road Surfacing, Landfill and Hydraulic Uses (74%); stakeholders report difficulties in adapting upcycled materials to meet the technical requirements of these applications, representing a direct barrier to market acceptance and industrial scaling of the ICARUS Secondary Raw Materials (SRMs).
- Relevance for the Project: This competence is essential for transforming laboratory results into marketable products, ensuring the success of ICARUS demonstrations and supporting their wider replication across the sector.

Digital Skills

Digital competences constitute a fundamental pillar of the Twin Transition (green and digital), particularly in industries that require traceability, interoperability, and data-driven optimisation.

- Domain content: Use of digital technologies for monitoring, data collection and analysis; and the application of Artificial Intelligence (AI), Machine Learning (ML) and the Internet of Things (IoT) to support operational decision-making.
- Critical gaps identified: Digital Product Passport (DPP) (53%); respondents reported significant difficulty in understanding and applying DPP requirements, a tool essential for ensuring legal compliance, full product traceability and transparency of sustainability information across the value chain. Real-time optimisation using AI, ML and IoT (47%); these competences are crucial for the real-time optimisation of upcycling processes in the ICARUS pilot plants, highlighting the need for advanced technical training to support industrial digitalisation.
- Relevance for the Project: Digital skills are essential in ICARUS to ensure traceability, regulatory compliance and real-time optimisation of upcycling processes. Without proficiency in DPP, AI, ML and IoT, it is not possible to achieve the efficiency and reliability required to validate and scale the materials developed within the project.

Upcycling Processes Skills

This domain focuses on the knowledge required to transform industrial waste into new materials with economic, environmental and industrial value.

- Domain content: Processes for the treatment, transformation and stabilisation of waste and by-products, as well as laboratory and operational techniques for producing upcycled materials.
- General Critical Gap (53%): The most significant gap relates to the treatment and transformation of waste and by-products, with more than half of stakeholders reporting deficiencies in this area — a central challenge for successful upcycling.

Project-relevant specific focus areas

The domain also covers the knowledge needed to work with the three waste streams studied in ICARUS:

- Steel Slag (37%): Stabilisation methods (controlled hydration and carbonation) and the production of PCC (Precipitated Calcium Carbonate).
- Lithium Aluminosilicate Residue – LAR (5%): Techniques for purifying, upgrading and conditioning this residue for ceramic applications.
- Cellulose from Urban Waste (5%): Technologies for recovering cellulose fibres from wastewater treatment effluents and municipal waste streams.

The skills analysis carried out through the questionnaire made it possible to identify, in a structured manner and aligned with the EQF, the main areas in which stakeholders require training reinforcement to keep pace with the Twin Transition and the technological challenges of ICARUS. Among the seven domains assessed, three areas stand out with particularly significant gaps — Sustainable Product Development, Digital Skills, and Upcycling Processes Skills — representing the technical, digital, and operational pillars necessary to transform waste into high-value materials and ensure their environmental, technical, and regulatory validation. The gaps identified, especially in sustainable product applications (74%), use of the Digital Product Passport (53%), and waste treatment (53%), confirm that professionals still lack essential competencies to guarantee the quality, safety, and applicability of the materials developed within the project.

Overall, the results show that the success of the ICARUS pilot demonstrations depends directly on the ability of professionals to master these three critical domains. Digital skills enable traceability and real-time optimisation; upcycling skills ensure that materials are technically viable and environmentally safe; and sustainable product development skills support the transition from laboratory outcomes to real industrial applications. Therefore, these conclusions reinforce the need to develop targeted training programmes, structured into Training Packs and Learning Paths, capable of equipping the workforce to implement, validate, and scale the innovative solutions of ICARUS across different industrial sectors.

5.2. Training Packs

The learning pathways and training structure of the ICARUS project have been organised into four Modular Training Packs, developed specifically to address the most critical skills gaps identified in the stakeholder questionnaire. Each pack has been designed to target the areas where the lack of knowledge is most significant, ensuring that the proposed training is focused, relevant, and aligned with the real needs of users.

The design of these packs is based both on the urgency of the identified competences and on the requirements of the different user groups (blue-collar and white-collar profiles). This structure guarantees coherence with the European Qualifications Framework (EQF) and ensures that the training offer effectively supports the Twin Transition (green and digital) within process industries.

The following section presents the list and description of the proposed Training Packs, which form the foundation of the training offer planned for ICARUS.

5.2.1. Training Pack 1

Training Pack 1: Sustainable Operations and Efficiency in Circular Processes

Target Profile: Plant Operators and Technicians; typically involved in upcycling activities, process operation, waste transformation, and the implementation of demonstration technologies.

EQF Level: 3–5 (Operational/Technical Levels).

Overall Objective: To ensure operational proficiency and the ability to integrate advanced technologies on the factory floor to optimise resource flows and improve energy efficiency, enabling autonomous execution of tasks.

Detailed Learning Outcomes

Foundations of Industrial Symbiosis (IS): Develop familiarity with the IS approach, including key concepts, methodologies, and the potential for resource reuse and recycling. This foundational understanding is essential for operators to contextualise their activities within broader circular processes.

Operational Efficiency and Systems Optimisation: Implement advanced technologies to optimise resource flows, addressing the gap in Technology Implementation (1). Energy Management of Equipment and Components: Monitor energy consumption efficiently and interpret data to ensure energy savings (2). Apply knowledge of Systems Optimisation and Process Analysis to enhance Energy Efficiency performance (3).

Applied Digitalisation and Monitoring: Use digital tools for process monitoring, a key requirement for tasks related to energy efficiency.

Operational Waste Treatment (Upcycling): Master techniques for the treatment and transformation of waste and by-products, including the optimisation of low-cost technologies such as drying, sieving and milling of Lithium Aluminosilicate Residue (LAR), and the pre-processing of Steel Slag for iron recovery. Understand cellulose recovery from wastewater treatment plants and the management of by-product valorisation processes (e.g., anaerobic digestion for biogas generation).

Priority Justification

Training Pack 1 addresses the critical gap in Technology Implementation, a competency essential for operators to effectively manage advanced technologies and sustainable production methods arising from the Twin Transition (Digital and Green). The aim is to strengthen an already operationally competent workforce so that it can apply, comply with, and optimise circular processes in real time.

5.2.2. Training Pack 2

Training Pack 2: Integrated Resource Management and Process Digitalisation

Target Profile: Engineers and Technical Managers (White-Collar).

EQF Level: 6–7 (Tactical and Technical Specialisation Levels).

Overall Objective: To integrate advanced digital technologies and modelling methodologies in order to optimise upcycling processes in real time and ensure full material traceability through the Digital Product Passport (DPP). The aim is to equip technical leaders to anticipate challenges, optimise systems, and drive systemic change through Circular Economy Business Models and Digital Competences.

Detailed Learning Outcomes

Process Modelling and Optimisation: Model the use value of Steel Slag for process optimisation using statistical and modelling tools. Apply modelling and statistical methodologies to optimise production variables and support data-driven decision-making.

Digital Product Passport (DPP) and Traceability: Identify the requirements and specifications for the Digital Product Passport, ensuring legal compliance and full traceability of ICARUS upcycled products across the value chain.

Advanced Digitalisation and Real-Time Optimisation: Use and apply digital technologies such as Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) to optimise pilot plant data in real time. Process digital data streams and integrate digital platforms to automatically optimise recycling process parameters, ensuring the quality and stability of Secondary Raw Materials (SRMs), such as recovered cellulose.

Detailed Management of Secondary Resources: Develop in-depth knowledge of the processes involved in the treatment and transformation of waste and by-products into new materials. Understand the application of Circular Economy Business Models and their economic implications.

Competences Developed

- Digital Skills (with a focus on DPP, AI/ML/IoT.
- Skills in Process Optimisation (use value modelling).
- Skills in Upcycling Processes (treatment and transformation of materials).

5.2.3. Training Pack 3

Training Pack 3: Standardisation, Certification and Systemic Innovation

Target Profile: Researchers and Trainers (White-Collar).

EQF Level: 6–8

Overall Objective: To address gaps in Systems Thinking and Standardisation Knowledge. This training aims to advance expertise in Industrial Symbiosis (IS) and the Circular Economy (CE). Its ultimate goal is to harmonise technical specifications and integrate certification procedures to facilitate market adoption and replication.

Detailed Learning Outcomes

Regulatory Validation and Compliance (End-of-Waste): Integrate Standardisation and Certification procedures into Research & Development (R&D) practices. Master knowledge of the End-of-Waste (EoW) Statute, including the European Commission's provisions. Acquire knowledge of Certification Methodologies and Legal Product Requirements. Develop the ability to harmonise Technical Specifications.

Development and Application of Sustainable Products: Adapt upcycled product formulations to meet specific technical requirements in Road Surfacing, Landfill and Hydraulic applications. Master knowledge related to the Composition and Development of Products using secondary raw materials. Optimise the formulation of new products (mortars, ceramics) with High-Quality Secondary Raw Materials (SRMs) to meet the technical requirements for strength, durability and performance demanded by the construction industry.

Sustainability Assessment and Environmental Safety: Conduct Environmental Performance Monitoring, including the ability to carry out leaching tests to ensure that upcycled materials (LAR, stabilised slag) do not release toxic elements into the environment. Perform Product Life Cycle Thinking Assessment, including the application of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC).

Systemic Innovation (Mastery Level): Apply Systems Thinking to analyse complex systems and identify interrelationships among different components of Industrial Symbiosis (IS). Achieve a mastery level, denoting individuals with highly advanced knowledge and skills who can take initiative, show adaptability in handling complex problems, lead and train others, and proactively build capacity.

Justification and Critical Emphasis

- The Highest Gap (74%): This Training Pack is prioritised because it addresses the most critical gap: the lack of knowledge regarding applications in Road Surfacing, Landfill and Hydraulic uses. Its aim is to close the key gap between laboratory knowledge and the real-world application of upcycled materials.
- Regulatory Barrier (63%): It addresses the End-of-Waste Statute (63% gap), a major regulatory bottleneck. As ICARUS focuses on waste valorisation, the legal transition from by-product to commercial product depends directly on demonstrating compliance with the European EoW criteria.
- Focus on EQF 6–8 Profiles: This module targets researchers and technical specialists (Engineers/Technical Experts and Researchers/Laboratory Technicians) who must master Environmental Performance Monitoring and scientific and regulatory validation.

5.2.4. Training Pack 4

Training Pack 4: Policy, Regulation and Communication for the Circular Economy

Target Profile: Policymakers and Associations (White-Collar).

EQF Level: 6–8 (Management, Governance and Strategic Levels).

Overall Objective: To develop the capacity to manage the complexity of cross-sectoral cooperation and regulatory governance, while fostering social acceptance and the integration of circular business models. This pack is essential for enabling the development and uptake of Circular Economy business models.

Detailed Learning Outcomes

Environmental Regulation and Compliance: Master the relevant Environmental Regulation (legislation, resource properties and waste-processing technologies). Become familiar with EU, national and regional regulations, legislation and policies on waste management and the circular economy in order to ensure regulatory compliance. Develop the ability to understand the implications of legislative changes, ideas and processes at both national and international level. Apply regulatory frameworks and policy-support tools.

Managing Complexity and Cross-Sectoral Collaboration: Manage the Complexity of Intersectoral Cooperation and act as a bridge between different stakeholders. Develop strong stakeholder-management skills to establish and maintain effective relationships between companies, local institutions and public bodies. Understand that the success of Industrial Symbiosis (IS) depends on collaboration and knowledge sharing between different organisations and stakeholder groups. Develop an entrepreneurial mindset, leadership abilities and change-management skills (soft skills).

Communication, Social Acceptance and Business Models: Raise stakeholder awareness of the importance of Industrial Symbiosis and develop the ability to interact and communicate effectively. Apply communication strategies for the Circular Economy, including the capacity to speak different sector-specific languages or jargon in order to demonstrate expertise and credibility. Understand Circular Economy Business Models and their economic implications. Promote Social Acceptance and foster community awareness. ICARUS will strengthen stakeholder engagement capacities through thematic workshops led by SocialFare to support social-impact assessment.

Competencies Developed

- Interpersonal and Management Skills: Managing the complexity of intersectoral cooperation, collaboration, networking and negotiation, leadership, adaptability and problem-solving.
- Industrial Symbiosis Skills: Environmental Regulation, Circular Business Models, and multidisciplinary knowledge, including economics and business.
- Transversal Skills: Systems Thinking (although explored in greater depth in TP3, it remains essential for the strategic vision required for this profile).

Justification of Priority and Critical Focus

Training Pack 4 is crucial because it addresses moderate to high gaps (32%–37%) in managerial and interpersonal domains—competencies that are essential for transforming intention into implementation. While TP1, TP2 and TP3 focus on technical and validation-related challenges, TP4 addresses governance and social acceptance, which are significant barriers to the effective and sustainable adoption of ICARUS upcycling solutions. Training in this area is vital to ensure that policymakers create a supportive legislative framework for upcycling, including cases such as cellulose recovered from Wastewater Treatment Plants (WWTPs).

5.3. Learning Paths

The Learning Path for the ICARUS project was designed as the central strategic framework of Work Package 10, guiding all capacity-building actions. Its definition is the result of a systematic assessment of skills gaps, the diagnosis of which provides the essential input for developing effective training programmes aligned with the real needs of end users.

Modular Structure and Alignment with the EQF

Based on these priorities, ICARUS structured four Modular Training Packs, designed for distinct user profiles and aligned with the European Qualifications Framework (EQF). The main differentiation is as follows:

- Blue-Collar Profiles (EQF 3–5), oriented towards operational and technical functions. Training Pack 1 is targeted at this group, focusing on practical competencies such as Technology Implementation, operation of upcycling processes, and basic digital monitoring.
- White-collar profiles (EQF 6–8), including engineers, technical managers, researchers, trainers and policy makers. Training Packs 2, 3 and 4 aim to deepen analytical, digital, regulatory and strategic skills, from which they can lead innovation, take initiatives and drive systemic transformation.

Integration with the Twin Transition (Green and Digital)

The Learning Path was also designed to directly support the Twin Transition, which is essential for process industries. Digital competences emerge as critical areas:

- Digital Product Passport (DPP), essential for traceability and regulatory compliance.
- AI/ML/IoT, indispensable for real-time optimisation in the pilot plants.

These needs are addressed primarily in Training Pack 2, ensuring that technical professionals acquire the digital capabilities required to validate and scale upcycling processes.

5.3.1. Module 1 (M1)

The structure of the ICARUS Learning Path is based on modularity and on the ability to adapt to different types of delivery, including e-learning, blended (b-learning), and face-to-face formats.

Module 1 — Sustainable Development and Validation of Upcycled Products (associated with Training Pack 3: Standardisation, Certification and Systemic Innovation) has been designed as a top-priority module, targeting the strategic qualification level (EQF 6–8).

Table 9. Module 1 structure

Category	Structure Detail
Associated Training Pack	Training Pack 3: Standardisation, Certification and Systemic Innovation.
Target Profile	White-Collar: Researchers and Trainers, Engineers/Technical Specialists, and Quality and Innovation Managers.
EQF Level	6–8
Suggested Duration	Modular and Flexible (Example: 40 hours – 16 hours synchronous/in-person + 24 hours asynchronous). The final duration will be defined by the University of Lorraine (UL) under Task 10.3.
Teaching Approach	Blended Learning (B-Learning), combining: E-learning (for theoretical concepts, LCA/LCC); Thematic Workshops and In-Person Sessions (for problem-solving and certification).
Priority	Maximum: Close the critical gap between laboratory knowledge and the practical application of upcycled materials in the market.

Table 10. Program content (M1)

Internal Module	Main Topics
M1.1: Fundamentals of Eco-design and SRM Formulation	Knowledge Mastery: Formulation of innovative products based on secondary raw materials. Upcycling strategies for LAR, cellulose, and steel slag in construction materials.
M1.2: Standardisation and Regulatory Compliance	Knowledge of the *End-of-Waste* (EoW) Statute and its provisions for Secondary Raw Materials (SRMs). Harmonisation of technical specifications and integration of certification procedures.
M1.3: Performance Validation and Environmental Safety	Methodologies for Monitoring Environmental Performance (leaching). Assessment of critical parameters in upcycled mortars and ceramics (strength, durability).
M1.4: Systemic Innovation and Life Cycle Analysis	Application of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) to compare upcycled solutions with the state of the art. Systemic Thinking for analysing complex systems and interrelationships within Industrial Symbiosis (IS).

The content focuses on the 74% gap (Sustainable Product Development) and the 63% gap (Standardisation/Quality).

Table 11. Learning outcomes (M1)

Bloom's Taxonomy (Level)	EQF Level	Specific Learning Outcome
Knowledge (Remember/Recognise)	6	Define the End-of-Waste (EoW) Statute and the legal requirements for the commercialisation of SRMs in the EU.
Comprehension (Explain/Interpret)	6–7	Explain the risk factors associated with leaching tests and the importance of monitoring environmental performance.
Application (Use/Adapt)	7	Adapt the formulations of upcycled products (such as mortars and ceramics) to meet specific technical requirements for Road Surfacing, Landfill and Hydraulic Applications.
Analysis (Relate/Structure)	7	Integrate Systemic Thinking to analyse how formulation decisions interrelate with regulation and the product life cycle (LCA/LCC).
Evaluation/Creation (Justify/Propose)	7–8	Integrate Standardisation and Certification procedures into R&D practices, proposing innovative solutions for the replication of SRMs in the market.

Learning Outcomes are defined progressively, aiming to create capacity and leadership.

Table 12. Suggested teaching typology (M1)

Delivery Format	Justification	Content Examples
E-Learning (Asynchronous)	For Knowledge Transfer (Bloom's levels: Knowledge, Comprehension). Allows modular flexibility.	Knowledge pills on the EoW Statute and LCA/LCC methodologies; detailed descriptions of SRM composition (LAR, slag).
In-Person Sessions / Webinars (Synchronous)	For Application and Analysis (Bloom's levels: Application, Analysis). Essential for engaging stakeholders.	Co-creation workshops and problem-solving sessions focused on adapting product formulations (74% skills gap). Q&A sessions with experts in Standardisation and Certification.
Problem-Based Learning (PBL)	For Evaluation and Creation, where participants solve complex scenarios.	Case study on Leaching Tests for materials from Demo Case 1 (LAR), where trainees apply environmental analysis to validate safety and EoW compliance.

The development of training materials (Task 10.3) will be led by the University of Lorraine (UL), using learner-centred methodologies such as gamification and knowledge pills.

The structure of Module 1 establishes a comprehensive and strategically aligned learning framework that directly responds to the most critical skills gaps identified in the ICARUS assessment. By integrating advanced technical content, regulatory knowledge, systemic thinking, and practical application, the module ensures that participants progress from foundational understanding to high-level mastery in upcycled product validation and circular innovation. Its blended and modular delivery enables flexibility while maintaining depth, ensuring that white-collar professionals at EQF Levels 6–8 acquire the expertise required to bridge the gap between laboratory research and market-ready solutions. Overall, Module 1 functions as a cornerstone of the ICARUS Learning Path, equipping future leaders with the competencies necessary to drive compliant, sustainable, and scalable upcycling practices across process industries.

5.3.2. Module 2 (M2)

Module 2 plays a central role in supporting the Twin Transition (Green and Digital) by focusing on the advanced competencies required to ensure the optimisation and traceability of ICARUS upcycling processes. Aimed at EQF Level 6–7 profiles, this module directly addresses the most critical gaps identified in Digital Skills and Process Optimisation, equipping professionals with the technical and analytical capabilities needed to operate, monitor, and improve integrated digital systems. The following section presents the structured proposal for this priority module, clearly outlining its components, objectives, and strategic contribution to the project.

Table 13. Module 2 structure

Category	Structure Detail
Associated Training Pack	Training Pack 2: "Integrated Resource Management and Process Digitalisation".
Target Profile	White-Collar: Engineers and Technical Managers.
EQF Level	6–7
Suggested Duration	Modular and flexible. The duration will be adapted to the delivery format.
Teaching Approach	Blended Learning (B-Learning), combining e-learning (digital concepts) with Problem-Based Learning and Workshops (for modelling and DPP).
Priority	High: Addresses the major gaps in Process Modelling (63%) and DPP (53%).

Table 14. Program content (M2)

Internal Module	Main Topics	Addressed Gap
M2.1: Digital Product Passport (DPP) and Traceability	Identification of DPP requirements and specifications. Ensuring legal compliance, traceability, and sustainability of upcycled products.	DPP (53% perceived gap).
M2.2: Use Value Modelling and Optimisation	Use of statistical and modelling methodologies and tools (e.g., MARS). Modelling the use value of Steel Slag for process optimisation.	Steel Slag Modelling (63% perceived gap).
M2.3: Real-Time Optimisation (AI, ML, IoT)	Application of Artificial Intelligence (AI), Machine Learning (ML), and Internet of Things (IoT) for real-time data flow optimisation.	Digital Skills (AI/ML/IoT) (47% perceived gap).
M2.4: Advanced SRM Management	Mastery of detailed knowledge of Waste and By-product Treatment and Transformation processes. Integration of Circular Economy business models.	Waste and By-product Treatment and Transformation (53% perceived gap).

Table 15. Learning outcomes (M2)

Bloom's Taxonomy (Level)	EQF Level	Specific Learning Outcome
Knowledge (Define/Describe)	6	Define the technical and operational requirements for Steel Slag Modelling and for Waste and By-product Treatment processes.
Understanding (Explain/Interpret)	6	Explain how digital technologies (AI, IoT) affect the industrial value chain and process optimisation in energy-intensive industries, supporting the Twin Transition.
Application (Use/Apply)	6–7	Use digital tools and ML algorithms for real-time optimisation of process parameters, ensuring the quality and stability of SRMs such as recovered cellulose.
Analysis (Model/Analyse)	7	Model the use value of steel slag to estimate its potential as a substitute in sintering plants. Identify the requirements and specifications of the Digital Product Passport (DPP) to ensure compliance.
Evaluation/Creation (Propose/Develop)	7	Develop and integrate digital platforms, and propose Circular Economy Business Models that use new digital and technical competencies to drive systemic change.

The module aims to develop the ability to anticipate, optimise and drive systemic change, through a progression from EQF level 6 to level 7 in digital and technical skills.

Table 16. Suggested teaching typology (M2)

Delivery Format	Justification	Content Examples
Advanced E-Learning (Asynchronous)	For acquiring knowledge on Digitalisation (AI/ML/IoT) and Process Modelling concepts (Bloom's Level: Knowledge, Understanding).	Courses on DPP requirements (Task 2.5) and knowledge pills on integrating optimisation algorithms into the cloud platform.
Thematic Workshops (Synchronous)	For the Analysis and Application of complex models. Focused on specific demonstration cases (Demo Cases 2 and 3).	Practical modelling sessions using Steel Slag data. Discussion and definition of DPP requirements.
Problem-Based Learning (PBL)	For the Evaluation and Creation of new solutions. Engineers work on real optimisation problems.	Solving quality-failure scenarios for SRMs (cellulose) and applying AI/ML to automate the optimisation of recycling parameters.

The highly technical and digital nature of Module 2 requires formats that allow practice with data and simulations, typically offered by a Blended Learning model.

Module 2, therefore, consolidates the essential digital, analytical, and technical competencies required to ensure the effective implementation of ICARUS upcycling processes. By addressing the most significant gaps in DPP compliance, process modelling, and real-time optimisation, the module equips engineers and technical managers with the capacity to operate integrated digital systems and support the Twin Transition. Its blended structure, combining advanced e-learning, data-driven workshops, and problem-based learning, ensures the practical application of concepts and the development of higher-level skills aligned with EQF 6–7. As a result, Module 2 provides a coherent and future-oriented framework that strengthens industrial resilience and enables systemic innovation within circular value chains.

5.3.3. Module 3 (M3)

This Module 3 represents the most advanced level of the ICARUS competence pyramid, designed to equip Researchers and Trainers (EQF 7–8). Its structure has been developed to build a combination of technical mastery, systemic vision, and regulatory capability, all essential competencies for transforming scientific knowledge into validated, certified, and market-ready upcycling solutions.

The module directly addresses the most critical gaps identified in the project — the lack of skills in Applications for Pavements, Landfills and Hydraulics (74%) and in Standardisation, Certification and End-of-Waste Status (63%). These gaps constitute the main barriers to the replication and uptake of ICARUS technologies, as they determine the ability to demonstrate technical performance, ensure environmental safety, and prove legal compliance. Module 3 is therefore structured to enable high-level professionals to develop autonomy and leadership in the scientific and regulatory validation of High-Quality Secondary Raw Materials (SRMs), ensuring their effective transition from the laboratory to industrial and real-market applications.

Table 17. Module 3 structure

Category	Structure Detail
Associated Training Pack	Training Pack 3, "Standardisation, Certification and Systemic Innovation".
Target Profile	White-Collar: Researchers and Trainers, Engineers/Technical Specialists, and Quality and Innovation Managers.
EQF Level	7–8
Suggested Duration	Modular and flexible.
Teaching Typology	Blended Learning (B-Learning). This is the most suitable format for integrating LCA/LCC theory with the application of certification procedures.
Priority	Maximum: Close the 74% gap in Construction Applications (Pavements, Landfills and Hydraulics).

Table 18. Program content (M3)

Internal Module	Main Topics	Critical Gaps/Focus
M3.1: Sustainable Product Validation	Adaptation of SRM formulations (LAR, Slag, Cellulose) to meet specific technical requirements in Pavements, Landfills and Hydraulic applications.	Construction Applications (74% gap).
M3.2: Compliance and Standardisation (Quality)	Mastery of End-of-Waste (EoW) status requirements (including leaching). Certification methodologies and legal product requirements.	EoW and Environmental Monitoring (63% gap).

M3.3: Life Cycle Analysis	Application of Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) to evaluate the sustainability and economic return of ICARUS solutions.	Product Life Cycle Thinking Assessment.
M3.4: Leadership in Systemic Innovation	Application of Systems Thinking to analyse complex systems and interrelations in IS/CE. Ability to proactively build capacity and lead change.	Systems Thinking.

The content of this module is designed to harmonise technical specifications and integrate certification procedures into R&D practices.

Table 19. Learning outcomes (M3)

Bloom's Taxonomy (Level)	EQF Level	Specific Learning Outcome
Knowledge (Master/Recognise)	7	Master knowledge on the Composition and Product Development of secondary raw materials and the associated Standardisation requirements.
Understanding (Explain/Interpret)	7	Carry out Environmental Performance Monitoring, interpreting leaching test results to ensure compliance with EoW standards.
Application (Adapt/Perform)	7–8	Adapt SRM formulations (LAR, Slag, Cellulose) to meet specific technical requirements for strength, durability, and performance in Hydraulic and Pavement Applications.
Analysis (Assess/Compare)	8	Perform Product Life Cycle Thinking Assessment (LCA/LCC), analysing and comparing the environmental and economic performance of new upcycling solutions against the status quo.
Evaluation/Creation (Harmonise/Lead)	8	Integrate Standardisation and Certification procedures into R&D practices and harmonise technical specifications to support market replication, leading systemic change.

Outcomes aim to progress knowledge (EQF 7–8), allowing trainees to demonstrate initiative and adaptability to complex problems.

Table 20. Suggested teaching typology (M3)

Delivery Format	Justification	Content Examples
E-Learning (Asynchronous)	For acquiring specialised technical knowledge in LCA/LCC, Regulation, and EoW Status.	Content on LCA/LCC inventories and data frameworks (Task 5.1/5.2).
In-Person Sessions / Problem-Based Learning (Synchronous)	For the Application and Validation of the 74% gap (Pavements/Landfills). Trainees must solve formulation and safety problems.	Workshops focused on leaching tests (Environmental Monitoring) for SRMs (LAR, Slag) and analysis of laboratory results.
Advanced PBL / Co-Creation	For achieving level progression (EQF 8), with a focus on Systemic Innovation and Standardisation.	Case studies on integrating certification procedures (related to the DPP) into new products, and the application of Systems Thinking.

This module requires formats that simulate the R&D environment and the rigour of regulatory validation.

Module 3, therefore, establishes the highest level of training within ICARUS, consolidating the scientific, regulatory and systemic innovation capabilities necessary to validate and integrate high-quality SRMs. By combining advanced technical content with rigorous assessment and certification practices, the module empowers specialists to bridge the gap between research results and market deployment. Its focus on harmonised specifications, environmental compliance and system-level leadership ensures that participants are prepared to guide the safe, standardised and scalable adoption of ICARUS technologies in industrial and construction applications.

5.3.4. Module 4 (M4)

This module is the gateway to the ICARUS Learning Path and aims to prepare factory floor and technical staff (blue-collar workers) to consistently and safely perform operations associated with Industrial Symbiosis (IS) and Energy Efficiency (EE). The content is structured to develop practical and technical skills that enable participants to understand processes, operate equipment efficiently, and support the daily implementation of the solutions developed in the project. The module promotes clear progression: from an initial level of proficiency (Basic Actor/Practitioner, EQF 1–2) to an Operational Specialist level (EQF 3–5), enabling workers to perform sustainability-related tasks with greater autonomy, precision and responsibility.

Table 21. Module 4 structure

Category	Structure Details
Associated Training Pack	Training Pack 1, "Sustainable Operations and Efficiency in Circular Processes".
Target Profile	Blue-Collar: Plant Operators and Technicians (EQF 3–5).
EQF Level	3–5 (Operational/Technical Levels: Practitioner to Expert proficiency).
Suggested Duration	Modular and flexible.
Teaching Type	E-learning / Vocational Education and Training (VET), ideally with a strong field-practice component and interaction with real technical equipment.
Priority	High: Address the gap in Technology Implementation (37% of respondents) to improve operational efficiency and optimise resource flows.

Table 22. Program content (M4)

Internal Module	Main Topics	Implementation Focus
M4.1: Introduction to IS and EE Fundamentals	Basic concepts of Industrial Symbiosis (IS). Energy Efficiency (EE) principles: using less energy to perform the same tasks.	Introduction to core concepts and methodologies for carrying out daily tasks.
M4.2: Operational Waste Management (Upcycling)	Knowledge of Waste and By-product Treatment and Transformation techniques. Optimisation of low-cost technologies (drying, screening, grinding of LAR; pre-processing of Steel Slag).	Focus on procedures for Cellulose Recovery from WWTPs and management of by-product valorisation (e.g., anaerobic digestion for biogas).
M4.3: Operational Optimisation and Digitalisation	Implementation of technologies to optimise resource flows. Use of digital tools for process monitoring. Efficient management and measurement of energy consumption data (energy management).	System optimisation and process analysis. Use of real-time data to optimise resource use.
M4.4: Operational Soft Skills	Effective management of task diversity. Knowledge of Sustainability and a systematic, diligent work approach.	Focus on functional skills such as Project Planning and Monitoring, essential for EE assessments.
The content of this module focuses on translating IS and EE concepts into daily practice on the factory floor, with an emphasis on process optimisation and secondary resource management (SRMs).		

Table 23. Learning outcomes (M4)

Bloom's Taxonomy (Level)	EQF Level	Specific Learning Outcome
Knowledge (Recognise/Recall)	3	Recall the core concepts of Industrial Symbiosis (IS) and define the concepts of Energy Efficiency (EE) and Resource Recovery.
Understanding (Explain/Summarise)	3–4	Explain the importance of energy data measurement for savings and describe the waste treatment flow (e.g., drying, sieving) to obtain SRMs.
Application (Use/Implement)	4–5	Implement advanced technologies on the shop floor to optimise resource flows, and use digital tools for process monitoring.
Analysis (Manage/Analyse)	5	Effectively manage the diversity of tasks and analyse the potential for efficiency improvements in operational processes (System Optimisation).

The results aim to raise the level of operator skills, allowing them to act autonomously (Practitioner or Expert), especially in energy efficiency and implementation of new technologies.

Table 24. Suggested teaching typology (M4)

Delivery Format	Justification	Content Examples
Vocational Education and Training (VET)	Development of Technical and Operational Skills and Energy Efficiency through vocational training and workplace learning.	Intensive simulation and interaction with real technical equipment (e.g., reactors, RBF filters for cellulose) to transfer theoretical knowledge to practical situations.
E-Learning / Microlearning (Asynchronous)	For the introduction of IS and EE concepts and the use of basic digital tools (Bloom's Level: Knowledge).	Knowledge Pills (KPM) on basic understanding of IS and safe handling of waste (LAR, Slag).
On-the-Job Training (OJT)	Essential for implementing technologies and optimising systems in operational environments.	Monitoring gas/energy management KPIs. Managing change and adapting to new operational practices.

Training for the Blue-Collar profile must prioritise practice (hands-on field training) and vocational education (VET).

Module 4 establishes the foundational skills required for factory floor and technical staff to actively contribute to the ICARUS project's sustainability objectives. By combining theoretical knowledge with hands-on practice, participants gain a solid understanding of Industrial Symbiosis (IS), Energy Efficiency (EE), and the management of secondary resources (SRMs). The module ensures that trainees progress from basic awareness to operational expertise (EQF 3–5), enabling them to perform daily tasks autonomously, efficiently, and safely. Emphasis on digital tools and real-time monitoring allows participants to implement and optimise resource flows, enhancing both environmental and operational performance.

Furthermore, Module 4 equips participants with essential soft skills, including task management, systematic work approaches, and project monitoring, which complement technical competencies and support continuous improvement. Through a blend of VET, e-learning, and on-the-job training, the module translates sustainability concepts into practical actions, bridging the gap between knowledge and operational application. As a result, blue-collar staff are empowered to take initiative, adapt to new technologies, and contribute meaningfully to energy-efficient and circular industrial practices, laying the groundwork for higher-level competence in the ICARUS Learning Path.

5.3.5. Module 5 (M5)

Module 5 is essential for training professionals in Governance and Strategy, addressing non-technical factors — such as regulatory, social and communication aspects — that often represent barriers to the large-scale implementation of Industrial Symbiosis (IS). This module is especially relevant for managers and decision-makers, as it focuses on the development of soft skills, leadership competencies and regulatory knowledge, areas identified as significant gaps in the project (37% perceived lack). By strengthening these capabilities, the module enables professionals not only to understand the institutional and social challenges of IS, but also to lead its strategic and sustainable adoption within organisations.

Table 25. Module 5 structure

Category	Structure Details
Associated Training Pack	Training Pack 4, "Policy, Regulation and Communication for the Circular Economy".
Target Profile	White-Collar: Policy Makers, Associations, and Project Managers.
EQF Level	6–8 (Management, Governance, and Strategy Levels).
Suggested Duration	Modular and Flexible.
Teaching Type	Blended Learning (B-Learning) / Thematic Workshops. Focused on stakeholder engagement and co-creation.
Priority	High: Develop skills in Environmental Regulation and Stakeholder Communication. Address the complexity of cross-sectoral cooperation (37% perceived gap).

Table 26. Program content (M5)

Internal Module	Main Topics	Addressed Gaps / Critical Focus
M5.1: Environmental Regulation and Frameworks	Master applicable Environmental Regulation (laws, resource properties, EoW). Apply regulatory frameworks and policy support tools.	Environmental Regulation (37% gap).
M5.2: Managing Cross-Sectoral Complexity (IS)	Manage the complexity of cross-sectoral cooperation and regulatory oversight. Promote the importance of Industrial Symbiosis (IS).	Cross-Sectoral Cooperation (37% gap).
M5.3: Circular Business Models and Strategy	Understand Circular Economy Business Models and their implications. Develop an entrepreneurial and leadership mindset.	Development of Circular Business Models.
M5.4: Communication and Social Acceptance	Apply communication strategies for the Circular Economy. Develop stakeholder engagement skills through thematic workshops (Task 10.6), led by SocialFare, to assess social impact.	Stakeholder Communication. Social Acceptance.
The main content focuses on legislation, policy support tools and communication strategies.		

Table 27. Learning outcomes (M5)

Bloom's Taxonomy (Level)	EQF Level	Specific Learning Outcome
Knowledge (Master/Recognise)	6	Master applicable Environmental Regulation, including legislation on waste management, energy, and CO2 emissions.
Understanding (Explain/Interpret)	6–7	Understand Circular Economy Business Models and their economic implications for the replication of ICARUS solutions.
Application (Apply/Manage)	7	Manage the complexity of cross-sectoral cooperation and apply effective communication strategies to raise stakeholder awareness of IS.
Analysis (Analyse/Evaluate)	7–8	Analyse regulatory frameworks and support policies to identify barriers (e.g., the regulatory gap for cellulose) and propose policy advocacy measures.
Evaluation/Creation (Lead/Propose)	8	Lead the development of Circular Business Models and propose social mitigation measures through Social Impact Assessment (SIA), fostering acceptance of new products.

The results of Module 5 aim to train leaders capable of influencing the regulatory and social environment, with Leadership being the most significant causal factor in IS.

Table 28. Suggested teaching typology (M5)

Delivery Format	Justification	Content Examples
E-Learning (Asynchronous)	Acquisition of knowledge on regulatory frameworks (e.g., legislation on waste & energy management & CO2 emissions) and Circular Business Model concepts.	Theoretical content on Environmental Regulation.
Thematic Workshops (Synchronous)	Essential for managing cross-sectoral complexity and stakeholder engagement. Led by SocialFare.	Co-creation workshops using tools like MIRO to inform Social Impact Assessment and define the Business Model.
Problem-Based Learning (PBL) / Simulation	Regulatory crisis simulations (e.g., barriers to EoW for WWTP Cellulose) for applying policy support tools.	Analysis of Critical Success Factors (CSFs) and causal relationships (DEMATEL) to determine where Leadership (causal CSF) should act to generate impact.

This package, which deals with engagement and strategy, uses interactive and co-creation formats.

Module 5 equips managers, policy makers, and project leaders with the knowledge and skills necessary to navigate the non-technical challenges of Industrial Symbiosis (IS). By combining regulatory expertise with a deep understanding of Circular Economy business models, this module ensures that participants can identify and address institutional, social, and policy barriers to implementation. Through targeted learning outcomes—ranging from mastering environmental legislation to analysing regulatory frameworks—professionals develop the capability to influence both organisational strategy and sectoral practices, bridging gaps that have previously limited the adoption and replication of ICARUS solutions.

Furthermore, the module emphasises leadership, stakeholder engagement, and social acceptance as critical drivers for systemic change. Interactive formats, including thematic workshops and problem-based simulations, allow participants to apply these skills in realistic scenarios, reinforcing their ability to manage complex, cross-sectoral challenges. By the end of the module, participants are prepared to lead the development of circular business models, implement policy advocacy measures, and foster social acceptance, ensuring that IS initiatives are not only technically feasible but also strategically and socially embedded within their operational contexts.

6. Conclusions

The analysis carried out under Deliverable D10.1 provides a solid foundation for the capacity-building and standardisation framework of the ICARUS project. This work made it possible to identify and characterise the different user groups, map their current competences, and systematically assess the existing gaps. As a result, a comprehensive and well-substantiated understanding of the training needs required to support the green and digital transition of process industries was achieved.

The results indicate that the most critical training needs are concentrated in three key areas: sustainable product development, industrial digitalisation, and material recycling and valorisation processes. These areas reflect the main challenges faced by companies within the context of Industrial Symbiosis (IS) and the Circular Economy (CE), which demand the integration of technical, digital, and regulatory skills. In particular, the analysis highlights gaps related to knowledge of product applications, compliance with End-of-Waste (EoW) regulation, and the use of advanced digital tools, such as the Digital Product Passport (DPP). These aspects underline the urgency of implementing targeted and specialised training actions.

The learning paths and training packs defined in D10.1 offer a structured, modular, and flexible response to these needs. Their design has been developed to suit different professional profiles — blue-collar (operational/technical) and white-collar (management/engineering) — and is fully aligned with the levels defined in the European Qualifications Framework (EQF). These learning paths will serve as an operational basis for the design, implementation, and evaluation of the training activities foreseen in the next phase of WP10, ensuring coherence, applicability, and tangible impact within the industrial contexts involved.

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8. Annex A: Survey of professional skills

Professional skills survey as part of the ICARUS project

Dear participant, this questionnaire consists of 24 questions and should take between 5 and 8 minutes to complete. Your participation is essential to help us analyse the need for professional skills in industrial symbiosis as part of the development of the ICARUS project and to map the stakeholders who could benefit from the results achieved in the project. There are no right or wrong answers. What matters is your perception. Thank you in advance for your cooperation.

Informed, Free and Clarified Consent. Your participation is voluntary, and you have the right not to participate. If you decide to take part in this survey, it is important that you know that you can withdraw at any time without any consequences for you.
Your responses will be kept confidential and anonymised. The data collected will be used only within the scope of the ICARUS project. I agree to participate in the survey under the terms outlined above.

Section 1 - This section seeks to characterise your institution so that we can obtain detailed information about the intentions of the ICARUS project.

1.1) Institution Name:

1.2) Type of Institution (you can tick more than one option):

( ) Public Institution
( ) Private Company
( ) University
( ) Vocatioanl education and training (VET) provider
( ) Non-governmental organisation
( ) International association
( ) National association
( ) Other:

1.3) Sector your institution operates in (you can tick more than one option):

( ) Energy & Utilities
( ) Transport & Logistics
( ) Industrial Manufacturing
( ) Information & Communication Technology
( ) Media & Communications

( ) Public Services
( ) Education & Training
( ) Research & Development
( ) Other: __________

1.4) Type of acitivty

( ) Academic training
( ) Lifelong learning / Professional training
( ) E-learning
( ) Research, Development and Innovation
( ) Standardisation and policy development
( ) Technology support centre
( ) Chemical manufacturing
( ) Ceramic manufacturing
( ) Cement and concrete production
( ) Steelmaking
( ) Glass
( ) Pulp and paper processing
( ) Food production
( ) Liquid Natural Gas
( ) Biofuels
( ) Petrochemical
( ) Production of PCC (precipitated calcium carbonate)
( ) Non-ferrous metal processing
( ) Metals
( ) Solar (energy generation)
( ) Wind (energy generation)
( ) Water (energy generation)
( ) Wastewater treatment
( ) Urban waste management
( ) Industrial recycling
( ) Construction material production
( ) Construction sector (housing & infrastructure)
( ) Airports
( ) Ports
( ) Road transport
( ) Maritime transport
( ) Logistics
( ) Mobility
( ) Project Developers (EU / International)
( ) Oil Company
( ) Editorial
( ) TV

( ) Social networks
( ) Information technology
( ) Other:

1.6) Number of workers/employees:
open question
1.7) Year of establishment (example: 1975):
open question
1.8) Country:
( ) Austria
( ) Belgium
( ) Bulgaria
( ) Croatia
( ) Cyprus
( ) Czechia
( ) Denmark
( ) Estonia
( ) Finland
( ) France
( ) Germany
( ) Greece
( ) Hungary
( ) Ireland
( ) Italy
( ) Latvia
( ) Lithuania
( ) Luxembourg
( ) Malta
( ) Netherlands
( ) Poland
( ) Portugal
( ) Romania
( ) Slovakia
( ) Slovenia
( ) Spain
( ) Sweden
( ) United Kingdom
Other:
1.6) Contact name:
open question

1.7) E-mail:
open question
1.8) Phone Number (optional):
open question
1.9) Institutional Website:
open question

Section 2 – This section seeks to identify your institution's interest in becoming a collaborator in the ICARUS project.
2.1) Has your institution been involved in any industrial symbiosis projects (past or present)?
Yes ( ) No ( ) N/A ( )
2.2) Would your institution like to participate/collaborate with the ICARUS project?
Yes ( ) No ( )
2.3) Would your institution like to collaborate with the ICARUS project by sharing knowledge and practices?
Yes ( ) No ( )
2.4) If you answered yes to the previous question, which areas of knowledge would your institution be interested in sharing as part of the ICARUS project? (You can indicate more than one option)
open question
2.5) Would your institution be interested in participating in the training pilots the ICARUS project will develop?
Yes ( ) No ( )
Section 3 - This section is crucial for the ICARUS project, as it seeks to identify the professional skills that need to be developed to respond to the industrial sector's new needs in the context of industrial symbiosis (You can tick more than one option).
3.1) Industrial Symbiosis Skills - Based on your perceptions, please select the skills you believe are most lacking in professional knowledge within your institution.
( ) **Systemic Thinking** - analyse complex systems and identify the interrelationships between different components.
( ) **Understanding Industrial Symbiosis and Energy Efficiency** - industrial symbiosis concepts, principles, and energy efficiency.
( ) **Environmental Regulation** - current environmental laws, regulations, resource properties, and waste processing technologies.
( ) **Circular Economy and Business Models** - circular business models and their practical applications, understanding the economic implications of industrial symbiosis.
( ) **Ecodesign and Life Cycle Assessment** - ecological design and product life cycle assessment.

3.2) Interpersonal and Management Skills - Based on your perceptions, please select the skills you believe are most lacking in professional knowledge within your institution.
( ) **Multidisciplinary (knowledge in engineering, environmental management, economics, social sciences…)** - ability to integrate different areas of knowledge through a holistic approach.
( ) **Entrepreneurial Mindset** - ability to approach proactively and innovatively in the search for solutions.
( ) **Problem Resolution/Solving** - ability to identify and solve complex problems.
( ) **Time and Change Management** - ability to effectively manage time and change.
( ) **Flexibility and Adaptability** - ability to adjust to unexpected challenges and developments by thinking creatively and finding innovative solutions to problems.
( ) **Leadership and Teamwork** - ability to lead and collaborate with others in implementing projects and solutions.
( ) **Communication** - ability to communicate clearly and transparently with various stakeholders.
( ) **Ethics and Objectivity** - ability to act with neutrality, objectivity, professionalism, and attention to ethical issues.
( ) **Managing a Diversity of Tasks** - ability to adapt to different responsibilities and processes.
( ) **Ability to Manage the Complexity of Intersectoral Cooperation** - ability to manage the complexity of intersectoral cooperation.
( ) **Importance of Industrial Symbiosis** - ability to manage and sensitise people on the significance of industrial symbiosis.
3.3) Technical and Operational Skills - Based on your perceptions, please select the skills you believeare most lacking in professional knowledge within your institution.
( ) **Product Composition and Development** - ability to compose and develop innovative products based on secondary raw materials.
( ) **Application of Innovative Management Tools** - ability to apply creative tools to promote the transition to a circular economy.
( ) **Implementation of Technologies** - ability to integrate advanced technologies to improve operational efficiency, identify opportunities and optimise resource flows.
3.4) Digital Skills - Based on your perceptions, please select the skills you believe are most lacking in professional knowledge within your institution.
( ) **Digital Skills** - ability to use and apply digital technologies as facilitators: artificial intelligence (AI), machine learning (ML) and Internet of Things (IoT)…
( ) **Digital Product Passport (DPP)** - ability to use DPP to facilitate product recycling, reuse and repair.
3.5) Skills in Upcycling Processes - Based on your perceptions, please select the skills you believeare most lacking in professional knowledge within your institution.
( ) **Treatment and Transformation of Waste and By-Products** - detailed knowledge of the treatment processes and transformation of waste/by-products into new materials.
( ) **Lithium Aluminosilicate Waste (LAR)** - knowledge and mastery of techniques for purifying, improving and packaging waste to be reused in construction and ceramic applications.
( ) **Cellulose from Urban and Industrial Waste** - knowledge of technologies for recovering cellulose from wastewater treatment plant effluents and absorbent hygiene products.
( ) **Steel Slag** - knowledge of slag stabilisation methods, including controlled hydration and carbonation, and identifying ways to produce precipitated calcium carbonate (PCC) from slag for construction applications.
3.6) Skills in Sustainable Product Development - Based on your perceptions, please select the skills you believe are most lacking in professional knowledge within your institution.
( ) **Innovative Ceramic Products** - Knowledge of how to replace primary raw materials, replacing them with aggregates using Lithium Aluminosilicate Waste.

( ) **Road Surfacing, Landfill and Hydraulic Application**s - knowledge about how to tailor and adapt product formulations to meet the requirements of different applications.
3.7) Skills in Quality and Performance Assessment - Based on your perceptions, please select the skills you believe are most lacking in professional knowledge within your institution.
( ) **Laboratory Tests and Quality Assessment**s - knowledge about recovered materials and final products, which includes the assessment of physical and chemical stability, density, rupture, hardness, colourimetry and water absorption of ceramic materials;
( ) **Assessment in the Context of Civil Construction: Performance of Products/Materials** - knowledge about evaluating parameters such as resistance to improvement, press time and expansion of mortars with upcycling materials;
( ) **Monitoring the Environmental Performance of Products** - knowledge about carrying out leaching analyses to ensure that they do not release toxic elements into the environment.
3.8) Skills in Process Optimisation - Based on your perceptions, please select the skills you believe are most lacking in professional knowledge within your institution.
( ) **Methodologies and Tools** - knowledge of statistical methods and modelling tools to analyse the results of testing campaigns and optimise production variables and parameters.
( ) **Steel Slag** - modelling knowledge to estimate the use value of the material as an alternative to other raw materials in sintering plants.
3.9) Skills in Standardisation and Normalisation - Based on your perceptions, please select the skills you believe are most lacking in professional knowledge within your institution.
( ) **Harmonisation of Technical Specifications** - Knowledge in harmonising technical specifications;
( ) **Certification Methodologies and Legal Requirements** - Knowledge of certification methodologies and legal product requirements;
( ) **'End of Waste' Statute** - Knowledge of the European Commission's End-of-waste (EoW) provisions.
Thank you for taking the time to fill out our questionnaire! To stay up to date with the latest updates from the ICARUS project, share your email below to receive the newsletter
*****Reserve space for email*****

9. Annex B: Survey of internal validation of results

This questionnaire will take less than 5 minutes to complete. It aims to validate topic data for WP10 trainings under Task 10.1.

Please, we ask you to identify yourself briefly. Thanks.

1

Contact details

First name

Last name

Company

This section aims to check your level of agreement regarding the ICARUS project's training themes, which stakeholders have indicated as scarce or priority.

On a scale of 1 to 10 (1 = totally disagree and 10 = totally agree), indicate your agreement with the importance of developing training within the ICARUS project on the topics listed below.

2

Environmental Regulation -current environmental laws, regulations, resource properties, and waste processing technologies.

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1: Totally disagree

10: Totally agree

3

Systemic Thinking - analyse complex systems and identify the interrelationships between different components.

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1: Totally disagree

10: Totally agree

4

Importance of Industrial Symbiosis - the ability to manage and sensitise people on the significance of industrial symbiosis.

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1: Totally disagree

10: Totally agree

5

Ability to Manage the Complexity of Intersectoral Cooperation - the ability to manage the complexity of intersectoral cooperation.

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1: Totally disagree

10: Totally agree

6

Implementation of Technologies - ability to integrate advanced technologies to improve operational efficiency, identify opportunities and optimise resource flows.

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1: Totally disagree

10: Totally agree

7

Product Composition and Development - ability to compose and develop innovative products based on secondary raw materials.

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1: Totally disagree

10: Totally agree

8

Application of Innovative Management Tools - ability to apply creative tools to promote the transition to a circular economy.

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1: Totally disagree

10: Totally agree

9

Digital Product Passport (DPP) - ability to identify DPP requirements and specifications, targeting legal compliance as well as product traceability and sustainability.

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1: Totally disagree

10: Totally agree

10

Digital Skills - the ability to use and apply digital technologies as facilitators: artificial intelligence (AI), machine learning (ML) and Internet of Things (IoT).

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1: Totally disagree

10: Totally agree

11

Treatment and Transformation of Waste and By-Products - detailed knowledge of the transformation of waste/by-products into new materials.

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1: Totally disagree

10: Totally agree

12

Steel Slag - knowledge of slag stabilisation methods, including controlled hydration and carbonation, and identifying ways to produce precipitated calcium carbonate (PCC) from slag for construction applications.

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1: Totally disagree

10: Totally agree

13

Road Surfacing, Landfill and Hydraulic Applications - knowledge to adapt product formulations to meet the requirements of different applications.

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1: Totally disagree

10: Totally agree

14

Innovative Ceramic Products - Knowledge of how to replace the primary raw materials, replacing them with aggregates using Lithium Aluminosilicate Waste.

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1: Totally disagree

10: Totally agree

15

Monitoring the Environmental Performance of Products - knowledge about carrying out leaching analyses to ensure that they do not release toxic elements into the environment.

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1: Totally disagree

10: Totally agree

16

Assessment in the Context of Civil Construction: Performance of Products/Materials - knowledge about evaluating parameters such as resistance to improvement, press time and expansion of mortars with upcycling.

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1: Totally disagree

10: Totally agree

17

Steel Slag - modelling knowledge to estimate the use value of the material as an alternative to other raw materials in sintering plants.

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1: Totally disagree

10: Totally agree

18

Methodologies and Tools - knowledge of statistical methods and modelling tools to analyse the results of testing campaigns and optimise production variables and parameters.

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1: Totally disagree

10: Totally agree

19

‘End of Waste’ Statute - Knowledge of the European Commission's End-of-waste (EoW) provisions.

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1: Totally disagree

10: Totally agree

20

Certification Methodologies and Legal Requirements - Knowledge of certification methodologies and legal product requirements.

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1: Totally disagree

10: Totally agree