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Deliverable

D8.2– Skill gap inventory and plan to develop the training curricula

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Executive Summary

Remanufacturing is increasingly recognized as a key strategy for manufacturing industries seeking to enhance resource efficiency, reduce cost, and minimize waste. It plays a vital role in the development of circular supply chains while addressing the growing demand for sustainable manufacturing solutions.

Digital transformation and environmental regulations further accelerate this shift, presenting organizations with the challenge of staying ahead of technological advancements while navigating complex legal and ethical challenges related to human-technology interaction. This has created a need for a highly skilled workforce that is agile enough to adapt to rapid changes in the workplace. In the European manufacturing sector, these challenges are amplified by significant talent gaps and skills shortages due to factors such as an ageing workforce, outdated strategic workforce planning, limitations in Science, Technology, Engineering, Mathematics (STEM) disciplines education and the rapidly evolving nature of work.

Engaging with industrial stakeholders to better understand their competency needs and adapting upskilling and reskilling strategies is essential to address these barriers. This approach will help bridge the skills gap and ensure that Europe's workforce remains competitive and resilient in the face of these challenges.

The objective of the R3-MYDAS project, funded under the Horizon Europe (HORIZON) program, is to develop a multi-actor framework for sustainable circular value chains for the remanufacturing of energy goods at the factory level, leveraging innovative digital technologies within three pilot cases: oil & gas components, e-vehicles batteries and wind turbine gearbox components. A key component of the project is its training strategy, which targets the technical skills gaps in remanufacturing among the project stakeholders (technicians, engineers, and managers).

In alignment with the above objective, Task 8.4 "Training and Skills Enhancing" of WP8 "Exploitation and Trainings" aims to bridge the gap in technical knowledge and competencies necessary for the partner organizations to develop and adopt the R3-MYDAS innovative solutions and design and deliver tailored training programs for the target workforce.

An in-depth skills gap analysis, conducted through desk research and qualitative methods involving industrial and research partners, will inform the development of technical training courses. These courses will include hands-on practical activities, simulation-based learning, and both online and face-to-face sessions leveraging Extended Reality (XR) technologies and innovative instructional methods such as microlearning and gamification. Tailored to address the pilot cases' specific knowledge and skills needs, the training will be delivered within the project duration. Its impact and effectiveness will be evaluated, with the results used to continuously refine and enhance

the training curricula, aiming to guarantee sustainability, engagement and continuity in the training strategies applied to the project.

As will be shown, each demo case requires different skill sets, including advanced additive manufacturing techniques for the remanufacturing of wind turbine gearboxes, as well as quality control strategies and systems integration tools to optimize the remanufacturing workflow of oil & gas components. Lastly, Artificial Intelligence (AI), Machine Learning (ML), data analytics, ethics and legal frameworks applied to Human-Technology Interaction (HTI) also represent a key need along with knowledge of battery engineering for organizations working on circular solutions for EV batteries. To address these skills needs, EITM will involve academic and research institutions from the R3-MYDAS consortium and leverage EITM's existing educational projects (e.g., EITM Academy, a learning platform dedicated to manufacturing, offering top-tier training from Europe’s leading experts from the manufacturing industry).

The training will not only support the upskilling and reskilling of the partners’ workforce but will also present a training framework able to guide organizations willing to improve their capabilities in circular remanufacturing models. Aligning training initiatives with industry needs is therefore a key activity that will significantly contribute to reducing the skills gap in manufacturing and ensuring a future-ready workforce.

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Definitions, Acronyms and Abbreviations

Acronym/ Abbreviation	Title
AI	Artificial Intelligence
AM	Additive Manufacturing
API	Application Programming Interface
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CAPP	Computer-Aided Process Planning
CNC	Computer Numerical Control
CSR	Corporate Social Responsibility
CX	Customer Experience
DfAM	Design for Additive Manufacturing
EIA	Environmental Impact Assessment
ESG	Environmental, Social & Governance
EV	Electric Vehicle
FDM	Fused Deposition Modelling
FEA	Finite Element Analysis
FCE-IAHP	Fuzzy Comprehensive Evaluation-Integrated Analytic Hierarchy Process
HMI	Human-Machine Interaction
HRI	Human-Robot Interaction
HTI	Human-Technology Interaction
HV	High Voltage
HX	Human Experience
ICS	Industrial Control Systems
ICT	Information and Communications Technology
IoT	Internet of Things
IP	Internet Protocol
ISO	International Organization for Standardization
IT	Information Technology
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
MES	Manufacturing Execution Systems
ML	Machine Learning
NLP	Natural Language Processing
PPE	Personal Protective Equipment

Acronym/ Abbreviation	Title
QA	Quality Assurance
QCP	Quality Control Procedures
R&D	Research and Development
RCA	Root Cause Analysis
RTO	Research & Technology Organization
SDLC	Software Development Lifecycle
SLA	Stereolithography
SLAM	Simultaneous Localization and Mapping
SLS	Selective Laser Sintering
SME	Small-Medium Enterprise
SoH	State of Health
SOP	Standard Operating Procedures
SPC	Statistical Process Control
SSH	Social Sciences and Humanities
STEM	Science, Technology, Engineering, Mathematics
UI	User Interface
XR (AR, VR)	Extended Reality (Augmented Reality, Virtual Reality)

Term	Definition
Andragogy	The method and principles of teaching adult learners.
Bloom's Taxonomy	A framework to establish and categorize measurable educational goals.
Learning Outcome	A statement describing what the learner should be able to know, do and understand at the end of the instruction period.
Learning Factory	Realistic manufacturing environments used for training and education purposes.
Microlearning	An educational strategy focusing on delivering content in small units.
Persona	A representation of a specific user to identify their goals, challenges, preferences and professional profile.
Rubric	A tool including grading criteria used to objectively assess performances, assignments, and activities. It usually includes grading ranges and descriptors of performance for each range.
Skills Taxonomy	A hierarchical structure of competency clusters and related skills, abilities and technologies.
Summative Assessment	Summative Assessments are used to evaluate the learning progress and achievement of learning outcomes at the end of a specific instructional period. They differ from formative assessments which are used to assess learning progress during the instructional period.

Term	Definition
	Results could be used to adjust teaching pace and/or content or to give learners feedback on their progress.
Technical Knowledge	Specialized knowledge and expertise to perform specific tasks or use specific tools, technologies or software. This may include proprietary processes or software.

1 Introduction

1.1 Project Information

Despite the multiple advantages of products remanufacturing, being widely recognised as an effective means for transitioning to a more circular economy, there is still need for improved research and experimental observations, to improve traceability and reliability of the final products from end-users' perspectives, as well as enhanced impacts monitoring. The primary R3-Mydas objective is to develop a multi-actor framework, integrating innovative digital technologies (ML for process and quality control, marketplace, graph models for defects detection, digital twins), advanced mechatronics (AM, laser-cladding, automated disassembly/reassembly) and newly developed approaches from SSH (extended TAM/UTAUT models, ethics and legal framework), for functionally, environmentally and economically sustainable circular value chains for remanufacturing of energy goods at the factory level (Oil&Gas crankshafts – demo 1, E-vehicles batteries – demo 2, Wind turbines gearboxes – demo 3).

R3-Mydas will deliver unprecedented impacts throughout the targeted value chains, as follows: up to 60% time reduction in programming for remanufacturing; up to 20% increased product quality; up to 30% rework reduction [Demo 1]; up to 30% improved detection of tiny deviations from normal behaviour; up to 50% faster anomaly localization; up to 30% increase the number of different modality data streams handled; up to 20% faster fusion process [Demo 2]; up to 99% reusage rate; -90% prevention rate; -75% lead time; up to 85% raw material savings potential [Demo 3]. R3-Mydas will deliver a marketplace associating to each remanufactured product or services/component for remanufacturing a Digital Passport-like set of information, ensuring full traceability. Finally, a dedicated training programme will be designed and delivered by EITM, targeting the P R3-Mydas project remanufacturing value chains (100+ training hours and 100+ diverse stakeholders engaged during the Project).

Table 1: The R3-Mydas consortium.

Number[1]	Name	Country	Short name
1(CO)	NETCOMPANY-INTRASOFT SA	Luxemburg	NCI
2	EUROPEAN FEDERATION FOR WELDING JOINING AND CUTTING	Belgium	EWF
3	EIT MANUFACTURING SOUTH SRL	Italy	EITM
4	FLENDER FINLAND OY	Finland	FLE-FI
4.1(AE)	FLENDER GMBH	Germany	FLE
5	AVL LIST GMBH	Austria	AVL

[1] CO: Coordinator. AE: Affiliated Entity. AP: Associated Partner.

Number[1]	Name	Country	Short name
6	TALLERES MECANICOS COMAS SLU	Spain	TMCOMAS
7	SPIN ROBOTICS IVS	Denmark	SPIN
8	ASOCIATION DE INVESTIGACION METALURGICA DEL NOROESTE	Spain	AIMEN
9	LAPPEENRANNAN-LAHDEN TEKNILLINEN YLIOPISTO LUT	Finland	LUT
10	INFORMATION TECHNOLOGY FOR MARKET LEADERSHIP	Greece	ITML
11	DEEP BLUE SRL	Italy	DBL
12	CHAROKOPEIO PANEPISTIMIO	Greece	HUA
13	IKERLAN S. COOP	Spain	Ikerlan
14	ZIKNES TECHNOLOGY SL	Spain	Ziknes
15 (AP)	CSEM CENTRE SUISSE D'ELECTRONIQUE ET DE MICROTECHNIQUE SA - RECHERCHE ET DEVELOPPEMENT	Switzerland	CSEM

1.2 Document Scope

The scope of this document, deliverable 8.2 of the R3-MYDAS project, is to present the results of the initial phase of Task 8.4 "Training and Skills Enhancing". Specifically, this deliverable outlines the methodology, findings, and strategic plans for addressing the skills gaps related to the industrial **remanufacturing area especially energy goods related**, focusing on the technologies and processes developed within the project.

The document aims to:

1. **Identify skills and knowledge gaps**: Highlight the specific technical and strategic competencies required for effective remanufacturing in the project's technical demo cases (Oil & Gas crankshafts, EV batteries, and wind turbine gearboxes) and compare them against the current state of the workforce by conducting a needs assessment to identify the knowledge and skill gaps.
2. **Engage stakeholders:** Incorporate insights from industry experts and training professionals to identify best practices, practical applications and existing materials suitable for the training.
3. **Develop a training plan**: Provide a structured approach for designing curricula that address the identified gaps, including considerations for innovative learning tools such as AI and AR applications.
4. **Provide a framework for delivery**: Propose methods for implementing and evaluating the training programs (i.e., training through various channels, including in-person workshops, webinars, and EITM learning platform Academy, formerly Skills.move) to ensure the effective transfer of skills and knowledge.

This deliverable serves as a groundwork for subsequent activities in Task 8.4, including curriculum development, training delivery, and impact assessment. The methodologies and findings detailed in this document will inform the creation of comprehensive training resources and support the long-term goal of upskilling professionals in remanufacturing processes.

1.3 Document Structure

According to the goal and objectives of the document and especially Task 8.4, this deliverable comprises six chapters as follows:

Chapter 1 introduces the R3-MYDAS project, the objectives and aims of the T8.4 and the purpose of D8.2.

Chapter 2 provides a detailed explanation of the approach and tools used to conduct the needs assessment, engage stakeholders, and identify best practices for training. This chapter includes the data collection methods, such as surveys, interviews, and workshops, and the criteria for analysing skill gaps.

Chapter 3 summarizes the findings of the skills and knowledge gaps identified within the workforce. It outlines the technical and strategic areas requiring development, categorized by business cases (Oil & Gas crankshafts, EV batteries, wind turbine gearboxes).

Chapter 4 presents the framework for the training curricula, detailing the proposed modules, learning outcomes and suggested delivery and assessment methods.

Chapter 5 provides a roadmap for the subsequent activities to be carried out to develop the course content and plan their delivery.

Chapter 6 summarizes the key findings and recommendations and outlines the next steps for advancing the training curricula, testing the materials, and refining the programs based on feedback.

2 Methodology

2.1 Methodological approaches and timeline

This chapter demonstrates the methodological approach to outline actionable strategies to define and measure the skill demands in manufacturing industries and design practical learning paths. The outlined methodology represents the main activities of T8.4 "Training and Skills Enhancing" that will be carried out during the execution phase of the R3-MYDAS project. The success of the task will be measured with the following Key Performance Indicators (KPIs):

- **KPI 1:** >6 training courses developed (at least 2 for each use case).
- **KPI 2:** >100 Training hours (within the project).
- **KPI 3:** Increase workforce acceptance and effectiveness of the training courses (parameters: Trainee satisfaction, at least 4 on a scale of 1-5; Skills development, at least 80% of correct answers at end-of-course test; Transfer of learning, apply at least 75% of the skills and knowledge learned during the training in their daily work).
- **KPI 4:** >45 engaged stakeholders (30 employees, 10 managers, 5 other stakeholders) at training workshops with demo cases and >100 engaged stakeholders through the EITM Academy (formerly Skills.move) learning platform.

The envisioned approach ensures that the identified skills and developed training curricula will fulfil the future workforce needs and facilitate the improvement of sustainable manufacturing across the EU. This methodology is designed to ensure the continuity and scalability of the training solutions beyond the project's lifecycle.

The methodology and approach consist of six interrelated steps, each addressing specific objectives and activities:

<u>Step 1: Skill Needs Assessment</u>

Objectives: Identify and categorize the required skills and knowledge for the remanufacturing processes.

Activities:

1. Comprehensive **literature review** and desk analysis**:**
    - Conduct a detailed review of existing research studies on remanufacturing skill gaps.
    - Identify best practices, standards, and competencies required for remanufacturing within each use case.
2. **Preliminary survey analysis**:
    - Develop and distribute an initial survey to gather general information on current skill sets, industry challenges and emerging needs. The full text of

the survey is available in the Appendix. This survey aimed to prioritize the identified skills through secondary sources according to consortium partners' technical knowledge. For a detailed description of the survey refer to 2.2.2.1.

Timeline: Relevant skills research, survey design and distribution were carried out during the period from M1 to M9.

Step 2: Current State Analysis

Objectives: Assess the current proficiency of the workforce and establish a baseline for skills and knowledge.

Activities: Analysing the survey, interview data and self-assessments to determine the current state of the workforce skills. The following activities were implemented for this phase:

1. **Skills Self-assessment** through a technical survey:
    - Design and distribute a second survey to analyse the proficiency of the workforce on the identified skills based on the first survey results to pinpoint the gaps for each demo case and the skill needs of each partner.
2. Conducting **interviews and workshops:**
    - Engage with industry experts from the project consortium including technical engineers, managers and HR professionals to gather qualitative insights into the skills needs and workforce strengths and weaknesses.
    - Collect data on specific skills required for implementing and advancing remanufacturing technologies within the project and anticipated future needs.

Timeline: The above activities were executed between M10 and M11.

Step 3: Gap Analysis

Objective: Analyse the gaps between current workforce skills and the required skills for remanufacturing.

Activities:

1. **Comparative analysis**:
    - Compare the current state of workforce skills (from Step 2) with the required skills (from Step 1), aiming to identify skill gaps for each business case.
    - Based on the partners' responses, focus on identifying critical gaps, particularly in technical knowledge, practical application, and strategic understanding.
2. **Gap prioritization:**

- Prioritize the identified gaps based on their urgency (as determined by partners), relevance, feasibility and potential impact on successfully implementing remanufacturing technologies (this activity may require further investigation and iterative analysis to reassess priorities and gaps until M24).

Timeline: The analysis of the research results was conducted progressively between M9 and M11. The skills prioritization will continue until M24.

Step 4: Curriculum Development

Objective: Develop training curricula to address the identified skills and knowledge gaps, ensuring alignment with industry needs and project goals.

Activities:

1. **Curriculum framework design:**
    - Identify the key topics to address the prioritized skills gaps, structure key modules and define learning outcomes, ensuring the courses cater to both technical and strategic learning needs.
    - Propose delivery and assessment methods based on the type of knowledge and skills to develop.
2. **Incorporation of existing projects and innovative learning tools:**
    - Identify existing digital courses on the EITM Academy, one of the largest European learning platforms 100% dedicated to manufacturing, designed by leading specialists of the European manufacturing ecosystem to foster innovation and skills preparedness in the current and future workforce.
    - Evaluate the feasibility of integrating AI and AR-supported applications to enhance learning outcomes.
3. **Stakeholder validation:**
    - Present the draft curricula to industry and academic partners to determine specific learning outcomes and request feedback and validation.

Timeline: Activity 1 related to the design of a curriculum framework for the three pilot cases took place between M11 and M12, while activities 2 and 3 will be completed by M14.

Step 5: Training Material Development

Objective: Create comprehensive training materials to support the delivery of the curricula through diverse and accessible channels.

Activities:

1. **Content development:**
    - Identify subject-matter experts among the project consortium and existing educational material to address training demand.

- Involve academic partners like LUT or other partners with training backgrounds to create new sources and/or upgrade the existing ones.
- Develop course materials, including lecture slides, manuals, videos, and interactive simulations, tailored to the technical requirements of each business case.
- Incorporate multimedia resources for online and offline learning formats.
- Design interactive and hands-on modules that simulate real-world scenarios, leveraging XR technologies where applicable.

2. **Delivery platform integration:**
    - Adapt materials for EITM Academy to enable online accessibility.
    - Academic partners like universities in the consortium can integrate the courses into their curriculum.
3. **Pilot testing:**
    - Conduct pilot tests of the training courses with internal project partners and industry stakeholders.
    - Collect participant feedback to refine the content.

Timeline: The development of the training content will be carried out between M14 and will be finalized by M24.

Step 6: Training Implementation and Evaluation

Objectives: Deliver the training programs to target stakeholders, assess their impact and refine materials for maximum effectiveness.

Activities:

1. **Training delivery:**
    - Continue and complete the activities from step 5.
2. **Impact Assessment:**
    - Use surveys, quizzes, and practical evaluations to measure learning outcomes and participant satisfaction.
    - Gather qualitative feedback through interviews and focus groups with trainees.
3. **Continuous Improvement:**
    - Update training materials and curricula based on feedback and assessment results – ensuring that the content and curricula meet the requirements set by the academic partners
    - Ensure iterative improvement to maintain relevance and effectiveness

Timeline: The delivery of the training programs will begin in M25, with some potential technical workshops to be delivered before M24 based on the progress of demo case solutions. Participants are expected to complete training around M32-M34 to allow enough time for feedback collection and implementation.

To establish the foundation for the objectives of Task 8.4, this deliverable, D8.2, focuses on identifying the required skills and knowledge (step 1), assessing the current workforce skill needs (step 2) and, determining the gaps between the current and needed skills (step 3) based on this analysis. Additionally, it also develops the primary framework for training curricula (step 4), which will be expanded upon in subsequent deliverables - D8.4 Training curricula development and assessment – (v1) by month 24 and its updated version (v2) by month 36 as the final output. Therefore, this deliverable presents a description of the activities from steps 1 and 2 in the following section (Skills Needs Assessment Methodology), while the analysis of the research results (step 3) and the preliminary curricula (step 4) are covered respectively in subsequent chapters.

2.2 Skills Needs Assessment Methodology

This section describes the methodology employed to identify the skills gaps and knowledge needs among the R3-MYDAS project partners. Specifically, it describes the rationale for the development and implementation of the activities listed in the previous section (steps 1, 2 and 3). Each activity is presented in detail in the following sections.

2.2.1 Literature Review and Desk Research

The task activities began with a comprehensive literature review of academic journal publications, EU-funded project outcomes, grey literature including dissertations and EU reports on manufacturing, Industry 4.0, green and digital skills, and industry-specific project reports (e.g., battery). Additionally, papers addressing critical challenges for the European labour force, such as skills shortages and mismatches in manufacturing, were reviewed to identify the underlying causes of these issues. The primary objective of the desk research was to identify key insights into skills gaps and future trends to develop a **skills taxonomy**—a hierarchical structure of competency clusters and related skills, abilities and technologies—tailored to the manufacturing sector and the R3-MYDAS stakeholders. The skills taxonomy (see A.1) serves as a foundational framework to guide research activities for the assessment of skills and knowledge gaps among the R3-MYDAS project partners. Given the diverse professional profiles within R3-MYDAS, a skills-based approach for our skills gap analysis—as opposed to a job- or task-based approach—was deemed the most effective starting point for the task, particularly in creating a skills taxonomy. This method emphasizes adaptability and flexibility across roles and applications, as required by the growing demand for flexible work structures in today's organizations [REF-05].

A sample of key sources consulted to identify key domains and skills includes the following:

- Azmat et al. [REF-01] explored the skills gap in the era of industrial digitalization, focusing on Cyber-Physical Systems, Industry 4.0 and Industrial Digitalization.

- Li et al. [REF-12] explored gaps in data science skills and domain knowledge requirements in the manufacturing industry:

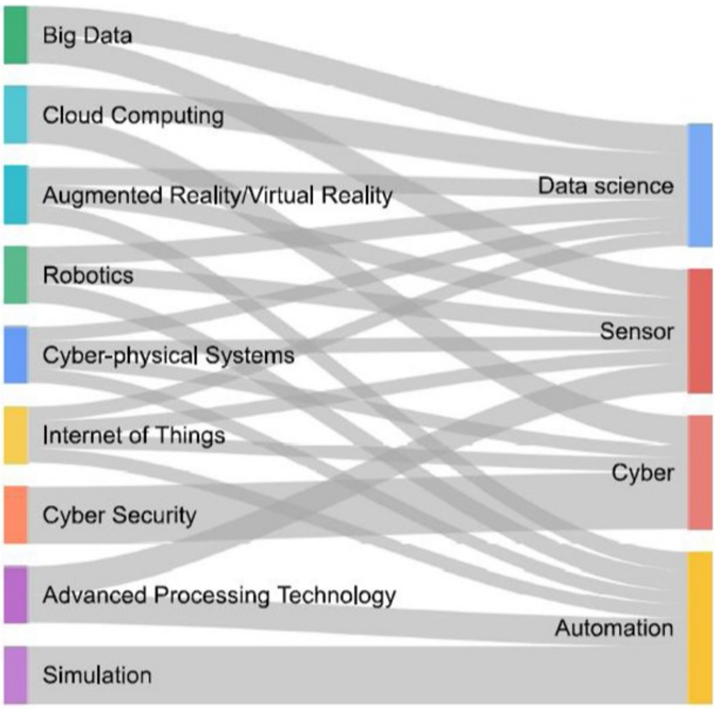

Figure 1: Technology Clusters (adapted from Li et al., 2021).

Technology Cluster	Keyword	Number of Skills and Qualification Retrieved	Example of skills and qualifications
Data Sciences	Data Mining	10	Data Mining, Text Mining, Forecasting, Machine Learning
	Data Management	11	SQL, Relational Databases, Oracle Databases
	Big Data	11	Spark, MapReduce, NoSQL
	Programming languages	11	Python, C#, C++, VB, PERL, C, Java
	Mathematical skills	12	Statistics, Hypothesis Testing, Operation Research, Probability
Automation	Automation	93	Manufacturing Automation, Logistic Automation, Process Automation
	Robotics	17	Robot Framework, Robot Welding, Robotic Programming
Cyber	Cloud	54	Cloud Computing, Cloud Application, Cloud Collaboration
	Cyber	16	Cyber Resilience, Cyber Engineering, Cyber Defense
Sensor	Sensor	16	Sensor Fusion, Image Sensor, Wireless Sensor Network
	Signal	49	Signal Conditioning, Signal Compression, Signal handling

Figure 2: Skills for Technology Clusters (Adapted from Li et al., 2021).

- Skevi et al. [REF-15], who focused on the root causes of skills gaps in manufacturing and proposed a flexible and agile approach to skilling workers for European factories.
- The Alliance for Batteries Technology, Training and Skills (ALBATTS) project [REF-08], funded by the Erasmus+ Sector Skills Alliances Programme. This project aims to explore a much-needed sectoral skills strategy to support the development of skills and job roles across the battery life cycle:

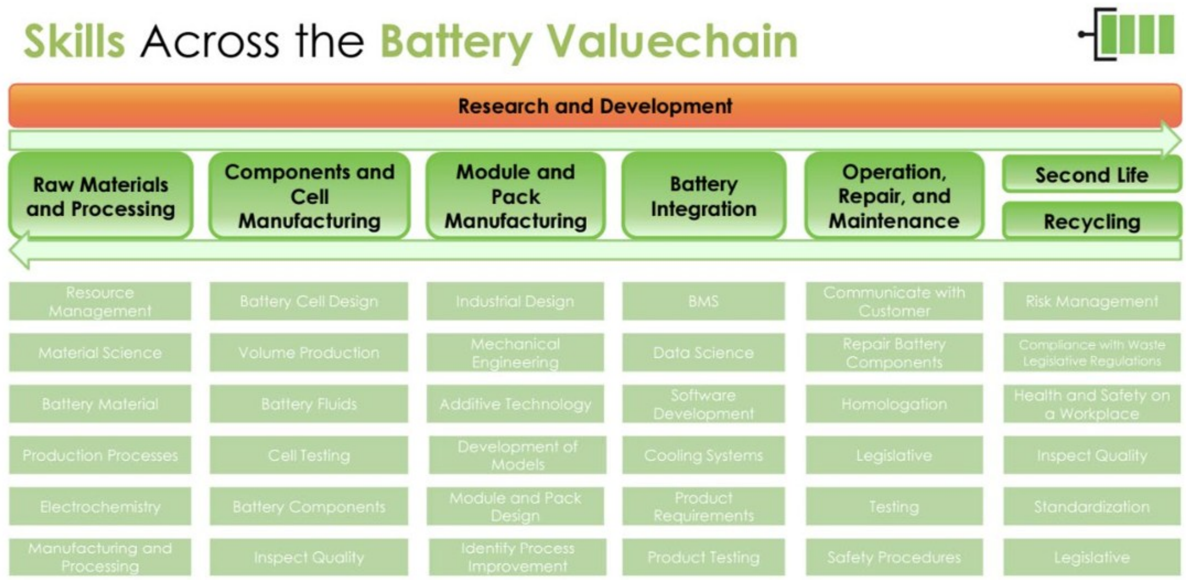

Figure 3: Skills Across the Battery Value Chain (European Commission, 2021, Project ALBATTS).

The steps taken to create the skills taxonomy include:

1. **Compiling a list of all skills** identified during the literature review analysis relevant to the manufacturing industry.
2. **Categorising the skills** per domain and subdomains to obtain a hierarchical structure.
3. Refining the list and categorization, **merging skills or removing competencies or abilities** that were too specific to obtain a taxonomy that was at the same time agile, manageable and comprehensive. We also leveraged AI to improve the categorization of skills, ensuring consistency, accuracy, and the absence of major gaps.

As a preliminary draft, the following table shows a partial categorisation of digital skills in the skills taxonomy (continued on the next page):

Table 2: A sample categorization of Digital Skills in Artificial Intelligence and Data Science.

Digital Skills Categorization for AI and Data Subdomains		
Domain	**Subdomain**	**Skills, Knowledge and Technologies**
Digital Technologies and Competencies	Artificial Intelligence	- AI for Anomaly Detection - Computer Vision - Deep Learning - Machine Learning - Natural Language Processing - Responsible AI - Explainable AI

		- Large Language Models (LLMs) - Cognitive Robotics - Cognitive System Design (SLAM, Sensor Fusion, Motion Planning, Robot Perception) - Cognitive Twin - Digital Twins - Synthetic Data - Automated Machine Learning (AutoML) - Semi-supervised Learning - Prompt Engineering
	Data Skills	- Data Cleaning and Preprocessing - Data Visualization - Data Analytics - Data Wrangling - Statistical Analysis - Predictive Analytics - Big Data Management - Data Security and Privacy - Cloud-Based Data Management - Data Governance and Compliance

After further refinement, considering the R3-MYDAS-specific project requirements and demo cases, twenty competency clusters were identified and used to inform the design of a preliminary survey to determine which areas should be prioritized for further development among the project partners. The first final version of competency clusters is as follows:

- Advanced Manufacturing Technologies: Additive Manufacturing
- Advanced Manufacturing Technologies: Design and Simulation Technologies
- Artificial Intelligence and Machine Learning
- Automation & Robotics
- Battery Science and Engineering
- Blockchain
- Circular Economy: Strategic and Operational Integration of Best Practices
- Cybersecurity (Industrial & IT Systems)
- Data Science and Big Data Analytics
- Electrical and Electronic Engineering
- Environmental, Sustainability and Regulatory Management
- Extended Reality (AR, VR)
- ICT and Networking
- Manufacturing Process Control and Optimization
- Materials Science
- Programming and Software Development
- Quality Assurance and Control
- Supply Chain Management
- Systems Integration & Industrial Internet of Things (IIoT)
- Waste and Resource Management

In addition to the above domain areas, a list of transferable and soft skills was also compiled:

- Community Management
- Corporate Social Responsibility (CSR)
- Creativity and Innovation
- Critical Thinking
- Design Thinking
- Entrepreneurship
- Human Experience (HX), User Experience (UX), Customer Experience (CX)
- Industrial Resilience
- Leadership and Team Management
- Learning
- Market Strategy
- New Manufacturing Business Models
- Problem Solving
- Project Management
- Safety Management & Compliance
- Strategic Thinking

We will now see in detail the activities carried out to assess skills priorities and needs, using the skills taxonomy as a reference framework.

2.2.2 Questionnaires and Interviews

This section outlines the research methods used for primary data collection to assess the skills and knowledge needs of the project partners, starting with online questionnaires and virtual interviews. We will now review the design and implementation of each method in detail.

2.2.2.1 Questionnaire for skills assessment

A first questionnaire was created and distributed to all project partners to gather a broad overview of topics of interest, skills needs and project-specific knowledge requirements from the partners.

The questionnaire, available in full in A.2, consists of three main sections:

1. **Organization Profile:** Identifies the profile of the responding partner.
2. **Training and Skills Requirements and Workforce:** Assesses the skills needed by organizations to achieve the project and demo case objectives and the target workforce.
3. **Skills & Training Recommendations:** This section allows partners developing solutions within the demo cases to recommend skills needed to adopt their solutions.

Sample questions from the questionnaires used to assess skills and knowledge needs include the following:

Q5. How important is it for your organization to develop or enhance the following skills and competencies to achieve the project objectives? Please rate the importance of each skill *for achieving the project's objectives, considering your organization's current capabilities and needs [Likert scale]*

Likert Scale options:

- *Skill is not needed*
- *Skill is somewhat needed*
- *Skill should be developed*
- *Skill is a high priority to develop*
- *Unsure*

List of skills: see the twenty technical competency clusters described in 2.2.1.

Q6. Will you require training for ***R3-Mydas project-specific technologies and/or knowledge****? If so, please provide additional details about the specific training requirements needed. [open field]*

Partners were also asked to provide information regarding the target workforce to upskill and/or reskill.

After distributing and collecting responses to the questionnaire, a skills self-assessment was designed to evaluate the target workforce's proficiency in the domain areas identified as top priorities by the partners. The next section outlines the design and implementation of this activity.

2.2.2.2 Target Workforce Self-Assessment

The next phase of the research involved assessing the skill levels and proficiency of the target workforce in the competency clusters that partners rated as *high priority to develop* in the preliminary questionnaire.

The design of the self-assessment was also informed by input received from the project partner leading Task 5.4, "Impact of the remanufacturing process on workers and fine-tuning industrial processes to new setup and dynamics", dedicated to analysing the current workforce, identify emerging roles and required skills, and create personas—specific representations of workers and user profiles—to define training needs and competencies for the R3-MYDAS environments.

The self-assessment was distributed only to partners who, in the previous questionnaire, identified technical skills needing development and generally all partners involved in the development or implementation of technological solutions for the three demo cases.

The questionnaire, available in full in A.3, is structured around three key sections:

1) **Participant profile**: In this section, respondents were asked to provide details about their age, gender, professional role, qualifications, primary responsibilities and skills used in their daily jobs.
2) **Skills and Knowledge Assessment:** This section began with preliminary open-ended questions about the respondent's role within the demo case and the relevant skills. However, the core focus of this section was a self-assessment of specific skills within domains pertinent to each demo case. An example is provided below.
3) **Learning Experience and Preferences**: The purpose of this section was to gather inputs about learning format preferences, resources to aid learning processes within the organization, skills development expectations, and certifications possessed.

To aid partners in its completion, we also indicated which demo cases each list of skill sets applies to depending on the priorities previously identified. Below is the question used to self-assess one's proficiency in a particular domain.

How would you rate your skills and knowledge in Artificial Intelligence and Machine Learning? (Demo Case 2; Cross-Dimensional Activities)

Likert Scale Options:

- *0 – N/A: I don't need this skill in my role.*
- *1 – Lacking: I struggle with this skill and would like to receive training on it.*
- *2 – Low: I have a basic understanding and can apply this skill at a fundamental level.*
- *3 – Medium: I have supported teams and contributed to projects where this skill was essential.*
- *4 – High: I can co-create and co-deliver services where this skill is critical.*
- *5 – Expert: I can present and teach this skill to a broad audience.*

List of skills in the AI and ML domain provided in the questionnaire (also available in A.1):

- Machine Learning Algorithms (Supervised, Unsupervised, Reinforcement Learning), Training, and Evaluation
- Data Preprocessing and Feature Engineering
- Model Training and Evaluation
- Neural Networks and Deep Learning
- Natural Language Processing (NLP)
- Predictive Maintenance Analytics
- Computer Vision
- Generative AI Models
- AI Ethics and Governance
- AI Frameworks and Libraries
- AI in Predictive Maintenance

The same question was asked for all the remaining competency clusters within the skills taxonomy.

For the next activity, we invited the partner's primary contacts, team leaders or Human Resources representatives to short interviews to further discuss the responses provided to the survey and dig dive into their specific needs.

2.2.2.3 Partners Interviews

Interviews were arranged and conducted following a semi-structured approach, aiming to clarify the exact needs within the previously selected skills clusters and the current proficiency levels across the current workforce. For instance, when partners mentioned the need for support in AI and Anomaly Detection in the earlier questionnaire, we followed up during the interview to gather input on the specific objectives related to this skill, the target workforce and whether they had already identified competencies or technologies they wished to enhance.

We also explored potential language requirements for training and asked whether partners felt there was a need for tailored training or workshops to support knowledge sharing on specific skills with demo case partners.

During this phase, most of the identified gaps were related to technical knowledge of the technologies developed by demo case partners. Additionally, we were unable to conduct interviews with all partners, prompting us to strategically plan the next activity, the Training and Skills Workshop, to further explore the skills gaps and review the related requirements.

2.2.3 Training and Skills Workshop

The Training and Skills Workshop, held during the 3rd plenary meeting in Graz, Austria on 12th and 13th November 2024, provided an opportunity for the partners of the three demo cases to collaborate and discuss skill needs and technical knowledge-sharing priorities.

The workshop was anticipated by a brief presentation by EITM outlining the results of the previous research activities, and a short introduction to the training priorities and Key Performance Indicators of T8.4, as shown in the figure below:

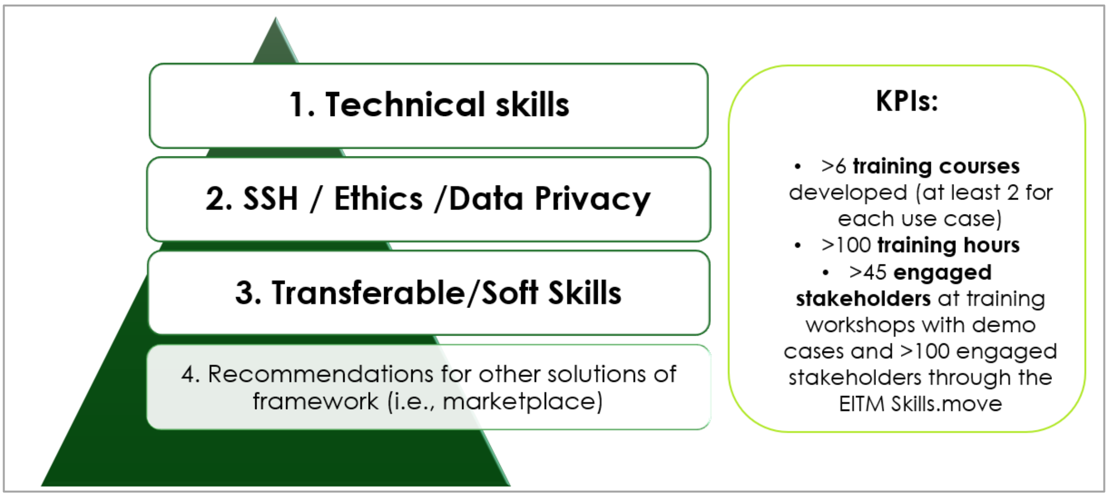

Figure 4: T8.4 Training Priorities and Key Performance Indicators (KPIs).

Although the primary focus of the task is on technical skills for remanufacturing, other domains within the R3-MYDAS framework, such as Social Sciences and Humanities (SSH) were included to help them identify skills essential or complementary (e.g., Human-Robot Interaction for tasks involving automation and robotics) to remanufacturing technical skills.

To support partners facing challenges in identifying gaps, we also provided a prioritized list to help them assess knowledge and skill needs:

1. **Current Workforce Gaps**: Identify existing gaps in the workforce that may hinder the development or implementation of demo case solutions.
2. **Technical Knowledge from Partners**: Address gaps in technical knowledge that need to be acquired from partner organizations.
3. **Future Trends and Staffing Needs**: Encourage partners to consider gaps related to future trends and strategies for quickly onboarding new staff to ensure sustainable expertise.
4. **Upskilling and Reskilling**: Focus on upskilling or reskilling the current workforce to meet evolving demands.

The workshop was structured around two key phases:

- **Skills Gaps and (Learner) Personas:** Each partner involved in a demo case was asked to identify skills and/or technical knowledge needs based on the framework provided along with the professional profile needing training.
- **Training Ideation:** Demo case partners gathered to ideate a possible training program, identifying commonalities, training format delivery, priorities and timeline for the delivery.

Below is a sample visual representation of the expected workshop results for a demo case group, designed to guide partners on the information and format anticipated when introducing the activity:

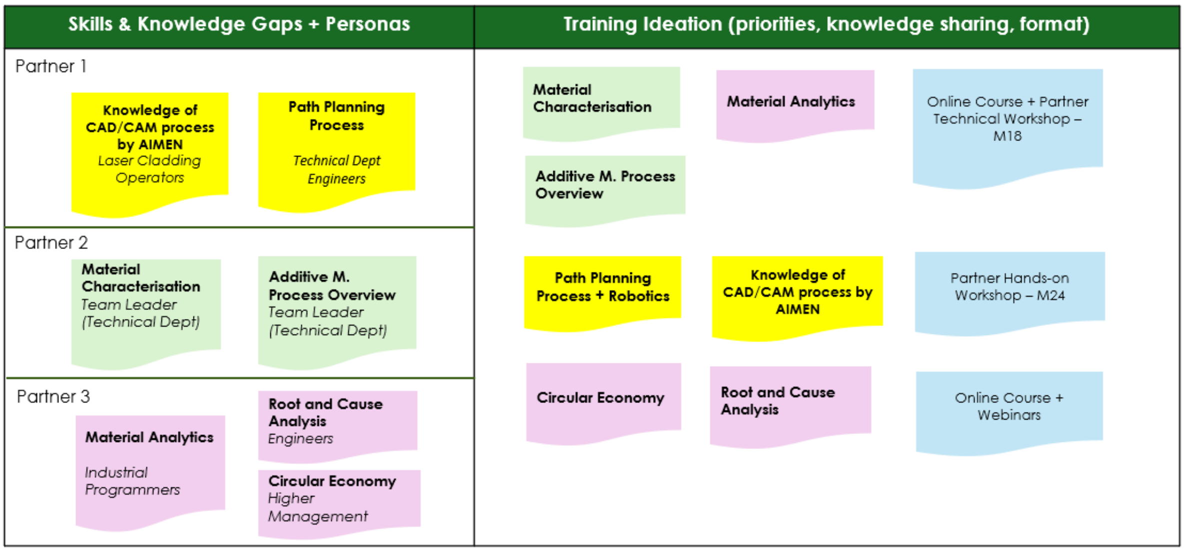

Figure 5: Sample visualization of expected Training and Skills Workshop results for each demo case.

While some partners had already identified skill needs during previous research activities, this workshop provided an opportunity to approach skills gap identification from a broader, more sustainable and strategic perspective. Additionally, it offered a chance to gather input from partners who had limited or no participation in earlier questionnaires and interviews.

Furthermore, the design of the training ideation phase is supported by the principles of Adult Learning Theory, also known as **Andragogy**. Involving partners in a creative training ideation exercise aligns with the Andragogy principle that adults learn best when actively involved in planning and evaluating their learning process [REF-11][REF-14]. Additionally, adult learners need to understand the **why**, **what**, and **how** of their learning experience [REF-11]. By presenting the purpose of task 8.4 (1- the why), explaining the task's priorities (2- the what), outlining the expected results and involving learners in the design (3- the how), this approach effectively concluded the skills gap identification activity.

2.2.4 Skills Gap Analysis

The initial strategy to analyse the identified gaps involved developing a scoring system to quantify skills gaps based on the urgency, importance, and feasibility of training. However, due to the diverse and evolving needs of each partner and the iterative nature of the skills needs assessment, the scoring system was not applied. Instead, a qualitative and iterative analysis was conducted to allow for greater flexibility in addressing the specific requirements of each partner. This adaptive approach ensured that the findings remained relevant and actionable.

Building on this qualitative analysis, the results from all research phase activities are presented below, organized by demo case to provide a clear overview of the identified skills needs and gaps.

3 Skill Needs Assessment: Key Findings and Skills Gap Analysis

This chapter presents the key findings from the skills needs assessment activities outlined in the previous chapter. It begins with an overview of the identified gaps and knowledge needs across all technical partners involved in the project, followed by a detailed analysis of the results for each demo case.

The preliminary questionnaire (described in Section 2.2.2.1 and available in A.2), completed by twelve of the fifteen partners in the consortium, highlights the strong relevance of sectoral topics such as **Systems Integration**, **Manufacturing Process Optimization**, **Automation, and Robotics**, which partners have identified as priority areas for professional development.

The figure below shows the percentage of partners who selected "This skill is a high priority to develop" for each skill area in response to the questionnaire question: "How important is it for your organization to develop or enhance the following skills and competencies to achieve the project objectives? Please rate the importance of each skill, considering your organization's current capabilities and needs". This analysis is based on responses from nine partners who provided input for this question.

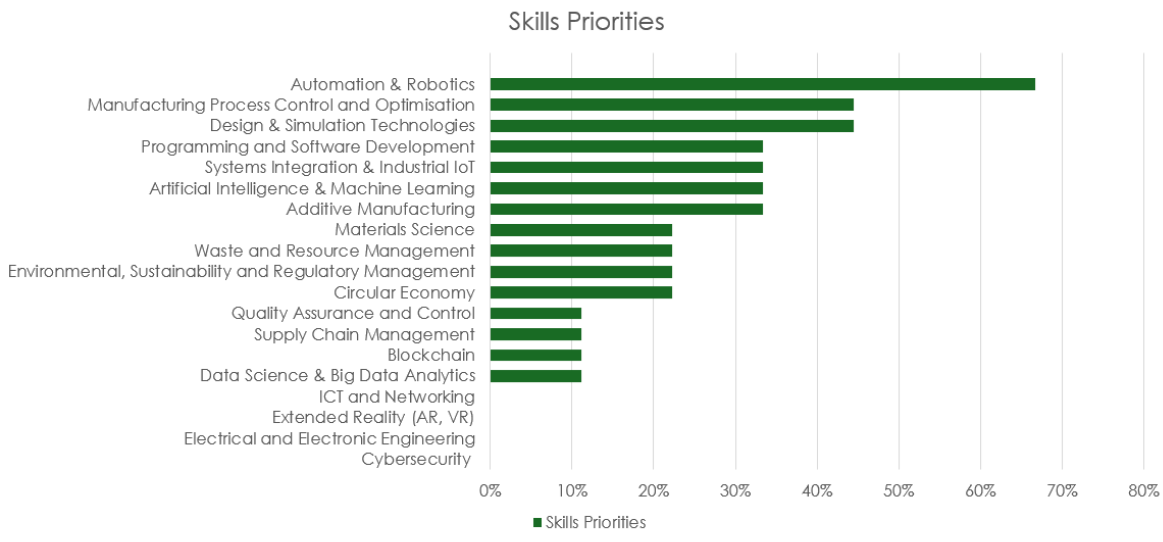

Figure 6: Partner Ratings for Sectoral Skills and Competencies in the Preliminary Survey.

Regarding soft and transferable skills, gaining knowledge in innovative business models was identified as a high priority by most partners, as illustrated in the figure below, which shows the percentage of partners who selected specific skills as essential for their organization's success in the project. This question was answered by ten partners.

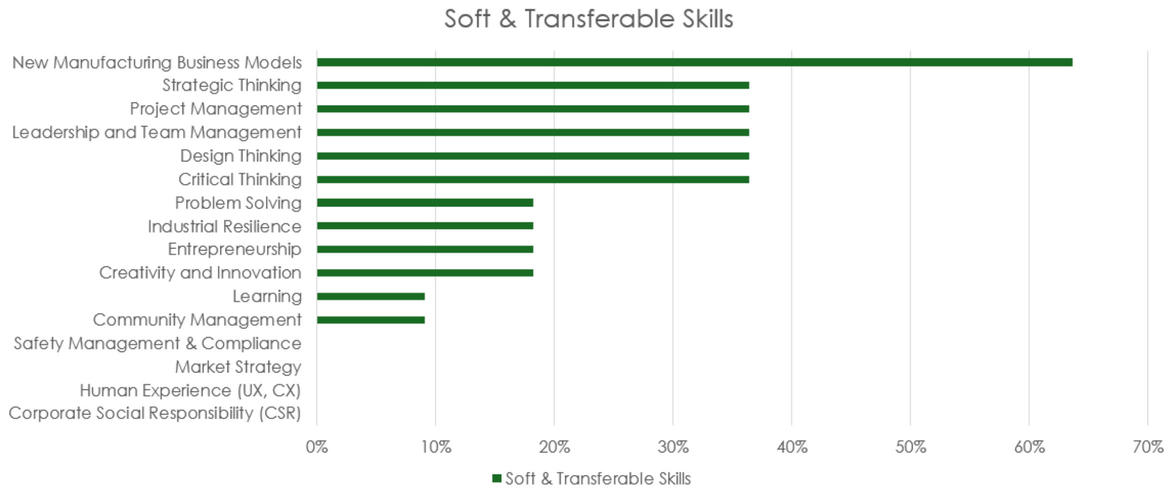

Figure 7: Partner Ratings for Soft and Transferable Skills in the Preliminary Survey.

The questionnaire also sought input regarding the underlying causes of the identified gaps. The key insights provided by the partners include:

- The R3-MYDAS project demands **specialized training and knowledge** in emerging technologies, which requires dedicated and tailored custom training.
- Insufficient training in the **application of new technologies** to remanufacturing processes.
- **Lack of statistical data** needed to evaluate and validate the performance of new technologies or processes being implemented.
- Strong foundational skills are present, however, **rapid advancements in technology** and **evolving market demands** require constant upskilling, particularly in areas like data analysis, automation, and predictive maintenance.

Overall, these insights were invaluable in establishing the foundation for engaging partners in the skills self-assessment and interview activities that followed. They provided key information to identify which partners to involve in the next phases and focus the training efforts. The self-assessment results offered a useful overview of the current workforce capabilities of the partners involved in the demo case activities. Lastly, interviews allowed us to clarify the information gathered and determine the partners' effective priorities.

In the following sections, we will delve into the specific skills needs for each demo case as emerged from the various activities previously described. For each demo case, we will briefly introduce the context, outline the competency profiles of the participating partners, and provide a detailed analysis of the technical skills needs and gaps identified.

3.1 Demo Case 1: Oil & Gas Components

The solution proposed within the Oil & Gas remanufacturing demo case focuses on developing a circular value chain for the remanufacturing of end-of-life oil & gas components. The solution is based on innovative technological advancements that incorporate full automation and the optimization of the repair process. Specifically, 3D scanning will be used to create a 3D model of deteriorated areas of the components. Path planning algorithms will guide a laser cladding robot to remanufacture the component.

The partners involved in the demo case offer a range of specialized technical skills. Key competencies, identified through a profiling of the partners and integrated with the results of the self-assessment completed by five participants across the three partners, include:

- **Mechanical and Surface Engineering:** Expertise in precision machining, special welding, reverse engineering and surface treatments like laser cladding and thermal spray.
- **Research in laser technologies applied to robotics and automation**: Knowledge of additive manufacturing and materials science, as well as design and simulation technologies.
- **Large-scale 3D printing and sustainable manufacturing:** Expertise in robotic printing technology for industrial manufacturing.

When asked about skill areas needing further development in the preliminary survey, all three partners rated **Automation and Robotics** as high-priority skill areas.

The following figure shows the percentage of respondents—out of three overall partners—who rated each skill as a priority for development.

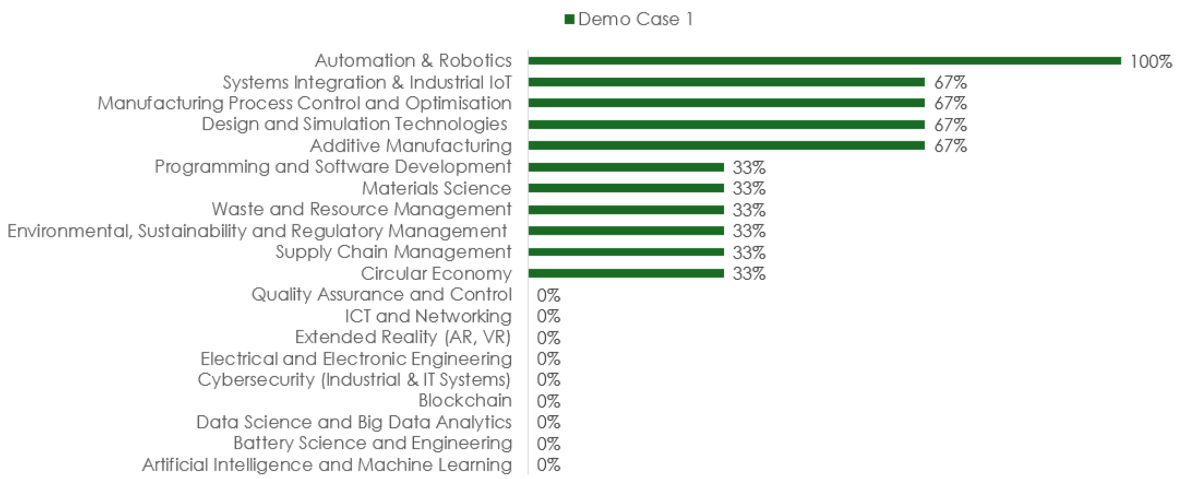

Figure 8: Demo Case 1 Partner Ratings for Skills and Competencies in the Preliminary Survey.

When asked about any project-related technical knowledge needed, positive responses were provided, highlighting the necessity of acquiring **technical knowledge transfer** for the specific solutions of the R3-MYDAS demo case. These include knowledge and operation of the developed 3D scanning process, CAD/CAM software and path planning software for the robotic system, as well as best practices to integrate these systems into the workflow of the lead partner of the demo case. Additionally, technical competencies related to predictive maintenance methods, and material analytics specific to the R3-MYDAS project were also reported as needed.

Overall, the prioritized skill and competency needs identified to support a sustainable, long-term competency development strategy include:

- Knowledge and operation of 3D scanning, CAD, and CAM software
- System integration
- Materials science
- Welding techniques and operations
- Programming skills
- Laser safety

Additional needs, which are of lower priority, include:

- Root Cause Analysis
- Knowledge and operation of path-planning software
- Laser cladding process and equipment operation
- Quality control plans and quality assurance

The target workforce needing competency development and technical knowledge acquisition includes:

- **Team leaders and higher management** - focusing on workflow optimization
- **Engineering professionals** – requiring in-depth technical training
- **Laser cladding operators and technicians** – technical training for the practical use of the solutions

It is important to highlight that most of the identified needs pertain to the partner responsible for piloting the realization and remanufacturing of the final product, as they will be implementing the newly developed solutions. Laser cladding, on the other hand, is primarily relevant to the partner developing the path-planning algorithms and is needed to gain an overview of the process requirements and optimize the application of the solution. Meanwhile, materials science expertise is essential for both the partner implementing the solution and the partner responsible for CAD model building and defining the laser cladding process conditions.

3.2 Demo Case 2: E-vehicle (EV) batteries

The objective of the second demo case is the development of a circular value chain for the remanufacturing of e-vehicle batteries through activities focusing on the purification and reuse of raw materials, development and implementation of advanced diagnostic techniques (Graph Deviation Networks) for anomaly detection and advanced machinery for optimizing the battery disassembly and reassembly during the remanufacturing. Lastly, an IoT framework will be deployed to monitor the battery's remanufacturing process and allow a data-driven optimization.

The four partners involved in this demo case bring diverse profiles and skill sets. The following key competencies are derived from the partners' profiling and the self-assessment responses of three staff members (CTO, project manager and technical project manager) across the demo case partner group:

- Expertise in **advanced technologies** and **engineering** solutions in the **automotive and mobility industries**, based on extensive in-house research, development, simulation and testing activities. This includes expertise in battery technologies.
- Expertise in **assembly technologies** and **collaborative robotic solutions**, integrating artificial intelligence, machine learning, electronic and electrical engineering, and embedded and control systems.
- Expertise in **digital solutions** such as **big data analytics**, advanced data mining, **machine learning** and **software programming and development**.
- Research and development in **precision manufacturing**, **digitalisation**, **cognitive mechatronics,** quality and process optimization (e.g., machine learning algorithms for quality control predictive models to be developed for this demo case).

The skills and knowledge areas highlighted as top priorities for development by partners in this demo case in the preliminary survey are primarily centred around **Machine Learning** and **Artificial Intelligence**. The following figure presents the cumulative percentages assigned to each topic by three of the four participating partners in the demo case (three out of four respondents).

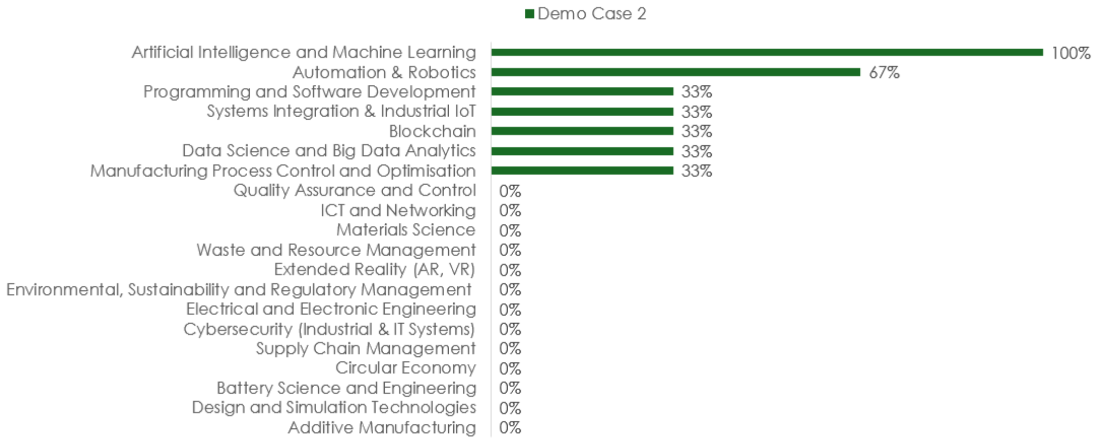

Figure 9: Demo Case 2 Partners Ratings for Skills and Competencies in the Preliminary Survey.

Initially, no urgent technical skill gaps were identified during the preliminary stages of the skills needs assessment. However, as the discussions progressed during interviews and the workshop, a technical gap was identified specifically in **AI-based Anomaly Detection** competencies. The identified gap focuses on the need for more advanced expertise in **AI algorithms, machine learning techniques**, and **data analytics** to improve predictive capabilities of faults and anomalies in the disassembly and remanufacturing of batteries.

Additionally, **Circular Economy best practices and models**, **battery development**, and **Human-Robot collaboration**, along with knowledge of **AI ethics and regulations**, were recognized as beneficial skills to further develop.

To summarize, the list of skills on which the demo case partners have reached a consensus is as follows:

- Machine Learning Algorithms (Supervised, Unsupervised, Reinforced)
- Model Training and Evaluation
- Neural Networks and Deep Learning
- Time Series Analysis
- Predictive Maintenance Analytics
- Data Security
- Manufacturing Execution Systems (MES)
- Production Scheduling and Planning
- Edge AI integration
- Cloud-based IoT platforms & Cloud Integration
- Battery Design Lifecycle
- Battery State of Health (SoH) understanding and evaluation models
- Safety in Battery Handling and Disassembly
- Circular Economy Principles

- Supply Chain Management
- Knowledge of Artificial Intelligence Act
- New Machinery Directive EU 2023/1230
- Human-robot collaboration (regulations, limitations, explainability and reliability)

As for the workforce identified as potential targets for the training programmes, the following groups were reported:

1. Technical Project Managers
2. Project Managers and R&D Project Managers
3. Software Developers and Industrial Programming Specialists
4. Senior Management (including Chief Technology Officer and Innovation Manager)

In conclusion, the identified skills are critical for addressing the evolving challenges within the battery sector and will undoubtedly equip the targeted workforce with key competencies required for the sector.

As AI competencies are essential for advancing quality control in the assembly and disassembly of the batteries, gaining a deeper understanding of the product lifecycle will enhance the partner's ability to deploy the monitoring framework and integrate data middleware to support remanufacturing. Additionally, strengthening knowledge of production operations and production planning systems will enable more efficient integration of monitoring systems across the battery value chain. These prioritized skills will be instrumental in navigating the dynamic battery industry, where the need for efficiency and seamless integration across technologies and systems is growing.

3.3 Demo Case 3: Wind Turbines gearboxes

The innovative solution to be developed within demo case 3 focuses on the redesign and remanufacturing of wind turbine gearbox components through new materials and design and mitigation methods to prevent and fix failures.

In case of failures, three options will be developed for the remanufacturing, which include the complete replacement of the component using improved technologies to avoid failures (subsurface fatigue mitigation); repair of the component using Additive Manufacturing (AM), integration of remanufacturing in the design to allow the reuse of decommissioned components to manufacture new components, reducing the need to source raw materials. This demo will also involve developing a methodology to evaluate high-strength gear materials, linking operational, gear design and material parameters of fatigue life, service life, and maintenance and manufacturing costs to perform a comparison of the best method for remanufacturing or repairing.

The range of expertise and skills provided by the partners of this demo case include:

- Expertise in the **design** and **manufacturing of gears**, repairs, spare parts, and other tools and components used for wind turbines.
- **Software programming**, **product design**, **advanced data analysis** and interpretation.
- Scientific and academic knowledge in wind turbine gearboxes, **mechanical engineering**, **IoT**, with academic research groups focused on **energy systems**, **sustainable technologies**, and **process optimization**.

The above data is derived from a high-level profile analysis of the partners, as data from the skills self-assessment is not available for this specific demo case.

The figure below presents the cumulative percentages of responses from the three partners in the demo case. One partner did not select any skills, indicating that they do not require any further training in technical skills.

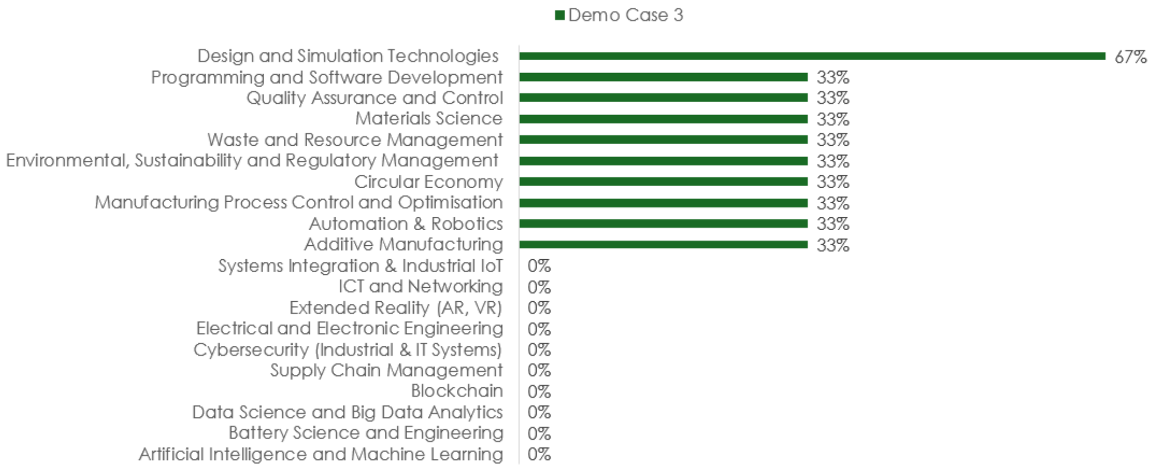

Figure 10: Demo Case 3 Partners Ratings for Skills and Competencies in the Preliminary Survey.

However, key insights from the Training and Skills workshop needs for the lead partner of the demo case around **Additive Manufacturing** to ensure the long-term reliability of remanufactured components. While AM represents a key strategy for cost savings and part repair, its adoption—particularly for components such as gears and in the wind turbine industry—remains cautious due to concerns over material performance, durability, and interior fatigue.

All skills and technologies presented below are based on the needs identified collectively by the partners and organized by urgency:

High-Priority

- 3D Printing Technologies and Methods
- Multi-material Printing
- Laser-based manufacturing (equipment operation and maintenance)
- Additive Manufacturing Failure Analysis, Risk Assessment and Quality Control

- Material Selection for Additive Manufacturing
- Process Optimization in the context of additive manufacturing
- Design for Additive Manufacturing (DfAM)

Medium-Priority

- Surface Treatment and Post-Processing Techniques
- Corrosion and Lubrication Simulations

Nice-to-have

- Binder Jetting Technologies

Future need

- Supply Chain and Marketplace Integration
- Digital Passport Implementation for gearboxes

The target workforce identified for the skilling strategies includes engineers of the lead partner's organization. Further discussions will be conducted with the demo case partners in the next phase of T8.4 to assess the current proficiency levels in the identified areas and to develop the profiles for the target workforce.

4 Training Curricula

The training curricula for each demo case are developed on the results of the skills needs assessment activities, introduced in Chapter 2 and presented in Chapter 3.

These curricula provide a high-level overview of the key topics and modules critical to the success of each demo case, addressing identified skills and knowledge needs. They also serve as a framework to guide industrial players in similar fields or applications, helping to identify effective upskilling and reskilling strategies and enhance workforce capabilities in innovative and sustainable practices in remanufacturing of energy goods.

Currently, the curricula are in the proposal phase and include suggested delivery and assessment methods. These will be refined in collaboration with R3-MYDAS academic partners during the next phase of Task 8.4, as outlined in Chapter 4. Depending on needs, courses will be further customized, merged or separated.

Proposed course formats range from blended professional courses—combining face-to-face components such as workshops with online learning and leveraging existing online material and platforms where possible—to Master-level courses that academic partners can integrate into their existing curricula. Content development strategies will be aligned with modern learning theories, such as **microlearning**, which delivers content in concise, focused lessons proven effective in today's agile work environments [REF-04]. Additionally, adult learning principles will ensure that content and assessments are relevant, practical, and immediately applicable in the workplace [REF-11]. At the same time, key partners' requirements, such as time constraints and delivery preferences, will be prioritized as much as possible to ensure the learning process is effective without being overwhelming for the participants. Assessment types and requirements will also align with the type of learning, whether formal or informal.

Technology integration will play a key role, incorporating online platforms and, where feasible, XR tools for simulations. These innovations will leverage ongoing projects involving project partners.

As the project progresses and additional data becomes available, the curricula will be validated and refined to ensure alignment with the specific needs of each partner and the overall project objectives. The following section provides a detailed look at the proposed curricula for each demo case.

4.1 Demo Case 1: Training Curriculum

The Oil & Gas demo case training curriculum addresses the knowledge and skills gaps identified by all partners involved in this demo case. Some courses target specific partners, and therefore, they are presented individually at this stage. However, as the feasibility of development is assessed further, content could be merged. For this reason, the proposed curriculum covers both high-priority and low-priority skills.

Below is a detailed proposed curriculum for Demo Case 1.

Course 1: Advanced Digital Remanufacturing Systems and System Integration

Learning Outcomes. By the end of the course, participants will be able to:

- Operate the partner's digital remanufacturing systems focusing on process and data optimization.
- Evaluate best practices to integrate systems ensuring smooth data flow and operational efficiency.

Course Outline:

1. **Introduction to 3D Scanning and Partner's CAD/CAM Software:** This module introduces participants to the partner's systems, teaching how to operate the 3D scanning system, navigate the CAD and CAM software and apply CAD model building algorithms to optimize scanned data.
2. **Introduction to Path Planning Software**: This module covers the partner's path planning software and optimized robotic paths for remanufacturing.
3. **CAM and Systems Integration:** This module covers how to prepare and export CAD models in appropriate formats for both CAM and path planning integration. Participants will also explore systems integration concepts, tools and models

Course 2: Laser Cladding Process Overview

Learning Outcomes. By the end of the course, participants will be able to:

- Understand the principles and steps involved in the laser cladding process.
- Gain knowledge of the equipment and materials used in laser cladding.

Course Outline:

1. **Introduction to Laser Cladding**: This module will provide an overview of the laser cladding process and learn about its advantages and challenges.
2. **Laser Cladding Equipment and Material Selection**: This module will cover in detail the essential equipment required for laser cladding and material selection.

Course 3: Materials Science for Laser Cladding

Learning Outcomes. By the end of the course, participants will be able to:

- Understand the impact of material properties (hardness, toughness, wear resistance) on the laser cladding process.
- Recognize how external factors like temperature, humidity, and air quality affect the performance of both base materials and cladding.

- Select and test material based on properties and external factors.

Course Outline:

- **Material Properties and Laser Cladding:** This module covers properties like hardness, toughness, and wear resistance and how they influence the cladding quality and durability of the final product.
- **External Factors and Their Influence:** Participants will learn how environmental conditions (temperature, humidity, and air quality) affect the performance of both the base material and cladding during the laser cladding process**.**
- **Selecting Materials for Cladding:** Participants will be guided in the selection of cladding materials based on their interaction with environmental factors and process parameters.
- **Practical Testing and Evaluation:** This module focuses on material testing such as hardness testing, toughness measurements, and wear resistance assessments to evaluate cladding effectiveness.

Course 4: Laser Safety for Industrial Applications

Learning Outcomes. By the end of the course, participants will be able to:

- Recognize and apply essential laser safety regulations.
- Identify potential laser hazards and take appropriate action to minimize these risks.
- Understand and implement proper safety protocols and personal protective equipment (PPE) for safe laser operation.
- Conduct basic laser hazard assessments in industrial settings and ensure compliance with safety standards.

Course Outline:

1. **Overview of Laser Safety Regulations and Standards**: Participants are introduced to laser safety standards, learn how they relate to their daily tasks and how to follow relevant guidelines to ensure safety during laser-based processes.
2. **Identifying Hazards and Implementing Safety Protocols:** This module focuses on recognizing laser hazards in the workplace (such as eye and skin damage), how to mitigate those risks, and how to use appropriate safety measures. The module will also cover basic hazard assessments, emergency protocols, and best practices for safe laser equipment operation.

Course 5: Quality Control for Laser Cladding

Learning Outcomes. By the end of the course, participants will be able to:

- Understand basic laser cladding quality control parameters
- Learn how to apply Quality Control Procedures (QCP) to monitor the laser cladding process.

- Perform inspections and testing to validate the quality of laser-cladded parts.
- Explore decision-making models and other advanced techniques to enhance QCP and QA in laser cladding.

Course Outline:

1. **Quality Control Procedures (QCP) for Laser Cladding:** Participants will learn to monitor key process parameters (laser power, speed, feed rate) and perform quality checks during and after cladding. Methodologies such as Statistical Process Control (SPC) and Six Sigma for monitoring and control processes will be introduced. Decision-making models like Fuzzy Comprehensive Evaluation-Integrated Analytic Hierarchy Process (FCE-IAHP) could also be covered.
2. **Quality Assurance (QA) in Laser Cladding:** This module explores QA practices, including testing methods and documentation.
3. **Inspection and Testing of Laser-Cladded Parts:** This module covers non-destructive testing and post-process inspections
4. **Continuous Improvement and Process Optimization:** Focus on process optimization using Lean Manufacturing and Predictive Analytics.

Course 6: Root Cause Analysis (RCA) for Laser Cladding Issues

Learning Outcome. By the end of the course, participants will be able to:

- Use RCA tools to identify, investigate, and resolve common issues in laser cladding.

Course Outline:

1. **Introduction to Root Cause Analysis (RCA) in Laser Cladding**: This module will introduce participants to the concept of root cause analysis and RCA tools (e.g., fishbone diagrams, 5 Whys).
2. **Problem-Solving and Corrective Actions**: Participants will apply RCA concepts to diagnose and address cladding issues.

Course 7: Advanced Welding for Remanufacturing

Learning Outcomes. By the end of the course, participants will be able to:

- Apply welding techniques to enhance precision and efficiency in remanufacturing applications.
- Optimize welding processes, develop troubleshooting techniques and evaluate quality control methods.

Course Outline:

- **Review of Basic Welding Principles and Tools:** This module introduces fundamental welding techniques, welding equipment, tools and safety procedures.

- **Advanced Welding Techniques:** This module covers modern techniques such as laser welding.
- **Welding Optimization:** Participants explore optimization techniques (e.g., how to minimize material waste).
- **Troubleshooting Common and Complex Welding Defects:** Participants will learn about complex welding issues, root causes and techniques to prevent defects.
- **Quality Control and Testing:** This module covers non-destructive testing methods, quality standards and certifications.

4.1.1 Instructional and Assessment Strategies

Instructional strategies proposed for the Demo Case 1 training courses include targeted sessions focused on the specific technologies and practices of the demo case. These will consist of workshops and regular knowledge-sharing sessions with project experts. The delivery formats for technical knowledge sharing (blended, online, or face-to-face) will be assessed in collaboration with demo case partners, as these decisions will depend on the timeline for developing and implementing technical solutions, the partners' requirements, and the feasibility of travel for face-to-face sessions. Additionally, a mentorship program across partners or among the workforce with different expertise, suggested by a partner, could be implemented. For instance, training on the laser cladding process and equipment could be delivered at the lead partner's facilities, while training on the partners' software solutions might be conducted online. Root Cause Analysis content could be tailored and delivered through a challenge-based learning model, where participants collaborate to identify the causes of a problem within their work context.

Summative assessment methods might include knowledge checks and quizzes on material properties, laser safety standards, and practical applications for Root Cause Analysis which will be evaluated on criteria agreed with the partner's management team. Participants could also engage in collaborative projects, such as producing guides or handbooks or proposing solutions for process optimization.

4.2 Demo Case 2 Training Curriculum

To enhance the success of the EV batteries demo case, the key skills and knowledge requirements identified by the partners are centred around **Artificial Intelligence**, **Machine Learning** and **Data Science** for predictive maintenance, Battery Technology and Manufacturing Processes and Systems. The curriculum can therefore address these topics as follows:

Course 1: Battery Technology

Learning Outcomes. By the end of the course, participants will be able to:

- Describe the stages of battery design, development, and testing.

- Evaluate the State of Health (SoH) of batteries and estimate their performance and lifespan.
- Implement safe practices for assembling, disassembling, and handling high-voltage batteries.

Course Outline

1. **Battery Design and Development Lifecycle:** This module introduces learners to the stages of battery design, development and testing.
2. **Battery SoH Foundation and Evaluation:** This module introduced the State of Health (SoH) of batteries and covers estimation methods for their performance and lifespan.
3. **Battery Assembly & Disassembly Process, Manipulation and Safety:** Practices and procedures for battery assembly, disassembly and manipulation will be covered, focusing on safe practices and technical guidelines for dealing with High-Voltage (HV) battery packs, including specialized equipment.

Course 2: Battery Manufacturing Execution Systems and Production Planning

Learning Outcomes. By the end of the course, participants will be able to:

- Understand battery production operations and the role of MES systems in battery production.
- Understand production scheduling and planning methods and evaluate how to integrate R3-MYDAS technology into the production system.

Course Outline

1. **Introduction to Battery Production Operations and MES Systems:** This module introduces battery production operations and the role of Manufacturing Execution Systems (MES) in smart manufacturing. It will cover how MES systems are used for performance monitoring, traceability, and quality control in large-scale battery production environments.
2. **Production Scheduling, Planning, and Integration of R3-MYDAS Technology:** This module covers the principles and practices of production scheduling and planning methods for battery production. The module could also cover practical activities to evaluate the integration of R3-MYDAS screw-driving technology into the production process.

Course 3: Data Analytics and AI for Battery Diagnosis

Learning Outcomes. By the end of the course, participants will be able to:

- Apply machine learning algorithms for anomaly detection and predictive maintenance tasks.
- Implement deep learning models and neural networks for anomaly detection.
- Analyse time-series data for predictive analytics and anomaly detection.

- Use AI and data analytics for predictive maintenance and quality control.
- Evaluate the integration of AI solutions on edge devices for real-time data processing and decision-making.
- Evaluate cloud-based IoT platforms and assess their integration for data-driven optimization.
- Understand data security and privacy in AI and IoT systems.

Course Outline:

1. **Machine Learning Algorithms, Training Models and Evaluation:** This module covers types of machine learning approaches (supervised, unsupervised, reinforced) and related algorithms. It will be tailored for the anomaly detection task of the demo case and based on the specific requirements of the partner leading the anomaly detection task. Training models will also be covered for the same purpose to enhance predictive maintenance capabilities. Lastly, the course will cover evaluation techniques and performance metrics.
2. **Neural Networks and Deep Learning:** Deep learning models and types of neural networks will be covered to understand how to apply them for real-time predictive maintenance.
3. **Time series analysis:** The focus of this module will be on techniques for analysing and forecasting data for predictive analytics and anomaly detection.
4. **Predictive Maintenance Analytics:** AI and analytics for quality and process control, tailored to the battery manufacturing and remanufacturing process.
5. **Edge AI integration:** The focus of this module will be on exploring AI solutions on edge devices for real-time data processing and improved data-driven decision-making. The module will explore its advantages and use cases, and it will be tailored to EV batteries and Battery Management Systems.
6. **Cloud-based IoT Platforms, Cloud Integration:** This module is meant to specifically serve the demo case task dedicated to the IoT framework used to monitor the battery remanufacturing process to allow data-driven optimization. Learners will be guided through cloud-based IoT platforms, key features and architecture for Cloud integration.
7. **Data Security in AI and IoT Systems:** This module will cover key principles for the preservation of data privacy and security, specifically referring to battery data, and remanufacturing processes when IoT systems and AI are integrated.

Course 4: AI and Robotics: Ethical, Legal, and Human Interaction Considerations

Learning Outcomes. By the end of the course, participants will be able to:

- Understand ethical AI standards and legal regulations in AI use.
- Apply and implement best practices in human-robot interaction (HRI), focusing on safety, ethics, legal requirements, and effective collaboration with collaborative robots.

Course Outline

1. **AI Act and Ethical AI practices:** Key ethical standards for the deployment of AI systems will be covered, including accountability, liability, and legal regulations.
2. **Human-Robot Interaction (HRI)**: This module focuses on the use of collaborative robots (cobots) in manufacturing environments. It covers legal requirements, best practices, and the socio-technical aspects of human-robot interactions, emphasizing the importance of safety, ethics, and effective collaboration.

Course 5: Circular Economy and Supply Chain Management for Battery Systems

Learning Outcome. By the end of the course, participants will be able to:

- Understand the essentials of the battery circular economy and the EV battery supply chain and apply best practices in demo case development.

Course Outline:

1. **Circular Economy:** Essentials of battery circular economy, regulatory requirements, waste hierarchy, and challenges of battery recycling.
2. **EV Battery Supply Chain:** Understand the battery supply chain, from raw materials extraction and processing to end-of-life recycling, key actors and their needs, and battery supply chain challenges.

4.2.1 Instructional and Assessment Strategies

Battery training would need to be delivered in a blended format. Synchronous or asynchronous online courses hosted on the EITM Academy Platform could be arranged for introductory courses on battery lifecycle, SoH, Battery Management Systems (as suggested by partners), as well as topics in AI and ML, including HRI and AI act and ethical standards.

Regarding Battery Assembly/Disassembly Process, Manipulation and high-voltage safety training, online training through recorded video tutorials, and face-to-face demonstrations could be arranged. In this case, XR could also be integrated to reinforce knowledge in a safe and more flexible environment. Additionally, technical guides could be integrated as mandatory resources.

Manufacturing production and MES modules would also benefit from a blended type of learning, integrating online teaching and the use of XR technologies for virtual simulations, and, if feasible, face-to-face workshops or factory visits.

Assessment strategies for ML and AI courses might include programming assessments, hands-on coding projects and quizzes, while for Edge AI integration scenario-based activities would be recommended.

For Time series analysis, data analysis assignments could be designed, providing learners with the opportunity to apply statistical models or machine learning algorithms to forecast future values.

Battery Assembly/Disassembly knowledge could be assessed through generic knowledge quizzes. Since the type of knowledge required is only foundational, there is no specific need to assess learners' practical knowledge through hands-on activities.

4.3 Demo Case 3 Training Curriculum

The priorities that emerged from the needs assessment of demo case 3 partners revolve around Additive Manufacturing technologies and methods.

Considering the specific competencies and knowledge reported by the partners and the priorities already identified, the curriculum presented below addresses the most urgent skills:

Course 1: Advanced Additive Manufacturing and 3D Printing Technologies

Learning Outcomes. By the end of the course, participants will be able to:

- Identify various 3D printing technologies and their applications.
- Recognize multi-material printing techniques.
- Demonstrate the operation and maintenance of laser-based manufacturing equipment.
- Compare the criteria for selecting materials in additive manufacturing processes.
- Apply optimization techniques for materials, workflows, and maintenance.
- Analyse failure modes and propose solutions for quality control and risk management.
- Apply design principles in additive manufacturing.

Course Outline

1. **Introduction to Additive Manufacturing**: This module covers the significance and potential of additive technologies (optional depending on the level of proficiency possessed among the targeted workforce).
2. **3D Printing Technologies**: The focus of this module is on various 3D printing methods (selected based on demo case and partners' needs), materials, and their applications. The module will also include a detailed look at the advantages and limitations of each technology.
3. **Multi-material AM Printing**: This module will explore techniques for printing with multiple materials (direct ink writing, material jetting, powder bed fusion, etc.), focusing on process setup, material compatibility, and design considerations.
4. **Laser-based Manufacturing (Equipment Operation and Maintenance)**: Within this module, learners will dive into laser-based methods used in additive

manufacturing and the operation and maintenance of equipment. Laser types and material interactions will be covered.

5. **Material Selection for Additive Manufacturing**: Learners will discuss the criteria and considerations when selecting materials for different additive manufacturing processes.
6. **Process Optimization for Additive Manufacturing**: The focus of the module is on optimization frameworks such as post-processing techniques, material usage optimization, workflow and resource optimization, and predictive maintenance.
7. **Additive Manufacturing Failure Analysis and Risk Assessment**: This module covers failure modes, quality control, risk factors assessments, and how to address common issues in additive manufacturing.
8. **Design for Additive Manufacturing (DfAM)**: This module explores design principles (e.g., part consolidation, geometric freedom, and biomimicry) specific to AM and computational design tools such as generative design, topology optimization and finite element analysis (FEA). The module will be tailored, in collaboration with academic partners, depending on the technical nature of the demo case solution and the partner's needs.

If feasible, and based on consultancy with subject-matter experts, the course might integrate also the second priorities on surface treatment and post-processing techniques (already partially covered in Module 6), as well as corrosion and lubrication.

There is also potential to merge topics into the curriculum to be developed for demo case 1, specifically on quality control for laser-based manufacturing.

4.3.1 Instructional and Assessment Strategies

The courses identified as a priority could be designed and developed in collaboration with academic partners and industrial stakeholders of the consortium possessing expertise in Additive Manufacturing.

There is high potential to use Extended Reality (XR) technologies for immersive and impactful learning experiences in AM. Integrating the use of XR in AM training, through simulations and interactive elements, allows for higher flexibility, accessibility as well as engaging learning experiences, offering opportunities for practical applications of theoretical learning.

Lastly, theoretical concepts on material properties and materials selection could be delivered through an asynchronous online course or live webinar. Face-to-face teaching or workshops would also be highly impactful in acquiring knowledge of equipment operation and maintenance.

The assessment methods for a course on Additive Manufacturing could include:

- **Scenario-based exercises in XR simulations**: These may include single, multiple-choice or open-ended questions or decision-tree-based paths, where learners are asked to make choices based on specific tasks, such as identifying errors, optimising processes, etc. In the end, answers may be evaluated based on efficiency, safety or cost-related aspects.

- **Physical Practical Tests**: Learners are asked to perform specific tasks within their workplace and evaluated on set criteria such as the ones mentioned above.
- **Case study analysis**: Real-world scenarios on the use of additive manufacturing where learners are asked to propose improvements, evaluate processes or suggest alternative approaches to a specific challenge or case.
- **Quizzes and Knowledge Checks**: These assessments evaluate knowledge of theoretical concepts such as material properties, process parameters, etc.

There are also opportunities to leverage the expertise in Additive Manufacturing (AM) from partners within the consortium to address these skills needs. In the next phase of the task, we will assess the feasibility of utilizing existing materials and organizing practical training sessions at the facilities of partners actively involved in AM.

5 Plan to develop the Training Curricula

The design of the training curricula will require further refinement of key elements before content is developed. These elements include establishing terminal objectives (i.e., the overall purpose or goal of the course), and the specific learning outcomes for each module. This activity will be executed in collaboration with the partners' target of the training, following once more andragogy principles and ensuring that the material effectively addresses their needs.

Additionally, depending on the level of development or customization required for each course, aspects such as course type (informational, how-to, etc.), type of delivery format (blended, online asynchronous, etc.), instructional strategies (video lessons, immersive learning technologies, face-to-face teaching) and methods (experiential, problem-based learning, etc.) and, lastly, assessments, will be defined in collaboration with industry partners and training providers. It will also be evaluated whether existing content, such as courses or modules already available on the EIT Manufacturing Academy platform, would need to be integrated into a larger learning path, adapted or customized with further elements (e.g., assessments, recommended reading or case studies).

To ensure that the activities above are executed effectively, they will be carried out as shown in the workflow below:

M13 – Further Refining and Validation Phase

1. **Leverage EITM existing projects:** Review material from **EITM Academy** and identify potential content addressing the selected topics. A course catalogue will also be shared with the target partners in the next step.
2. **Conduct partner interviews**: Arrange calls with partners of each demo case to:
    - Set or refine priorities for training topics (where missing).
    - Define or validate terminal objectives and finalize learning outcomes using Bloom's taxonomy, a framework to establish and categorize measurable educational goals [REF-02].
    - Validate proposals for course type, delivery methods preferences, and instructional strategies.
    - Confirm the learner profile (addressing missing information where necessary).
    - Evaluate EITM courses' relevance to the identified objectives.

M14 – Evaluation of Training Providers

1. **Sourcing Training Providers:** Once input from target partners is finalized, a curriculum document will be shared with the consortium to identify further training providers. Providers will assess which content areas they can contribute to, offer insights on content development feasibility, and agree on delivery methods.
2. **Identify and evaluate opportunities for leveraging innovative learning tools:**
    - **EITM Academy Platform**: Evaluate the integration of new material to be developed into the EITM Academy learning platform and confirm the use of existing EITM labelled courses.
    - **XR2LEARN:** Funded by the European Commission's Horizon Europe Program, this project fosters the cross-border development of human-centric XR applications in education. As an associated partner in the project ecosystem, EITM South can facilitate cross-project synergies within the R3-MYDAS project by leveraging the XR2LEARN project's activities in different ways:
        - **XR2LEARN platform**: As a one-stop-shop platform enabling stakeholders to collaborate and matchmake in the creation of XR applications, R3-MYDAS partners could leverage the platform to communicate, share interests, and build XR educational solutions collaboratively.
        - **XR2Learn Forum**: As a platform that connects educators, innovators, and XR enthusiasts, the forum offers opportunities for R3-MYDAS partners to collaborate on developing XR applications for educational contexts and access expert resources like webinars, case studies, and technical updates.
        - **XR Projects Clustering**. XR2Learn is part of a cluster that involves 8 EU-funded projects (XR2Learn, XR2Industry, OpenVerse, VOXReality, Motivate XR, XR5.0, MASTER, XR4ED) in the area of XR for education and training. This cluster offers opportunities for accessing knowledge and opportunities that R3-Mydas can exploit, including multiple open calls funded by some of the cluster projects. For instance, R3-Mydas partners can apply to one of the incoming open calls to develop specific XR-based solutions and partner with technology providers found in the aforementioned forum.
3. **Follow-up Calls:** Organize follow-up calls with partners to finalize plans and coordinate the development of training material.

M15–M24 – Content Development and Quality Check

1. **Course Development and integration:** Develop training content and assessments based on the agreed framework, incorporating partner input and leveraging existing EITM materials where applicable. For existing resources,

evaluate their integration into learning paths. The development phase will also include designing assessments, grading rubrics and ensuring that learning outcomes, content, assessments and rubrics are aligned.

2. **Learning tools and technologies:** Begin the process of sourcing and coordinating the use of technologies for learning, based on the identified opportunities (e.g., XR2LEARN). Begin the integration of courses on the EITM Academy Platform.
3. **Partners' Involvement:** Update consortium on development status during the next plenary meeting, test and iterate the development of content where feasible (e.g., with technical knowledge).
4. **Conduct Quality Review:** Continuously monitor content development to ensure alignment with the validated learning outcomes, instructional strategies, and delivery methods. Once the material is finalised, conduct quality review checks.

In addition to utilizing existing projects and resources, EITM will also evaluate other opportunities among the services it offers that could enhance the success of Task 8.4. These include networking and community-building opportunities for corporates and SMEs, access to funding programmes to accelerate sustainable growth, and other initiatives aimed at expanding skills and competencies (e.g., EITM education and training calls for proposals, and dissemination of innovation).

For the exception of technical knowledge sharing, for which the timeline of delivery should adapt and be flexible according to the partners' needs and technical progress within each demo case, the delivery of subject-matter courses (i.e., additive manufacturing, battery development, manufacturing processes, etc.) is aimed to begin around month 25.

Lastly, where feasible, course structure design will be optimized based on shared needs across the three demo cases.

6 Conclusion

This report provided an overview of the methodology designed to carry out the activities of Task 8.4 "Training and Skills Enhancing" applied to the R3-MYDAS project three demo cases, from skills gap analysis to training delivery and impact evaluation.

The task, which is executed throughout the R3-MYDAS project duration, has begun with the assessment and analysis of the gaps in technical knowledge and skills for the R3-MYDAS project partners through activities such as desk research, and by engaging partners through questionnaires, interviews and workshop to assess skills needs. The input collected has informed the creation of three training curricula, one for each demo case, detailing potential modules content, and instructional and assessment strategies.

The training curriculum proposed for Demo Case 1 (Oil & Gas crankshafts) focuses on **strategies for technical knowledge acquisition** of partners' solutions, along with modules covering key concepts and methods for systems integration, welding and laser safety, as well as an overview of the laser cladding process.

Courses for Demo Case 2 (EV Batteries) focus on **Artificial Intelligence and Machine Learning for anomaly detection and predictive maintenance** techniques. They also provide an overview of the battery lifecycle, battery assembly and disassembly, and State of Health evaluation methods. IoT platforms and cloud solutions, Human-AI/Robot interaction, and relevant AI and robotics regulatory frameworks will also be covered.

The Demo Case 3 (Wind Turbine Gearboxes) training curriculum explores **Additive Manufacturing** in detail, covering equipment operation and maintenance, failure analysis, process optimization, design and material selection.

The objective of the next phase of the task (M13) is to validate and refine the proposed training curricula, before moving into the content development and sourcing phase (M14-M24). This includes identifying opportunities to leverage existing educational material or develop new resources in collaboration with key training providers among the R3-MYDAS consortium. We will also ensure accurate alignment of course content with learning outcomes, resources and assessments as well as quality reviews before the delivery. Technology and innovative learning practices, including Virtual Reality, gamification, microlearning, and online learning, will be evaluated and integrated if they enhance and maximize the delivery and retention of the content.

The subsequent phase focuses on the implementation and delivery of training (M25-M34) involving continuous evaluation practices to ensure engagement and effectiveness of training.

Lastly, the collection of learners' and partners' feedback, along with an analysis of course assessment results will guide improvements and refinement of the training curricula (M34-M36).

In conclusion, this report outlines the comprehensive approach taken to address a key factor in the success of the R3-MYDAS demo cases: ensuring that the workforce is equipped with the technical knowledge and competencies to achieve the project objectives. Efforts will focus on maintaining the relevance and effectiveness of content, while considering the specific needs of the target learners and partners, ensuring a seamless, memorable, and impactful learning experience. As the project progresses, continuous evaluation and feedback will drive improvements, ensuring that the training remains aligned with the evolving needs of both the partners and the industry.

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Appendix A

This appendix includes the skills taxonomy that identifies key competencies clusters and skills relevant to the manufacturing sector. It also includes the templates of the questionnaire for skills assessment and self-assessment distributed among the R3-MYDAS partners.

A.1 Skills Taxonomy

Additive Manufacturing and Materials Science

- Materials Science and Characterisation
- Material Selection for Additive Manufacturing
- 3D Printing Technologies and Methods (SLA, FDM, SLS)
- Design for Additive Manufacturing (DfAM)
- Process Optimisation for Additive Manufacturing
- Laser-based Manufacturing (equipment operations, maintenance)
- Surface Treatment and Post-Processing Techniques
- Corrosion and Lubrication
- Additive Manufacturing Failure analysis and risk assessment
- Advanced and Composite Materials
- Testing and Quality Control
- Electrochemistry
- Electrical Conductivity and Resistance
- Materials Regulatory Standards and Compliance
- Binder Jetting
- Multi-material Printing

Artificial Intelligence and Machine Learning

- Machine Learning Algorithms (Supervised, Unsupervised, Reinforcement Learning), Training, and Evaluation
- Data Preprocessing and Feature Engineering
- Model Training and Evaluation
- Neural Networks and Deep Learning
- Natural Language Processing (NLP)
- Predictive Maintenance Analytics
- Computer Vision
- Generative AI Models
- AI Ethics and Governance
- AI Frameworks and Libraries (e.g., TensorFlow, PyTorch)
- AI in Predictive Maintenance

Automation and Robotics

- Robotic Fundamentals
- Advanced Robotics Algorithms (including SLAM, Path Planning, Motion Planning)
- Sensor Integration and Fusion Techniques
- Robot Perception and Decision-Making

- Vision Systems and Processing (Image Processing, Object Recognition)
- High-Performance Robotic Computing
- Real-time Data Processing
- Knowledge and Operation of 3D Scanning and Positioning Technologies
- Calibration Techniques for Automation and Robotics
- Feedback Control Systems
- Preventive and Predictive Maintenance

Battery Chemistry and Engineering

- Battery Design and Development Lifecycle
- Battery Chemistry & Materials Knowledge
- Electrochemical and Thermal Analysis Techniques
- Mechanical Analysis of Battery Components
- Battery Assembly and Testing
- Battery Health and Safety Management
- Quality Assurance and Regulatory Compliance
- Battery Remanufacturing Techniques
- Battery Dismantling and Material Recovery

Blockchain

- Knowledge of Blockchain Basics
- Blockchain Platforms
- Smart Contracts
- Blockchain Interoperability and Scalability Solutions
- Supply Chain and Marketplace Integration
- Digital Passport Implementation
- Data Privacy and Security in Blockchain Systems
- Data Management in Blockchain Systems
- Environmental, Social & Governance (ESG) Reporting via Blockchain

Circular Economy, Supply Chain and Environmental Management

- Knowledge of Circular Economy Principles, Practices and Models
- Life Cycle Assessment (LCA) Methodologies
- Environmental Impact Assessment (EIA)
- Waste Minimization and Management Techniques
- Knowledge of Environmental Regulations
- Cost Efficiency and Supply Chain Optimisation
- Risk Management in Supply Chains
- Sustainable Procurement Practices
- Sustainable manufacturing processes
- Sustainability Reporting

Data Protection, Ethics and Technology Impact

- Data Protection and Privacy Risk Management
- Data Governance Practices
- Data and Technology Ethics
- Knowledge of Artificial Intelligence Act

- Knowledge of ethical implications of technology
- Data Science and Big Data
- Data Analysis
- Data Preparation and Management
- Data Mining Techniques
- Exploratory Data Analysis
- Data Visualisation Techniques and Tools
- Time Series Analysis
- Big Data Technologies
- Cloud Data Platforms

Design and Simulation Technologies

- Computer-Aided Design (CAD)
- Computer-Aided Manufacturing (CAM)
- Computer-Aided Process Planning (CAPP)
- Finite Element Analysis (FEA) (including Stress and Thermal Analysis)
- Reverse Engineering
- 3D Modelling, Simulation, and Digital Twin Development
- Prototyping and Virtual Testing
- Generative Design
- Topology Optimisation

Electronic and Electrical Engineering

- Circuit Design
- Electrical Systems
- Power Electronics
- Sensors and Actuators
- Embedded Systems
- Control Systems
- Electromagnetics
- Testing and Troubleshooting
- Simulation Software
- Regulatory Standards
- Safety Standards

Manufacturing Process Control and Optimisation

- Process Optimization and Continuous Improvement (Lean, Six Sigma, SPC)
- Digital Transformation
- Manufacturing Execution Systems (MES)
- Root Cause Analysis (RCA)
- Process Mapping
- Production Scheduling and Planning
- Quality Control Procedures (QCP)
- Knowledge of Standards Development
- Supply Chain Management
- Inventory Control

Quality and Risk Management

- Knowledge of Quality Management Systems and Frameworks
- Knowledge of ISO Standards
- Standard Operating Procedures (SOPs)
- Documentation and Reporting Standards
- Risk Assessment, Response and Mitigation
- Development of Quality Assurance Plans
- Project Quality Planning and Control

Software Development and Programming

- Programming Languages (Python, C++, Java, JavaScript, C#, Ruby)
- Software Development Life Cycle (SDLC)
- Version Control Systems
- Agile Development Methodologies (Scrum, Kanban)
- API Development
- Software Engineering Principles
- Database Management
- DevOps Practices
- Cloud Computing
- User Interface (UI) and User Experience (UX) Design Principles
- Microservices Architecture
- Security Best Practices in Software Development

Systems Integration and Industrial IoT

- TCP/IP Protocols and Networking Fundamentals
- Network Architecture and Design
- Wireless Networking Technologies
- IoT Communication and Industrial Protocols
- Middleware Solutions
- Cloud-Based IoT Platforms & Cloud Integration
- Edge Computing Solutions
- Edge AI Integration
- Edge Analytics
- Data Transmission and Real-time Communication
- Data Aggregation and Analysis
- Integration Methodologies and System Architecture Design
- Network Troubleshooting and Diagnostics
- Cybersecurity for IoT and Networked Systems
- Programmable Logic Controllers (PLC) Programming
- Industrial Control Systems (ICS)
- Human-Machine Interface (HMI) Development
- Industrial Internet of Things (IIoT)
- Data Security and Privacy Compliance

Transferable and Soft Skills

- Creativity and innovation
- Critical thinking
- Design thinking

- Entrepreneurship
- Industrial resilience
- Leadership and team management
- New manufacturing business models
- Problem-solving
- Strategic thinking
- Project management
- Change Management

A.2 Questionnaire for Skills Gap Assessment

General Instructions

This survey is meant to help us uncover the skills and expertise needed for organizations to meet the R3-MYDAS project objectives and demo case requirements, focusing on areas and target audience requiring upskilling and reskilling.

If you are uncertain about any aspects, please provide any insights or information you have, as this will be valuable input. Alternatively, indicate if you require assistance with that aspect. We will address any unknowns thoroughly during follow-up activities.

Please be assured that the information shared in this survey will be used solely for the purposes described above and will not be shared or used beyond this scope.

Organization Profile

1. Name of the organization: [open field]
2. Type of organization: [single choice]

- SME
- Start-up
- Large Company/Enterprise
- University/Research Institute
- Research and Technology Organization (RTO)
- Consulting Firm
- Industry Association
- Other (please specify)

3. Which of the following categories best describes the industry your organization operates in? (you may select all that apply) [multiple choice]

- Automotive
- Batteries
- Digital, Technology and ICT Services
- Education
- Electronic equipment (E.g., Semiconductors, etc.)

- Energy
- Logistics and Transportation
- Machinery
- Manufacturing
- Research and development (R&D)
- Robotics and Automation
- Supply Chain
- Utilities
- Waste and disposal services
- Wholesale and retail trade
- Other: [open field]

4. Please briefly describe your role within the organization [open field]

Training and Skills Requirements and Workforce

This section identifies the key skills required to achieve the project's objectives and the target audience for skills development. While many of the listed skills may apply to various fields, they are intended specifically for the project context. We will refine them based on your feedback and input.

If your organization is providing services or expertise in the project and does not require training or skills enhancement, you may skip this section entirely or any questions that you find irrelevant.

5. How important is it for your organization to develop or enhance the following skills to achieve the project objectives?
6. Please rate the importance of each skill for achieving the project's objectives, considering your organization's current capabilities and needs [Likert Scale]

   - Skill is not needed
   - Skill is somewhat needed
   - Skill should be developed
   - Skill is a high priority to develop
   - Unsure

List of skills and knowledge areas:

- Advanced Manufacturing Technologies: Additive Manufacturing
- Advanced Manufacturing Technologies: Design and Simulation Technologies (CAD, CAM, Digital Twins, etc.)
- Automation & Robotics: Advanced Robotics Algorithms, Human-Machine Interaction, etc.
- Manufacturing Process Control and Optimization
- Artificial Intelligence and Machine Learning
- Battery Science and Engineering

- Data Science and Big Data Analytics
- Blockchain
- Circular Economy: Strategic and Operational Integration of Best Practices
- Supply Chain Management
- Cybersecurity (Industrial & IT Systems)
- Electrical and Electronic Engineering: Circuit Design, Electrical Systems, Power Electronics, Sensors, etc.
- Environmental, Sustainability and Regulatory Management (LCA, Auditing and Impact Assessment, Policy & Regulation)
- Extended Reality (AR, VR)
- Waste and Resource Management
- Materials Science
- ICT and Networking
- Quality Assurance and Control
- Systems Integration & Industrial IoT
- Programming and Software Development

7. Will you require training for R3-MYDAS project-specific technologies and/or knowledge? If so, please provide additional details about the specific training requirements needed. [open field]

8. Have you already identified any subskills/specific technologies/software for which your project team will need training, or would you need guidance? You may also use this section to add any other useful details regarding the skill sets needed. [open field]

9. Are there any non-technical skills that would enhance your organization's success in the project? If so, please select them from the list below [multiple choice]

- Community Management
- Corporate Social Responsibility (CSR)
- Creativity & Innovation
- Critical Thinking
- Design Thinking
- Entrepreneurship
- Human Experience (HX): User Experience (UX), Customer Experience (CX)
- Industrial Resilience
- Leadership and Team Management
- Learning
- Market Strategy
- New Manufacturing Business Models
- Problem Solving
- Project Management
- Safety Management and Compliance
- Strategic Thinking
- Other [open field]

10. What are the primary factors contributing to the gap between your organization's current skills – both in terms of new capabilities and the enhancement of existing ones – and those required to achieve the project objectives? (Factors might include, for example, lack of training, evolving market demands, advances in technology, specific project requirements, or other relevant factors) [open field]

11. Could you identify or specify any categories of personnel who may need skills development for the project and provide an approximate number of individuals overall? If you're unsure, we can help determine this in follow-up activities. (e.g., Higher Management; Supervisors/Team Leaders; Middle management; Engineering Professionals; Technicians/Operators; Other) [open field]

12. Would you be open to providing personnel at a later stage to complete a self-assessment on the skills identified in this survey? [open field]

Skills Recommendations

13. If your organization is providing services or expertise in the project, please fill in this section to help us understand the skills required to effectively adopt and integrate the project solutions within Organizations.

14. If your organization is providing technology, services, or expertise for the project, what skills do you think are necessary for other organizations to fully integrate and adopt your solutions? Please specify these skills and identify the target audience within the project's partner organizations and potential workforce. [open field]

15. Does your organization have any training programs that cover the skills mentioned in the previous question? If so, please briefly describe them here. [open field]

Survey Feedback and Improvement Suggestions

16. What are your thoughts on the overall design and content of the survey, and do you have any suggestions for improvement?

A.3 Skills Self-Assessment Questionnaire

General Instructions

This Skills Self-Assessment Questionnaire is part of the R3-MYDAS project (project number:101138738), which aims to create a multi-actor framework for remanufacturing, repurposing, and recycling energy goods through advanced mechatronic and digital technologies.

In this questionnaire, we will ask for information regarding your professional profile, including your skills, work experience, and educational background. Our goal is to understand the skills needed to effectively implement the R3-MYDAS demo case solutions.

Please be assured that your responses to this questionnaire will remain anonymous and will be used solely for the purposes of the project. While the overall data will be compiled and shared in a public report, no individual responses will be disclosed.

Section 1: Participant Profile

1. Please select your organization [single choice]
   - TMCOMAS
   - ZIKNES
   - AIMEN
   - AVL
   - Spin Robotics
   - ITML
   - CSEM
   - LUT
   - Flender Finland Oy

2. Age [single choice]

   - Under 25
   - 25-34
   - 35-44
   - 45-54
   - 55-64
   - 65 and over

3. Gender [single choice]

   - Male
   - Female
   - Prefer not to say

4. Highest Education Level [single choice]

   - High School or equivalent
   - Bachelor's Degree
   - Master's Degree
   - Doctorate

- Other (please specify)

5. Years Employed at the Organization:

- Less than 1 year
- 1-3 years
- 4-6 years
- 7-10 years
- More than 10 years

6. Total number of years of experience in your field [single choice]

- Less than 1 year
- 1-3 years
- 4-6 years
- 7-10 years
- More than 10 years

7. Please provide your job title [open field]

8. What are your primary responsibilities within your role? [open field]

9. What are the top 3-5 key skills and areas of knowledge that you use to effectively perform your daily tasks at work? [open field]

10. Please provide details about any previous work experience, including any roles you've held in different fields or industries, if applicable. [open field]

Section 2: R3-MYDAS Demo Case Skills and Knowledge Assessment

In this section, we ask you to provide details about your responsibilities in the activities of the R3-MYDAS project and demo cases. Additionally, we request an overview of the skills you possess and your level of proficiency in key areas identified by your organization as key priorities.

11. How are you currently involved, or how will you be involved, in the activities of the R3-Mydas project and/or demo case that your organization is working on? [open field]

12. What are the key skills and knowledge that you will need to perform your tasks within the project and/or demo case? [open field]

In the following questions, we kindly ask you to assess your proficiency level across a list of skills, technologies, and knowledge areas. Each question will specify which demo case(s) the skills are more relevant for, so that you can identify what to focus on:

- Demo Case 1: Oil & Gas Crankshaft
- Demo Case 2: EV Batteries
- Demo Case 3: Wind Turbines Gearboxes
- Cross-dimensions: Partners working on project cross-dimensions

Please note that some skill sets may be more relevant to your role than others. If any skills are not applicable to your role, please select N/A. To assess your proficiency, select a rating from the following scale for each skill listed:

- 0 – N/A: I don't need this skill in my role.
- 1 – Lacking: I struggle with this skill and would like to receive training on it.
- 2 – Low: I have a basic understanding and can apply this skill at a fundamental level.
- 3 – Medium: I have supported teams and contributed to projects where this skill was essential.
- 4 – High: I can co-create and co-deliver services where this skill is critical.
- 5 – Expert: I can present and teach this skill to a broad audience.

13. How would you rate your skills and knowledge in Systems Integration and Industrial IoT? (Demo Cases 1 and 2; Cross-Dimensional activities) [Likert Scale]

- TCP/IP Protocols and Networking Fundamentals
- Network Architecture and Design
- Wireless Networking Technologies
- IoT Communication and Industrial Protocols
- Middleware Solutions
- Cloud-Based IoT Platforms & Cloud Integration
- Edge Computing Solutions
- Edge AI Integration
- Edge Analytics
- Data Transmission and Real-time Communication
- Data Aggregation and Analysis
- Integration Methodologies and System Architecture Design
- Network Troubleshooting and Diagnostics
- Cybersecurity for IoT and Networked Systems.
- Data Security and Privacy Compliance

14. How would you rate your skills and knowledge in Electrical and Electronic Engineering? (Demo Cases 1 and 2; Cross-Dimensional activities)

- Circuit Design
- Electrical Systems
- Power Electronics
- Sensors and Actuators
- Signal Processing

- Embedded Systems
- Control Systems
- Electromagnetics
- Testing and Troubleshooting
- Simulation Software Proficiency
- Regulatory Standards
- Communication Systems
- Safety Standards

15. How would you rate your skills and knowledge in Automation and Robotics? (Demo Cases 1 and 2; Cross-Dimensional activities)

- Robotic Fundamentals
- Advanced Robotics Algorithms (including SLAM, Path Planning, Motion Planning, Computer Vision)
- Sensor Integration and Fusion Techniques
- Robot Perception and Decision-Making
- Vision Systems and Processing (Image Processing, Object Recognition)
- High-Performance Robotic Computing
- Real-time Data Processing
- Knowledge and Operation of 3D Scanning and Positioning Technologies
- Calibration Techniques for Automation and Robotics
- Feedback Control Systems
- Preventive and Predictive Maintenance

17. How would you rate your skills and knowledge in Manufacturing Process Control and Optimization? (Demo Cases 1 and 2; Cross-Dimensional activities)

- Process Optimization and Continuous Improvement (Lean, Six Sigma, SPC)
- Digital Transformation
- Manufacturing Execution Systems (MES)
- Root Cause Analysis (RCA)
- Process Mapping
- Production Scheduling and Planning
- Quality Control Procedures
- Knowledge of Standards Development
- Supply Chain Management
- Inventory Control

18. How would you rate your skills and knowledge in Software Development and Programming? (Demo Cases 1 and 2; Cross-Dimensional activities)

- Programming Languages (Python C++, Java, JavaScript, C#, Ruby, etc.)
- Software Development Life Cycle (SDLC)
- Version Control Systems
- Agile Development Methodologies (Scrum, Kanban)

- API Development
- Software Engineering Principles
- Database Management
- DevOps Practices
- Cloud Computing
- User Interface (UI) and User Experience (UX) Design Principles
- Microservices Architecture
- Security Best Practices in Software Development
- Programmable Logic Controllers (PLC) Programming
- Industrial Control Systems (ICS)
- Human-Machine Interface (HMI) Development
- Industrial Internet of Things (IIoT)

19. How would you rate your skills and knowledge in Additive Manufacturing & Materials Science? (Demo Cases 1 and 3)

- Materials Science and Characterisation
- Material Selection for Additive Manufacturing
- 3D Printing Technologies and Methods (SLA, FDM, SLS)
- Design for Additive Manufacturing (DfAM)
- Process Optimisation for Additive Manufacturing
- Laser-based Manufacturing (equipment operations, maintenance)
- Surface Treatment and Post-Processing Techniques
- Corrosion and Lubrication
- Additive Manufacturing Failure analysis and risk assessment
- Advanced and Composite Materials
- Testing and Quality Control
- Electrochemistry
- Electrical Conductivity and Resistance
- Materials Regulatory Standards and Compliance
- Binder Jetting
- Multi-material printing

20. How would you rate your skills and knowledge in Blockchain? (Demo Case 2)

- Knowledge of Blockchain Basics
- Blockchain Platforms
- Smart Contracts
- Blockchain Interoperability and Scalability Solutions
- Supply Chain and Marketplace Integration
- Digital Passport Implementation
- Data Privacy and Security in Blockchain Systems
- Data Management in Blockchain Systems
- Environmental, Social & Governance (ESG) Reporting via Blockchain

21. How would you rate your skills and knowledge in Data Science and Big Data? (Demo Case 2)

- Data Analysis

- Data Preparation and Management
- Data Mining Techniques
- Exploratory Data Analysis
- Data Visualisation Techniques and Tools
- Time Series Analysis
- Big Data Technologies
- Cloud Data Platforms

22. How would you rate your skills and knowledge in Battery Chemistry and Engineering? (Demo Case 2)
    - Battery Design and Development Lifecycle
    - Battery Chemistry & Materials Knowledge
    - Electrochemical and Thermal Analysis Techniques
    - Mechanical Analysis of Battery Components
    - Battery Assembly and Testing
    - Battery Health and Safety Management
    - Quality Assurance and Regulatory Compliance
    - Battery Remanufacturing Techniques
    - Battery Dismantling and Material Recovery

23. How would you rate your skills and knowledge in Artificial Intelligence and Machine Learning? (Demo Case 2; Cross-Dimensional Activities)
    - Machine Learning Algorithms (Supervised, Unsupervised, Reinforcement Learning), Training, and Evaluation
    - Data Preprocessing and Feature Engineering
    - Model Training and Evaluation
    - Neural Networks and Deep Learning
    - Natural Language Processing (NLP)
    - Predictive Analytics
    - Computer Vision
    - Generative AI Models
    - AI Ethics and Governance
    - AI Frameworks and Libraries
    - AI in Predictive Maintenance

24. How would you rate your skills and knowledge in Quality and Risk Management? (Demo Cases 2 and 3)
    - Knowledge of Quality Management Systems and Frameworks
    - Knowledge of ISO Standards
    - Standard Operating Procedures (SOPs)
    - Documentation and Reporting Standards
    - Risk Assessment, Response and Mitigation
    - Development of Quality Assurance Plans
    - Project Quality Planning and Control

25. How would you rate your skills and knowledge in Design and Simulation Technologies? (All Demo Cases; Cross-Dimensional Activities)
    - Computer-Aided Design (CAD)
    - Computer-Aided Manufacturing (CAM)
    - Computer-Aided Process Planning (CAPP)
    - Finite Element Analysis (including Stress and Thermal Analysis)
    - Reverse Engineering
    - 3D Modelling, Simulation, and Digital Twin Development
    - Prototyping and Virtual Testing
    - Generative Design
    - Topology Optimization

26. How would you rate your skills and knowledge in Circular Economy, Supply Chain and Environmental Management? (All Demo Cases)
    - Knowledge of Circular Economy Principles, Practices and Models
    - Life Cycle Assessment (LCA) Methodologies
    - Environmental Impact Assessment (EIA)
    - Waste Minimization and Management Techniques
    - Knowledge of Environmental Regulations
    - Cost Efficiency and Supply Chain Optimisation
    - Risk Management in Supply Chains
    - Sustainable Procurement Practices
    - Sustainable manufacturing processes
    - Sustainability Reporting

27. How would you rate your skills and knowledge in Data Protection, Ethics, and Technology Impact? (All Demo Cases; Cross-Dimensional Activities)
    - Data Protection and Privacy Risk Management
    - Data Governance Practices
    - Data and Technology Ethics
    - Knowledge of Artificial Intelligence Act
    - Knowledge of ethical implications of technology

28. How would you rate your skills and knowledge in the following transferable and soft skills? (All Demo Cases; Cross-Dimensional Activities)
    - Creativity and innovation
    - Critical thinking
    - Design thinking
    - Entrepreneurship
    - Industrial resilience
    - Leadership and team management
    - New manufacturing business models
    - Problem solving
    - Strategic thinking
    - Project management
    - Change Management

29. Are there any additional skills not mentioned here that you think might be helpful for the project or for your role? [open field]

30. What languages do you speak, and how would you rate your proficiency in each (beginner, intermediate, advanced, or native speaker)? [open field]

31. What skills do you feel most equipped with for implementing the R3-Mydas project and/or demo case solutions that your organization is working on? [open field]

Section 3: Learning Experience and Preferences

32. How do you prefer to learn new skills? (Select all that apply) [Multiple Choice]

- Instructor-led training
- Online courses (self-paced)
- Workshops or hands-on sessions
- Group learning or collaborative environments
- Reading manuals or guides
- One-on-one coaching
- Other:

33. In your opinion, what could your organization do to make the acquisition and development of new skills smoother for you? [open field]

34. Have you taken any training or development programs in the past that you found beneficial in your role? If so, please indicate approximately when the training was taken and what you found beneficial. [open field]

35. Please list any certifications you hold and any mandatory training you have completed that are required for your current role. [open field]

36. Is there anything else you'd like to share about your skills development needs or expectations related to the R3-MYDAS project? [open field]