SkiComCu-Lifelong Learning Course for skills & competences in the Copper sector

Project number:	23043
Project short title:	SkiComCu-LL
Project starting date:	September 2023
Project ending date:	August 2026
Project duration:	45 months

SkiComCu long term action plan and 10-year foresight report

Internal Identifier:	EITRM122076
Description:	This document presents the methodological approach used to gain insights on the future of the copper sector towards the year 2035. Future skills and competences needs are identified, recommendations to address those needs are provided, as are guidelines to keep the SkiComCu project framework relevant for the future. A roadmap for 2035 lists actions and timelines for updating and maintaining SkiComCu, while keeping engagement with relevant stakeholders.
Included in BP year:	2024
Date:	30/09/2024
Version No.:	1

Table of Contents

List of Figures

List of Tables

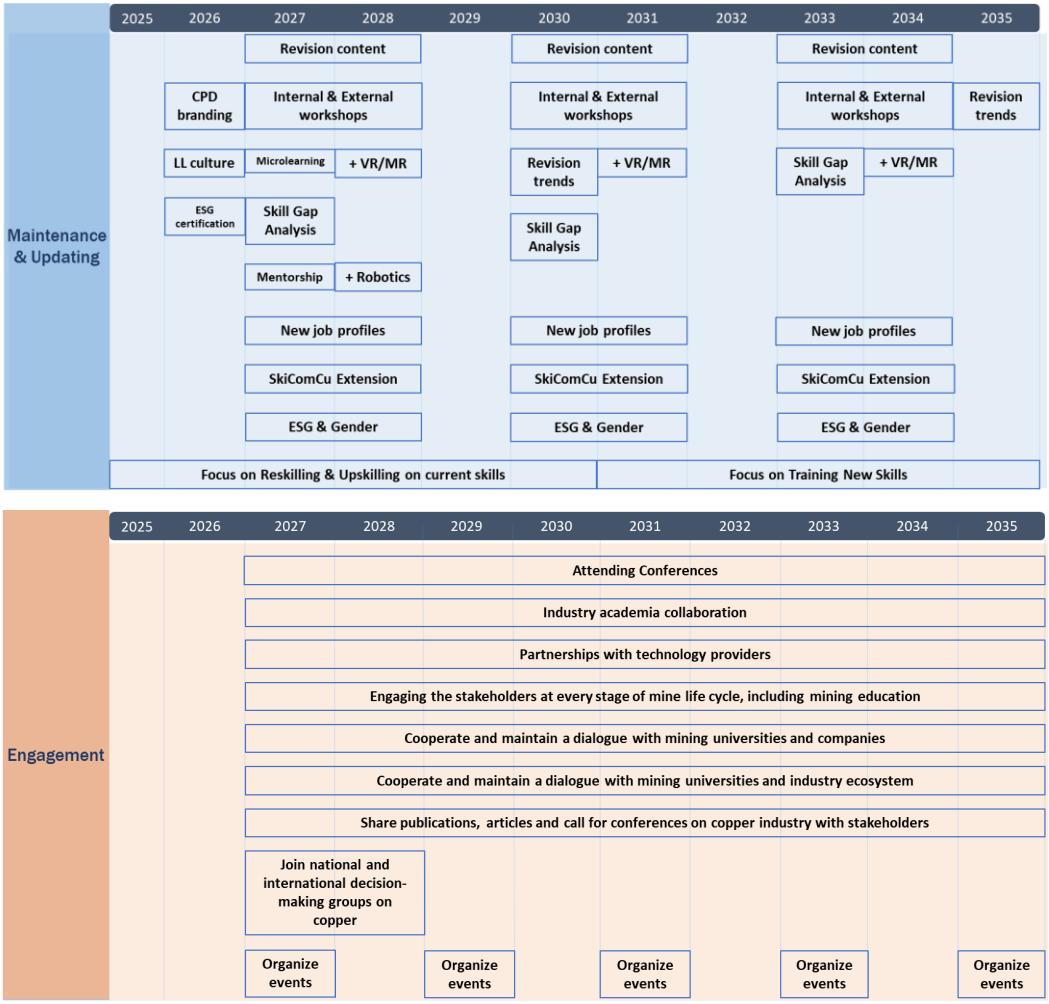
Executive Summary

SkiComCu, as a framework implemented through dedicated training and platform, is in development. The goal is to have such framework ready to be rolled into testing training centres in 2025. However, since SkiComCu aims to continue after the project timeframe, it is necessary to have a long term, sustainable plan. This document focuses on the aftermath of the Project timeframe, offering a window into the future, towards 2035. It presents insights into a 2035 future as well as dedicated actions to address trends and changes in the copper sector.

Foresight adapted methodologies of desk research, Delphi survey, backcasting and roadmapping were implemented, making use of internal and external expert knowledge, views and opinions across each stage of the copper value chain. The results of these exercises were processed, resulting in the creation of a 10-year foresight view of SkiComCu and the copper sector, as well as a roadmap (a long-term action plan).

The 10-year foresight view creates a picture of the future that acts as a guideline for the future of the copper sector and, consequently, the SkiComCu framework. The list of skills and competencies needs, trends and drivers, gaps and issues, and recommendations for SkiComCu lifelong learning course are addressed in a dedicated chapter of the report. Recommendations are translated into actions that are mapped in the long-term action plan.

The roadmap showcases defined actions and timelines for implementation of the actions needed to maintain the impact of SkiComCu beyond the EIT RawMaterials funded period. These actions are presented in two sub-roadmaps, one dedicated to the constant update and maintenance of the SkiComCu framework; the other focusing on engagement actions towards stakeholders of the copper sector. The actions span the years 2025 to 2035. The roadmaps resulting from this work are as follows:



The results of the present research revealed the necessary steps and procedures to review and update the SkiComCu course in the next years. Recommendations and suggestions included in the roadmaps will highly contribute to the goals and objectives of SkiComCu in the future and, therefore, it is advisable that these actions are followed by the team leading and implementing the SkiComCu framework in future efforts.

Objectives, and EIT Impact Framework and KIC Impact

Objectives

Objective	Description	Status
Present a long-term action plan and 10-year foresight report to keep tools and methodologies developed within SkiComCu relevant in the future	This report presents the results of the implementation of foresight-adapted tools (desk research, Delphi survey, backcasting, roadmapping), gathering opinions and views of experts, to present the two main objectives. The 10-year foresight aspect is reflected in the mapping of (all for 2035): skills and competences, trends and drivers, and gaps and issues in the Cu sector. The long-term action plan is represented in the for of a roadmap, divided into two complementary ones. The first dedicated to updating and maintaining the SkiComCu platform, the other dedicated to engagement with stakeholders. Both roadmaps show actions and timelines for implementation.	Achieved

EIT Impact Framework and KIC Impact

Number	KPI	Contribution of this deliverable
KICN01-11	Improve gender balance in the RM sector	The roadmap lists an action to do a gender revision on SkiComCu every 2-3 years after the project is over. If gender balance is not achieved, actions can be taken in advance of content/programme revision to address the issues.

Number	KPI	Contribution of this deliverable
EITHE08.1	Participants in NON-labelled education activities, programs, and trainings	The roadmap lists actions to update and maintain the Lifelong Learning tools and platform developed within the SkiComCu project, including constant content revision and remarking the need to extend the training to the Cu sector in other countries. Actions listed will contribute to higher number of participants, but only after the project timeline.

1 Introduction

The SkiComCu long term action plan and 10-year foresight report, hereby presented, is the outcome of the work performed as part of Task 2.4 - SkiComCu medium and long-term strategic framework of this project, included in WP2 - Long term strategic Framework and Methodology for SkiComCu lifelong learning. As it can be perceived from its name, work is aimed at developing tailored competence profiles, thereby identifying all relevant competence gaps for newcomers in the sector. The main goal for Task 2.4 is to present a mechanism for the continuous and timely identification of possible and probable future needs for skills and competencies along the copper value chain, while, at the same time, showcase an action plan for the future.

Deliverable 2.3 - SkiComCu long term action plan and 10-year foresight report, therefore, aims at providing a framework for the future assessment of skills and competencies needs in the copper sector. This resulting document offers a long-term action plan tied with a foresight purposed view on the sector within a 10-year frame (towards 2035). It serves as a basis for future continuation of the SkiComCu project framework after the funding period by providing a roadmap with actions and timelines to be implemented by direct and indirect stakeholders of SkiComCu.

The work presented in this deliverable is linked to a methodological approach that considers at its core the development and implementation of exercises with stakeholders to collect data on future skills and competencies gaps, obtained from experts in the sector, collection of data from external sources (e.g. reports, strategic agendas) to complement the findings and development of a roadmap/framework that suggest actions to take into account in order to "solve" future skills/competencies bottlenecks and better adapt the SkiComCu outputs to be as future proof as possible.

2 Methodology and Data collection

To achieve the goals set out in the previous chapter, work used the implementation of foresight-adapted tools and methodologies, aimed at integrating both internal and external academia, research and industry (ultimate focus) expertise across the value chain. The following approaches were used during the development of the task (Figure 1):

1. Desk research/Horizon Scanning
2. Delphi Survey
3. Backcasting
4. Roadmapping

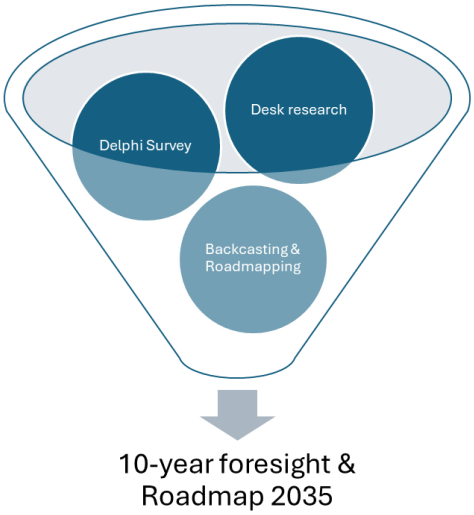


Figure 1: Methodological approach used to deliver the 10-year foresight report & corresponding 2035 roadmap.

2.1 Desk research/Horizon Scanning

Before the definition and implementation of the foresight exercises (*sensu latu*), it was necessary to gather information on the current and near future skills and competencies needs from the literature. These serve as a basis for the work of Task 2.4. Therefore, a number of reports and scientific papers (including roadmaps, foresight studies and reports from many projects and initiatives focusing on the relevant topics) were screened in a process that in foresight is known as Horizon Scanning. A few examples of reviewed documents include:

- Advanced Materials Initiative (2023). Strategic Materials Agenda.

- Chirgwin (2021). Skills development and training of future workers in mining automation control rooms.
- Correia et al. (2020). International qualification framework for the raw materials sector. INTERMIN project deliverable 3.1.
- EY (2019). The Future of Work: the Changing Skills Landscape for Miners.
- EY (2019). Future of work: The economic implications of technology and digital mining.
- Government of South Australia (2017). South Australia's Copper Strategy.
- International Finance Corporation (2023). NET ZERO ROADMAP TO 2050 For Copper & Nickel Mining Value Chains. Technical report.
- International Copper Study Group (2023). The World Copper Factbook 2023.
- Konrat Martins & Bodo (2019). Report on skills gaps. INTERMIN project deliverable 2.1.
- Morkun et al. (2019). Defining the Structure of Environmental Competence of Future Mining Engineers: ICT Approach.
- RFC Ambrian (2022). The Pathway for Copper to 2030 – Copper market analysis.
- S&P Global (2022). The Future of Copper: Will the looming supply gap short-circuit the energy transition?

These documents were screened to extract relevant information regarding skills and competencies in the copper sector as a whole, but also in its operational stages (exploration, mining, processing, recycling) in particular. The information gathered from these sources allowed the creation of dedicated tables (Table 1 to Table 4) with Drivers (external factors influencing development), Gaps (missing factors), Issues (problems) and Trends (general direction to which things are moving) identified for four main parts of the copper value chain (in this report defined as Exploration, Mining, Processing & Material engineering, and Recycling) and sub-themes for each of these (Skills & Competencies, Stakeholders/Interested parties, Education, Tools). This was a way to compartmentalize the findings in a structured manner that can contribute to the next steps. The following tables summarise the results and they are divided by stage of the value chain. This work is complementary to the desk research of Task 2.1 and reflected in Deliverable 2.1.

Table 1: Drivers, Gaps, Issues and Trends for the Exploration stage of the copper value chain.

Value chain aspects	Sub-theme	Driver/Gaps/Issues/Trends etc
Exploration	Skills & Competencies	Communication and negotiation skills to talk with local stakeholders to get Social License to Operate Problem-solving Decision-making

	Stakeholders/Interested parties	Governments and Permitting authorities Local communities Mining companies
	Education	Geological mapping Geochemical sampling Geophysical surveys Remote sensing
	Tools	Electromagnetic equipment X-ray

Table 2: Drivers, Gaps, Issues and Trends for the Mining stage of the copper value chain.

Mining	Skills & Competencies	Digital fluency Big data analysis Continuous improvement process Environmental Impact Assessment Teamwork skills Communication skills
	Stakeholders/Interested parties	Governments and Permitting authorities Local communities Mining companies
	Education	Underground mining Open-pit mining Mineral processing Solvent extraction Conventional electrowinning (SXEW process) Milling / Concentrate production
	Tools	Drills: used to create holes in the rock to place explosives, which are then detonated to break up the rock and expose the copper Crushers: the copper ore is crushed into smaller pieces to make it easier to handle and to prepare it for processing

Table 3: Drivers, Gaps, Issues and Trends for the Processing & Material Engineering stage of the copper value chain.

Processing & Material engineering	Skills & Competencies	Digital fluency Operate and maintain advanced automation and digitalization technologies in manufacturing processes Develop and interpret the results of artificial intelligence Quality control (CAPA) Contribute to innovation and continuous improvement Welding technologies Additive manufacturing and 3D printing Human-Machine interface programming M2M communication
	Stakeholders/Interested parties	Mining and Materials engineering industries Permitting authorities Local communities
	Education	Networking activities and actions to include women and vulnerable groups Modular hybrid approach (combination of physical and online trainings) Physical metallurgy Mineral processing, Pyrometallurgy: smelting, converting, fire refining, electrolytic refining, slag cleaning Hydrometallurgy: leaching, solvent extraction, electrowinning
	Tools	Virtual Reality (VR) Augmented Reality (AR) Mixed Reality (MR)

Table 4: Drivers, Gaps, Issues and Trends for the Recycling stage of the copper value chain.

Recycling	Skills & Competencies	Resource and energy efficiency Reduction of emissions in supply chain Lifecycle analysis Recycling and circular economy practices
	Stakeholders/Interested parties	Mining industries Governments and Permitting authorities Local communities Water and wastewater industries: copper can be extracted from water and wastewater

	Education	Electrochemical processes Electrowinning process Seperation process
	Tools	Shredders Cable recycling equipment CJD E-Cycling recycling plant

The following steps in the process are based on these results and other information collected, from which the Delphi Survey statements and questions were derived.

2.2 Delphi Survey

The SkiComCu project deployed the Delphi Survey approach as the main step in its foresight process. The Delphi survey methodology has been firstly designed as a forecasting technique to support technological development and implementation for many technology lines, but was later implemented for other purposes as well. The main aim of this technique is to drive the participants/experts to a consensus on different topics, throughout statements and questions, made in two or more rounds. This technique is anonymous, building on group communication, so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem or question (Linstone and Turoff, 2002; Shariff, 2015). In the Delphi technique, experts (the participants) are asked to consider, classify and comment their reasoning on a number of questions or statements that can take several structures.

The Delphi process is different from other types of surveys and questionnaires. First, a list of relevant interested experts is pre-compiled. Second, there is a possibility for experts to comment and explain their opinion on any of the statements. Third, answers are analysed, statistics built and shared with the experts for further comments, resulting in new rounds of questions. Finally, the objective of a Delphi is to reach a consensus within the expert pool on the statements.

The SkiComCu Delphi Survey was built in three rounds between the months of March and August 2024, with round 1 running in April, round 2 running in June/July 2024, and round 3 in August 2024. The Delphi Survey methodology was used as a way to engage with experts and collect their views and opinions on the current and future state of the copper value chain, especially trying to understand the future skills and competencies needs that will arise in the sector due to current and upcoming changes. While the first two rounds were dedicated to gather skills and competencies needs for the future, as well as other complementary information such as how stakeholders perceive a platform and training such as SkiComCu, the third round was dedicated to obtaining a vision on the importance of selected skills and competencies for the future of the copper value chain.

2.2.1 Delphi Survey technical aspects

The EUSurvey platform (https://ec.europa.eu/eusurvey/) allowed proper development of Delphi statements and questions and data collection from experts while following EU's privacy guidelines for data collection and processing. Basic statistics and answers are collected by the platform and later treated. Further statistical analysis of the results was done with Microsoft Excel and with the help of online tools.

An experts' database was created to list possible interested participants – including SkiComCu experts, consortium contacts, internet search on research and industry-relevant experts. This was coupled with an open "Call for Experts" campaign on social media and the website.

All three rounds used a similar structure, only diverging in the Delphi-related statements and questions presented.

Common sections for each of the rounds included:

- Introduction: Information about the project.
- Objectives and participation in the Delphi Survey: explanation of the objectives of the Delphi Survey, rules for participation and follow-up.
- Personal data: collection of data for statistical purposes – nationality, gender, age, sector, level of expertise (Geosciences, Copper value chain, Management, Technology, Other).

Round 1 specific statements and questions:

- Delphi statements: the statements of the Survey to be addressed by the experts (by agreeing or disagreeing and commenting).
    - The copper sector already has workforce with the necessary skills and competencies to address the value chain needs for the next 10 years.
    - New job profiles will arise along the copper value chain by 2035.
    - A dedicated EU-wide training methodology and platform are essential to provide skills and competencies to the workforce in the copper sector.
    - The implementation of XR (Extended Reality), particularly VR (Virtual Reality), AR (Augmented Reality), and/or MR (Mixed Reality) approaches to simulate typical environments and situations in copper mines and smelters, including recycling plants, will add great value to the training of the future workforce in the sector.
    - Stakeholders should be involved throughout the whole value chain.
- Delphi questions: the open questions of the Survey to be answered by the experts.
    - What are the main needs, gaps and priorities in the copper value chain and Industry?

- How can educational institutions and training providers adapt their curricula to better align with the evolving needs of the copper industry in terms of skills development and new job profiles?
- What are the new tools, equipment and other technologies that will be widely implemented across the copper value chain in 2035?
- How can industry stakeholders, including employers, educational institutions, and professional associations, collaborate to ensure a skilled and adaptable workforce for the future of the copper sector?
- Envision the characteristics of a future-ready professional in the copper sector. What combination of skills, competencies, and personal attributes will define his/her success in the industry by 2035? What can this professional do to stay up-to-date with his/her skills/competencies bottlenecks and gaps as the industry evolves?

- Skills selection: matrix for the collection of skills and competencies across the value chain.

Round 2 specific statements and questions:

- Delphi statements: the statements of the Survey to be addressed by the experts (by agreeing or disagreeing and commenting).
  - New training programmes and platforms outside of universities should focus on each stage of the value chain instead of providing an overall training covering the entire value chain.
  - Training materials should be focused on upskilling the current workforce instead of addressing potential needs of future job profiles in the copper sector.
  - Different EU countries have different copper needs. Therefore, a EU wide lifelong learning course shall be complemented with national-level training, tailored to the needs of the different countries.
- Delphi questions: the open questions of the Survey to be answered by the experts.
  - What types of job profiles will be part of the copper value chain in 2035? What are the drivers for new job profiles and skills needs for 2035?
  - What would be the ideal cooperation method between stakeholders to keep the copper value chain topped up with workforce with skills and competencies?
  - How often should training programmes addressing the copper value chain be revised and adapted?
  - What solutions do you envisage that can provide future-proof and updated set of skills and competencies to the workforce in the copper sector (training, re-skilling and up-skilling)?

- What are the main P(Political), E(Environmental), S (Social), T (Technological), E(Economic) and L (Legal) factors changing the copper industry between now and 2035?
- What are the main Trends and Emerging Issues driving the copper sector, per stage of the value chain (exploration, extraction, processing, recycling)?

- Skills selection: matrix for the collection of skills and competencies across the value chain.

Round 3 specific statements and questions:

- 2035 Exploration skills ranking: Presentation of a selection of skills and competencies arising from the previous rounds, asking experts to rank from 1 (lowest) to 5 (highest) how the following skills and competencies will be in demand by 2035 for the copper exploration stage.
- 2035 Mining skills ranking: Presentation of a selection of skills and competencies arising from the previous rounds, asking experts to rank from 1 (lowest) to 5 (highest) how the following skills and competencies will be in demand by 2035 for the copper mining stage.
- 2035 Processing skills ranking: Presentation of a selection of skills and competencies arising from the previous rounds, asking experts to rank from 1 (lowest) to 5 (highest) how the following skills and competencies will be in demand by 2035 for the copper processing and materials engineering stage.
- 2035 Recycling skills ranking: Presentation of a selection of skills and competencies arising from the previous rounds, asking experts to rank from 1 (lowest) to 5 (highest) how the following skills and competencies will be in demand by 2035 for the copper recycling stage.

Each round of the Delphi entailed qualitative and quantitative data collection of the answers provided by the experts to statements and questions. Annexes 1 and 2 contain summary results for the first two rounds, respectively.

2.3 Backcasting

Backcasting is another foresight dedicated method. This method usually involves the development of normative scenarios and exploration of their feasibility and implications, connecting desirable long term future scenarios to the present situation (Robinson, 2003; Robinson et al. 2011).

Backcasting starts with the definition of a desirable future. For the SkiComCu purpose, this future is the one where the identified trends, skills and competencies exist as mapped from the desk research and Delphi Survey. From there, the process works backwards and tries to identify actions and timelines that connect this future to the present. In this project's case, this means the definition of concrete actions that will allow the course to stay up to date and sustainable with future developments of the copper value chain. Results from the backcasting thought process are linked with and incorporated in the roadmapping process.

2.4 Roadmapping

Roadmapping is the strategic process of determining the actions, timeline, and resources needed to take the initiative from vision to reality.

The goal of the SkiComCu roadmap is to present possible options for action implementation throughout the years for the future adaption of the SkiComCu framework towards 2035 in an effort to have adapted content to the changes, challenges and needs of the copper value chain.

3 Results

This chapter brings together the main results delivered thanks to the methodological approach. First, the 10-year foresight aspect is showcased through the identification of future skills and competencies needs, trends, gaps, issues and recommendations, all about SkiComCu, the copper sector and their intersection. These are the results arising mainly from the implementation of desk research and Delphi survey. The second part corresponds to the integration of the results compiled through backcasting and roadmapping methodologies.

3.1 A 10-year foresight: from 2025 into 2035

For the foresight part of this report, a span of 10 years is calculated from 2025 to 2035. During 2025, the SkiComCu framework, as defined in the project agreement, will be mostly operational with its first iteration of structure and content well defined. With the help of the foresight tools, it is possible to shed light on the upcoming years towards 2035. This mid-to-long term view of the copper sector and its intricacies will help the SkiComCu framework to become adapted to future outcomes taking advantage of trends while being aware of challenges. Several aspects are covered with the help of foresight including upcoming skills and competencies needs, gaps & issues, trends & drivers and recommendations for adaptation.

3.1.1 Skills and competencies needs throughout the copper value chain

Several skills and competencies needs were identified with the help of the methodological approach, with the skills identified through desk research (which focus more on the near future) being confirmed or updated with the help of data gathered from the experts through the Delphi Survey (which in turn focus more on mid to long future). Results show that both groups of skills – hard/technical and soft skills – will be in high demand in the future of the copper sector, specifically for the sectors of exploration, mining, processing and recycling, with these skills being highly influenced by the trends and drivers affecting the sector, combined with a high demand for soft skills. In the same line, necessary competencies will also adapt to the changing in the sector, highly influenced by the uptake of new technologies as well as the need of institutions to adhere to more sustainability, social and governance aspects.

On the technical side of skills and competencies, the most important upcoming needs are related to the use of several technologies such as robotics, Artificial Intelligence, Machine Learning, remote control, automation, and IT proficiency. These technological-related skills must be paired with professional competencies – relevant

for each sub-sector of the value chain – without forgetting that the workforce will still need on-ground experience as a complement.

On the other hand, for soft skills and competencies, it was found that open mindedness, teamwork, communication, flexibility, willingness to develop and improvement at every stage of professional development path, will be essential for professionals, which will also need to be synergistic, able to multitask, be multilingual, and socially oriented.

The most important skills for each of the four stages of the value chain are mentioned below, ranking from most important to least important, following an assessment of the Delphi Survey results. This order of skills, which follows experts' opinions, is a mean to prioritize learning and training through the SkiComCu platform by adapting content and tools to address the most important needs and challenges first.

Table 5: Skills and competencies needed for copper exploration.

Most important	Important	Least important
Communication with stakeholders, Negotiation skills & Community relations	Knowledge of and capacity to use portable analytical equipment	Multitasking
3D and 4D modelling	Open mindedness	Reporting
Problem Solving and Decision-making	Knowledge of environmental regulations	Knowledge in 2 or more languages & Work in multicountry environments
Ability to communicate effectively	Artificial Intelligence and Machine Learning	Initiative
Proficiency in Remote sensing, Satellite Imagery & GIS software	Flexibility	Administration & Project Management
Digital skills with on-ground exposure	Resilience in harsh environments	
Proficiency in advanced geophysical techniques	Safe operation of equipment	
Big data & Data handling, compilation and analysis	Use of IT intensive techniques	
Cooperation and Teamwork	Safe working practices	

Geology of mineral deposits in new environments (e.g. space, deep sea)		

Table 6: Skills and competencies needed for copper mining.

Most important	Important	Least important
Health and Safety	Leadership & Management	Knowledge in and application of energy efficiency & energy savings processes
Knowledge of deep mining	Performing under stress	Fleet management
Automation & remote control technology	Resilience in harsh environments	Multitasking
Ability to communicate effectively	Problem solving & Decision-making	Installing, operating and manufacturing advanced extraction technologies
Safe operation and maintenance of autonomous and robotic equipment	Open mindedness	Flexibility
Knowledge of tailings management	Big data & Data handling, compilation and analysis	
Communication with stakeholders, Negotiation skills & Community relations	Knowledge in 2 or more languages & Work in multicountry environments	
Ability to integrate new solutions in existing systems	Knowledge of extractive metallurgy	
Digital skills with on-ground exposure	Reporting	
Use of artificial intelligence & machine learning tools	Risk assessment	
Cooperation & Teamwork		
Knowledge of digital twins		

Table 7: Skills and competencies needed for copper processing:

Most important	Important	Least important
Safe operation of equipment	Communication	Leadership & Management
Knowledge of physical metallurgy	Adaptability & Flexibility	Reporting
Knowledge of Hydro-pyro-metallurgy	Cooperation & Teamwork	Knowledge in 2 or more languages & Work in multicountry environments
Knowledge and application of Health and Safety protocols	Result orientation	Multitasking
Modern processing ideas	Use of Artificial Intelligence & machine learning tools	Resilience in harsh environments
Knowledge of energy efficiency & energy recovery processes	Ability to integrate new solutions in existing systems	
Problem solving & Decision-making		
Open mindedness		
Data handling, compilation and analysis		
Digital skills		
Being innovative and having knowledge on innovation processes		
Use of robotics, remote control & automation tools		

Table 8: Skills and competencies needed for copper recycling:

Most important	Important	Least important
Knowledge and application of circular economy concepts	Use of robotics, remote control & automation tools	Flexibility
Knowledge and application of Health and Safety protocols	Knowledge of urban mining	Leadership & Management

Knowledge of energy efficiency & energy recovery processes	Communication	Multitasking
Responsibility	Cooperation & Teamwork	Reporting
Safe operation of equipment	Knowledge of physical metallurgy	Focus & Stamina
Quality control	Knowledge of urban mining	
Problem solving & Decision-making		
Data handling, compilation and analysis		

3.1.2 Trends and Drivers

Trends and Drivers are the main changing points that act as guidelines for the possible future. In this case, identifying and tracking trends is a very important process in preparing for the future needs and challenges. Trends and drivers tend to reshape and change over years. Several trends were identified, although it is important to note that these trends will show varying degrees of importance, with some materializing earlier than others, while some will not materialize at all. This is where regular tracking can help.

Identified trends for the copper sector as well as influences from general exploration, mining, processing and recycling fields include:

- Technology is changing fast through the whole value chain. Some jobs will adapt while new jobs will be created. Therefore, new job profiles will arise along the copper value chain by 2035. These will be mostly related to the use of Artificial Intelligence, Machine Learning, Virtual Reality, Augmented Reality, remote controlled operation systems and autonomy of machines, as well as to the overall incorporation, operation and maintenance of new technologies. Information and Data processing (e.g. through the use of computer programmes) will also scale up. Normalization of remote working coupled with the goal of removing people from mines, will further influence the creation of new job profiles. ESG and Sustainability will also become relevant and contribute to further change.
- Key job profiles for the upcoming period will include: Sustainability and Environmental Managers, Automation and Robotics Engineers, Data Scientists and Analysts, AI and Machine Learning Specialists, Renewable Energy Integration Specialists, Circular Economy Experts, Cybersecurity Experts, Remote Operations Managers, Health and Safety Coordinators, Blockchain Analysts, Operators of remotely controlled mining machines, Supervisors of autonomous mining machines, Technologists in copper recycling (as well as in battery recycling processes), Physical metallurgists, Pyrometallurgists, Hydrometallurgists, and Specialists in logistics.

- The utilization of soft skills coupled with the technical skills will be essential for the workforce to perform their tasks.
- The copper sector will see an important uptake of high-tech instruments in its operations, including the use of AI, unmanned equipment and implementation of green technologies (for example, changing the energy sources of operations into renewable energy sources, extended battery life, extended end-of-life for products and equipment, etc).
- Key enablers of decarbonisation of operations (e.g. retrofitting mobile equipment to battery or biofuels) will be among the first copper sector technologies to be updated.
- All stages of the value chain will observe the appearance and slow normalization of new tactics and processes. For exploration, there will be a bigger relevance of deep underground exploration, coupled with more precise underground mining, while new hydrometallurgical routes will influence processing and recycling of copper products. Technologies that enable these steps will be favoured in implementation. The scarcity of mineral resources may also change the way that exploration and exploitation of copper ores are conducted - which may also be conditioned by geopolitics and particularities for each country.
- Through the higher importance given to Environmental, Social, and Governance, as well as to Sustainability, it is expected that stakeholders will become more integrated with the entire copper value chain activities. Stakeholders will be particularly important to unblock the stages of copper exploration and exploitation, which will see the sector adapting to better engage with stakeholders and achieve Social License to Operate.
- The copper sector is set to face skill shortages overall on quantity and quality, due to the changes in the value chain towards different types of exploration, mining, processing and recycling. New technologies being implemented have higher upskilling requirements for the current workforce.
- Other important trends and drivers are showcased with the help of the PESTEL categorization:
    - Political and Legal
        - The European copper sector will face strong competition from the Asian market (European legislation is comparatively much more restrictive, leading to defensive solutions such as forced cost reduction).
        - Forthcoming changes in the regulations to extract copper and other ores.
        - Possibility to have exploration and mining activities in environmentally protected areas.
        - European and world geopolitical situation (e.g. wars, trade wars), affecting policy making decisions and implementation.
        - Legal limitations for Pb (lead) affecting copper production (lead is an element present in copper ore and often produced with the copper metal).

- The guidelines and implementation of the Critical Raw Materials Act as a guiding policy document, as well as any other national and European agendas drafted to support exploration, mining, processing and recycling activities.
- Achieving or failing to achieve the energy transition and meeting the energy goals.
- A European single stop permitting processing for exploration and mining of ores.
- Government policies and regulations around mining practices, environmental protection, and occupational safety that can impact operational costs and methods.
- Changes in trade policies tariffs and sanctions can affect global supply chains and market access.
- Political stability in copper-producing countries, with political unrest or instability disrupting production and supply.
- Resource nationalism with governments exerting more control over natural resources, affecting foreign investments and operations.
- Environmental legislation focused on stricter environmental laws and regulations governing mining activities and waste management.
- Health and safety regulations focused on ensuring occupational health and safety in mining operations.
- Permitting processes, which become complex and lengthy for new mining projects can delay development and increase costs.
- Intellectual property on new technologies and innovations through patents and other intellectual property rights.

o Social and Environmental

- Broader application of Environmental, Social and Governance (ESG) standards.
- Sustainable development and more importance of sustainability aspects.
- Demographic changes.
- Land use of areas for exploration and mining vs. other activities.
- Need of copper for the electrification of society, with bigger uptake of electrical vehicles.
- Raising of NIMBY behavior (Not In My BackYard).
- Changes in consumer patterns.

- Increasing amount of copper from secondary raw materials sources.
- Growing ecological awareness of the society.
- Social License to Operate, as gaining and maintaining the support of local populations and stakeholders is crucial for ongoing operations.
- Emphasis on Corporate Social Responsibility (CSR), resulting from increased expectations for companies to contribute positively to social and economic development in mining regions.
- Sustainability practices with growing emphasis on sustainable mining and reducing the environmental footprint of mining operations.
- Climate change impacts, such as extreme weather events, disrupting mining operations and supply chains.
- Resource depletion, especially in high-grade copper ore reserves, resulting in the need of more efficient extraction techniques and exploration of new deposits.
- Community relations with local communities and addressing social concerns related to mining operations.
- Workforce demographics, with aging workforce and the need to attract younger talent with the right skills for modernized operations, as well as growing remote working practices.

o Technological

- Development or discovery of other materials that can substitute copper in its essential applications.
- Technology transfer of new technologies from other sectors into the copper sector, changing tools and techniques.
- Renewable energy uptake, resulting in increased demand for copper due to its essential role in renewable energy technologies (e.g., wind turbines, solar panels) and electric vehicles. The copper industry also needs to use renewable energy for cost savings in the technological area - especially in the context of including green energy as a permanent energy source in mining and processing operations (continuity of supply, energy storage problems). This trend also encompasses the socio-economic spectrum.
- Higher recycling rates of copper products, changing value chain copper use patterns.

- Introduction of small modular reactors as power sources for smaller copper smelters/processes.
- Mainstreaming of state-of-the-art processes, Artificial Intelligence and similar technological advancements.
- Adoption of automation and robotics to improve efficiency, safety, and productivity.
- Data analytics and Internet of Things reflected in utilization of big data and advanced analytics to optimize copper operations, predictive maintenance, and resource management.
- Advanced exploration techniques with the use of advanced geological exploration technologies to locate new copper deposits more efficiently.
- Sustainable technologies aimed at reducing the environmental impact of copper extraction and processing.

o Economic

- Greater localization of supply chains in internal markets.
- Climate-change induced investments into adapting operations.
- Investments that facilitate the green transition of businesses.
- The substitution of copper may decrease its price, making it economically disadvantageous to be explored, exploited, processed or recycled.
- Subsidies for the copper value chain to raise internal EU production.
- Market demand, translated into fluctuations in global demand for copper driven by sectors like construction, electronics, renewable energy, and electric vehicles.
- Volatility of copper prices, which are due to supply and demand dynamics, market speculation, and economic conditions.
- Cost of production on the rise with higher operational costs, including labor, energy, and compliance with environmental regulations.
- Investment and financing as reflected in the availability of capital for exploration, development, and technological innovation in the copper industry.

3.1.3 Gaps and Issues in the copper sector

The gaps and issues observed in the copper value chain are intimately connected to the trends presented above. Changes will always introduce some sort of gaps, issues and challenges into the system that need to be solved through dedicated actions (from near term to long term implementation). With the help of the foresight adapted exercises, it was found that there are several gaps and issues that affect, will continue to affect or will appear in the copper value chain going forward.

A particular challenge that educational tools developed within SkiComCu will face is regarding entering the market. Presently, there are several training institutions available (e.g. faculties, technology centres, others) offering training in the same areas as SkiComCu. However, SkiComCu is unique with its training platform approach, content and specialization for the copper industry, minimizing the impact of such a challenge. Experts also see a future EU-wide training methodology and platform as desirable but not essential, which needs to be kept in mind. The EIT Deep Tech Talent Initiative and its team are a good example to follow.

Another great challenge identified is the focus on virtual training and learning, when the real experience to work "in the field" should not be entirely replaced. This is of particular importance for the exploration and mining stages, where a balance should be kept.

Engagement and involvement of stakeholders in the project continuation (as well as in the copper value chain as a whole) is a fundamental challenge. Such interaction is seen as being needed for the development of the primary industries and considered as one of the major challenges facing the copper industry worldwide. Connected to this challenge is the challenge of stakeholders understanding the need and important role for copper and all its stages of the value chain (e.g. connection of copper with green transition, meeting energy targets). For EU countries' societies it is fundamental for them to understand the costs and benefits of mining and mineral processing (of copper as well as other materials) the impacts of the industry, and the challenges that primary industries must face, needing to improve their performance (in terms of economics, environmental, social and governance issues).

Finally, knowledge, development and implementation of hydrogen-related technologies in the copper sector, which is seen as having huge potential to solve energy demand, is also one of the bigger gaps in this sector. It is expected that hydrogen will highly contribute to energy, raw materials and economic transformation, and the copper sector, by including this type of energy in its processes, could be one of the leading sectors for society.

Per stage of the value chain, the following gaps and issues were identified:

Exploration:

- Meeting the growing demand for copper is not a simple task. It requires expertise to get to the copper deposits without harming the environment more than the copper ultimately helps it, as a material utilized in renewable energy sources. Resources are significantly more difficult to find and extract, and successful

companies are increasingly those that transform practices and invest in technology—all while being quick making the necessary changes.

- Appearance and normalization of a series techniques and methods that do not have workforce to meet skills and competencies demands for their implementation and operation:
    - Remote sensing techniques, portable analytical equipment like portable XRF or LIBS, 3D modelling
    - Utilization of more sophisticated geochemical methods to improve the accuracy and efficiency of mineral exploration.
    - Leveraging big data analytics and artificial intelligence to identify potential mineral deposits more effectively.
    - Increasing use of remote sensing technologies and satellite imagery to conduct preliminary surveys and identify promising exploration sites.
    - The decline and depletion of easily accessible high-grade copper reserves, necessitating the exploration of more remote or deeper deposits.
    - Stricter environmental regulations impacting exploration activities and requiring more thorough impact assessments.
    - The need for better engagement with local communities and indigenous groups to gain social license for exploration activities.
    - Decreasing importance of ores in reference to copper scrap.
    - Quest to find new deposits, even at remote and challenging areas.

Mining:

- Develop skills in installing, operating and manufacturing advanced extraction technologies as well as advanced drilling, sensing, sorting and processing technologies.
- Foster skills in the operation and maintenance of autonomous and robotic equipment.
- Develop technical expertise in material sciences.
- Increasing focus on energy efficiency in mining operations, including renewable energy sources, such as green hydrogen.
- Appearance and normalization of a series of techniques and methods that do not have workforce to meet skills and competencies demands for their implementation and operation:
    - Sustainable extraction.

- More efficient extraction methods, applicable in difficult geological conditions, automated and autonomous.
- Deep mining.
- Permitting procedures for opening a mine.
- Raising SLO issues.
- Increasing pressure to lower the carbon footprint of copper mining through cleaner energy sources and more efficient technologies.
- Growing implementation of automated machinery and robotics to improve safety and efficiency in mining operations.
- Increasing focus on energy-efficient extraction methods to reduce operational costs and environmental impact.
- Adoption of digital twin technology to simulate mining operations and optimize processes in real-time.
- Increasing scrutiny and regulation regarding water use in mining, particularly in arid regions.
- Enhanced focus on safe and sustainable management of tailings to prevent environmental disasters.
- Adapting extraction practices to mitigate the effects of climate change and extreme weather events.

Processing (including metal forming stage):

- Appearance and normalization of a series techniques and methods that do not have workforce to meet skills and competencies demands for their implementation and operation:
  - Robotics and automation.
  - Growing use of hydrometallurgical techniques, such as bioleaching, which are more environmentally friendly for copper recovery than traditional pyrometallurgical methods.
  - Implementation of technologies to recover and reuse energy within processing plants to reduce overall energy consumption.
  - Integration of real-time monitoring systems and IoT devices to optimize processing operations and reduce downtime.
  - Increasing pressure to lower the carbon footprint of copper processing through cleaner energy sources and more efficient technologies.

- Stricter regulations around emissions and waste from processing plants, necessitating investment in cleaner technologies.
- Demand for greater transparency and traceability in the copper supply chain, from mine to end-user.
- More efficient methods, providing better recovery.
- Increasing of copper scrap in processing (also direct processing to final materials).

Recycling:

- Appearance and normalization of a series techniques and methods that do not have workforce to meet skills and competencies demands for their implementation and operation:
  - Robotics and automation.
  - The recovery of copper from electronic waste and other urban sources is becoming increasingly important as primary copper resources become scarcer.
  - Adoption of circular economy principles, focusing on the recycling and reusing of copper to reduce the need for new mining.
  - Development of advanced recycling technologies that can more efficiently extract copper from scrap and waste materials.
  - New laws and regulations promoting recycling and the use of recycled materials in manufacturing processes.
  - Challenges in the collection, sorting, and processing of recyclable materials, requiring better infrastructure and systems.
  - Ensuring the quality and purity of recycled copper to meet the standards required for various applications.
  - Smaller, local, less energy demand plants for recycling with more advanced processing on site (complex recycling to the final products or advanced by-products in the same plant to decrease cost of logistic).

3.1.4 Recommendations and considerations for the implementation of SkiComCu framework

When asked about the SkiComCu training approach, experts and stakeholders that joined the foresight exercises were generally supportive of the project's goals and objectives. They tend to agree that SkiComCu

as a training platform for the copper sector would highly contribute to training, upskilling and reskilling of workforce, especially since it brings a joint effort between partners (academia, research and industry) to face the challenges that affect the sector.

One of the most important aspects raised by experts is the need that training programmes have to be revised regularly. They suggest that both the content and the platform of the programme of SkiComCu should be revised and adapted every 3 to 5 years. However, in extreme cases of rapid change, this timeframe could be reduced to 2 years. This is due to the technological advancements as well as other common trends influencing political, socio-economic and environmental decisions, which ultimately affect the way that the copper sector adapts to changes. Periodic reviews on the content and format of the training materials should be done with assistance of experts and current industry staff for each stage of the value chain via consultations (e.g. Delphi Survey, Focus Groups) and workshops (e.g. roadmapping workshops, visioning workshops).

Despite the efforts towards reskilling and upskilling of current workforce, which are valid and may bring faster results, it needs to be considered that they will not solve the problem of an ageing workforce in the copper sector. Experts mention that the future is in young employees, who need to be "shown" the advantages of working in the copper sector such as the estimated income and opportunities for professional development. Workforce should be made aware of their importance in the entire production process and role as co-creators of wealth.

Experts believe that the basis for future-proof and updated set of skills and competencies for the copper sector workforce needs to be built on capacity building instruments aligned with the same objectives. This is a crucial condition for the successful implementation of the SkiComCu platform and training programme in the copper sector.

A greater list of recommendations and considerations for SkiComCu, its partners and the whole sector can be found in Annex 3. While some of the recommendations are incorporated into the next chapter (see the roadmap) due their intimate relation with SkiComCu, others are not. However, it is still recommended that this list is reviewed by project, partners and stakeholders alike and (at least some) recommendations put into practice in the future.

3.2 Long term action plan (roadmap towards 2035)

The picture of the copper sector towards 2035 can be taken from the data collection and processing. These data indicate that the copper sector will see some of the currently identified trends becoming reality and that will lead to a partially-changed sector dictated by high use of technology throughout the value chain supported by AI, ML, VR, AR, remote and autonomous machines, which in turn, will reflect the appearance of new job profiles dedicated to addressing the use of these tools. Stakeholders throughout the value chain will be more integrated into the different steps of exploration, mining, processing and recycling – with different levels of

new technology and techniques implementation - contributing to the sector's SLO and ESG values, which will only grow in importance. For training of workforce for the sector, standardization of training content and a system of microcredentials[1] for workers will be leveraged. It is expected that upskilling of current workforce becomes a norm. Inherent to these changes and adaptations are also the changes in skills and competencies for professionals, resulting in considerable skill shortages, arising from the implementation of new technological approaches, and leading to problems with the workforce.

Starting with this general view of the sector in mind, and taking into account the goals of the SkiComCu project for the future (e.g. further implementation of SkiComCu to other countries), the roadmap with actions and timelines for the SkiComCu pathway can be drafted for the period 2025-2035. The roadmap is divided in two main areas listing respective actions: 1) Maintenance & Updating and, 2) Engagement. The first one lists actions that should be pursued in order to keep the training platform and materials updated, taking into consideration further changes in the sector. The latter focus on communication and dissemination actions that would benefit both SkiComCu as well as the copper sector as a whole with strategic input about the lifelong learning course.

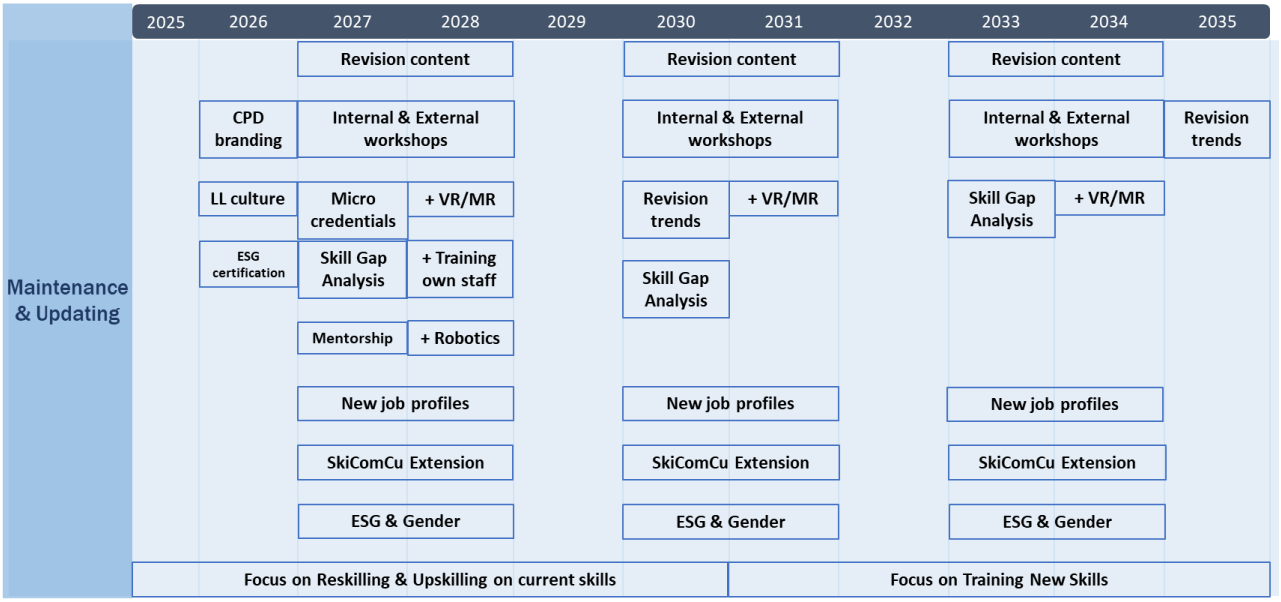


Figure 2: SkiComCu Roadmap presenting actions and timeline for Maintenance and Updating its platform and training.

Actions presented in the maintenance and updating part of the roadmap are meant to be implemented at regular intervals through the upcoming years, to ensure constant updating of the SkiComCu framework. The actions are spanning different timeframes (one-time actions or at regular intervals), depending on their nature and ultimate objective. Actions included in this roadmap are:

[1] Definition of microcredentials: https://education.ec.europa.eu/education-levels/higher-education/micro-credentials

1. Continuous Personal Development (CPD) branding, Lifelong Learning culture and ESG certification (2026): One of the first steps to take after the framework is first implemented is looking into getting the SkiComCu platform to adhere to relevant certifications and branding of the programme that can create a better perception of its goals and objectives with the stakeholders. Although not a direct update of the platform or training, these steps will contribute to its proper implementation.
2. First revision (2027-2028): The first revision of the platform and content needs to happen 2-3 years after the launch of SkiComCu as a platform. This is an essential part for the successful continuation of SkiComCu. A full revision of content and platform should be based on several sub-steps, which should be implemented around the same time as the content revision is planned for:
    a. Implementation of internal and external workshops: Periodic reviews on the content and format of the training materials should be done with assistance of experts and current industry staff for each stage of the value chain via consultations (e.g. Delphi Survey, Focus Groups) and workshops (e.g. roadmapping workshops, visioning workshops) in a way to obtain direct information and data from people involved in the copper sector, leading to a better update of both the platform and training, addressing challenges and needs faced by industry. These techniques can be implemented online, in person, or a mix of both.
    b. Microlearning/Microcredentials: Developing and offering of microlearning credentials, developed as bite-sized groups of information as on-demand training modules that employees can complete at their own pace to continually enhance their skills.
    c. Skill Gap Analysis: Perform a Skill Gap Analysis with an in-depth assessment of the sector and its ramifications to identify skill gaps within the current and future workforce and update the SkiComCu training to better achieve re-skilling and up-skilling addressing the gaps.
    d. Mentorship: Establishment of mentorship programmes, where the SkiComCu team acts as mentors (or establishes partnerships with experts) to the industry, having experienced employees that can guide and train new or less experienced workers, facilitating knowledge transfer and skills development.
    e. More VR/MR, more robotics: Develop and use several trainings and demonstrations with the use of simulators and Virtual Reality/Mixed Reality. A training offering specialized training in the operation, maintenance, and programming of automated systems and robotics used in the copper industry should be also offered within the SkiComCu framework.
3. Second revision (2030-2031): The second revision of the platform and content needs to happen 2-3 years after the first. This revision should follow similar steps as for the first one. However, the most important to implement for this revision would be the implementation of internal and external workshops, a new Skill Gaps Analysis, a first revision of trends and drivers affecting both the sector

and the world, and finally a new update on the technological offering with even more support for the use of VR/MR and similar tools.

4. Third revision (2033-2034): The third revision of the platform, follows the same approach as the second revision, including the implementation of the exact same steps. In this case, the revision of trends should be done after the content revision, since 3 years spanning between trend revision would be a rather short period.
5. New job profiles (2027-2028, 2030-2031, 2033-2034): New job profiles will appear either from scratch or as an adaptation of current ones. It is necessary to couple the content revision with an analysis on the job profiles and adapt content to the appearing jobs.
6. SkiComCu Extension (2027-2028, 2030-2031, 2033-2034): At the same time while revisions are made, efforts need to be established to extend the use of the SkiComCu platform and training centres to other countries besides the ones set in the project. First targeting European countries, later trying to become more international. This step will be achieved with the help of engagement with stakeholders in said countries.
7. ESG & Gender (2027-2028, 2030-2031, 2033-2034): It is in SkiComCu's nature to adhere to the best Environmental, Social and Governance KPIs, with Gender equality being used as a flagship. For SkiComCu to continue true to its principles going forward, it is then necessary to also perform regular checks into these topics. These will be reflected in the operation of SkiComCu as well as in the number of females, young people and participants from less fortunate strata.
8. Focus on Reskilling, Upskilling and Training (2025-2035): The last points shown in this roadmap are related to the focus on reskilling and upskilling of currently needed skills during the first 5 years of SkiComCu existence, with a shift in importance to Training of new skills in the last 5 years.

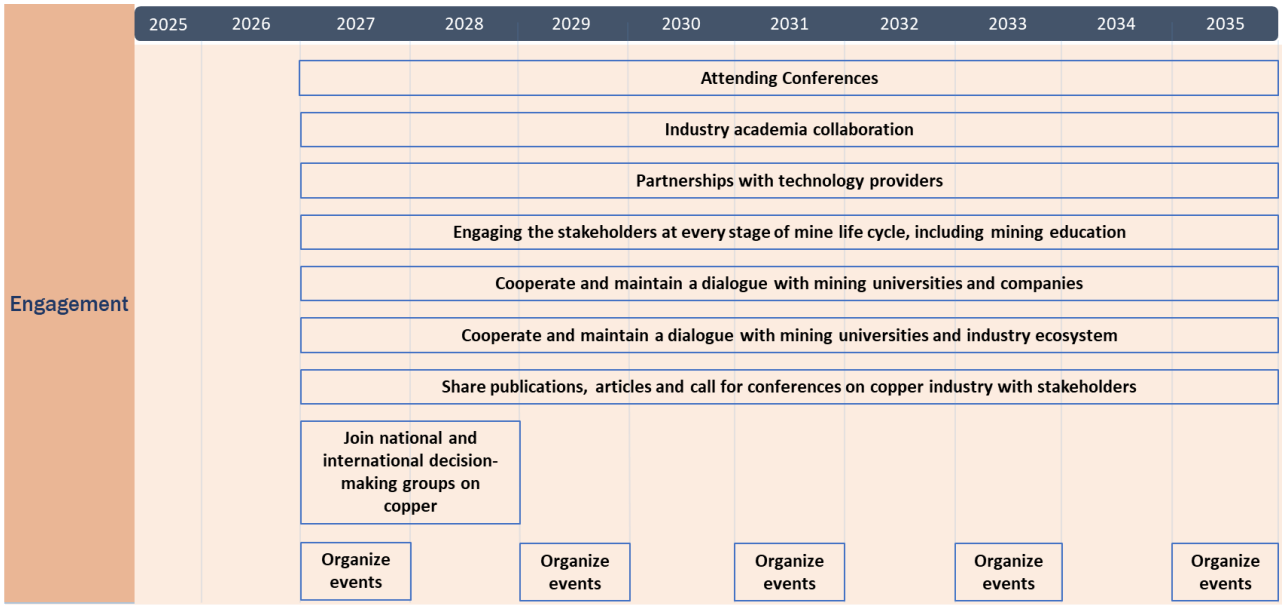


Figure 3: SkiComCu Roadmap presenting actions and timeline for Engagement with stakeholders, boosting both the platform and training themselves, as well as the whole sector.

Most actions listed in the Engagement part of the roadmap span through the years – this should be seen as a continuous effort that is needed right after the project lifetime is over (engagement actions are already defined for the SkiComCu project duration). There are two distinct instances from this pattern. First, to **join national and international groups and bodies related to the copper sector (2027-2028)** is a one-time action that should be done as soon as after the platform is established to boost its impact going forward. Secondly, the **organization of events (2027, 2029, 2031, 2033, 2035) (conferences, trade fairs, dedicated meetings with stakeholders)** could become a periodic effort, also with the goal of boosting the efficiency and use of the platform by stakeholders throughout Europe, at the same time as information can be collected from stakeholders and influence the updating and maintenance of the SkiComCu framework. The remaining actions, which are continuous **(2027-2035)**, presuppose:

1. **Attending conferences**: SkiComCu personnel should attend conferences (more technical conferences as well as skills and competencies conferences) whenever the opportunity arises, at national, EU and even international scope, to stay up-to-date with the newest developments and trends in the copper sector, as well as contributing to the dissemination of the programme.
2. **Industry-Academia collaboration**: As an industry-led and focused platform, the SkiComCu team needs to foster Industry-Academia collaboration and partnerships. These could result and contribute to the exchange of personnel between stakeholders (e.g. in the form of secondment), especially from academic partners to research and industry partners to further tailor and/or acquire the necessary skills and competencies to perform tasks in the sector.

3. **Partnerships with technology providers**: The SkiComCu team needs to expand its connections to innovative technology providers, which can be involved in further development of the platform and training by using upcoming technologies.
4. **Engaging the stakeholders at every stage of the Cu mine life cycle, including mining education, and Cooperate and maintain a dialogue with mining universities and companies (ecosystem)**: The SkiComCu team must engage stakeholders throughout every stage of the life cycle as well as throughout every side of the knowledge triangle (academia, research, industry), since its approach has a wide scope and can reach different stakeholders fulfilling their needs for reskilling, upskilling and training.
5. **Share publications, articles and call for conferences** on copper industry with stakeholders: By acting as a reference point for information dissemination, SkiComCu would benefit from the improved knowledge from stakeholders (staying updated about the demand and trends in the sector), leading to a better understanding about the skills and competencies that are needed, thus facilitating the uptake of the SkiComCu training by those same stakeholders.

Overall, engagement with stakeholders in these (and other forms) is also relevant to collect data that can influence the maintenance and updating of the SkiComCu platform and training.

4 Conclusions and Final recommendations

Desk research, Delphi Survey, Backcasting and Roadmapping methods were used as main steps in a methodological approach to achieve the goal set to Task 2.3: to map the skills and competences that will be in demand in the future of the copper sector. The end goal of the task is to prepare SkiComCu as a future-proof lifelong learning course through a set of actions and timeline to address future needs in the sector. The deliverable presents a long-term action plan and 10-year foresight report to achieve this objective.

Desk research was used to collect baseline data on trends, challenges and other aspects for the copper sector, setting the stage for the remaining part of the work. The Delphi Survey, prepared and launched in three rounds, had the participation of internal and external experts who provided their opinions and comments on a set of statements and questions on the current and future of SkiComCu. Fourty eight participants from Bulgaria, Greece, Poland, Portugal, Spain, Brazil and Chile joined the Delphi Survey across the three rounds. In particular, the exploration, mining, processing and recycling of copper. Several trends, gaps, challenges, skills and competencies needs and recommendations for 2035 were mapped.

The SkiComCu roadmap incorporates backcasting and roadmapping approaches. The timeline for the roadmap is 2025-2035 (10-year span) and is divided into two sub-roadmaps: one dedicated to Maintaining and Updating the platform and content; and the other focuses on Engagement activities. These roadmaps are complementary, and actions should be performed in parallel. The roadmaps present a selection of actions for implementation at certain timeframes as a mean to keep SkiComCu relevant throughout the next years.

Despite the reduced number of participating experts (48) in the Delphi Survey, it was still possible to get enough data following experts' views, opinions and recommendations. Overall, the planned objective of the deliverable was achieved as demonstrated with the look into 2035 and the creation of the roadmaps. The work of this task will not directly impact the SkiComCu as an EIT RawMaterials project, but will contribute to its continuation after the project lifetime.

Actions listed in the roadmap (as well as in Annex 3) are guidelines for a future adaptation. While these are first suggestions made by experts in the fields related to SkiComCu, there are other ways to achieve SkiComCu's goals of continuation with actions not listed in this report. Therefore, it is recommended that the roadmaps are revised and adapted in the upcoming years, addressing changes in the copper sector and SkiComCu itself, to keep the framework up-to-date.

References

Advanced Materials Initiative (2023). Strategic Materials Agenda.

Bonakdarpour, M., & Bailey, T. M. (2022). The future of copper: Will the looming supply gap short circuit the energy transition. S&P Global.

Chirgwin, P. (2021). Skills development and training of future workers in mining automation control rooms. Computers in Human Behavior Reports, 4, 100115.

Correia et al. (2020). International qualification framework for the raw materials sector. INTERMIN project deliverable 3.1.

EY (2019). The Future of Work: the Changing Skills Landscape for Miners.

EY (2019). Future of work: The economic implications of technology and digital mining.

Government of South Australia (2017). South Australia's Copper Strategy.

International Finance Corporation (2023). NET ZERO ROADMAP TO 2050 For Copper & Nickel Mining Value Chains. Technical report.

International Copper Study Group (2023). The World Copper Factbook 2023.

Konrat Martins & Bodo (2019). Report on skills gaps. INTERMIN project deliverable 2.1.

Morkun, V. S., Semerikov, S. O., Morkun, N. V., Hryshchenko, S. M., & Kiv, A. E. (2018). Defining the structure of environmental competence of future mining engineers: ICT approach. URL: https://arxiv.org/pdf/1807.00805.

RFC Ambrian (2022). The Pathway for Copper to 2030 – Copper market analysis.

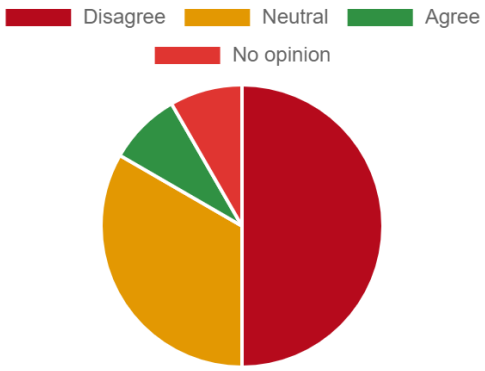
Robinson, J., Burch, S., Talwar, S., O'Shea, M. & Walsh, M. (2011). Envisioning sustainability: Recent progress in the use of participatory backcasting approaches for sustainability research. Technological Forecasting & Social Change, 78.

Shariff, N. (2015). Utilizing the Delphi Survey Approach: A Review. Nursing and Care, 4, 3.

Turoff, M., & Linstone, H. A. (2002). The Delphi method-techniques and applications.

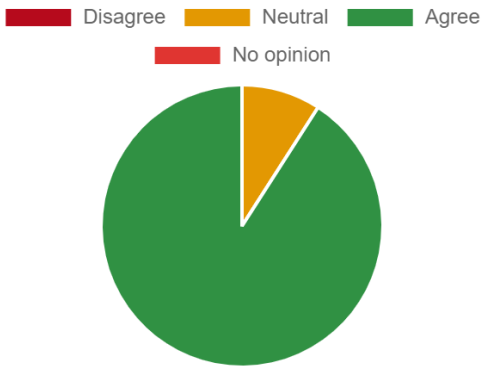
Annex 1: Delphi Survey Round 1 - Results

1. The copper sector already has workforce with the necessary skills and competencies to address the value chain needs for the next 10 years.



Most experts tend to disagree or be neutral towards the statement, revealing that they believe that the copper sector does not have workforce with the required skills and competencies for implementation of the many steps of the value chain in 10 years from now. They see the lack of skills and competencies for more production, more robotics and more automation as the leading causes. The challenges facing mining, particularly in Europe, are also listed as culprits. Lastly, one expert stated that the European copper sector will face skill shortages – both on quantity and quality, justifying this with new technologies throughout the value chain having upskilling requirements for the current workforce.

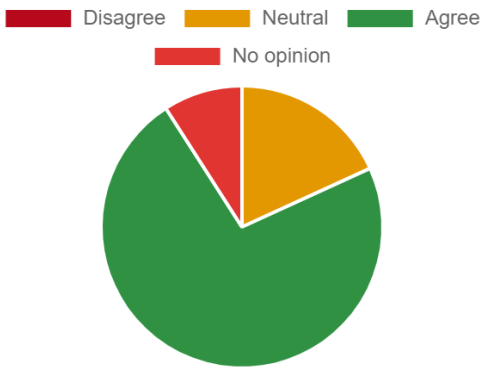
2. New job profiles will arise along the copper value chain by 2035.



It is commonly agreed among the experts that new job profiles across the copper value chain will arise in the upcoming years. The main reason for changing profiles lies in the rapid changing technology,

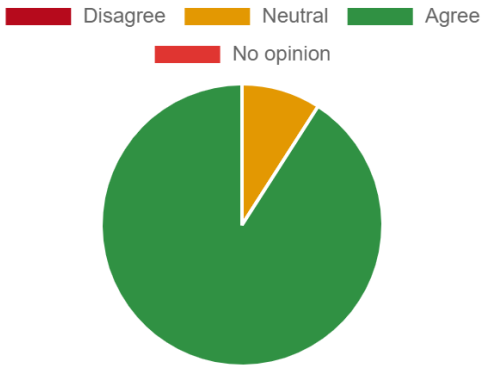
especially on the incorporation, operation and maintenance of new technologies . This will be translated into jobs that currently exist, being adapted, while entirely new ones will still need to appear. All in all, new jobs will appear along the value chain. This is however a trend that will be seen in the whole of the mining industry, and not specifically for copper, meaning that workforce can come from other parts of the mining sector.

3. A dedicated EU-wide training methodology and platform are essential to provide skills and competencies to the workforce in the copper sector.



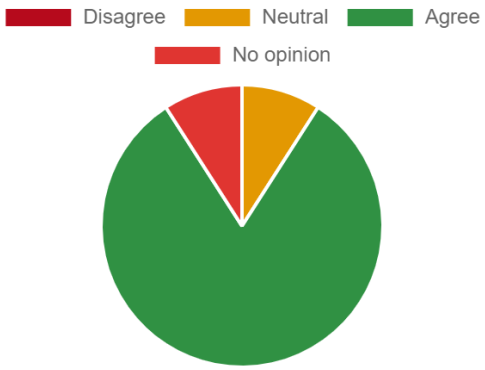
A majority of respondents believe that a dedicated EU-wide training methodology, accompanied by a unique technological platform, is essential to deliver skills and competencies that are/will be needed to the copper sector workforce. A dedicated platform is seen as an excellent tool for training and re-skilling workforceinto the specifics of the copper value chain. In order to be successful, this platform needs to address the best available techniques that are useful for the European context, including typical mineralisation and deposits, best mining methods, environmental management, permitting, copper metallurgy, copper products as well as strategic downstream applications. Experts mention that there is an interesting number of training institutions presently providing training (faculties, technology centres etc), but that a dedicated traininig platform would be useful to complement them, especially when dedicated to the copper value chain. One expert calls for the challenge of training to be jointly tackled across countries and institutions in Europe.

4. The implementation of XR (Extended Reality), particularly VR (Virtual Reality), AR (Augmented Reality), and/or MR (Mixed Reality) approaches to simulate typical environments and situations in copper mines and smelters, including recycling plants, will add great value to the training of the future workforce in the sector.



New technology tools and methods are commonly seen as game-changers for the training and upskilling of the copper sector workforce, taking into account the future changes that the sector will face. These should be implemented in trainings as soon as possible, since future changes towards the incorporation of new technology tools in the Cu value chain are already being seen, and companies need to start to adapt as fast as possible. One expert mentions that, despite the usefulness of the mentioned techniques, they will not completely replace the real experience to work "in the field", and that trainings should take this factor into account when designing their curricula.

5. Stakeholders should be involved throughout the whole value chain.



Experts agree that proactive involvement of stakeholders is desirable and even necessary across the copper value chain. They mention mining as a particular type of economic activity that must engage stakeholders at every stage of mine life cycle, including mining education, citing the involvement of stakeholders as the biggest challenge for the copper industry worldwide. A positive aspect of this

integration of stakeholders is that businesses done in this way will be preferred and rewarded by stakeholders. Stakeholders must be brought to the sector actions to understand the whole value chain and the importance of copper for society.

6. What are the main needs, gaps and priorities in the copper value chain and Industry?

   Participants named as main needs and gaps for the copper value chain:

   - Process automatization
   - New prospection and exploration methods
   - Substitution
   - Green transition
   - Remote machines operators
   - Autonomous machine supervisors
   - New software and AI operators/users
   - Digitalization, Industry 5.0
   - Skilled workforce
   - Education
   - Skilled employees
   - Reuse and recycling

7. How can educational institutions and training providers adapt their curricula to better align with the evolving needs of the copper industry in terms of skills development and new job profiles?

   Educational institutions and training providers should do the following to adapt their curricula:

   - Cooperate and maintain a continuous dialogue with Raw Materials universities and Raw Materials companies
   - Follow the innovation projects, articles, case studies etc
   - Should not forget about providing solid fundamentals and keep a strong interaction with the industry ecosystem.
   - Create and maintain synergies with the copper industry

- Collaborate between educational institutions and industry, governed by the government and Policymakers
- Involving more industry players in projects led by academia

8. What are the new tools, equipment and other technologies that will be widely implemented across the copper value chain in 2035?

   Experts believe that the following technological approaches will be relevant in 2035:

   - Standarization of training content and system of microcredentials
   - Artificial Inteligence, Machine Learning, Virtual Reality, Augmented Reality
   - Remote and autonomous machines
   - Automation, Unmanned equipment
   - High-tech instruments
   - Green technologies
   - New exploration tactics
   - Development of new Social License to Operate
   - New production processes
   - Change in the energy sources

9. How can industry stakeholders, including employers, educational institutions, and professional associations, collaborate to ensure a skilled and adaptable workforce for the future of the copper sector?

   Skilled and adaptable workforce in the copper sector can be achieved through:

   - Collaboration between University and Industry
   - Exchanging experiences
   - Ensuring the government support
   - Drawing on the solutions of more technologically advanced countries
   - Organizing events, fairs, workshops, about needs and new implemented technologies possibilities

- Ensuring platforms for sectoral dialogues and innovation that can offer value to stakeholders
- Creating consortia of industrial partners, HEIs, RTOs and NGOs
- Providing resource and dedicated departments

10. Envision the characteristics of a future-ready professional in the copper sector. What combination of skills, competencies, and personal attributes will define his/her success in the industry by 2035? What can this professional do to stay up-to-date with his/her skills/competencies bottlenecks and gaps as the industry evolves?

    A future-ready professional in the copper sector will be/have:

    - Combination of being open-minded, high level of high-tech experience, teamwork and communication skills
    - Technical education, flexibility, willingness to develop and its implementation at every stage of professional development path
    - Professional skills combined with new tech skills (e.g. AI, ML, remote control)
    - Digital skills, Safe operation of equipment, Digital literacy
    - IT proficiency, technology competence, materials knowledge
    - Synergistic, multitask, multilingual, and socially oriented

11. List of demanded skills and competencies for 2035 (Exploration):

    - Initiative
    - Negotiation skills
    - Cooperation
    - Problem solving
    - Decision making
    - Teamwork
    - Ability to interact with diverse backgrounds and stakeholders
    - Communication
    - Reporting

- Project management
- Flexibility
- Open mindedness
- Confidence
- Languages
- Work in multicountry environments
- Resilience in harsh environments
- Digital skills
- Geophysics
- Geosciences
- Earth science
- Geology of mineral deposits in new environments (space, deep sea)
- Critical raw materials
- Use of AI and ML
- Upgraded GIS Software
- Data handling, compilation and analysis
- Digitalization
- Remote sensing
- Use of IT intensive techniques
- Operation of Equipment
- Administration

12. List of demanded skills and competencies for 2035 (Mining):

- Solving problem
- Decision making
- Cooperation

- Teamwork
- Ability to communicate effectively
- Negotiation
- Leadership and management skills
- Flexibility
- Motivated
- Open minded
- Performing under stress
- H&S
- Reporting
- Digitalization
- Data analysis
- Energy efficiency
- Automation
- Analytics
- Remote control
- AI/ML
- Ability to integrate new solutions in existing systems
- Operation of Equipment
- Remote management of equipment
- Energy savings
- Fleet management
- Using specific tools
- Professional knowledge
- Geosciences
- Extractive metallurgy

- Engineering
- Goal setting and achievement
- Languages
- Work in multicountry environments
- Resilience in harsh environments

13. List of demanded skills and competencies for 2035 (Processing):

- Innovation
- Problem solving
- Decision making
- Cooperation
- Teamwork
- Communication
- Adaptability
- Leadership and management skills
- Open mindedness
- Motivated
- Result orientation
- Flexibility
- H&S
- Reporting
- Modern processing ideas
- Data analysis
- Energy efficiency
- Automation
- Analytics

- Remote control
- AI/ML
- Ability to integrate new solutions in existing systems
- Operation of Equipment
- Metallurgy
- Project management
- Digital skills
- Using specific tools
- Professional knowledge
- Materials science
- Physical metallurgy
- Hydro-pyro-metallurgy
- Languages
- Work in multicountry environments
- Resilience in harsh environments
- Productivity

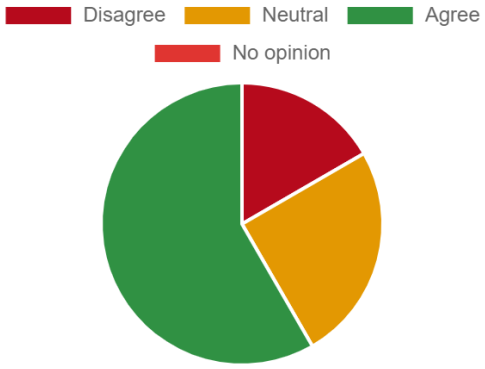
14. List of demanded skills and competencies for 2035 (Recycling):

- Problem solving
- Decision making
- Cooperation
- Teamwork
- Communication
- H&S (Health and Safety)
- Reporting
- Flexibility

- Data analysis
- Energy efficiency
- Automation
- Remote control
- Operation of Equipment
- Material science
- Professional knowledge
- Physical metallurgy
- Environmental studies
- Digital skills
- Compiling data
- Operating equipment
- Responsibility
- Project management
- Motivated
- Focus and stamina

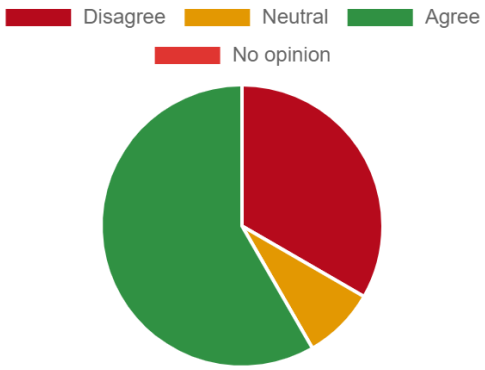
Annex 2: Delphi Survey Round 2 - Results

1. New training programmes and platforms outside of universities should focus on each stage of the value chain instead of providing an overall training covering the entire value chain.



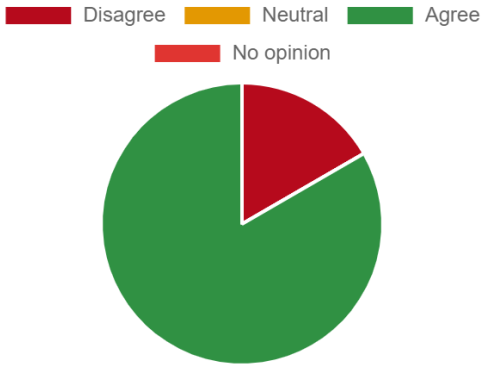
The majority of respondents believe that training programmes need to have a clear focus per stage of the value chain, instead of a more complete but less in-depth training. However, neutral and disagreement comments arise against this statement reasoning that there is space for both types of training – covering specific stages and more general one -, although covering specific issues, e.g., overall training programmes could focus on transversal skills and competencies, while targeted programmes for the different value chain stages could target specific skills for that stage. They also mention that current learning during university stages lacks in several areas of demanding skills and competencies, especially on the soft skills, which is why both types of trainings would benefit prospective employers.

2. Training materials should be focused on upskilling the current workforce instead of addressing potential needs of future job profiles in the copper sector.



There is a generalized agreement amongst experts in that training materials for the copper sector should focus on upskilling personnel instead of being drafted for new appearing job profiles. Despite this common view, there a few opposing opinions. First, participants that agree with the statement mention that upskilling is a better approach in the situation of shortage of skilled workers, adapting current workforce with in demand skills, guaranteeing jobs with corresponding skills needs. On the other side, experts mention that while upskilling is indeed the better approach, new job profiles must not be forgotten – when appearing they will need to be covered with dedicated training materials, bring a more balanced approach (70% upskilling, 30% new training).

3. Different EU countries have different copper needs. Therefore, a EU wide lifelong learning course shall be complemented with national-level training, tailored to the needs of the different countries.



A great share of the replies to this statement agree with the fact that it is possible to have a EU wide lifelong learning course for the copper sector, but this (or these) needs to be complemented with dedicated training at national level, specifically adapted to the geological settings (affecting mineralization) of countries (which have great impacts, especially in the exploration and mining stages). A good approach could be to consider training for exploration and mining being more specific, and training for processing and recycling more generalized. Trainings also need to be adapted per stage of value chain, which should precede the influence of country settings when designing curricula and methodology.

4. What types of job profiles will be part of the copper value chain in 2035? What are the drivers for new job profiles and skills needs for 2035?

This question is divided into two, each with each own sub-answers. Regarding new job profiles arising in the copper sector between 2025 and 2035, experts list jobs that go inline with the visible trends for the industry: Sustainability and Environmental Managers, Automation and Robotics Engineers, Data Scientists and Analysts, AI and Machine Learning Specialists, Renewable Energy Integration Specialists, Circular Economy Experts, Cybersecurity Experts, Remote Operations Managers, Health and Safety Coordinators, Blockchain Analysts, operator of a remotely controlled mining machine/supervisor of an autonomous mining machine, technologists in copper recycling (as well as in battery recycling processes), pyrometalurgists, hydro and

electrometalurgists and specialists in logistics. These new arising profiles will be parallel to more traditional ones.

As for the main drivers associated with the appearance of new job profiles and skills needs for 2035, experts list: remote-controlled operational systems; digital skills like information and data processing (computer programmes); soft skills like adaptability/ flexibility, development of new methods for processing and recycling, advancements in technology and materials, scarcity of (mineral) resources, geopolits, New technologies, Digitalization, Remote working, Removing people from the mines, Technological Advancements, Sustainability and Environmental Concerns, Digital Transformation, Regulatory and Compliance Requirements, Global Economic and Market Trends, growing demand for the copper metal vs availability of raw materials, with increasing meaning of secondary raw materials, as copper scrap and WEEE, Use of AI in geological exploration and mineral production.

5. What would be the ideal cooperation method between stakeholders to keep the copper value chain topped up with workforce with skills and competencies?

Cooperation models between stakeholders across the value chain are necessary to advance the sector and have prepared workforce for current and future challenges. For main cooperation mechanisms experts suggest engagement on social media groups comprising academic, research and the industry sectors, to bring discussions, new publications, news articles, call for conferences, and other materials that allow the members to stay updated about the demand and trends in the sector, having representatives from the three sides of the knowledge triangle should participate in both international and national-level groups, Companies (either vertically or horizontally integrated) need organizing events and inviting other stakeholders for collaboration, continuous communication and knowledge exchange in events (fairs, conferences, dedicated meetings) and having start-ups/entrepresise-universities cooperation agreements.

It is suggested to pursue a supported by a multifaceted approach, emphasizing collaboration, continuous education, and proactive engagement based on:

- Collaborative Partnerships: Industry-Academia Collaboration: Establish partnerships between copper industry companies and educational institutions to develop tailored curriculum and training programs that address current and future skills needed in the copper value chain. Government Involvement: Engage with government bodies to create policies and provide funding for training programs, apprenticeships, and skill development initiatives.
- Continuous Learning and Development Training Programs: Implement ongoing training programs for existing employees to keep their skills up-to-date with the latest technological advancements and industry practices. Certification Courses: Encourage and provide access to certification courses that validate the competencies and skills of the workforce in specific areas of the copper value chain.
- Proactive Recruitment and Talent Management.

- Technology Integration: E-learning Platforms: Utilize online learning platforms to provide flexible and accessible training opportunities for employees across different locations.
- Simulation and VR Training: Incorporate advanced technologies like simulations and virtual reality (VR) to offer immersive training experiences that can enhance practical skills.
- Stakeholder Engagement and Communication: Regular Forums and Workshops: Organize regular forums, workshops, and conferences where stakeholders can share insights, challenges, and best practices related to workforce development. Feedback Mechanisms: Implement robust feedback mechanisms to continuously assess the effectiveness of training programs and make necessary adjustments.
- Sustainability and Social Responsibility
- Future-Proofing Skills: Forecasting Future Needs: Regularly analyze industry trends and technological advancements to predict future skill requirements and adjust training programs accordingly. Lifelong Learning Culture: Cultivate a culture of lifelong learning within organizations to ensure employees are always ready to adapt to new challenges and opportunities.

Lastly, experts also advise the copper sector members to engage with different sectors - both within and outside the mining, processing and recycling aspects - to learn what technologies are appearing as well as what changes are affecting other sectors. Cooperation has to bring some value to all stakeholders involved.

6. How often should training programmes addressing the copper value chain be revised and adapted?

Experts suggest that training programmes targeting the copper value chain should be revised and adapted every 3 to 5 years. However, in extreme cases of rapid change, this timeframe could be reduced to 2 years. This is due to the technological advancements as well as other common trends influencing political, socio-economic and environmental decisions, which ultimately affect the way that the copper sector adapts to changes. Periodic reviews on the content and format of the training materials should be done with assistance of experts and current industry staff for each stage of the value chain via consultations and workshops.

7. What solutions do you envisage that can provide future-proof and updated set of skills and competencies to the workforce in the copper sector (training, re-skilling and up-skilling)?

Experts made several suggestions as possible solutions to have the copper sector workforce ready with the necessary skills and competencies. The main ideas include:

- Education and training programme leaders need to attend conferences at EU-level and worldwide, and follow dedicated groups on social media - such as LinkedIn - to stay up-to-date with the newest developments and trends in the sector.

- Engagement with different sectors - both within and outside the mining, processing and recycling aspects - to learn what technologies are appearing as well as what changes are affecting other sectors. Participate in skills and competencies-related conferences.
- Develop and use several trainings and demonstrations with the use of simulators and Virtual Reality/Mixed Reality.
- Training for currently employed staff, including analysis of current and future situation on the copper market and value chain. This will allow them to plan further skilling actions.
- Industry-Academia Collaboration through exchange of personnel (secondment).
- Continuous Professional Development.
- Making use of or developing Online Courses and Webinars covering essential skills, technological advancements, and industry-specific knowledge.
- Offer Microlearning Modules as on-demand training modules that employees can complete at their own pace to continually enhance their skills.
- Structured Apprenticeship Programs that combine classroom instruction with on-the-job training, allowing new workers to gain practical experience while learning.
- Mentorship Programs where experienced employees guide and train new or less experienced workers, facilitating knowledge transfer and skill development.
- Automation and Robotics Training, offering specialized training in the operation, maintenance, and programming of automated systems and robotics used in the copper industry.
- Skill Gap Analysis with regular assessments to identify skill gaps within the workforce and develop targeted re-skilling and up-skilling programs to address these gaps.
- Cross-Training Programs and Initiatives that allow employees to learn different roles within the company, enhancing their versatility and adaptability.
- Establishing partnerships with Technology Providers from several areas.
- Individual Development Plans with the design of personalized career development plans for employees, outlining their learning and growth path within the organization.
- Lifelong Learning Culture to foster values and support continuous learning and development, encouraging employees to pursue ongoing education and skill enhancement.

Despite the efforts towards re-skilling and up-skilling of current workforce, which are valid and may bring faster results, it needs to be considered that they will not solve the problem of an ageing workforce in the copper sector. Experts mention that the future is in young employees, who need to be "shown" the

advantages of working in the copper sector such as the estimated income and opportunities for professional development. Workers should be made aware of their importance in the entire production process and role as a co-creator of wealth.

8. What are the main P(Political), E(Environmental), S (Social), T (Technological), E(Economic) and L (Legal) factors changing the copper industry between now and 2035?

Experts mentioned the following trends as the main guidelines for changes and adaptations influencing, directly and indirectly, the copper value chain throughout its different stages:

Political and Legal aspects:

- Strong competition with the Asian market (European legislation is comparatively much more restrictive, leading to defensive solutions such as forced cost reduction).
- Changes in the regulations to extract copper and other ores.
- Mining in environmentally protected areas.
- Geopolitical situation (especially eastern theatre).
- Legal limitations for Pb (lead) will affect copper production, as lead is an element present in copper ore and often produced with the copper metal.
- The Critical Raw Materials Act as a guiding policy document.
- The energy transition and energy goals.
- European single stop permitting processing.
- Government Policies and Regulations around mining and processing practices, environmental protection, and worker safety that can impact operational costs and methods.
- Changes in Trade Policies Tariffs and Sanctions can affect global supply chains and market access.
- Political Stability in copper-producing countries is crucial. Political unrest or instability can disrupt production and supply.
- Resource Nationalism with governments exerting more control over natural resources, affecting foreign investments and operations.
- Environmental Legislation focused on stricter environmental laws and regulations governing mining activities and waste management.
- Health and Safety Regulations focused on ensuring worker safety and health in mining operations.
- Permitting Processes, which become complex and lengthy for new mining projects can delay development and increase costs.

- Intellectual Property on new technologies and innovations through patents and other intellectual property rights.
- Technological development - demand for copper, wars and armed conflicts - problems in copper supply, mining in difficult conditions, environmental restrictions.

Socio-environmental aspects

- Broader application of Environmental, Social and Governance (ESG) standards.
- Sustainable development.
- Demographic changes.
- Need of copper for the electrification.
- Raising of NIMBY behavior (Not In My BackYard).
- Changes in consumer patters.
- Increasing amount of copper from secondary raw materials sources.
- Introduction of electric vehicles.
- Growing ecological awareness of the society.
- Accelerating administrative processes.
- Reducing administrative burden.
- Social License to Operate, as gaining and maintaining the support of local populations and stakeholders is crucial for ongoing operations.
- More Corporate Social Responsibility, resulting from increased expectations for companies to contribute positively to social and economic development in mining regions.
- Sustainability Practices with growing emphasis on sustainable mining and reducing the environmental footprint of mining operations.
- Climate Change impacts, such as extreme weather events, can disrupt mining operations and supply chains.
- Renewable Energy uptake, resulting in increased demand for copper due to its essential role in renewable energy technologies (e.g., wind turbines, solar panels) and electric vehicles.
- Resource Depletion, especially in high-grade copper ore reserves, necessitates more efficient extraction techniques and exploration of new deposits.

- Community Relations with local communities and addressing social concerns related to mining operations.
- Workforce Demographics, with aging workforce and the need to attract younger talent with the right skills for modernized operations.

Technological aspects

- Creation or discovery of other materials that can substitute copper in its essential applications.
- New technologies appearing from other sectors.
- Higher recycling rates of copper products.
- Introduction of Small Modular Reactors as power sources for smaller copper smelters/processes.
- Mainstreaming of state of the art processes, Artificial Intelligence and similar technological advancements.
- Adoption of Automation and Robotics to improve efficiency, safety, and productivity.
- Data Analytics and Internet of Things reflected in utilization of big data and advanced analytics to optimize copper operations, predictive maintenance, and resource management.
- Advanced Exploration Techniques with the use of advanced geological exploration technologies to locate new copper deposits more efficiently.
- Sustainable Technologies aimed at reducing the environmental impact of copper extraction and processing.

Economic aspects

- Integration of supply chains in internal markets.
- Climate-change induced investments into adapting operations.
- Investments that facilitate the green transition of businesses.
- The substitution of copper may decrease its price, making it economically disadvantageous to be explored, exploited, processed or recycled.
- Subsidies for the copper value chain to raise internal EU production.
- Market Demand, translated into fluctuations in global demand for copper driven by sectors like construction, electronics, renewable energy, and electric vehicles.
- Volatility of copper prices, which are due to supply and demand dynamics, market speculation, and economic conditions.

- Cost of Production on the rise with higher operational costs, including labor, energy, and compliance with environmental regulations.
- Investment and Financing as reflected in the availability of capital for exploration, development, and technological innovation in the copper industry.

9. What are the main Trends and Emerging Issues driving the copper sector, per stage of the value chain?
    a. Exploration main trends
        i. Successful companies are increasingly those that swiftly transform practices and invest in technology.
        ii. Quicker mineral exploration, including remote exploration, all while being cost efficient.
        iii. Advanced Geophysical Techniques: utilization of more sophisticated geophysical (i.e. portable analytical equipment like portable XRF or LIBS, 3D modelling) and geochemical methods to improve the accuracy and efficiency of mineral exploration.
        iv. Big Data management, Artificial Intelligence and Machine Learning: Leveraging big data analytics and artificial intelligence to identify potential mineral deposits more effectively.
        v. Increasing the use of remote sensing technologies and satellite imagery to conduct preliminary surveys and identify promising exploration sites.
        vi. Decreasing importance of ores in reference to copper scrap.
        vii. Quest for new deposits, even in challenging environments.
        viii. Reuse of tips and dams for resources.
    b. Exploration main emerging issues
        i. Meeting the growing demand for copper is not a simple task due to the expertise necessary to obtain copper without harming the environment.
        ii. Resources are significantly more difficult to find and extract, also with lower grades.
        iii. Resource Depletion seen in the decline of easily accessible high-grade copper reserves, necessitating the exploration of more remote or deeper deposits, associated with worse working conditions.
        iv. Stricter Environmental Regulations impacting exploration activities and requiring more thorough impact assessments.

v. Need for better engagement with local communities and indigenous groups to gain social license to operate for exploration activities.

c. Extraction main trends

i. Developing skills in installing, operating and manufacturing advanced extraction technologies as well as advanced drilling, sensing, sorting and processing technologies.

ii. Fostering skills in the operation and maintenance of autonomous and robotic equipment.

iii. Development of technical expertise in material sciences.

iv. Sustainable extraction.

v. Growing implementation of automated machinery and robotics to improve safety and efficiency in mining operations.

vi. Increasing focus on energy-efficient extraction methods to reduce operational costs and environmental impact.

vii. Raise in the importance of Digital Twins technology to simulate mining operations and optimize processes in real-time.

viii. More efficient extraction methods, applicable in difficult geological conditions.

ix. Smaller, less energy demand plants for extraction.

x. Energy reduction and energy efficiency in mining processes.

d. Extraction main emerging issues

i. Meeting the growing demand for copper is not a simple task due to the expertise necessary to obtain copper without harming the environment.

ii. Resources are significantly more difficult to find and extract, also with lower grades.

iii. Water Usage and Management especially on increasing scrutiny and regulation regarding water use in mining, particularly in arid regions.

iv. Enhanced focus on safe and sustainable management of tailings to prevent environmental disasters.

v. Adapting extraction practices to mitigate the effects of climate change and extreme weather events.

vi. Increasing pressure to lower the carbon footprint of copper mining through cleaner energy sources and more efficient technologies.

e. Processing main trends
    i. Robotics and Automation
    ii. Growing use of hydrometallurgical techniques, such as bioleaching, which are more environmentally friendly than traditional pyrometallurgical methods
    iii. Energy Recovery and Efficiency, with implementation of technologies to recover and reuse energy within processing plants to reduce overall energy consumption.
    iv. Real-Time Monitoring systems and IoT devices to optimize processing operations and reduce downtime.
    v. Increasing of copper scrap in processing (also direct processing to final materials).
f. Processing main emerging trends
    i. Increasing pressure to lower the carbon footprint of copper processing through cleaner energy sources and more efficient technologies
    ii. Stricter regulations around emissions and waste from processing plants, necessitating investment in cleaner technologies.
    iii. Demand for greater transparency and traceability in the copper supply chain, from mine to end-user.
g. Recycling main trends
    i. Robotics and Automation.
    ii. Urban Mining focused on the recovery of copper from electronic waste and other urban sources that is becoming increasingly important as primary copper resources become scarcer.
    iii. Adoption of circular economy principles, focusing on the recycling and reusing of copper to reduce the need for new mining.
    iv. Technological Advances resulting in the development of advanced recycling technologies that can more efficiently extract copper from scrap and waste materials.
    v. Smaller, local, less energy demand plants for recycling with more advanced processing on site (complex recycling to the final products or advanced by-products in the same plant to decrease cost of logistics).
    vi. Energy reduction and energy efficiency processes.
    vii. New technological advances.

h. Recycling main emerging issues

i. New laws and regulations promoting recycling and the use of recycled materials in manufacturing processes.

ii. Challenges in the collection, sorting, and processing of recyclable materials, requiring better infrastructure and systems.

iii. Ensuring the quality and purity of recycled copper to meet the standards required for various applications.

Annex 3: List of Recommendations

Experts highlighted several ideas and recommendations that could be considered as integration steps into the next training versions of SkiComCu . The following recommendations are particularly relevant and should be taken into account by the SkiComCu consortium:

- Education and training programme leaders need to attend conferences at EU-level and worldwide, and follow dedicated groups on social media - such as LinkedIn - to stay up-to-date with the newest developments and trends in the sector. In addition, periodic reviews (each ~5 years) on the content and format of the training materials should be done with assistance of experts and current industry staff for each stage of the value chain via consultations and workshops.
- Engagement with different sectors - both within and outside the mining, processing and recycling aspects - to learn what technologies are appearing as well as what changes are affecting other sectors. Participate in skills and competencies-related conferences.
- Develop and use several trainings and demonstrations with the use of simulators and Virtual Reality/Mixed Reality.
- Training for currently employed staff, including analysis of current and future situation on the copper market and value chain. This will allow them to plan further skilling actions.
- Foster Industry-Academia collaboration through exchange of personnel (secondment), especially from academic partners to research and industry partners to acquire the necessary skills and competencies to perform tasks in the sector.
- Invest in Continuous Professional Development (CPD). Continuing Professional Development refers to the learning activities professionals engage in to develop and enhance their abilities. CPD is a holistic approach towards the enhancement of personal skills and proficiency throughout a professional's career, that needs to be at the core of the SkiComCu methodology.
- Make use of or develop own Online Courses and Webinars (e-learning) covering essential skills, technological advancements, and industry-specific knowledge.
- Offer Microlearning Modules and Microcredentials as on-demand training modules that employees can complete at their own pace to continually enhance their skills.
- Develop Structured Apprenticeship Programs that combine classroom instruction with on-the-job training, allowing new workers to gain practical experience while learning.
- Create Mentorship Programs (with SkiComCu own and external partners) where experienced employees guide and train new or less experienced workers, facilitating knowledge transfer and skill

development. An exchange programme between different institutions could also benefit this approach.

- There must be a training on Automation and Robotics, offering specialized training in the operation, maintenance, and programming of automated systems and robotics used in the copper industry.
- Regularly perform a Skill Gap Analysis with periodic assessments of the sector and its connections to identify skill gaps within the workforce and develop targeted re-skilling and up-skilling programs to address these gaps.
- Invest in Cross-Training Programs and Initiatives that allow employees to learn different roles within the company, enhancing their versatility and adaptability as well as other soft skills.
- Establish partnerships with Technology Providers from several areas.
- Invest in Individual Development Plans with the design of personalized career development plans for employees, outlining their learning and growth path within the organization.
- SkiComCu needs to foster a Lifelong Learning Culture to create and develop values and support continuous learning and development, encouraging employees to pursue ongoing education and skill Enhancement.
- It would be easier to adapt the current workforce with in-demand skills (both now and in the near future). It would also have advantages for the workforce - new skills, guaranteed job.
- The SkiComCu platform has to address the best available techniques in light of the European copper sector context, including typical copper mineralization and deposits, also taking into account the regional and national differences.
- The SkiComCu training needs to adapt its focus across several topics: suitable mining methods, Pyro- and hydrometallurgy of copper, Semi-finished and fabricated products, Environmental management and permitting, strategic downstream application such as copper foil production for batteries.
- SkiComCu would, as a training platform and stakeholder leader, benefit from engaging the stakeholders at every stage of mine life cycle, including mining education.
- Training materials should be addressed both to current workforce and to future job profiles. A balance between upskilling and future needs would be ideal for a training. However, the main focus of these materials (~70%) should be on the current skills.
- Despite all possible adaptation, if a totally new job profile appears in the future, then that would need to be covered with dedicated training materials specifically for that. Specially for the exploration phase, as each country has its own geological settings that will control the mineralization. However, processing and recycling might be less dependent on the particularities of each country.

- All of the spheres of capacity building for copper employees (training, re-skilling and up-skilling) should be developed in parallel and on an ongoing basis in SkiComCu. Reskilling and upskilling may bring faster results, but will not solve the problem of an ageing workforce. The future is in young employees, who need to be "shown" the advantages of working in this sector (level of earnings, opportunity for professional development, workers should be made aware of their importance in the entire production process and role as a co-creator of wealth.
- Engage with different sectors - both within and outside the mining, processing and recycling aspects - to learn what technologies are appearing as well as what changes are affecting other sectors. Participate in skills and competencies conferences.
- SkiComCu trainings and demonstrations must make use of simulators, VR/MR/AR or a mix of these.
- The SkiComCu training for currently employed stuff, needs to include an analysis of the current and future situation on the copper market and value chain. This will allow companies to plan further skilling actions, building on the results of the SkiComCu training.
- A transparent and informed business will be preferred and rewarded by stakeholders, so SkiComCu should adhere to ESG values.
- Educational institutions and training providers should 1) cooperate and maintain a continuous dialogue with mining universities and mining companies, 2) follow the innovation projects, articles, case studies and, 3) not forget about providing solid fundamentals and keep a strong interaction with the industry ecosystem

The best way for SkiComCu to become relevant in the future is by spreading its word and showcasing its programme. This can only be achieved with the support of stakeholders throughout the value chain. Several cooperation methods between the stakeholders of the copper value chain should be considered to provide, directly and indirectly, the existing and new workforce along the different stages with in-demand skills and competencies to perform their jobs. SkiComCu could implement:

- Collaboration between educational institutions and industry, governed by the government; educational institutions and training providers should have more common projects and more firms/companies invited in the academic authorities
- Encouraging engagement on social media groups comprising academic, research and the industry sectors is suggested as one of the options. Bringing stakeholders together could bring benefits to the value chain by fostering discussions, sharing of new publications, news articles and call for conferences, for example. This exchange would allow stakeholders to stay updated about the demand and trends in the sector, leading to a better understanding about the skills that are needed . Furthermore, it is suggested that representatives from the three sides of the knowledge triangle – academia, research and industry - should participate in both international and national-level groups.

- Another suggestion is the organization of events such as conferences, trade fairs and dedicated meetings, fostered by companies throughout the value chain. Companies (including start-ups) should also foster university-enterprise cooperation agreements, for the exchange of personnel to learn skills and competencies in different working environments. These actions should be coupled with invitations and interactions with other sectors both within and outside the mining, processing and recycling aspects, offering a learning opportunity and showing best practices on technologies, trends and challenges. A feedback mechanism could be implemented to continuously assess the effectiveness of training programs and make necessary adjustments.
- Direct collaborative partnerships between Industry-Academia should become normative to develop tailored curricula and training programs that address current and future skills needed in the copper value chain. Governments should also be engaged in this process for the creation of policies and providing funding for training programs, apprenticeships, and skill development initiatives.
- Other option includes the use of Continuous Learning and Development Training Programs, for current employees to keep their skills up-to-date with the latest technological advancements and industry practices. Certification Courses can be used to validate the acquired competencies and skills in specific areas of the copper value chain.
- Online learning platforms are able to provide flexible and accessible training opportunities for employees across different locations, as simulations and VR training are able to incorporate advanced technologies to offer immersive training experiences that can enhance practical skills.
- The final suggestion is to make regular assessments of industry trends and technological advancements to predict future skills requirements and adjust the training programs accordingly. This step needs to be coupled with a Lifelong Learning Culture within organizations to ensure that employees are always ready to adapt to new challenges and opportunities.
- As a final note, experts mentioned that any cooperation schemes implemented in favour of the copper value chain must bring some kind of value to all the involved stakeholders.