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Alliance for Batteries Technology, Training and Skills

2019-2023

The Battery Landscape of the EU: Legislation, Production, Skills, and Geopolitical Challenges

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D4.11 Sectoral Intelligence definition for sub-sector ISIBA - Release 3

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List of Abbreviations

AI	…	Artificial Intelligence
AR	…	Augmented Reality
BES	…	Battery Energy Storage
BESS	…	Battery Energy Storage System
BMS	…	Battery Management System
CNC	…	Computer Numerical Control
CO2	…	Carbon Dioxide
DMM	…	Digital Multimeters
DoC	…	Drivers of Change
EU	…	European Union
EV	…	Electric Vehicle
LCA	…	Life Cycle Assessment
OEM	…	Original Equipment Manufacturer
PPE	…	Personal Protective Equipment
VET	…	Vocational Education and Training
VR	…	Virtual Reality

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Executive Summary

Deliverable 4.11, "Sectoral Intelligence definition for sub-sector ISIBA - Release 3", represents state-of-the-art research and work conducted by Work Package 4 during 2022 and 2023. The present study, therefore, provides a comprehensive overview of the following deliverables produced during the above period:

- Deliverable D4.9 - Future Needs Definition for sub-sector ISIBA – Release 3, covering "ALBATTS Workshops: European Battery Ecosystem – Job Roles and Competencies now and in the future"
- Deliverable 4.10 - Desk research and data analysis for sub-sector ISIBA – Final report, covering "Batteries in the EU: Recent Legislative Evolution and Introduction to the Machines, Operators' Skills and Competencies in Production"

Deliverable D4.9 - Future Needs Definition for sub-sector ISIBA[1] is the third and final round of workshops covering both webinars and interviews with experts exploring the following topics:

- **Lithium - European Sourcing and Skills:** skills and competence information from the first stage of the battery value chain, minerals, and processing by studying lithium mining and extraction.
- **Second Life Bus Batteries in BESS Residential Applications:** interview on a project exploring the use of second-life bus batteries in stationary residential applications and which job roles, skills and competencies are required.
- **BMS and Control Systems**: battery management system and the control of the batteries, where innovative hybrid-battery packs and the respective power converters are described, along with an example of lithium car starting batteries and batteries for automotive OEMs and off-highway applications.
- **Future geopolitical challenges in the source of raw materials and the battery value chain:** experts from the European Commission providing key insights about the state of raw materials, especially battery materials, along with the impacts of the Russian invasion of Ukraine and the policies, strategies and ideas being implemented to mitigate similar situations in the future, mainly in the battery industry.

[1] See chapter 2-6 of the present report

- **Skills Transition:** exploring the training opportunities available for individuals seeking employment within the battery industry.

Deliverable 4.10 - Desk research and data analysis for sub-sector ISIBA – The final report[2] discusses the significance of the Critical Raw Materials Act and the Net Zero Industry Act in the battery sector's context during the green and digital transition. The former focuses on ensuring a sustainable supply of key materials like lithium and cobalt, emphasising diversification and recycling. The latter promotes resilience in net-zero technology, considering manufacturing and future skill requirements. It also provides a final forward-looking perspective on the main Drivers of Change shaping the industry. The report also delves into battery production's skill and competence needs, specifically in mid- and downstream processes, emphasising operator skills, technical proficiency, and a continuous improvement mindset. Finally, the study explores the modern education and training methods for the battery industry, including the use of Virtual Reality (VR), Augmented Reality (AR), Artificial Intelligence (AI), and Digital Twins to create engaging and tailored learning experiences for a highly skilled workforce.

[2] See chapter 1 of the present report

Introduction and Methodology

The report's methodology aligns with the report structure, which involves annual reporting on chosen battery applications or cutting-edge domains. The examination of trends, technologies, stakeholders, and skills/job roles is conducted through a combination of desk research and workshops/interviews as part of the deliverable:

- Deliverable D4.9 - Future Needs Definition for sub-sector ISIBA – Release 3, covering "ALBATTS Workshops: European Battery Ecosystem – Job Roles and Competencies now and in the future". Webinars and interviews featured various experts spanning the entire battery value chain. The webinars adhered to a standard format, involving a moderator overseeing the presentations, an ALBATTS member introducing the project, and subsequent presentations by invited speakers. The interviews followed a similar structure, with a moderator/interviewer guiding the event and posing questions to the speaker/interviewee. Towards the conclusion of both event types, the moderator addressed questions from the audience submitted in the chat box during the session.
- Deliverable 4.10 - Desk research and data analysis for sub-sector ISIBA – Final report, covering "Batteries in the EU: Recent Legislative Evolution and Introduction to the Machines, Operators' Skills and Competencies in Production". This study followed a structured desk research process and literature review based on new data and information to complement previous desk research[3].

As part of this study, the following information is therefore summarised:

- Chapter 1: Batteries in the EU: Recent Legislative Evolution and Introduction to the Machines, Operators' Skills and Competencies in Production
- Chapter 2: Webinar: Lithium - European Sourcing and Skills
- Chapter 3: Interview: Second Life Bus Batteries in BESS Residential Applications
- Chapter 4 Webinar: BMS and Control Systems

[3] Release 1 is available at:
https://www.projectalbatts.eu/Media/Publications/5/Publications_5_20201106_123821.pdf
Release 2 is available at:
https://www.projectalbatts.eu/Media/Publications/23/Publications_23_20210920_83914.pdf
Release 3 is available at:
https://www.projectalbatts.eu/Media/Publications/68/Publications_68_20220912_82848.pdf

- Chapter 5: Interview: Future geopolitical challenges in the source of raw materials and the battery value-chain
- Chapter 6: Webinar: Skills Transition

In each chapter, a dedicated section on skills and recommendations – specifically on re-/up-skilling, specific skills needs, and needed job profiles are analysed for each domain and topic.

1 Batteries in the EU: Recent Legislative Evolution and Introduction to the Machines, Operators' Skills, and Competencies in Production

1.1 KEY FINDINGS OF THE DESK RESEARCH[4]

1.1.1 The Critical Raw Materials Act and The Net Zero Industry Act

This subchapter delves into two pivotal EU legislative acts, the Critical Raw Materials Act and the Net Zero Industry Act, addressing the strategic importance of supply chain resilience and sustainability in key sectors, notably battery production. The Critical Raw Materials Act targets the EU's dependence on vital raw materials, specifically focusing on battery production. It mandates stress tests, supply chain mapping, and recycling to ensure resilience. Simultaneously, the Net Zero Industry Act, aimed at boosting net-zero technologies, fosters transparency, skills enhancement, and innovation, offering support to battery manufacturers to meet 90% of European battery demand by 2030.

The critical minerals, including lithium, cobalt, nickel, manganese, and graphite, play a fundamental role in battery performance. Propelled by the green and digital transition, the sector faces heightened demand, leading to the introduction of the Critical Raw Materials Act. The Act emphasises mineral mapping, geochemical campaigns, and domestic sourcing objectives. Despite challenges like varying mining infrastructures across countries, the Act aims to secure a diverse global supply chain, identifying potential mining locations like Portugal, Sweden, and Finland.

In December 2022, the Council and the European Parliament reached a general provision on new rules "**towards a sustainable, circular, European battery supply chain**", representing a very important and revolutionary step to ensure the circularity of batteries. In June 2023, the proposal was finally adopted by the European Council, permanently replacing the battery directive of 2006. Mandates include ambitious waste collection targets, lithium recovery goals, and minimum recycled content levels for various materials. A recycling efficiency target for nickel-cadmium batteries is set for 80% by 2025. The regulation introduces a "battery passport" for lifecycle tracking, ensuring compliance with recycling requirements and assessing environmental performance. As part of broader EU initiatives, circularity is emphasised in regulations like the Critical Raw Materials Act and the Net Zero Industry Act, emphasising recycling, reuse, and workforce reskilling.

[4] D4.10 - Desk research and data analysis for sub-sector ISIBA- Release 4

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1.1.2 Macro Trends, Drivers of Change: A Forward-Looking Perspective

The ALBATTS project's data analysis identifies key Drivers of Change (DoC) in the battery sector, which is crucial for understanding its evolution and future dynamics. These drivers include climate goals, globalisation, and new technologies with subcategories such as reducing CO2 emissions, access to raw materials, and cybersecurity. Each DoC's significance, urgency, and occurrence are analysed, indicating the increasing importance of globalisation and emphasising the EU's need for a competitive advantage in critical raw materials sourcing. The climate goals, regulation, and environmental challenges remain significant, constituting 47% of occurrences. Looking towards 2030, all identified DoCs remain vital, guiding skills forecasting and the ALBATTS project's core mission.

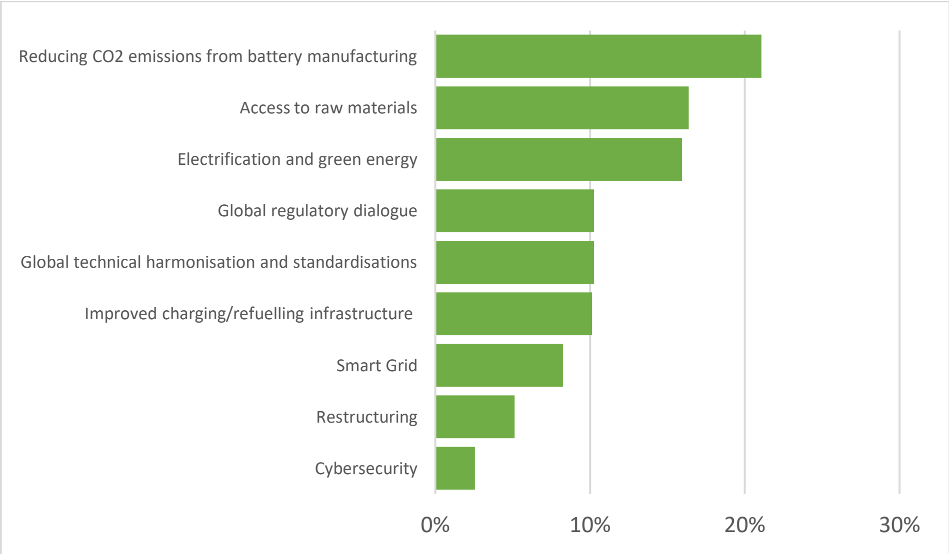

Figure 1. Occurrence of each DoC according to the ALBATTS WP4 Desk Research Release 4[5]

Moving forward, the sector must address key challenges, interrelated and critical for sustainability, resilience, and circularity. Holistic sustainability involves a comprehensive approach, considering energy efficiency, emissions reduction, and positive environmental impact, coupled with a focus on social dimensions like health, safety, fair-trade standards, human rights, and inclusive dialogues. Resilience requires strategic partnerships, EU funding, investment support to secure critical raw material supply, and data transparency for legal compliance. Lastly, embracing circularity as a key factor for the battery industry's future involves transitioning to a circular business model, fostering environmental benefits,

[5] D4.10 - Desk research and data analysis for sub-sector ISIBA- Release 4

economic potential, and cross-industry collaborations for increased resilience and risk mitigation.

1.1.3 Production Equipment in Electrode Manufacturing

Mixing Equipment: Vital Role of Planetary Mixers and Ball Mills in Electrode Manufacturing

The importance of mixing equipment, specifically planetary mixers and ball mills, remains substantial in electrode manufacturing. Planetary mixers, characterised by a rotating, stationary container and agitator, find widespread use in the production of electrode paste and slurry. Their efficacy lies in efficiently blending high-viscosity materials across diverse batch sizes. Similarly, ball mills featuring rotating drums filled with grinding media are commonly employed for powder blending and refining processes.

Coating Equipment: Precision Coating Solutions with Slot Dies, Doctor Blades, and Roll Coaters

Coating equipment is pivotal in ensuring precise and uniform coatings on electrode materials. Examples such as slot dies, doctor blades and roll coaters are crucial in this process. Slot dies, utilised for controlled coating applications, offer advantages such as high uniformity and adjustable thickness. Working in tandem with slot dies, Doctor blades contribute to maintaining coating thickness consistency. Simultaneously, roll coaters, employing rollers for uniform coatings, prove suitable for high-volume production scenarios.

Drying Equipment: Essential Components for Electrode Drying

Drying equipment is a vital component in electrode manufacturing, facilitating the thorough drying of electrodes. Ovens, providing a controlled environment with adjustable temperature settings and timers, cater to batch and continuous production requirements. Vacuum dryers, excelling in removing moisture at lower temperatures and reduced pressure, play a key role in preserving the properties of sensitive electrode materials. Crucial considerations for drying equipment encompass capacity, temperature control, energy efficiency, and specific requirements tailored to the electrode materials being processed.

Slitting Equipment: Precision Cuts for Electrode Materials with Slitters and Rewinders

Slitters, designed to slit large rolls of materials such as metal foils or coated substrates, utilise razor blades or rotary knives for precision cuts. Key features of slitters in electrode manufacturing include width and diameter capacity, accuracy, speed and productivity, automation and control, and safety features. Rewinders complement slitters by rewinding slit electrode materials into smaller rolls suitable for further processing or packaging. Factors to consider for rewinding equipment include roll diameter and width capacity, tension control for maintaining material integrity, core handling to support appropriate core sizes, and automation features for efficient roll changeovers and material handling.

Electrode Stacking Equipment: Precision Assembly with Stacking Machines for Lithium-Ion Batteries

Integral to the lithium-ion battery electrode manufacturing process, the equipment for stacking electrodes holds paramount importance. These machines intricately handle the meticulous stacking and alignment of numerous layers of anode and cathode materials, along with separators, to construct the electrode structure. The electrode stacking process's precision significantly influences the resulting battery's performance and quality.

1.1.4 Production Equipment in cell assembly

Cell Stacking Equipment

Equipment designed for cell stacking automates the systematic and efficient stacking of individual cells or batteries, playing a vital role in battery pack production across applications such as electric vehicles, portable electronics, and energy storage systems.

Tab Welding Equipment

Ultrasonic welders, widely used in manufacturing lithium-ion batteries for electric vehicles and other devices, provide a reliable and efficient method for joining battery cell components. Utilising a high-energy laser beam, laser welding technology is employed to melt and fuse materials during cell assembly, particularly for combining components like battery tabs, terminals, and busbars.

Winding Machines

In battery cell assembly, winding machines precisely wind and assemble electrode components, separators, and current collectors into a streamlined cell arrangement.

Electrolyte Filling Equipment

Specialised in battery production, electrolyte vacuum filling machines and injection filling machines precisely add electrolyte to battery cells. These machines ensure accurate and efficient electrolyte filling, vital for the ionic conductivity required in cell electrochemical reactions.

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Sealing Equipment

Heat sealers in battery manufacturing play a crucial role in ensuring a hermetic and secure enclosure during battery cell assembly, creating dependable and leak-proof seals.

Crimping Machines

Utilised in battery cell assembly, crimping machines establish electrical and mechanical connections among various parts of a battery cell, connecting terminals, tabs, or connectors to electrodes, ensuring a reliable and low-resistance electrical channel.

Formation Equipment

Battery cyclers, or formation equipment, are integral in battery production, facilitating initial charging and discharging cycles to condition and activate cells. These machines, equipped with safety features, ensure consistent and efficient formation, enabling automated processes and quality control.

Voltage/Current Testing Equipment

Used for measuring electrical systems, voltage/current testing equipment ensures efficiency and safety. Instruments like Digital Multimeters (DMM), clamp meters, power analysers, oscilloscopes, and programmable power supplies provide versatility in maintenance, troubleshooting, and electronic equipment testing. Current shunts and precision resistors measuring high current levels are used in power distribution and industrial machinery.

1.1.5 Module and pack assembly

The assembly of battery modules is a complex process involving various components such as cells, cooling systems, battery management systems, sensors, casing, cables, electrical connections, and protection circuits. Due to the degree of customisation and the high number of different kinds of products and process variations, it is not possible to create a definition of a single exact module assembly process. Essentially, three cell geometries—pouch cells, cylindrical cells, and prismatic cells—are used in battery modules. The process involves intricate steps, from pre-assembly inspections and electrical contacting to thermal integration and final testing. Different connection methods, including laser welding, ultrasonic welding, and screwing, are employed based on precision, efficiency, and cost considerations.

For prismatic cells, the battery pack assembly consists of nine steps. The process begins with pre-assembly inspections, where suitable cells undergo analysis, cleaning, and stacking. Insulation and tensioning follow, involving clamping devices to minimise swelling and the insertion of plastic plates for electrical isolation. The subsequent steps include electrical contacting, mounting slave circuit boards, insertion of cell modules, electrical and thermal integration, sealing and leak tests, charging and flashing, and a final end-of-line testing phase. Each step is crucial for ensuring the quality, functionality, and safety of the battery modules and packs produced.

This comprehensive approach highlights the intricacies involved in crafting battery modules and packs, emphasising the importance of precision, testing, and adherence to safety standards throughout the assembly process.

The battery module automatic assembly line, driven by intelligent robotic technology, operates collaboratively with various automated equipment throughout the assembly process. The fully automated line handles tasks such as incoming, conveying, sorting, testing, glueing, screw locking, labelling, packaging, and palletising. The layout of each station is meticulously designed to optimise efficiency, with options like tree structure, series structure, and parallel structure based on product characteristics and production rhythm. Multiple companies offer solutions for automatic assembly lines of battery modules, exemplified by Hylaser Machine's machining line that covers assembly steps up to Electrical Contacting. The summarised steps include cell glueing, module stack pressing with alternating stacking tools, strapping with automated steel cable ties, insulation testing, laser cleaning for pole maintenance, and busbar assembly with laser welding, showcasing the comprehensive automation in battery module production.

The manufacturing process of rack modules and cabinets, involving plastic deformation of metal sheets, follows a systematic six-step procedure. Beginning with punching and cutting, executed with precision through CNC machines or laser tools, the process moves on to bending in specialised machines, where accuracy adjustments are made after initial bends. Welding, a crucial step, can be manual or automated, with manual welding requiring technical expertise and automatic options involving robot arms. Following welding, polishing is a straightforward step using a polish machine. The metal sheets undergo powder coating after washing, degreasing, and silane treatment, involving spraying with a gun and curing in an oven. The final step is assembling, requiring basic tools to integrate fully manufactured metal sheets into the completed rack modules and cabinets.

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1.1.6 Dry and clean rooms

In battery production, precision is imperative for electronic and chemical processes. Gloveboxes and dry rooms are instrumental in maintaining the required conditions. Gloveboxes create a controlled, oxygen and humidity-free environment suitable for handling sensitive battery materials, primarily used in research labs. On the other hand, dry rooms and clean rooms are mainly used in industrial labs and manufacturing plants. Dry rooms maintain low humidity levels to preserve material integrity during manufacturing, offering a contamination-free space to ensure the quality of battery components. Battery materials exhibit diverse sensitivities, demanding specific environmental conditions. Clean rooms, crucial for electronic components, minimise particulate matter, preventing short circuits. They maintain relative humidity between 40 to 60%. In contrast, dry rooms share dust control measures but excel by keeping relative humidity below 1%. The strategic allocation of clean rooms and dry rooms in battery manufacturing aligns with the specific sensitivities of materials, ensuring each space serves its specialised role in maintaining the integrity and quality of the components throughout the fabrication process.

1.1.7 Modern Approach Towards Learning

Education and training for production equipment involve the widespread use of VR and AR digital tools in modern courses. Below are several examples.

The PV and Storage Optimization Tool is an online resource for assessing the economic viability of PV+Storage systems, factoring in load profiles, production, and electricity costs. Users input data such as electrical consumption, solar irradiation, and system sizes, and the tool calculates metrics like the Levelized Cost of Electricity and Net Present Value. The "StoRES Living Lab" provides an interactive platform displaying data from pilot sites, enabling users to experiment with energy storage parameters and assess PV and BESS sizing through a parametric study.

Digital Tools at Virtual Practical Training in Engineering Fields: the Simulated Enterprise project, funded by the European Social Fund and conducted between 2011 and 2013 in partnership with Romanian universities, aimed to enhance the employability of university graduates in engineering fields. It involved the development of an integrated information platform simulating real working technology companies, providing practical training for students.

Building a block of a life-size vessel simulating the working conditions of a shipyard within the educational environment: CIFP Ferrolterra, a technical VET school in Ferrol, Spain, collaborated with Navantia, a major European shipyard, to create the Freeboard PE project. The initiative provided students with a simulated naval work environment, replicating real shipyard conditions. This involved constructing a life-size part of a ship's hull. VET students specialising in welding and boiler making and HE students in metallic construction enhanced their skills through hands-on training and applying industry standards. The hands-on training focused on manufacturing, assembly, and repair processes, including welding, machining, and shaping techniques.

VR Training Simulations offer a safer alternative to live high-voltage systems training, eliminating the associated danger. Aptiv, a global technology leader, provides a comprehensive VR learning platform through Gemba. This platform enhances trainee engagement and knowledge application, with VR-trained individuals recalling up to 75% of the learning material within 24 hours. This effectiveness surpasses traditional e-learning methods.

AR offers a unique approach compared to traditional training methods. Traditional exams, whether paper or digital, often fail to evaluate trainees' grasp of real-world concepts. Hands-on assessments, while valuable, lack data on human error and overall performance. AR bridges this gap by combining the strengths of both methods. It subjects trainees to hands-on examinations while capturing crucial data for program improvement. AR recognises errors like incorrect part usage, out-of-order assembly steps, prolonged task completion, or safety risks.

Factory simulation is essential for more than just manufacturing optimisation; it explores options and enhances communication. For companies using automation, for example, Siemens Digital Industries Software provides an advanced system for battery factory simulation, covering battery modelling, engineering, and consulting services. This comprehensive solution accelerates battery design by virtually exploring variants and assessing multi-level performance, from system simulation to 3D and CFD simulation. Engineers can model various cell chemistries, evaluate battery pack designs, and consider charging, thermal management, and control strategies for optimal vehicle performance.

A digital twin is crucial for bridging the development-reality gap in the complex battery industry. It visualises numerous parameters impacting cell quality using technologies like artificial intelligence. Functioning as the battery's brain, the digital twin provides real-time information and future insights, enhancing safety and sustainability.

Utilising AI for battery optimisation, particularly in machine learning, can contribute to managing the complexities of battery cell development. The multitude of parameters influencing cell qualities, such as anodes, cathodes, separators, electrolytes, and housing materials, can be effectively addressed by AI. AI enhances manufacturing quality and production efficiency by recognising process parameters yielding desirable outcomes. While the current focus lies on machine learning for process optimisation, there's substantial potential in development, especially when coupled with a digital twin. This integration allows precise adjustments in a controlled digital environment, minimising the need for extensive experimental matrices. The journey towards fully automated development is underway, aiming to provide application-specific materials and cell designs effortlessly. AI's role in predicting electrochemical properties accelerates development processes, facilitating material pre-selection and exploring novel, underexplored materials.

1.2 SKILLS AGENDA AND RECOMMENDATIONS

1.2.1 Skills and Job Roles at The Macro Level

The European battery manufacturing sector is experiencing rapid growth, creating a demand for professionals possessing specific skills and competencies. While many of these have been identified earlier, this serves as a recap of what we have encountered in our studies. A proficient workforce, equipped with diverse technical and vocational expertise, is essential for ensuring the efficient and sustainable production of batteries, spanning the entire lifecycle from raw material extraction to recycling processes:

- The supply of raw materials
- Proficiency in high-volume production processes and techniques
- Chemistry of future batteries and material purity
- knowledge of battery manufacturing equipment (that we primarily focus on this deliverable)
- Automation systems, including their maintenance
- Electrical and mechanical skills
- knowledge of battery recycling and the safe handling of lithium-ion batteries by recycling facility workers

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The sector also requires legislation, circularity, sustainability, and digitalisation knowledge. Understanding new technologies and materials in battery production and expertise in artificial intelligence and big data are also essential.

Regulatory and Industry Knowledge will be needed, including, for example, the following areas:

- Battery Passport and EU's Battery Regulation
- Circular economy principles
- Sustainable production practices
- Sustainable sourcing of raw materials
- Battery recycling processes

On the application side, the increasing number of electric vehicles and various battery energy storage systems in the market require skilled electricians and mechanics trained to operate these systems. Additionally, we must not forget the safety aspect: the first responders of the fire and rescue services need to be skilled and competent to perform with these systems when a disaster strikes as well.

The numerous job roles we have encountered during our project include, for example:

- Battery chemist
- Battery engineer
- Battery material scientist
- Battery pack assembler
- Battery production manager
- Battery quality control technician
- Battery recycling technician
- Battery research and development scientist
- Battery safety engineer
- Battery systems engineer
- Battery test engineer

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- Battery thermal management engineer
- Environmental health and safety specialist
- Industrial engineer
- Logistics Specialist
- Manufacturing Engineer
- Process engineer
- Supply chain specialist

1.2.2 Skills And Competencies Needed in Mid- and Downstream Production of Batteries

Acquiring the necessary skills and competencies for the diverse equipment and machines utilised in battery production is important. Performing in a complex production setting requires a versatile skill set. Crucial to the process, operators contribute significantly by combining technical proficiency in equipment operation with meticulous attention to detail. Successful manufacturing operations hinge on integrating safety compliance, effective troubleshooting, and a commitment to continuous improvement. It is recommended to prioritise the development of these competencies for enhanced productivity and quality assurance.

1.2.2.1 General skills and competencies needed in electrode manufacturing and cell assembly

As discussed below, individuals should possess various skills and competencies to excel in operating electrode manufacturing and battery assembly.

Technical knowledge is paramount, encompassing a thorough understanding of equipment principles, operations, and maintenance, including machine models, functionalities, programming, and troubleshooting. Proficiency in equipment operation and calibration is crucial, involving correctly setting up machines and ensuring precise calibration for accurate dispensing. This extends to knowledge of calibrating sensors, nozzles, valves, and other components. Programming and machine operation competence is necessary for programming machines for specific tasks and optimising settings to meet different product requirements.

Materials handling skills are essential, requiring proficiency in managing various materials used in the assembly process and understanding material properties, storage requirements, and proper handling techniques. Quality control is vital, demanding attention to detail, focusing on quality control measures, and implementing checks at various assembly stages with corrective actions.

Individuals must possess strong problem-solving and troubleshooting abilities to identify and resolve technical issues during the assembly process, addressing problems with machines, materials, or components. Effective communication and collaboration skills are also essential, involving clear communication with team members and stakeholders and collaboration to streamline workflows, share knowledge, and address challenges. Time management is a key competency, requiring efficient task prioritisation and optimisation of machine use for maximum productivity.

Safety awareness is crucial, with individuals expected to comply with safety protocols and regulations, understand potential hazards, and take necessary precautions. Continuous learning is emphasised, encouraging individuals to stay updated with technological advancements and industry trends while actively seeking opportunities for professional development.

1.2.2.2 Equipment-specific Skills and competencies needed in electrode manufacturing

For those engaging with specific equipment categories, cultivating particular skills and competencies is essential for optimal performance. In handling **Mixing Equipment** like **Planetary Mixers and Ball Mills**, individuals should be able to manage high-viscosity materials efficiently. Troubleshooting skills are paramount for addressing operational issues, and a commitment to environmental compliance is crucial.

In **Coating Equipment**, including **Slot Dies, Doctor Blades, and Roll Coaters**, proficiency in adjusting coating parameters is indispensable. Mechanical aptitude for routine maintenance ensures the equipment's longevity and meticulous record-keeping skills are necessary for tracking production data accurately.

Working with **Drying Equipment**, such as **Ovens and Vacuum Dryers**, demands analytical thinking for effective troubleshooting and adaptability to changing priorities. Documenting equipment operation is vital for maintaining a seamless process.

Hand-eye coordination is a key skill for making precise adjustments for those working with **Slitting Equipment**, including **Slitters and Rewinders**. A strong sense of quality consciousness is essential for upholding standards, and adaptability to changing production requirements is crucial.

Finally, **Electrode Stacking Equipment**, like **Stacking Machines**, requires individuals with mechanical aptitude for routine maintenance. Record-keeping skills are again emphasised for production data and adaptability to accommodate changing production requirements.

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1.2.2.3 Equipment-specific Skills and competencies needed in cell assembly

For those working with **cell stacking equipment,** competence in various stacking techniques, whether manual or automated, is essential. Individuals should be adept at adapting their skills based on the specific machine and application requirements.

With **tab welding equipment** proficiency in different welding techniques, such as **ultrasonic or laser welding**, is crucial. The ability to adjust methods based on the machine and application ensures optimal performance.

When one operates **winding machines,** a fundamental understanding of mechanical systems is necessary for routine maintenance and effective troubleshooting when issues arise. Additionally, hand-eye coordination, good manual dexterity and coordination are essential for precise material handling and adjustments during winding processes.

With **electrolyte-filling equipment** such as **vacuum filling machines and injection filling machines**, individuals should showcase competence in programming the filling system, tailoring it for specific tasks, and adjusting settings to ensure optimal performance.

When it comes to **sealing equipment**, a basic understanding of mechanical systems is crucial for routine maintenance and effective troubleshooting when issues arise.

Good manual dexterity and coordination skills are necessary with **crimping machines** to handle wires or cables and make precise adjustments during crimping processes.

For operating **formation equipment,** proficiency in data acquisition, interpretation, and analysis is crucial for comprehensive testing evaluations.

When using **voltage-current testing equipment, i**ndividuals should demonstrate the ability to set up testing equipment, configure measurements, and adhere to safety protocols when dealing with live circuits.

1.2.2.4 Skills and competencies needed in module and pack assembly

In the pre-assembly phase, it is essential to have a deep understanding of cell testing. Expertise in Electrochemical Impedance Spectroscopy, voltage measurements, and capacity analysis ensures a comprehensive cell quality and performance assessment before assembly. Additionally, operators should possess knowledge of adhesive application, particularly in handling polyurethane adhesive. This skill is crucial for ensuring the proper bonding of cells during stacking. Furthermore, a strong emphasis on adhering to safety protocols is necessary, especially when working with solvents and other potentially hazardous materials, to maintain a secure working environment for the entire team.

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With insulation and tensioning, competence in clamping techniques is highly valuable. Proficiency in using clamping devices to press and tension stacked cells minimises cell swelling during operation. Knowledge of appropriate plastic plates and housing materials for insulation, coupled with expertise in various assembly techniques such as glueing, bandaging, or screwing, is crucial for securing cells within the housing effectively.

In the electrical contacting phase, welding expertise is a key requirement. Individuals skilled in using laser welding or ultrasonic welding techniques establish robust electrical connections between current collectors and contact tabs. Additionally, competency in using screws and other fastening methods for electrical connections, along with quality control and the ability to conduct resistance measurements and electrical continuity tests, ensures the reliability of these connections.

Mounting the slave circuit board and housing cover demands individuals with careful circuit board handling. Knowledge of proper handling procedures during installation to prevent damage is vital. Expertise in welding or screwing tools for attaching the circuit board securely and the ability to connect the Battery Management System (BMS) to the temperature, current, and voltage sensors via plug connections are also essential.

Inserting cell modules and attachments requires competency in cooling system integration. Individuals should be skilled in installing cooling plates and other components needed for liquid cooling, ensuring efficient thermal management of the battery pack. Additionally, proficiency in using screwing tools for secure attachment within the housing adds an extra layer of rigidity and protection against vibrations during operation.

In the electrical and thermal integration phase, electrical connection expertise is needed. Knowledge of integrating protection equipment like relays, fuses, and pre-charge systems into electrical connections ensures the safety and reliability of the high-voltage system. Understanding thermal management principles and providing the effective dissipation of heat generated during operation is equally important. Moreover, connecting the BMS Master to the cooling system and slave circuit boards and establishing effective communication and control within the battery pack is a key competency.

Sealing and leak testing demand proficiency in sealing techniques, using rubber seals or glue to seal pack housing or cover edges to prevent moisture ingress and ensure pack integrity.

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Expertise in leak testing procedures to verify correct sealing and meet required safety and performance standards is important.

Charging and flashing require competence in testing procedures, utilising testing stations for thorough electrical and thermal assessments to ensure the battery pack functions correctly before finalisation. Additionally, expertise in verifying the proper functioning of the BMS ensures adequate communication with cells, sensors, and subcomponents.

Finally, at the end of the line, final testing proficiency is essential. This includes assessing the performance of the BMS, temperature sensors, slave circuit board, and other subcomponents to confirm their proper functioning. Competence in state-of-charge assessment, achieved through cycling the battery pack to establish the desired state of charge and verify operational capacity, is crucial. Moreover, individuals should possess the skill to label the battery pack appropriately, providing essential information for proper identification and ensuring adequate packaging for shipment.

1.2.2.5 Skills and Competencies Needed in a Battery Module Automatic Assembly Line

In the stage of cell glueing, precision is paramount. Individuals involved should exhibit skill in accurately placing battery cells onto the feeding conveyor belt, ensuring proper alignment and positioning. Competency in adhesive application is equally essential, focusing on accurately and uniformly applying adhesive material to facilitate reliable bonding between cells and other components. Moreover, a foundational understanding of basic equipment operation is necessary, demonstrating the ability to operate cleaning and glueing equipment effectively for consistent, high-quality results.

In module stack pressing, proficiency in robotic handling is a key requirement. Individuals must operate robots to feed cells and insulating plates into the stacking tool, ensuring precise alignment and smooth movement. Coordination and timing skills are crucial, involving the ability to coordinate the actions of the cell stacking robot, insulation board stacking robot, and clamping cylinder for precise and secure cell stacking.

In the strapping phase, manual assembly and equipment operation skills are necessary. Individuals should be capable of manually installing middle partitions, insulation boards, end plates, and steel cable ties with accuracy and security. Moreover, skills in using the extrusion sliding table and pressing the extrusion start button for automated strapping contribute to the strapping processes.

For insulation, competency in quality inspection is fundamental. Individuals must visually inspect and test insulation between cells, pole series, and housing, identifying potential issues or defects impacting battery safety and performance. Attention to detail is a critical skill in this phase, ensuring a thorough examination of insulation integrity.

In the laser cleaning phase, proficiency in robotic programming is essential. Individuals should demonstrate skill in programming robots for automatic height adjustment, distance measurement, and precise laser cleaning based on coordinate data.

Moving on to busbar assembly and laser welding, the coordination of robotic actions is a key competency. Individuals must exhibit skill in accurately positioning and welding busbars based on calculated offsets and welding positions.

Individuals must conduct preventive maintenance as part of **the service and maintenance for a battery module automatic assembly line**. Regularly scheduled maintenance is essential to ensure optimal functioning of all equipment, robots, sensors, and other components. Troubleshooting skills are crucial, enabling identifying and diagnosing issues that may arise during operation, such as sensor malfunctions or robotic errors. Technical expertise in the assembly line components is necessary for performing repairs, adjustments, and replacements. Effective collaboration and communication with maintenance and technical teams are essential for addressing complex or specialised service requirements. Additionally, maintaining detailed records of service and maintenance activities, including schedules, repairs, and replacements, is important for traceability and continuous improvement.

1.2.2.6 Rack module and cabinet manufacturing

With punching and cutting, proficiency in utilising a CNC machine is paramount. The operator should possess technical knowledge encompassing programming, setup, and troubleshooting of computer numerical control (CNC) systems. Additionally, the ability to read and interpret engineering drawings and blueprints is crucial for accurate CNC programming. Material knowledge, focusing on various types of metal sheets and their properties, is necessary to optimise cutting and punching parameters. Competency in CNC machine setup, including loading tools, setting cutting paths, and ensuring proper workpiece positioning, is essential. Basic maintenance skills for the CNC machine, ensuring optimal performance and longevity through regular cleaning and maintenance, are also recommended.

Moving to bending, individuals involved should demonstrate proficiency in various bending techniques such as air bending, bottoming, and coining to achieve the desired angle and precision. A solid understanding of different bending tools and the ability to select appropriate tooling based on material thickness and bending requirements is crucial. Skills in setting up the bending machine and adjusting backstops, gauges, and other parameters for accurate bending are also recommended. Moreover, the ability to perform quality control, inspecting and verifying the accuracy of bent metal sheets to meet dimensional tolerances and quality standards, is essential.

In welding, competence in various welding processes, such as TIG (Tungsten Inert Gas), MIG (Metal Inert Gas) or spot welding, depending on materials and joint requirements, is a key requirement. Understanding the compatibility of different metals and filler materials for strong and reliable welds is necessary. Thorough knowledge of welding safety protocols and personal protective equipment (PPE) ensures a safe working environment. The ability to inspect welds for defects and ensure they meet industry standards and specifications is a critical competency.

For polishing, knowledge of surface preparation techniques, including sanding and cleaning, is necessary before polishing to achieve the desired finish. Proficiency in using various polishing methods, such as abrasive wheels or buffing, is required to achieve the desired surface smoothness and shine. Understanding different metal characteristics and how they respond to polishing is essential to avoid over-polishing or damaging the material. Familiarity with finishing standards and customer requirements ensures the final product meets the desired appearance and quality.

In the powder coating phase, expertise in using the powder coating spray gun to apply an even and consistent coating on metal sheets is crucial. This includes adjusting the gun settings, controlling the flow rate, and achieving the desired thickness. Competency in surface preparation with competency in preparing the metal sheets before the powder coating process is crucial. This includes washing, degreasing, and ensuring the surfaces are clean and contaminant-free. Knowledge of different powder coating materials and their properties is essential. This allows operators to select the appropriate powder coating material for the specific metal sheets and application requirements. It is important to understand the curing process and how to properly set the oven temperature and time for effective curing without causing any defects. Compliance with safety and environmental standards is crucial in this context. Operators must adhere to safety guidelines while handling powder coating materials

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and operating equipment, being vigilant about potential hazards and following appropriate handling procedures. Additionally, operators must be well-versed in environmental regulations associated with powder coating, including the correct disposal of unused powder and effective waste management practices. Quality control and inspection skills, ensuring uniformity, adhesion, and defect-free powder-coated metal sheets, contribute to the final product meeting quality standards and customer requirements.

With assembling metal sheets, a robust set of skills and competencies is essential. A strong foundation in mechanical assembly techniques is vital for effectively joining metal sheets. This encompasses aligning parts accurately, inserting fasteners, and ensuring a proper fit and finish. Additionally, competency in reading and interpreting engineering drawings is essential for a comprehensive understanding of assembly instructions, dimensions, and tolerances. Knowledge of diverse fastening methods, such as screws, bolts, nuts, rivets, or welding, is crucial, with the choice depending on the design and material of the metal sheets. Proficiency in utilising various hand tools, including wrenches, screwdrivers, hammers, and pliers, is necessary to execute assembly tasks with precision. Furthermore, the capability to use power tools like drills, impact drivers, and pneumatic tools is important for expediting the assembly process and achieving consistent results. Skills in using measuring tools such as calipers, rulers, and levels are essential to ensure precise positioning and alignment throughout the assembly. Effective communication within the team is paramount for coordinating assembly tasks, sharing insights, and working together efficiently. A keen eye for detail and the ability to conduct quality checks at various stages of the assembly process are necessary to ensure that the final product meets rigorous quality standards. Moreover, a strong emphasis on safety awareness is critical. Knowledge of safety protocols when handling tools, materials, and heavy objects is essential to prevent workplace accidents and maintain a secure working environment.

1.2.2.7 Glovebox, dry room and clean room-related skills and competencies

With a glovebox, it is crucial to possess proficiency in its operation and maintenance. This involves adeptly operating the control panel, setting gas flow rates, controlling humidity levels and temperature, and optimising the glovebox's internal atmosphere. Familiarity with routine maintenance tasks, such as checking gas supplies, replacing filters, and maintaining proper sealing, is essential. Handling inert gases, like nitrogen or argon, is a fundamental skill needed to create an oxygen and humidity-free environment within the glovebox. Material handling inside the glovebox demands skilful execution to prevent contamination or exposure to external moisture and oxygen. Knowledge of material transfer techniques using attached gloves and airtight transfer chambers is important. Safety protocols specific to glovebox operation, including emergency shutdown procedures, gas leak detection, and handling hazardous materials, should be well understood. The ability to troubleshoot common issues like gas leaks, faulty seals, or improper pressure levels is vital for seamless glovebox operation. Competency in glove change procedures, ensuring airtight seals and preventing contamination, is a requisite skill. Additionally, knowledge of glovebox maintenance procedures, such as cleaning the interior, replacing damaged components, and performing routine checks, is important. Understanding material compatibility with the glovebox environment is especially crucial when dealing with reactive or moisture-sensitive materials. Accurate record-keeping of glovebox operation, maintenance, and material transfers is paramount for traceability and quality control. Effective communication within the team is necessary to coordinate tasks, report issues, and ensure smooth glovebox operation.

Achieving a clean environment within a Clean Room requires essential skills and competencies. Understanding and strictly adhering to clean room protocols is fundamental, encompassing gowning procedures, hygiene practices, and contamination control measures that collectively maintain the cleanliness of the environment. Proficiency in material handling is indispensable, encompassing the careful manipulation of materials, tools, and equipment to prevent contamination and uphold cleanliness standards within the clean room. Competency in gowning, correctly donning and doffing clean room garments and personal protective equipment (PPE), such as gloves, masks, and coveralls, is crucial for creating a contamination-free work environment. Knowledge of aseptic techniques is necessary to avoid introducing contaminants and sustain sterile conditions while performing tasks within the clean room. Operating clean room-specific equipment, such as laminar flow hoods and particle counters, requires proficiency to ensure proper functionality and prevent contamination. Skills in cleaning and maintaining a clean room environment are paramount, involving routine cleaning of surfaces, equipment, and workstations according to established procedures. Accurate documentation and record-keeping of activities, materials used, and any deviations from clean room procedures are essential for traceability and quality control. Attention to detail enables identifying and addressing potential contamination risks, such as

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particle generation, with appropriate corrective actions. Effective communication and collaboration within the clean room team are critical to ensure smooth operations and minimise the risk of contamination. Understanding emergency procedures and protocols within a clean room environment, including handling spills, equipment malfunctions, and other unexpected situations, is vital for a comprehensive skill set in maintaining a clean and controlled working environment.

Operating a Dry Room demands a specific set of skills and competencies. Competency in environmental control systems is vital, requiring the ability to operate and adjust systems such as dehumidification units and temperature controls to maintain the desired low humidity level within the dry room. Skill in using humidity monitoring equipment is essential for continuously measuring and monitoring humidity levels, ensuring they consistently align with specified ranges. Knowledge of routine maintenance tasks for the dehumidification system, including filter replacement and system checks, is crucial for proper functioning. Additionally, the ability to identify and troubleshoot issues affecting the dry room's environmental control system and promptly address them is a key competence. Understanding proper material handling techniques is necessary to prevent contamination and moisture exposure in the dry room environment. This includes knowledge of procedures for transferring materials in and out of the dry room without compromising the low humidity conditions. Awareness of safety protocols specific to the dry room environment is essential, encompassing precautions for handling sensitive materials in low-humidity conditions. Accurate record-keeping of humidity levels, maintenance activities, and material transfers is crucial for traceability and quality control. Understanding the compatibility of materials with low-humidity environments is important to ensure that only suitable materials are brought into the dry room. Effective communication within the team is necessary to coordinate tasks, report issues related to the dry room's environmental control, and ensure smooth operations. Skills in responding to environmental alarms or deviations from desired humidity levels are vital, requiring the ability to take appropriate actions to restore proper conditions. Maintaining cleanliness and organisation within the dry room is imperative to prevent dust or particulate contamination and ensure an efficient working environment.

2 Webinars and interviews

2.1 WEBINAR: LITHIUM - EUROPEAN SOURCING AND SKILLS[6]

2.1.1 Webinar

The webinar titled "Lithium - European Sourcing and Skills" marked the initiation of the third round of workshops organised under Task 4.4, held on April 27, 2022. The event concentrated on the initial stage of the battery value chain, specifically exploring lithium mining and extraction processes. Key questions addressed included the geographical locations of lithium deposits, extraction methods, recyclability, and the requisite job roles, skills, and competencies in this sector.

Dr Gerardo Herrera and Dr Patrice Christmann emphasised the growing dependence on foreign lithium sources, projected a significant increase in demand by 2050, and warned of a potential supply gap in Europe. They identified the global competition for battery-grade raw materials as a security concern and advocated for strengthening EU production and diversifying supply sources. They stressed the importance of public communication. Mr Asko Saastamoinen outlined the evolving landscape of lithium exploration and mining, emphasising the shift to digitalised and sophisticated processes. Dr Blandine Gourcerol highlighted lithium's significance in batteries, detailed various sources, and identified European deposits. Dr Carlos Nogueira underscored lithium's strategic importance and addressed environmental concerns in its treatment.

2.1.2 Skills agenda and recommendations

Dr Gerardo Herrera and Dr Patrice Christmann emphasised, among other things, the need to **develop expertise and skills, highlighting the priority of re-/upskilling within the European Commission's agenda**.

Mr. Asko Saastamoinen noted the **high demands for skills and know-how in the digitalised and sophisticated mining landscape, particularly in geology, metallurgy, process operations, and chemical and process operations**. According to him, the availability of employees is not very high at the moment, in Europe and especially in Finland, which is a challenge for employers. Dr Blandine Gourcerol outlined **key competencies in exploration, mineral characterisation, geochemistry, lithium isotopes analyses, market and use analyses, and sustainable processing & recycling**. Dr Nathalia Vieceli and Ms Lea Rouquette

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stressed **the need for multidisciplinary skills in recycling, chemistry, metallurgy, and safety in the critical role of battery recycling** for the green transition. Dr Carlos Nogueira advocated for **increased education in chemical/extractive metallurgy.**

Skills, competencies, job roles and education related to hard-rock mining:

Skills and Competencies

- Technology proficiency for mining-related positions
- Key white-collar skills related to geology, metallurgy, and process operations
- Key blue-collar skills related to chemical & process operators, mine operators
- Workplace skills: working in teams, flexibility, resilience, development attitude
- Safety, environment, and IT skills (digitalisation entering the mining business).
- Fit for the team

Job Roles and Education

- Job roles: Process Operators, Qualified chemical process operators, multiskilled electricity or maintenance technicians, Maintenance Technicians (Electricity, automation, mechanical), Laboratory technicians, Chemists, Supervisors, Engineers with technical education and industrial experience, Mining roles like geologists, drillers, loaders, drivers.
- Basic education needed: Process, chemical, Mechanical, electricity, automation engineering, Geology, chemistry
- Mining and process industries require people with vocational or special education.
- The right mindset is essential for the match between people and employers
- Schools and universities: Core skills combined with special skills needed in the field of business

Work Areas

- Mines, Concentrator and chemical plants, Maintenance, Laboratories, Logistics, Supportive, and administrative functions.

Job roles (thus also the education areas) related to the extraction of lithium from geothermal sources and brines:

- Geologists

- Geochemists
- Metallurgists
- Engineers (chemical, electrochemical)
- Job role areas:
    - Exploration
    - Mineral characterisation
    - Geochemistry & lithium isotope analyses
    - Market and use analyses
    - Sustainable Processing & Recycling

Recommendations on the skills and training for metallurgical processing:

- Resume the training effort in chemical/extractive metallurgy in universities (in Metallurgical/Materials Engineering, among others), which has been mostly forgotten in recent years in Europe;
- Promote advanced courses focusing on the new purification technologies to apply in industrial projects, aiming at attaining the high purity required battery-grade Li compounds;
- Promote training in process sustainability, a fundamental topic for the success of projects of new lithium refining facilities:
    - Water management
    - Energy needs and alternative energy sources (e.g. H2)
    - Optimization of reagents/chemicals usage

Skills, competencies, and knowledge needed in recycling of batteries:

- recycling, chemistry, battery production, life cycle assessment, social sciences,
- chemical engineering, mining, material sciences, design for recycling
- technical competencies, metallurgy, analytical techniques
- law and regulations, battery safety
- education about handling batteries: stockpiling batteries safely before recycling requires taking measures and a well-educated staff.

2.2 INTERVIEW: SECOND LIFE BUS BATTERIES IN BESS RESIDENTIAL APPLICATIONS[7]

2.2.1 interview

The first interview and second event in the third round of webinars for Task 4.10, titled "Second Life Bus Batteries in BESS Residential Applications: Job Roles, Skills, and Competences," occurred on November 22, 2022. Conducted with Mrs Ylva Olofsson, System Design Engineer & Project Manager at Volvo GTT, the session aimed to investigate the utilisation of second-life bus batteries in stationary residential applications and identify the necessary job roles, skills, and competencies for such endeavours.

2.2.2 Skills agenda and recommendations

Skills, competencies, and knowledge:

- Laboratory management
- Electrical safety for fire hazards and battery safety
- Systems design engineering
- Project management
- Creativity
- Engineering skills
- Management skills
- Sustainable energy expertise
- Strategic development
- Knowledge of battery chemistry
- Ageing testing expertise (PhD)
- Environmental impact assessment (LCA studies)
- Legal knowledge (agreements, IP rights)
- Knowledge of the electricity market, spot market
- Sales skills
- Data analysis and processing (big data)
- Software development and algorithm knowledge
- Cabling and connection expertise (electrical engineering)
- Thermal management and cooling expertise

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Mindset and personality traits:

- Interest in societal change and sustainability
- Bravery (self-confidence)
- Leadership skills
- Adaptable to change
- Openness to acquire new skills

Job roles:

- Research engineer
- Battery laboratory management
- Systems Design Engineer
- Project Manager
- Strategic Development
- Sales Professional

Understanding:

- Importance of Safety in Residential Areas
- Balancing Safety Costs and Research Needs
- Maximizing Battery Use Before Recycling
- Importance of Detailed Life Cycle Assessments (LCA)
- Team Composition and Skills for 2nd Life Battery Projects
- Leadership as a Key Factor in Business Success

Future Considerations:

- Continuous Research on 2nd and 3rd Life Battery Applications
- Exploration of Business Viability and Pricing Models
- Engagement in Conversations about the Future of Batteries in Europe

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2.3 WEBINAR: BMS AND CONTROL SYSTEMS[8]

2.3.1 Webinar

Battery Management Systems (BMS) and Controls Systems: Job Roles, Skills & Competencies, held on November 24th, 2022, featured guest speakers Mr Jorge Pinto from Vasco da Gama CoLAB, Mr Josef Tichanek from Olife Corporation, and Mr Mika Kauppila from Valmet Automotive. The session emphasised the significance of BMS and Control Systems in Stationary Energy Storage Systems, EV Charging Stations, and Electric Vehicles. The BMS system serves as the core of the battery system, managing power input and output and balancing battery modules and cells in electric applications. The safety functionality is the most critical aspect of battery management systems. Consequently, acquiring the proper skills is essential. Each speaker outlined their position and the expertise required for tasks associated with BMS system completion.

Despite the complexity of these systems, they exhibit considerable flexibility in accommodating new technologies in the battery field. Speakers emphasised that while software changes frequently, the hardware remains relatively stable.

An important revelation pertains to shifts in the automotive industry, with old batteries transitioning to the second-life market, where the BMS plays a pivotal role in ensuring overall battery module safety. A suggestion was also made regarding the high usability of second-life batteries in solar storage systems.

2.3.2 Skills agenda and recommendations

BMS - state of technology and identified skill and competence areas

- Basic requirements
  - Protect the battery and user;
  - Ensure the safe operation of the battery - Safe Operation Area (SOA)
- Current technology (2022):
  - Optimization of the battery use
  - Increase battery lifespan
- Future requirements (2030)
  - Self-diagnosis (advanced sensor technologies)
  - Remaining useful life (RUL)

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- Adaptive state-space models
- Integrate BMS functions in power electronics
- Increased interoperability:
    - State-estimation standard models
    - Internal parameters transparency
    - Enable battery hybridisation
    - Standard COMs protocols

Emphasised key positions:

- Thermal BMS Manager (Figure 2)
    - crucial due to the natural charging and discharging processes of batteries
- Functional Safety Manager (Figure 4)
    - a pivotal position in BMS development
    - a key managerial position overseeing the technicians

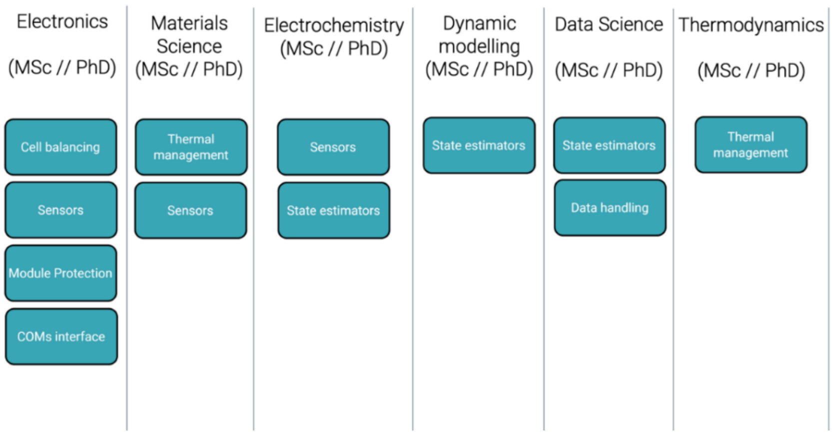

Figure 2. Description of professional skills. Source: Jorge Pinto's presentation[9]

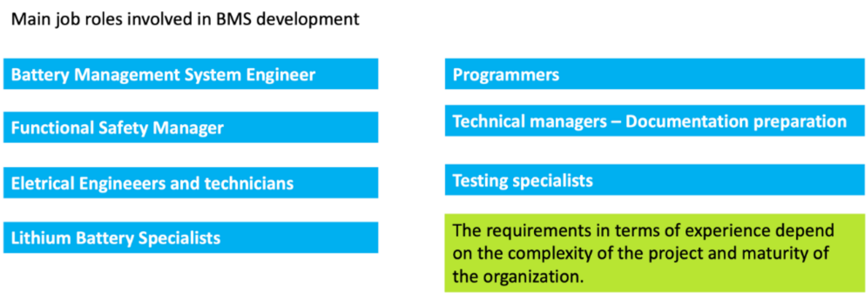

Figure 3. A list of job roles and skills. Source: Josef Tichanek's presentation[1]

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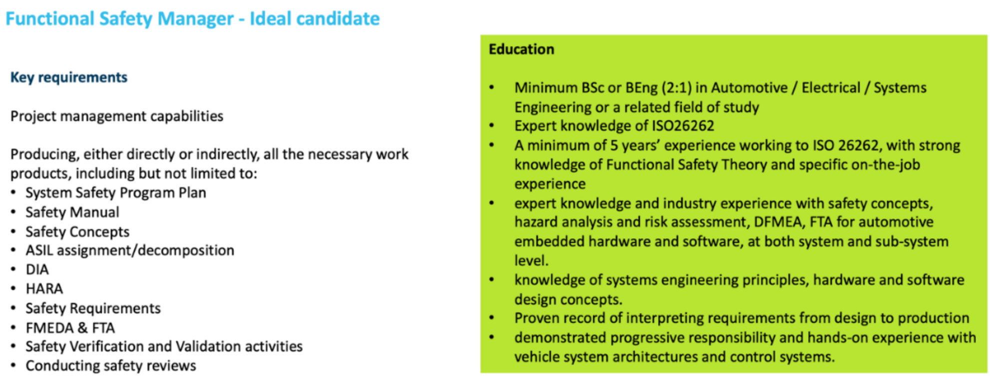

Figure 4. Description of a Functional Safety Manager. Source: Josef Tichanek's presentation[10]

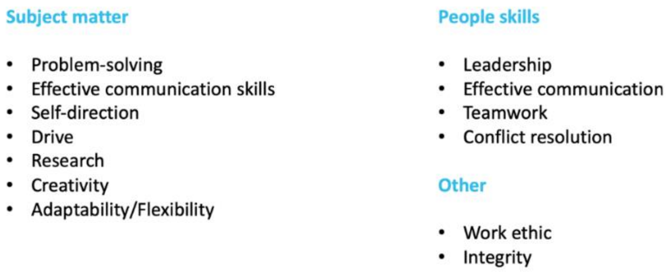

Figure 5. List of soft skills. Source: Josef Tichanek's presentation[10]

BMS functions and software elements are very complex. Such various elements are also a great challenge for specific job roles and skills required for each position within the BMS functionality (Figure 6).

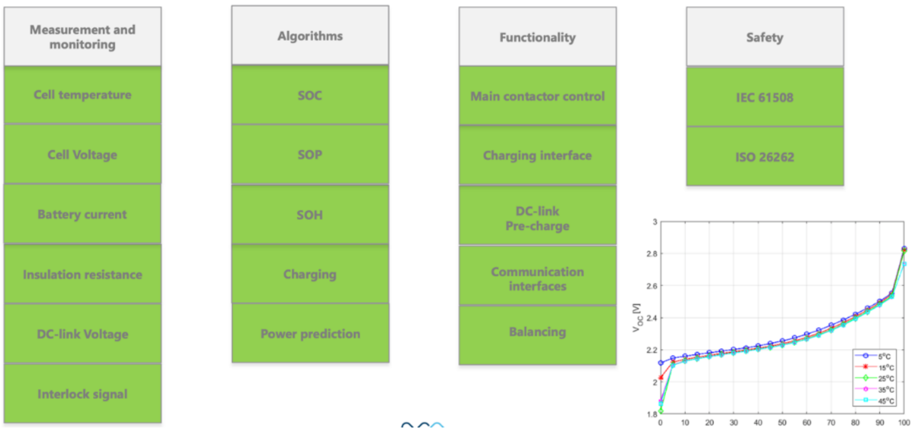

Figure 6. BMS functions and software elements. Source: Mika Kauppila's presentation[10]

The most relevant areas for BMS research, production, and development for Valmet Automotive are across hardware and software (Figure 7).

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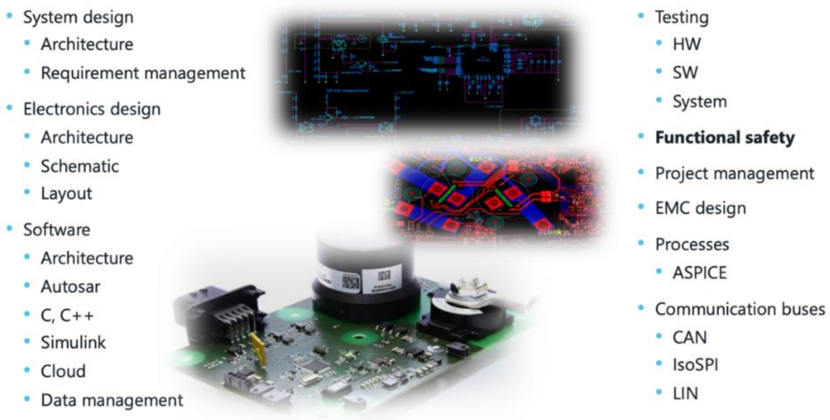

Figure 7. Relevant skill areas. Source: Mika Kauppila's presentation[11]

2.4 INTERVIEW: FUTURE GEOPOLITICAL CHALLENGES IN THE SOURCE OF RAW MATERIALS AND THE BATTERY VALUE-CHAIN[12]

2.4.1 Interview

The webinar titled "Future geopolitical challenges in the source of raw materials and the battery value-chain", part of Task 4.10's third round, held on January 19, 2023, featured Mr Daniel Cios, Policy Officer – Raw Materials at DG Grow, European Commission. Amidst Europe's current supply challenges, exacerbated by the Russia-Ukraine war impacting natural gas availability, essential commodities like electricity face price hikes. This conflict also affects crucial material supplies relevant to the battery industry. The interview aimed to delve into the conflict's implications on raw material supply for batteries and pinpoint critical job roles, skills, and competencies necessary to navigate these challenges.

2.4.2 Skills agenda and recommendations

Regarding the key job roles, skills, and competencies required within the raw material sector for battery production, the demand extends to R&D technicians and developers, as well as professionals adept in **industrial processes and proficient in operating manufacturing plants**. **Manufacturing expertise** is paramount**, encompassing machine operation and process optimisation.** Establishing comprehensive training programs by universities, corporations, and institutions is imperative; the inception of the Battery Academy stands as a testament, having already equipped approximately 800,000 individuals with essential skills. University curricula must encompass **geology, metallurgy, mining engineering, and material science**

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courses. Moreover, the focus should lie on attracting and engaging students, ensuring that this training path promises promising career prospects. A challenge persists as universities grapple with a shift, witnessing students migrating from materials-oriented courses towards IT. To counter this, disseminating compelling opportunities becomes crucial, encouraging more students into materials-focused education.

Developing specialised technological skills and training initiatives focusing on pivotal areas essential for **green and digital transitions** is recommended. These critical fields encompass ci**rcularity, raw and advanced materials, energy-intensive manufacturing industries, clean-tech, and digital technologies**. Additionally, international sourcing of raw materials, managing supply chains and related risks, and logistics are important skill and knowledge areas (Figure 8). It is also important to **understand and forecast political risks, the demand for materials and technology, sourcing from primary and secondary materials, finding substitutes and diversifying the source of the materials** are the strategies to mitigate future materials shortage.

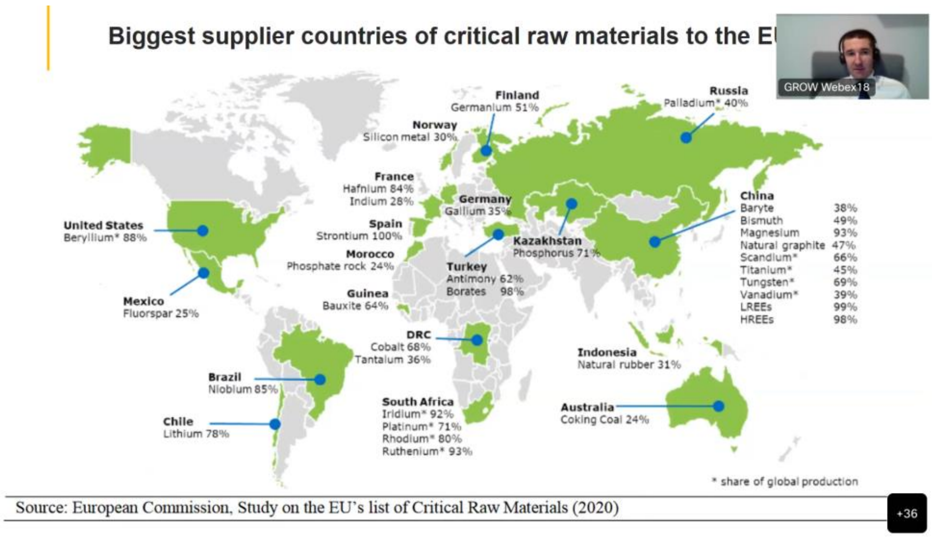

Figure 8. Global distribution of raw material supplies. Source: Daniel Cios's presentation[13]

2.5 WEBINAR: SKILLS TRANSITION[14]

2.5.1 Webinar

The webinar titled "Skills Transition in The Battery Industry: Training People from Other Industries" concluded the workshop round 3 conducted under Task 4.4, held on February 9th, 2023. This event aimed to comprehensively explore the processes involved in transitioning

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skills for employees across blue- and white-collar levels. The focus was to understand the possibilities and challenges encountered in skill transition through the experiences shared by our Swedish speakers, Mr. Tore Karlsson (discussing adult education at VUX and its collaboration with Northvolt in Skellefteå) and Mr. Fredrik Hannerz (highlighting the partnership between Volvo Cars Company and Gothenburg Technical College, particularly in the realm of electric vehicles).

2.5.2 skills agenda and recommendations

Key findings and recommendations

- High demand in the battery sector; 85% of roles require VET qualifications.
- Continuous skill evolution is needed for career adaptation.
- Retraining and upskilling are vital for transitioning declining sectors to emerging fields.
- Industry requires new courses and innovative training methods.
- Predicted by 2030: 2.4M jobs needing significant retraining, 1.6M for reskilling, 610K for minor shifts, and 225K require substantial retraining for new profiles.
- Northvolt's plant in Skellefteå impacted the region, necessitating understanding its effects across various sectors and companies.
- VUX provides re/upskilling to individuals with diverse backgrounds.
- Many individuals enrol in VUX education programs to change their careers.
- Encourage women to technical education: highlight the chance to join the transformation and help the environment rather than focus solely on technology.
- Recognizing the significance and challenges of change management is crucial.
- Addressing opposition during the change process is an essential aspect.
- Vehicle electrification displacing fossil fuel specialists.
- Understanding participant needs during up/reskilling is paramount.
- Curiosity stimulation aids comprehension in learning.
- Encouraging eagerness to learn by emphasising that while much is new, most remain the same in the case of, for example, the transition from Internal Combustion Vehicles (ICV) to Electric Vehicles (EV).
- With EVs, an understanding of chemistry and physics is required.
- E-mobility courses focus on questions related to occurrences and the reasons behind them, but the pivotal question remains, "What's in it for me?"

- Flexibility: curriculum adaptation based on student and company feedback is essential.
- Shortage of trainers and teachers poses a challenge.
- There will be jobs in the future that do not currently exist.

Skills and Competencies:

- Technical Proficiency: Understanding battery technology, electrification processes, chemistry, and physics related to EVs.
- Adaptability: Continuously adapting to evolving industry needs and technological advancements.
- Change Management: Skills to manage and facilitate transitions, address resistance and drive organisational change.
- Stimulating curiosity among learners, encouraging questioning and analytical thinking.
- Communication and Education: Teaching, training, and educational skills to engage learners effectively.
- Flexibility and Innovation: Developing new training methods and curricula to meet industry demands.
- Problem-solving: Addressing challenges related to curriculum design, trainer shortages, and participant needs.

Job Roles:

- Change Management Specialists: Guiding organisations through transitions and managing resistance.
- Educators/Trainers: Developing and delivering training programs for up/reskilling in e-mobility.
- Curriculum Designers: Crafting educational material tailored to the needs of the evolving industry.

Knowledge Areas:

- Battery Technology: battery components, their functioning, and advancements.
- Electrification Processes: vehicle electrification and related technical processes.
- Change Management Strategies: how to manage and lead transitions effectively.
- Educational Psychology: how adults learn and adapt training methods accordingly.
- Industry Impact Analysis: industry development effects on sectors and communities.

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Miscellaneous Insights:

- Future Jobs: Anticipating and preparing for jobs that may emerge due to technological advancements.
- Vocational Education and Training (VET): Vital for most roles in the battery sector.
- Transitional Programs: Such as the Automation Operator Programme at VUX catering to career shifts.
- Understanding Participant Needs: Crucial during transitions for effective up/reskilling.
- Industry-Centric Approach: Adapting curriculum and training programs based on industry feedback and demands.

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