Alliance for Batteries Technology, Training and Skills

2019-2023

Sectoral Skills Intelligence and Strategy

for the European Battery Sector

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Deliverable D3.13 Analysis of Sectoral Intelligence – Release III

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[Project ALBATTS (project-albatts.eu)](project-albatts.eu)

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Executive Summary

This deliverable represents the third version of the Sectoral Skills Strategy and Intelligence based on the gathered information throughout the four years of the project ALBATTS (schematically represented in **Figure 1**).

The document is composed of two main parts; the first is the **Sectoral Skills Strategy** which contains the general strategic steps/actions that need to be followed to boost the overall re-/up-skilling and skills development within the European battery sector. Six focal areas are identified, each of them containing a list of steps and focus points (timeframe, target groups, rationales, and ALBATTS actions as example actions are specified).

The second part of the report focuses on the **Sectoral Skills Intelligence:** in addition to the general strategic steps/actions, a set of practical recommendations and considerations is provided and mapped against the battery value chain and other areas of interest within the battery value chain where specific target groups are identified. Data-oriented results regarding skills needs and state-of-the-art provision are provided as well. Value chain steps and areas of interest are described in detail (scope, activities, processes), while providing qualitative and quantitative data on skills and job roles needed are provided.

Updates in the Third Release

The following was updated in the second release of the report:

- Information on the ALBATTS stakeholder network;
- Updated Sectoral Key Steps and Sectoral Skills Strategy;
- Data on needed job roles and skills needs were updated – highlighted concepts based on the workshops;
- Information on the defined Job Roles;
- Revision of the whole document.

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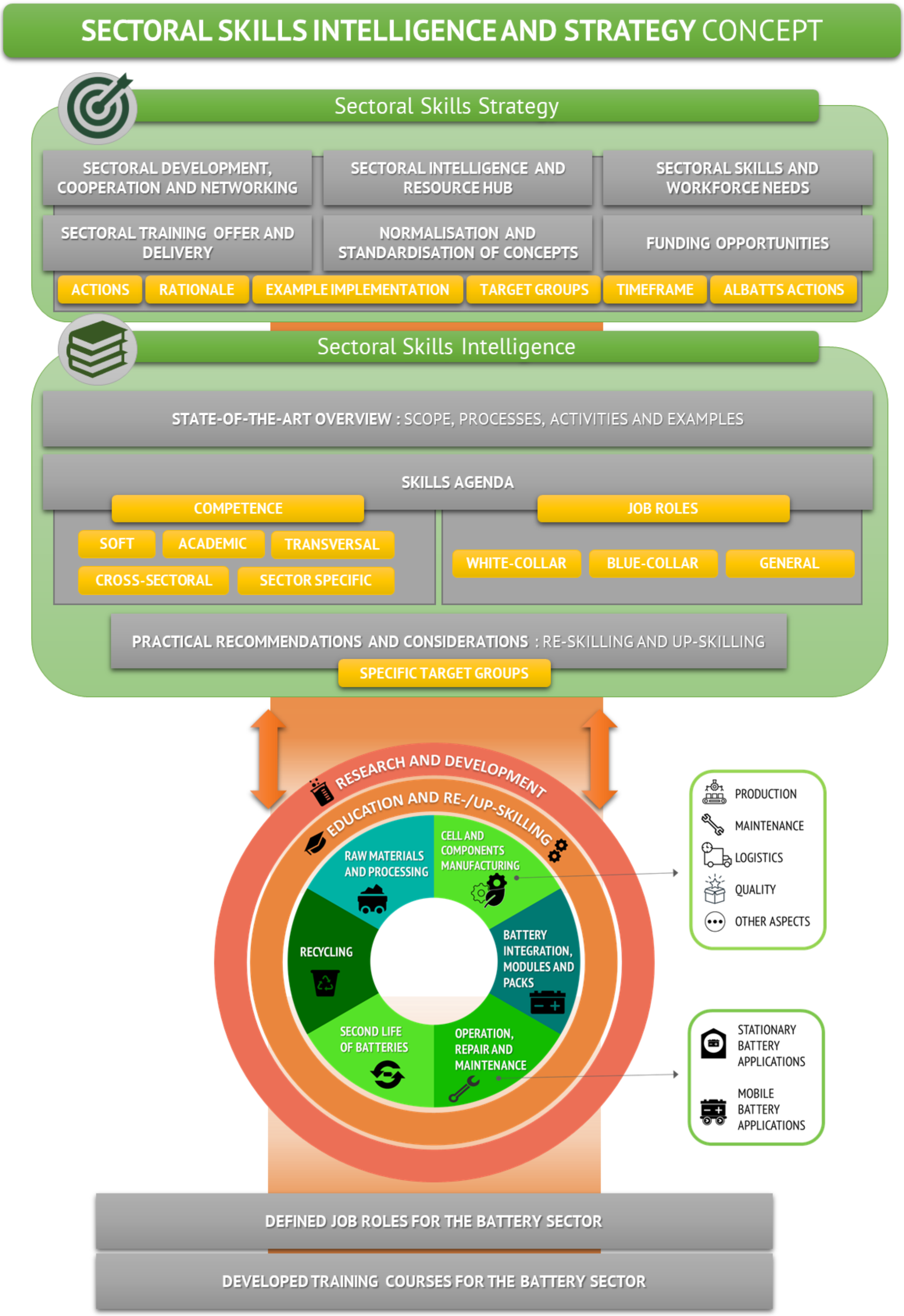

Figure 1: Overall Sectoral Skills Intelligence and Strategy Concept

Introduction

This document represents the **third and last** release of the **Sectoral Skills Strategy and Intelligence** and provides the strategic steps to be taken by the sectoral stakeholders to improve the re-/up-skilling within the emerging European battery sector.

Battery production is scaling up rapidly – the sector is moving from battery plants with a capacity of 4-10 GWh/y to up to 40 GWh/y or even 80 GWh/y. Producing more batteries in each plant results in much higher efficiency. The demand is mainly boosted by the needs of e-mobility. It is also generating increased demand from numerous other companies in the value chain, encouraging efforts to establish and convert production capacities, and creating a need for a supply of battery components and services such as maintenance, among other things. This transition of the whole ecosystem is influenced, not only, by several major trends, such as: Green Transition and sustainability, digitalisation, new business models, or resiliency of the value-chains and industry[1].

Stationary applications of batteries play an essential role in the ecosystem, not only when it comes to industrial and private energy storage use cases, the charging infrastructure, backup systems for IT, telecommunications, or others.

With this volume production of batteries and other mentioned trends need to be accompanied with development of skills and facilitation of a competent workforce along the value chain, which supports the sector's competitiveness, innovation, and overall development. This is where the sectoral skills strategy and the project ALBATTS consortium (partnership and sectoral stakeholders) with its analyses and recommendations come into play.

Project ALBATTS

Project ALBATTS (Alliance for Batteries Technology, Training and Skills), as a blueprint for sectoral cooperation on skills in the battery sector lasting for four years from 2019 to 2023

[1] Directorate-General for Internal Policies of the Union (European Parliament), Brown, Flickenschild, Mazzi, Gasparotti, Panagiotidou, Dingemanse, Bratzel. (2021, October 21). The future of the EU automotive sector. Retrieved November 20, 2022, from https://op.europa.eu/en/publication-detail/-/publication/56ff3240-32e4-11ec-bd8e-01aa75ed71a1/language-en

with 20 full partners from 10 European countries, aims to contribute to the electrification of transport, green energy, and environmental goals in Europe by gathering demand and supply sides of competences in the battery value chain.

The main goals of the ALBATTS project are:

- mobilize and coordinate critical players within the battery ecosystem;
- contribute to transport electrification and EU environmental goals in a significant way;
- gather demand and supply sides of competencies in the battery value chain;
- identify skills and job role needs throughout the whole battery production lifecycle from cell production to battery systems in stationary and mobile applications.

ALBATTS Stakeholder Network

Project ALBATTS, within the four years of implementation, attracted 443 registered sectoral stakeholders and a higher multiplying number of people interested to follow its activities and by that contributing to the overall awareness of skills development in the European battery sector. In addition, project stakeholders have registered to receive regular newsletters with news from the sector, up-to-date, state-of-the-art results of the project, and invitations to webinars to discuss current topics of the re-/up-skilling within the sector. Metrics and other information about the project stakeholders can be found in **ANNEX B: Stakeholder Metrics**, geographical metrics are visible in **Figure 2**.

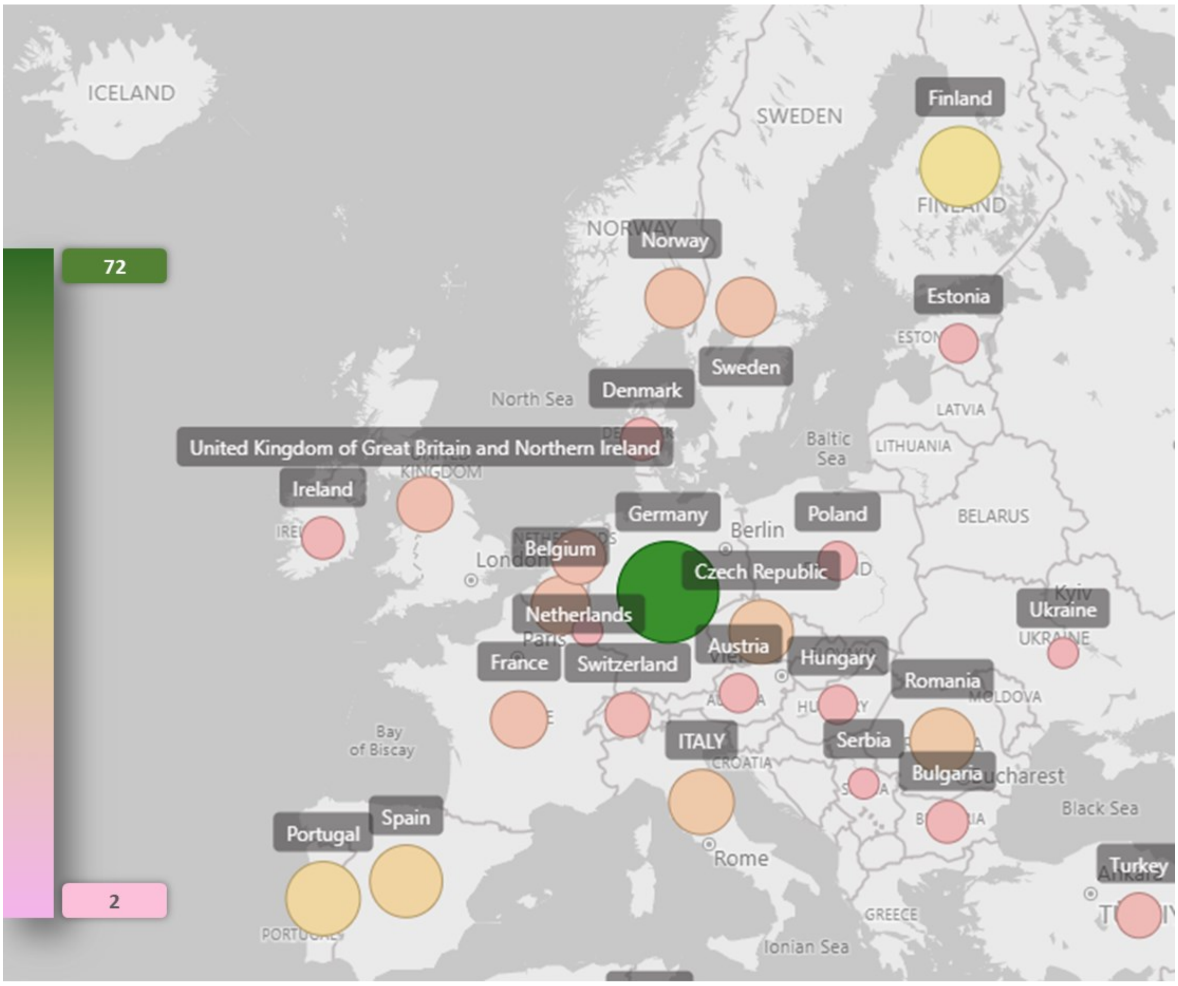

Figure 2: Project ALBATTS Stakeholders

List of Abbreviations

GWh/y	...	Gigawatt hour per year
5G	...	Telecommunications of 5th generation
5S	...	Workplace organization method
8D	...	Eight discipline problem solving
ACEA	...	European Automobile Manufacturers Association
AGV	...	Automatic Guided Vehicles
AI	...	Artificial Intelligence
ALBATTS	...	Alliance for Batteries Technology, Training and Skills
AR	...	Augmented Reality
ASA	...	Automotive Skills Alliance
ASPICE	...	Automotive Software Process Improvement and Capability
BESS	...	Battery Energy Storage System
BEV	...	Battery Electric Vehicle
BMS	...	Battery Management System
BTM	...	Behind-the-Meter Batteries
BTMS	...	Battery Thermal Management System
CAD	...	Computer-Aided Design
CECRA	...	European Council for Motor Trades and Repairs
CLEPA	...	European Association of Automotive Suppliers
CO2	...	Carbon Dioxide
CSR	...	Corporate Social Responsibility
DoC	...	Drivers of Change
DoD	...	Depth of Discharge
DRIVES	...	Development and Research on Innovative Vocational Education Skills
EACEA	...	European Education and Culture Executive Agency
EAFRD	...	European Agricultural Fund for Rural Development
EBA	...	European Battery Alliance
EC	...	European Commission
ECU	...	Electronic Control Unit
EFSI	...	European Innovation Partnership
EGF	...	European Globalisation Adjustment Fund for Displaced Workers
EIT Raw Materials	...	European Institute of Innovation and Technology – Raw Materials
EQF	...	European Qualifications Framework
ERASMUS+	...	European Community Action Scheme for the Mobility of University Students

ERDF	...	European Regional Development Fund
ERP	...	Enterprise Resource Planning
ESCO	...	European Skills/Competence, Qualifications, and Occupations
ESF+	...	European Social Fund+
ESF+ EaSI	...	European Social Fund+ and EU Programme for Employment and Social Innovation
ETIP	...	The European Technology and Innovation Platform
ETRMA	...	European Tyre and Rubber Manufacturers Association
EU	...	European Union
EV	...	Electric Vehicle
GHG	...	Greenhouse Gas
GWh	...	Gigawatt hour
HE	...	Higher Education
HMI	...	Human Machine Interface
HR	...	Human Resources
ICE	...	Internal Combustion Engine
ICT	...	Information Communication Technology
IoT	...	Internet of Things
IPCEI	...	Important Projects of Common European Interest
IT	...	Information Technology
JIT	...	Just in Time
JTF	...	Just Transition Fund
KPI	...	Key Performance Indicator
LIB	...	Lithium-Ion Battery
LPG	...	Liquified Petroleum Gas
MOOC	...	Massive Online Open Course
NFRD	...	The Non-Financial Reporting Directive
PDSA	...	PDSA
PFMEA	...	Process Failure Mode Effects Analysis
PfS	...	Plan-Do-Study-Act
PhD	...	Doctor of Philosophy
QMS	...	Quality Management System
R&D	...	Research and Development
RO-RO	...	Roll-on/Roll-off
RRF	...	Recovery and Resilience Facility
SME	...	Small and Medium-sized Enterprises
SoC	...	State of Charge

SoH	...	State of Health
SPOC	...	Small Private Online Course
STEM	...	Science, Technology, Engineering, and Mathematics
SURE	...	Support to mitigate Unemployment Risks in an Emergency
SW	...	Software
TQM	...	Total Quality Management
V2G	...	Vehicle to Grid
VET	...	Vocational Education and Training
VR	...	Virtual Reality
VRE	...	Variable Renewable Energy
VSB-TUO	...	Technical University of Ostrava
WEEE	...	Waste Electrical and Electronic Equipment
WFD	...	EU Water Framework Directive
WP4	...	Work Package 4
WP5	...	Work Package 5
XR	...	Extended Reality

Methodology

This document provides a **Sectoral Skills Strategy** and an overall summary of the **Sectoral Intelligence** gathered. It is based on three streams of information, where different tools are used: (1) desk research; (2) online survey and qualitative personal interviews; and (3) workshops. These three streams cover topics of sectoral intelligence that were defined as follows: (1) stakeholders; (2) technologies; (3) drivers of change; (4) skills, competencies, and job roles; (5) sector attractiveness; (6) education and training; (7) training delivery and methods. For each phase of the value chain within the battery sector, all tools were used to gather valuable information regarding the defined topics.

Detailed Document Composition and Structure

The document is composed of two main parts:

- Sectoral Skills Strategy
- Sectoral Skills Intelligence

Sectoral Skills Strategy focuses on the provision of strategic actions to boost the skills development of the European battery sector. As a result, the following have been identified (**Figure 3**):

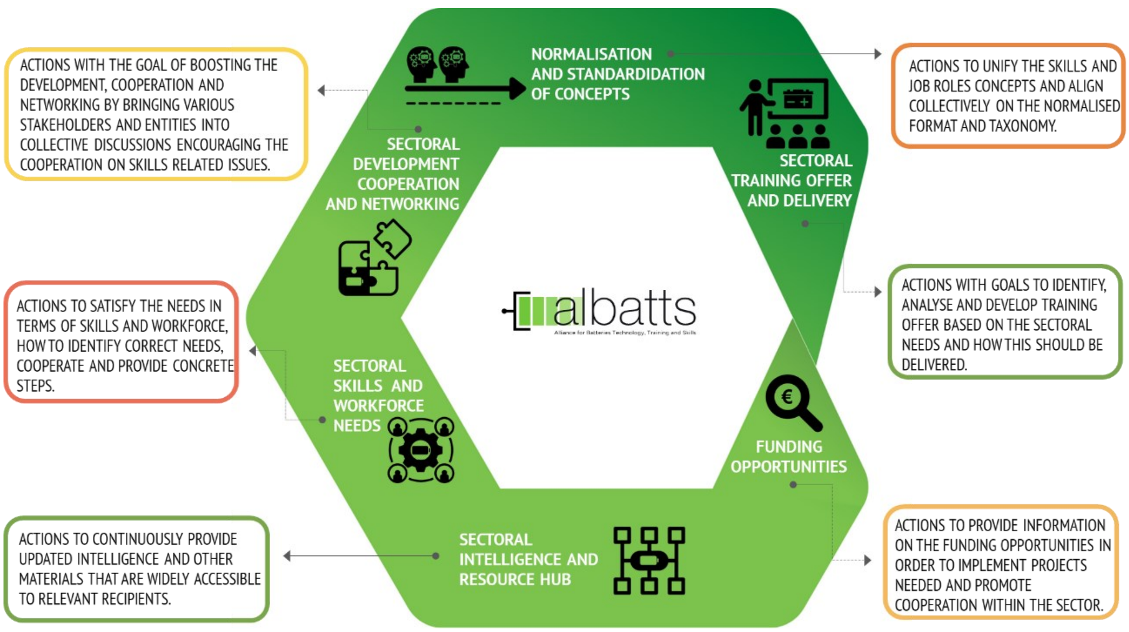

Figure 3: Visualisation of Main Areas of General Strategic Steps

Each action, in addition, contains information on:

Table 1: Definition of Target Groups

TARGET	**Target Groups** **target groups that should be active within this action**
WHOLE ECOSYSTEM	**Description:** Actions and recommendations are relevant for the whole European battery ecosystem and all active stakeholders. **Scope:** All target groups below.
INDUSTRY	**Description:** Actions and recommendations are relevant for industrial stakeholders. **Scope:** Enterprises (micro, SMEs, Large), Sectoral Associations, Technology Centres, and similar.
TRAINING PROVIDERS	**Description:** Actions and recommendations are relevant for training providers. **Scope:** Entities active in training provision/definition and other related areas, including academia, industry, or other subjects.
ACADEMIA	**Description:** Actions and recommendations are relevant for academia. **Scope:** Entities active in the definition of curricula, teaching, or training. This includes especially universities, high schools, and other entities mainly active in providing formal education or research.
POLICY MAKERS	**Description:** Actions and recommendations are relevant for policymakers. **Scope:** National, regional, or local authorities/policymakers.
EUROPEAN COMMISSION	**Description:** Actions and recommendations are relevant for European Commission that should be involved. **Scope:** European Commission and related entities.

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Table 2: Definition of Timeframe

TIMEFRAME	**Timeframe** **indication on time dimension and how urgently the stakeholders should act**
CONTINUOUS	**Description:** Actions should be considered in the long term, and the attention given should be continuous, e.g., continuous analysis, implementation, etc.
URGENT	**Description:** Actions should be considered urgently in the short term, and the attention given should have a high priority.

Table 3: Definition of ALBATTS Actions

albatts ACTIONS	**ALBATTS Action** **statement of the ALBATTS project consortium and how the project is involved within this step** **Provided as an example action**
ENDORSING	**Description:** raising awareness of certain actions or topics, overall involvement in the issue on multiple levels, and contribution to the overall improvement of the situation of considered areas of interest.
WITHIN SCOPE AND PLANNED	**Description:** actions and activities within certain topics or issues are within the project plan scope and planned for future years of the project.
PARTICIPATING/ IMPLEMENTING	**Description: the** project is practically involved in the improvement or implementation of changes of certain topics and works towards the improvement, this could be e.g., development of training material, provision of state-of-the-art materials, organization of events, or similar.
ANALYSING	**Description:** The project is involved in the improvement or implementation of certain topics or issues on a more theoretical basis, where possible solutions, methodological approaches, or strategies are being analyzed. This can be reflected in the project outputs.
NOT IN SCOPE	**Description:** certain topics or issues are not being analyzed or implemented by the project, but this fact is being acknowledged and the consortium is fully aware of it. This status may change in the future years of the project.

Sectoral Skills Intelligence provides insights into the state-of-the-art and skills/job roles needs of the specific areas of interest/trends identified and described above. Every area of interest/trend is described from the perspective of the **scope**, **skills agenda**, and practical **recommendations and considerations** as defined below:

- **Scope Description:** definition of area borders; description of activities and processes within the area, and overall description.
- **Skills Agenda:** data analysis of skills needs and demanded job roles/profiles based on the job advertisements and other information collected:
    - Quantitative analysis provides charts and data visualization of the job advertisements collected (522). Demanded job roles are visualized by word cloud based on the occurrence in relation to the skills/knowledge; and skills needs with the bar or pie charts in three categories of competence: (1) academic; (2) cross-sectoral specific; (3) sector-specific (**ANNEX A: Skills Concepts**). In addition, concepts endorsed by the stakeholders during the interviews/workshops are highlighted within the charts (yellow for 1 endorsement, dark orange for 2 endorsements).
    - Qualitative additional supportive information that cannot be quantified, such as expertise or additional information from workshops or other sources.
- Practical **recommendations and considerations**: a set of recommendations or considerations for specific areas of interest, value chain steps, or trends covering actions in terms of strengthening various competence; re-skilling/up-skilling on specific topics; and others. Recommendations and considerations are supported by mapping of concrete target groups and are defined as seen below:
    - **Target Groups:** examples of specific target groups that are influenced within these areas of interest.

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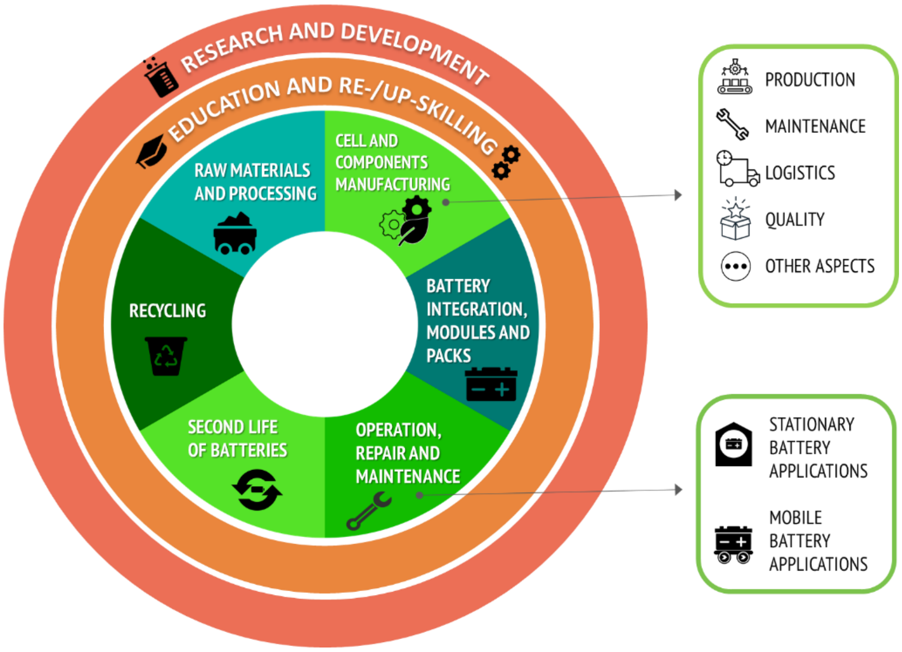

Figure 4: Visualisation of the Main Areas of Interest

This generic structure applies to all identified areas of interest. The only exceptions are the following:

- **Soft and Transversal Basic Competence** is analysed for the whole value chain
- **Trends, Factors, and Drivers of Change**
    - Does not contain skills agenda and recommendations and considerations
- **Training, Education, Re-/Up-skilling**
    - Does not contain skills agenda

Skills Agenda Data Acquisition and Processing

The overall definition of the area of interest/trend/value chain steps is contained within the skills agenda section - describing and visualizing the needs in terms of skills and job roles, which can be viewed from two perspectives (both perspectives represent limited views in the scope of collected data):

(1) **Quantitative analysis:** charts are based on the competence matrix (for data collection) which is being continuously updated in the project ALBATTS and contains the data gathered from job advertisements and offers.

Job advertisements were analyzed and mapped to the corresponding value chain steps or departments within the battery production facility. This enables to query job roles relevant to specific areas of interest and see which skills are needed. This is also done "from the other side" where relevant skills are identified and mapped to the specific area of interest, set of job roles that are composed of each of the skill mappings analyzed, and by this approach, it is possible to develop the occurrence metrics for the job role and see which is more occurring for the mapped skills set. Endorsement or identification of the concept during the workshop, survey, or interview is accounted in the quantitative analysis by highlighting the concept in the charts or results.

(2) **<u>Qualitative analysis:</u>** contains experts' opinions or information that cannot be quantified and merged with the data used for the quantitative analysis. This contains mostly workshop results, relevant reports or documents, or survey/interview results.

More information on the methodology can be found within the **ANNEX A: Skills Concepts**, where concrete definitions and structures are defined and described in more detail.

Project ALBATTS

The third release of a

A) Sectoral Skills Strategy

Proposals on how to approach the Re-/Up-skilling

to ensure the development of the European Battery Sector

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1 Sectoral Key Steps and Sectoral Skills Strategy

Sectoral key steps of the second version of the **Sectoral Skills Strategy** serve as a roadmap for the skills agenda within the European battery sector, each of the steps outlines the needed actions for various target groups and processes to boost the competence development, cooperation and re-skilling and up-skilling of the workforce in the future or in a specific timeframe. Rationales and example implementation in a form of project ALBATTS action is provided as well. The graphic visualisation of the key steps is visible in **Figure 5**:

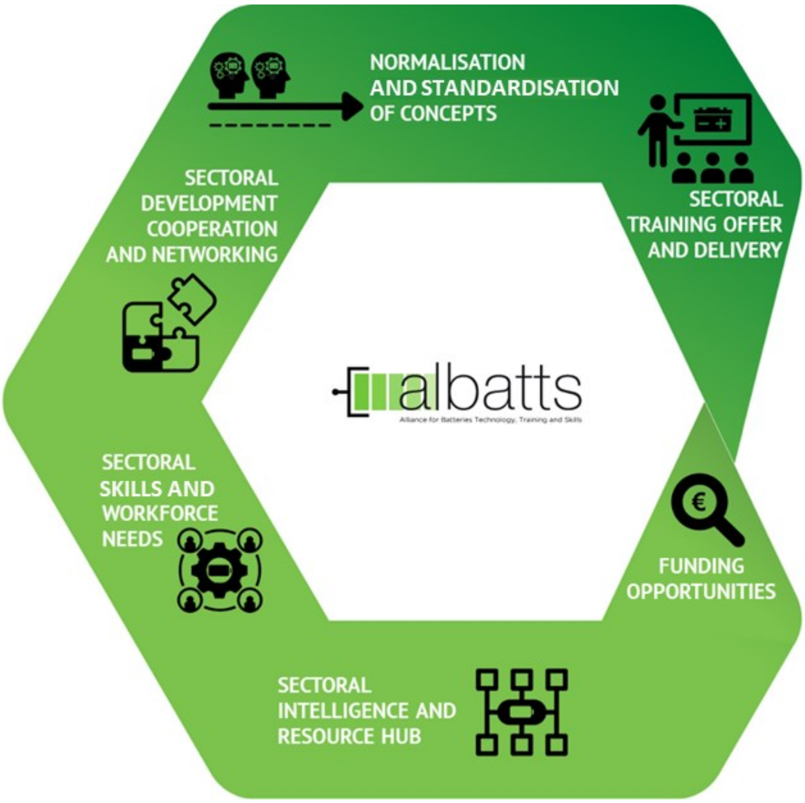

Figure 5: Visualisation of Main Areas of General Strategic Steps

1.1 SECTORAL DEVELOPMENT, COOPERATION, AND NETWORKING

Definitions of target groups, timeframe, and ALBATTS actions are provided in the methodology section.

1.1.1 Battery Application Stakeholder Cooperation

The cooperation between stationary and mobile battery application stakeholders and key players needs to be strengthened.

Rationale: to improve and speed up the work on the common topics not only within the skills and employment.

ALBATTS is **endorsing** this action by facilitating webinars and other events, where different stakeholders can network and cooperate further on different issues related to the battery applications and others, this is also connected to the direct involvement in the Automotive Skills Alliance (ASA), where battery topics are being discussed with broader partnership, mainly with the focus on skills agenda in the automotive-mobility sector and beyond. Through ASA, the partnership has outreach and collaboration with InnoEnergy Skills Institute or BEPA.

1.1.2 Overall Cooperation

The overall cooperation and specific cooperation models between various EU initiatives, projects, universities, VET provides, industry, companies, regions, municipalities, social partners, and other subjects need to be strengthened and implemented via PfS large scale partnership, such as Automotive Skills Alliance.

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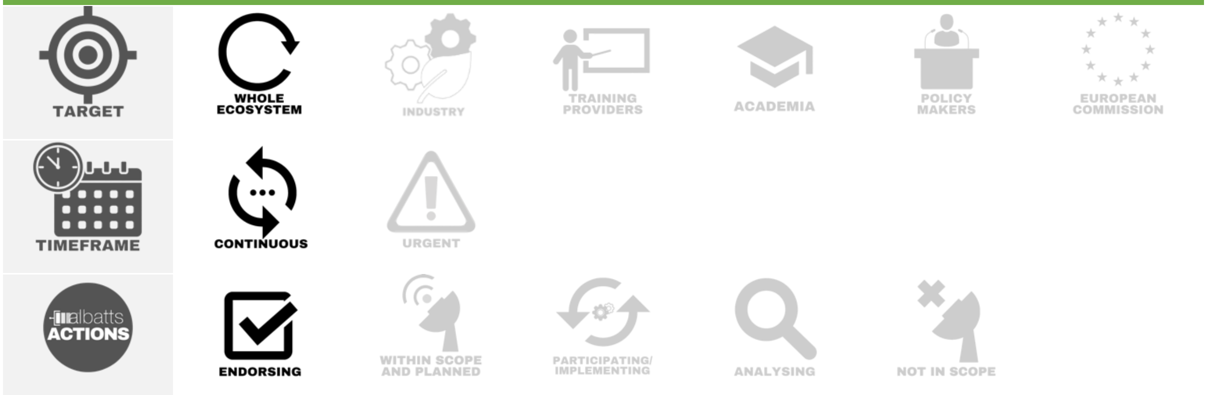
Rationale: to improve the linkage between the groups to boost the work on common topics not only within the skills agenda.



ALBATTS is **endorsing** this action by facilitating webinars and other events, where different stakeholders can network and cooperate further on different issues, this is also connected to the direct involvement in the Automotive Skills Alliance (ASA), where battery topics are being discussed with broader partnership, mainly with the focus on skills agenda in the automotive-mobility sector and beyond.

1.1.3 Academia/Industry Cooperation

Cooperation between secondary, tertiary schools and industry needs to be strengthened.

Rationale: to foster better approach to update of the training material and curricula in order to have skilled newcomers into the industry as well as better cooperation within the life-long-learning programmes development which may be applied within the private sector (up-skilling or re-skilling on the job).

ALBATTS is **endorsing** this action by facilitating webinars and other events, where academic and industrial stakeholders can network and cooperate further on different issues, this is also connected to the direct involvement in the Automotive Skills Alliance (ASA), where battery topics are being discussed with broader partnership, mainly with the focus on skills agenda in the automotive-mobility sector and beyond.

1.1.4 Sector Attractiveness

There is a need to boost and foster the sector attractiveness.

Rationale: in order to attract newcomers (young scientists, job changers, blue and white collars) into the industry to close the skills gaps as well as experienced workforce.

ALBATTS is **endorsing** this action by facilitating webinars and other events related to the European battery ecosystem and overall raising the awareness of the importance of skills development in the sector. It also concerns the participation on various events related to the battery sector or other where this need is presented by the project consortium.

1.1.5 Importance of Skills Transition from the Related Sectors

Information and data on how skills and competences can be transferred from similar sectors (ICE vehicle production or process industry, etc.) to the emerging battery sector need to be available and accessible for the whole sector. This information needs to contain projections and scenarios of the current trends impact on the employment.

Rationale: so the employers, regions or other stakeholders may benefit from the knowledge when onboarding new workforce. This would also help the sector to be prepared for the future implications of future trends.

Project ALBATTS is **implementing** an overall roadmap and strategy for the skills development in the European battery sector (Sectoral Skills Intelligence and Strategy), this also include overview of the impact of various trends on the employment as well as future scenarios. ALBATTS Partnership released a report and held webinar on skills transition where these topics were **analysed**.

1.1.6 Projects and initiatives

There is a need to boost, integrate, endorse and implement results and findings of the projects/initiatives supporting the development of the European battery ecosystem and other issues related to the staff and competence shortage or skills agenda development, such as (1) European Battery Alliance; (2) The European Skills Agenda and Pact for Skills; (3) Automotive Skill Alliance (ASA), including relevant Blueprint Projects; (4) European Battery Innovation – IPCEI; (5) BEPA; and other.

Rationale: so the sectoral stakeholders may benefit from the shared knowledge and future development is more efficient. This also concerns the elimination of the same work double funding.

Project ALBATTS is **participating** and cooperating on the skills development issues within different European Initiatives, such as ASA. The ASA has a strategic partnership collaboration with the European Battery Alliance Academy since November 2022. Some partners submitted successfully a proposal on training of VET teachers in the battery sector – CaBaTT – this is an example of sustainable approach.

1.1.7 Information Sharing

Sharing of information is crucial for the development of the competence needs as well as the overall European battery ecosystem.

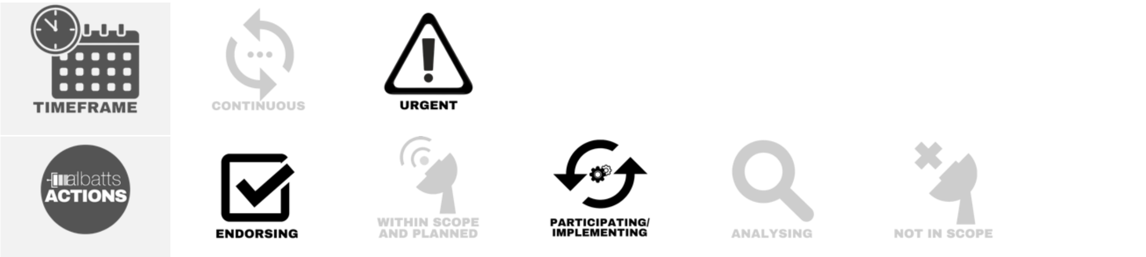
Rationale: so the sectoral stakeholders may benefit from the shared knowledge and future development is more efficient. This also concerns the elimination of the same work double funding.

Project ALBATTS is **endorsing** the information sharing and itself **implementing** this action by organizing events, delivering outputs, and participating in the broader discussions on an overall level.

1.1.8 Mobilization of experts

Experts across the whole European battery value chain and ecosystem need to be attracted and mobilized including foreign experts bringing much-needed know-how and experience.

Rationale: to improve the overall expertise within the European battery sector and to boost the research and development.

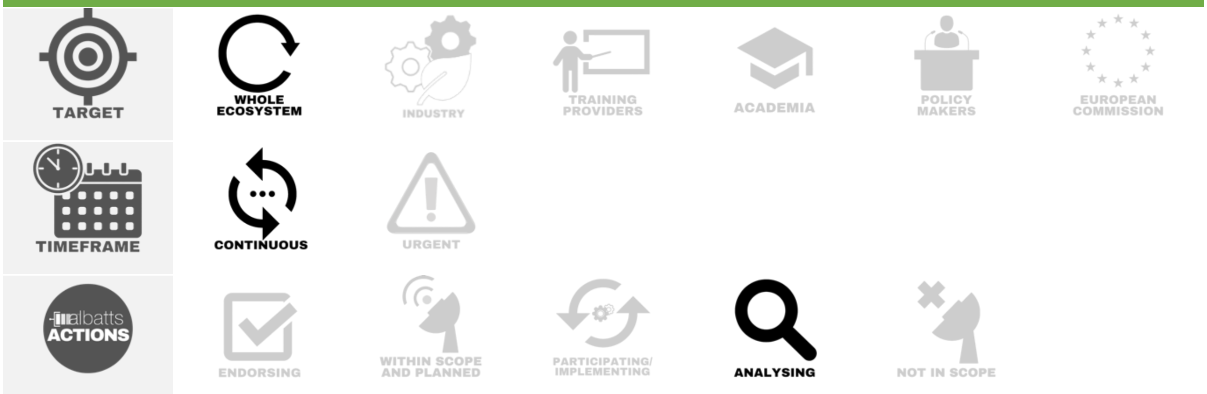


Project ALBATTS is **endorsing** this action by raising awareness of these issues within various outputs and events that are being organized – such as teachers forum organised previously by ALBATTS and currently by the partnership of CaBaTT – also supported by the Automotive Skills Alliance with the study visits events, not only for teachers.

1.1.9 Future Scenarios

Future scenarios in terms of re-skilling and up-skilling, as well as sector development, need to be developed.

Rationale: so the employers may benefit from the knowledge when onboarding new workforce. This would also help the sector to be prepared for the future implications of future trends.



Project ALBATTS is **analyzing** the future needs and influence of the trends on the employment within the European battery sector.

1.2 SECTORAL INTELLIGENCE AND RESOURCE HUB

Definitions of target groups, timeframe, and ALBATTS actions are provided in the methodology section.

1.2.1 State-of-the-Art Information Sharing

Reliable state-of-the-art information needs to be provided to sectoral stakeholders and interested entities. Resources or knowledge hubs that are public, reusable, and easily accessible are needed.

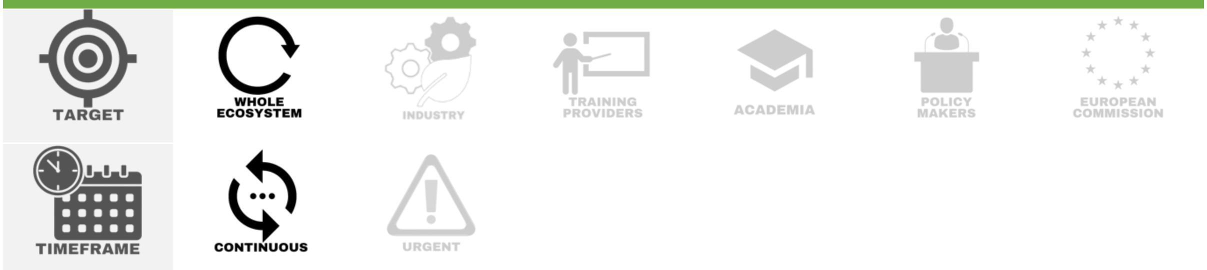
Rationale: to improve the overall expertise within the European battery sector. It is beneficial for the sectoral stakeholder to have and access to the up-to-date state of the art.

Project ALBATTS is **implementing** this action by providing valuable state-of-the-art information via the project deliverables, organization of events, and others. This is also being **endorsed** on the overall level.

1.2.2 Continuous Update

Sectoral intelligence needs to be continuously updated.

Rationale: to enable development of the training and learning material which is coherent with the current trends.



Via the project structure and the approach to the project deliverable, project ALBATTS is **implementing** continuous updates of the state-of-the-art by providing updated desk research and other deliverables covering relevant topics, this is being **endorsed** on the overall level.

1.2.3 Open Discussion

A platform for collective discussion on the problematic and important topics of sectoral intelligence needs to be established with different stakeholders and experts involved.

Rationale: to discuss current problematic issues so it is possible to come up with more efficient solutions.

Project ALBATTS is **implementing** the open discussion via the events that are being organized as well as by participating within the PfS and Automotive Skills Alliance by this, the open discussion is being **endorsed**.

1.2.4 Recommendations and Considerations

There is a need for provision and sharing of practical recommendations or considerations to the sectoral stakeholders and players to expand their knowledge and fuel the discussion.

Rationale: so the good practices may be followed, which leads to improved sectoral development on skills.

Project ALBATTS is **implementing** and providing recommendations and consideration for the European battery sector. Project is also **endorsing** this on the higher level within the Automotive Skills Alliance, for example.

1.3 SECTORAL SKILLS AND WORKFORCE NEEDS

Definitions of target groups, timeframe, and ALBATTS actions are provided in the methodology section.

1.3.1 Skills and Workforce Shortage

Shortage of skilled workforce and consequent competence need to be addressed on all levels: (1) geographical - national, regional, and local level; (2) relevant proficiency – EQF3-8; (3) value-chain – from raw materials mining and processing to recycling. All types of competencies need to be addressed: (1) soft; (2) transversal; (3) cross-sectoral specific; (4) sector-specific or job-specific; (5) green and digital;

Rationale: so the right training and learning material which fits the needs may be developed.

Skills needs are being **analyzed** by the project ALBATTS against all mentioned metrics, project is also **endorsing** and stressing the importance of this action.

1.3.2 Continuous Update

Sectoral skills and workforce need to be continuously tracked, updated, and data publicly available.

Rationale: so the training offer is coherent with the current trends.

Project ALBATTS is **analyzing** the skills needs and **endorsing** the continuous update by providing up-to-date state-of-the-art information. This is also supported by the long-term plan of sustaining and updating of the training offer within the Automotive Skills Alliance after the project end.

1.3.3 Future Technologies, Innovation, and R&D

The skills needed for new and innovative technologies and processes need to be identified, which concern research and development as well. The availability of R&D infrastructure is also of high importance.

Rationale: so the right training offer may be developed.

Project ALBATTS is **analyzing**, stressing, and **endorsing** the importance of new technologies, innovation, and research and development by focusing on these topics within the project outputs.

1.3.4 New Battery Applications Competences

New competencies concerning forthcoming battery applications need to be continuously identified and considered – mobile, stationary, and other.

Rationale: so the right training offer may be developed.

Project ALBATTS is **analyzing**, stressing, and **endorsing** the importance of new battery applications and connected technologies and skills by focusing on these topics within the project outputs.

1.3.5 Strategy and Roadmap

Strategy and roadmap towards the re-skilling and up-skilling within the European battery system need to be developed and continuously updated. Synergies between strategies within the battery and other sectors should be proactively looked for.

Rationale: to advice the sectoral stakeholders on the high-level approach and actions towards the re-/up-skilling within the European battery sector.

Project ALBATTS is **endorsing** the development of the strategy and roadmap for the European battery sector and overall skills agenda by **implementing** the strategy and roadmap with the future releases.

1.4 SECTORAL TRAINING OFFER AND DELIVERY

Definitions of target groups, timeframe, and ALBATTS actions are provided in the methodology section.

1.4.1 Continuous Update

Sectoral training offer needs to be designed, developed, and continuously updated based on the sectoral needs of industry.

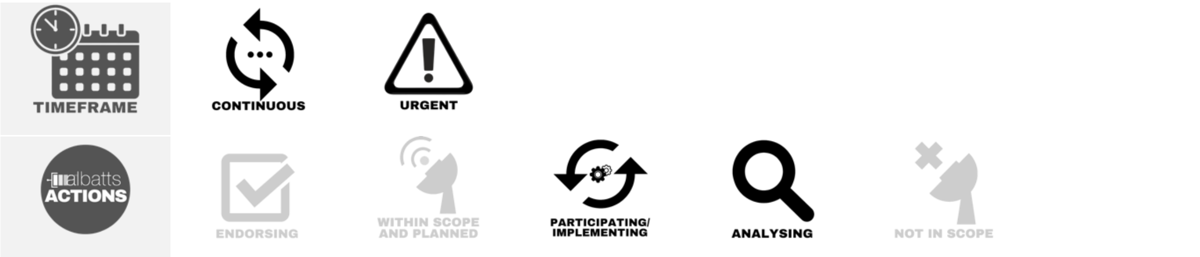
Rationale: so the trainees are prepared for their working life and their knowledge is according to the current trends.

Project ALBATTS is **implementing** (Courses (project-albatts.eu)) training modules, which will be continuously updated based on sectoral needs.

1.4.2 Modular Training

There is a need to develop up-to-date modular training, individual modules, and units based on the sectoral needs of industry and on micro-learning.

Rationale: so it is possible to compose bigger training units based on specific needs of various target groups.



Project ALBATTS is **implementing** training modules based on modular concepts and **analyzing** the best possible solutions for their delivery.

1.4.3 Curricula

Curricula need to be updated - Higher Education, VET, apprenticeships, internships, lifelong learning, and others.

Rationale: to satisfy the demand and needs of industry and to facilitate the current trends.

Project ALBATTS is **analyzing** and **implementing** needed changes in curricula to facilitate the European battery ecosystem needs.

1.4.4 Education Requirements

Specific education and quality requirements and need to be adopted and developed. Such as assessable competence units based on ECTS and ECVET principles with learning outcomes approach; EQAVET quality criteria (system level); and peer learning.

Rationale: to satisfy the employment needs of companies within the battery sector.

With the support of the Erasmus+ Programme of the European Union

Project ALBATTS is **endorsing** and **analyzing** possible education requirements for the battery ecosystem.

1.4.5 Interdisciplinary Education

Interdisciplinary education programmes for VET and HE should be rolled out focusing on STEM, digital and green skills – adaptation of the curricula and national/regional frameworks are needed. Transversal skills and key competences need to be validated.

Rationale: so the students are prepared for the work within the battery industry which requires a wide range of competence.

Project ALBATTS is **endorsing** and **analyzing** the interdisciplinary education within the European battery sector.

1.4.6 Standardization

There is a need for a standardized approach to apprenticeship programmes, internships, and overall education programmes.

Rationale: so it is transferable and mappable. This enables the recognition of workers knowledge or competences across different programmes.

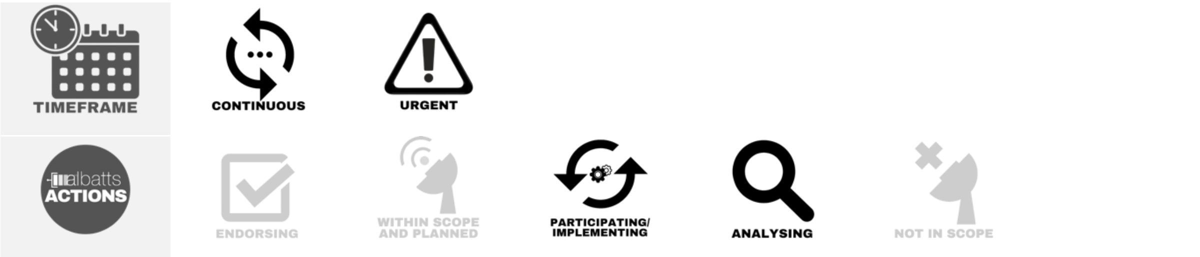
Project ALBATTS is **endorsing and analyzing** the standardization of education and training within the European battery sector.

1.4.7 Training Methods / Re-Up-Skilling Instruments

Innovative, inclusive, and effective training methods need to be explored, implemented, and adapted to initial education and up-/re-skilling programs as well as various re-/up-skilling instruments and tools: (1) work-based learning[2]; (2) on-boarding training in factories; (3) innovative and up-to-date programs based on educational resources; (4) training by internal and external experts; (5) digital and specific seminars for industry; (6) standardized online courses (MOOCs and SPOCs); (7) training of trainers; (8) access to learning infrastructure for SME's and other target groups; (9) centers of excellence and innovation; (10) specialized training centers with simulated training environment - AR/VR training, e.g. VR Labs; (11) adult education and learning programmes; (12) education testbeds; (13) flexible and blended learning solutions; and (14) double degree education programmes; (15) adaptive learning; (16) joint educational programs, including transnational learning. In addition, proper training methods need to be selected for different target groups, e.g., blue- or white-collar workers, or mass re-skilling or up-skilling for the battery production, or other parts of the ecosystem.

Rationale: so that the most efficient and suitable tools and instruments may be chosen by companies or individuals.

[2] What is work-based learning (WBL)? What is Work-Based Learning (WBL)? (n.d.). Retrieved November 28, 2021, from https://www.axcelerate.com.au/post/what-is-work-based-learning-wbl.



Project ALBATTS is **analyzing** possible means of training delivery and **implementing** selected methods based on the different instruments, such as MOOCs, adaptive learning, onsite training, and others.

1.4.8 Levels of Education

All relevant levels of education need to be focused on blue- and white-collar workers - EQF 3-8

Rationale: since the battery sector needs workers across all levels of education.

Project ALBATTS is **endorsing** the importance of all levels of education and **analyzing** the different requirements and needs for specific levels of education. Project ALBATTS is developing training for VET as well as HE level.

1.4.9 Certifications and Micro-Credentials

Training certification and the micro-credential system should be introduced for the successful trainees – lightweight, coherent, easy to implement, and understand system needs to be put in place, micro credentials should be awarded per training unit. There is a need for one micro-credential specification and standard, such as connection to the Europass micro-credentials and certificate supplements.

Rationale: so the learners may prove their competences in more convenient way, and everyone follows one scheme which is coherent across the industry. It also enables easier validation of the informal and non-formal learning at the job.

Project ALBATTS is **endorsing** the importance of certification and micro-credentials for training recognition and **using** the Automotive Skills Alliance digital badges.

1.4.10 Learning Accounts

Introducing a learning account can boost the recognition and management of the learning achievements.

Rationale: to track the progress of individuals which may be proven by micro-credentials for example.

Project ALBATTS is **endorsing** the importance of learning accounts and will **use** the learning accounts within the Automotive Skills Alliance Skills Hub system which enables to store micro credentials and other progress of individuals.

1.4.11 Languages

It is necessary to facilitate training in various languages. Multi-lingual training is essential, especially for VET and lower levels of education. It is vital to identify different language needs for different training and job positions.

Rationale: to increase accessibility within the multicultural working environments.

Project ALBATTS is **endorsing** the importance of multi-lingual training, mainly for the lower levels of education, and **developing** the training for technical English for battery production.

1.4.12 Learning Pathways

It is crucial to enable and provide clear and dynamic learning pathways within the training courses across different levels of proficiency (adaptive learning), that are highly connected to the modularity concepts of the training offer.

Rationale: so the training offer may be targeted based on the needs of trainees.

Project ALBATTS is **endorsing** the importance of the provision of learning pathways and **implementing** an adaptive learning training content.

1.4.13 Training Providers

It is vital that various training providers across Europe are activated.

Rationale: to boost the cooperation and efficiency of the developed training solutions that will cover the most urgent future needs.

Project ALBATTS is **endorsing** the importance of connecting training providers and their cooperation by facilitating different events and being part of PfS implementation – Automotive Skills Alliance for example.

1.4.14 Competent Trainers and Tutors

It is vital that various training providers across Europe are activated under the continuous train the trainers programme for sectoral skills update together with companies' tutor development programmes, mobility and international forums.

Rationale: to boost the cooperation and efficiency of the developed training solutions that will cover the most urgent future needs.

Project ALBATTS is **endorsing** the importance of connecting training providers and their cooperation by facilitating different events and being part of PfS implementation – Automotive Skills Alliance for example. ALBATTS is also **implemented** a training the trainers battery forum – BATTForum, where VET teachers across all Europe exchange good practices and learn about the battery sector – currently this is run by the CaBaTT consortium which came from the ALBATTS partnerships.

1.5 NORMALISATION AND STANDARDIZATION OF CONCEPTS

Definitions of target groups, timeframe, and ALBATTS actions are provided in the methodology section.

1.5.1 Categorization and Classification

There is a need for classification, granularity, and categorization of job roles, skills, and competence (concepts) framework used on the EU-wide level.

Rationale: so that there is a common approach, and it is possible to see coherences between the job profiles and skills/competences or knowledge.

Project ALBATTS is stressing and **endorsing** the importance of categorization and classification of competence concepts and to use the common taxonomy. The frameworks are **analyzed** and used, such as ESCO and ASA Skills Hub.

1.5.2 Coherence

Continuous update and consistency of the concepts with the sectoral needs and intelligence is assured.

Rationale: so that the defined concepts reflect the current sectoral needs.

Project ALBATTS is assuring the coherency of the concepts within the battery sector by **implementing** frameworks such as ESCO and ASA Skills Hub.

1.5.3 Available Tools and Instruments

It is essential to take advantage of the existing instruments and databases (ESCO, ASA Skills Hub, or other national information hubs and databases related to competencies or job profiles concepts) of concepts that are aligned with widely used skills frameworks.

Rationale: to have an up-to-date knowledge and not to use up the existing resources.

Project ALBATTS is **implementing** frameworks such as ESCO and ASA Skills Hub and by that **endorsing** their use.

1.5.4 Framework Interlinks

It is essential to assure the coherence of the various concepts by developing a mapping approach between the frameworks (ESCO, EQF, ASA Skills Hub, other); this also concerns the exploration of the possibilities of certification or credential systems linkage.

Rationale: so that there is a possibility to interlink the various concepts with the coherent granularity.

Project ALBATTS is **implementing** frameworks such as ESCO and ASA Skills Hub and by that **endorsing** their use and linkage to other initiatives or those who implement it as well.

1.5.5 Reference Provision

It is crucial to develop a set of standardized and broadly accepted reference job profiles based on the needs of the battery ecosystem that are aligned and coherent with the widely used classification frameworks (such as ESCO, ASA Skills Hub, European Core Profiles, and other). This set needs to be publicly available and put into use by updating relevant knowledge hubs and databases. This is not only for the job profiles, but for the skills and competences as well, there should be a set of reference competence, which are relevant for the battery sector – transversal competence (key competences, soft competence, STEM competence, digital competence), cross-sectoral technical, academic, sector specific and other.

Rationale: so that the sectoral stakeholders may use the profiles as a guidance on what is needed in the sector, to use them as a curricula or for a company onboarding, for example.

Project ALBATTS is **implementing** and **endorsing** the reference provision of the concepts by providing up-to-date state-of-the-art and coherency with ESCO or ASA Skills Hub, project ALBATTS is also providing example battery sector relevant occupational profiles as a reference in a form of Skills Cards ([Skills Cards (project-albatts.eu)](project-albatts.eu)).

1.6 FUNDING OPPORTUNITIES

A detailed overview of the funding opportunities can be found in the **ANNEX D: Funding Opportunities Summary**.

Definitions of target groups, timeframe, and ALBATTS actions are provided in the methodology section.

1.6.1 Accessible Through Financial Intermediaries

Funding opportunities accessible through financial intermediaries, such as (1) InvestEU; and (2) EFSI 2 Skills and Education Guarantee Pilot;

1.6.2 Accessible Through National Authorities

Funding opportunities accessible through national authorities, such as (1) Recovery and Resilience Facility (RRF); (2) REACT-EU (Recovery Assistance for Cohesion and the Territories of Europe); (3) European Social Fund Plus (ESF+ under shared management); (4) ERDF (European Regional Development Fund); (5) Just Transition Fund (JTF); (6) Digital Europe Programme; (7) Erasmus+ (new MFF); and (8) European Agricultural Fund for Rural Development (EAFRD).

1.6.3 Accessible Through European Commission

Funding opportunities are accessible through European Commission, such as (1) ESF+ EaSI Strand; (2) European Globalisation Adjustment Fund (EGF); and (3) European Instrument for Temporary Support to Mitigate Unemployment Risks in an Emergency (SURE).

1.6.4 Discussion Platform

Provision of a platform for a discussion with stakeholders, and support of the project matching.

Rationale: to access and attract the needed funding and skilled workforce to manage the transition of the ecosystem.

With the support of the Erasmus+ Programme of the European Union

Project ALBATTS

B) Sectoral Skills Intelligence

Practical Recommendation/Considerations

and

Overall State-of-the-Art and Skills Needs

for the Development of the European Battery Sector

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2 Trends, Factors, and Drivers of Change

Based on inputs from an ALBATTS project partner expert[3] meeting, a specific set of trends concerning new technologies was identified:

- **Battery capacity/energy density:** i.e., electric vehicles with longer range are likely to push climate goals forward;
- **Improved charging performance:** better and faster-charging tools help boost the use of Battery Electric Vehicles (BEV);
- **Country independence:** both in terms of battery production and materials (e.g., fabrication of own cells);
- **Battery as a structure:** this refers to being able to use any structure (foundation of a house, chassis of a car, structure of an airplane) as a battery to reduce space, and maintain the right weight or the centre of gravity;
- **Heat conversion into electrical energy:** investing in processes to reconvert heat waste (Heat waste is thermal energy that can be used for example to heat water and the consequent steam causes rotation in a turbine that then turns the thermal energy into kinetic energy that is then converted to electricity with a generator) into electrical energy for the circularity of the process;
- **Safety:** especially regarding charging/recharging/ and discharging of batteries;
- **Energy accessible everywhere:** energy storage systems are key for the transition to sustainable energy sources, helping to maintain (and grow) current energy infrastructure stable and continuous everywhere.

Moreover, according to the Fraunhofer report[4], the decarbonization of the sector and investment into modest large-scale production (with the importance of automation and control of production processes, reduction of scrap and energy consumption), a circular economy with a focus on the sustainability of batteries is needed. As the demand for batteries rises (demand is expected to be dominated by electromobility), it is essential to satisfy

[3]One-to-one meeting with Professor Helena Braga, Engineering Physics Department, University of Porto (PT), 25/05/2021
[4] Thielmann, A., Neef, C., Hettesheimer, T., Ahlbrecht, K., Ebert, S. (2021). (rep.). Future Experts Needs in the Battery Sector. EIT RawMaterials; Fraunhofer. Retrieved from https://eitrawmaterials.eu/wp-content/uploads/2021/03/EIT-RawMaterials-Fraunhofer-Report-Battery-Expert-Needs-March-2021.pdf

customer needs. It is not practical to transport batteries from Asia, and therefore battery production hotspots need to be developed in the EU and other nearby areas in the world. Furthermore, this is a question of European control over its car manufacturing sector and consequently its battery production. There is a clear European interest in controlling the quality of the batteries, the work conditions in the whole supply chain, and the type of energy used for battery production. With the demand comes the upscaling of production, which leads to a lower number of jobs per GWh. Solid-state batteries, alternative chemistries, and the mobility of the people should be taken into consideration. There are considerable investments in the EV revolution when it comes to the drivers of change in the automotive industry (e. g. Daimler, Volkswagen, or Ford). Energy-intensive manufacturing and charging of EVs will require renewable sources of energy to reduce their environmental impact. In addition, many cities and countries have announced the phasing out of conventional vehicles (equipped with ICEs), hence the reason the market share of EVs is increasing. Due to this increase, customer requirements will have to be satisfied: (1) fast charging solutions and charging infrastructure availability; (2) alternative battery exchanging and swapping; (3) more extended range of EVs.

2.1 DRIVERS OF CHANGE

The methodological approach adopted by ALBATTS project partners to have an overview of the available literature regarding Drivers of Change (DoC) and how they influence the battery sector (i.e., those factors which are key to transforming an industry).

For the most part, the analysis is those representing the whole battery value chain and compiled by respected consultancy organizations or projects. Complementing the literature review, recent project results[5] were integrated as well as a one-to-one interview to eventually validate such results and, for this desk-research process, the identified DoC were analysed

5Survey Results for Battery Sector. (2021). https://www.project-albatts.eu/Media/Publications/19/Publications_19_20210601_185540.pdf based on **Occurrence**[6], **Importance**[7], and **Urgency**[8]. In detail, the project grouped the intelligence into 3 main Groups and 9 specific Drivers of Change:

- **Climate goals, regulation, and environmental challenges**

  Batteries are one of the most important climate targets drivers to decarbonize road transportation and support the transition to a renewable power system.

  a. Reducing CO_2 emissions from battery manufacturing: since the production of batteries requires significant amounts of energy, an increase in the share of renewable energies and energy efficiency in the battery value chain would be a substantial step for decreasing CO_2 emissions from battery production.

  b. Electrification and green energy: batteries can fundamentally reduce GHG emissions in the transport and power sectors as they are a systemic enabler of a substantial shift to bring transportation and power to greenhouse gas neutrality playing an increasingly important role.

  c. Widespread charging/refueling infrastructure: commercialization of a technology based on batteries. The easier the access to a reliable and suitable charging infrastructure is, the quicker the development of such new technologies will occur.

- **Globalization**

  globalization is the process of interaction and integration among people, companies, and governments worldwide. Because the modern world is increasingly globalized, political/strategic choices cannot be made without taking into account the reactions of other world nations. Over the next years, production in global markets for EV batteries is expected to grow strongly and the EU production must completely change its position to create a competitive advantage.

  a. Access to raw materials: with a rapid increase in numbers of EVs, activities linked to raw materials become critical, especially if some resources (limited in

6 Indicating whether a Driver of Change was cited in analysed reports reviewed

7 An evaluation by the ALBATTS project partners, based on the context in which the specific Driver of Change is discussed, focused on its possible status in the future and on its direct implications on changes in the sector

8 A specific time frame (year), which can be noticed from the text of the analysed document, in which the Driver of Change will become particularly necessary or will make its consequence felt overwhelmingly

terms of quantity or geographical presence and almost absent in Europe) are necessary to produce key components.

b. Global regulatory dialogue: the European Commission will need to play a fundamental role in the elaboration of policies and strategies, from which the battery sector could benefit from a modernization process of the EU legislation on batteries. Batteries placed on the EU market should become sustainable, high-performing, and safe throughout their life cycle.
c. Restructuring: the European battery sector is expected to undergo structural changes due to the development of a zero-emission mobility paradigm/framework and as a flexible facilitator of the intermittent renewable energy sources. The industry, in particular SMEs, will need to assess and, if necessary, redefine their position in the value chain as well as increase their capacity to integrate digital technologies and circular economy concepts in their production processes.

- **New technologies**

  The need for urgent and intense actions against climate change is widely recognized, and batteries are an essential item/element for storing energy in electric vehicles and making renewable energy a reliable alternative source.

d. Cybersecurity: the exponential growth of IoT into BMS connected to a network, cloud infrastructures, and the navigation and location information necessary to optimize the smart grid infrastructure can compromise customer privacy and security, requiring providers to keep communications secure. This threat landscape requires the industry to modify the security approach, to guarantee the internal one linked to the resilience of the infrastructures to cyber-attacks.
e. Global technical harmonization and standardization: the supply chain structure within the sector will need to meet the challenges brought about by the introduction of new technology and meet changing market conditions.
f. Smart Grid: storage is one of the most important smart grid components due to its key role in complementing renewable energy generation. With the proper amount and type of storage broadly deployed and optimally controlled,

renewable generation can be transformed from an energy source into a dispatchable generation source.

The desk-research intelligence was confirmed by a survey that validated the information collected from two different perspectives, the application sub-sector answers only for stationary/other industrial applications, responses only for mobile application of batteries, or responses by stakeholders that are active in both sub-sectors.

The second perspective of the analysis is the industrial stakeholders' point of view in comparison to education providers` point of view, where the industrial stakeholders cover the answers from companies, sectoral and industrial associations, and technology centres, whereas answers from education providers cover educational institutions such as universities, VET providers/Umbrella organizations, colleges, or private education providers.

Based on the ALBATTS research, results are characterized as follows:

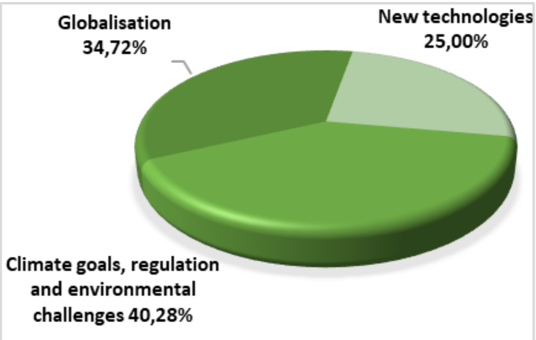


Figure 6: DoC occurrence - 2020 desk research

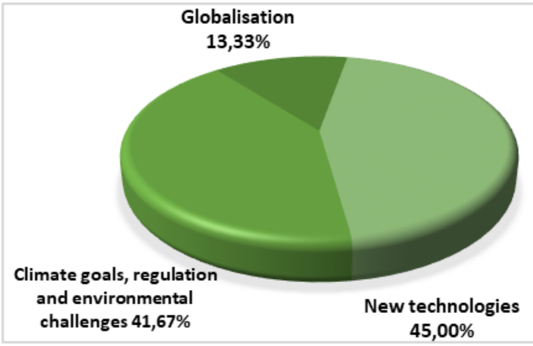
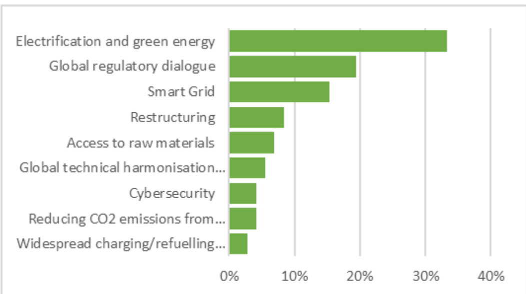


Figure 7: DoC occurrence - 2021 desk research

Comparing the **occurrence** of the DoC in both desk research reports (**Figure 6** and **Figure 7**), "Climate goals, regulation, and environmental challenges" have almost the same weight, but "new technologies" have a higher expression, and "Globalisation" decreased its weight.



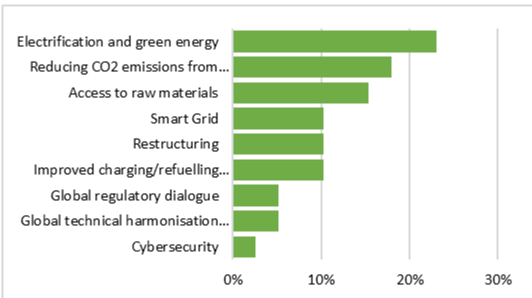


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Figure 8: Occurrence of DoC sub-categories - 2020 desk research

Figure 9: Occurrence of DoC sub-categories - 2021 desk research

Comparing research analysis for each DoC sub-category, **Figure 8** and **Figure 9** show "Electrification and green energy" remaining equally frequent while "Reducing CO_2 emissions from battery manufacturing" jumped to second place and "Access to raw materials" is the 3rd.

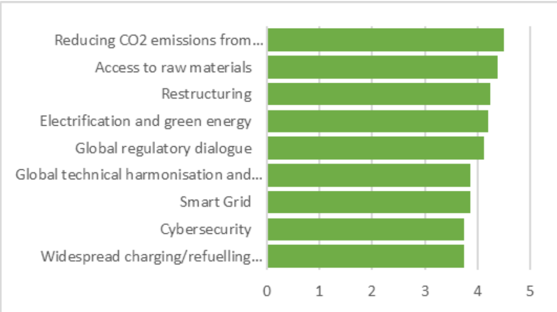

Figure 10: Importance of DoC sub-categories - 2020 desk research

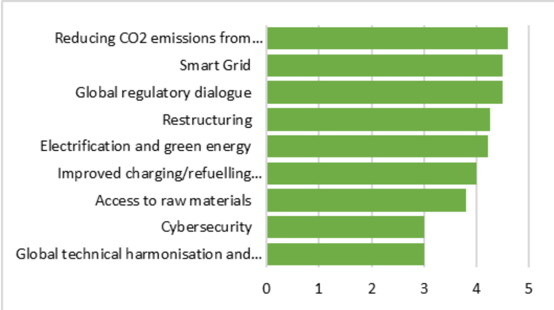

Figure 11: Importance of DoC sub-categories - 2021 desk research

When analysing the **importance** of each sub-category in both research reports (**Figure 10** and **Figure 11**), it is evidenced that "reducing CO_2 emissions from battery manufacturing" remains the most important while "smart grid" and "global regulatory dialogue" have been upgraded.

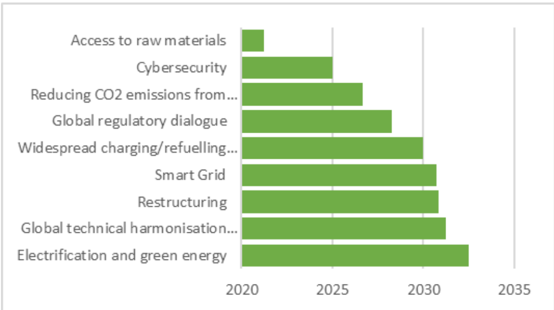

Figure 12: Importance of DoC sub-categories - 2020 desk research

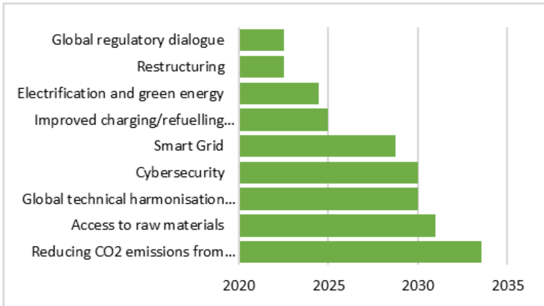

Figure 13: Importance of DoC sub-categories - 2021 desk research

Lastly, **Figure 12** and **Figure 13** analyse and compare the **urgency** of each DoC sub-categories. "Global regulatory dialogue" turned out to be the most urgent to tackle, together with "restructuring". "Reducing CO_2 emissions from battery manufacturing", despite being the most important and frequently quoted in the literature, is a challenge to be faced in the long term (after 2030).

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

Raw materials are essential for the manufacturing process of technologies, which are vital for the green/digital transition. As three of the primary critical raw materials (lithium, cobalt,

nickel) are fundamental for battery production, the diversification of the supply chain and the internal recycling, processing and production of these resources are essential to comply with future requests for this industry, which are expected to grow in the following years.
The Eurometaux Site estimates the future battery needs in the European Union in the context of the green and digital transition. By 2050, the demand for the production of European batteries is expected to reach up to 3500% of Europe's lithium consumption today, 330% of cobalt, and more than 100% of nickel[9].

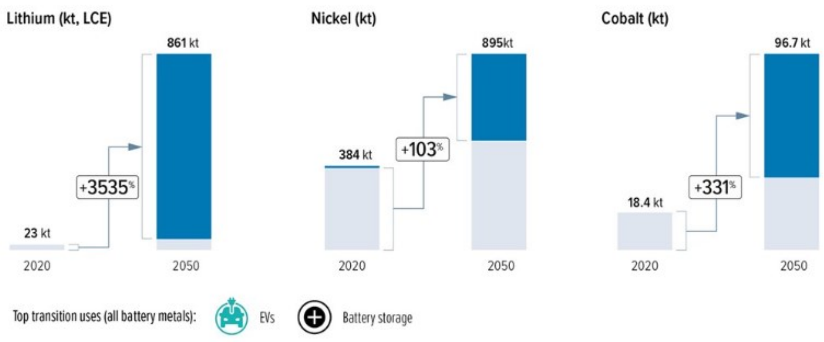

Figure 14: Europe's metal needs until 2050. Battery metals (blue: energy transition uses, grey: other uses)

According to the RECHARGE European industry association, recycling will be a crucial solution to comply with future batteries requests, covering 40-70% of the metals needed for batteries from 2040 onwards[10].

The **Critical Raw Materials Act**[11] underlines the growing need to address the European dependency on imported critical raw materials by diversifying the supply chain and securing domestic production. In the regulation's document, many aspects are considered: the economic one, as public and private financial investments are essential to secure a strong value chain[12]; the necessity to monitor the exploration of raw materials in the European

[9] Eurometaux Site, *Metals for Clean Energy. Pathways to solving Europe's raw materials challenge,* in https://eurometaux.eu/metals-clean-energy/, 19 of June 2023.
[10] RECHARGE Position Paper, *on the Critical Raw Materials Act,* November 2022.
Available at: https://rechargebatteries.org/wp-content/uploads/2022/11/RECHARGE-paper_Critical-Raw-Materials-Act_public-consultation_November-2022.pdf
[11] European Commission Site, *Critical Raw Materials Act,* in https://single-market-economy.ec.europa.eu, accessed June 15th, 2023.
[12] Ivi, pp. 8-9.

Union's territory[13]; and the need to evaluate the environmental footprint during the production of these sources to ensure that critical raw materials placed in the European Union are as sustainable as possible[14].

The Critical Raw Materials Act plays a vital role in the growth and sustainability of the battery industry. Companies identified by European Member States that manufacture "strategic technologies" (including batteries for energy storage and e-mobility)[15] must perform every two years[16]:

- An accurate mapping that shows where the strategic raw materials used during their production process are extracted, processed or recycled;
- A stress test of their supply chain of strategic raw materials, which consists of assessing its vulnerability/security: the test consists of creating scenarios that could impact the disruptions and their potential effects.

Finally, the Act further specifies that the Commission would encourage the recycling process of these sources by introducing financial incentives (such as discounts, monetary rewards and deposit-refund systems). Member States will also play a focal role in encouraging the recovery of raw materials from extractive waste[17].

The European Commission proposed the Net Zero Industry Act in March 2023[18]. As the manufacturing industry is going to be more and more affected by the green and digital future requirements, the main goal of this Act is to achieve a situation of resilience for what concerns the availability of net-zero technologies, which are at the centre of the geostrategic interests[19]. The objective is to ensure that by 2030, the European manufacturing capacity reaches at least 40% of the Union's annual deployment needs[20]. In recent years, energy-

[13] Ivi, p. 9.
[14] Ivi, p. 14.
[15] regulation of the European Parliament and of the Council of the 16 of March 2023, establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020, art. 23, p. 37.
[16] Ibidem.
[17] Ivi, art. 25, p. 39.
[18] European Commission Site, *The Net-Zero Industry Act: Accelerating the transition to climate neutrality,* in https://single-market-economy.eu, accessed June 22nd, 2023.
[19] regulation of the European Parliament and of the Council of the 16 of March 2023, *on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net-Zero Industry Act),* 2023/0081, p. 2.
[20] Ivi, p. 12.; *and* FES Germany Site, *The Key provisions in the EU's Net Zero Industry Act,* in www.justclimate.de.fes, 30 March 2023.

intensive industries have been suffering from the impacts of the energy crisis: such industries will need access to net-zero technologies such as batteries, heat pumps, solar panels, and fuel cells to remain competitive in the future [21].

The Net Zero Industry Act identifies different objectives that have to be addressed to successfully scale up the manufacturing of green technologies, such as:

- Necessity to make available all the information regarding the Net Zero Industry project;
- Guaranteed access to markets for these technologies;
- Skills-enhancement;
- Innovation in the field;
- Creation of a Platform that ensures the exchange of best practices, information and issues.

The Net Zero Industry Act is considered a big step forward for all the industries involved, including the battery industry[22]. Batteries play a crucial role in the European Union's strategic autonomy, and they are a fundamental part of this declaration. Given their role, they should benefit from even faster permitting procedures, and support from additional crowd-in investments[23]. This regulation strongly encourages battery manufacturers to "consolidate their technology leadership"[24]. For battery technologies, European manufacturers are encouraged to produce 90% of European battery demand (which translates to reaching a European manufacturing capacity of 550 GWh by 2030)[25].

Another fundamental point is assessing the future skills needed in the industries affected by the Net Zero Industry Act Regulation. Member States will, therefore, need to identify the skills needed, develop education and training programs, and financially support the industries, explicitly focusing on SMEs[26].

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[21] Ibidem.
[22] Ivi, p. 19.
[23] Ivi, p. 20.
[24] Ivi, p. 22.
[25] Ibidem.
[26] regulation of the European Parliament and of the Council of the 16 of March 2023, *on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net-Zero Industry Act),* 2023/0081, p. 33.

Many stakeholders in the battery industry consider both the Net Zero Industry and the Critical Raw Materials Acts as "real game changers" for improving the competitiveness of the European battery value chain[27].

2.1.2 Minerals and Processing

Minerals are fundamental for battery production: lithium, cobalt, nickel, manganese and graphite are, in fact, crucial for battery performance, longevity and energy density[28]. The shift to cleaner energy systems will increase the request for these minerals: the green and digital transition will make the battery sector one of the fastest-growing segments, thus impacting the request for these resources[29].

The Critical Raw Materials Act mentions in various points the importance that mineral mapping, geochemical campaigns and geoscientific datasets will have in the future[30] . It establishes that Member States should make available the information while exploring these sources on their territory[31]. The recovery of critical raw materials from extractive waste will also have positive implications, such as revaluing mining sites, which will gain a new economic value and a new industrialisation process[32].

First of all, the regulation sets important objectives for what concerns the consumption of mined strategic minerals:

- 10% of these should be sourced domestically;
- The global supply chain should be diversified, as no more than 65% of the European annual consumption of minerals should come from a single third country[33].

[27] Colthorpe A., *Net Zero Industry Act makes Europe competitive in battery value chain, trade groups said,* in www.energy-storage.news, 21 March 2023.
[28] IEA Site, *In the transition to clean energy, critical minerals bring new challenges to energy security,* in www.iea.org, accessed 26th June 2023.
[29] Ibidem.
[30] regulation of the European Parliament and of the Council of the 16 of March 2023, establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020, p. 9.
[31] Ibidem.
[32] Ibidem.
[33] EIU Site, *EU acts to secure access to critical raw materials,* in https://www.eiu.com/n/eu-acts-to-secure-access-to-critical-raw-materials/ , 17 March 2023.

The European regulation towards better-achieving minerals, including their processing, recycling and extraction, is considered very ambitious for different reasons. First, the EU will face several challenges in achieving its objectives because of how long the investigation of existing mines brings. Second, European countries have different levels of mines in their territories: it is estimated that Portugal, Sweden and Finland are the most likely locations for new mines, but all three are likely to face their own legislative barriers[34].

2.1.3 Circularity

Circularity refers to the sharing, leasing, reusing, repairing, refurbishing, and recycling of existing materials and products as long as possible to extend the latter's life[35]. The main advantage of achieving a circular economy is to optimise the resources, reduce the consumption of raw materials, and recover waste, thus reaching a consumption model that ensures sustainable growth over time[36]. In this framework, ensuring a longer life cycle for batteries is fundamental[37].

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 crucial and revolutionary step to ensure the circularity of batteries[38]. The life cycle of batteries is supposed to be more sustainable in the future thanks to this first agreement, which covers the entire battery life cycle, from design to end-of-life.

The proposal will apply to all types of batteries sold in the European Union's territory (portable batteries, SLI batteries, light means of transport, and batteries providing power for wheeled vehicles, such as electric scooters and bikes[39]). One of the main goals is a mandatory requirement for a minimum percentage of recycled content[40].

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[34] EIU Site, *EU acts to secure access to critical raw materials,* in https://www.eiu.com/n/eu-acts-to-secure-access-to-critical-raw-materials/ , 17 March 2023

[35] European Parliament, *Circular economy: definition, importance and benefits,* in www.europarl.europa.eu, 24 May 2023.

[36] Repsol Site, *What is circular economy and why is it important,* in www.repsol.com, accessed July 27th, 2023.

[37] European Council, Council of the European Union Site, *Infographic – Towards a sustainable, circular, European battery supply chain,* in www.consilium.europa.eu, accessed 11th of July, 2023.

[38] Ibidem.

[39] European Parliament, *Batteries: deal on new EU rules for design, production and waste treatment,* in www.europarl.europa.eu, 9 December 2022.

[40] European Council, Council of the European Union Site, *Council and Parliament strike provisional deal to create a sustainable life cycle for batteries,* in www.consilium.europa.eu, 9 December 2022.

In June 2023, the proposal was finally adopted by the European Council, permanently replacing the battery directive of 2006[41]. This regulation covers the sustainability criteria mentioned above, reconfirming the necessity to recycle a minimum of the battery content.
The regulation also sets labelling requirements with implementing a "battery passport", which will be introduced in 2027. The Battery Passport will be essential to specify the materials' chemistry, origin, and state of health, thus representing a powerful tool to track batteries throughout their life cycle and supporting the establishment of life extension and end-of-life treatment systems[42].

Given the new European requirements, many repercussions are expected for the battery manufacturing industry: implementing new methods that can more easily lead to battery recycling will indeed be very common. For example, the "design for recycling" process will imply a careful selection of materials for new battery chemistries and an improvement for existing ones to facilitate their future recycling[43]. The design for recycling (also defined as eco-design) will comprehend the application and study of methodologies. One of them is the Life Cycle Assessment (LCA), an analysis that allows the evaluation of the environmental impact of a product throughout its life cycle.

In this context, the theme of circularity also appears in the Critical Raw Materials Act[44]. The document's text specifies that the Act should contain measures to increase the circularity and sustainability of the critical raw materials (among which are substances that are essential to produce batteries)[45]: recycling measures are encouraged, as they are fundamental to achieving a circular economy in the context of the green transition[46].

Similarly, **the Net Zero Industry Act** aims at reaching a circular system among its main objectives[47]. In the Act, the evaluation of possible net-zero solutions must consider different

[41] European Council Site, *Council adopts new regulation on batteries and waste batteries,* in www.consilium.europa.eu, 10 July 2023.
[42] ALBATTS Deliverable D4.4, *Battery Manufacturing,* 2021, p. 23.
[43] CIC Energigune Site, *Recycling of Lithium-Ion Batteries: the way for a sustainable energy transition,* in https://cicenergigune.com/en/blog/recycling-lithium-ion-batteries-sustainable-energy-transition, 25 May 2021.
[44] See above paragraph, 2.1: Critical Raw Materials Act.
[45] regulation of the European Parliament and of the Council of the 16 of March 2023, establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) 168/2013, (EU) 2018/858, 2018/1724 and (EU) 2019/1020, p. 1, par. 3.
[46] Ivi, p. 12, par. 42.
[47] regulation of the European Parliament and of the Council of the 16 of March 2023, *on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem (Net-Zero Industry Act),* 2023/0081, p. 2.

factors that are fundamental to achieving circularity, such as[48] the durability and reliability of the solution, the ease of repair and maintenance, the ease of upgrading and refurbishment, the ease and quality of recycling, and the consumption of energy, water, and other resources.

As the European framework is directed towards a circular system, the battery industry will see a promotion of battery recycling and reuse, leading to the need to develop more skills and knowledge on the battery ecosystem. Different job roles will arise in this context, such as battery engineer, data scientist, analyst, data engineer/architect, software engineer and software architect[49]. An up/reskilling process is also necessary to ensure the workers' safety, as handling batteries can lead to different hazard levels.

2.2 MACRO TRENDS, DRIVERS OF CHANGE: A FORWARD-LOOKING PERSPECTIVE

The desk research and data analyses of the ALBATTS project have regularly produced an update of the main Drivers of Change in the sector, encompassing both mobile battery applications and stationary & industrial applications[50]. Therefore, A forward-looking perspective is of utmost importance to understand the future dynamics of the sector in light of the recent regulatory evolution at the EU level.

The driver of "globalisation" has re-gained progressive importance for this desk research, as the EU will have to increase its competitive advantage by, for example, improving the sourcing of critical raw materials for batteries. The climate goals, regulation, and environmental challenges remain significant in percentage (47%), as companies must commit to extensive decarbonisation and true sustainability.

[48] Ivi, p. 24.
[49] ALBATTS Workshop of the 27th of January 2023.
[50] Release 1 is available at: https://www.project-albatts.eu/Media/Publications/5/Publications_5_20201106_123821.pdf
Release 2 is available at: https://www.project-albatts.eu/Media/Publications/23/Publications_23_20210920_83914.pdf
Release 3 is available at: https://www.project-albatts.eu/Media/Publications/68/Publications_68_20220912_82848.pdf

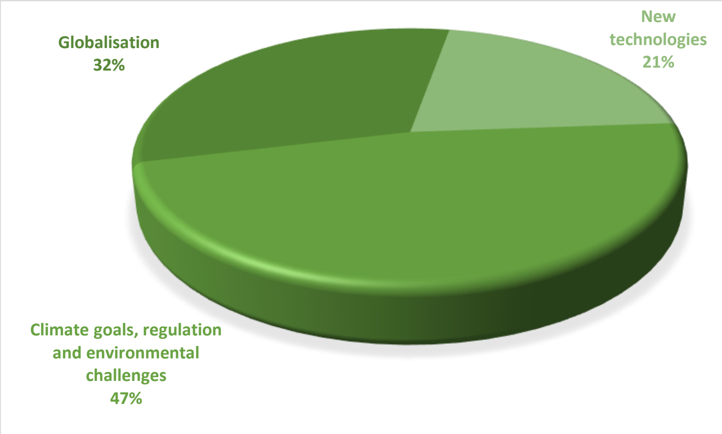

Figure 15: DoC occurrence – desk research Release 4

Regarding each DoC subcategory, as announced by the Critical Raw Materials Act and reiterated by the International Energy Agency, the increase in battery demand drives the demand for critical materials[51]. It is, therefore, evident how the subcategory "access to raw materials" within the DoC "globalisation" has increased in occurrence in the literature compared to the projections of the first desk research (Release 1)[52]. Release 2 already evidenced this trend[53].

2030 is a year where ambitious targets must be met across the battery value chain. From the first desk research of the ALBATTS project until now, all Drivers of Change identified continue to remain significant, and the outlook for the sector from today until 2030 shall allow proper skills and jobs forecasting and anticipation processes (this is the core of the ALBATTS project). As a way forward and guidance for future research and implementation strategies, the primary needs to be addressed by the sector from a high-level perspective can be summarised below (considering that they are strictly interrelated):

- **Holistic sustainability**: The battery sector is critical to achieving climate neutrality, and the decarbonisation targets are to be met by the EU. To do this, fundamental is having a holistic approach that, besides focusing on energy efficiency and emissions reduction, can achieve a truly positive environmental impact, such as safeguarding biodiversity and protecting natural habitats and land. At the same time, the social

[51] International Energy Agency Site, *Trends in batteries*, in https://www.iea.org/reports/global-ev-outlook-2023/trends-in-batteries, 2023.
[52] Please see page 26 of Release 1 available at: https://www.project-albatts.eu/Media/Publications/5/Publications_5_20201106_123821.pdf
[53] Please see page 19 of Release 2, available at: https://www.project-albatts.eu/Media/Publications/23/Publications_23_20210920_83914.pdf

dimension of sustainability shall be considered: health, safety, fair-trade standards, human rights, and inclusive dialogues[54] are critical.

- **Resilience:** In light of the recent regulatory evolutions, achieving a resilient battery value chain means focusing on strategic partnerships. Fundamental is EU public funding and investment support and de-risking financing tools for strategic projects outside the EU to secure the CRM supply to the EU[55]. At the same time, ensuring constant data availability and transparency for compliance with legal requirements in the form of "Track and trace "is critical.
- **Circularity**: adopting a circular business model is expected to be a key factor for the future of the battery industry. The transformation from a linear battery value chain to a circular one will bring significant environmental benefits and enormous economic potential to open the door to various opportunities. A circular business model can increase the entire value chain resilience and mitigate risks (e.g., battery waste disposal). Again, cross-industry collaboration and partnerships are essential.

Additional resources may be found in the **ANNEX C: Relevant Resources on Battery Legislation**.

[54] McKinsey & Company Site, *Battery 2030: Resilient, sustainable, and circular,* in www.mckinsey.com, 16 January 2023.
[55] RECHARGE Position Paper, *on the Critical Raw Materials Act,* November 2022.
Available at: https://rechargebatteries.org/wp-content/uploads/2022/11/RECHARGE-paper_Critical-Raw-Materials-Act_public-consultation_November-2022.pdf

3 Raw Materials and Processing

The role of raw materials in the growth of the European battery value chain is, as it is well known, quite critical. A battery cell producer cannot function in a competitive market without or with too expensive raw materials. The level of dependence on Asia, Australia, and the American continents is very high. According to the last EU raw materials criticality list from 2020, 74 % of all battery raw materials originate in China, Latin America, and Africa and this trend is expected to proliferate with increased European demand for expanding cell production. Only aluminium, manganese, copper, and nickel are not listed as directly critical for European supply (**Figure 16**).[56]

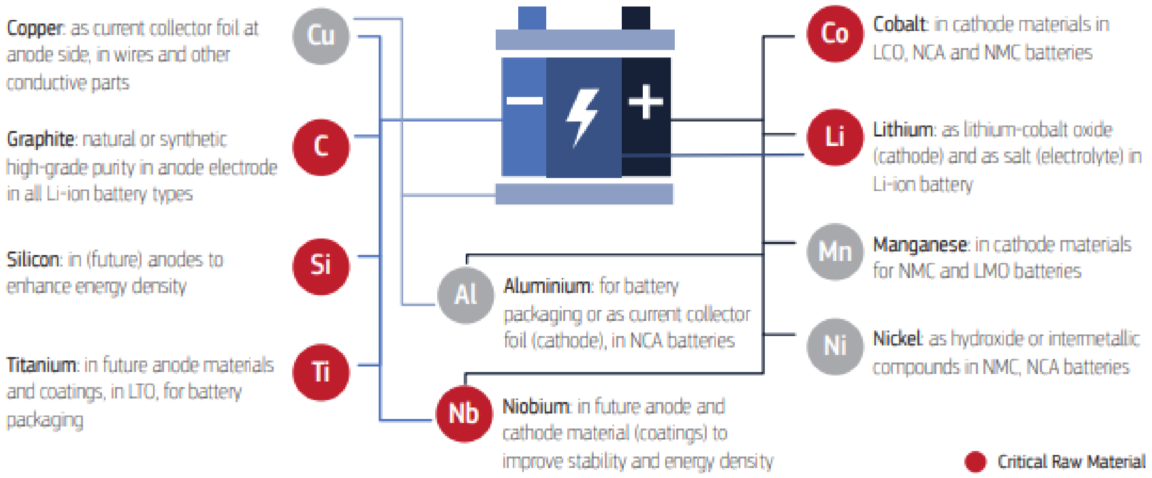

Figure 16 Critical raw materials for Europe (in red).[57]

There are, however, many European initiatives on the policy level to remediate this situation, by new European sourcing (mines, concentrator, and refining facilities) and a very high level of recycling.[58] At present, a European cell producer typically gets raw materials through:

1) import from companies on other continents,
2) new European sourcing as a desirable alternative to remediate the situation,
3) recycling operations to take care of the raw materials used optimally.

[56] Critical Raw Materials List 2020. Raw Materials Information System. (n.d.). Retrieved November 28, 2021, from https://rmis.jrc.ec.europa.eu/?page=crm-list-2020-e294f6.
[57] European Commission, Joint Research Centre): Bobba, S., Carrara, S., Huisman, J. (co-lead), Mathieux, F., Pavel, C. (co-lead) (2020) Critical Raw Materials for Strategic Technologies and Sectors in the EU - A Foresight Study. https://rmis.jrc.ec.europa.eu/uploads/CRMs_for_Strategic_Technologies_and_Sectors_in_the_EU_2020.pdf
[58] Sustainable supply of raw materials from EU Sources. Internal Market, Industry, Entrepreneurship and SMEs. (n.d.). Retrieved November 28, 2021, from https://ec.europa.eu/growth/sectors/raw-materials/policy-strategy/sustainable-supply-eu_en.

The raw material phases of the value chain thus consist of the following three optional sets of steps, often in combination:

a) For importing raw materials from other continents

- Overview and review of sourcing and buying options (price, quality, traceability, due diligence, political aspects, dependability, etc.)
- Procurement, negotiation, and buying process
- Delivery contracts or trade, co-ownership of mines and refineries, etc

b) For new European sourcing

- Prospecting, mining concession, mining operations, concentrating
- Refining of concentrated ore into raw materials

c) For sourcing from recycling, the options and alternative steps are

- Recycling as part of cell production, to regain from substandard cells
- Recycling of used/collected batteries

Problems with **b)** are beginning to show in Europe. Cell producers want European raw materials produced as close to the cell plant as possible. However, the national processes for prospecting permits and mining concessions are prolonged and plans for new mines are controversial in the ore-carrying regions in Europe. People want mining to happen elsewhere and have many democratic means to make their voices heard and slow down the process.

3.1.1 Skills Agenda[59]

ALBATTS project does not have, among the project partners, mining companies, refineries, etc., but there are contacts with some companies in this sector and with EIT Raw Materials. Mining and refining companies traditionally take care of the most needed up-and-reskilling in-house, and processes are highly automatized. However, not many of them are working with the needed virgin raw materials, and there are not many open mines in Europe. So, we can draw general conclusions concerning skills for handling risks of relevant raw materials, orientation on their use in the battery industry, and probably the same kind of upskilling needed elsewhere.

[59] Definitions and methodology are described in the methodology section, this is covering the development of the analysis within this chapter.

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

Figure 17: Raw Materials and Processing - Job Roles Analysis – Blue Collars

Figure 17 shows the occurrence analysis of the job roles for the raw materials and processing. Blue-collar workers observed have expertise in **process and machine operation; material planning and handling; calibration, maintenance and instruments; material engineering; safety** and others. White-collar workers have expertise in **material engineering/science (cathode, anodes, electrolytes); production control; audits; inspections and quality; supply chain management; production/manufacturing, maintenance,** and others.

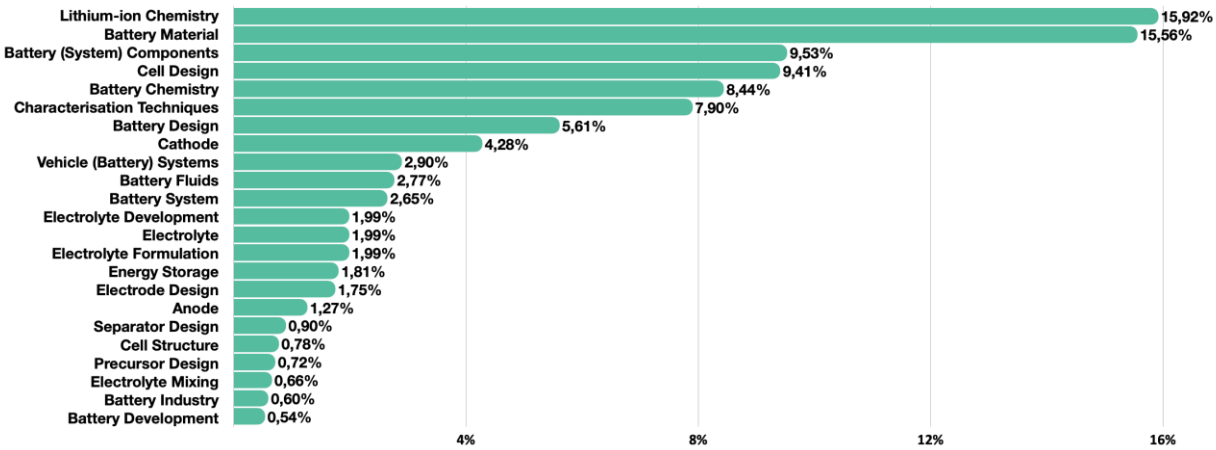

Figure 18: Raw Materials and Processing - Sector-Specific Competence

Figure 18 represents selected, the most occurring sector-specific competence for raw materials and processing.

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

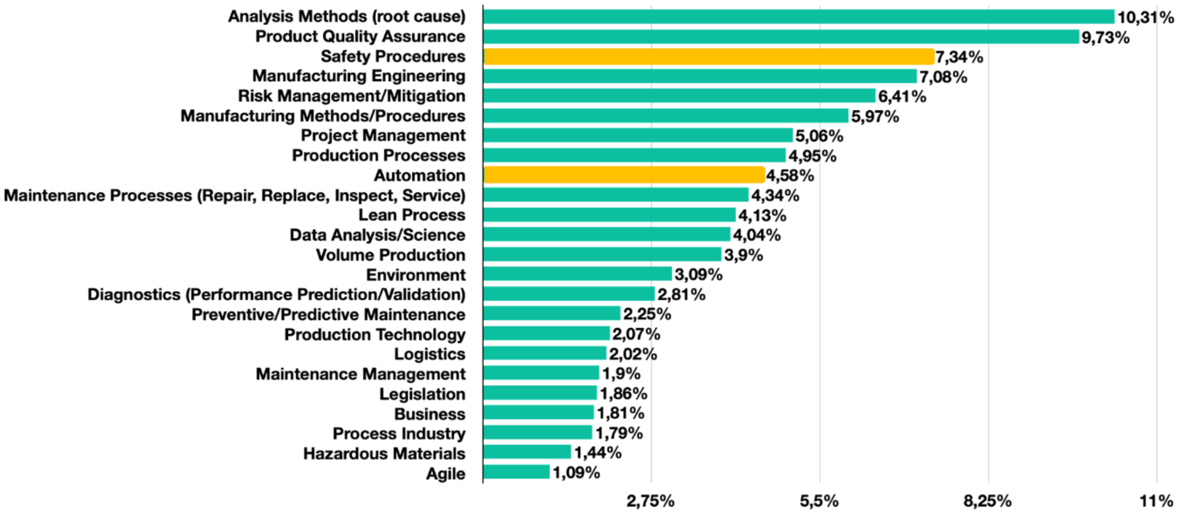

Figure 19: Raw Materials and Processing - Cross-sectoral Specific Knowledge

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

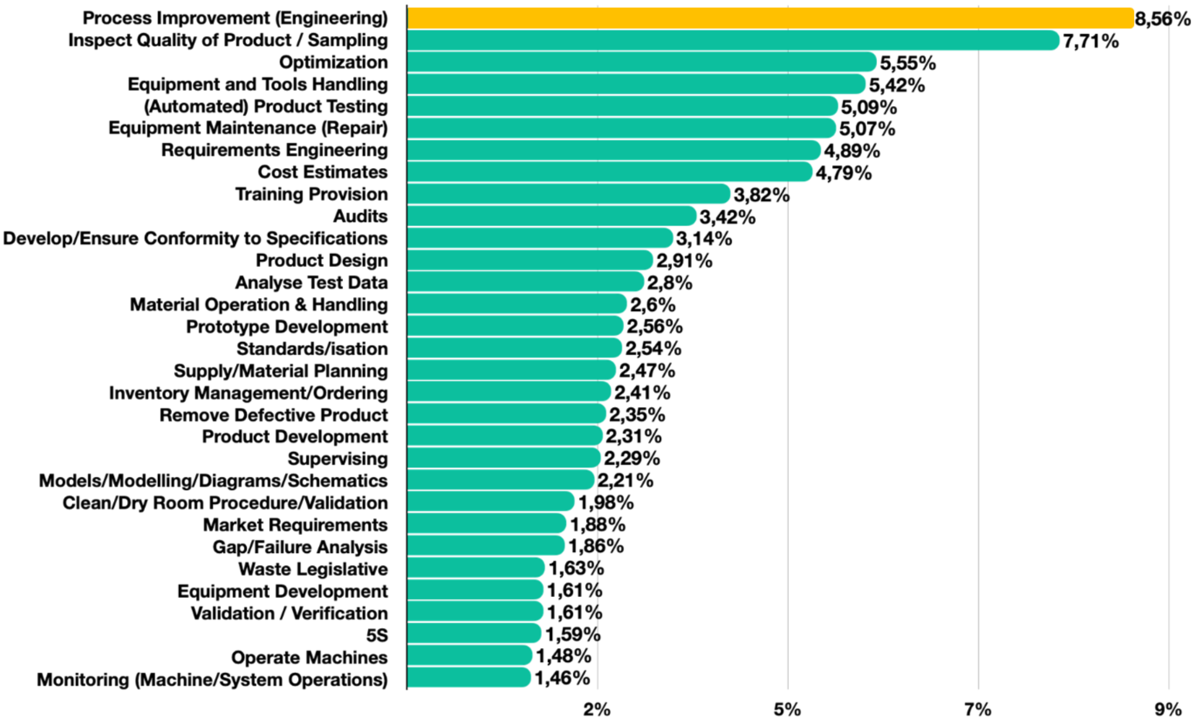

Figure 20: Raw Materials and Processing - Cross-sectoral Specific Skills

Figure 20 and **Figure 19** represents selected, the most occurring cross-sectoral specific competence for raw materials and processing.

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

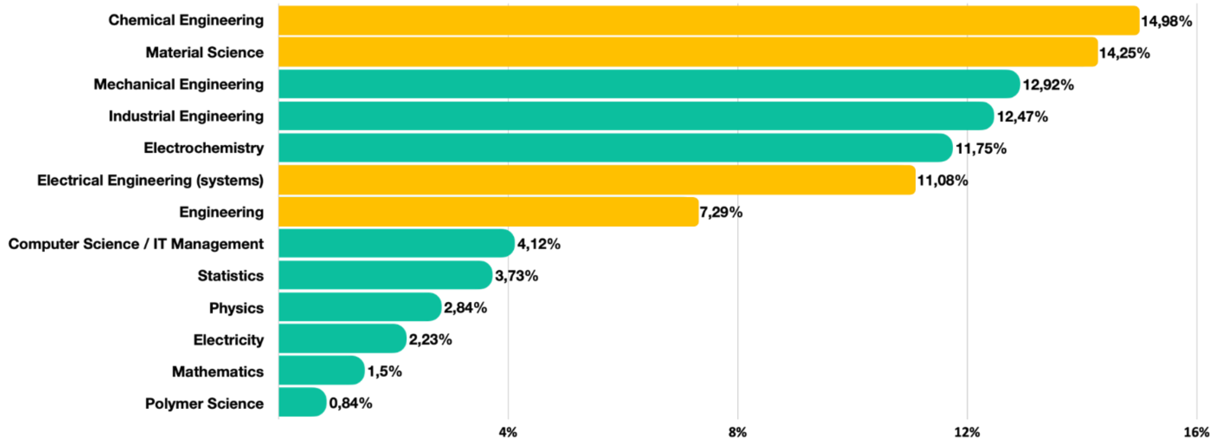

Figure 21: Raw Materials and Processing - Academic Competence

Figure 21 represents selected, the most occurring academic competence for raw materials and processing.

3.1.2 Practical Recommendations and Considerations

- Strengthening the awareness on the critical raw materials questions for Europe and connected emerging trends.
- Development of new skills needs (and relevant training material) for mining and refining raw materials for both white and blue collar workers.
- Manpower is required in mining, concentrator and chemical plants, maintenance, laboratories, logistics, and supportive/administrative functions.
- Basic education required includes process, chemical, mechanical, electricity, and automation engineering as well as geology and chemistry.

Target groups: prospecting and mining companies, refineries, and their white- and blue-collar workforce; branch organizations; and authorities involved in exploration permits and mining concessions.

4 Cells and Components Manufacturing

Components and cell manufacturing step follows the raw materials and processing value chain step and concerns the manufacturing and development of different components for battery cells and the production of cells.

This section describes the Gigafactory perspective. Different departments and their roles are described further below. Areas of interest covered are as follows[60]:

- Production and Maintenance
- Logistics
- Quality
- Other departments and Aspects, specifically: purchasing, human resources, finance, sales, and digitalization

4.1 PRODUCTION AND MAINTENANCE

A **production department** performs one of the key activities of a Li-ion battery manufacturing company. It can be considered a **volume department** due to having a relatively high number of employees when compared to the other departments.

The production department can be divided into two main sections (note: the "upstream production" part can be done in-house or outsourced):

1) **"An upstream"** production that prepares the input electrode materials. This production phase, where **chemical** processes take place, requires a lower number of employees than the following downstream production phase. Managing the processes is done from **a control room** that is not unlike what can be seen, for example, in the modern process industries such as chemical, pharma, and paper plants. The control room operators' tasks include monitoring and adjusting computerized controlling of the machines' pressure, temperature, and speed.

2) **"A downstream"** production section that involves the other production steps such as electrode manufacturing, cell assembly (depending on battery design - prismatic, pouch, cylindrical) that is the most labor-intensive part, and cell finishing.

[60] Mainly based on the set of interviews done with the Northvolt, which is the significant source of information for the following section.

Significant parts of the production process (particularly until the cells are sealed) are performed in **clean and dry rooms** in a dustproof and low humidity environment implying considerable investment and operating costs.

Automated processes, automatic material handling devices, AGVs (Automatic Guided Vehicles), Big Data analytics, AI, and IoT are being employed to allow economies of scale, optimize the processes, and increase quality, yield, and throughput. The **level of automation** in battery production can be expected to increase from the ramp-up phase to the maturity of a factory.

In the increasing competition among the battery producers, **scaling** of the production is highly desirable as it can significantly reduce the investments and running costs.

The battery producers strive to achieve a lean production process with fewer steps and occupying lower surfaces. Possible battery **manufacturing innovations** include e. g. dry electrode manufacturing thanks to which it would be possible to skip several production steps and save considerable time and costs.

Future battery technologies such as solid-state batteries will have a significant impact on some battery manufacturing processes and would require the possibility of a flexible adaptation of the production line.

In the production department, the white- (engineers, managers) and blue-collar ratios (technicians, operators) can be approximately 15-20 % - 80-85 % (in Northvolt, for example).

Maintenance: The battery production line is a very complex system, and the manufacturing needs special conditions - the dry and clean rooms, for example, need periodic maintenance. Software maintenance needs to be carried out as well. Companies are trying to introduce **preventive maintenance** concepts aiming to prevent failures during production and outages. Within **predictive maintenance**, parts of the line should monitor themselves and predict when interventions will be needed. Considering start-up companies, the importance of maintenance personnel is especially significant when setting up all the machines along the production lines.

The white- and blue-collar ratios are approximately 50-50 (in Northvolt, for example).

- Blue collars (mechanical technicians, electricians, instrument technicians, and warehouse technicians)
- White collars (engineers: maintenance, mechanical, electrical, automation, industrial, etc. and managers in upstream/downstream production)

4.1.1 Skills Agenda[61]

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

Figure 22: Production and Maintenance - Job Role Analysis | Blue-collar

Figure 22 shows the occurrence analysis of the blue-collar job roles for production and maintenance, with the expertise in battery assembly; quality; machine/process operation; calibration; and others.

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

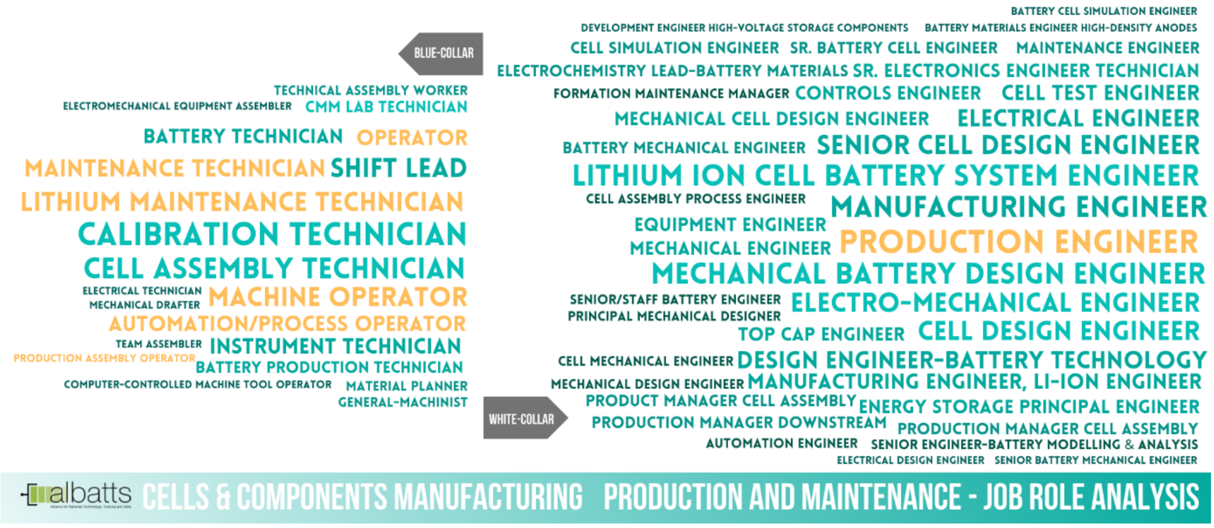

Figure 23: Production and Maintenance - Job Role Analysis | White-collar

Figure 23 shows the occurrence analysis of the blue-collar job roles for production and maintenance, with the expertise in battery assembly; quality; machine/process operation; calibration; as well as the occurrence analysis of the white-collar job roles for production and maintenance.

[61] Definitions and methodology are described in the methodology section, this is covering the development of the analysis within this chapter.

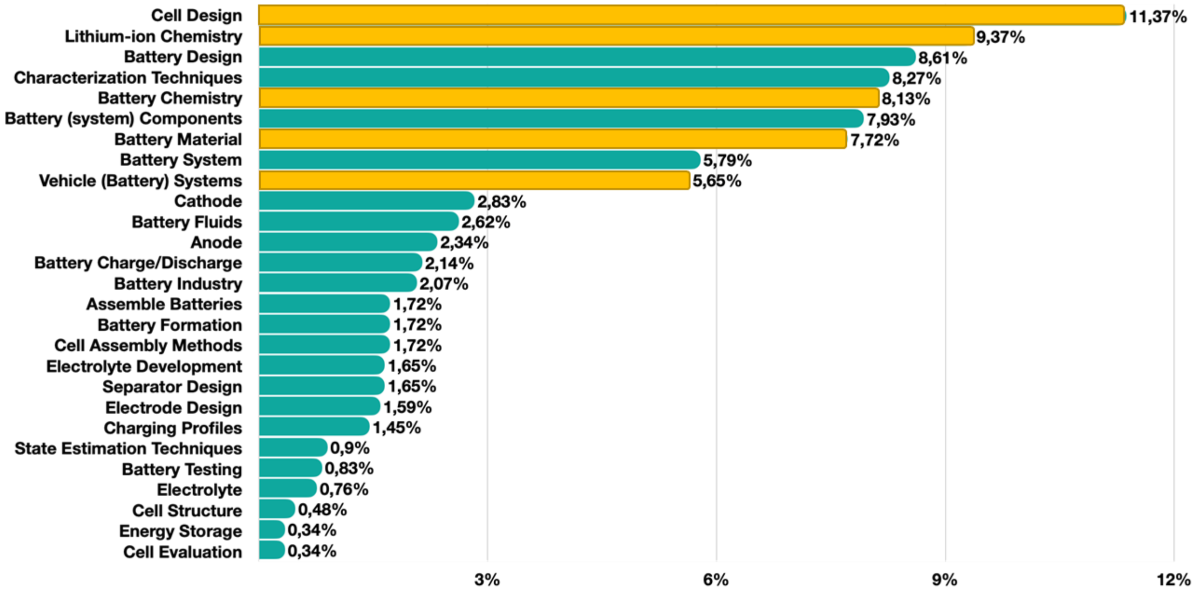

Figure 24: Production and Maintenance - Sector-Specific Competence

Figure 24 represents selected, the most occurring sector-specific competence for production and maintenance.

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

Orange-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants more than once

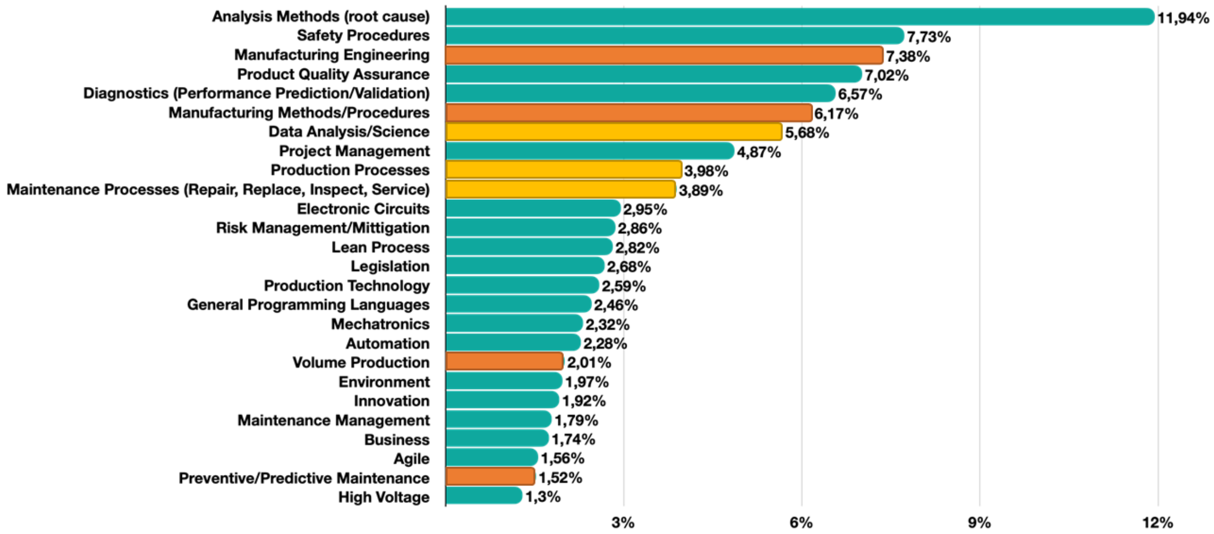

Figure 25: Production and Maintenance - Cross-sectoral Specific Knowledge

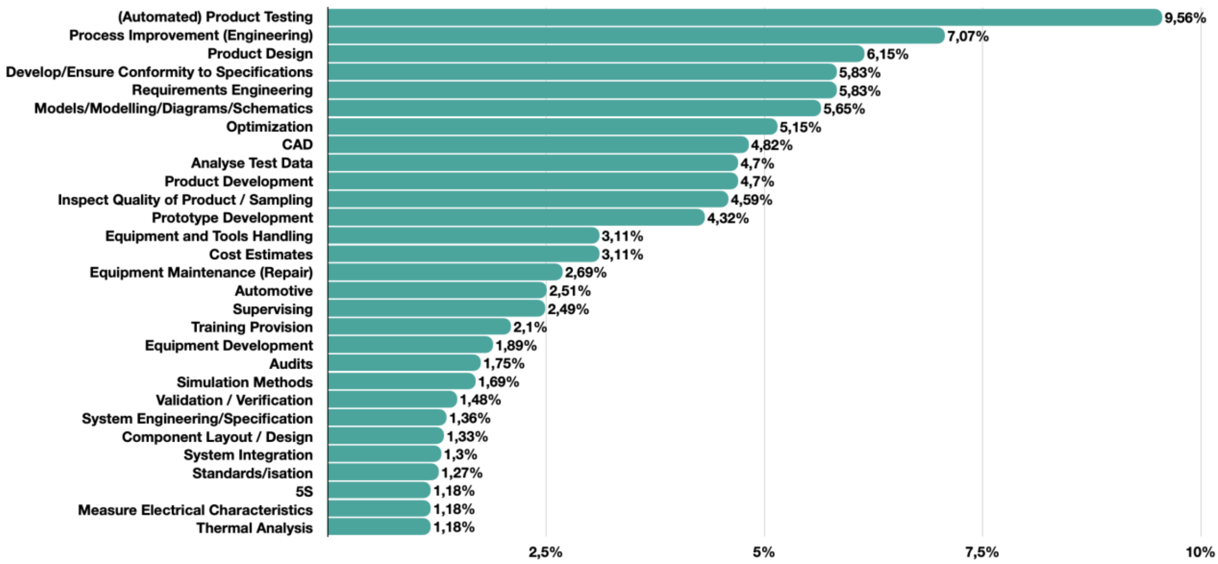

Figure 26: Production and Maintenance - Cross-sectoral Specific Skills

Figure 25 and Figure 26 represents selected, the most occurring cross-sectoral competence for production and maintenance.

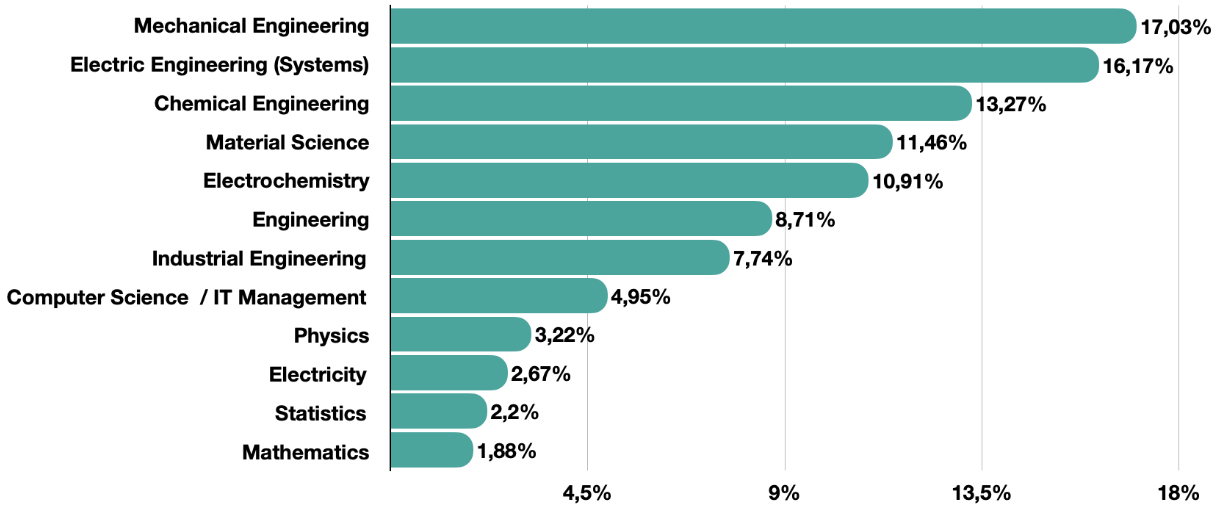

Figure 27: Production and Maintenance - Academic Competence

Figure 27 represents selected the most occurring academic competence for production and maintenance: chemistry; mechanical engineering; electrical engineering; electrochemistry; and others.

4.1.2 Practical Recommendations and Considerations

Production:

- Strengthening of skills and competencies related to battery production to provide a high level of understanding in the fields of **electrochemistry, electronics, mechanics, process engineering, manufacturing technology, automation (with production systems), battery assembly, and digitalization in manufacturing**.
- In general, increase the ability to speak and understand foreign languages, particularly **English** (in Northvolt, for example).
- White-collar specific needs:
  - Increasing competencies in **production and material engineering, production planning, production management, shift management, process engineering, cell design, machine learning and optimization, modelling, and simulation.**
  - Strengthening the focus on **large-scale manufacturing**, understanding of **chemical processes** and **quality, risk, and safety management**.

- **Battery industry-related knowledge/skills:** battery material, battery chemistry, battery fluids, battery components, battery testing, defective products removal

- Blue-collar specific needs:
  - “Upstream” production – increasing knowledge to understand the **risks, envision the safety issues,** and how **chemicals** behave.
  - “Downstream” production – increase **machine understanding, high speed mechanical assembly, 5S skills,** and the ability to **troubleshoot**.
  - Overall production system understanding.
  - Knowledge/skills: **material handling, Clean/Dry Room Procedure/Validation, Inspect Quality of Product / Sampling, material pressing, electrode process, fine mechanics, HMI (Human Machine Interface)**

Regarding the increased levels of production automation in the foreseeable future, increased competence concerning **data analytics, maintenance, product process optimization**

Target Groups: Educational institutions, battery producers, recruitment companies, head-hunters, consultants.

Maintenance:

- Apart from the general battery-related education, strengthening the skills and competencies to ensure understanding of **setting up the production, preparing the related structures, commissioning the machines, chemical, and mechanical assembly, automation experience, and mechanical understanding of the automated systems** combined with understanding the related **software and calibration.**
- Strengthening general **IT and data analysis skills** to cover future needs.
- Battery skills (also mentioned in the context of Production)
- “Dry and clean room” maintenance (including room contamination measurement)
- Predictive and preventive maintenance
- Diagnostics

Target Groups: Educational institutions, battery producers, recruitment companies, head-hunters, consultants.

4.2 PRODUCTION EQUIPMENT

This chapter studies the skills and competencies needed with various equipment and machines used in battery production. Navigating a complex production environment demands a diverse skill set. From technical expertise in equipment operation to paying attention to detail, operators play a pivotal role in ensuring productivity and quality. The fusion of safety compliance, troubleshooting, and a commitment to continuous improvement forms the backbone of successful manufacturing operations.

1.1.1 Electrode manufacturing

Europe's electrode manufacturing, crucial for automotive, energy storage, and renewables, thrives in Germany, France, the UK, Italy, and Sweden. Driven by EV demand, the region aims to bolster its battery industry with EU-backed R&D, reducing import reliance. Stringent environmental regulations shape sustainable practices, and the supply chain integrates domestic and global raw material sourcing, including importing precursors. Automation and digitisation enhance efficiency and quality standards in European electrode manufacturing.

Mixing equipment (e.g., Planetary Mixers and Ball Mills) in electrode manufacturing, the significance of mixing equipment, particularly planetary mixers and ball mills, is high. Planetary mixers, featuring a rotating, stationary container and agitator, are widely employed for electrode paste and slurry production. They efficiently blend high-viscosity materials across various batch sizes. Ball mills, characterised by rotating drums filled with grinding media, are often utilised for powder blending and refining processes.

Coating equipment (e.g., slot dies, doctor blades, roll coaters) ensures precise and uniform coatings to electrode materials. Slot dies are used in controlled coating applications, offering advantages like high uniformity and adjustable thickness. Working in tandem with slot dies, Doctor blades maintain coating thickness consistency. Roll coaters, utilising rollers for uniform coatings, are suitable for high-volume production.

Drying equipment (e.g. ovens, vacuum dryers) is a vital component in electrode manufacturing, ensuring electrode drying. Ovens provide a controlled environment with adjustable temperature settings and timers, catering to batch and continuous production requirements. Vacuum dryers excel in removing moisture at lower temperatures and reduced pressure, preserving the properties of sensitive electrode materials. Essential considerations with drying equipment include capacity, temperature control, energy efficiency, and specific requirements for processing electrode materials.

Slitting equipment (e.g. slitters, rewinders) are designed to slit large rolls of materials like metal foils or coated substrates and employ razor blades or rotary knives for precision cuts. Critical features of slitters for 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 encompass 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 (e.g. stacking machines) is integral to the lithium-ion battery electrode manufacturing process, and the equipment for stacking electrodes is crucial. These machines involve meticulously stacking and aligning numerous layers of anode and cathode materials, along with separators, to construct the electrode structure. The electrode stacking process's precision significantly influences the battery's performance and quality.

1.1.2 Skills and Compete Needed in Electrode Manufacturing

General Skills Associated with All Equipment Categories:

- **Technical Knowledge:**
  - Understand principles, operation, and maintenance of equipment.
  - Familiarise with specific machine models, functionalities, programming, and troubleshooting.

- **Equipment Operation and Calibration:**
  - Set up equipment correctly, ensuring proper calibration for accurate dispensing.
  - Knowledge of calibrating sensors, nozzles, valves, and other components.
- **Materials Handling:**
  - Proficiency in handling various materials used in the assembly process.
  - Knowledge of material properties, storage requirements, and proper handling techniques.
- **Programming and Machine Operation:**
  - Competence in programming machines for specific tasks.
  - Adjust settings and optimise performance for different product requirements.
- **Quality Control:**
  - Attention to detail and focus on quality control measures.
  - Implement quality checks at various assembly stages and take corrective actions.
- **Problem Solving and Troubleshooting:**
  - Identify and resolve technical issues during the assembly process.
  - Troubleshoot problems with machines, materials, or components.
- **Safety Awareness:**
  - Comply with safety protocols and regulations.
  - Understand potential hazards and take necessary precautions.
- **Communication and Collaboration:**
  - Effective communication with team members and stakeholders.
  - Collaborate to streamline workflows, share knowledge, and address challenges.
- **Time Management:**
  - Efficiently manage time to meet production targets and deadlines.
  - Prioritise tasks and optimise machine use for maximum productivity.
- **Continuous Learning:**
  - Stay updated with advancements in technology and industry trends.
  - Seek opportunities for professional development.

Equipment Category-Specific Skills:

- **Mixing equipment (e.g., Planetary Mixers, Ball Mills):**
  - Ability to handle high-viscosity materials.
  - Troubleshooting skills for operational issues.
  - Compliance with environmental regulations.
- **Coating Equipment (e.g., Slot Dies, Doctor Blades, Roll Coaters):**
  - Proficient in adjusting coating parameters.
  - Mechanical aptitude for routine maintenance.
  - Record-keeping skills for production data.
- **Drying equipment (e.g., Ovens, Vacuum Dryers):**
  - Analytical thinking for troubleshooting.
  - Adaptability to changing priorities.
  - Documentation skills for equipment operation.
- **Slitting Equipment (e.g., Slitters, Rewinders):**
  - Hand-eye coordination for precise adjustments.
  - Quality consciousness for maintaining standards.
  - Adaptability to changing production requirements.
- **Electrode Stacking Equipment (e.g., Stacking Machines):**
  - Mechanical aptitude for routine maintenance.
  - Record-keeping skills for production data.
  - Adaptability to changing production requirements.

1.1.3 Cell assembly

The European cell assembly industry is witnessing significant growth, particularly in the automotive sector, where it is crucial for electric vehicle (EV) battery production. Ongoing European research and development focus on enhancing cell assembly technology's performance, energy density, safety, and sustainability. The establishment of Gigafactories by significant industry players emphasises comprehensive production, covering the entire battery-making process, including cell assembly.

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Cell stacking equipment encompasses machinery or devices specifically engineered to automate individual cells or batteries' organised and efficient stacking. Widely utilised in the production and assembly of battery packs, these machines play a crucial role in various applications, including electric vehicles, portable electronics, and energy storage systems.

Tab welding equipment (ultrasonic welders, laser welders) plays an essential role in the battery cell assembly. Ultrasonic welders are extensively used, especially in manufacturing lithium-ion batteries for electric vehicles (EVs) and various equipment, offering a reliable and efficient method for joining battery cell components. Laser welding technology is employed in battery production for cell assembly, utilising a high-energy laser beam to generate localised heat that melts and fuses materials. Laser welders are particularly useful for combining components such as battery tabs, terminals, and busbars.

Winding Machines are essential in the cell assembly process for battery technology, specifically for manufacturing battery cells. These devices are crafted to precisely wind and assemble the electrode components, separators, and current collectors into a streamlined cell arrangement.

Electrolyte Filling equipment (vacuum filling machines, injection filling machines) plays a specialised role in battery production, specifically for adding electrolytes to battery cells. Electrolytes, crucial for supplying the ionic conductivity essential for electrochemical reactions inside cells, are precisely and effectively filled into battery cells through these machines. Similarly, electrolyte injection filling machines are employed in battery cell assembly to ensure accurate and efficient filling of battery cells with the electrolyte solution. These devices provide precise control over the amount and distribution of the electrolyte, ensuring optimal performance and security of the battery cells.

Sealing Equipment is utilised in the battery manufacturing process. Heat sealers are specialised machinery crucial for ensuring an airtight and secure enclosure during battery cell assembly. This technique, widely adopted in the battery production industry, involves using heat sealers to create a dependable and leak-proof seal for battery cells.

A crimping machine is utilised in battery cell assembly; a crimping machine is a specialised machinery crucial for establishing electrical and mechanical connections among various parts of a battery cell during the manufacturing process. This technique, widely adopted in the battery manufacturing industry, involves crimping machines to connect terminals, tabs, or connectors to the electrodes, creating a reliable and low-resistance electrical channel.

Formation equipment battery cyclers, or formation equipment, are integral in battery production, facilitating the initial charging and discharging cycles needed to condition and activate cells. These machines, comprised of components like a customised power supply, control system for parameter adjustment, and data acquisition for quality assurance, ensure consistent and efficient formation. Safety features guarantee secure operation, including temperature sensors and emergency shutdown mechanisms. Formation equipment enables automated processes, quality control through data collection, and flexibility for different battery types.

Voltage/current testing equipment is used for measuring electrical systems, ensuring efficiency and safety. The Digital Multimeter (DMM) is a versatile tool for measuring voltage, current, and resistance in maintenance and troubleshooting. Clamp meters offer non-invasive current measurement by clamping around conductors. Power analysers provide in-depth electrical power analysis. Oscilloscopes display graphical representations of electrical waveforms for analysis. Programmable power supplies regulate voltage and current for testing electronic equipment in various applications. Current shunts precision resistors measuring high current levels, are applied in power distribution and industrial machinery.

1.1.4 Skills and competencies needed in cell assembly

General Skills Associated with All Equipment Categories:

- **Technical Knowledge:** Understand the principles, operation, and maintenance of specific equipment used in battery assembly, including machine models, functionalities, and troubleshooting.
- **Equipment Setup and Calibration:** Ability to set up and calibrate machinery for accurate and precise operations, adjusting parameters as needed.

- **Material Handling:** Proficient in handling relevant components, understanding their properties, dimensions, and proper handling techniques to maintain quality.
- **Quality Control:** Attention to detail for implementing and ensuring quality control measures at various stages of the assembly process.
- **Troubleshooting:** Identify and resolve technical issues promptly, whether related to the machinery, parameters, or materials.
- **Safety Awareness:** Comply with safety protocols, understand potential hazards, and take necessary precautions for a secure working environment.
- **Communication and Collaboration:** Effectively communicate with team members and stakeholders, fostering collaboration for streamlined workflows.
- **Time Management:** Efficiently manage time, prioritise tasks, and optimise machinery use to meet production targets and deadlines.
- **Continuous Learning:** Stay updated on technological advancements and industry trends, seeking opportunities for professional development.

Equipment Category-Specific Skills:

- **Cell Stacking Equipment:**
  - **Stacking Techniques:** Competence in various stacking techniques, manual or automated, based on machine and application requirements.
- **Tab Welding Equipment (Ultrasonic Welders, Laser Welders):**
  - **Welding Techniques:** Proficiency in different welding techniques, such as ultrasonic or laser welding, depending on the machine and application.
- **Winding Machines:**
  - **Mechanical Aptitude:** Basic understanding of mechanical systems for routine maintenance and issue troubleshooting.
  - **Hand-eye Coordination:** Good manual dexterity and coordination for precise material handling and adjustments.
- **Electrolyte Filling Equipment (Vacuum Filling Machines, Injection Filling Machines):**
  - **Programming and System Operation:** Competence in programming the filling system for specific tasks and adjusting settings for optimal performance.
- **Sealing Equipment:**

- **Mechanical Aptitude:** Basic understanding of mechanical systems for routine maintenance and issue troubleshooting.

- **Crimping Machine:**
  - **Hand-eye Coordination:** Good manual dexterity and coordination for handling wires or cables and making precise adjustments.
- **Formation Equipment:**
  - **Data Analysis Skills:** Proficiency in data acquisition, interpretation, and analysis for comprehensive testing evaluations.
- **Voltage/Current Testing Equipment**

Test Setup and Configuration: Ability to set up testing equipment, configure measurements, and adhere to safety protocols for live circuits.

4.3 LOGISTICS

What we know at this stage about in- and outbound logistics for cell factories and logistics inside a battery cell Gigafactory is outlined below.

Environmental priorities: A European Gigafactory must follow the existing regulations and be able to face upcoming environmental regulations. The CO_2 footprint for battery cell production must be reduced to more acceptable levels by optimizing

- Local sourcing of raw materials
- Fossil-free means of transport
- Shorter and fewer transports of raw materials and other production inputs
- Use of green recyclable energy in all phases of production
- Raw material percentage coming from recycling of batteries
- Traceability of all raw materials and other production inputs
- Vertically integration with long production lines, for more control over the production.

For example, Northvolt aims at reducing CO_2 footprint to only 20% of present cell production CO_2 levels by mainstream Asian cell manufacturers by 2030.

Inbound logistics: A cell gigafactory needs considerable volumes of raw materials and other supplies every day.[62] The production scale also means that disturbances in material inputs and supplies are very expensive and must be avoided as best possible. One strategy is to have suppliers and subcontractors placed nearby with their production or warehousing. A Gigafactory is big enough to demand close production and warehousing locations from essential suppliers. This is a different approach to the "just-in-time" supply chain, where the warehouse is on the road and supplies are supposed to arrive just when needed.

Outbound logistics: As in the example from Northvolt, the 16 GWh battery production in the first two lines to be commissioned (of 60 GWh to be ready by 2025) will result in 85,000 tons of Li-Ion batteries per year in cylindrical and prismatic formats to be shipped out. Thus, the volume of inbound supplies is about double the outbound product volumes. The main transports will be by railway and sea transport, connecting at the Skellefteå harbor (Skelleftehamn) 11 km from the site, where a particular section of the harbor is being prepared for Northvolt. The plans for the near future are to run this link with EV autonomous trucks on a separate road as a demonstration project. At full production in 2025, about 900 trucks will load and unload every day at the Northvolt Skellefteå plant, or once every 4 minutes. The situation will be similar for other gigafactories, but solutions will vary due to local conditions.

For international logistics planning, expertise is needed and can be outsourced or be done in-house, but control over the environmental and economic priorities must be maintained. Northvolt, as being our pilot example here, has contracted the Swedish logistic company. The cooperating shipping company is Wallenius SOL, which will for Northvolt have two new LPG-driven special RO-RO ships.

Inhouse logistics: European cell gigafactories will be highly automated, including as expected internal factory logistics. In an Industry 4.0 environment, many activities are coordinated by the generated data streams from the production. The distribution of materials for replenishing machines with input materials will often be done by the machines ordering the material

[62] Environmental Impact Statement: *Teknisk beskrivning Northvolt Ett – Utökad anläggning för storskalig produktion av litiumjonbatterier*, Northvolt. Link: https://docs.google.com/viewer?url=https%3A%2F%2Fwww.nexi.go.jp%2Fenvironment%2Finfo%2Fpdf%2F18-028_EIA2.pdf Accessed on 24.06.2021

themselves. Electric driver-less trucks will run and charge themselves by inductive charging and find their way around with sensors and augmented reality. The warehouses will be highly automated as well. For Northvolt, this automation will also to some degree include the harbor 11km away with its Northvolt-dedicated warehouses. Automatic trucks are planned to travel back and forth with input materials one way and batteries on the return.
The speed of the production line exceeds a meter per second[63], and the transfer of material to the next stage of production is automated.

Recycling logistics: An essential source of new battery materials will be recycled batteries, both substandard batteries directly from the production line and collected old Li-Ion batteries. Northvolt plans to source 50% of its raw material from decommissioned batteries in 2030.[64] The recycling of batteries from the production is ideally recycled close to the factory, while collected scrap batteries can be processed into new materials in many places. The transport of old Li-Ion batteries to processing demands security arrangements, as dedicated containers.[65] Fires caused by short-circuiting thermal runaways are not uncommon in the collection of batteries for recycling.

The work with logistics will be demanding, governed by environmental regulations and concerns, and require a deep understanding of the systems and safety issues around them.

4.3.1 Skills Agenda[66]

[63]BatteryBits. (2021, November 18). Battery Manufacturing Basics from catl's cell production line (part 1). Medium. Retrieved November 24, 2021, from https://medium.com/batterybits/battery-manufacturing-basics-from-catls-cell-production-line-part-1-d6bb6aa0b499.
[64] News chat with Peter Carlsson, Northvolt's CEO https://norran.se/artikel/northvolts-vd-peter-carlsson--blir-det-en-ny-fabrik-i-umea-har-kan-du-lasa-chatten-i-efterhand/jv91k7yl Accessed on 24.11.2021
[65] Container for lithium-ion batteries DENIOS. DENIOS. (n.d.). Retrieved November 28, 2021, from https://www.denios.co.uk/shop/cleaning-and-waste-disposal/container-for-lithium-ion-batteries/.
[66] Definitions and methodology are described in the methodology section, this is covering the development of the analysis within this chapter.

Figure 28: Logistics and Purchasing - Job Role Analysis | White Collars

Figure 28 shows the occurrence analysis of the job roles for the logistics. Blue-collar workers observed have expertise in **material handling; process operation; planning; inventory management**; and others. White-collar workers have expertise in **planning; logistics; automation; production; supply chain management; process engineering**; and others. Generic job roles are active in **purchasing and others**.

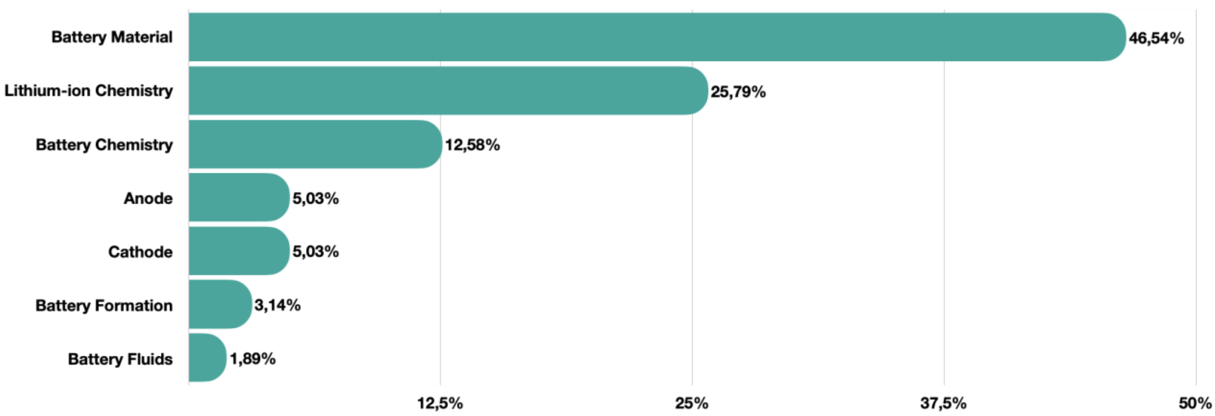

Figure 29: Logistics and Purchasing - Sector-Specific Competence

Figure 29 represents selected, the most occurring sector-specific competence for logistics.

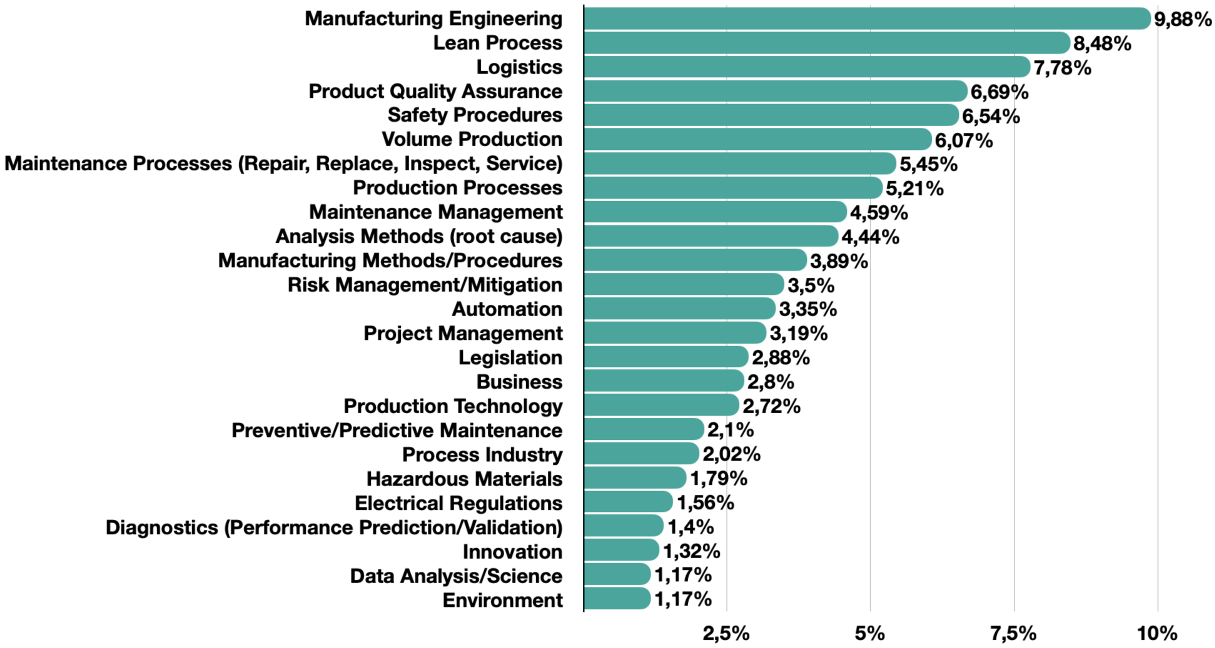

Figure 30: Logistics and Purchasing - Cross-sectoral Specific Knowledge

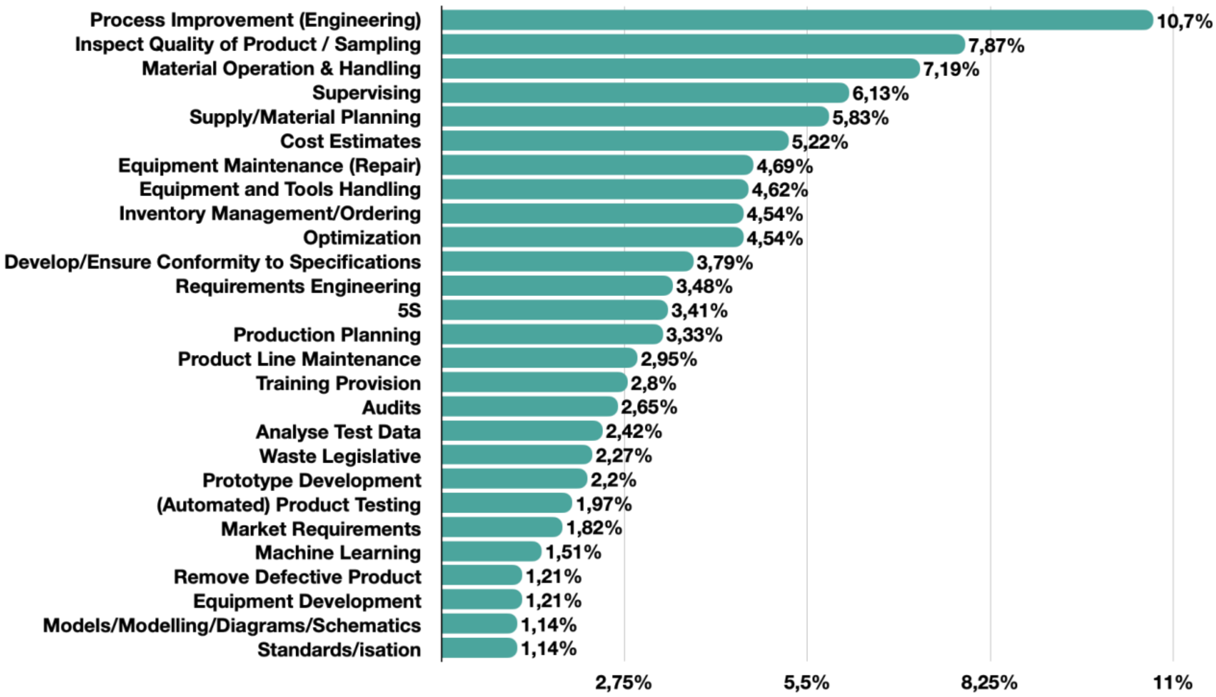

Figure 31: Logistics and Purchasing - Cross-sectoral Specific Skills

Figure 30 and **Figure 31** represents selected, the most occurring cross-sectoral specific competence for logistics.

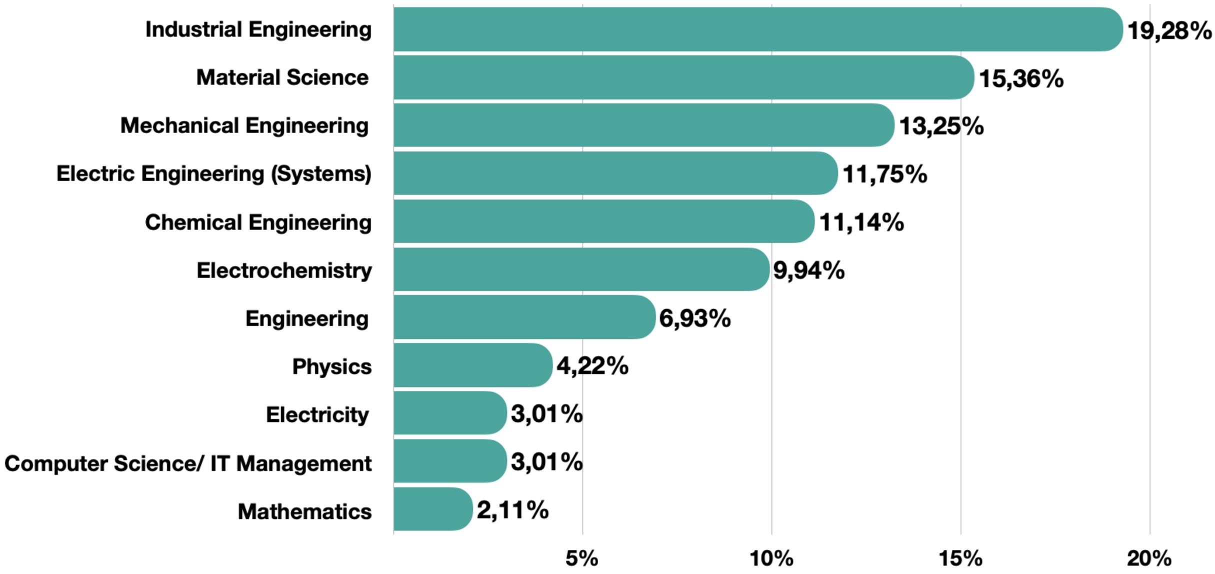

Figure 32: Logistics and Purchasing - Academic Competence

Figure 32 represents selected, the most occurring academic competence for logistics.

Skills related to automated transport and logistic planning will be in high demand, and knowledge on handling hazardous goods, especially in recycling. The job roles include mainly white-collar positions such as **logistics developers, logistics business analysts** and those who work with compliance with logistics. Many of them have master's degrees in logistics, computer science, and similar. Blue-collar workers are needed in positions as **material handlers, forklift and truck drivers, warehouse technicians**, **inventory controllers** etc.

The development is expected to bring such skill needs as **understanding automatic flow, automatically guided vehicles, warehouse automatization and warehousing, IoT, Industry 4.0**, etc.

4.3.2 Practical Recommendations and Considerations

All aspects of logistics when it comes to battery production should be considered:

- Environmental priorities
- Production facility construction logistics
- Inbound logistics
- Outbound logistics
- International logistics planning

- In-house logistics
- Recycling logistics

Target Groups: battery producers, battery plants, stakeholders active within the logistics field, and the above-mentioned logistics aspects.

4.4 QUALITY

Quality aspects can be approached from different perspectives. This section describes the quality within the Gigafactory – functions, quality management systems, as well as audits.

4.4.1 Quality as a part of a Gigafactory's functions

Quality is monitored throughout the entire manufacturing process in a Gigafactory. This can be executed, for example, by several teams that function for various purposes. These teams may include **Quality Control, Construction Quality, Quality Postproduction, Customer Quality[67], Continuous Improvement Team[68].**

4.4.2 Quality Management Systems in a Gigafactory

The Quality Management Systems, QMS, in a Gigafactory require many specialists who have responsibilities that might involve:

- development and improvement of a Quality Control Plan for Li-Ion batteries production
- execution of PFMEA-Process Failure Mode Effects Analysis and high-risk areas elimination
- monitoring of quality data using statistical process control to identify gaps in the assembly process
- creation and updating of Pareto charts to identify and quantify quality issues
- troubleshooting and root causing (e.g., 8D)
- providing support for successful implementation of standards and continuous certification

[67] Northvolt. Customer Quality Engineer: Northvolt. Jobylon. Retrieved June 14, 2021, from https://emp.jobylon.com/jobs/19142-northvolt-customer-quality-engineer/.
[68] Northvolt interview, 28.5. 2021

4.4.3 Quality audits

Continuous Improvement Methodologies - The goal of an internal audit is to ensure that records are in place to confirm compliance with the processes and to find problems and weaknesses that would otherwise stay hidden[69]. Many Gigafactories use several types of QMS such as the following ones: **TQM (**Total Quality Management**), Kaizen, PDSA (**Plan, Do, Study, Act**), Six Sigma** (measurable metrics), **Lean Manufacturing** (minimizing waste with simultaneous maximization of productivity)

Staff and recruitment:[70] Northvolt case is used as an analog for the staff structure in the overall quality function in Gigafactories in this subchapter.

The quality team consists of engineers and technicians. The engineers have normally experienced personnel with Ph.D. or master's degree educational backgrounds. They function in such job roles as **Quality Control Engineers, Analytical Chemists, Technical Writers, Customer Quality Engineers, Quality Management Specialist, and Supplier Quality Engineers**.

Technicians often come from educational backgrounds of high school or vocational levels. They perform quality controls within the manufacturing labs and often work in shifts, following the production planning.

Training and upskilling of the quality staff are provided with an extensive internal training program. Additionally, the learning while in the job method is being applied.

Challenging to find skills and competencies, and positions that are difficult to fill:

- **Cleanroom managers** and specialists who can support building the cleanrooms
- **Researchers** with laboratory experience, especially with batteries
- **Methodology development experts** (with battery backgrounds)
- **Quality engineers** (with battery backgrounds)

The future staff development: the personnel need to stay on track and upskill themselves along with the development of battery technology. This implies continuous internal **lifelong learning**. Furthermore, with the new technologies and increasing production volumes, there

[69] What is the ISO 9001 standard? A straightforward overview. 9001Academy. (2021, November 8). Retrieved November 28, 2021, from https://advisera.com/9001academy/what-is-iso-9001/.
[70] Northvolt interview, 28.05. 2021

is a need to investigate **automated systems** and **material flows** and in the **quality control** process. The importance of automation comes from the fact that it is impossible to operate similarly to a standard research laboratory since there is a need to take many quality samples (thousands). Consequently, technology is needed to help to process the vast volumes of samples and stay scalable.

4.4.4 Skills Agenda[71]

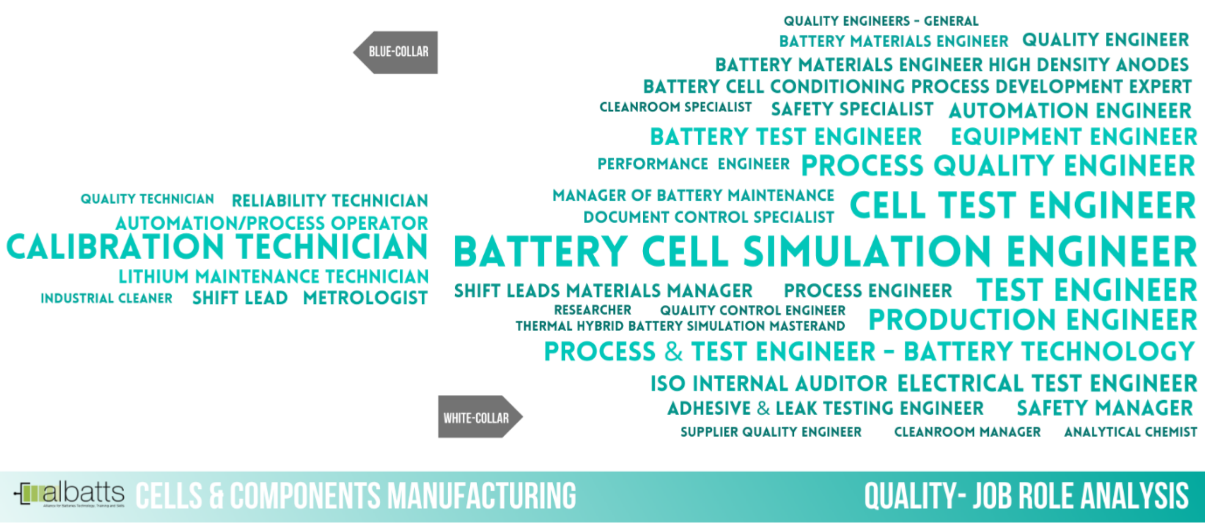

Figure 33: Quality - Job Role Analysis | White Collars

Figure 33 shows the occurrence analysis of the job roles for the quality. Blue-collar workers observed are having expertise in: **testing; automation and process operation; quality; calibration; document control; battery analysis**; and others. White-collar workers are having expertise in: **testing; test automation; automation; quality; process improvement and engineering; simulation; audits**; and others. Generic job roles are active in: **general roles different types of quality**.

[71] Definitions and methodology are described in the methodology section, this is covering the development of the analysis within this chapter.

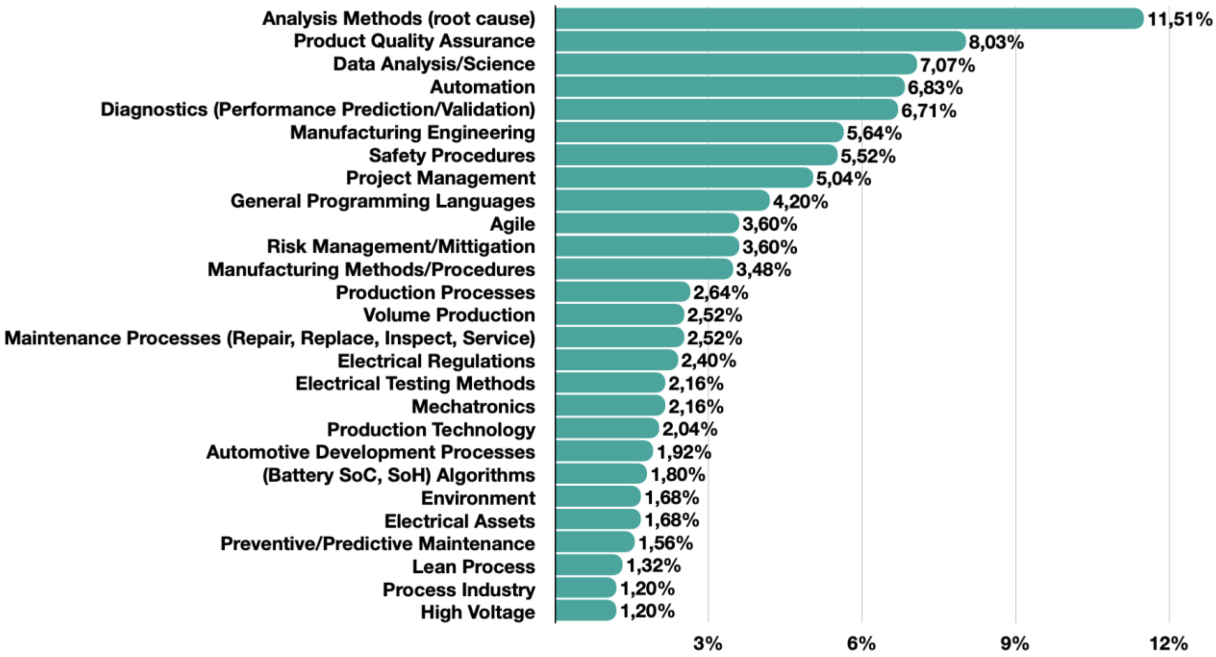

Figure 34: Quality - Cross-sectoral Specific Knowledge

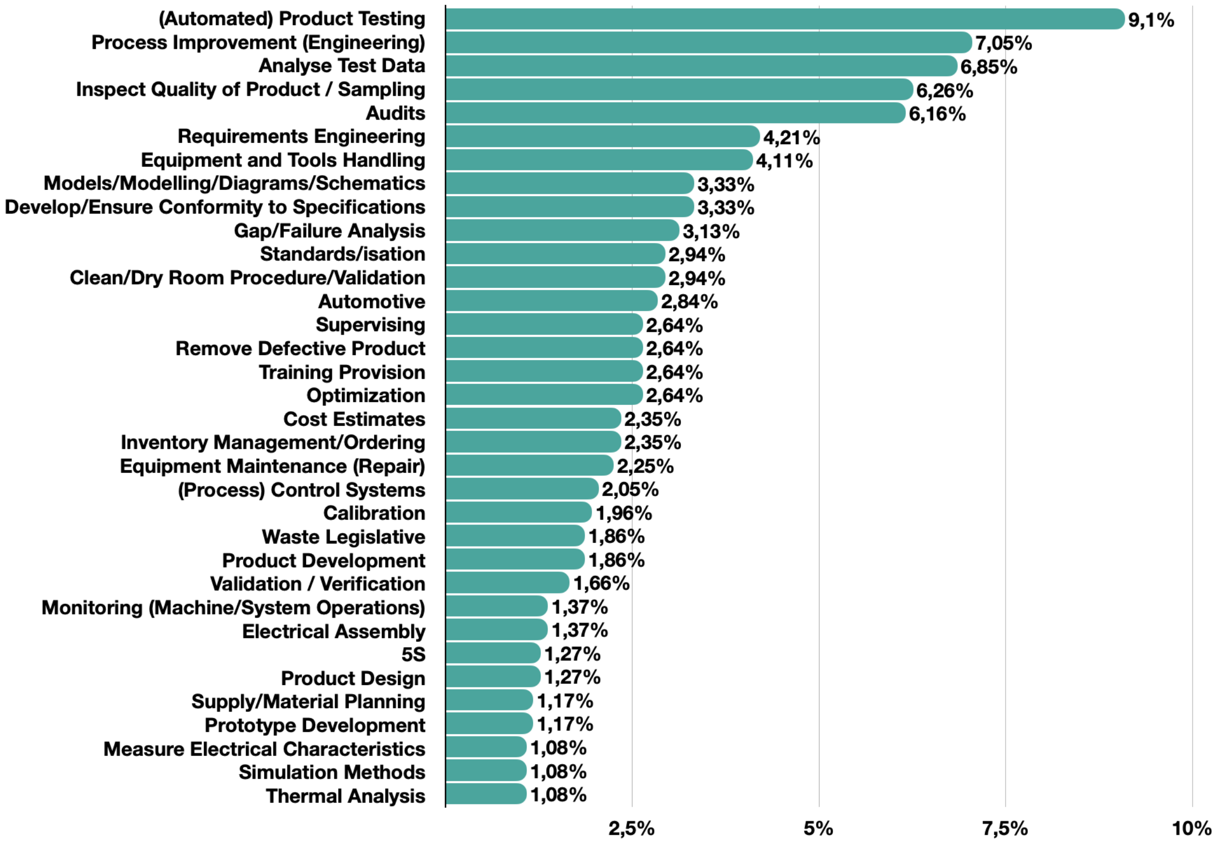

Figure 35: Quality - Cross-sectoral Specific Skills

Figure 34 and **Figure 35** represents selected, the most occurring cross-sectoral specific competence for quality.

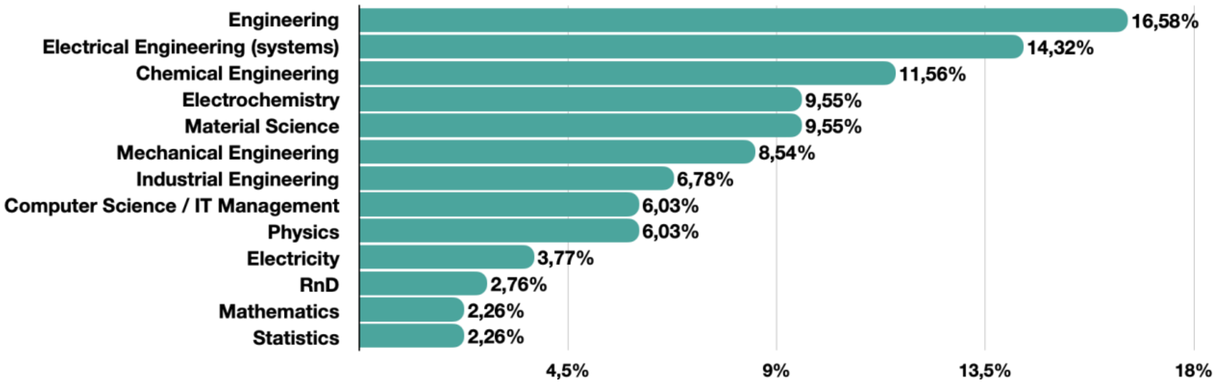

Figure 36: Quality - Academic Competence

Figure 36 represents selected, the most occurring academic competence for quality.

4.4.5 Practical Recommendations and Considerations

Battery technology and production: in the case of quality-related positions in battery production, it is vital to have skills and knowledge on battery technologies and related manufacturing processes and associated standards and legislation. Therefore, we recommend providing education and training in the following areas:

- battery technologies, systems related development
- battery production processes
  - electrode production, cell assembly, and pack formation
  - battery system components
  - automated systems
  - high-volume production
- raw materials (analysis)
- material flows and inventory
- battery testing and quality control
- risk and safety procedures, hazard analysis

Quality management systems and methods: Although universal and not specifically battery specific only, we recommend strengthening skills and knowledge related to quality management systems and methods:

- **Standards**
- **Legislation**

- **The Quality Management Systems, methods, and related aspects/issues:** (1) Quality systems such as ISO 9001 and 14001, IATF16949; (2) Methods such as TQM, Kaizen, PDSA, Six Sigma, Lean Manufacturing; (3) MSA's (Measurement System Analysis); (4) Quality KPI's; (5) Auditing: (5a) developing and implementing quality control audit plans; (5b) evaluating production stages; (5c) testing the composition appearance and functionality of completed products; (5d) documenting defects and suggesting improvements; (5e) reporting; (6) Overall continuous improvement
- **Sampling**
- **Training other employees on quality standards and procedures**
- **Quality control in production processes**
    - **Quality Assurance includes:** (1) Material and cell validation; (2) Advanced product quality planning; (3) Production part approval process.
- **Testing standards**
- **Testing methods and means:** (1) Intrusive or non-intrusive and destructive or non-destructive; (2) Testing infrastructure; (3) Application of the state-of-the-art methods and devices; (4) Postproduction quality checks; (5) Quality monitoring; (6) Cooperating with research and development

Supporting skills and knowledge: In addition to the above, we recommend enhancing the following: (1) Electrician, technician, and electric engineering-related VET/higher education; (2) Laboratory work skills and experience; (3) Planning and maintaining cleanrooms and dry rooms; (4) IT skills; (5) Language skills (English); (6) Teamwork skills; (7) Complex problem solving and process optimization; (8) ERP systems; (9) Lifelong learning of relevant skills and knowledge; (10) Understanding and complying with customer requirements and satisfaction; (11) developing, defining, and executing the qualification process and documentation for customer's feedback.

Target Groups: Educational institutions, battery producers, recruitment companies, talent acquisition experts, consultants

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4.5 OTHER ASPECTS (DEPARTMENTS)

This section describes other aspects of battery manufacturing, mainly the purchasing, human resources, finances, sales, and digitalization with its respective departments and needs.

4.5.1 Purchasing

This department deals with purchasing in different areas such as materials, equipment, services, construction, and infrastructure or purchasing dedicated to a specific project. For example, in the case of Northvolt, they also have a localization team within the purchasing department responsible for attracting suppliers to locate their facilities nearby. This team works in tandem with local or regional authorities and helps suppliers to navigate in the process of establishing themselves in the proximity of the battery manufacturing plant.

Skills agenda: Most of those dealing with purchasing are white collars working as **managers, material engineers, purchasing coordinators, purchasing specialists, category managers, raw material specialists, procurement analyst,** etc. Master's degrees in purchasing, logistics, sourcing is among the ideal education backgrounds.

Partial quantitative analysis is done as a joint with the logistics department in **section 4.3.1**.

Practical Recommendations and Considerations:

Strengthening competencies related to battery specific purchasing: purchasing skills, raw materials, raw material market, managing raw material deliveries (hazardous materials – chemical safety and waste handling), identifying market requirements for documentation, raw material related production equipment, battery production equipment, equipment, and tools handling, mechanical engineering, an inspection of product quality/sampling, process improvement and product testing.

Strengthening knowledge: battery materials, the global trends, analysis methods, production processes, safety procedures, business processes, product quality assurance, laws and regulations, environmental management, social responsibility, orientation in global politics and mineral conflicts complexities, communication (with suppliers), automation

Strengthening **language skills.**

Target Groups: educational institutions, producers and manufacturers in the battery value chain, recruitment companies, talent acquisition experts, consultants.

4.5.2 Human Resources

Like other industrial and manufacturing companies, the human resources department in a Gigafactory can deal with various issues including recruitment, headhunting, retention of workers, brand/talent attraction issues, personal development, work contracts, payrolls, workplace issues, labour law, and may also be dealing with trade unions.

It administrates personal data of the employees, deals with relocation (visas, migration, housing, schools, “feel at home” programs), and is responsible for onboarding and training (virtual, on-the-job, internships turned to employment), etc. Women might be the dominating gender within the human resources department.

Skills agenda: In terms of job roles and required skills, an industry background is less critical. Employees do not need to have battery education or background, while experience in recruitment and the attracting potential new employees are valued. Creativity, the ability to get used to quick thinking in the fast-growing industry, quick adaptation to the start-up situation in the case of some of the Gigafactories are also valued qualities.

Regarding the nature of the workforce and the expected speed of the organizational growth in upcoming Gigafactories, additional resources working with migration, relocation, onboarding, and integration can be expected to be needed compared to already established industries.

Since most of the employees joining the industry lack the necessary experience, the internal technical training team is of the highest importance (they need experience in building up training strategies, setting up training, and operational knowledge of a broad range of training methodologies). As employees of the Gigafactories are being recruited from various countries, cross-cultural communication skills are required from the human resources personnel.

With the increasing number of people being hired into newly built Gigafactories, AI can be introduced to the recruitment processes, helping to handle the workload, e. g, pre-processing of job applications.

Practical Recommendations and Considerations:

Recruitment needs[72] - HR-related roles include, for example: (1) Recruiters; (2) Office managers and coordinators; (3) Training specialists; (4) Training content developers; (5) HR coordinators; (6) specialists.

For the HR employees, industry background is less critical, and they do not need to have battery education. However, technical production and industry understanding is recommended.

Human resources specific: We recommend paying attention to the following **knowledge** when training and educating employees on HR-related positions in battery manufacturing companies: (1) Talent acquisition in general; (2) Human resources (management); (3) Labour legislation is important to understand in the recruitment processes (including labour unions); (4) Understanding general employee wellbeing related issues such as health and safety standards; (5) HR strategy development, benchmarking best practices.

With the **skills** that are needed to support the human resources-related functions we recommend the following: (1) Recruitment related skills are needed; (2) Training, both organizing and providing it – collaboration with various teams and persons with adequate technical background and skills inside the organization (for example manufacturing); (3) Process Improvement to continuously develop the HR mechanisms (talent acquisition and beyond); (4) Change Management – The pace of development in the battery industry is fast and continuous, especially with a start-up; (5) Sales and marketing skills (including social media) are required to sell and promote a company to potential employees and to support the recruitment processes.

Technology/industry-specific: It is beneficial to understand the industry where you are recruiting and operating. We recommend paying attention to the following **knowledge** when training and educating employees on HR positions in battery manufacturing:

- Manufacturing Engineering
- Battery Industry

[72] Northvolt interview, 28.5. 2021

- Process Industry

Other supporting skills and knowledge: (1) Due to an increasing share of the potential employees being from overseas, cross-cultural communication, relocation processes, and social integration are important; (2) Supervising, teamwork, networking, communication, interpersonal, and reporting skills; (3) English and language skills in general; (4) Coordination and administration; (5) Due to the increasing level of digitalizing and automation also in the HR processes such as managing volumes of applications the following skills are beneficial – analysis methods, artificial intelligence as well as general IT skills; (6) Problem Solving/Troubleshooting.

Target Groups: Educational institutions, companies in battery manufacturing, recruitment companies, head-hunters, consultants, government employment agencies.

4.5.3 Finance

A finance department in Gigafactories is like those in other companies in other fields of business. Characteristic to the battery manufacturers is that most of them are in a start-up or early stage. Raising capital is needed to finance building and developing a company, including all its functions from R&D to business development, recruitment, buying materials, ramping up production, etc. Therefore, they may have regular huge investment rounds occurring even more than once per year. Due to those reasons, the financial departments in battery manufacturing companies are bigger than in a start-up or early-stage company in general.

Skills agenda: Depending on the position, the education requirements include a degree in: (1) accounting; (2) business; (3) finance; (4) controlling; (5) economics or similar.

Having several years of work experience is preferred. Occasionally, experience beyond finance may be required. For example, in the Analytics and Performance Manager’s position, manufacturing business experience from a technical environment is required.

Skills required in a financial department include experience with:

- ERP systems,
- Microsoft Office tools

- Business intelligence solutions

Experience and willingness to work in teams are needed. Additionally, good communication skills, flexibility, sense of quality, can-do attitude, ability to cope with high-pressure international environments, and willingness to take new challenges are desired skills and abilities. Battery manufacturing is a fast-moving business, thus requiring a high level of energy and enthusiasm.

Examples of Finance related roles:

- Business Controller
- Tax Manager
- Financial Controller
- Accountant
- Project Controller
- Analytics and Performance Manager

4.5.4 Sales

In the case of battery manufacturers and using Northvolt as an analog battery manufacturer start-up here, generally, the sales as a function have evolved from attempting to find customers into business development. In the case of Northvolt's early stage, it was about creating strategic partnerships, finding, and approaching connections. However, these days it is not uncommon for customers to come to battery manufacturers because of the development of the past five years.

What is characteristic of a sales department of a battery manufacturer is the emphasis on **building partnerships with customers**. Depending on their products and field of business, **each customer wants their battery cells to behave differently and uniquely**. Consequently, a high engineering involvement is needed in these teams, if compared to many other industries. There are dedicated engineers involved with the sales processes. They, for example, work with the sample development.

Skills Agenda: In the case of Northvolt key account teams, with 15-25 members in different roles, have been formed around the customers. The roles include, for example, **technical sales managers, key account managers, technical project managers, customer service manager, and coordinators**. Key account managers collaborate internally with cell designer teams. Technical project managers also work with customers. The coordinator's role is about fulfilling documentation requirements that are high among target industries.

Most of the sales staff do have an engineering background, but there are also those with pure business background with experience from automotive or any other target industry.

Regarding the future development of sales and the related roles, it can be assumed that the importance of having and managing relationships will never disappear.

Practical Recommendations and Considerations:

Recruitment needs[73] **-** sales/business development related roles include, for example:

- Key Account Manager
- Business Development Manager
- Senior Director Business Development
- Lead Application Engineer
- Sales & Customer Support Specialist

The usually recruited staff members have a technical background and previous experience. For example, existing relationships and know-how about navigating within the target industries are challenging to find. On the other hand, those working in coordinator roles can be relatively junior and freshly graduated.

Battery technology: with sales-related positions, it is important to have at least basic **knowledge** of battery technologies. Therefore, we recommend providing education and training in the following areas: (1) Basic electrical engineering knowledge; (2) Understanding of battery systems including energy storages, design, and components as well as the related industry; (3) Safety with batteries: functional and related procedures; (4) Understanding Product Quality Assurance; (5) Basic information of the potential target markets and industries (for example automotive industry, raw materials market).

[73] Career. Northvolt. (2021, October 25). Retrieved August 5, 2021, from https://northvolt.com/career/.

With the technical **skills** that are needed to support the sales department/functions, we recommend the following:

- Prototype and sample development
- Standardization
- Battery cell structure
- Understanding sustainability as one of the selling points

Business development/sales: we recommend paying attention to the following **knowledge** when training and educating employees to sales-related positions in battery manufacturing companies: (1) Market trends; (2) Understanding business management (how to do business in the battery ecosystem); (3) Value chain and overall ecosystem; (4) Strategy Development; (5) Legislation - understanding the battery-related legal framework of each market area (for example EU, North America) and the framework around setting up contracts; (6) Benchmarking - ability to identify and apply best practices in several areas such as how to operate in a specific market sector/area; (7) cross-cultural communication when selling to foreign markets/cultures (both knowledge and skill).

With the business development related **skills,** we recommend paying attention to the following: (1) Understanding the markets, their requirements, how they function, and how to operate in them (product, price, place, promotion, etc.); (2) Product Management; (3) Sales related skills; (4) actual sales functions/measures; (5) pricing mechanisms; (6) contracts; (7) understanding purchasing mechanisms in the target markets (for example, auto industry); (8) interpersonal skills; (9) negotiating - documentation skills (documentation requirements are high among target industries); (10) Communication and interaction with customers - to understand customer needs and requirements (ensuring conformity to customer's specifications); (11) building and managing partnerships.

Other supporting skills and knowledge: (1) Teamwork - Internal communication; (2) Leadership; (3) Project Management; (4) Presentation skills; (5) Language skills (English is the most important, but also other major market area related language skills recommended); (6) ERP systems (SAP, etc.); (7) Coordination.

Target groups: educational institutions, companies in battery manufacturing, recruitment companies, head-hunters, consultants.

4.5.5 Digitalization

Digitalization and automatization of the Gigafactory ecosystem and other aspects of battery manufacturing are being considered and developed by various battery producers or research institutes, such as the Fraunhofer institute.

Overall improvement in production times or energy consumption is improved with the addition of cutting down the human resources by implementing mechanization, automation, digitalization, IoT, and cloud-based service concepts.

Digitalization can improve and optimize the scrap management and overall production chain. Other essential aspects are: (1) traceability concepts of manufacturing data, which enables to track the production more efficiently and development of digital twin; (2) digital twin is a model based on the production data and represent characteristics of the physical product which will self-adapt and due to the machine learning/deep learning which is being implemented- this leads to the establishment of predictive maintenance; (3) modelling and simulation throughout the whole manufacturing process, this leads to the life cycle optimization.

Skills Agenda: Battery manufacturers and new Gigafactories are expected to leverage digitalization and may have dedicated digitalizing teams whose name and setup vary from company to company. These teams support production and related traceability by working with the software used in various machines, integration, cloud management and data handling, and general IT support. The automatization of systems in different levels and functions such as production, quality, logistics, human resources will require personnel, not excluding blue-collared, to be more and more IT skilled – data science, physical/machine learning modelling of battery manufacturing system and other experience will be required. In addition, earlier mentioned application of Digital Twins and Virtual Reality for training and education further emphasizes the **need for IT/digital skills**. In terms of staff and talent, there is a substantial need for IT skilled people in various levels from production floor operators to engineers, etc. **Software developers and engineers** are generally very much in demand. For example, in maintenance, the teams responsible for maintaining the machines must do it together with maintaining software systems.

Practical Recommendations and Considerations:

- Overall digital skills should be focused when it comes to the volume battery production
- Concepts of traceability, digital twin, or machine learning/artificial intelligence should be considered as important
- Modelling and simulation on different levels – cells, packs, overall battery systems, etc.
- Data analytics, data science, big data
- Automation

Target groups: battery producers, industry, and academia in need of digital development and mentioned concepts.

5 Battery Integration, Modules, and Packs

Battery integration covers the process of pack compilation, where the pack usually consists of several blocks of battery modules, battery management systems, and other systems, for example, thermal regulation systems.

This part of the value chain concerns different aspects such as: (1) testing and validation (end of line testing and other related tests – functional testing, performance testing, connection scanning, electrical testing, calibration, part checks); (2) electronics packaging (electrical insulation, mechanical links, and other, optimization in terms of heat transfer); or (3) safety aspects and risk mitigation (related mainly to the thermal runaway and explosion), which is being assured by BMS, where different topologies may be implemented to keep the battery within the safety operation region in terms of voltage, current, and temperature during the charge, discharge, and some instances at open circuit. Furthermore, regarding the BMS, other features and functions are observed and implemented: (1) monitoring of voltage; (2) contactor control; (3) isolation monitoring; (4) temperature measurement and control; (5) state of charge, health, and other metrics' measurements.

A different perspective can be taken on a more general level, where different integration processes can be described for various battery applications – from cell to complete battery system and how it is connected to the application (EV or stationary battery system).

Example of the automotive integration process:

- Integration of cells into the battery module
- Integration of the battery modules with an electronic unit
- Integration of the battery into the car

In parallel:

- ECU SW component integration; ECU SW integration; ECU target system integration; ECU system qualification.
- Consideration and assessment on Automotive SPICE and ISO26262 and other standards.

Example of the maritime integration process:

- Assembly of the battery modules
- Assembly of pack controller

- Integration into vessel

Example of stationary applications integration process:

- Assembly of battery modules
- Assembly of battery racks
- Integration in a proper enclosure
- Integration with power conversion system and grid interface

5.1.1 Skills Agenda[74]

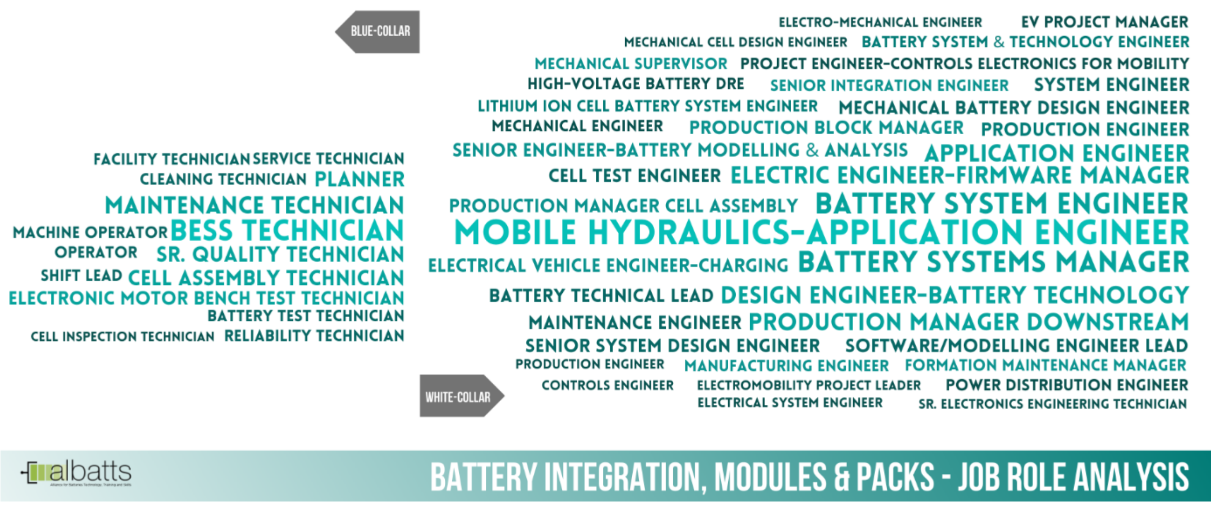


Figure 37: Battery Integration, Modules and Packs - Job Role Analysis | Blue Collars

Figure 37 shows the occurrence analysis of the job roles for the battery integration, modules, and packs. Blue-collar workers observed are having expertise in **battery analysis; testing; quality**; and others. White-collar workers are having expertise in **testing; software development; modelling; battery systems; battery management systems; validation; electrical engineering; design**; and others.

[74] Definitions and methodology are described in the methodology section, this is covering the development of the analysis within this chapter.

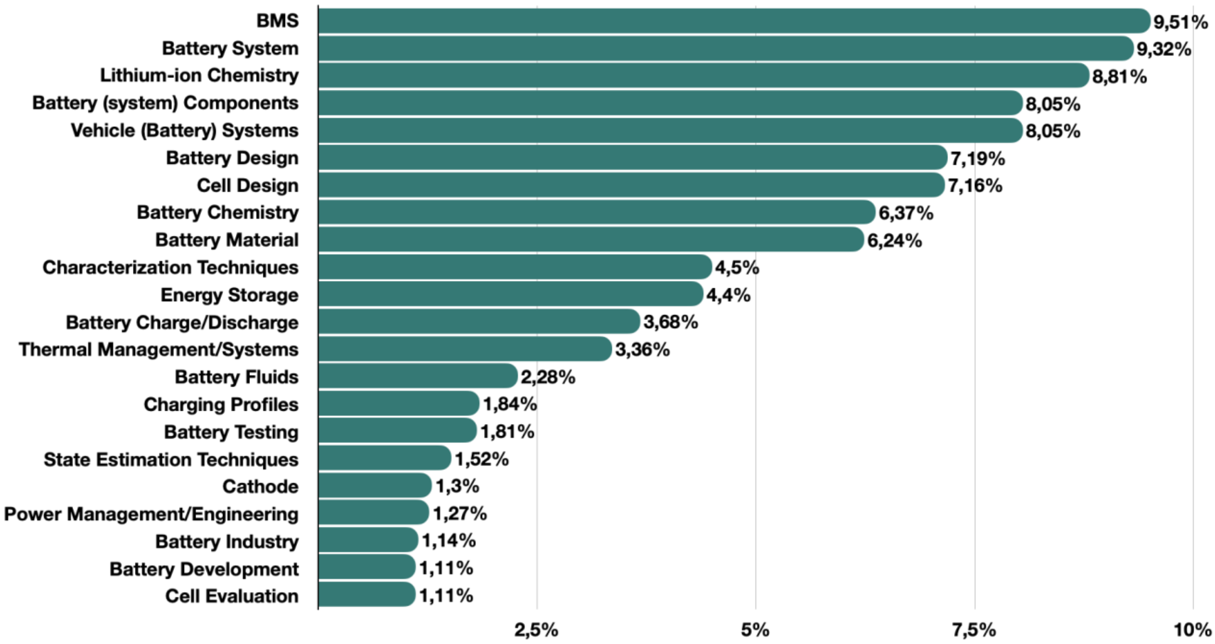


Figure 38: Battery Integration, Modules and Packs - Sector-Specific Competence

Figure 38 represents selected, the most occurring sector-specific competence for battery integration, modules, and packs.

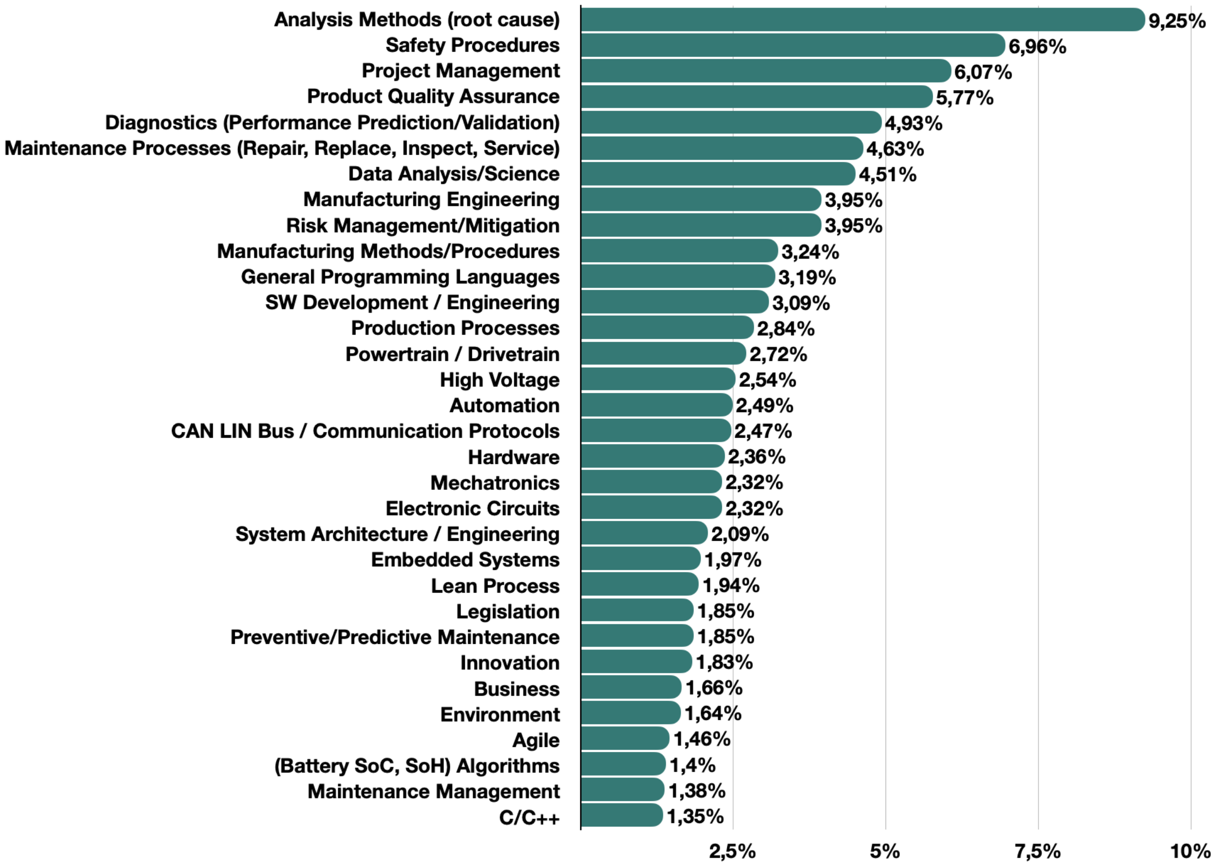


Figure 39: Battery Integration, Modules and Packs - Cross-sectoral Specific Knowledge

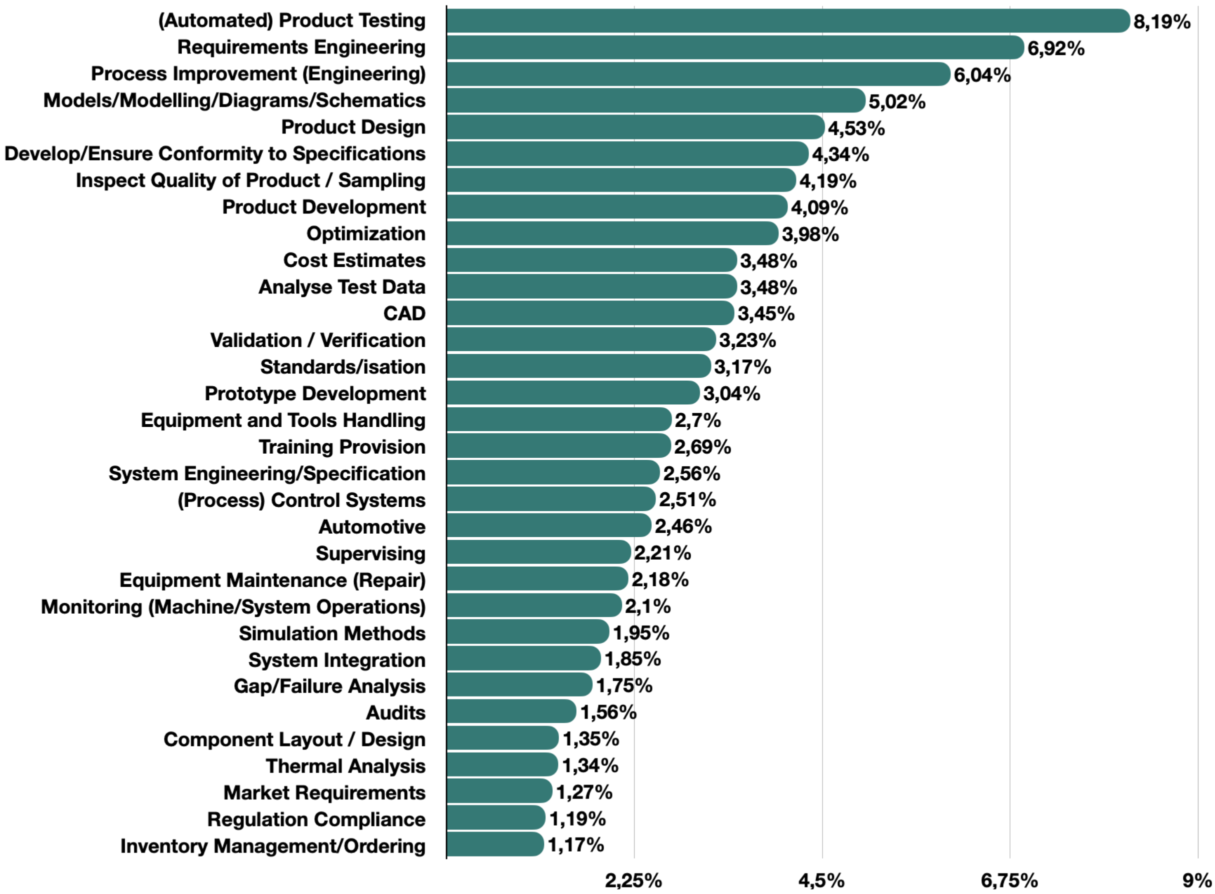


Figure 40: Battery Integration, Modules and Packs - Cross-sectoral Specific Skills

Figure 39 and Figure 40 represents selected, the most occurring cross-sectoral specific competence for battery integration, modules, and packs.

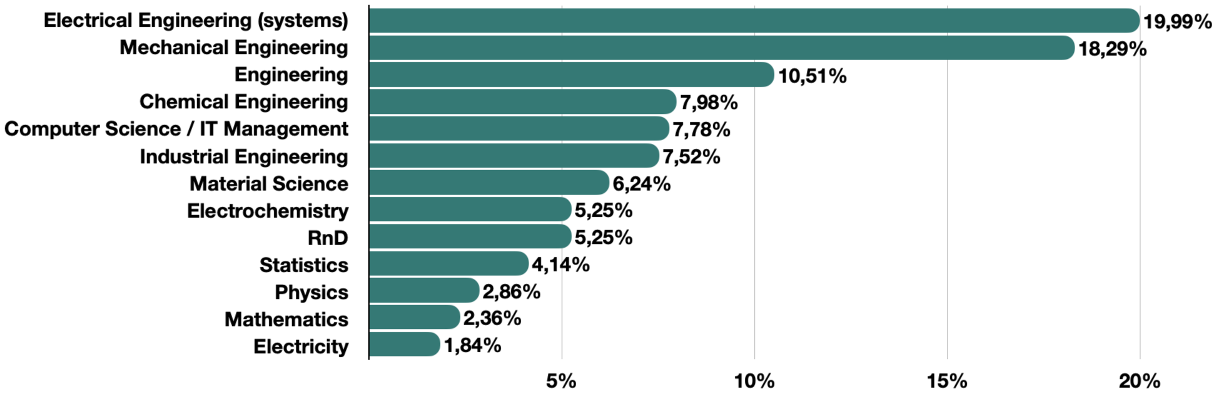


Figure 41: Battery Integration, Modules and Packs – Academic Competence

Figure 41 represents selected, the most occurring academic competence for battery integration, modules, and packs.

5.1.2 Practical Recommendations and Considerations

- Strengthening competence in BMS development to achieve development in efficiency, predictable behaviour, and risk mitigation – concern is a battery system safety;
- Understanding the battery systems topologies and components
- Research and development within the BMS – concern is a battery system safety; efficiency and more advanced features of the system;
- Development of more efficient SoC and SoH algorithms;
- Battery integration and control - testing of integrated battery system within the application;
- Development and improvement of a framework for quality assessment and assurance;
- Development and research on BTMS - thermal management issues and other aspects – (1) safety; (2) physical or mechanical performance; (3) durability; (4) ripple current; (5) accuracy of measuring instruments; (6) materials for fire resistance and electronics packaging,
- Strengthening of cooperation between integrators, manufacturers, and BMS suppliers.
- Development of competence within the standardization and frameworks for integration process and procedures of battery modules and whole systems.
- Overall digital skills

Target groups: battery integrators; BMS manufacturers; modules and packs manufacturers and integrators; and other system manufacturers.

6 The Operation, Repair, and Maintenance

Information related to the operation, repair, and maintenance is extensively described in the outputs of WP4 and WP5 Sectoral Intelligence reports for stationary and mobile applications. Therefore, this section will contain an executive summary for both outputs.

The operation, repair, and maintenance on an overall level is concerned with the application of batteries and battery systems in mobile or stationary applications, needed competence, and occupational profiles.

6.1 STATIONARY APPLICATIONS

Main areas of interest and trends identified for stationary applications of batteries with provided recommendations on how to further boost the development and availability of the skills and competences are the following:

- General Stationary Applications
- Cost-efficiency
- Safety
- Resiliency and/or Self-sufficiency
- Sustainability

Sub-areas of interest or sub-trends are listed below each main area of interest or trend description below.

6.1.1 General Stationary Applications

In **General Stationary Applications**, we study the trends that are related to the use of battery energy storage systems (BESS). Based on them we recommend further actions.

Various needs as well as the provided benefits in heavy-duty, grid/off-grid, and telecom applications are increasing the use of BESS. These include for example

- supporting the process of reaching sustainability goals by combining BESS with variable renewable energy (VRE) systems and
- bringing resiliency and reliability with backup systems.

What we recommend is further training on understanding

- the battery energy storage technologies,
- the areas of applications,
- system integration and
- management skills.

The heavy-duty use areas of applications position the reliability of a power supply as an area of high importance. Consequently, the need for skills related to maintenance and repair is highlighted. The main job roles supported by the trends include for example

- **application engineers,**
- **energy storage project engineers** and
- maintenance positions such as **field service engineers** etc.

Sub-areas of interest or sub-trends:

- Increased need for energy storage with heavy-duty applications
- The proliferation of battery energy storages commercially in public places
- Growing competition in the energy storage market
- 5G cellular network deployment, batteries in telecommunications
- Commoditization of base stations
- Grid and off-grid systems and applications
- Smart grid

6.1.2 Cost-efficiency

Not unlike industries and markets in general, **Cost-efficiency** is a common driver of development with battery energy storage.

The application of stationary battery systems to decrease electricity costs is a driving force for the increasing use of stationary batteries. Solar and wind power systems are intermittent. Consequently, they need to be supported with integrated batteries to provide electricity also at night and in less windy conditions. Additionally, the periods when electricity prices are lower, for example at night, can be exploited with batteries.

Those working with BESS with the aim of cost efficiency, in various ways, include:

- technical staff
- personnel for enabling managing the business side and smooth customer interaction from consultants to sales-related roles

Our recommendations on education and training include:

- understanding battery systems
- electrical engineering
- project planning
- ability to build models along with performing energy-related cost calculations

Sub-areas of interest or sub-trends:

- Decrease electricity costs by placing stationary battery systems

6.1.3 Safety

As **Safety** is always paramount, there is high importance in creating regulations and legislation that cover it in the context of batteries. There are risks related to battery fires as we have identified in our previous research.

In the context of batteries and safety we have identified for example the following job roles:

- **safety managers** and
- **safety specialists**
- knowledge and skills on safety for **installation/service technicians**

There are also other significant roles that supporting safety:

- **test engineers,**
- **inspection technicians,**
- **auditors**, and beyond.

We recommend gaining an understanding of the **battery-related safety issues** and **existing regulations and legislation**. In this context, we emphasize the need to create and update electrical equipment regulations and legislation accordingly to ensure the safety of users

We also recommend the training that is needed when disaster strikes: ensuring that **firefighters** possess adequate skills.

Sub-areas of interest or sub-trends:

- Create regulation and legislation on the topic of battery safety

6.1.4 Resiliency and self-sufficiency

Resiliency and self-sufficiency are important qualities with systems that have a critical role and of which functionality must be consequently ensured and troubleshoot. With battery energy storage it means availability of power in any conditions and circumstances. The areas in which availability of electricity is paramount include for example military applications, offshore oil, and gas operations as well as telecom systems. Batteries act as backup power systems for blackout situations. Integrated with VRE, BESS provides an intermittent power source.

The job roles in this context include various engineer positions that are needed in consultant roles. They include for example

- **battery system engineers**,
- **energy engineers** and
- **application engineers**.

Maintenance roles are important due to the critical nature of batteries in this context. Therefore, we recommend training on maintenance and repair-related skills in addition to the battery technology-related skills that are needed with integrating BESS with renewable systems.

Sub-areas of interest or sub-trends:

- Increasing BESS use in military applications
- Increasing use in offshore oil and gas applications + vessels

- Base stations need batteries to support their power requirements
- Provide electricity in remote places where centralized electricity is not sustainable
- Transfer from lead-acid batteries to Li-ion batteries in cellular network base stations

6.1.5 Sustainability

The **Sustainability** element of batteries is realized with second life application, integration of battery systems with renewable energy sources, the need for sustainable resilient base stations, and beyond. While batteries support sustainability the sustainability of the batteries themselves is important as well.

With second life application, we have discovered such job roles as cell test engineers and various other engineer positions. The recommended skills include testing, quality inspection, and repairing.

The integration of renewable energy systems needs engineers with various skills from battery systems to algorithms.

With the base stations, sustainability and resiliency are being realized, for example, by moving from using diesel generators to the application of batteries as backup systems. There are several job roles in this context such as battery maintenance-related, inspectors, business developers, safety specialists, and beyond. With related skills, we identified for example project management, skills related to the sustainability of base stations, and engineering competencies related to batteries and their integration.

Sub-areas of interest or sub-trends:

- Second life applications
- Integration of battery systems with renewable energy sources, with the goal of decarbonization
- The need for sustainable and resilient base stations

5.6.4 Other Industrial and Stationary Battery Applications

The following applications and areas are shortly introduced and linked.

Data Centres: Usage of batteries and UPS systems as a backup power source. The chapter discusses the criticality and essentiality of these battery applications and related issues of carbon footprint, renewable energy applications and various trends of shifting towards batteries from diesel generators as a backup solution - **Access the chapter**

Renewable Power Farms: Application of Battery Energy Storage (BESS) in the context of renewable energy and connected trends such as the war in Ukraine, policy, energy diversification, and compliance with the Green Deal. The most significant renewable energy sources are covered: 1) wind power farms, 2) hydroelectric power, and 3) solar plants - **Access the chapter**

Heavy Work Machines: Entering the border between the stationary and mobile applications of batteries, namely in 1) mining equipment; 2) forest machines; 3) cargo handling, and 4) heavy construction equipment.

Mainly the trend of replacement of diesel-powered machines with electrified or hybrid solutions is discussed - **Access the chapter**

BESS in Residential Applications: Reasons and trends causing BESS solutions and renewable energy demand in residential areas and facilities are discussed - **Access the chapter**

Job roles and skills needs within this domain were analysed and categorised by the production lifecycle. The following categories were identified, and needed skills and job roles based on the job advertisements were outlined:

- Design and Development;
- Manufacturing;
- Maintenance;
- Sales, Services, and Support or Technical Project Management.

Please see the following chapters for more details:

- Industrial and Stationary Applications

6.2 MOBILE APPLICATIONS

Main areas of interest and trends identified for mobile applications (passenger EVs and maritime vessels are being focused on in this report) of batteries with provided recommendations on how to further boost the development and availability of the skills and competences are following:

- EV Battery servicing, repair, and dismantling
- EV customer needs and related services
- Autonomous driving, vehicle to grid
- EV Testing, certification, type approval, roadworthiness tests
- Electrification of vessels

The overall need for skills/competence and knowledge on electric drives and EV technology is needed as well.

Sub-areas of interest or sub-trends are listed underneath each main area of interest or trend description below.

6.2.1 EV Battery servicing, repair, and dismantling

Activities and trends related to servicing, maintenance, repair, and dismantling of batteries installed in electric passenger vehicles. Skills and competence for EV batteries maintenance and repair that need to be strengthened include especially these areas: EV and battery diagnostics and repair in general; troubleshooting; high voltage competence and qualification; battery charge and discharge; battery management systems; safety; relevant standards and regulations knowledge. The lack of workers with high voltage qualifications seems to be rather urgent. Knowledge, and skills in second life, safe handling, refurbishment, and recycling of batteries, digitalization, and traceability of battery lifecycle are also needed when dismantling the EV battery. Dealerships and vehicle repair shops need to be adjusted, especially in terms of safety. They often need to build and operate charging stations at their premises, sometimes complemented by storage systems and solar panels. VR/AR training environment may be efficient means of training delivery in this area.

Sub-areas of interest or sub-trends:

- Servicing, repair, and maintenance of electric vehicles and EV batteries
- End of life – dismantling of batteries
- Adaptation of dealerships, service, and repair shops

6.2.2 EV customer needs and related services

Selection of customer services related to the operation of EVs and their batteries. The range and volume of information provided in dealerships can vary across the regions. Methodological guidance, such as different manuals and training to the employees in dealerships, car rental, or shared mobility companies, could help in this regard. When it comes to smart charging and fleet management business, competencies in many areas need to be combined - **battery and charging systems, business and software development, telematics, and grid functions**. Companies dealing with charging infrastructure design, installation, and maintenance also need various competencies – including **engineering, mastering building permit processes, battery-relevant safety, or IT and payment solutions**. First-responders, **fire fighters**, and rescue services need new methods, tactics, and specific training to deal with emergencies related to EV batteries. Research and development of new extinguishers or procedures will need to react to current and future battery technologies. We can also expect higher demand for towing and mobile charging services in the future. Competence within the **driving schools** should be updated, together with teaching materials, and strengthened to facilitate the electrification of road transport and structural changes in the automotive sector.

Sub-areas of interest or sub-trends:

- Advising customers in dealerships, car rentals, and secondary market
- Smart charging, fleet management, data sharing services
- Charging infrastructure design, installation, and maintenance
- Rescue services, roadside assistance
- Education in driving schools

6.2.3 Charging and Charging Infrastructure

Batteries are electrochemical sources of electrical energy. When the battery is connected to a device, the battery starts providing the power, and a chemical reaction occurs. Power transfer could be supported by cables in traditional circuits or wirelessly.

Cable power transfer is the most reliable connection possible, with the capability to transfer large amounts of energy with the lowest power losses. **Wireless** power transfer is more user-friendly, with no need to plug in cables; however, the power transfer is less effective. Several types of wireless transfers are usually based on electromagnetic principles; nevertheless, not all can provide enough power for mobile applications such as electric cars or buses. Typically, vehicles are charged slowly using **AC** (alternating current) up to 22 kW or fast via **DC** direct current up to 350 kW.

Battery Degradation due to charging

Understanding the battery degradation during fast charging is crucial to improving battery performance and lowering the concerns of electric vehicle owners. High current and voltage stress the battery's internal structure, as lithium ions are forcefully extracted from the positive electrode, transferred by the electrolyte, and subsequently to the negative electrode, potentially forming cracks that threaten the battery's life.

Fast charging can recharge the battery quickly; however, the side effect is excessive **heat** production. When this heat is not managed correctly, it can lead to chemical reactions, physical changes, and the growth of so-called **"dendrites"** that endanger the functioning of the battery.

Low temperatures can also negatively affect the battery's performance and lifespan. When the battery is fast charged while cold, it can lead to the "**lithium plating**" effect when lithium atoms are not transported into the anode but accumulate on its surface, potentially leading to short circuits and battery failure.

To reduce or eliminate the adverse impacts of the temperature, manufacturers use **battery management systems** that manage charging power and battery cooling and heating when needed.

Charging Principle

Charging of a battery slows down at around **80%** of the state of charge (SoC) due to **increased heat**. The charger switches to a slower mode for the remaining 20% to **stabilise** the battery's ions, preserving its lifespan and health. As a result, the time needed to charge the battery from 80% to 100% can be similar to the time required to charge from 0% to 80%.

Some applications provided by vehicle manufacturers and some charging point operators (CPOs), enable charging stops at various limits, such as 80%, 90%, or 95%. Such a limitation can reduce waiting times for other electric car users, increase charging point utilisation, and improve overall efficiency.

6.2.4 Autonomous driving, vehicle to grid

Relates to technical areas of autonomous driving and vehicle to grid (V2G) concepts and services. As EVs seem to be easier controlled by autonomous systems than ICE vehicles, they are an essential driver of autonomous mobility. **Cybersecurity** skills/competence and knowledge related to the mobile applications of batteries in electric vehicles need to be prioritized when applying concepts of autonomous vehicles to ensure customer safety and privacy. When it comes to the Vehicle to Grid concept, it can bring crucial opportunities not only for improving renewable energy sources integration into the energy grid. Battery and grid-relevant knowledge, together with **IT skills**, will be needed to be strengthened.

Sub-areas of interest or sub-trends:

- Autonomous driving
- Vehicle to grid (V2G) concept

6.2.5 EV Testing, certification, type approval, roadworthiness tests

Focuses on activities and trends related to technical aspects of electric vehicles and charging infrastructure before they can be placed on the market and put into operation and periodic roadworthiness tests of electric vehicles. Relevant technical expertise is closely linked to

legislation and standards knowledge. Given the systemic shift and increasing complexity of the process of testing and homologation brought by EVs, massive investments in new technologies and systems for testing, certification companies, and technical services need to be made. At the same time, employees of these companies will need to expand and improve their knowledge and skills, especially in electrical and **high voltage** fields and **interoperability**. In addition, these companies usually cover testing of charging infrastructure as well. Among others**, digital communication, grid connection guidelines**, and different **safety standards** must be complied with. So far, specific processes for EVs during periodic roadworthiness tests do not exist. However, with the increased number of EVs in operation and development of the used cars market, attention to this area could be expected, as well as a need for upskilling existing employees or hiring new ones.

Sub-areas of interest or sub-trends:

- Testing of electric vehicles
- Testing and certification of charging infrastructure
- Type approval of electric vehicles
- Periodic roadworthiness tests of electric vehicles

6.2.6 Electrification of vessels

Vessels travel across the oceans and can be more challenging to reach for service personnel than an electric road vehicle. For this reason, **remote diagnostics** and **over-the-air updates** are necessary. Apart from battery-related expertise (such as electrochemistry, high voltage qualification, or mechanical engineering), **digital technology competence** (remote diagnostics & fault finding, cybersecurity, data transfer, communication protocols, etc.) is crucial. Like electric vehicles, electrified vessels are better suited for autonomous sailing. Therefore, strengthening the skills and training people in digital technology for autonomous systems **- data scientists, test engineers, software developers, cloud solutions experts, and cybersecurity experts** and **engineers**, is necessary. For product design and consulting, combining skills of internal combustion engines, batteries and programming are crucial. In addition, knowledge of **safety requirements** for maritime should be strengthened (e.g., thermal management, off-gas handling, system-level safety, or risk evaluation).

Sub-areas of interest or sub-trends:

- Servicing – remote diagnostics, repair, and maintenance of electric vehicles
- Autonomous electrified vessels
- Customer product design, consulting, fleet management

6.2.7 Other Mobile Battery Applications

The following applications and areas are shortly introduced and linked.

Heavy-Duty Vehicles: Mobile applications of batteries in trucks, buses, and utility vehicles are discussed in the context of where they stand in electrification. Specific technologies and trends are discussed - **Access the chapter**

Vans: Vans' electrification and specifics compared to the other commercial vehicles are drawn - [Access the chapter]

Motorbikes, Micro-mobility, e-bikes: The electrification and connected trends of customer demand and new business models of shared mobility connected to motorbikes, micro-mobility, and e-bikes are discussed - [Access the chapter]

Aerospace: The usage of batteries in space applications such as spaceships or satellites is being discussed. Other applications in drones or planes are outlined - [Access the chapter]

Inland Waterway Vessels: Electrification of vessels in city centres and areas where clean air is desired - [Access the chapter]

Job roles and skills needs within this domain were analysed and categorised by the production lifecycle. The following categories were identified, and needed skills and job roles based on the job advertisements were outlined:

- Design and Development;
- Manufacturing;
- Maintenance;
- Sales, Services, and Support or Technical Project Management.

Please see the following chapters for more details:

- Mobile Applications

7 Second Life of Batteries

The development of second-life applications of (mainly) EV batteries is expected to rise consistently because the number of decommissioned vehicles will increase as sales skyrocket. Importance will be gained as well due to various reasons and challenges, such as storage, recycling, grid stabilization, and green energy harvesting which are a must given the massive decarbonization plans of the European Union, as stipulated in the Paris Agreement and the subsequent documents. Furthermore, escalating energy prices will bolster the alternative solutions aiming at improving energy efficiency and cost mitigation.

This positive trend will occur even though some factors are negatively affecting the development of second-life applications such as:

- The disinclination of some owners to have their vehicle or batteries replaced after the battery capacity drops significantly
- The limited technical compatibility of the EV batteries with various second life applications;
- The extended variety of battery types coming from old electric vehicles;
- The hurdles of repurposing the EV batteries.

EV batteries are likely to be repurposed as a part of the stationary application due to the aforementioned and other requirements needed to achieve feasible production costs as well as testing and safety standards.

Currently, the collection of batteries for repurposing is done mainly by manufacturers (or in partnership with third-party operators). Independent collection networks are still in their infancy, mainly because of the low volumes available and the associated risks with handling spent/defective batteries. However, this trend will likely develop in another direction as the new innovative technologies will make the diagnosis of batteries and cells much easier and more accurate.

7.1.1 Skills Agenda[75]

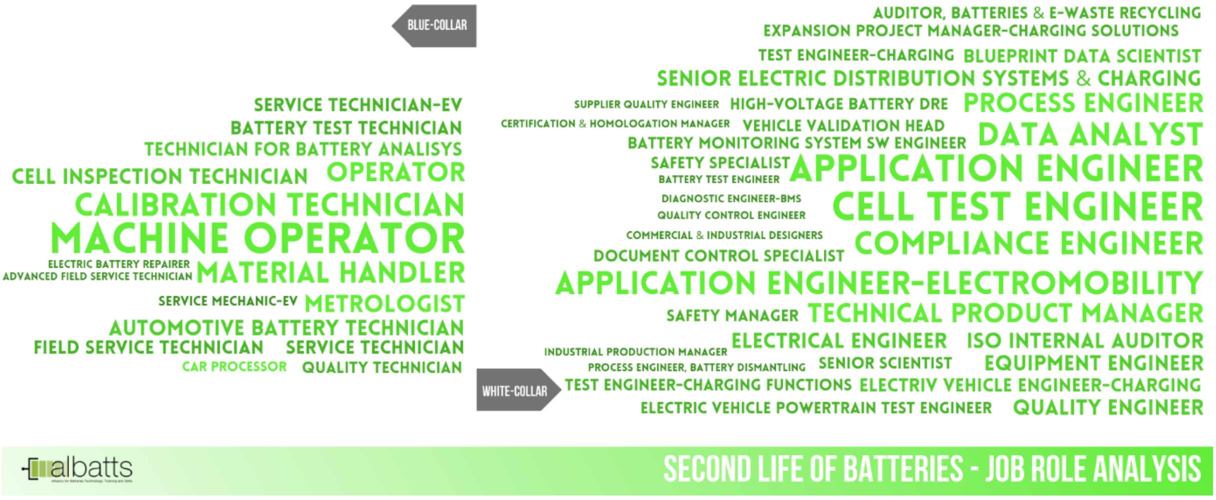
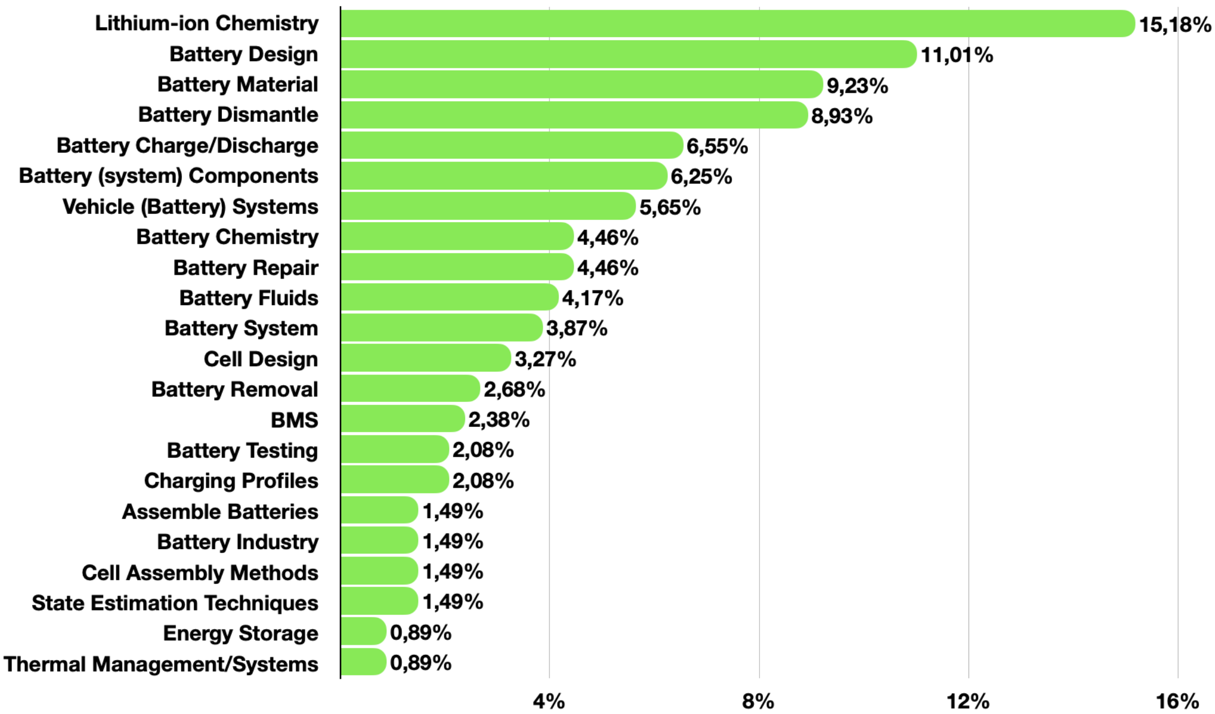


Figure 42: Second Life of Batteries - Job Role Analysis | Blue Collars

Figure 42 shows the occurrence analysis of the job roles for the second life of batteries. Blue-collar workers observed are having expertise in **handling; operation; testing; inspection**; and others. White-collar workers are having expertise in **safety; audits; quality; testing;** and others.



[75] Definitions and methodology are described in the methodology section, this is covering the development of the analysis within this chapter.

Figure 43: Second Life of Batteries - Sector-Specific Competence

Figure 43 represents selected, the most occurring sector-specific competence for the second life of batteries.

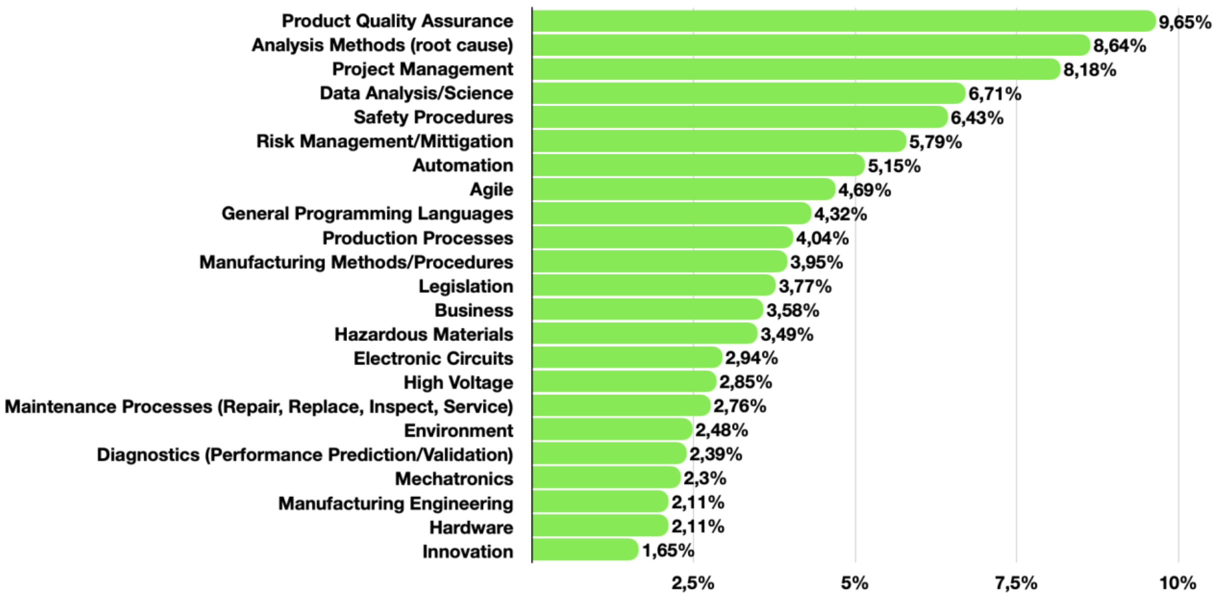


Figure 44: Second Life of Batteries - Cross-sectoral Specific Knowledge

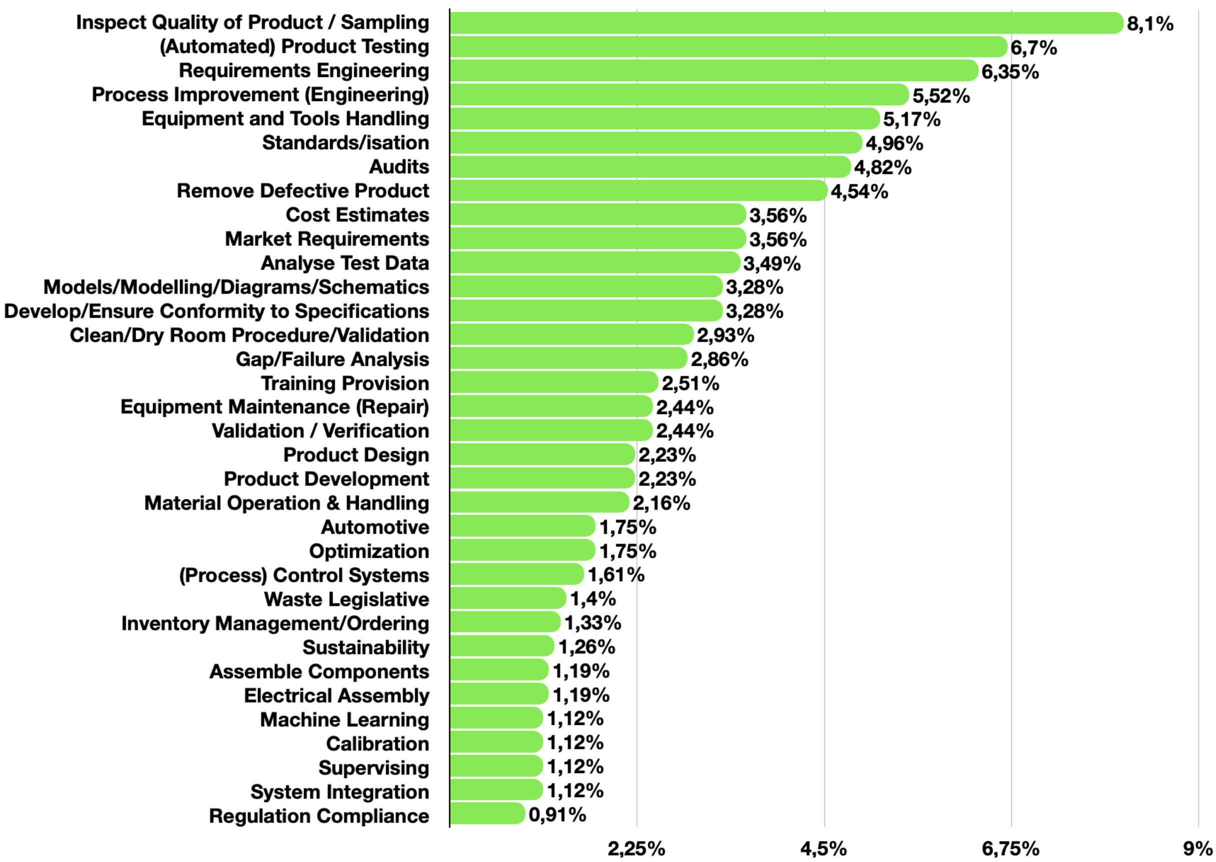


Figure 45: Second Life of Batteries - Cross-sectoral Specific Skills

Figure 44 and **Figure 45** represents selected, the most occurring cross-sectoral specific competence for the second life of batteries.

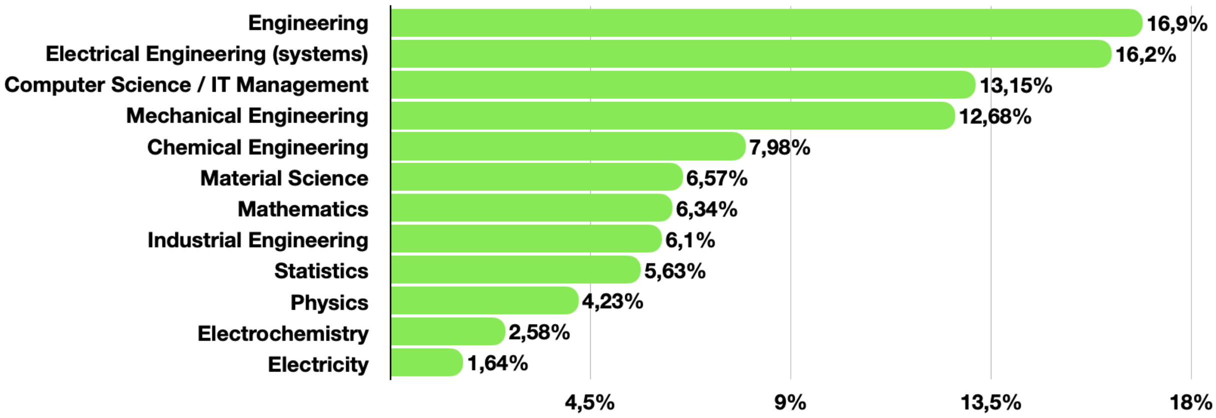


Figure 46: Second Life of Batteries - Academic Competence

Figure 46 represents selected, the most occurring academic competence for the second life of batteries.

As a result of the aspects above, the job roles associated with battery management in second life applications can be divided into four categories, according to the main stages of this battery value chain step. This can be described from the qualitative point of view as follows:

- **Diagnostic + Preparation for second-life applications & manipulation**: battery testers, battery formation, battery removal, battery repair, battery dismantle, cell evaluation, state estimation techniques, inspect the quality of product/sampling, remove the defective product, equipment, and tools handling, install low voltage wiring, fasten components, logistics, state estimation techniques, material operation and handling, metal stamping, metal forming, hardware, forklift;
- **Implementation, maintenance, and repair of associated hardware**: thermal management/systems, calibration, process control systems, public safety, voltage adjusting, monitoring machine operations, electrical equipment regulations, mechatronics, hazardous materials, cooling systems, thermal analysis, electromechanical components, maintenance processes, safety procedures;

- **Software adaptation and grid integration**: BMS, electrical assembly, electrical equipment, alternative energy, system architecture, algorithms, calibration, digital skills;
- **Legislation and pricing**: business, data analysis/science, cost estimates, Kaizen, supervising, process improvement, simulation methods, legislation, requirements, risk management, system specification, resource management, standards/ standardization, alternative energy, regulation compliance.

7.1.2 Practical Recommendations and Considerations

Good practices on cooperation and networking on second life application of batteries – this may include various projects, some of them involving vehicle manufacturers, such as:

- Nissan and Green Charge Network partnership – EV batteries into BTM storage systems in the USA;
- Mercedes-Benz– second-life battery storage for a recycling plant in Germany;
- Mercedes and Beijing Electric Vehicle partnership – energy storage system based on used EV batteries in China;
- Hyundai Motor Company and UL partnership to explore the safe deployment of used EV batteries for stationary energy storage in North America.

<u>Target groups</u>: Stakeholders that are active in the implementation of second life applications, policy makers.

8 Recycling and Sustainability

The European Union has one of the strictest legal frameworks in the world in terms of air quality, CO_2 emissions, chemical substance management, waste management, and energy efficiency. These must be complied with by all the economic operators within the Union.

Batteries are covered in the EU Directive 2006/66/EC. This Battery Directive sets recyclability requirements (50 % for the battery removed from the vehicle and 75 % for the battery that is embedded into a scrapped vehicle). They are bound to get stricter within a regulation that is currently being processed.

Further mandatory sustainability requirements and conditions apply to the battery manufacturers that need to be carefully observed and complied with by the operators.

These include:

- the Non-Financial Reporting Directive (NFRD – 2014/95/EU, the precursor of the future Corporate Sustainability Reporting Directive)
    - the Extended Producer Responsibility (EPR) principle which is explicitly stipulated by the Waste Framework Directive – 2008/98/EC (WFD) and WEEE (Waste of Electrical and Electronic Equipment – Directive 2012/19/EU)
- Battery Directive (2006/66/EC)
- End-of-Life Vehicles Directive (2000/53/EC).

The Extended Producer Responsibility (EPR) seeks to reduce the environmental impact of products throughout their lifespan, from production through end-of-life. It holds the producer, administratively and financially, responsible for closing the lifecycle loop of its products once they reach the end-of-life stage.

On the other hand, some optional principles and objectives are to be taken into consideration to achieve sustainability. Even though they are voluntary, battery manufacturers often choose to abide by certain environmental and sustainability principles. They included the **corporate social responsibility (CSR) mechanism**, a self-regulating business model that helps a company to

- be socially accountable to its stakeholders and the public
- achieving **environmental and sustainability targets and objectives**, for example
    - green labels or eco-labels for the consumer market or

- unregulated, usually self-elaborated targets and objectives

Gigafactories need to develop their production processes so that they meet **the legal frameworks of the sustainability and environmental protection legislation**. Additionally, they need to pay attention to

- **the responsible procurement of certain raw materials** that are either scarce or sourced in an unsustainable, unethical manner
- **the high energy consumption and the power supply** and **the potential impact of specific greenfield projects that need prior deforestations and land-use change**
- **waste handling** – relevant policies and regulations as well as relevant material recovery

One of the most important issues affecting battery manufacturing is the long-term effect of transport electrification on the power industry: in 2019, the green energy output is approximately 20 % at the EU level. When the number of electric vehicles increases, the consumption will soon follow, and it will also have to be sourced from green sources to continue pursuing sustainability targets.

8.1.1 Skills Agenda[76]

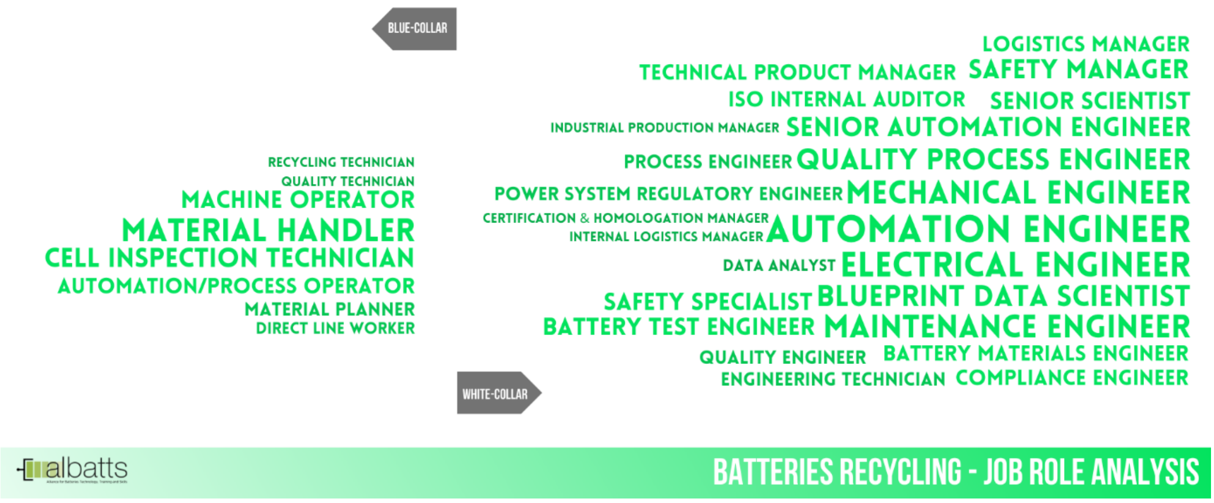


Figure 47: Job Role Analysis | Blue Collars

[76] Definitions and methodology are described in the methodology section, this is covering the development of the analysis within this chapter.

Figure 47 shows the occurrence analysis of the job roles for the recycling of batteries. Blue-collar workers observed are having expertise in **material handling; operation; machines; recycling**; and others. White-collar workers are having expertise in **audits; safety; quality; process engineering**; and others.

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

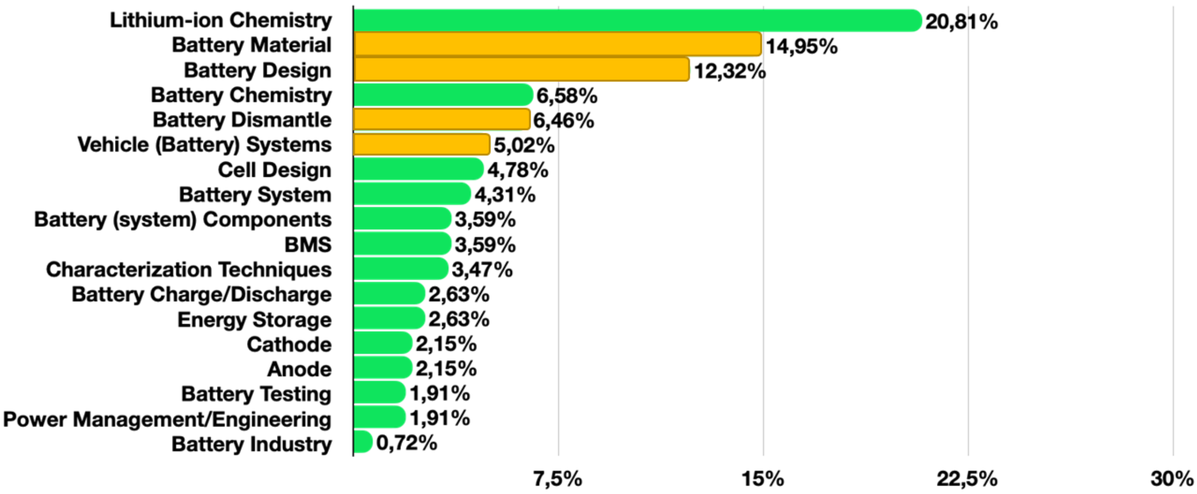


Figure 48: Recycling - Sector-Specific Competence

Figure 48 represents selected, the most occurring sector-specific competence for recycling.

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

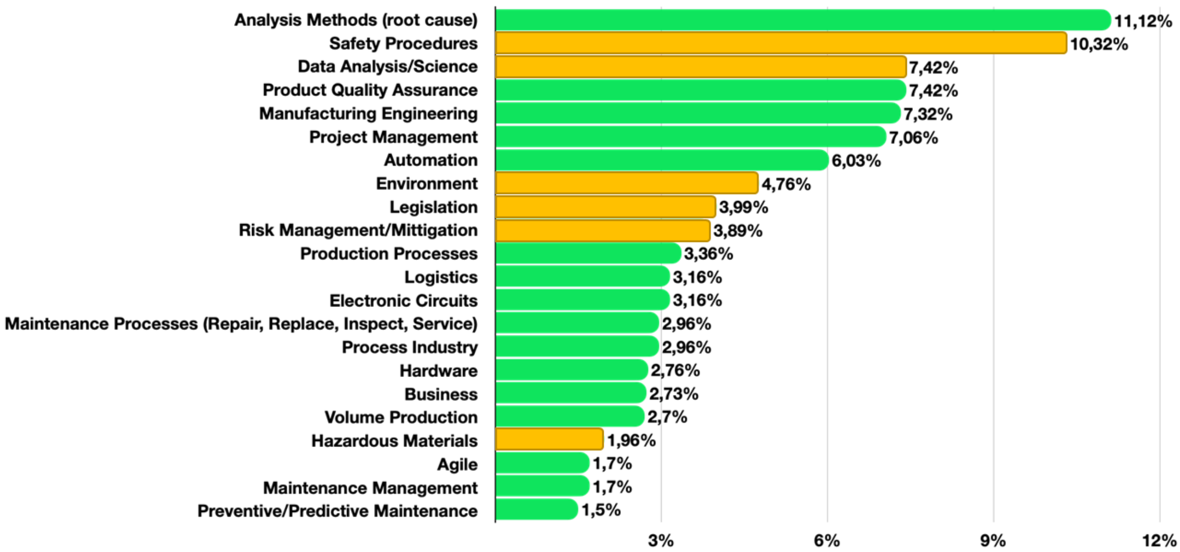


Figure 49: Recycling - Cross-sectoral Specific Knowledge

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

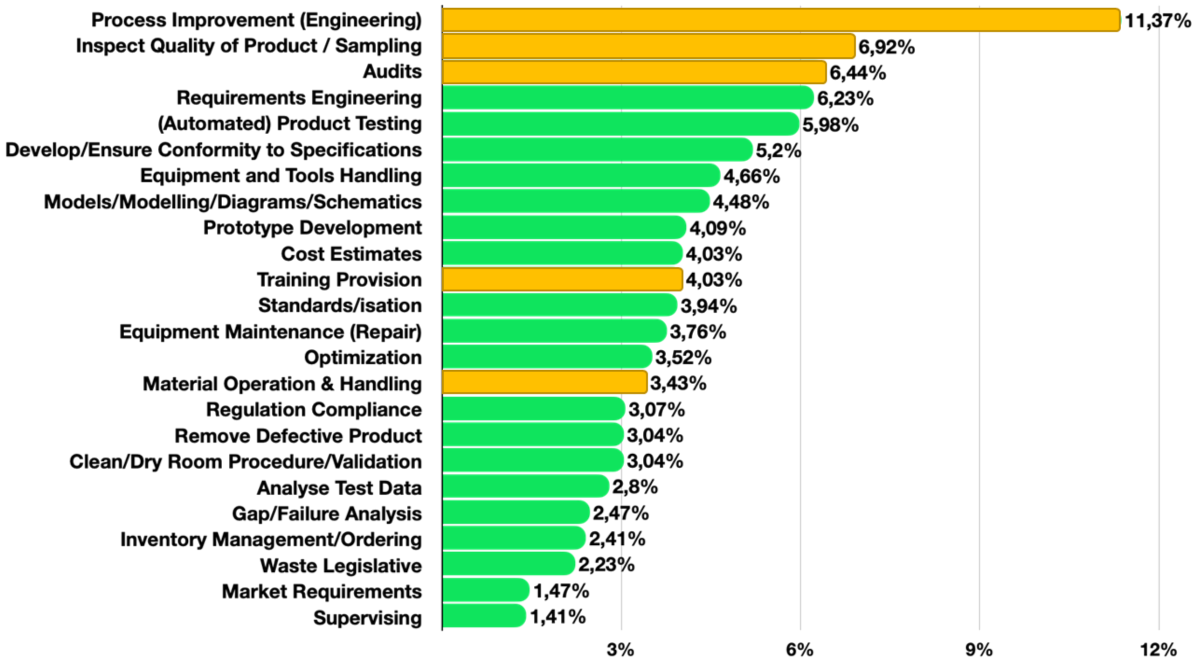


Figure 50: Recycling - Cross-sectoral Specific Skills

Figure 49 and **Figure 50** represents selected, the most occurring cross-sectoral specific competence for recycling.

Yellow-highlighted rows – concept was endorsed/mentioned during the workshop/interview by the participants

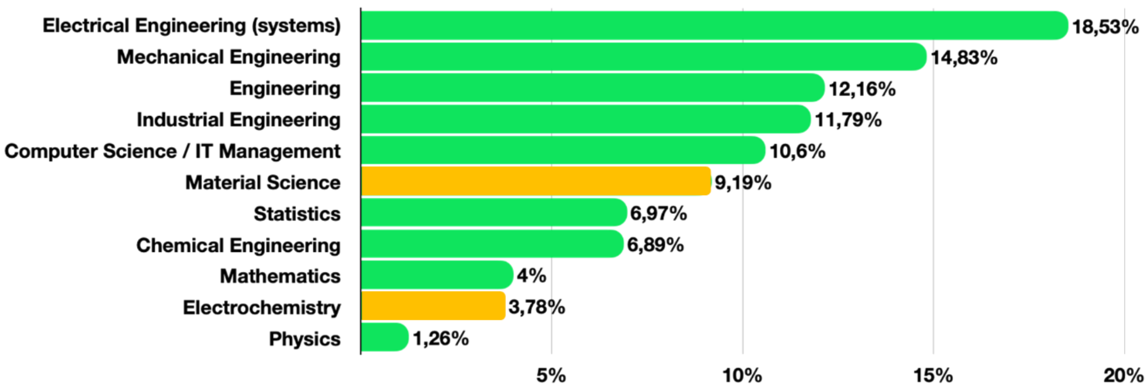


Figure 51: Recycling - Academic Competence

Figure 51 represents selected, the most occurring academic competence for recycling.

The job roles include for example **operators, shift leaders, production managers, and recycling managers**. In the set-up phase of recycling plants, most staff are university-educated white-collar employees, including, for example, researchers and production set-up personnel. Recycling processes are developed by **process engineers and planners**. For example, at Northvolt, this staff has been hired from the field of battery recycling research. Additionally, the recycling process needs to be developed including strategies for battery collection, methods, and systems. After a plant becomes more established**, the share of blue-collar employees with vocational education will increase**.

For example, Northvolt trains and upskills its staff with external education programs combined with internal training. It collaborates with a local university of applied sciences to provide courses on battery recycling and battery specifics.
In the future automation is expected to increase. This will mean decreasing routine tasks while bringing, for example, tasks related to the maintenance of the automated systems.

8.1.2 Practical Recommendations and Considerations

Recruitment needs according to the ALBATTS project findings, the most extensive recruitment challenges currently concern the hiring of engineers and researchers. In the set-up phase of recycling plants, most staff are university-educated white-collar employees. However, after a plant becomes more established, the share of blue-collar employees with vocational education increases.

Recycling technology and processes: with the battery recycling-related positions, it is important to know battery technologies and recycling processes (chemical/physical) themselves. Therefore, it is recommended to provide education and training in the following areas: (1) Environmental management and circular economy concepts; (2) Battery design - Battery components: Cell, anode, cathode, electrolyte and Precursor design, Electrode design, Separator design; (3) Battery material (material science) - Battery fluids and chemistry (Lithium-ion) and other materials and their properties; (4) Vehicle and other battery systems; (5) Material flow including procurement; (6) Battery testers; (7) Recycling knowledge to enable developing recycling programs - Recycling processes and technologies, R&D, Automation; (8) Production Planning.

In terms of **skills'** needs in the battery recycling processes, the following should be paid attention to: (1) Logistics including battery collection; (2) Battery Removal; (3) Characterization Techniques; (4) Cell Structure and evaluation; (5) Battery Charge/Discharge; (6) Battery Dismantle; (7) Equipment and Tools Handling (recycling-related); (8) Automation; (9) Material Operation & Handling; (10) Supply/Material Planning; (11) Hazardous materials, waste handling; (12) Chemical/physical recycling processes.

<u>Environment and legal:</u> Regarding environmental legislation, it is important to understand related national and EU directives. We have also discovered the importance of safety. Therefore, we recommend providing education and training in the following **knowledge** areas:

- Promotion and training of sustainability
- Safety
  - Safety Procedures
  - Functional Safety
  - Hazardous Materials
- Legislation
  - Related EU/national directives
  - Battery Passport

The related **skills** fall into the following areas:

- Ensuring Public Safety
- Waste Management Legislation

<u>Resources-related and supporting skills:</u>

- Strategies for battery collection, methods, and systems
- Language skills (English)

<u>Target groups</u>: educational institutions, government agencies, companies in the battery recycling business, recruitment companies, head-hunters, consultants.

9 Training, Education, Re-/Up-Skilling

Below we will discuss trends and opportunities with importance for the supply of competency for the battery manufacturing sector's machine operators, material handlers, and other categories of blue-collar workforce. It is important to remember that these categories are about 75 % of all employees in a battery cell factory. The following section will focus more on the white-collar workforce and higher education.

9.1 VOCATIONAL EDUCATION, EQF 3-6

Horizontal European initiatives: the **Pact for Skills** initiative was launched in November 2020, and an "ecology pilot" was launched within this pact, **Automotive Skills Alliance**, led by ACEA, CECRA, CLEPA, ETRMA, and VSB-TUO with ALBATTS highly involved. The focus is a more ambitious up- and reskilling process in the industry than before, with initiative and funding in cooperation.

In a speech at a press conference following an EBA Meeting in Portugal on March 12th, 2021, the EC Vice President Šefčovič addressed the fast-emerging skills challenge in the European battery sector.[77] VP Šefčovič tasked EIT Innoenergy "to team up with the interested Member States to prepare their country-specific project proposals [and to] launch a so-called EBA250 Academy, developing curricula and training content based on the industry's skills needs and in partnership with local training professionals." ALBATTS is now proceeding into closer communication with EBA Academy as the missions overlap under the Automotive Skills Alliance and EBA Academy Memorandum of Understanding.

In addition, the "**EDU Battery Network**" has been formed, an informal group of EC initiatives on battery education and training. Participants are, besides ALBATTS; Battery 2030+, Batteries Europe (ETIP), EIT InnoEnergy/ EBA Academy, Drives, Alistore, Fraunhofer Batterien Allianz, and the MESC master education network.

Profiled adult education and training programmes for battery cell factories: A battery plant is not so well suited for education and training on a bigger scale due to IPR restrictions, the clean- and dry-room environment, and the fast-moving production flow.

[77] Press corner. European Commission - European Commission. Retrieved November 28, 2021, from https://ec.europa.eu/commission/presscorner/detail/en/speech_21_1142.

Northvolt Ett in Skellefteå is a European pilot for many coming European battery plants. In addition, a local *Automation Operator* programme for adults is offered by adult education (VUX) in Skellefteå, Sweden, in cooperation with Northvolt. Examples of courses are *Industrial processes, Remedial maintenance, Production Equipment, Employed in the Industry, Technical English, Digitalization*. Certificates for operating forklift trucks, overhead cranes, and licenses for hot works are also included. A new profile, "Material Handler", will start in late 2021.

This adult course package solution can become an interesting European benchmark example for the training of blue-collar employees for Li-Ion cell factories. A special lab environment for training has been built up at Campus Skellefteå, with mostly Festo CP Factory lab equipment.[78]The about 30 factories that are now planned or being built all over Europe will probably, most of them, have local education and training solutions outside the factory, provided by public or private educational institutions, and in the local language. To be noted is that direct battery knowledge is only a minor part of what is needed for machine operators, technicians, and maintenance staff in battery manufacturing. What seems equally essential are general and transversal skills for work in modern manufacturing environments of the type "Industry 4.0". This kind of modern manufacturing has a high degree of automation. It includes the Internet of Things (IoT) and machine learning, forming a production environment where machines communicate and learn from the production-generated data. Education providers are thinking about how to train people for the role of "Operator 4.0".[79]

Simulated training environments: It is difficult to get practice in a battery plant before employment. A pilot plant can be an alternative but is often owned by the industry, IPR-sensitive, and occupied with R&D activities. However, some pilot lines are owned by universities and research institutes. If not for physical access, these may be more available for forming a digital twin as a basis for VR and AR training.

A network for developing XR solutions for the training of operators in battery plants has been formed by RISE (Research Institutes of Sweden), Fraunhofer Batterien Allianz, Chalmers, and

[78] CP factory – the cyber-physical factory. CP Factory – The Cyber-Physical Factory - CP Factory - Learning factories, CIM/FMS Systems - - Learning Systems - Festo Didactic. (n.d.). Retrieved November 28, 2021, from https://www.festo-didactic.com/int-en/learning-systems/learning-factories,cim-fms-systems/cp-factory/cp-factory-the-cyber-physical-factory.htm?fbid=aW50LmVuLjU1Ny4xNy4xOC4xMjkzLjc2NDM.

[79] Kaasinen, E., Schmalfuß, F., Özturk, C., Aromaa, S., Boubekeur, M., Heilala, J., ... & Walter, T. (2020). Empowering and engaging industrial workers with Operator 4.0 solutions. *Computers & Industrial Engineering*, *139*, 105678. https://www.sciencedirect.com/science/article/pii/S036083521930066X Accessed 25.11.2021

Braunschweig universities. In addition, four ALBATTS partners are members of a reference group. EIT InnoEnergy has developed some VR training modules and games[80] , and some universities offer VR games for general chemistry teaching and learning, including electrochemistry.[81] There is also a growing market for industrial VR environment software and readymade environments.[82] A few training providers across Europe started investing or have invested already in small VR labs in anticipation of the high demand.

With VR training, a learner can train skills relevant for a piece of manufacturing equipment, be allowed to make mistakes, test different scenarios, and practice problem-solving in a way that is hardly possible in a producing factory. The optimal solution for this kind of training could be a precise digital representation of a specific full-scale manufacturing machine. Because of industrial confidentiality policies, this seems not to be easy to implement outside employment at a cell manufacturer. However, pilot cell production lines at universities, labs, and research centres can be the basis for VR training. Even if the machine the learner is meeting in a factory is both bigger and of another brand than the digital version in training, the previous VR learning can facilitate onboarding training as a machine operator in the actual factory. VR can also be used as a selection instrument in recruitment. AR, augmented reality, can have many learning applications within a factory and inside a VR environment.

More flexible and more blended learning solutions from institutional providers: From March 2020, the Covid19 pandemic led to many school classrooms and university campuses closing, and traditional teaching had to go online. The situation has been challenging to education providers, but it has, in addition, also brought valuable insights into alternative ways to organize and run education. As a result, models of new normality for education and training access are now being formed, often called “hybrid”, “blended”, and “flipped” models. These are generally more flexible and inclusive by using combinations of online and physical spaces, digital and analog communication, shifts between synchronous and asynchronous online or physical modes of communication, and studies.

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[80] Learning apps. Learning games | EIT InnoEnergy. Retrieved November 30, 2021, from https://www.batterygame.sea.innoenergy.com/.
[81] Franco, A. A., Chotard, J. N., Loup-Escande, E., Yin, Y., Zhao, R., Rucci, A., ... & Lelong, R. (2020). Entering the Augmented Era: Immersive and Interactive Virtual Reality for Battery Education and Research. https://chemrxiv.org/engage/api-gateway/chemrxiv/assets/orp/resource/item/60c74bc59abda206e7f8d15f/original/entering-the-augmented-era-immersive-and-interactive-virtual-reality-for-battery-education-and-research.pdf Accessed 24.11.2021
[82] Example: https://www.infinitefoundry.com/ Accessed 25.11.2021

The conventional MOOC courses on battery and electromobility are mostly the same as listed in D 6:1 in February 2020, with one good European addition: EIT Manufacturing's MOOC on the Futurelearn platform: *Battery Manufacturing: Trends in Battery Engineering*.[83]
However, the diversified global course offerings of MOOC courses from major platforms as Coursera, EdX, and Futurelearn, can already be used for many of the up-and reskilling needs in the battery and electromobility value chain. Not all courses needed for the value chain are about batteries.[84] Some previous education background, study skills, and proficiency in English may be required.

Education programmes and courses from new or untraditional providers: A clear trend is the many emerging courses on battery and charger safety and handling by first responder organizations, workers protection authorities, transport branch organizations, and so on. This is a sign that Li-Ion battery equipment is becoming more common in many contexts, and handlers and the public need to be aware of the risks. In addition, several YouTube channels with educational ambitions have emerged and often produce up-to-date materials that can be used in various ways, with awareness of copyright and IPR issues.

Conclusions:

The adult and technician educations at the vocational level are the central focus for the ALBATTS project. ALBATTS will increase the overview by concentrating on the known Gigafactory "hot-spots" and the VET providers close to these. Prototypes of education and training solutions, like those available in Skellefteå, can be valuable for VET providers when forming their solutions in cooperation with the regional industry. The trend that education and training solutions can become more flexible and mobile is helpful. Still, VET education also needs to include training and actual experiences in physical labs and VR and XR environments. The European horizontal initiatives on various levels will hopefully benefit ALBATTS, both for communication and feedback in the project work and for implementing results and continuing value after the project's finalization.

[83] FutureLearn. Battery engineering: Trends in manufacturing - online course. FutureLearn. Retrieved November 28, 2021, from https://www.futurelearn.com/courses/trends-in-batteries-manufacturing.
[84] For examples of accessible MOOC courses corresponding to needs in the battery sector, see the simultaneously published ALBATTS Deliverable 6.2, section 4.2.3, page 100ff.

Lower education recommendations:

- Support horizontal European initiatives, such as PfS – ASA, EBA Academy, EDU Battery Network
- Develop battery/electromobility profiled adult education and training programmes
- Promote simulated training environments
- Promote flexible, modular, and more blended learning solutions from institutional providers
- Identify education programmes and courses from new or untraditional providers

9.1.1 Education and Training on Production Equipment

The transition to a carbon-neutral economy and the rise of electromobility present a significant challenge in education and training for employees in new manufacturing processes, particularly in gigafactories. To effectively address this challenge, education strategies have been developed, focusing on critical areas:

1. Technical Skills Development: Private and public training programs are established to continuously upskill employees in various manufacturing aspects, including technologies, machinery operations, automation, and robotics.

2. Cross-Training Opportunities: Specialised training in multiple areas within gigafactories is encouraged, promoting flexibility for employees in specific job roles.

3. Continuous Learning: Large institutions provide continuous learning opportunities through workshops and online courses to enhance professional development and keep up with industry advancements.

4. Leadership Development: Higher-level education programs focus on managerial skills, decision-making, effective communication, and other soft skills for managers and future leaders within gigafactories.

5. Collaboration and Knowledge Sharing: Gigafactories promote collaboration and knowledge sharing among employees through teamwork, projects, and regular meetings, fostering process innovation.

6. Sustainability and Green Technologies: Companies align with environmental objectives, training employees to focus on energy-efficient processes, water and waste reduction, and recycling initiatives.

7. Soft Skills Development: Soft skills such as teamwork, problem-solving, and communication receive increased attention to create a compelling and diverse working environment.

8. Career Development: Companies provide clear growth paths within the organisation to motivate employees and support their professional development in various job roles.

9. Partnership with Education Institutions: Collaboration with local universities, technical schools, and vocational training centres is emphasised to attract new candidates and create customised education programs.

10. Employee Feedback and Evaluation: Continuous feedback and evaluation of employees' needs and job satisfaction are crucial metrics for managers to maintain good performance and tailor educational programs.

Moreover, several EU job roles and skills education providers, such as ASA and InnoEnergy Skills Institute, offer specialised courses for gigafactory employees, contributing to the workforce's development.

The modern approach towards learning integrates digital tools, including VR and AR, and simulation-based techniques. Examples include:

- Simulation-based education for PV and storage optimisation tools.
- Virtual practical training in engineering fields through simulated enterprises.
- Building life-size vessel simulations in a technical VET school to provide real-world experiences.
- VR training simulations by Aptiv for assessing trainee engagement and knowledge application in high-voltage systems.
- AR, combining hands-on examinations with data capture for enhanced training versus traditional training methods.
- Battery factory simulation models by Siemens Digital Industries Software for design and engineering acceleration.

Lastly, utilising digital twins in gigafactories bridges the gap between development and reality, providing a safer and more effective environment for training. The application of artificial intelligence (AI) in battery cell development, optimisation, and materials selection showcases the potential for advancements in this rapidly evolving field.

9.2 HIGHER EDUCATION, EQF 7-8

Many European universities are already active with education offerings in the battery chain on the EQF 7 (master level) and EQF 8 (Ph.D. education level). It is no longer only programmes offered; many higher education providers also offer free-standing courses for up-and-reskilling and new courses for ordinary students.

There are, in addition, many open questions about focus, education volumes, curricula, university-industry collaboration, and so on. Two recent reports, *Future Expert Need in the Battery sector*[85] (from now on called *Experts Needs*) from Fraunhofer and EIT Raw materials, and Batteries Europe's *Position paper on Education and Skills*[86] (from now on called *Position paper*), discuss these levels of European education. ALBATTS is connected to both reports but has EQF levels 4- 6 as a primary focus.

The *Expert Needs* report looks towards 2030 and beyond, in three categories of the value chain:

a) Materials industries (raw materials, active materials to components),
b) Production industries (process/ cells/ modules/ packs, including equipment manufacturers),
c) System integrators (direct applications, 2nd life applications, etc.)

The report finds that these have obvious education-related issues in common as a) Systemic cross-discipline battery knowledge, b) Digitalisation and a digital mindset, and c) Soft skills. There is also a significant need for the up-and reskilling of experts in all three categories now working in other industries. They can have valuable expertise to apply to the battery sector while lacking battery knowledge.

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[85] Thielmann, A., Neef, C. Hettesheimer, T., Ahlbrecht, K. & Ebert, S (2021) Future Expert Needs in the Battery Sector. EIT Rawmaterials & Fraunhofer.https://eitrawmaterials.eu/wp-content/uploads/2021/03/EIT-RawMaterials-Fraunhofer-Report-Battery-Expert-Needs-March-2021.pdf

[86] Domingko, A., Maleka, D. & Thielmann, A. (2021) Education and Skills Task Fore – Position Paper. Batteries Europe https://ec.europa.eu/energy/topics/technology-and-innovation/batteries-europe/news-articles-and-publications/education-skills-position-paper_en

Both reports agree that European academic education and training on expert levels are generally of very high quality and that European research also benefits from many kinds of available funding. However, the *Position paper* emphasizes that education offerings are undersized overall, while the *Expert Needs* report is more cautious and differentiated.

The *Expert Needs* mentions three critical categories of experts within materials industries; *Electrochemists, inorganic material scientists, and R&D experts on emerging battery materials trends and disruptive technologies.* The need for *process engineers* and various *experts in recycling* is also mentioned as crucial and experts in *upper management*, leaders with detailed knowledge of the battery sector. The report recommends that the industry be aware of this and educate academic experts in control rather than the other way around. For the digitalization knowledge and skills needed, the *Expert Needs* report wants engineering experts in the materials sector to learn IT rather than use general IT people and teach them batteries. In addition, there is an obvious need for *project managers* with experience in handling complex and large projects and disruptive manufacturing technologies. These can be experts from similar industries who need upskilling concerning battery production. In addition, logistics experts need to manage the traceability of materials throughout the production and technologies as ASRS (automated storage and retrieval systems). *Finally, system integrators* can be experienced electrical or electrochemical engineers or engineers coming from the ICE industry. These are essential in many ways, especially as problem solvers in manufacturing.

Both reports issue many ideas and recommendations to both industry and academia on the education of experts on the master and Ph.D. levels. Here are some leading suggestions for improvement:

- Communication between academia and industry to identify the concrete needs
- Interdisciplinary programmes in cooperation between academia and industry
- Internships and other platforms for exchange between academia and industry,
- Curricula adapted for battery experts in electrochemistry, production, and applications
- Specialized and differentiated online courses ICTs to enhance the education process,
- Supply of preparation and upskilling courses preceding onboarding training in the industry,
- Reskilling solutions for experts from the ICE- and other relevant sectors,
- Training and practice infrastructure (pilot plants, labs, simulations),

- Train-the-trainer / teach the teacher programs,
- Public information about the industry,
- Education testbeds,
- European standardized options for national courses or programs.
- Cooperation on attractiveness for the sector.

A new, unconventional, and interesting education and training provider is Battery Associates – a network of professionals in the field. The organization runs "Battery MBA"[87,88], a programme with weekly lectures from professionals working in the sector, interactions, discussions, and even labs with distributed equipment. It is meant for already active professionals that are interested in leadership positions in the battery sector.

Conclusions:

The reports both from Fraunhofer and BatteriesEurope agree on most issues, with minor variations in emphasis. Adapting curricula to actual needs in the industry is essential, as well as upskilling and reskilling solutions that can make good use of more connections and platforms between academy and industry.

The general outcomes of these studies on the expert levels do not differ considerably from what ALBATTS finds is needed in EQF 4-6, other than what the different levels of education imply. Need of transfer from other industries, the need for upskilling and reskilling solutions, increased use of online ICT solutions, education testbeds, and more communication and platforms between education and industry.

Higher education recommendations:

- Communication between academia and industry to identify the concrete needs
- Interdisciplinary programmes in cooperation between academia and industry
- Internships and other platforms for exchanges between academia and industry,
- Curricula adapted for battery experts in electrochemistry, production, and applications
- Specialized and differentiated online courses ICTs to enhance the education process,

[87] Training Detail – DRIVES Compass, retrieved November 28, 2021. Training Detail - Drives Compass (drives-compass.eu)
[88] Batterymba. Battery Associates. Retrieved November 28, 2021, from https://www.battery.associates/batterymba.

- Supply of preparation and upskilling courses preceding onboard training in the industry,
- Reskilling solutions for experts from the ICE- and other relevant industries,
- Training and practice infrastructure (pilot plants, labs, simulations),
- Train-the-trainer / teach the teacher programs,
- Publicly available information about the sector,
- Education testbeds,
- European standardized options for national courses or programs.

Cooperation on attractiveness for the sector.

9.3 TRANSVERSAL COMPETENCE ANALYSIS

This section provides an analysis for the overall sector in terms of transversal competence, meaning the soft competence and general basic competence, definitions may be found in the **ANNEX A: Skills Concepts**.

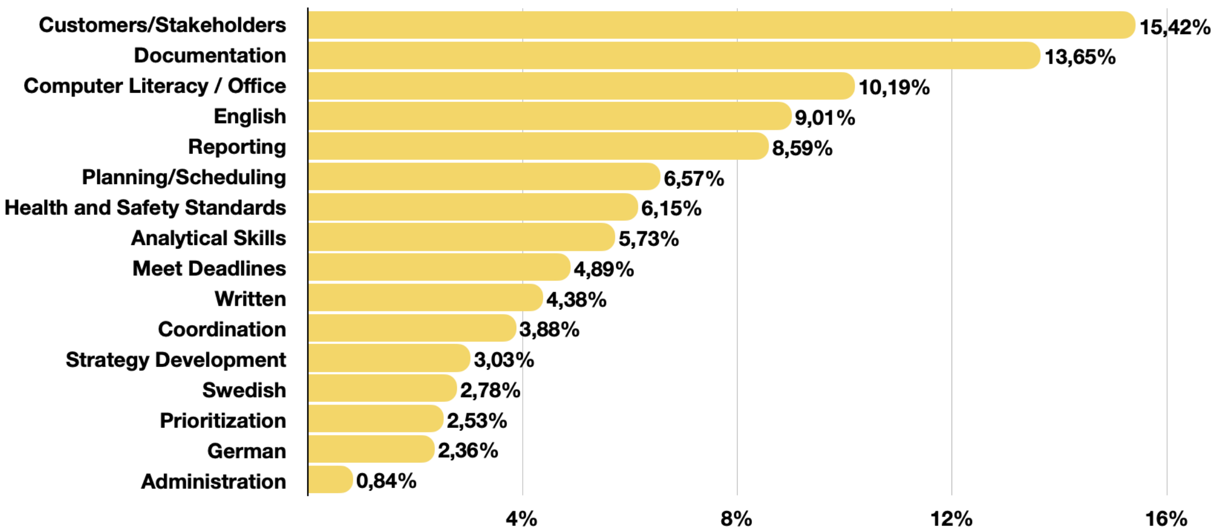

Figure 52: General Transversal Competences

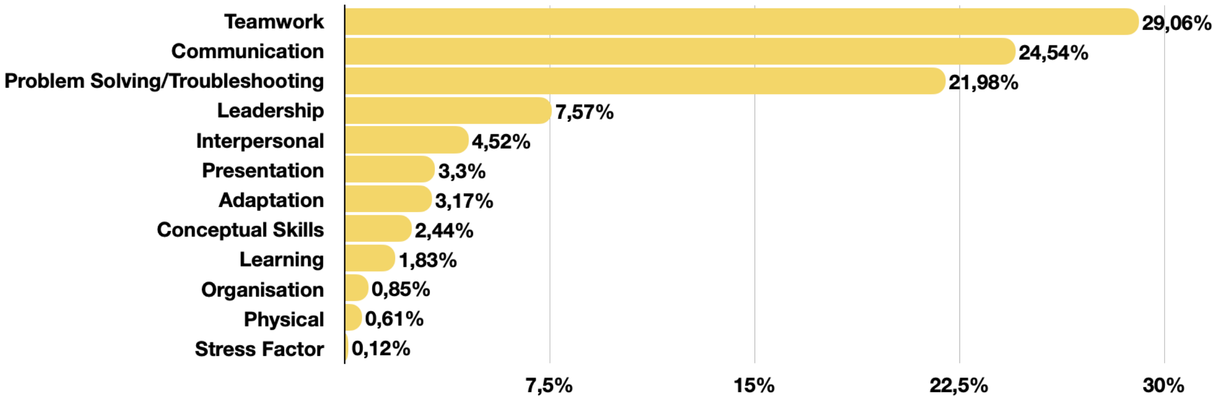

Figure 53: Soft Competences

10 Research and Development

R&D, from the **perspective of a battery manufacturer,** is one of the key phases of LIB production with a big **potential** for further development and a significant impact on **competitiveness**.

It consists of the following **steps**:

- Research - idea to basic experiment
- Development - laboratory validation tests
- Up-scaling and Industrialization - proving that the technology works in a real operating environment

Given the available resources and capabilities, there is a big difference between small producers and big ones in battery manufacturing research. **Small** manufacturers usually have research and development department within their battery factories unlike **large** manufacturers, such as LG Energy Solutions, Samsung, BYD, etc., that typically have separate R&D campuses or centres.

Figure 54: Location of main battery R&D centres

As the battery value chain is still developing in Europe, almost all LIBs' big players have their research **out of Europe**. In contrast, the country with the most concentrated battery research and production is **South Korea**, the homeland of LG, Samsung, and SK Innovation.

To remain competitive and accommodate various requirements by customers, R&D activities are at the **core of battery manufacturing**, covering areas like active material development, cell design, or cell performance (testing, validating the cells, etc.)[89]

Since the EU is gradually building up its competence base, human resources for this type of job are still **scarce in Europe**. The battery players established in Europe need to source from abroad, from countries like Korea, Japan, China, or India[90] via dedicated headhunting.

The battery industry also conducts projects with domestic and **international universities and research institutes**, co-creates bachelor´s and master´s programmes[91], or offers internships. This cooperation also ensures continuous upskilling of their employees.

Furthermore, to strengthen the ability of the R&D workforce, battery manufacturers also operate **learning groups** where employees share their experience and knowledge, support their employees through various systems, including academic training, in-house programmes, and the dissemination of excellent educational content.[92]

When it comes to **the most promising future energy storage technologies**, where intensive R&D activities are carried out by numerous companies, research institutions across the world, ALBATTS report *D5.4 R&D and Technological Perspectives for the Battery Sector*[93] focuses in detail on the following technologies, relevant stakeholders, and job roles & skills:

[89] ALBATTS report D4.4 p. 147, available at https://www.project-albatts.eu/Media/Publications/23/Publications_23_20210920_83914.pdf (last accesssed on 7/10/2021)
[90] ALBATTS report D4.4 p. 147, available at https://www.project-albatts.eu/Media/Publications/23/Publications_23_20210920_83914.pdf (last accesssed on 7/10/2021)
[91] ALBATTS report D4.4, p. 147 available at https://www.project-albatts.eu/Media/Publications/23/Publications_23_20210920_83914.pdf (last accesssed on 7/10/2021)
[92] ALBATTS report D4.4 p. 148, available at https://www.project-albatts.eu/Media/Publications/23/Publications_23_20210920_83914.pdf (last accesssed on 7/10/2021)
[93] ALBATTS report D5.4, available at https://www.project-albatts.eu/Media/Publications/21/Publications_21_20210831_213355.pdf (last accessed on 7/10/2021)

- **Lithium-ion batteries (LIB)** – improving cathode, anode, and electrolyte to increase energy density, charging speed, safety, lifespan, reduce costs, weight and volume needed, and avoid the use of scarce minerals, such as cobalt.
- **Lithium-sulphur batteries** – a promising alternative to lithium-ion technology with the possibility of 100 % Depth of Discharge (DoD), higher energy density, and lower expected environmental impact.
- **Sodium-ion batteries (NIB)** - where no lithium, a scarce mineral, is needed. NIB does not need Cobalt to maximize its energy density and will evolve from part of the R&D developed for LIBs.
- **Structural batteries -** can carry a mechanical load while storing electrical energy. They can be incorporated in the structure of, e. g., a vehicle or a house, and have big potential to reduce the space needed to store the battery within an application, and especially not affecting the structural equilibrium, which is paramount for electrical vehicles.
- **Supercapacitors and ultracapacitors -** can deliver quick bursts of energy during peak power demands, quickly store energy, and capture excess power that is otherwise lost. They complement efficiently other energy storage technologies in today's applications because they can charge while protecting them.
- **Fuel cells -** are especially important for heavy-duty vehicles such as buses as they have a higher energy density than batteries and are lighter.
- **Metal-air batteries -** such as lithium-air are also designated fuel cells as they obey similar principles as those ruling fuel cells. With very high theoretical capacity, the metal-air batteries suffer from the need for catalysts besides the traditional components of all the batteries.
- **Lithium-air batteries -** possess specific energy that is theoretically comparable to gasoline and is, therefore, very attractive. However, there are many technological challenges yet to be dealt with and overcome.

10.1.1 Skills Agenda[94]

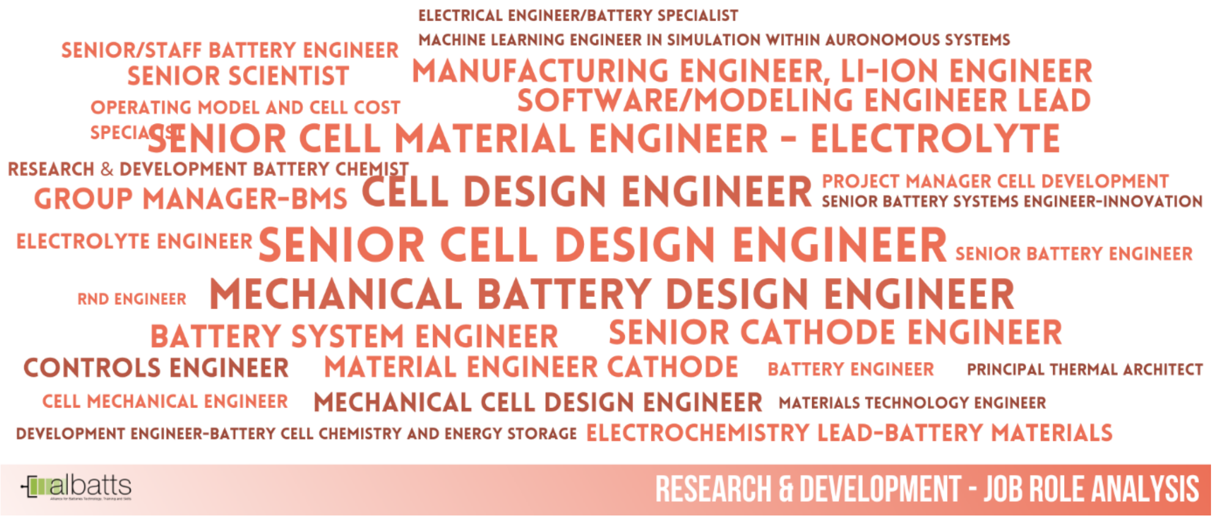

Figure 55: Research and Development - Job Role Analysis

Figure 55 shows the occurrence analysis of the job roles for the research and development of batteries. White-collar workers are having expertise in **cell design; material engineering; battery systems; manufacturing**; and others. Generic job roles are active in **scientists; researchers**; and others.

[94] Definitions and methodology are described in the methodology section, this is covering the development of the analysis within this chapter.

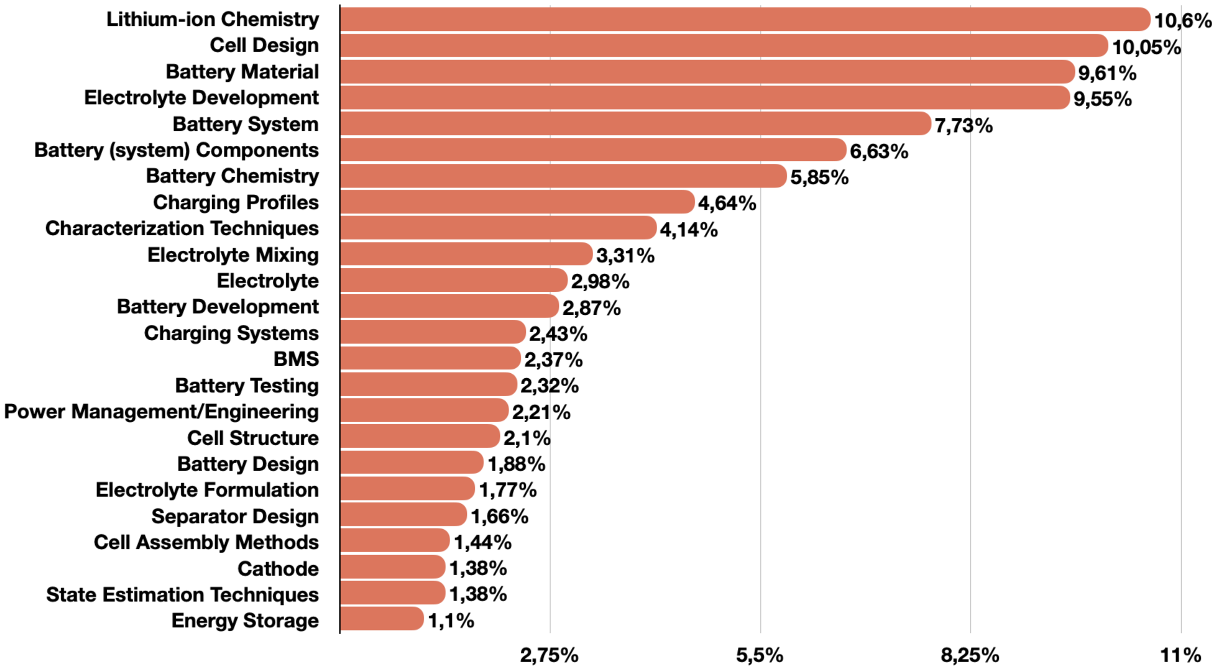

Figure 56: Research and Development - Sector-Specific Competence

Figure 56 represents selected, the most occurring sector-specific competence for research and development.

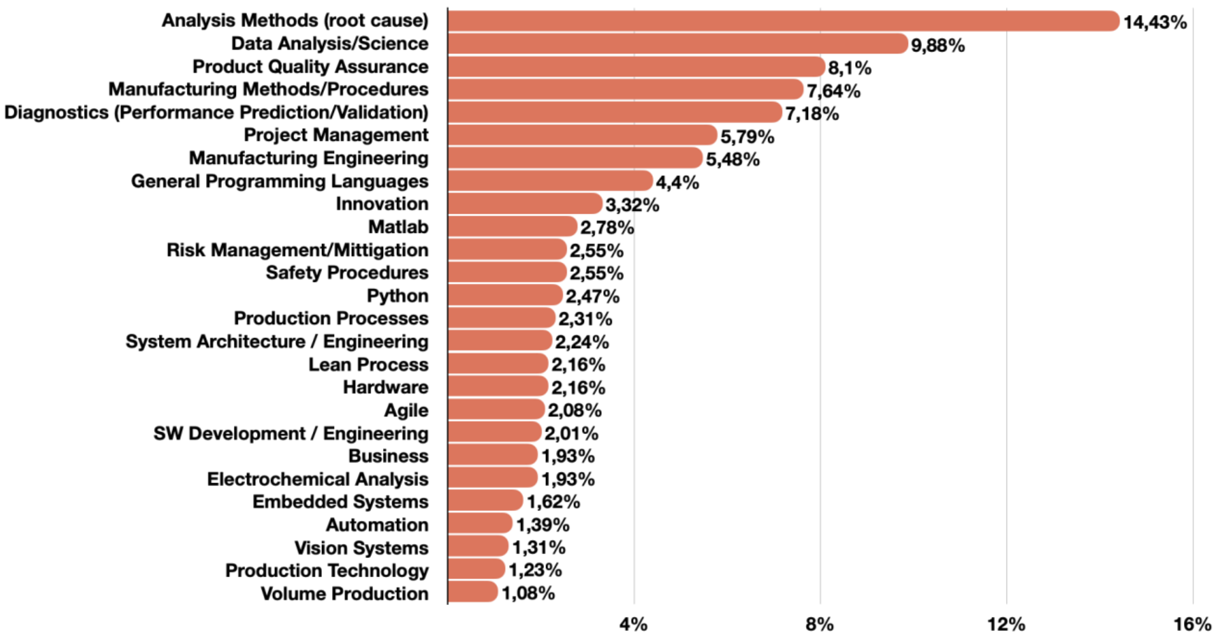

Figure 57: Research and Development - Cross-sectoral Specific Knowledge

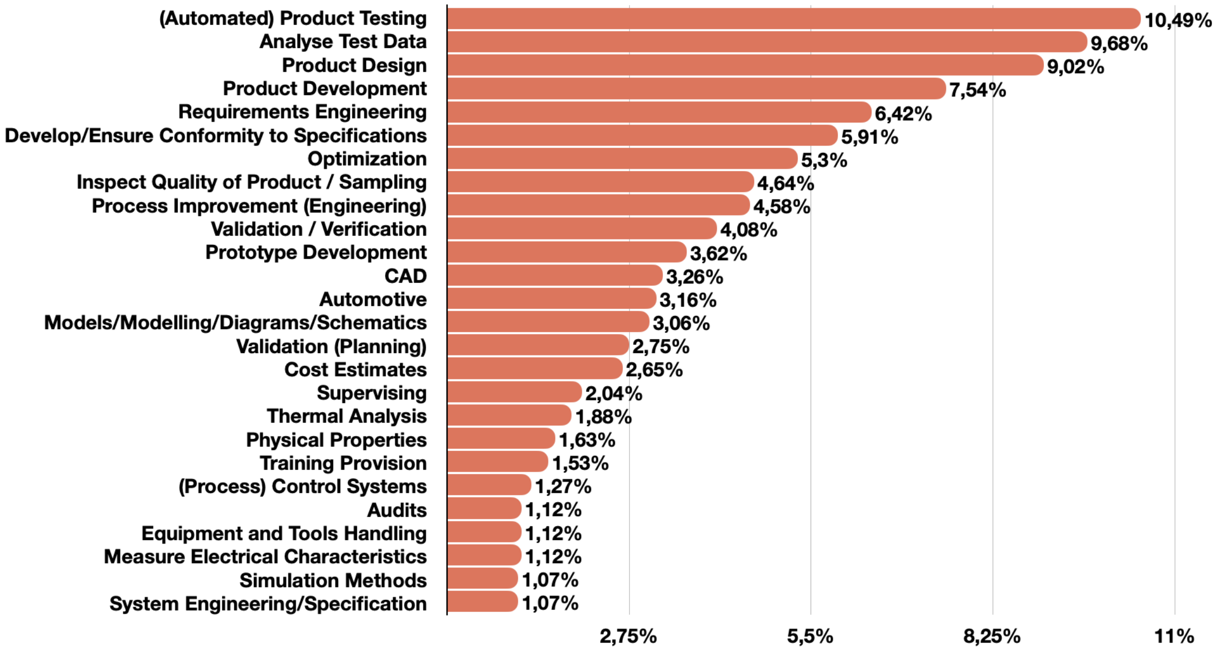

Figure 58: Research and Development - Cross-sectoral Specific Skills

Figure 57 and **Figure 58** represents selected, the most occurring cross-sectoral specific competence for research and development.

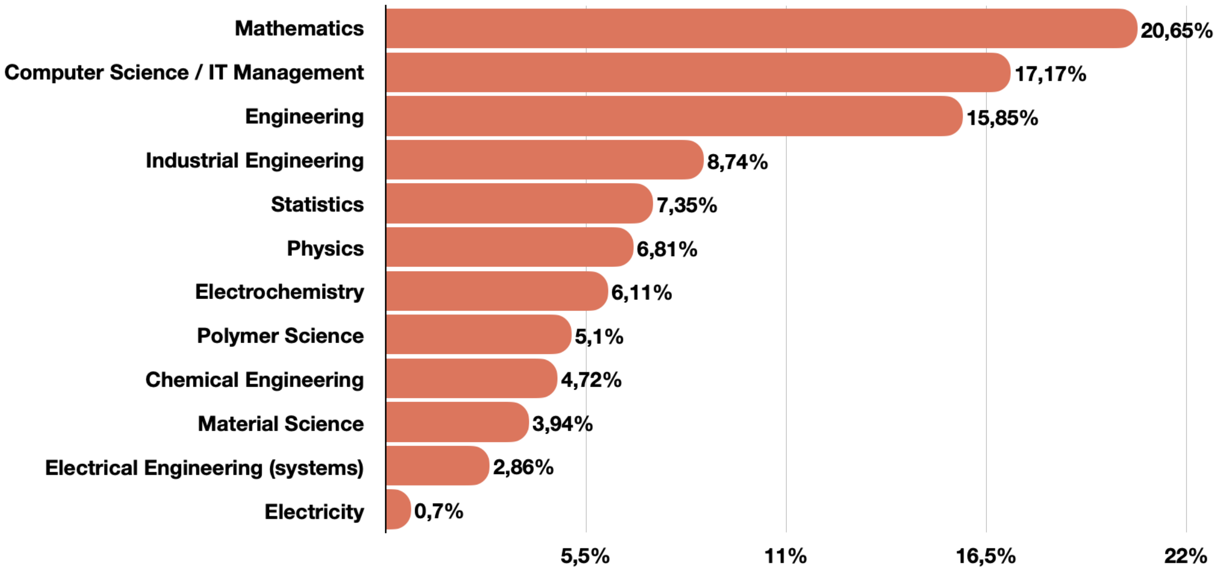

Figure 59: Research and Development - Academic Competence

Figure 59 represents selected, the most occurring academic competence for research and development.

10.1.2 Practical Recommendations and Considerations

- Strengthening of competencies relevant to **electrochemistry**, particularly those related to **characterization techniques, cell evaluation** and **validation**, **electrolyte development, thermal management, cell design, battery components, lithium-ion battery chemistry, battery design,** and **battery materials.**

Target groups: vehicle manufacturers, battery producers, technology companies, R&D institutions.

11 Defined Job Roles and Training for European Battery Sector

As stated before, there is a need for the EU-wide defined training and job role definitions which are then used by the sectoral stakeholders – these definitions need to be updated collectively by the ecosystem. Project ALBATTS has defined 26 job roles in a form of Skills Cards for the whole value chain.

- 15 skills cards on HE level; and
- 11 skills cards on the VET level.

Coverage of the value chain may be seen in the Figure below (for VET and HE respectively):

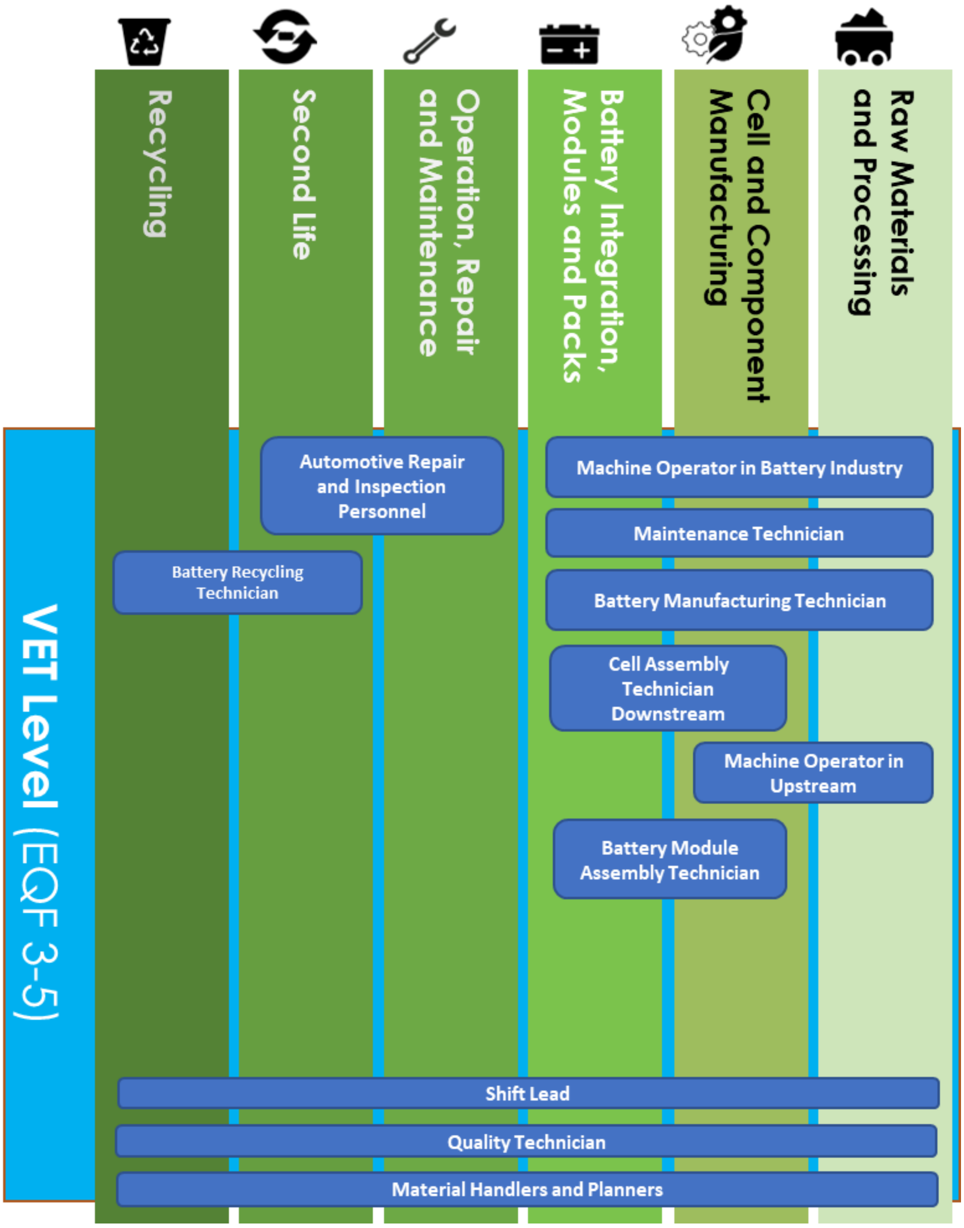

Figure 60: Job Roles for VET Level

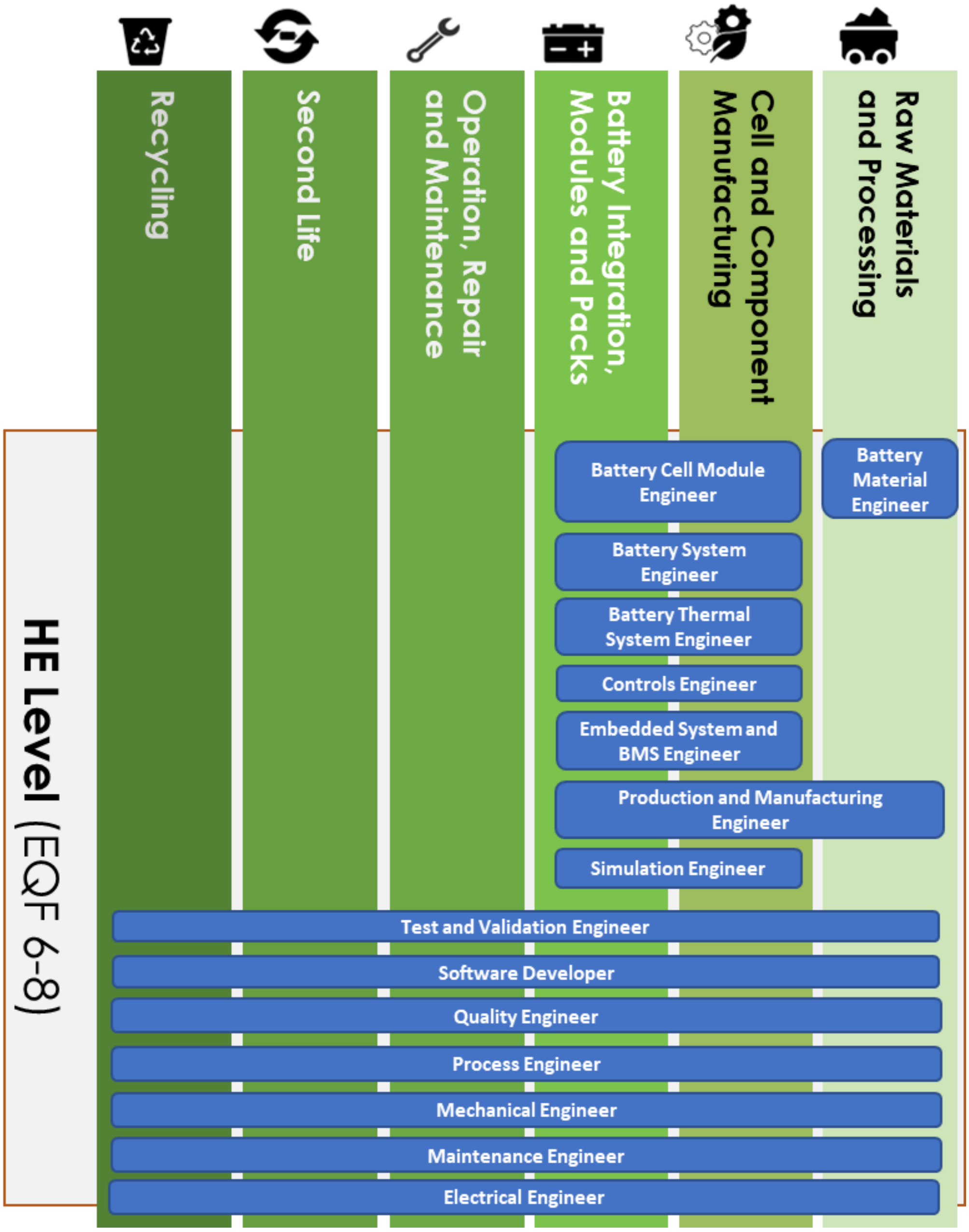

Figure 61: Job Roles for HE Level

For the aforementioned definitions, there is a need for the training courses to be developed and piloted, project ALBATTS has developed such courses which are available for the whole ecosystem, these courses may be found under this link: [Courses (project-albatts.eu)](https://www.project-albatts.eu).

Courses were developed in collaboration with the sectoral stakeholders and based on current state-of-the-art and skills intelligence. Coverage of the value chain is visible in the figure below.

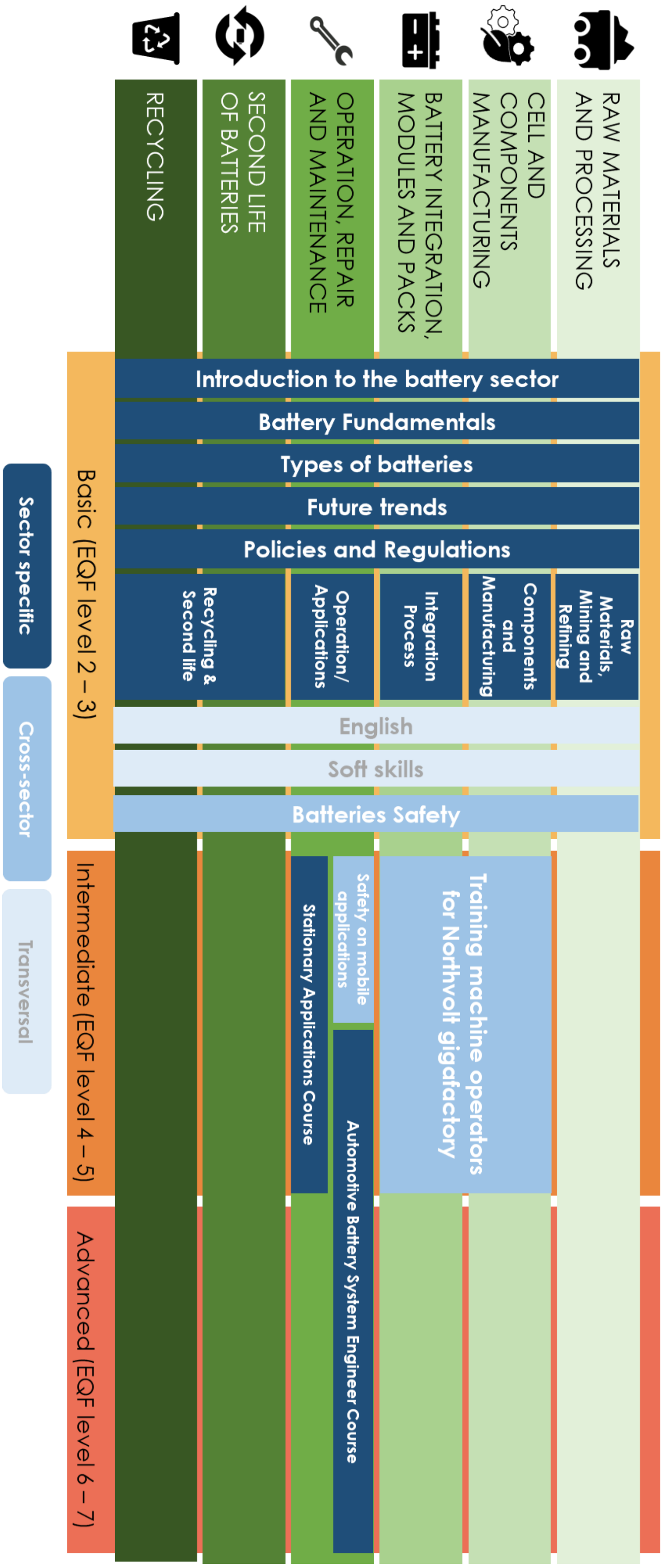

Figure 62: Develop Training Courses in ALBATTS Project

12 Outlook and Next Steps

This is the third release of the Sectoral Skills Intelligence and Strategy. This version provided updated proposals for high-level strategical actions, practical recommendations connected to the areas of interest within the European value chain and a state-of-the-art overview and qualitative/quantitative analysis of the skills/job roles needs, there are opportunities how to proceed further.

References

This report is based on the previous research done in the ALBATTS project, this includes synthesis of the information from the project deliverables and factsheets, which can be accessed here, other supplementary sources are described below:

- D6.1 - Report on State-of-Art of job roles and education in the sector
- D3.3 - Desk Research and Data Analysis of the sector as a whole- Release 1
- D3.4 - Survey results for the Battery sector
- D3.5 - Analysis of Future Needs - Release 1
- D3.6 - Analysis of Sectoral Intelligence - Release 1
- D3.7 - Desk Research and Data Analysis - Release 2
- D3.8 - Analysis of Future Needs - Release 2
- D4.5 - Sectoral Intelligence definition for sub-sector ISIB - Release 1
- D4.8 - Sectoral Intelligence definition for sub-sector ISIBA - Release 2
- D5.5 - Sectoral Intelligence definition for sub-sector IMBA - Release 1
- D5.8 - Sectoral Intelligence definition for sub-sector IMBA - Release 2

Table 4: References

Footnote	Reference
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45	ALBATTS report D5.4, available at https://www.project-albatts.eu/Media/Publications/21/Publications_21_20210831_213355.pdf (last accessed on 7/10/2021)
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13 Annex

13.1 ANNEX A: SKILLS CONCEPTS

Annex A defined skills concepts classification in more detail:

(1) soft competencies – the combination of individuals, skills, social skills, communication skills, character or personality traits, attitudes, career attributes, social intelligence, and emotional intelligence quotients, among others, that enable people to interact with their environment, work well with others, perform well, and achieve their goals with complementary hard or sector-specific/transversal skills; **(2) academic competences** – basic and complex skills that are the primary focus of the academic institution, henceforth to provide knowledge for further development in student's career; **(3) general transversal competences** – general ability or expertise which may be used in a variety of roles or occupations; **(4) cross-sectoral specific competencies** – specific ability or expertise that can be used across multiple sectors or domains in more concrete context; **(5) sector-specific competencies** – are particular or specialized skills necessary to perform particular jobs in specific sectors.

With the support of the Erasmus+ Programme of the European Union

13.2 ANNEX B: STAKEHOLDER METRICS

Annex B provides all metrics related to the stakeholder database after 3 years of the project:

- **Stakeholder Count:** 414 Stakeholders;
- **Stakeholder Type**: (Figure 63);
    - **Corporation Size**: (Figure 64);
    - **EQF levels covered**: (Figure 65);
- **Value Chain Distribution**: (Figure 66)
- **Geographical Distribution** (Figure 2);

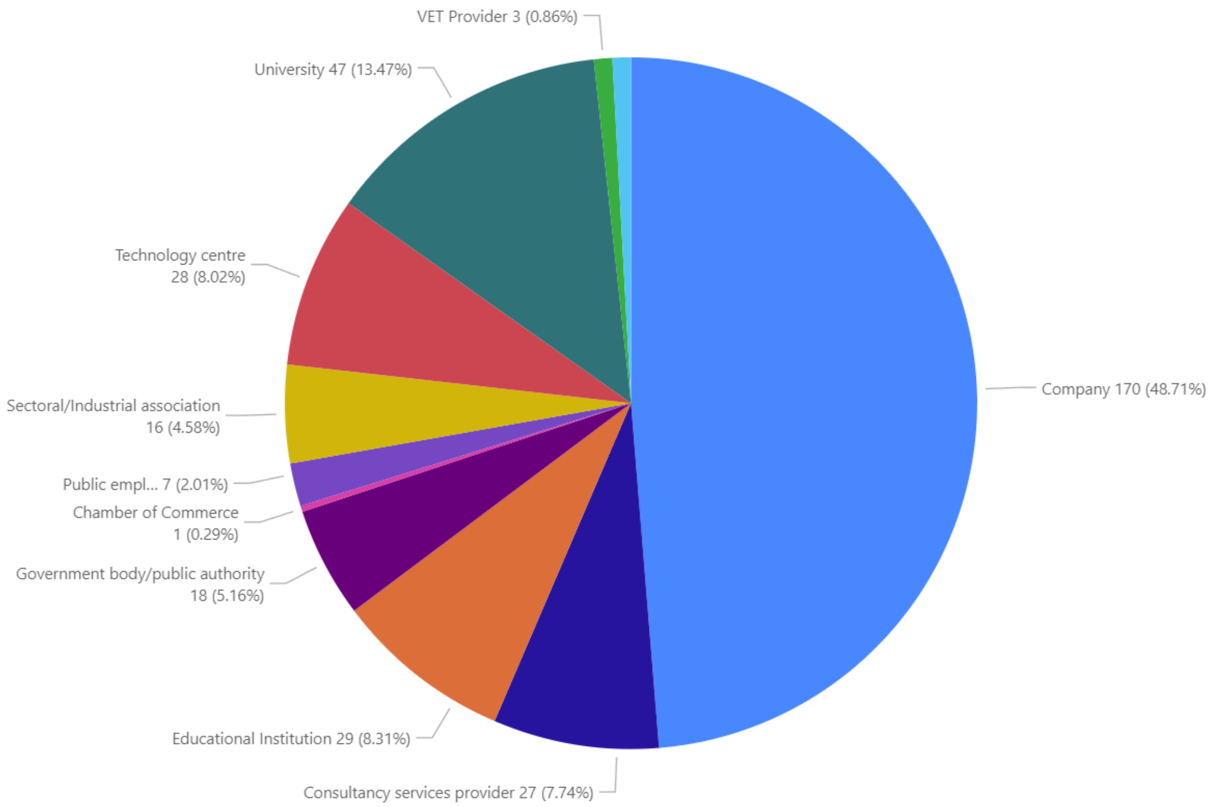

Figure 63: Stakeholders by Type

Figure 64: Corporations by Size

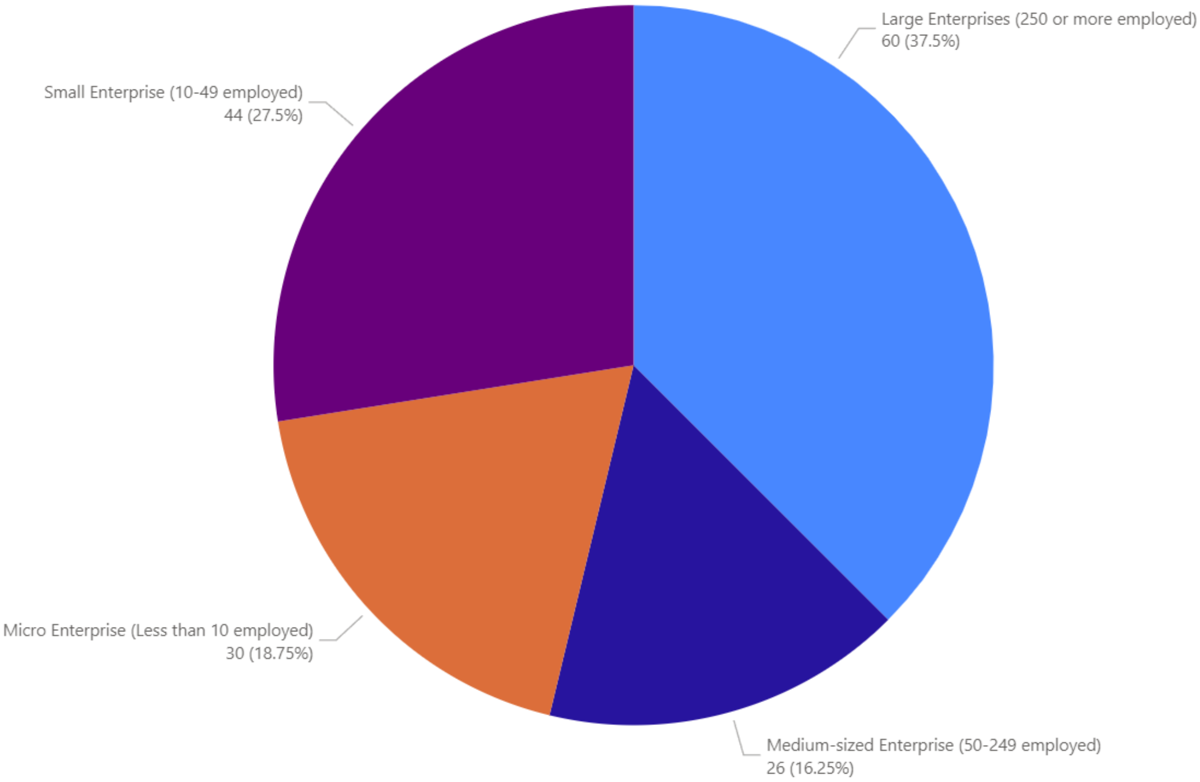

Figure 65: Education Institutions by EQF

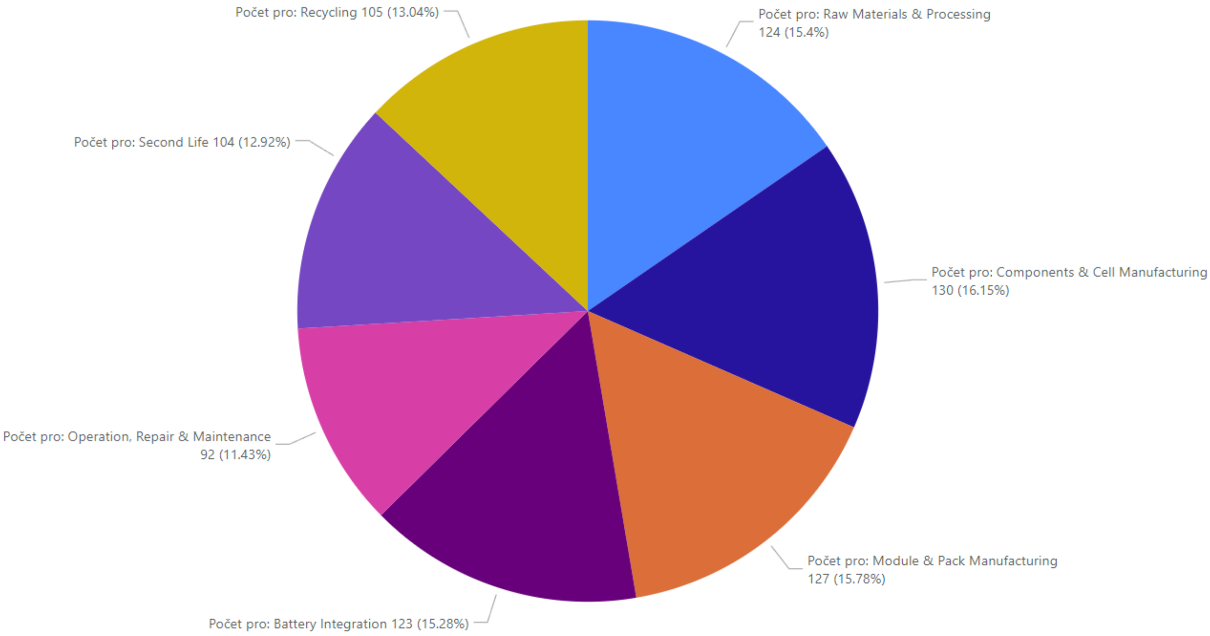

Figure 66: Stakeholders by Value Chain Distribution

13.3 ANNEX C: RELEVANT RESOURCES ON BATTERY LEGISLATION

This annex gathers relevant resources on battery legislation.

Batteries

→ Proposal for a Regulation of the European Parliament and the Council concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020 - New EU regulatory framework for batteries Setting sustainability requirements

→ New EU regulatory framework for batteries: Setting sustainability requirements (EP Think Tank)

→ COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Sustainable and Smart Mobility Strategy – putting European transport on track for the future

→ Commission proposal for a Council Recommendation on VET

→ Communication on a European Skills Agenda

→ Communication "European Skills Agenda for sustainable competitiveness, social fairness and resilience"

→ Improving adults' basic skills ("Upskilling pathways recommendation") – evaluation

→ European Agenda for Adult learning

→ 2016 New Skills Agenda for Europe

→ The 2020 European Skills Agenda

Secondary Use of Batteries legislation

The Batteries Directive requires that the European Commission, assisted by Member States, develops in detail some of its provisions on, e.g. labelling or reporting. The Decisions and Regulations adopted in this context are listed below,

→ Commission Decision 2008/763/EC establishing, pursuant to Directive 2006/66/EC of the European Parliament and of the Council, a common methodology for the calculation of annual sales of portable batteries and accumulators to end-users
→ Commission Decision 2009/851/EC establishing a questionnaire for Member States reports on the implementation of Directive 2006/66/EC of the European Parliament and of the Council on batteries and accumulators and waste batteries and accumulators

→ Commission Regulation (EU) No 1103/2010 establishing, pursuant to Directive 2006/66/EC of the European Parliament and of the Council, rules as regards capacity labelling of portable secondary (rechargeable) and automotive batteries and accumulators
→ Commission Regulation (EU) No 493/2012 of 11 June 2012 laying down, pursuant to Directive 2006/66/EC of the European Parliament and of the Council, detailed rules regarding the calculation of recycling efficiencies of the cycling processes of waste batteries and accumulators
→ Overview of EU Waste Legislation on Batteries and Accumulators

Recycling

→ DIRECTIVE (EU) 2018/851 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2008/98/EC on waste
→ Directive 2004/12/EC of the European Parliament and of the Council of 11 February 2004 amending Directive 94/62/EC on packaging and packaging waste - Statement by the Council, the Commission and the European Parliament

13.4 ANNEX D: FUNDING OPPORTUNITIES SUMMARY

A. EU funding instruments for up-skilling and re-skilling

Funding instruments are based on Commission proposals[95].

Accessible through financial intermediaries

European programme/fund	Application process	Scope regarding skills	Expected volume for 2021-2027 (total budget of programme/fund)
InvestEU	• Through the European Investment Bank Group, implementing partners and financial institutions located in the Member States • Repayable finance including debt and equity finance. • Starting in 2021	The Social investment and skills window (SISW) will cover both the demand and supply side of skills. Support will target students and learners, SMEs and mid-caps as well as providers of training.	InvestEU: €26.2 billion SISW: €2.8 billion (EU Budget Guarantee)
EFSI 2 Skills and Education Guarantee Pilot	• Through the European Investment Fund and financial intermediaries located in the Member States • Debt finance instruments	The Skills and Education Pilot is a new debt financing initiative dedicated to stimulating investments in education, training, and skills. Final beneficiaries include	€50 billion (EU Budget Guarantee)

[95] Accessible at: Employment, Social Affairs and Inclusion. EU funding instruments for upskilling and reskilling - Employment, Social Affairs & Inclusion - European Commission. (n.d.). Retrieved December 16, 2021, from https://ec.europa.eu/social/main.jsp?catId=1530

European programme/fund	Application process	Scope regarding skills	Expected volume for 2021-2027 (total budget of programme/fund)
	• 2021	students and learners, SMEs, mid-caps, and training providers.	

Accessible through national authorities

European programme/fund	Application process	Scope regarding skills	Expected volume for 2021-2027 (total budget of programme/fund)
[https://ec.europa.eu/commission/pressRecovery and resilience facility (RRF)](https://ec.europa.eu/commission/press)	• Grants and loans • Process closely linked with European Semester and each country's recovery and resilience plan, which will be assessed by the Commission • From mid-2021 until 2026	Reskill and upskill (Development of education and training to support green and digital transition and resilience)	€723.8 billion
REACT-EU (Recovery Assistance for Cohesion and the Territories of Europe)	• Additional resources for the ESF/ERDF 2014-2020 • Programming period from 2021 to 2023	Skills development and relevant infrastructure and equipment linked to fostering crisis repair in	Total €50.6 billion (12.3 billion of ESF allocated in support of labor market measures, social

European programme/fund	Application process	Scope regarding skills	Expected volume for 2021-2027 (total budget of programme/fund)
		the context of the COVID-19 pandemic and preparing a green, digital and resilient recovery of the economy.	inclusion, and education and training).
[European Social Fund Plus (ESF+ under shared management)]()	• Grants • Programming period from 2021 to 2027	Modernizing education and training systems. Promoting equal access to quality and inclusive education and training. Providing flexible upskilling and reskilling opportunities for all. Anticipating new skills requirements based on labor market needs.	€87.3 billion
[ERDF (European Regional Development Fund)]()	• Grants • Programming period from 2021 to 2027	Infrastructure and equipment for education and training. Development of skills supporting industrial transformation and smart specializations.	€200.4 billion

European programme/fund	Application process	Scope regarding skills	Expected volume for 2021-2027 (total budget of programme/fund)
Just Transition Fund (JTF)	• Grants • 2021-2027	Development of skills focused on reskilling of workers in regions affected by the economic and environmental transition	€17.5 billion
Digital Europe Programme		High-level digital skills	€6.761 billion
Erasmus+ (new MFF)	• Through national authorities (mobility and strategic partnerships) • Through EC (dedicated calls) • Grants	Learning mobility of learners and staff (trainers, people responsible for upskilling in reskilling) Strategic partnerships working on new and better solutions supporting upskilling and reskilling Projects defining cooperation models with SMEs to support upskilling and reskilling Blueprints for Sectoral Cooperation Centers of Vocational Excellence	
European agricultural fund for rural development (EAFRD)	• Grants (Progr. period from 2021 to 2027)	Knowledge exchange and information in rural areas	€95.5 billion

Accessible through the European Commission

European programme/fund	Application process	Scope regarding skills	Expected volume for 2021-2027 (total budget of programme/fund)
ESF+ EaSI Strand	• Grants • 2021-2027	Support for innovative approaches in the field of upskilling and reskilling	€676 million
European Globalisation Adjustment Fund (EGF)	• Grants • Applications through national authorities • At the earliest from mid-2021	Upskilling and reskilling of workers at risk of losing their job due to globalisation, as a result of a restructuring event at local level	a maximum annual amount of €186 million
European instrument for temporary Support to mitigate Unemployment Risks in an Emergency (SURE)	• Loans • Already available from 2020	SURE exclusively supports national short-term work schemes (i.e. salary compensation for reduced working time). Where envisaged under STWS, SURE can provide also support to upskilling and reskilling measures for workers benefitting under the schemes.	up to €100 billion