Alliance for Batteries Technology, Training and Skills

2019-2023

Intelligence in Battery Manufacturing and Battery Technology

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D3.7 Desk Research and Data Analysis – Release 2

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Table of Contents

Alliance for Batteries Technology, Training and Skills -ALBATTS – Project number 612675-EPP-1-2019-1-SE-EPPKA2-SSA-BThe European Commission's support for the production of this publication under the Grant Agreement № 2019-612675 does not constitute an endorsement of the contents, which reflects the views only of the authors, and the Commission cannot be held responsi¬ble for any use which may be made of the information contained therein.

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Executive Summary

This document provides a summary of findings from a second iteration of the desk research, where battery manufacturing, research and development of new and innovative battery chemistries and battery types are discussed.

Section 1 provides an updated analysis of the drivers of change within the European battery sector with more specific technological drivers of change added.

Section 2 provides a summary of the battery manufacturing with the focus on Gigafactory structure, more specifically:

- **Relevant Stakeholders:** (1) battery manufacturers (gigafactories, small and niche scale); (2) Europe vs. World outlook overview; and (3) Suppliers and customers.
- **Production and Maintenance**
- **Logistics:** (1) environmental; (2) construction; (3) inbound/outbound; (4) inhouse; (5) recycling; (6) staff.
- **Quality:** quality as a part of gigafactories, QMS and audits.
- **Research and Development**
- **Sustainability and Recycling**
- **Other Departments:** (1) purchasing; (2) human resources; (3) sales; (4) finance; (5) digitalisation;

Section 2 continues with the analysis of job advertisements for the production and maintenance; quality; and logistics and purchasing. A set of recommendations for education is provided within the last part of **section 2**.

Section 3 provides a summary of the future battery technologies – relevant stakeholders and technologies, specifically:

- Li-ion batteries and path forward;
- Li-sulphur batteries;
- Sodium-ion batteries;
- Structural batteries;
- Supercapacitors and ultracapacitors;
- Fuel cells;
- Metal-air batteries.

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Section 3 contains an analysis of job roles and skills as well as an overview of the relevant higher education.

Section 4 provides a summary of key challenges that resulted from this research.

Introduction

This report provides an overview of the battery production from the perspective of different aspects and departments – their functions, activities, processes, and skills need. This is supported by the overview of the future battery technologies that are relevant for the future development of the sector – skills and job roles needs are presented as well.

Methodology

The report is structured of two main parts, for which following information sources were used:

(1) Gigafactories – battery manufacturing: online sources and reports were scanned and analysed; this was supported by the offline interviews with the Nothvolt representatives.

(2) Future battery technologies: online sources and various sources were analysed; this was supported by the expertise from FEUP.

Additional document is supported by the drivers of change analysis which is based on the previous research done within the ALBATTS project with addition of specific technological drivers of change.

Each part of the document contains an analysis of key challenges, which are summarised at the end of the document.

List of Abbreviations

2Zero	...	Towards Zero-Emission Road Transport
8D	...	Eight disciplines problem solving
ACEA	...	European Automobile Manufacturers Association
AGV	...	Automated Guided Vehicles
AI	...	Artificial Intelligence
ASRS	...	Automated Storage and Retrieval Systems
BESS	...	Battery Energy Storage Systems
BEV	...	Battery Electric Vehicle
BMS	...	Battery Management System
BTMS	...	Battery Thermal Management System
CECRA	...	European Council for Motor Trades and Repairs
CLEPA	...	European Association of Automotive Suppliers
CO2	...	Carbon Dioxide
COVID-19	...	Coronavirus disease 2019
CSR	...	Corporate Social Responsibility
DoC	...	Driver of Change
DRC	...	Democratic Republic of the Congo
EBA	...	European Battery Alliance
EC	...	European Commission
EPR	...	Extended Producer Responsibility
EQF	...	European Qualifications Framework
ERP	...	Enterprise Resource Planning
ETRMA	...	European Tyre and Rubber Manufacturers Association
EU	...	European Union
EV	...	Electric Vehicle
FEUP	...	Faculdade de Engenharia da Universidade do Porto (Faculty of Engineering – University of Porto)
GWh	...	Gigawatt hour
HEV	...	Hybrid Electric Vehicle
ICE	...	Internal Combustion Engine
IoT	...	Internet of Things
IPCEI	...	Important Projects of Common European Interest
IPR	...	Intellectual Property Rights
JV	...	Joint Venture

kWh	…	Kilowatt hour
LFP	…	Lithium Iron Phosphate
LIB	…	Lithium-Ion Battery
Li-S	…	Lithium Sulphur
LPG	…	Liquefied Petroleum Gas
mAh.g-1	…	Specific capacity
MBA	…	Master of Business Administration
MEA	…	Mode Effects Analysis
MOOC	…	Massive Online Open Course
MW	…	Megawatt
NCA	…	Nickel-Cobalt-Aluminium
NFRD	…	Non-Financial Reporting Directive
NMC	…	Nickel-Manganese-Cobalt
OEM	…	Original Equipment Manufacturer
PCU	…	Power Control Unit
PDSA	…	Plan, Do, Study, Act
PFMEA	…	Process Failure Mode Effects Analysis
PhD	…	Doctor of Philosophy
PHEV	…	Plug-in Hybrid
PV	…	Photovoltaics
QMS	…	Quality Management System
R&D	…	Research and Development
RES	…	Renewable Energy Systems
RO-RO	…	Roll-on/Roll-off
RSS	…	Renewable Storage System
SEI	…	Solid Electrolyte Interphase
TQM	…	Total Quality Management
TWh	…	Terawatt hour
VET	…	Vocational Education and Training
VR	…	Virtual Reality
WWEEE	…	Waste Electrical and Electronic Equipment Directive
WFD	…	EU Water Framework Directive
XR	…	Extended Reality

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1 Drivers of Change

This section provides and updated overview of the Drivers of Change (DoC) that are influencing the European battery sector (i.e., those factors which are key to transforming an industry). The methodological approach adopted by ALBATTS project partners, to have an updated overview of the DoCs, was the same as in the first desk research[1], however focusing more on recently published reports of a more technical nature. The reports are, for the most part, those representing the whole battery value chain and compiled by respected consultancy organisations or projects. Complementing the literature review, recent project results[2] were integrated, as well as a one-to-one interview[3] to eventually validate such results and, for this desk research process, identified DoCs were analysed based on **Occurrence**, **Importance** and **Urgency**[4].

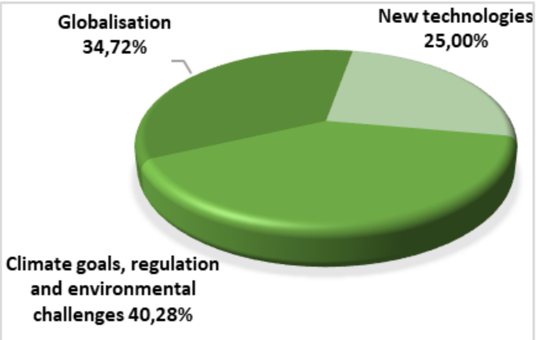

Figure 1: DoC occurrence - 2020 desk research

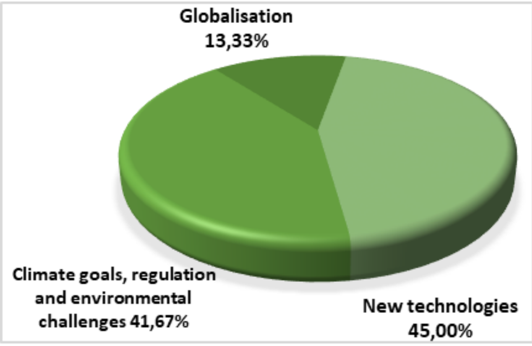

Figure 2: DoC occurrence - 2021 desk research

Comparing the **occurrence** of the DoC in both desk researches (**Figure 1** and **Figure 2**), "Climate goals, regulation, and environmental challenges" have almost the same importance, but "new technologies" have a higher relevance, and "Globalisation" decreased its weight.

[1] *Intelligence in Mobile Battery Applications (D5.1 Desk Research & Data Analysis IMBA – Release 1).* (2020). https://www.project-albatts.eu/Media/Publications/4/Publications_4_20200930_12811.pdf
[2] *Survey Results for Battery Sector*. (2021). https://www.project-albatts.eu/Media/Publications/19/Publications_19_20210601_185540.pdf
[3] *One-to-one meeting with Professor Helena Braga, Engineering Physics Department, University of Porto (PT), 25/05/2021*
[4] Original selection of DoCs is described in the D3.3 Desk Research and Data Analysis of the sector as a whole - Release 1. (2020). https://www.project-albatts.eu/Media/Publications/9/Publications_9_20201211_85443.pdf

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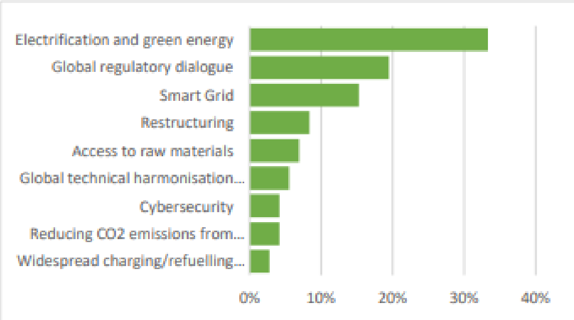

Figure 3: Occurrence of DoC sub-categories - 2020 desk

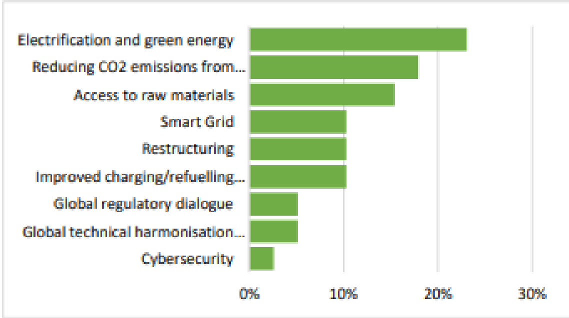

Figure 4: Occurrence of DoC sub-categories - 2021 desk research

Comparing research analysis for each DoC sub-category, **Figure 3** and **Figure 4** show "Electrification and green energy" remaining equally frequent while "Reducing CO2 emissions from battery manufacturing" jumped to second place whereas "Access to raw materials" climbed to the 3rd.

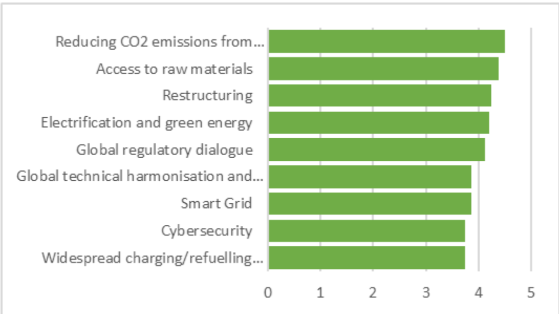

Figure 5: Importance of DoC sub-categories - 2020 desk research

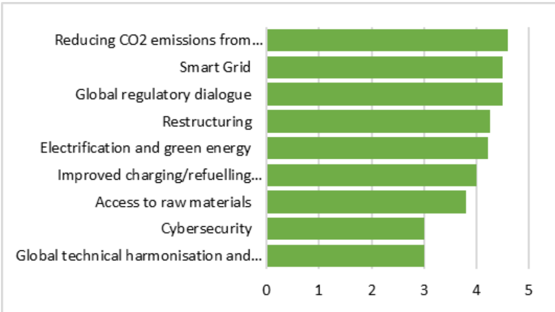

Figure 6: Importance of DoC sub-categories - 2021 desk research

When analysing the **importance** of each sub-category in both researches (**Figure 5** and **Figure 6**), it is evidenced that "reducing CO2 emissions from battery manufacturing" remains the most important while "smart grid" and "global regulatory dialogue" have been upgraded.

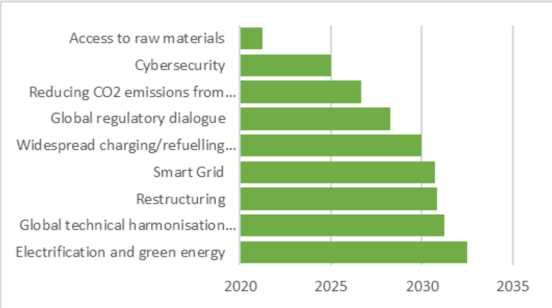

Figure 7: the urgency of DoC sub-categories – 2020 desk research

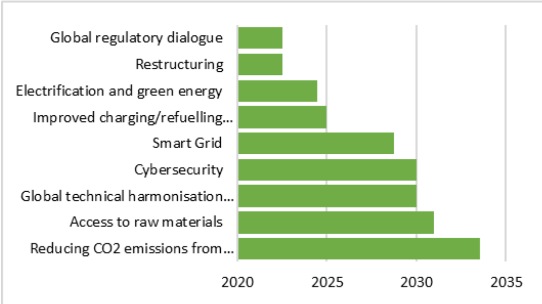

Figure 8: urgency of DoC sub-categories - 2021 desk research

Lastly, **Figure 7** and **Figure 8** analyse and compare the **urgency** of each DoC sub-category. "Global regulatory dialogue" turned out to be the most urgent to tackle, together with "restructuring". "Reducing CO2 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).

Based on inputs from an ALBATTS project partner expert[5] meeting, a more specific set of Drivers of Change for new technologies was added:

- **Battery capacity/energy density:** i.e., electric vehicles with longer range are likely to push climate goals forward;
- **Improved charger performance:** better and faster charging devices/ help boost the use of Battery Electric Vehicles (BEV);
- **Self-dependency:** both in terms of battery construction and materials (e.g., fabrication of cells locally);
- **Battery as a structure:** this refers to being able to use any structure (foundation of a house, chassis of a car, fuselage of an airplane) as a battery case to better use space, reduce weight and/or lower the centre of gravity;
- **Heat conversion into electrical energy:** investing in processes to reconvert wasted heat (kinetic energy) into electrical energy for the circularity of the process;
- **Safety:** especially regarding charging/recharging and discharging of batteries;

[5]One-to-one meeting with Professor Helena Braga, Engineering Physics Department, University of Porto (PT), 25/05/2021

- **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 functional everywhere.

1.1 EU FRAMEWORK

The EU commitment to become the first climate neutral continent globally translated into the **European Green Deal** that brought about the goal to reduce net greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels which requires changes in many domains, including mobility and the energy sector. As batteries are a "sine qua non" element of this transition, the demand for increased battery capacity in Europe would amount to 400 – 1 000 GWh by 2030.[6] To avoid being dependent on imports from third countries, especially Asia, Europe needs to build capacities on its territory and, at the same time, focus on second life and recycling. The production capacities currently announced in Europe by Asian, American, or domestic companies are at the level of 800 GWh by 2030, possibly over 1 TWh.[6]

The right enabling conditions, including the legislative environment, need though to be put in place. The EU is thus publishing strategies of different kinds containing specific measures. At a more cross-cutting level, it is the **New Industrial Strategy for Europe,** updated in spring 2021, following the COVID-19 pandemic, which was accompanied by mapping **EU strategic dependencies and capacities**, focusing also on raw materials and batteries. The **Action Plan on Critical Raw Materials** belongs to the sector specific ones. To speed up development in the battery sector, the European Commission launched the **European Battery Alliance** (EBA) in 2017 and adopted the **Strategic Action Plan on Batteries** in 2018.

Support to research, development and innovation is crucial to driving new technologies, also in the battery value chain. The EU funding programme **Horizon Europe** and **Important Projects of Common European Interest** (**IPCEIs**) represent key instruments in this regard.

Legislation, such as the **"Fit for 55"** package and the **Battery Regulation** proposal, should underpin the development from the regulatory side.

Considering there will be hundreds of thousands of jobs needed for the battery value chain in Europe, EU action is vital also in the education and skills area. The overall **European Skills**

[6] VDMA Roadmap Battery Production Equipment, Update 2020

Agenda is complemented by sectoral initiatives and projects like Automotive Skills Alliance (ASA), Alistore-ERI, Battery 2030+, EBA250 Academy or the ALBATTS project itself.

1.1.1 Research, Development, and Technological Perspectives

Achieving the goals of the Paris Agreement to limit global warming to below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels[7] requires a profound transformation of energy systems, industrial sectors, and transport, while batteries are the most important enablers for decarbonisation of road and maritime transport and transition to a renewable power system. Therefore, Europe needs to ramp up its battery production, which must be based on continuous research, development, and innovation to improve the current technology and come up with significant improvements, attract talents and achieve a competitive position at the global level. In this process, EU support plays a crucial role, encouraging and accelerating private R&D investments and activities.

There are important research and innovation initiatives and instruments at the EU level, which include:

- The main research and innovation funding programme **Horizon Europe**, European Structural and investment funds, etc.;
- Important Projects of Common European Interest (**IPCEIs**) in areas of strategic importance to the EU economy, two IPCEIs on batteries were launched in 2019 and 2020;
- Industry-led communities, **technological and innovation platforms**, such as Batteries Europe and Smart Networks for Energy Transition;
- **Co-programmed European partnerships** [between the European Commission and mostly private (and sometimes public) partners], such as BATT4EU, Towards Zero-Emission Road Transport (2Zero) or Zero-Emission Waterborne Transport;
- **Large-scale research initiatives**, like Battery 2030+;
- Different **projects supported by the EU research and innovation funding programmes**, e.g., LiPLANET, whose mission is to create, among others, a network of research pilot lines to produce lithium battery cells.

[7] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed on 12/10(2021)

Also the **European Battery Alliance**'s industrial workstream, EBA250, where EIT InnoEnergy acts as a network manager, has, among its priority actions, “Grow Europe’s R&I capacity”.

1.1.2 Possible Challenges

There is a need for continuous training of public sector employees in terms of new technologies and their challenges, so that it would be properly reflected in legislation, strategies, funding, or other support schemes; a continuation of different communication platforms of the public sector with industry representatives is also useful and should be considered.

1.2 BATTERY PASSPORT

The **Battery Passport** is an integral part of the new Batteries Regulation proposal[8] by the European Commission, inspired by a Global Battery Alliance concept[9]. Being a digital representation, a “twin” of a physical battery, it should store important information accessible to different stakeholders along the value chain. It should thus enable better maintenance and service, the second life of batteries and more efficient recycling.

The Battery Passport should be backed by an **electronic exchange system** set up by the European Commission. According to the proposal, information and data shall be sortable and searchable, respect open standards for third party use and be fed in a machine-readable format. The system should contain information like the composition of the battery, its carbon footprint, the amount of recycled content, its rated capacity, the expected battery lifetime, the internal battery cell and pack resistance or the temperature range the battery can withstand when not in use. The system might be ready by January 2026 or later, depending on the length of the negotiation process and its results.

By the same time, industrial batteries, and electric vehicle batteries with a capacity above 2 kWh placed on the EU market should have an electronic record (i.e., Battery Passport), which should be unique for each battery[8]. Each battery should possess a unique identifier, printed, or engraved on it. The Battery Passport should be accessible online, through electronic systems interoperable with the electronic exchange system mentioned above.

[8]https://ec.europa.eu/environment/topics/waste-and-recycling/batteries-and-accumulators_en (accessed on 26/07/2021)
[9]http://www3.weforum.org/docs/WEF_GBA_Battery_Passport_Overview_2021.pdf (accessed on 26/07/2021)

2 Gigafactories - Battery Manufacturing

The term "Gigafactory" was coined by Elon Musk in 2013 and, throughout the time, it has become the term of choice for the battery production facility with the production capacity of around 1 GWh (mainly in the Europe). The main concepts of the gigafactories are:

- **Fast upscaling**
- **Economies of scale**
- **Energy self-sufficiency**
- **Vertical integration**
- **A long production line**
- **Automation and industry 4.0 technology**
- **A high level of automation in parallel with many employees**
- **A geographic positioning of buildings to true north**

2.1 STAKEHOLDERS

This section describes various stakeholders relevant for the European battery value chain.

2.1.1 Gigafactories - Battery Manufacturers

Battery production is currently scaling up rapidly in Europe. We are moving from battery plants with a capacity of 4-10 GWh/year potentially to 40 GWh/year and even 80 GWh/year while also having smaller scale and niche manufacturers. The boom in battery-electric mobility is having an impact on the battery value chains. Battery manufacturing related projects have consequently been planned around Europe by several operators.

They include for example:

- Northvolt
- Volkswagen, in collaboration with Northvolt
- Tesla
- ACC – Automotive Cells Company
- Freyr

- Morrow Batteries
- Britishvolt
- SVOLT Energy Technology
- Farasis Energy
- LG Chem/LG Energy Solutions
- Contemporary Amperex Technology Co. (CATL)
- SK Innovation
- InoBat Auto
- Italvolt

Batteries are becoming one of the most important commodities in the world. Until now, European electric vehicles (EVs) and other mobile or stationary applications have been dependent on batteries imported from outside Europe, primarily from Asia. This, however, is about to change. Only a few years ago, Europe did not have the industrial facilities or the expertise to produce batteries. Although Asia still dominates in global battery production, the EU and Europe in general is progressing towards battery self-sufficiency by 2025.

2.3.1 Smaller Scale and Niche Manufacturers

There are smaller niche operators that are specializing in such technologies as, for example, solid-state batteries that are potentially the greatest rival to lithium-ion batteries. These companies, from Europe and beyond include, for example:

- **Factorial Energy**
  - a R&D company working with large automakers and other OEMs to provide the world's first solid-state battery for EVs and other applications
- **SES (Solid Energy Systems)**
  - the company has developed a Li-metal solution that, according to them, is more practical and powerful than current solid-state alternatives
  - current batteries are designed for drone applications
- **EnerVenue**

  - the company is focused on the metal-hydrogen battery technology for the aerospace industry
- **Ion Storage Systems**
  - It develops and manufactures battery solutions for military applications and aerospace systems
  - Following the solid-state battery structure, it is using ceramic separators and other materials from low-cost sources
- **StoreDot**
  - the company is developing a fast-charging battery designed for EVs to overcome their users' range and charging anxiety
- **GBatteries**
  - Their technology relies on charging Lithium-ion batteries including regular traction ones using an adaptive pulse charging algorithm, speeding up the process of charging without compromising lifecycle
- **OXIS Company**
  - The company is developing a technology using lithium-sulphur (Li-S) on the cathode and lithium-metal on the anode
  - their battery cell chemistry does not contain cobalt, manganese, nickel, or copper
  - it is suitable for airplane applications

Although news about new battery technologies is emerging almost on the daily basis, many of these technologies derive from university environments and are still far from the real-world applications in terms of being ready to be built on a Gigafactory scale. From discovering the facts, receiving the first grants and a solid financial support, there is a need to have massive economic and human capital resources to have a successful market entry with a battery cell that is competitive in terms of both price and technology.

2.3.2 Outlook: Europe vs World

Currently, there is a severe imbalance in the battery cell manufacturing market. Broken down into countries, the Asian output is divided into three shares corresponding to the leading local players: China, with 350 GWh/year (76.9 % of total), South Korea, with 18 GWh/year (4.1 % of total) and Japan, with 17 GWh/year (3.9 % of total). China is currently way ahead, within Asia Pacific region which comprises 80% of global manufacturing capacity. Even though North America is obviously behind Asia, it still scores better than Europe with a total cell manufacturing capacity of 42 GWh/year (out of which 35 GWh/year were achieved by Tesla alone), which makes up for a market share of 9.2 %.

The current picture of the global battery manufacturing shows Europe is lagging behind despite, for example, having very ambitious legislation on CO2 emissions from vehicles (mandatory targets for passenger cars, light commercial vehicles, and heavy commercial vehicles) and globally prominent and technologically advanced automotive industry.

Nowadays, Europe`s market share, from this point of view, is below 7%. In contrast, according to the World Economic Forum, Chinese manufacturers, together with Tesla and its Japanese partner Panasonic, command an 85% share of the global lithium-ion battery market, which is expected to reach the $300 billion mark by 2030.

Europe has extensive plans to catch up though. Ambitious battery projects are progressing in countries like Germany, France, Slovakia, Poland, Sweden, and Norway.

European advantages include, for example, the capability to produce green batteries and its advanced automotive industry. The opportunities include focusing on niche markets, new technologies and related intellectual property. European weaknesses include struggling to build economies of scale to compete with Asians. In terms of threats, Asian rivals are also planning to build more capacities across Europe in the coming years where they can bring advantages in cost efficiency and, product, & service quality.

2.1.2 Suppliers

Raw material suppliers: This section refers to the suppliers (detailed information, including the names and links to the respective suppliers at pg. 54 in D4:4) of main raw materials used in the production of batteries, namely:

- **Lithium[10] -** Australia currently has the most extensive production of lithium, followed by Chile, China, and Argentina. Portugal has Europe's most extensive lithium

[10]https://www.automotivelogistics.media/electric-vehicles/electric-vehicle-battery-supply-chain-analysis-2021-how-lithium-ion-battery-demand-and-production-are-reshaping-the-automotive-industry/41924.article Accessed 25.08.2021.

production and reserves (such as Montealegre and Barroso). There are also smaller suppliers for car manufacturers as Volkswagen or BMW.

- **Cobalt -** There are many smaller suppliers of cobalt around the world, dominated by deposits in the DRC, which is problematic of many reasons. Belgian Umicore, a recycling company, has developed an ethical framework to address this.[11] The German BASF has a "Cobalt for Development" project in the DRC. Northvolt wants to source cobalt from known deposits in Sweden and not use cobalt from the DRC. The use of cobalt in batteries is often reduced in new cell chemistries.
- **Nickel -** Glencore, based in Switzerland, has a refinery in Norway. Russian Norilsk Nickel is a huge supplier, and German BASF and Russian Norilsk Nickel have supply agreements for refineries in Finland.
- **Manganese -** South Africa has 78% of the world's known Manganese reserves, followed by China, Australia, and Africa. Manganese is not classified as a critical raw material.
- **Graphite -** Graphite, could be natural or synthetic. China is the main producer of natural graphite, but there are European resources and suppliers[12], in Norway and Germany). On the other hand, synthetic graphite can be produced everywhere, from petroleum and coal. A mix is often preferred by battery manufacturers.

Battery component suppliers:

- **Cathode Materials suppliers -** Some battery plants have an upstream production phase for producing cathode materials in-house (Northvolt). Other battery plants with shorter production lines must buy these cathode materials off the global market. BASF is building a cathode plant in Grünheide (Germany) and has a cathode materials plant in Finland. Others are planned to enter production (Poland & Finland)[13].
- **Anode materials suppliers -** Purchasing anode materials is viewed as possible even if the cathode materials are made in-house (Northvolt).

[11] https://www.umicore.com/en/sustainability/value-chain-and-society/sustainable-cobalt/ Accessed 25.08.2021.
[12] https://investingnews.com/daily/resource-investing/battery-metals-investing/graphite-investing/europes-graphite-supply-chain/ Accessed 25.08.2021.
[13] https://www.vasek.fi/vaasa-region-development-company/communication-and-information-2/news/johnson-matthey-chose-vaasa-for-sustainable-battery-materials-plant- Accessed 25.08.2021.

- **Copper foil (for the anode) suppliers -** The copper foil used is very thin, usually about 10 µm (0,01 mm). This explains why no European copper foil producer is yet into this supply chain, dominated by China. There are also Japan-based suppliers. Hungary and Luxembourg are the European countries with production plans.
- **Aluminium foil (for cathode) suppliers -** Many European companies produce aluminium foils, but what is needed is a very thin version, usually from 12 µm (0,012 mm).
- **Electrolyte suppliers -** Main suppliers are based in Japan or China, but a Chinese company has a branch in Poland[14], where the LG Chem battery plant is located.
- **Separator suppliers[15] -** Germany, Sweden and Poland are identified as having production facilities**.**

<u>**Cell manufacturing machinery suppliers:**</u>

- **Cell plant machinery suppliers, examples[16] -** It should be noted that the brand of machines used in a Li-Ion Gigafactory is not always public information.

Many suppliers sell equipment for all or most production phases, but some sell only one or two types of machines. Battery production is ramping up fast, but the machinery of Gigafactory size is often bought from Asian manufacturers, who often also have a more attractive price tag. Technically, European companies can become more competitive in a long-term perspective.

<u>**Battery cell suppliers:**</u>

Main global battery cell suppliers, some with planned and/or existing European locations

About 75% of the current battery cell manufacturing capacity in 2021 is located in Asia, but not all capacity is for vehicle propulsion. Other 13% of capacity is in Europe and 10% in the USA (details at the pg. 59).

EV vehicle parts, battery packs and systems suppliers: At pg. 60 there are examples of such suppliers for the:

[14] https://gthr.pl/en/about-us/ Accessed 25.08.2021.
[15] https://www.prnewswire.com/news-releases/global-battery-separator-trends-industry-255510721.html Accessed 25.08.2021.

- Battery Management Systems (BMS) Suppliers
- Battery Thermal Management Systems (BTMS) Suppliers
- Battery Case Suppliers, general (battery boxes and similar)
- European Battery Pack Assembly plants (or plants connected to OEMs as suppliers)
- EV drivetrains and components suppliers (examples)
- Power Control Units (PCU), converters & inverters Suppliers (examples)
- Regenerative braking systems suppliers (examples)

In all these sectors, European companies are competitive. OEMs often want to produce the battery packs for their vehicles inhouse, as it is a competitive feature (including safety, life cycle, driving range, vehicle weight, cooling of batteries, charging characteristics).

HEV, PHEV and EV assembly plants (EV suppliers to consumers): The main car manufacturers, announced many assembly plants globally for HEV, PHEV and EV vehicles (over 230 locations globally, at the date of this report).

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Conclusions:

There will likely be some time before we see a complete and effective European supply chain for electromobility. The suppliers of raw materials, battery materials and machinery are primarily situated in Asia. Most cell factories are also located in Asia. European stakeholders have a significant potential to develop their supplying capacity on raw materials, refining capacity and machine production, but this does not happen as fast as European battery cell plants are emerging. European policy initiatives can have good effect here, while they focus on environmental objectives, and not on protective trade measures, which would risk becoming counterproductive.

Regarding the skills needs, many jobs can be created in Europe once existing and new companies adapt to the demands from the expanding European battery and electromobility sector.

2.1.3 Customers

This section provides analysis of the customers that are relevant for the battery plants and battery production on overall level.

Global electric vehicle battery market: The global electric vehicle battery market size is projected to reach $84 billion by 2025. Li-ion batteries have been the primary solution for automakers to power plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). High-energy density, charge retention capacity, and low maintenance are some of the benefits that have accelerated the growth of Li-ion as leading battery technology.

International Trade in Batteries: For lithium-ion battery trade, over the last years, the United States and Germany managed to import almost as much as China, but China still holds a large share of the world's exports. Battery cells are traded under a broader statistical reporting number for battery parts, making it challenging to accurately track imports and exports globally since that trade data includes many other products besides traction battery cells such as the ones incorporated into electric vehicles that are imported from outside European Union.[17]

[17] https://www.usitc.gov/publications/332/working_papers/supply_chain_for_ev_batteries_2020_trade_and_value-added_010721-compliant.pdf, page 16 – accessed on Oct 15, 2021.

Electric Vehicle Battery Supply Chain: The battery manufacturing supply chain has three main steps: **cell manufacturing, module manufacturing**, and **pack assembly**.

The main customers (or better said, "users") for batteries are the car manufacturers. Many joint ventures or cooperation agreements were sealed over the last years. Forming JVs is one option/solution of automakers to secure supply, costs, and quality of the batteries for electric vehicles. In terms of companies that make batteries for electric cars, LG Energy Solutions, CATL, Panasonic, BYD, Samsung SDI, and SK Innovations dominate the manufacturing. Most of these companies are based in China, Japan, or South Korea.

Other transportation: The energy mix in aviation and maritime is like the one in the road transport sector, whereas in the rail subsector, 42% of energy use is electric.

In maritime, alternative fuels and power sources vary significantly for different ship segments and upon their technical applicability and commercial viability. Direct electrification is expected to play a minor role beyond the shortsea segment.

Maritime transport is, by far, the most energy-efficient mode of transport in terms of joules/ tonne-kilometre. Almost 3% of the world's final energy demand, including 8% of the world's oil, is consumed by ships, mainly international cargo shipping. As direct electrification is expected to be viable only in the shortsea segment and few low- and zero-carbon fuel alternatives are available and practical today, maritime transport is considered a hard-to-abate sector.

Almost 4% of the consumed world's energy and 2% of carbon emissions are generated by civilian aircraft. Most recently, with the substantial investment in batteries and specifically in electric aircraft, commercial flights are starting to become a reality. A commercial electric aircraft is an aircraft powered by electric motors. Electric power may be supplied by a variety of methods including batteries, solar cells, ultra-capacitors, fuel cells and **power beaming**. Electrification of aircrafts not only offers the capability to reduce emissions but could also unlock the potential for more energy-efficient aircrafts and brand-new architectures and use cases. As a result of the advantages of increasing electrification in terms of reduced weight, greater reliability, lower maintenance costs and increased efficiency, it is expected that a continuation or even acceleration of the MEA trend as long as the current higher costs of some electrical systems can be restrained. As safety in aviation is of paramount importance, evolutionary changes are expected, implemented through step-by-step adoption of

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electrically powered equipment in additional aircraft systems. Among major players in the value chain which are currently developing commercial electric aircrafts and their necessary components, we could name Boeing, Airbus S.A., Wright Electric, Israel Aerospace Industries, Bye Aerospace, Dufour Aerospace, Electric Aircraft Corporation, Embraer SA, Pipistrel Aircraft, Siemens, Rolls Royce, GE Aviation, and others.[18]

Stationary applications: Battery Energy Storage Systems (BESS) are demonstrating to be valuable assets in the decarbonization of the energy sector. Numerous drivers of change contribute to the increasing popularity of integrating batteries in the electric grid, such as decreasing costs, flexibility, stabilization of the electric grid, funding programs, renewable energy sources integration, etc. In the long-term outlook, BESS + photovoltaic (PV) and energy shifting applications show the steepest growth until 2030, with an expected annual investment from $8,6 billion in 2020 to $30,1 billion in 2030[19].

European Market Overview: The European Commission considers the batteries' value chain as highly strategic, where the European Union (EU) must invest and innovate to strengthen the industrial policy strategy[20]. Since the EU Green Deal, the Commission began reviewing relevant legislation to assess what amendments or additions are required to turn the EU carbon neutral by 2050. Thus, energy storage technologies are expected to become increasingly eligible for funding, consolidating the business and deployment in the EU[21].

While energy storage is recognized as a key to achieving carbon neutrality, batteries are becoming the most demanded technology. The main drivers of change for the increasing popularity of batteries are

- the tendency to decrease costs,
- the flexibility of applications such as regulation of voltage and frequency,
- the possibility to reduce peak demand charges,
- the integration of RES,
- the possibility of backup power supply,
- the relative ease of installation,

[18]https://www.visiongain.com/report/top-20-companies-developing-commercial-electric-aircraft-2020/, last accessed on October 14, 2021
[19]https://www.energy.gov/sites/prod/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf Accessed on 20.08.2021
[20]https://ec.europa.eu/energy/topics/technology-and-innovation/energy-storage_en#eu-initiatives-on-batteries Accessed on 20.08.2021
[21]https://www.nortonrosefulbright.com/es-es/knowledge/publications/1a7a8794/energy-storage-updater Accessed on 20.08.2021

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- the huge potential for market growth in the future.

Commercial and Industrial Applications: Europe still heavily relies on fossil fuels for energy generation, the main greenhouse gas emissions source, with around 80% of the total emissions[22]. Thus, different scenarios were created by the Commission in line with the commitment under the Green Deal and the Paris Agreement that define the distribution of energy sources by 2050 in such a way that it supports reaching the defined goals. In these scenarios, BESS have been used as auxiliaries, which limited their application. However, many new applications are being developed, and stationary energy storage is becoming a more relevant element in the electric grid.

Residential Applications: The closer the energy storage is to the end-user, the more profitable it can be[23]. Residential BESS is installed in the end-user's household. The main functions of them are to provide flexibility and balancing services, enabling maximizing the integration of variable RES (the prosumer[24]) and electric transportation charging.

For example, in Germany, in 2019, 60 000 new residential energy storage systems were installed, translating into 250 MW and 490 MWh new installed capacity, adding a cumulative value of 185 000 RSS installed with a cumulative capacity of 750 MW and 1420 MWh. On the other side, in this country, storage facilities are being built in the same location as the RES electricity plants, either in self-production or industrial production. The combination provides an advantage related to the package of laws that encourage renewable energy generation.

2.2 PRODUCTION AND MAINTENANCE

This section describes two major departments of the Gigafactories, the production and the maintenance.

2.2.1 Production

This production department is responsible for LIB manufacturing as one of the key activities performed by a battery manufacturing company. Therefore, it can be considered a **volume**

[22]https://op.europa.eu/en/publication-detail/-/publication/a6eba083-932e-11ea-aac4-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=37085&WT.ria_f=3608&WT.ria_ev=search Accessed on 20.08.2021

[23] https://www.eurobat.org/images/news/publications/eurobat_batteryenergystorage_web.pdf Accessed on 20.08.2021

[24] a person who buys electronic goods that are of a standard between those aimed at consumers and professionals

department having a relatively high number of employees, compared to the other departments.

The production department can be divided into two main sections:

1) **"upstream"** production preparing the input materials. This production section, where **chemical** processes take place, requires a much lower number of employees than the following downstream production phase. The **control room** may be used to manage the processes and it is not unlike what can be commonly 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. The "upstream production" can be done in-house or outsourced.

2) **"downstream"** production section, involving all the other production steps such as electrode manufacturing, cell assembly (depending on battery design - prismatic, pouch, cylindrical), cell finishing that are more of a **mechanical** nature,

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

The battery producers strive to achieve a lean production process with fewer production steps and occupying less space. 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, most likely to be replacing LIB technology, will have a significant impact on some battery manufacturing processes and would require the possibility of a flexible adaptation of the production line.

Challenges:

- Cost savings - increased throughput - scale-up or speed-up
- Increased productivity - higher yields - minimization of scrap

- Quality – improvements of process stability, cell performance and safety
- Sustainability – higher energy and resource efficiency
- Deployment of Industry 4.0 - increasing of the automation, use of automatic material handling devices, AGVs (Automatic Guided Vehicles), Big Data, AI, IoT
- The ability to adapt the production to future battery technologies

2.2.2 Maintenance

The battery production line is a very complex system and unplanned **production outages** can bring significant losses, hence proper maintenance and quick repair are vital.

The **dry and clean rooms** need periodic maintenance, the measurement of room contamination must be verified regularly. According to the actual trends such as **Industry 4.0** or **predictive maintenance**, parts of the line should monitor themselves and predict when maintenance will be needed.

Another type of maintenance is **software maintenance**, where software and automation engineers can update the software of the production line. Manufacturers have been introducing **preventive maintenance** concepts aiming to prevent failures during production and outages.

Challenges:

Ensuring smooth production and quality of the product while keeping running cost low.

2.3 LOGISTICS

This is a short overview of what is publicly known about transport logistics for the Northvolt Ett factory in Skellefteå, an example of how it would look like for other European Li-Ion battery plants. It covers transport of supplies, products, and workforce to and from the plant, not plant-internal logistics.

2.3.3 Environmental Priorities

Northvolt aims at sustainable battery production to contribute to fossil-free global transport by reducing CO2 footprint to only 20% of present cell production compared to other manufacturers. This will be accomplished by using green electric power in the plant, secured through the local electricity producer Skellefteå Kraft (hydro- and wind power only), and other measures, in combination.

Northvolt´s strategy aims at vertical integration of manufacturing and a long in-house production chain. Northvolt buys raw materials directly from producers to make active battery materials in their upstream production. Northvolt aims at supplying battery production in 2030 with 50% of the raw materials reclaimed from old, recycled EV batteries. Other priorities include complete traceability of raw materials and other production inputs.

2.3.4 Construction Logistics

Logistic Contractor and PEAB are the main building contractors, but there are a large number of subcontractors from Scandinavia, continental Europe, and Asia. For the installation of machinery, many large components are transported via sea and then special trucks cover the remaining 11 kilometres.[25]

2.3.5 Inbound Logistics

Northvolt Ett needs only for the first two production lines (16 GWh of 60 GWh) considerable volumes of raw materials and other supplies.[26] Northvolt wants or demands significant suppliers to be located nearby with both production and warehousing, if possible. Apparently, 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”, “just-in-sequence” supply chain, where the warehouse is down the road and supplies arrive right when needed from various remote locations.

2.3.6 Outbound Logistics

The 16 GWh battery production in the first two lines 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, connecting at the Skellefteå harbour (Skelleftehamn) 11 km away

[25] https://northvolt.com/articles/nv1-sept2020/ Accessed on 24.06.2021

[26] 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

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from the site, where a special section of the harbour is being prepared especially 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.

For international logistics planning, the Swedish company Scanlog was contracted by Northvolt[27], and the cooperating shipping company Wallenius SOL has already begun to transfer machinery and production equipment through Skelleftehamn and will later have two new LPG-driven special RO-RO ships for Northvolt.

2.3.7 Inhouse Logistics

We do not have details on in-house logistics, but as the Northvolt Ett will be a very automated plant with an Industry 4.0 concept, and internal transports will also be highly automated.

2.3.8 Recycling Logistics

Northvolt plans to source 50% of its raw material from decommissioned batteries in 2030.[28] This includes both used collected batteries and substandard batteries recycled directly from the production line. A recycling plant, Revolt, will be built in the direct vicinity of the production units, as Northvolt also has a co-venture with Norwegian Hydro; Hydrovolt, with a recycling facility in Fredrikstad, Southern Norway.

2.3.9 Staff Logistics

The Northvolt Ett plant will have over 3000 employees in 2025. Many will live with families in Skellefteå and neighbouring communities, but some, especially experts and consultants, will probably commute in periods from other parts of Sweden, Europe, and the world. Collective transport to and from work is advised and enabled.

[27] http://www.scanlog.se/en/northvolt-nominates-scanlog/ Accessed on 24.06.2021
[28] 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 24.06.2021

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2.3.10 Conclusions on job roles and skills

Skills related to automated transport and logistic planning will be in high demand, as well as knowledge on handling hazardous goods, especially in the recycling. The job roles include[29] mainly white-collar positions such as logistics developers, logistics business analysts and those who take care of 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, etc.

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

2.4 QUALITY

This section describes the quality department within the Gigafactory, mainly the aspects of quality management systems or auditing processes.

2.4.1 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**[30]**, Continuous Improvement Team**[31]**.**

2.4.2 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

[29] Northvolt interview, 28.5. 2021
[30] https://emp.jobylon.com/jobs/19142-northvolt-customer-quality-engineer/ last accessed on 14.6.2021
[31] Northvolt interview, 28.5. 2021

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- troubleshooting and root causing, e.g., 8D
- providing support for successful implementation of standards and continued certification

2.4.3 Quality audits

In regard to the quality auditing, we can describe following aspects:

Continuous Improvement Methodologies:

The goal of an internal audit is to ensure that records are in place to confirm compliance of the processes and to find problems and weaknesses that would otherwise stay hidden[32]. 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[33]

Northvolt case is used as an analogue for the staff structure in the overall quality function in Gigafactory's in this subchapter.

The quality team consists of engineers and technicians. The engineers are normally experienced personnel with PhD or master's degree educational backgrounds. They function in such job roles as Quality Control Engineers, Analytical Chemists, Technical Writers, Customer Quality Engineers 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 according to 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/specialists (with battery backgrounds)

[32] https://advisera.com/9001academy/what-is-iso-9001/ last accessed on 03.7.2021
[33] Northvolt interview, 28.05. 2021

- 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 is a need to look into automated systems and material flows also within 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 process the vast volumes of samples and stay scalable.

2.5 RESEARCH AND DEVELOPMENT

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

It consists of the following **steps**:

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

There is a big difference between small producers and big ones in battery manufacturing research, also given the available resources and capabilities. **Small manufacturers** usually have their own research and development department within their battery factories unlike **big manufacturers**, which usually have separate R&D campuses or centers.

As the battery value chain is still developing in Europe, almost all big players in the field of LIBs have their research **out of Europe** for now. In contrast, the country with the most concentrated battery research and production is South Korea.

Challenges:

- Finding and testing new materials for battery components such as anode, cathode and electrolyte that will ensure sustainability, enhanced safety, increased capacity, and extended life span of the batteries
- Finding new, easier ways to produce batteries

Gaps:

- Lack of education programs on batteries in EU
- Lack of chemical and technical battery engineers

2.6 SUSTAINABILITY AND RECYCLING

The European Union has one of the strictest legal frameworks in the world in terms of air quality, CO2 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 are applicable 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

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producer administratively and financially responsible for closing the lifecycle loop of its own products once they reach the end-of-life stage.

On the other hand, there are optional principles and objectives that are to be taken into consideration in order to achieve sustainability. Even though they are voluntary, battery manufacturers often choose to abide by certain environment 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 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 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**

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

Job Roles and Skills:[34]

The job roles include, for example, operators, shift leaders, production managers and recycling managers. In the set-up phase of the recycling plants, most staff are university educated white-collar employees, including, for example, researchers and production set-up

[34] Northvolt interview, 2.6. 2021

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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 fully established, the share of blue-collar employees with vocational education will increase. The biggest recruitment challenges occur in hiring engineers and researchers.

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.

2.7 OTHER DEPARTMENTS

This section describes smaller departments or teams which contribute to the overall ecosystem of the Gigafactory. This could refer to either a more specialised department or team, such as digitalisation or a more general department relevant in various domains, such as purchasing, human resources, finance, and sales.

2.7.1 Purchasing

This department deals with purchasing in different areas such as materials, equipment, services, construction, and infrastructure or purchasing dedicated to a specific project. In the case of Northvolt, for example, they also have a localization team within the purchasing department responsible for attracting suppliers to locate their facilities nearby.

The blue-collar workers include, for example, material handlers, planners or technicians. Most of those working for purchasing are white collars working as managers, material engineers, purchasing coordinators, purchasing specialists, category managers etc. Master's degrees in purchasing, logistics, sourcing are among the ideal education backgrounds.

2.7.2 Human Resources

Like many 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, labor 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 on-boarding and training (virtual, on the job, internships turned to employment), etc. Women might be the dominating gender within the human resources department.

Since employees of the Gigafactories are being recruited from various countries, tens of different nationalities with different cultures and backgrounds may be expected to work side-by-side, requiring a sensitive intercultural approach of 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, the pre-processing of job applications.

2.7.3 Sales

In the case of battery manufacturers and using Northvolt as an analogue battery manufacturer start-up here, generally, the sales as a function have evolved from merely attempting to find customers into business development. In the company's early stage, it was about creating strategic partnerships, finding, and approaching connections. However, the tides have been turning more recently, and it is not uncommon for customers to approach battery manufacturers. This is a consequence of the development of the past five years, during which the markets have woken up more to the use of batteries in different areas of applications.

What is characteristic to 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. Achieving customer satisfaction is the ultimate objective, and engineers have a specific role in ensuring it.

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Job roles and skills: Northvolt has formed key account teams around its customers. These teams usually consist of 15-25 members in different roles. The positions in these teams include, for example, key account managers, technical project managers and coordinators. Key account managers also collaborate internally with cell designing teams. Technical project managers also work with customers. The coordinator's role is about fulfilling documentation requirements that are tough among target industries.

In terms of education, most of the sales staff do have engineering backgrounds. However, there are also those with a pure business background experienced working within automotive or any other target industry.

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 valuable and challenging to find. On the other hand, those working in coordinator roles can be rather junior and freshly graduated.

Sales/business development related roles include for example:[35]

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

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. What remains an interesting question mark is the impact of Covid-19 since, before the pandemic, it was common to visit customers in person. The challenge consists of maintaining good relationships without visits and face-to-face interaction.

2.7.4 Finance

Finance departments in Gigafactories are similar to companies in other fields of business. Characteristic to the battery manufacturers is that most of them are in a start-up or early

[35] https://northvolt.com/career/ last accessed 5.8.2021

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 an early-stage company in general.

Depending on the position, the education requirements include a degree in accounting, business, finance, controlling, economics or similar. Several years of work experience is preferred. Occasionally, experience beyond finance may be required.

Skills required in a financial department include experience with ERP systems and proficiency with Microsoft Office tools, business intelligence solutions, and working in teams. 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.

Examples of Finance related roles:

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

2.7.5 Digitalisation

Digitalisation 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 Fraunhofer Institute.

Overall improvement in production times or energy consumption must be achieved in the context of cutting down on human resources by implementing mechanisation, automation, digitalisation, IoT and cloud-based service concepts.

Digitalisation can improve and optimise the scrap management and overall production chain.

Other important 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 represents characteristics of the physical product which will self-adapt and, due to the machine learning/deep learning which is being implemented, lead to the establishment of predictive maintenance.

2.8 JOB ROLES AND SKILLS

Relevant job advertisements and data from interviews with Northvolt were analysed. Every department was described from the activities/processes perspective as well as from the perspective of needed job roles and competences.

The following competence classification is used for categorisation (more information on the classification[36]): **(1) soft competences**; **(2) academic competences**; **(3) general transversal competences**; **(4) cross-sectoral specific competences**; **(5) sector-specific competences**.

Three main departments were analysed in quantitative way for each of the category, smaller departments and teams were described in qualitative way. Top competence for each category and the most frequently occurring job roles will be listed here.

Qualitative description of smaller departments/teams can be found here:

- **Section 2.7** per department.

2.8.1 Production and Maintenance

Most frequently occurring job roles and competences for production and maintenance are described in this section.

Table 1: Production and Mantenance Job Roles

Job Roles	
Blue-Collar	**White-collar**
operators	production engineers
machine operators	manufacturing engineers
battery stackers	automation engineers
maintenance technicians	material engineers

[36] Publications_23_20210920_83914.pdf (project-albatts.eu) p.169

mechanical maintenance technicians	maintenance engineers
calibration technicians	cell engineers
automation technicians	battery and battery pack engineers
instrument technicians	(electro)chemical engineers
equipment technicians	variety of manager roles
electrical maintenance technicians	mechanical engineer
shift leader	electrical engineer

Competence	
Soft	Teamwork; problem solving; communication; adaptation; learning …
Academic	Chemistry; mechanical- electrical- engineering; electrochemistry …
General Transversal	Health and safety standards; reporting; documentation; customers …
Cross-sectoral Specific	Quality; sampling; process improvement; testing; analysis methods; production processes; safety procedures; quality assurance …
Sector Specific	Characterization; cell assembly; battery dismantling; battery assembly; battery components; battery materials; battery chemistry; battery and cell design …

2.8.2 Quality

Most frequently occurring job roles and competences for quality are described in this section.

Job Roles	
Blue-Collar	**White-collar**
Industrial cleaner	Process engineer – lean and kaizen
Clean/dry room staff	Quality engineer
Process operator	Test engineer
Battery/cell test technician (automation, simulation, development)	Other standardisation and regulatory compliance personnel
Quality technician	Mechanical supervisor
Inspection technician	Inspection engineer
Calibration technician	ISO auditor
Metrologist	
Customer and supplier quality technician	

Competence	
Soft	Teamwork; communication; problem solving; presentation …
Academic	Electrical engineering; mechanical engineering; chemistry; engineering …
General Transversal	Reporting; computer literacy; health and safety standards; documentation; customer and stakeholder communication …
Cross-sectoral Specific	Clean/dry room procedures; testing; inspect quality; sampling; process improvement; audit; product quality; automation; analysis methods; safety procedures …
Sector Specific	Characterisation techniques; battery dismantling/removal; repair; charge/discharge; battery chemistry; battery components and materials

2.8.3 Logistics and Purchasing

Most frequently occurring job roles and competence for logistics and purchasing are described in this section.

Job Roles	
Blue-Collar	**White-collar**
Material handler	Material engineers – active materials
Material planner, -planner	Material engineers – components
Purchasing roles	Management roles
Content technician	Management roles – value chain
Inventory technician	Management roles – purchasing
Logistics technician	Management roles – logistics
	Management roles – inventory

Competence	
Soft	Communication; problem solving; teamwork; interpersonal; presentation
Academic	**General** chemistry; material science; electrochemistry
General Transversal	Negotiation with customers/stakeholders; computer literacy; documentation; planning/scheduling; strategy development
Cross-sectoral Specific	Market requirements; process improvement; supply/material planning; purchasing; quality; requirement engineering; automation; logistics; manufacturing engineering; project management
Sector Specific	Battery material knowledge; volume production

2.9 EDUCATION

Below we will discuss some trends and opportunities with importance for the supply of competency for the battery manufacturing sector's machine operators, material handlers and other blue-collar workforce. It is important to remember that these categories make up about 75% of all employees in a battery factory.

2.9.1 Horizontal European Initiatives

The **Pact for Skills** initiative was launched in November 2020, and a "pilot ecology" was launched within this pact, **Automotive Skills Alliance**, led by four major associations: ACEA, CECRA, CLEPA and ETRMA, where ALBATTS is highly involved. The focus is a more ambitious up- and reskilling in the industry, stronger than before, with initiative and funding in conjunction.

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.[37] 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 EBA250 Academy as the missions overlap.

In addition, EDU Battery Network has been formed, an informal group of EC initiatives on battery education and training. Participants are, for example, the Battery 2030+ projects, EIT InnoEnergy/ EBA250 Academy, Fraunhofer Batterien Allianz, the MESC master education network, etc.

2.9.2 Battery-/electromobility Profiled Adult Education and Training Programmes

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

Northvolt Ett in Skellefteå is a European pilot for many coming European battery plants. 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, Digitalisation*. 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 could 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. The about 30 factories that are now being built all over Europe will

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

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.

2.9.3 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, it`s IPR-sensitive, and occupied with R&D activities.

A network for developing XR solutions for training operators in battery plants has been developed by RISE (Research Institutes Sweden), Fraunhofer Baterien Allianz, Chalmers and Braunschweig universities. In addition, four ALBATTS partners are members of a reference group. EIT Innoenergy has developed some VR training modules and games. Some universities offer VR games for learning for general chemistry teaching and learning, including electrochemistry.

2.9.4 More Flexible, Modular and More Blended Learning Solutions from Institutional Providers

In March 2020, the pandemic led to the closing of many schools and university campuses and changing traditional teaching into an online mode. The situation has been challenging to education providers, but it has, in addition, also brought valuable insights into alternative ways to organise and run education. As a result, models of new normalities for education and training access are now being elaborated.

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 Futurelearn: *Battery Manufacturing: Trends in Battery Engineering*.

2.9.5 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 organisations, workers protection authorities, transport branch organisations, 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.

A new, unconventional, and interesting education and training provider is **Battery Associates** – a network of professionals in the field. **"Battery MBA"** is 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.

2.9.6 Challenges and Outlook

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 very valuable for VET providers when forming own solutions in cooperation with the regional industry. The trend of education and training solutions becoming more flexible, and mobile is helpful. Still, VET education also needs to include training and actual experiences in physical labs and in VR and XR environments. The European horizontal initiatives on various levels will hopefully be beneficial to ALBATTS, in terms of both communication and feedback in the project and implementing the results after the project's closure.

3 Future Battery Technologies

This section provides a summary of future battery technology, innovation and research and development in new and innovative battery chemistries or types of batteries. Stakeholders active in research and development, information on needed job roles and skills as well as education are summarised and described as well.

3.1 STAKEHOLDERS [38]

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

Figure *XY* Location of main battery R&D centres

[38]ALBATTS report D.4.4, pp. 142 – 194, available at https://www.project-albatts.eu/Media/Publications/23/Publications_23_20210920_83914.pdf (last accesssed on 7/10/2021)

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.).

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

The battery industry also conducts projects with domestic and **international universities and research institutes**, co-create bachelor´s and master´s programmes, or offer 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.

More details on the R&D topic from the perspective of a battery manufacturer can be found in ALBATTS report *D4.4 Battery manufacturing*.

3.2 TECHNOLOGY

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*[39] focuses in detail on the forthcoming technologies, relevant stakeholders and job roles & skills. Currently used li-ion batteries, Li-sulphur, sodium-ion, structural batteries, supercapacitors, ultracapacitors and fuel cells will be described in the following sections.

[39] 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)

3.2.1 Li-ion Path Forward

The reason LIBs are so popular is that lithiated graphite anode only differences itself from the Lithium anode 0.1-0.3 V when fully charged, which means that LIBs may have high electrical potential. This means that batteries perform adequately in high voltage systems with volumetric limitations. Graphite is however approximately one order of magnitude less capable of storing electricity than Lithium. The main research goals on anode, cathode, and electrolyte aim to increase energy density, charging rate, safety, lifecycle, to reduce costs, and avoid the use of scarce minerals, such as cobalt.

Negative Electrodes (anode): The most commonly used material for anode is graphite. Its capacity is 372 mAh.g-1 and its lifecycle is similar to NMC cathodes, which can be a problem in the future. Silicon (Si) has been researched as an anode because is a cheap and common material with a very high capacity (3579 mAh.g-1 for Li15Si4 phase); nevertheless, the battery has a slightly lower potential than the one with graphite anode. Usually, the Si is mixed with the graphite to < 15% of Si, to avoid the complications arising from extreme volume changes. The volume change leading to fast degradation of the cell must be addressed and solved. A promising usage of Si is as a composite with graphite.

Positive Electrodes (cathodes): Cathodes are typically a combination of several oxides' active materials. One of the main drivers of change of cathode research is the need to reduce or eliminate Cobalt therefrom.

NMC (Lithium Nickel Manganese Cobalt oxide) cathode has an experimental (practical) capacity of 150 mAh.g^{-1}. Nowadays, the most common ratio for NMC is NMC622 ($LiNi_{0.6}Mn_{0.2}Co_{0.2}O_2$) but the research is focusing on NMC811 ($LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$), an NMC cathode with lower Cobalt content.

NCA (Lithium Nickel Cobalt Aluminium oxide) cathode has an experimental (practical) capacity of 175 mAh.g^{-1}. This cathode material was developed by Panasonic for Tesla.

LFP (Lithium Iron Phosphate) cathode has a lower nominal voltage than NMC and NCA and a practical capacity of 160-170 mAh.g^{-1}. LFP cathode has several advantages as low risk of thermal runaway, improved lifecycle, higher sustainability, etc.

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Electrolytes: The most important problem associated with liquid and gel electrolytes is their flammability. Another common technical problem with traditional liquid electrolytes is their electrochemical window of stability. This parameter can be potentially overcome by using electrolyte additives and by forming an SEI layer.

Solid electrolytes can potentially solve the safety issues in LIBs and allow the use of Lithium as the anode, which expands the anode-cathode pairs that can be used in a battery and possibly the energy density of each battery cell. One of the solid electrolyte problems is that, conversely to liquid, solid electrolytes have lower ionic conductivity at room temperature and cannot soak the electrodes, making it harder to fabricate efficient battery cells.

3.2.2 Li-Sulphur

Li-S batteries are one of the most promising post-Li-ion battery technologies. Li-S batteries have a lesser environmental impact because they don't contain heavy metals and sulphur may be sourced from recycled materials.

Li-S batteries have lower nominal voltage than Li-ion batteries but can have higher capacity. Another advantage of Li-S cells is their 100 % depth of discharge in comparison with 80 % (or less) for the LIBs.

The Lithium-Sulphur battery cells have a long shelf-life, with no charging required when left unused for an extended period. Li-ion batteries require a recharge every 3-6 months to prevent failure, which often causes significant warranty issues.

The biggest challenge related to Li-S batteries is their limited cycle life. Other problems are poor electrode conductivity and poor stability at higher temperatures.

3.2.3 Sodium-ion

Sodium-ion batteries (NIBs) are still in development, but they are considered cheaper alternatives to LIBs. Sodium is the fourth most prevalent element on the planet, and it is much cheaper (about $135–165 per ton) than lithium carbonate (around $5000 per ton).

NIBs work on the same principles as LIBs. They are suitable for high voltage applications and their cathodes' specific capacity varies from 70 to 140 $mAh.g^{-1}$. As LIBs batteries, they use carbon but in the amorphous state, with disordered plans, to allow for easier Na insertion.

The biggest challenge related to NIBs is the difficult insertion of sodium ions into the anode and cathode leading to lower cycle life and a fast decrease in battery capacity.

3.2.4 Structural Batteries

In comparison to all previously mentioned, the concept of structural batteries is not dependent on cell chemistry or not defined by a type of electrodes or electrolyte. Structural batteries are defined as devices that can catty a mechanical load while having an electrical energy storage capability, thus it is important that mechanical loads, while in use, can be carried. Structural batteries tend to be all-solid-state due to the nature of their purpose (safety and mechanical loads).

There are two types of structural batteries:

- **Laminated structural battery** where battery is placed between structural elements;
- **3D-fiber structural battery** where carbon fibres are used in the electrochemical processes.

Structural batteries, when combined with Lithium-ion based batteries, have shown to be great opportunity to achieve overall goals, such as: (1) high energy and power density; (2) quick charge; and (3) long lifecycle.

<u>Challenges:</u>

Development, manufacturing, and research on structural batteries pose new challenges for researchers, such as:

- operating temperature limits of power elements used during the curing of high-performance composites and adhesives (used for structural batteries);
- the use of the flammable liquid electrolyte even if in resin or polymer electrolytes, which is critical for application in structural elements that may be exposed to high mechanical loads and structural failure;
- the application of the multifunctional element to a limited temperature range;
- the use of carbon fibres/graphite as anodes enduring lithiation/delithiation leading to a quick degradation therefore reducing lifespan;
- the necessity for a complex BMS narrows its applications;
- the cost.

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3.2.5 Supercapacitors and Ultracapacitors

Supercapacitors or ultracapacitors are one of the typical non-conventional energy storage devices and are based on similar working principles to those of batteries – they are more suitable energy storage when available power is more imperative than energy.

In comparison to internal combustion engines, batteries, and fuel cells, super- and ultracapacitors can deliver quick bursts of energy during peak power demands and quickly store energy. Excess power can be captured, which would have been otherwise lost.

3.2.6 Fuel Cells

Fuel cells are becoming more prominent on the market since the synthesis of hydrogen from the hydrolysis of water became viable. There are different kinds of fuel cells working in different temperatures.

Fuel cells are important for heavy-duty vehicles such as buses as they have a higher energy density than batteries.

3.2.7 Metal-air Batteries

Metal-air batteries adhere to similar principles to those ruling fuel cells. There are multiple configurations, such as: (1) lithium-air; (2) aluminium-air; (3) zinc-air; (4) magnesium-air; or (5) sodium-air.

Most of the commercial uses for metal-air cells are primary cell. These batteries possess a theoretical specific energy which is comparable to gasoline.

Challenges:

Problems leading to a very high internal resistance and a very short lifecycle made the research investment in this technology lose its vitality in recent years.

3.3 JOB ROLES AND SKILLS

Relevant job advertisements and data from interviews with Northvolt were analysed. Research and development department and, in general, as a discipline, was described from the activities/process's perspective as well as from the perspective of needed job roles and competences.

Following competence classification is used for categorisation (more information on the classification[40]): **(1) soft competences**; **(2) academic competences**; **(3) general transversal competences**; **(4) cross-sectoral specific competences**; **(5) sector-specific competences**.

Most occurring job roles and competence for research and development are described in this section.

Table 2: Research and Development Job Roles

Job Roles
Research Areas – engineers and researchers
Battery engineering – mechanical- electrical- material- chemical- and other
Cell design – anode, cathode, electrolyte, separators, and other parts
Development – software, modelling, production, maintenance, testing

Table 3: Research and Development Competence

Competence	
Soft	Teamwork; communication; problem solving; adaptation; interpersonal
Academic	Chemistry; material science; electrochemistry; electrical engineering
General Transversal	Customers/stakeholders; reporting; documentation; plan/schedule
Cross-sectoral Specific	Testing; data analysis; design; prototyping; requirement engineering; validation; analysis methods; data analysis/science; manufacturing engineering and methods/production processes
Sector Specific	Characterization techniques; cell evaluation/validation; electrolyte development; thermal management; electrolyte formulation; cell design; battery components; battery chemistry; battery design; battery materials

3.4 EDUCATION

This section will summarise and focus mainly on the EQF levels 7-8.

There are many European universities already active with education offerings in the battery chain on the EQF 7 (master level) and EQF 8 (PhD education level). There are, in addition,

[40] Publications_23_20210920_83914.pdf (project-albatts.eu) p.169

many open questions about focus, education volumes, curricula, university-industry collaboration and so on.

Two recent reports, *Future Expert Need in the Battery sector*[41] (hereinafter called *Experts Needs*) from Fraunhofer and EIT Raw materials, and Batteries Europe's *Position paper on Education and Skills*[42] (hereinafter 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), and 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 up-and reskilling 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.

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* emphasises 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 digitalisation 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.

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[41] 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

[42] 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

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 PhD levels. Here are some main points 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
- Specialised and differentiated online courses ICTs to enhance the education process,
- 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,
- Public information about the sector,
- Education testbeds,
- European standardised options for national courses or programs.
- Cooperation on attractiveness for the sector

3.4.1 Challenges and Conclusions

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

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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.

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4 Key Challenges

This section describes and summarises key challenges within this document, which are mapped to the identified categories based on the document structure and described topics.

- There is a need for continuous training of public sector employees in terms of new technologies and their challenges, so that it could be properly reflected in legislation, strategies, funding, or other support schemes.
- Development of different communication platforms of the public sector with industry representatives.
- Development and improvement of supplying capacity on raw materials, refining and machine production.

4.1 PRODUCTION AND MAINTENANCE

This section covers challenges relevant for production and maintenance.

4.1.1 Production

- Cost savings - increased throughput - scale-up or speed-up
- Increased productivity - higher yields - minimization of scrap
- Quality – improvements of process stability, cell performance and safety
- Sustainability – higher energy and resource efficiency
- Deployment of Industry 4.0 - increasing of the automation, use of automatic material handling devices, AGVs (Automatic Guided Vehicles), Big Data, AI, IoT
- The ability to adapt the production to future battery technologies

4.1.2 Maintenance

- Ensuring smooth production and quality of the product while keeping running cost low.

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4.2 LOGISTICS

- Development of automatic flow, automatically guided vehicles, warehouse automatization, IoT, Industry 4.0.

4.3 QUALITY

- Continuous lifelong learning
- Automated systems, material flow, quality control process
- Scalability of production and automation, sampling

4.4 RESEARCH AND DEVELOPMENT

- Finding and testing new materials for battery components such as anode, cathode and electrolyte that will ensure sustainability, increased safety, capacity, and extended life span of the batteries
- Finding new, easier ways to produce batteries

4.5 RECYCLING AND SUSTAINABILITY

- Awareness of different sustainability requirements and conditions, as well as legal frameworks and legislation – responsible procurement of certain raw materials; the high energy consumption and the power supply
- Importance of certain environment and sustainability principles, such as CSR and EPR

4.6 EDUCATION

- Support of horizontal European initiatives
- Battery and electromobility profiled adult education and training programmes
- Development of simulated training environments
- More flexible, modular, and blended learning solutions
- Development of new education programmes and courses
- Communication between academia and industry to identify the concrete needs
- Interdisciplinary programmes in cooperation between academia and industry

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- Internships and other platforms for exchange between academia and industry,
- Curricula adapted for battery experts in electrochemistry, production, and applications
- Specialised 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 industries,
- Training and practice infrastructure (pilot plants, labs, simulations),
- Train-the-trainer / teach the teacher programs,
- Public information about the sector,
- Education testbeds,
- European standardised options for national courses or programs.
- Cooperation on attractiveness for the sector

4.7 BATTERY TECHNOLOGY

This section covers selected challenges relevant for the battery technology.

4.7.1 Structural Batteries

Development, manufacturing, and research on structural batteries pose new challenges for researchers, such as:

- operating temperature limits of power elements used during the curing of high-performance composites and adhesives (used for structural batteries);
- the use of the flammable liquid electrolyte even if in resin or polymer electrolytes, which is critical for application in structural elements that may be exposed to high mechanical loads and structural failure;
- the application of the multifunctional element to a limited temperature range;
- the use of carbon fibres/graphite as anodes enduring lithiation/delithiation leading to a quick degradation therefore reducing lifespan;
- the necessity for a complex BMS narrows its applications;
- the cost.

4.7.2 Metal-air Batteries

Problems leading to a very high internal resistance and a very short lifecycle made the research investment in this technology lose its vitality in recent years.

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