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Alliance for Batteries Technology, Training and Skills
2019-2023

Deliverable 6.1

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Report on state-of-art of job roles
and education in the sector

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REPORT ON STATE OF THE ART OF JOB ROLES AND EDUCATION IN THE SECTOR

Report Title:	Report on state-of-art of job roles and education in the sector		
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Version Control				
Version	Name	Partner	Changes	Date
0.5	Draft	SKEA		27/02/2020
1.0	Final	SKEA	Editorial changes, addition of courses and master programmes	29/02/2020
1.1	Updated after EC feedback, for internal /external review	Innoenergy, Uppsala university	Additions, corrections	10/04/2020
1.2	Corrected submission	SKEA	Additions, corrections	14/07/2020
1.3	Corrections, additions	SKEA	Page numbers, grammar revision and proofreading, addition of some Northvolt work roles	07/10/2020

Document data:	Filename:	Deliverable 6_1 Report on State-of-Art		
	Pages:	54	No. of annexes:	0
	Status:	(draft/final)	Dissemination level:	Public
Project title:	Alliance for Batteries Technology, Training and Skills		GA No.:	612675
WP title:	Report on state-of-art of job roles and education in the sector		Project No.:	612675-EPP-1-2019-1-SE-EPPKA2-SSA-B
			Deliverable No:	D 6.1
Date:	Due date:	29/02/2020	Submission date:	29/02/2020
Keywords:				
Reviewed by:	A Reviewer at EITInnoEnergy		Review date:	01/04/2020
	A reviewer at Uppsala university		Review date:	17/06/2020
Approved by:			Approval date:	

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EXECUTIVE SUMMARY

This document summarises the desk research accomplished by the team of partners responsible for the activity on 'Education and Training' (WP6). It reflects the state-of-art of job role description and education in the battery sector, which will be a point of departure for the development work.

The report provides an overview of the descriptions of battery-related skills and occupations according to the European Skills/Competences, Qualifications and Occupations (ESCO). Further, it discusses as a reference the job roles described in job ads for the Tesla/Panasonic Gigafactory 1. The report goes on to provide examples of education and training courses on varying levels of education. We have used the EQF framework (European Qualifications Framework) for categorisation of education levels.

Focus in the search for examples of educations has been on directly battery-associated education programmes and courses and learning material and other learning resources, namely for batteries and battery applications. An extra effort was made around Chemistry education, especially inorganic chemistry and electrochemistry, since these categories of jobs are in high demand in cell factories.

The desk research also presents other education and training opportunities, as Massive Online Open Courses (MOOC) courses and sources of open educational resources.

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INTRODUCTION

The aim of the ERASMUS+ Sector Skills Alliances project ALBATTS is, according to the application, to

"…make a major contribution to the electrification of transport and green energy use in Europe by having organisations on the demand and supply side of competence to meet, communicate, analyse state of the art and make an open and useful plan in a European perspective." (Quote from the application).

This "blueprint" for the batteries and electromobility sector, will be developed by 20 partners in 11 countries during four years, 2019-2023. The project contains the following Work Packages and Steering group:

- WP1: Management, SKEA, Skellefteå kommun
- WP2: Dissemination, EUPPY, Eupportunity
- WP3: Sectoral Intelligence, VSB-TUO, University of Ostrava
- WP4: Intelligence in Stationary Applications: MERINOVA
- WP5: Intelligence in Mobile applications: AIA
- WP6: Training: VAMIA / ATEC (shared leadership)
- The Steering group is led by ACEA.

The work packages 3, 4 and 5 are "sectoral intelligence" work packages. They perform the data collection and analysis for the project concerning stakeholders, emerging job roles and other relevant factors along with sectors of the value chain, for later delivery to WP6, Education and Training. WP6 will define emerging job roles and develop needed new learning material, modules, and curricula. Adaptive learning structures and micro-learning will also be pilot-tested and tried out. The results will be used for later dissemination among stakeholders and implementation in national policy and actual education and training.

A potential problem was foreseen at the project application stage: It will take many months for WP6 partners to get the organised results from the WP 3-5 sectoral intelligence process, and the WP6 work must start anyway. This is the background to this deliverable. We wanted WP6 partners, and all partners, to know some of what is there already at the start of the project; Definition of job roles, available curricula and available education and training solutions for the batteries and electromobility sector. This deliverable is a result of a first scanning of what has been possible to find in the spring of

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2020. It has no claims to be exhaustive, and it delivers examples of existing education and training in connection to the battery and electromobility value chain.

By having some initial shared orientation, the partners will be able to track ongoing development also outside the project, both in organised and sometimes in ad-hoc ways. By ensuring that we have some shared knowledge of the state-of-art for WP6, we can also coordinate our work with other stakeholders and agents. Research universities are developing new master education concepts besides their research activities. Local and regional public educational organisations want to assist companies when starting and expanding in their region. Transnational organisations use education to promote and enable their goal achievement. Organisations selling education to workplaces are offering training concepts, and so on. The earlier we get to know this landscape and share the knowledge among project partners and network collaborators, the better we will be able to understand and act successfully in this developing environment of education and training questions for the batteries and electromobility sector.

This WP deliverable is not intended to be any makeshift version of what WP3-5 will come to deliver in their reports with designed methods. This deliverable 6:1 is limited to what have by partners been known or been detectable by desktop research and networking at the time of writing. From this, a selection has been made. The scope is focused only on *high-density batteries, energy storage and electromobility*. Besides this, it is, of course, essential to know what the needs are in car factories when converting production to electric propulsion, how work in raw materials and recycling facilities will be developing and how applications will be implemented in land-sea- and air transport and in electrical grids. This will be more illustrated by the intelligence work with stakeholders, surveys and workshops in the methodology used in WP 3, 4, and 5. For this, we have to wait. This report is not directly concerning these job roles and education needs; it focuses on battery knowledge and electromobility, also this connected to batteries.

The deliverable is also fresh produce, which relevance will deteriorate fast with time. Education offerings come and go. Besides, we are very aware of the limitations of not knowing what has not been found. Our listings of education on different EQF levels are not exhaustive. It provides interesting examples within the plethora of existing education and training in the field. To the readers of this deliverable report, we ask for understanding in these respects and welcome all comments and additional information. This deliverable is necessary for internal use in ALBATTS WP6. Still, it is also

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provided as a public document if it can, in this stage of development in 2020, contribute to fulfilling other knowledge needs.

Other organisations and projects are also trying to get a similar overview in the present slice of time. The background is roughly the same as the background for the ALBATTS project; all want to enable fast development of a working value chain of batteries and electromobility by knowing state of the art and starting from this developing competence provision solutions. *EIT InnoEnergy*[1][2] and *EIT Raw materials*[3] both have their perspectives, gather and analyse education information and promote and provide education. The *Battery2030*[4] Research Roadmap initiative focuses on higher levels of European education and curricula, Batteries Europe[5] also has ongoing task force work and are coming with a report in the autumn of 2020, *European Battery Alliance*[6] has a broad approach to competence development concerning batteries. The latest is an upcoming proposal for an industrial European Partnership on the Industrial battery value chain[7] , which also wants to take initiatives concerning education and training. ALBATTS is continuously exchanging information with these partly overlapping parallel European initiatives to avoid unnecessary double work but also to exchange understandings and take initiatives together.

[1] A big thanks to ***Dimitra Maleka*** on InnoEnergy Scandinavia for providing with valuable info on EIT InnoEnergy courses and on shorter vocational courses

[2] https://www.innoenergy.com/for-students-learners/

[3] https://eitrawmaterials.eu/eit-rm-academy/

[4] https://battery2030.eu/

[5] https://ec.europa.eu/energy/topics/technology-and-innovation/batteries-europe_en

[6] http://www.eba250.eu

[7] https://ec.europa.eu/info/files/european-partnership-industrial-battery-value-chain_en

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1 BATTERY JOB ROLES AND SKILLS

1.1 ESCO occupations and skills descriptions

European job roles, called occupations, are listed, categorised, shortly described in the ESCO database[8] in all the European Union languages. ESCO stands for *European Skills, Competences, Qualifications and Occupations*. For each occupation, ESCO shows several alternative names for the same occupation, which are not recommended. Necessary skills are listed for each occupation, as well as complementary skills. These skills are of two categories: *knowledge* (theoretical orientation) and *skills*. There are now, in February 2020, listed in total 2942 occupations and 13485 skills in the ESCO database. A third category connected to occupation is, when applicable, a formal qualification sorted after EQF level 1-8; there are 9457(in February 2020) qualifications. The ESCO database aims to enable work mobility by an understanding on the European level – transferrable also to national systems of occupations, skills and qualifications. Information about legal aspects, as European or national regulations for working in an occupation, are provided by a link to the Regulated Professions Database of the Commission[9].

1.1.1 Battery Occupations in ESCO

In ESCO, we focus on three occupations which seem vital for work with energy-high-density battery cells. We focus on battery assembler, battery test technician and automotive battery technician.

”Battery assembler.”

ESCO description:

> ”Battery assemblers are welding and assembling the battery components such as electronics parts, wiring, and casing around the cells.”

Comment: In general, this occupation description can include many kinds of battery cell producing machine operators in Li-Ion cell plants as well as workers in battery packing plants. However, what is understood behind this description is lead-acid batteries, which is problematic.

[8] https://ec.europa.eu/esco/portal/
[9] http://ec.europa.eu/growth/single-market/services/free-movement-professionals/qualifications-recognition_en

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”Battery test technician”

ESCO description:

> ”Battery test technicians use positive and negative wired plugs to test the battery's resistance capacity. They also test rejected batteries to determine their flaws.”

Comment: In general, this occupation description can function for many workers both in the production and service of Li-Ion and other high-density battery packs for the propulsion of vehicles. However, in Li-Ion cell production, it is a qualified task for a formation engineer to determine flaws for a cell and send it to recycling. Testing goes on in many stages during the production chain.

”Automotive battery technician”

ESCO description:

> ”Automotive battery technicians assemble, install, inspect, maintain and repair batteries in motor vehicles. They use electrical test equipment to confirm good working condition after installation. They evaluate batteries to determine the nature of power problems. They also prepare old batteries for disposal.”

Comment: The description of the occupation is OK, but understood as concerning mainly lead-acid start batteries, not battery packs for the propulsion of vehicles. Increasingly the motor is electric, and the battery is not only for starting the vehicle. The word ”disposal” could at least be changed into “recycling”.

1.1.2 Battery Skills in ESCO

For each occupation, some skills are presented as necessary or complementary for an occupation. Below are the directly battery-related skills, related to the occupations above, as described in ESCO:

”Operate battery test equipment” (Type of Skill: Skill)

> “Operate equipment used for battery testing, such as a soldering iron, a battery tester, or a multimeter. Detect flaws affecting the battery's performance, test the battery's capacity for accumulating charge, or test its voltage output.”

”Battery assembly” (Skill)

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"Manufacture batteries using hand tools, power tools or automated machines. Understand and read plans and blueprints regarding the technical aspects of batteries to comprehend specifications and requirements."

"Battery chemistry" (Type of Skill: Knowledge)

"The different battery types according to the representative chemical components used in the anode or the cathode such as zinc-carbon, nickel-metal hydride, lead-acid, or lithium-ion."

"Battery fluids" (Knowledge).

"The characteristics and properties of battery fluids."

"Repair battery components" (Skill)

"Repair battery components through replacing cells, repairing wiring, or spot-welding cells."

"Battery components" (Knowledge)

"The physical components, such as wiring, electronics and voltaic cells that can be found in batteries. The components vary according to size and type of battery."

"Battery testers" (Knowledge)

"Electronic devices that test the state of batteries. Battery testers can test the charge present in battery cells, test the battery's capacity for accumulating charge and detect flaws that may influence the battery's performance, depending on the type of battery tester."

These skills descriptions are adequate for what they are intended to describe. Today batteries are different, and much more in focus for change of society. Skills and knowledge will have to be added. A more thorough analysis and discussion in the ALBATTS project will later have to propose either additions and specifications to the above description of occupations and skills or to propose a new series of occupations and task concerning energy-high-density batteries for propulsion of vehicles and for balancing electric grids. This kind of decision demands empirical work in close contact with industry. A new balancing of recommended qualification levels for some occupations may also come in question.

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1.2 Job roles reference object: Gigafactory 1

1.2.1 Background Tesla Gigafactory One

When Tesla began producing electric cars in 2008, starting with the Tesla Roadster, they chose not to use pouch- or prismatic batteries with their more significant volume per unit. Instead, Tesla used the small cylindrical 18650 batteries (18x65 mm) which at the time were found mostly in consumer electronics like laptops. The idea was to be able to control the temperature by cooling the batteries more effectively at acceleration and charging. The cylindrical batteries were also cheaper to mass-produce.

In the Tesla Gigafactory 1 in Sparks, Reno, Nevada, the Tesla partner Panasonic is since 2016 manufacturing batteries for the Tesla cars. When fully expanded, this production will have a capacity of 35 GWh energy storage per annum. It started production in 2016 with producing the 18650 cylindrical batteries for the TESLA Powerwall and Powerpack and the Tesla Model S and X. The newer model 3 uses developed 2170 cylindrical batteries. The 2170 cell is around 50% larger by volume than the 18650, but it can deliver almost double the current (the 18650 delivers 3,000 mA, and the 2170 has been tested at 5,750-6,000 mA).[10]

1.2.2 The Gigafactory as a raw model

The Tesla Gigafactory 1 is the raw model for Northvolt Ett in Skellefteå, Sweden, and cell and car Gigafactories in general. It is about production at economies of scale by a high grade of automation and by vertical integration[11]. Ideally, there would be a mine for raw materials at one end of the factory and finished marketable products in the other end. Another Gigafactory feature is to have subcontractors in place or close to the plant[12].

Two of the founders of Northvolt AB (started as SGF AB, Swedish Gigafactory, 2015[13]) in Sweden had been involved in the planning of Tesla/Panasonic Gigafactory 1. They had the idea to start a similar

[10] https://insideevs.com/news/332915/tesla-2170-battery-cells-greater-power-at-comparable-cost/

[11] https://www.supplychain247.com/article/telsas_gigafactory_supply_chain_vertical_integration

[12] Cooke, P. Gigafactory Logistics in Space and Time: Tesla's fourth gigafactory and its rivals. https://www.researchgate.net/publication/338866915_Gigafactory_Logistics_in_Space_and_Time_Tesla%27s_fourth_gigafactory_and_its_rivals

[13] https://www.breakit.se/artikel/6773/finansprofilen-harald-mix-backar-tesla-svenskens-nya-batterifabrik

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plant in Europe. This was in 2015, at the time when it was becoming increasingly apparent that the European value chain for electric vehicle production was not there at all. Asia and the US were far ahead.[14] Production of batteries was the critical part. Europe had close to nothing.

In the process of finding the best location for a European battery-cell gigafactory, a selection process in several steps was applied. Many Swedish and Finnish communities competed and answered the questions from Northvolt. One of the items on Northvolt's "shopping list" was the availability of "Skilled labour force and vicinity to universities". A comment from Northvolt meant to be clarifying was "It's an automated process; you don't need cheap labour, but you do need skilled engineers. Energy is a very important part of the cost. Europe needs to do something".[15]

1.2.3 The Gigafactory as a reference object

When in October 2017 it was finally decided that Norra Bergsbyn in Skellefteå municipality in Northern Sweden was to become the place of the Northvolt LI-Ion cell factory, education providers were curious about the need of education and training. Higher education takes time – and also the planning of new university education has long lead times. It was very soon discovered that the establishment of Northvolt Ett (One) was going to be a lot faster than the education of new specialised engineers. On the other hand, it was questioned which percentage of engineers would be needed for the totally 2500-3000 jobs in the factory. The specialisation level of engineers was also an open question.

To have some clues about skills need and job roles in a big battery cell production facility, a benchmark study began in Skellefteå municipality. The study object was Panasonic's production in Tesla Gigafactory 1 in Reno, Nevada. Very little general information about job roles and work organisation was publicly available, and the production had started in 2016 with the help of hundreds of technical assistants from Panasonic's Asian cell plants.[16] Northvolt would not have similar possibilities.
However, what was publicly available was web-based job ads on the Panasonic Energy North America web site[17] at linkedIn.com and the job search service indeed.com. These jobs were also sometimes discussed and commented on Glassdoor.com. The data collection was done during roughly a year. Same or very similar jobs ads began to re-appear, and the data collection ended when the data was

[14] Lebedeva, N., Di Persio, F., & Boon-Brett, L. (2016). Lithium ion battery value chain and related opportunities for Europe. European Commission, Petten.
[15] https://www.ft.com/content/29e1e89e-0273-11e7-ace0-1ce02ef0def9
[16] https://electrek.co/2019/12/30/tesla-gigafactory-1-panasonic-ready-ramp-up-battery-cell-production/
[17] https://careers.na.panasonic.com/industries/panasonic-energy-north-america

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saturated (when not many new data was coming in). A better job can improve with more extensive data, but the data collected was estimated to be enough to give some indications.

A job ad is not a detailed description of a job role or an occupation, but specifies demands for candidates and also gives an image to the potential applications of what to expect of the job. The job ads were collected, analysed, categorised and discussed.[18] Some cautious conclusions could be drawn. The complete list, excluding the chemistry jobs in upstream production with the production of active battery material from raw material which is not there at all at this Tesla Gigafactory 1 (but in Northvolt Ett) is presented below. The categorisations are not Tesla/Panasonics. Other categorisations are, of course entirely possible.

ENGINEERING:

Battery Engineer (Formation), Battery Engineer (Assembly), Quality Engineer, Production Engineer, Production Engineer - Stamping Press, Project Engineer – Electrical, Production Electrical Engineer, Production Engineer - Vision Systems, Battery Engineer (Electrode), Controls Engineer, SAP Engineer, ASRS Engineer, Top Cap Engineer, Lead Tool Install Engineer (Electrode)

LOGISTICS, PRODUKTION, MAINTENANCE:

Material Planner, Material Handler, Entry Level Operator, Machine Operator, Cell Inspection Technician, Process Inspection Technician, Maintenance Technician, Facilities Maintenance Technician, Help Desk Technician, Equipment Technician (Electrical Controls), Metrologist, ISO Internal Auditor, Document Control Specialist, Workplace Coordinator, Calibration Technician, Production Planner

MANAGEMENT:

Production General Manager, Assistant Production Manager, Production Supervisor, Shift Lead, Shift Lead Materials Management, ISO 9001 Project Manager, Calibration Shift Lead, Production Engineering Supervisor (Top Cap), Production Engineering Supervisor (Electrode), Quality Manager, Workplace Project Manager, Electrical Controls Team Supervisor, Production Equipment Maintenance Supervisor, Quality Control Engineering Manager.

[18] Unpublished material catalogue at Skellefteå municipality, containing job ads and an encyclopaedia of terms and example of production flow sheets for integrated Li-Ion cell factories. This product is in Swedish and English mixed, for local use.

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SECURITY & SAFETY:

Security Supervisor, Assistant Security Manager, Senior Safety Manager, Safety Specialist, Safety Technician

OTHER SERVICES / MANAGEMENT:

Project Scheduler, Technical Writer, Translator/Interpreter, ISO Communication and Training Specialist

HUMAN RESOURCES:

Sr. HR Coordinator, Senior HR Manager - Client Support, Contract Recruiter, Talent Development Manager, Learning and Development Manager, Contract Recruiting Coordinator, Compensation Analyst

ECONOMY:

Sr. Business Analyst, Fixed Asset Accountant, Purchasing Supervisor, Buyer, Accounts Payable Accountant, Construction Cost Analyst, Procurement Assistant General Manager

1.2.4 Conclusions and reflections on the reference object

From this collected job ad data, some cautious reflections and conclusions can be made. This has only value as a reference. Countries are different; company cultures are different, plants producing the same product can be differently organised. But here are some cautious conclusions:

1) **Specially named battery engineering jobs are few.** Some few jobs are addressing special battery knowledge on the engineering level in their job titles. *"Battery engineer (assembly)", "battery engineer (electrode), "battery engineer (formation)", "battery engineer (top cap)"*. However, the candidates wanted are of more general engineering kind; bachelor of science with a 4-year exam in mechanical engineering, industrial engineering, electrical engineering, electrochemical engineering and similar. Training will be done in the workplace when starting a new job. Here are clips from the job ad for a battery engineer (formation). The formation is the process phase in the very end of production of Li-Ion cells where batteries are charged and discharged many times according to designed patterns. This is both to "train" the batteries, so they reach the wanted

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characteristics, and to test and sort out and send to recycling the batteries that underperform or malfunction. There are many other kinds of engineers in the data as well, but with general qualifications. This job ad data does, however, provide sections addressing needed skills and recommended or demanded qualifications. Below is a quote for the job "***Battery engineer (formation)***"[19]:

[19] https://www.linkedin.com/jobs/view/battery-engineer-formation-at-panasonic-usa-1256904944/

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Responsibilities Include

- Being part of Panasonic's formation process. The formation group is responsible for the systems that carry out charging and discharging of the batteries under multiple sets of conditions.
- Conduct research and development work for battery cell formation and testing process to improve cell formation process on safety, quality, and productivity with new and existing production lines.
- Analyze and evaluate battery cell electrical performance data collected in laboratory experiments and pre-production operations to determine direct and interaction effects of the formation equipment and processes under evaluation.
- Analyze operating procedures and functions of battery cell formation equipment and process to reduce time and cost of formation processes.
- Perform root cause analysis to systematically identify and fix sources of defects.
- Provide engineering support to battery cell formation team and cell assembly production team to resolve manufacturing process issues.
- Work closely with safety and quality control teams to improve battery cell formation process on safety and quality issues.
- Work closely with other team members to increase understanding of failure modes, performance and life expectancy of cell products.
- Apply principles and knowledge of chemical engineering to solve environmental problems.
- Other duties may be assigned.

Basic Qualifications

- Bachelor's degree (B.S. in Chemical Engineering, Electrochemical Engineering, Materials Engineering, or related field) from four-year college or university.
- Experience including internships or curricular training in a manufacturing environment, particularly with lithium-ion battery cell formation and/or testing.
- Experience with battery cell formation process design and its influence on SEI analysis in the laboratory.
- Advanced proficiency with Microsoft Office Suite (Word, Excel, PowerPoint, etc).
- Strong verbal and written communication skills to facilitate successful interactions with team members and management.

Desired Qualifications

- M.S. degree in Chemical Engineering, Electrochemical Engineering, Materials Engineering, or related field.
- Experience with root cause analysis, defect reduction, and failure analysis.
- Strong programming, statistical, and data analysis skills with tools such as Python, MATLAB, and JMP.
- 3+ years of experience working hands-on with lithium-ion batteries.
- Experience in laboratory analysis using X-Ray, SEM, microscope, CMM or similar methods in the lab is desired.
- Certifications or training in Six Sigma methodologies.

Figure 1 Battery engineering job ad, (screen image) "Battery Engineering (Formation)"

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A comment to this is that Northvolt is today expecting about 10% of employees in the Northvolt Ett in Skellefteå to be engineers, about 300 of 3000. Some of these will work in management on different levels; others are experts.

2) **Machine operators is a broad category**. The most common jobs, as interpreted from the data, seems to be the ”**machine operator**” and ”**material handler**”. These are very general job titles and in reality may provide occupations and with partly different skill sets, levels and in various phases of the production line. Panasonic has experienced some difficulties with recruiting these categories of the workforce, since there are also jobs announced as ”entry-level machine operator” with lower formal demands, providing some kind of apprenticeship learning. There are also man-power businesses providing workforce in these job categories. Nearby community colleges cooperating with Panasonic has arranged entry-level training to enable candidates to prepare for these two job categories, as in Truckee-Meadows Community College’s *Panasonic Preferred Pathway* (P3) training concept[20]. These short educations are not so much about battery cell production as about the industrial environment, automation, robotics, safety and security as well as the use of standard tools. On-boarding training must be entered in the factory, depending on the phase in the production line. The typical demands for entering these jobs seem to be a finished high school or

[20] https://www.tmcc.edu/applied-technologies/p3

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the GED (validation on the same level). Industrial experience, of course, wanted. The following is a quote from a job ad for a Machine Operator:

Primary Role and Responsibilities

When assigned to the Operator position:

- Has the authority to stop the process to avoid making sub-standard product.
- Reads all SDS' and possesses thorough knowledge of all oil and chemical labeling and storage requirements.
- Operates and starts- up the machines
- Ability to identify problems and minor troubleshooting
- Delivery of materials to production floor.
- Ability to analyze, estimate workload and perform multi-tasking.
- Assist Maintenance Technicians in preventative maintenance procedures such as lubricating machinery
- Monitors processes and performs continuous image inspections and visual quality checks of the products to ensure acceptance standards are met.
- Basic skills in Microsoft Office (Excel, Word, PowerPoint).
- Ability to use material bar code scanners
- Understanding of First in, First out (FIFO)
- Be-able to follow work instructions and Standard Operating Procedures (SOP).
- Prepares documentation as required.
- Maintains a clean and safe work area 5s. Understands department workflow, processes & detailed oriented.
- Excellent communication with co-workers both verbally and with good written skills.

Qualifications

To perform this job successfully, an individual must be able to perform each essential duty satisfactorily. The requirements listed below are representative of the knowledge, skill, and/ or ability required. Reasonable accommodations may be made to enable individuals with disabilities to perform the essential functions.

Education/ Experience

High School Diploma or GED (General Education Development) required.

Physical Demands

The physical demands described are representative of those that must be met by an employee to successfully perform the essential functions of this job.

While performing the duties of this job, the employee is regularly required to do the following:

- stand and walk for extended amounts of time;
- use hands to handle or feel objects, tools, or controls;
- reach with hands and arms;
- talk and hear.
- The employee is occasionally required to climb or balance.
- The employee must regularly lift and/ or move anywhere from 25 pounds to 100 pounds.
- Specific vision abilities required by this job include close vision, color vision, peripheral vision, depth perception, and the ability to adjust focus.
- Must be able to work up to 12- hour shifts

Figure 2 Screen image quote from job ad for "Machine Operator."

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- Required to wear PPE (personal protective equipment) such as but not limited to; hard hat, respirator, gloves, eye protection, steel toe boots, etc.

Work Environment

- Must be able to work in a construction environment. Exposure to heat, dust, and noisy conditions.
- Must be able to work in a clean room environment. Exposure to heat, dust, and noisy conditions.

Language Skills

Ability to read and comprehend simple instructions, short correspondence, and memos. Ability to write simple correspondence. Ability to effectively present information in one-on-one and small group situations to customers, clients, and other employees of the organization.

Mathematical Skills

- Ability to add, subtract, multiply, and divide in all units of measure, using whole numbers, common fractions, and decimals.
- Work within the Metric and Standard systems of measurement.

Figure 3 Screen image, job ad for "Machine Operator."

3) **Technicians are in high demand.** In the Gigafactory workforce, there are **specialist technician** jobs on the European EQF 5-6 level, in the US usually a two-year technical associate degree from a community college. Cell Inspection Technician, Process Inspection Technician, Maintenance Technician, Facilities Maintenance Technician, Help Desk Technician, Equipment Technician, Document Control Specialist, Workplace Coordinator, Calibration Technician, etc. These jobs reflect the high-quality demands on both the production environment and the products. The text below is from a job ad for a **cell inspection technician**[21]:

[21] From a job ad at indeed.com, now removed.

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SUMMARY/ ESSENTIAL FUNCTIONS

- Conduct disassembly (break down) analysis of rejected Li-ion cells while adhering to safety regulations in a manufacturing and laboratory environment.
- Collect data to assist in root cause analysis using analytical equipment in quality control labs (microscope, SEM/EDAX, CT).
- Summarize and communicate data and results from analytical equipment and other investigations.
- Participate and provide feedback of results to production and quality control teams. Adhere to inspection and disassembly Standard Operation Procedures (SOPs) for common action items.
- Organization, inventory, cleanliness, and general upkeep of workspace and laboratory. Follow principles and knowledge of safety and environment protection in production.
- Ability to work in a collaborative environment.
- Other duties may be assigned.

EDUCATION, EXPERIENCE, & QUALIFICATIONS

To perform this job successfully, an individual must be able to perform each essential duty satisfactorily. The requirements listed below are representative of the knowledge, skill, and/or ability required. Reasonable accommodations may be made to enable individuals with disabilities to perform the essential functions.

- Associate degree in General Engineering or related field from two-year College.
- Two years similar experience in a manufacturing environment or laboratory setting; or equivalent combination of education and experience.
- Experience with analytical equipment (e.g. SEM/EDAX) is a plus.

REASONING ABILITY

- Ability to apply basic principles of logical or scientific thinking to production and practical problems.
- Ability to utilize nonverbal symbolism (formulas, scientific equations, graphs, etc.,) in work.
-

MATHEMATIC SKILLS

- Ability to comprehend and apply principles of basic engineering mathematics.
- Understanding basic statistical principles is a plus.

Figure 4 Screen image, a quote from job ad for "Cell Inspection Technician"

4) **Industry 4.0 jobs are notable**. There are some jobs in the Gigafactory One reflecting the high level of automation and pace of innovation following with the Industry 4.0 concept (Higher-level Automation, Internet of Things and Machine Learning in combination). An example is ***ASRS Engineer*** (Automated Storage and Retrieval Systems), ***NPI Engineer*** (New Product Introduction) and ***Production Engineer Vision Systems.***

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5) **Chemistry jobs are lacking.** What is missing in the dataset from Gigafactory 1 are jobs in the "upstream" production; the chemistry-dominated processing of raw materials into active battery materials; production of anodes and cathodes. For Gigafactory 1, these products come from Panasonic plants overseas. The upstream production ***is*** part of Northvolt Ett (One) and any more vertically integrated battery cell production. Cathode production will be part of the Northvolt Ett, but anode production will be subcontracted. The upstream production is together with the formation the most energy demanding phases of battery cell production. A lot of chemists and lab staff are needed – but does not show up in the job ads from Panasonic production in the Tesla Gigafactory.

1.2.5 Northvolt's ongoing development of work organisation and job roles

Northvolt will be starting its main production unit in Skellefteå with one production line in 2021, of totally five, in 2024/2025. Presently, a pilot factory is operating at Northvolt Labs in Västerås in Mid Sweden, where product samples are produced and production and workflow modelled for later upscaling in Skellefteå. Some job roles have been defined as essential ones in battery cell production:

- **Plant manager**, Director of production – The highest level, one per factory.
- **Upstream production area manager** (creation of active material) and
- **Downstream production area manager** (cell assembly steps).[22]
- **Process Block area managers** for dry electrode, wet electrode, formation, cell assembly.[23]
- **Shift managers** belong to a specific block and are team lead for operators.[24]
- **Automation Process Operators** are a common job title, with differing work tasks along the production line.[25] This group of jobs connect to preparatory education at Yrkesvux (adult vocational education) in Skellefteå, formed together with Northvolt to connect to onboard training in the factory.

[22] https://emp.jobylon.com/jobs/61131-northvolt-production-area-manager-upstream-skelleftea/
[23] https://emp.jobylon.com/jobs/63780-northvolt-process-block-area-manager-wet-electrode/
[24] https://emp.jobylon.com/jobs/63556-northvolt-shift-manager-create-the-worlds-greanest-battery-with-us/
[25] https://emp.jobylon.com/jobs/62943-northvolt-automation-process-operator-create-the-worlds-greenest-battery-with-us/

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Some other critical job roles are

- **Maintenance engineers** [26]
- **Maintenance technician**[27]
- **Quality engineer**[28]
- **Clean room and contamination control specialist**[29]
- **Quality control technician/measuring**[30]

The development continues and the ALBATTS project will in WP3,4 and 5 follow this closely and also relate it to parallel development in other Li-Ion cell factories. In comparison with the work distribution at our reference example, panasonic Energy North America in TESLA Gigafacvtory in Reno, it is a cautios guess that work roles in Sweden are generally more broadly defined and a worker is expected to cover more than his or her special area.

[26] https://emp.jobylon.com/jobs/58744-northvolt-maintenance-engineer-northvolt-ett-skelleftea/
[27] https://emp.jobylon.com/jobs/63540-northvolt-maintenance-technician/
[28] https://emp.jobylon.com/jobs/63393-northvolt-germany-process-quality-engineer-mfd-germany/
[29] https://emp.jobylon.com/jobs/33377-northvolt-clean-room-and-contamination-control-specialist/
[30] https://emp.jobylon.com/jobs/43824-northvolt-quality-control-technician-measuring/

2 BATTERY-RELEVANT EDUCATION IN EUROPE OR ONLINE

The partners in WP6 live in different parts of Europe, master different languages and have their professional networks for information supply. We have together tried to take a snapshot of what relevant education we can find right now, in February 2020. We know that we have not seen everything, and welcome comment on our selection and presentation. The following is a collection of examples.

2.1 Disclaimers and reservations

With **"Europe"** we have here used a **broad definition** and meant European countries, both EU member countries and candidate countries. We have also included Switzerland, Iceland and Norway and the UK as well (which just left the European Union). They are all in the EHEA, the European Higher Education Area, and they are Bologna declaration signatory countries[31]. We have, as far as possible, tried to find something relevant in each country studied. This also means that some big countries with many universities active in the relevant fields do not become equally treated. Especially Germany and France most probably are underrepresented. In these countries, we have mostly listed the obvious and research related.

We have searched for ***directly battery-associated*** education programmes and courses and learning material and other learning resources. The ALBATTS project will later go in wider circles when we work more in detail with stakeholder databases in the whole value chain. But here we have searched for batteries and battery applications.

As is already generally known, **chemistry**-educated and skilled workforce are in high demand and in countries low supply in many and battery production needs a lot of chemists. Therefore, we have searched extra for Chemistry education, especially inorganic chemistry and electrochemistry.

We have tried to harmonise our **search criteria**, but it can have been interpreted differently. National education systems also have different traditions on how specialisation is made and balanced against the general disciplinary education with specialisation electives. An institution can offer an education which looks very specialised and attractive without own research trying to recruit students to a trendy content. A research-intensive and specialised institution can have programmes that appear as very general, while they provide a lot of richer possibilities to qualified specialisation within the education environment.

[31] http://ehea.info/page-full_members

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We have used the **EQF categorisation** of education levels, as there are mappings in place from national qualifications systems.

2.2 EQF 4-Level education

EQF 4 is education and training on the upper secondary level, in some countries called gymnasium. This level also applies to adult education at the same level. Examples:

AUSTRIA

In Austria, there is a set of schools in the natural science branch (normal gymnasium with specialisation) where students in the 11th and 12th ear of school learn about Li batteries and have a laboratory in school. Also, in Austria, there is a set of specialised technical schools (5 years technical) where energy management is a specialised field and **energy engineers** with an "Ing." title are educated. This is distributed among all regions. E.g.

- Energy management systems Salzburg, Austria[32]
- Energy management HTL Steyr[33]

CZECH REPUBLIC

Autotronics Engineer - hybrid and electric road vehicles. The education contains OHS, protections, legal regulations, environmental requirements related to hybrid and electric vehicles, knowledge and comprehension of technical documents for electric cars, batteries construction and placement in cars, Diagnostics of batteries, Repairments. This is an upper secondary vocational education related to Czech national qualification standards for "autotronics"[34] Education is offered at the secondary technical school at Trebic[35].

[32] http://www.htl-salzburg.ac.at/elektrotechnik-diplomarbeiten/577.html

[33] https://www.htl-steyr.ac.at/index.php/abteilung-elektronik/energiemanagement-green-it

[34] http://www.narodnikvalifikace.cz/en-us/qualification-1621

[35] https://www.spst.cz/secondary-technical-school-trebic

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THE NETHERLANDS

Batterijspecialist[36] , battery specialist, is a vocational education on battery and e-mobility applications for service providers to homeowners, for small vehicles, mobile devices, etc. It aims to enhance competence for electricians or mechanics but also functions as a foundation for entrepreneurial work in emerging energy storage and electrification sectors. The education is of a blended format and run by SYNTRA, a training network driven by an entrepreneurship organisation, SYNTRUM. This programme is developed together with Innoenergy.

PORTUGAL

In Portugal, the upper secondary general education school leaving certificate giving access to higher education has been assigned to NQF/EQF level 3. The reason is to distinguish it from secondary education qualifications obtained through double certificated pathways or secondary education qualifications plus a professional internship of at least six months aimed at further study, assigned to level 4.

A course as **Technician in Automotive Mechatronic**[37] is an Apprenticeship and Adult VET course. The main activities are to proceed with maintenance, diagnose anomalies and carry out repairs on the various mechanical systems, electrical and electronic components for cars according to the parameters and technical specifications defined by the manufacturers and with the applicable safety and environmental protection rules. The course Includes diagnosis and repair in electric vehicles and hybrid electric vehicles, including repair and maintenance of the batteries. ATEC[38], CEPRA[39], DUAL[40] and IEFP[41] are course providers.

SLOVENIA

Chemistry technician. EQF4 programmes are offered at the Solski centres in Celje, Ljubljana and Novo Mesto, and in the RUŠE Grammar School and High School of Chemistry. There is also an EQF4 **environmental technician** programme offered in 25 schools[42].

[36] https://www.syntra-limburg.be/opleidingen/batterijspecialist

[37] refers to the new version to be approved in the following months by the National Agency for Qualifications

[38] https://www.atec.pt/

[39] https://www.cepra.pt/portal/

[40] https://www.dual.pt/

[41] https://www.iefp.pt/

[42] http://gradbena.si/programi/srednje-strokovno-izobrazevanje/okoljevarstveni-tehnik/

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Worker in technological processes. A more general EQF3 2 year programme is the "Worker in technological processes" programme given at 23 schools[43] as adult education and as shorter lower secondary education. The programme is a preparatory education for entering industrial environments as a beginner or apprentice, similar to the training offered in the Panasonic P3 programme at TMCC.edu in Reno, preparing people for machine operator jobs[44].

SWEDEN

"**YrkesVux"** (Adult vocational education) in Skellefteå, have new battery-cell-production preparatory courses under development for a start in 20/21[45]. It will become a customised course package for preparing for basic and standard jobs at the Northvolt plant in Skellefteå. In its first version be an 18-week package, **"Automation operator"** containing modern industrial concepts and general skills, including work in an automation lab. Northvolt has been a development partner, and the idea is to have a relatively seamless transfer to on-boarding training in the factory. Next version of this education package will be more flexible, permitting students to study most of it remotely. ALBATTS project has followed and supported the development work and will be part of ongoing evaluation and continuous change. It can develop into a prototype of a broader European education standard package.

This education package is inspired by the Truckee-Meadows Community College's (TMCC.edu) preparatory education for work at the Panasonic/Tesla battery cell factory[46].

2.3 EQF 5-Level education

AUSTRIA (in cooperation with GERMANY)

Graz is the leading engineering site with some ten thousands employees of MAGNA[47] , and former MAGNA eCar became Samsung SDI battery systems Austria[48]. Samsung SDI has a major development side with technical engineers south of Graz and manages the establishment of a large battery plan in Hungary recently. Also Austria's largest automotive research company AVL[49] is developing and testing batteries for manufactures, e.g. Tesla.

[43] https://paka3.mss.edus.si/registriweb/ProgramPodatki.aspx?ProgramId=5722

[44] http://catalog.tmcc.edu/degrees-certificates/programs/manufacturing-technologies/skill-cert-advanced-manufacturing-p3/#text

[45] https://www.skelleftea.se/yrkesutbildning

[46] https://www.tmcc.edu/applied-technologies/p3

[47] https://www.magna.com/company/company-information/magna-groups/magna-steyr

[48] https://www.samsungsdibs.at/de/standorte/#austria

[49] www.avl.com

The university cluster around this initiative is teaching the engineers that work in this development. Different programs train and teach.

- **Battery engineers**: The Institute of technical chemistry at TU Graz[50] teach battery development, design and testing, and focus on chemical processes to increase the lifetime of batteries.
- **Battery control engineer:** The Institute of technical informatics at TU Graz teaches the electronics and software to develop embedded systems, including battery management systems[51].
- **Battery functional safety manager:** ISCN together with TU Graz Institute of Technical Informatics developed the ECQA[52] Certified Functional Safety Manager / Engineer Job Roles and offer that as university courses and training together on the market, also for the battery management systems safety[53].
- **Battery vehicle integrator.** The Frank Stronach institute of TU Graz (founded by MAGNA at the university) and the University of Applied Sciences Johanneum and the Automotive Mechatronics and Automotive Engineering Studies teach the integration of batteries into vehicles and testing of it.
- **Battery recycling specialist**: The Montanuni Leoben has a study program in which they research and teach techniques to recycle Li batteries, and they test the concepts together with Saubermacher, a major waste company in Austria.

Relationship to GERMANY:

- AVL in Graz (who sponsors research at TU Graz) has large EU research projects in partnership with Fraunhofer in Germany.
- The Frank Stronach Institute hosts PhDs and diploma work at BMW and VW, in battery research projects.

PORTUGAL

In Portugal, a non-higher-level qualification is placed at NQF level 5, the diploma in technological specialisation. There is a modality of short-cycle higher education, specialised advanced technical courses (CTeSP), designed using the learning outcomes approach but, as yet, with no assigned level.

[50] Head Univ.-Prof. Dr. Martin Wilkening

[51] Institute head of technical informatics Prof. Kai Römer

[52] European Certification and Qualification Association http://www.ecqa.org/

[53] Contact is here Dr Richard Messnarz (ISCN) and Dr Georg Macher (TU Graz).

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The course **Specialized Technician in Energy Management and Control** is a "Technological Specialization Course". Main activities are to develop project activities, planning, management, control, installation, maintenance and repair of solutions involving electrical, electromechanical, automation and command equipment, driving force, signalling and protection, renewable energies, HVAC systems and communications. The aims are to obtain high energy performance systems, increasing energy availability, respecting the safety standards for people and equipment. Education and Training Providers are ATEC[54] and CICCOPN[55].

The course **CTeSP in Electric and Hybrid vehicles** is a "Specialised advanced technical course" (CTeSP[56]). Main activities are to plan, execute and supervise the maintenance, diagnosis and repair of motor vehicles and their components, with particular emphasis on electric and hybrid propulsion. Education and Training Provider is the Politécnico de Leiria[57]. The Politécnico de Setúbal offers the **CTeSP in Electric vehicles[58].**

SWEDEN

Production and Process technicians. Three 2-year higher vocational programmes (yrkeshögskola) are to start in Skellefteå autumn of 2020, Sweden, for preparing the start of the Northvolt Ett Li-Ion battery plant. These education programmes have different profiles;

- Production Technician; Digitalisation and computer-aided production
- Production Technician; Automated Manufacturing Processes
- Process Technician; Maintenance and Reliable Operation

None of these is exclusively directed at work in Li-Ion plants. Students can also take other directions after their exam, but these educations will offer battery-related theory and skills training. The apparent reason for starting these education programmes are the start of Northvolt Ett in the municipality of Skellefteå, with production starting in late 2021.

Electric vehicle specialist[59]. Higher vocational education in Swedish Yrkeshögskola. The education provider is Xenter, Botkyrka, Stockholm.

[54] http://www.atec.pt
[55] https://www.ciccopn.pt/
[56] http://www.ctesp.pt/
[57] https://www.ipleiria.pt/home/
[58] http://www.si.ips.pt/ips_si/
[59] https://www.yhguiden.se/reportage/https-www-xenter-se-utbildning-specialist-elmotordrivna-fordon

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Technician for Electric Vehicles[60] [61]. Higher vocational education in Swedish Yrkeshögskola. The education provider is TUC Sweden (Tranås Utbildningscenter).

2.4 EQF 6-Level education

The EQF 6 level of education is the post-upper-secondary level or the first cycle of higher education in the Bologna process. A standard label is Bachelor, BSc. The specialisation level can be different between national systems and also between universities in the same country. Some prefer a very general first cycle education to prepare for a second cycle with specialised master education. But the Bologna process also demands that all cycles should prepare for a constructive exit to the job market as well. Examples of education at the EQF6 level:

GERMANY

RTWH Aachen University

- Energy-Master of Business Administration[62] (BSc)

Technische Hochschule Ingolstadt

- Bachelor of Engineering in Electromobility[63]

IRELAND

University College Cork, Ireland

University College Cork offer an ordinary bachelor's degree in **Process and Chemical Engineering**. The programme is designed to teach the fundamentals of process and chemical engineering[64].

NORWAY

NTNU Norwegian Technical University

- Material technology 3-year bachelor[65]

[60] https://www.yrkeshogskolan.se/hitta-utbildning/sok/utbildning/?id=6888
[61] https://www.tucsweden.se/yrkeshogskola/vara-utbildningar/elfordonstekniker/
[62] https://www.rwth-aachen.de/cms/root/Studium/Vor-dem-Studium/Studiengaenge/Liste-Aktuelle-Studiengaenge/Studiengangbeschreibung/~bmmx/Wirtschaftsingenieurwesen-B-Sc-Fachric/?lidx=1
[63] https://www.thi.de/en/executive-education/degree-programmes/elektromobilitaet-beng
[64] https://www.ucc.ie/en/ace-dpce/
[65] https://www.ntnu.no/studier/alle?admissions=1&search=materialteknologi

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- Chemical engineering 3-year bachelor[66]
- Renewable energy in the Marine environment 3-year bachelor (engineering)[67]

Renewable energy[68] (BSc)

2.5 EQF 7-Level education

Master educations are very important for universities, and increasingly more so in the context of the Bologna process and the forming of the EHEA, the European Higher Education Area. It should be the normality with a general first cycle higher education, 3-4 years, in one country, and the second cycle of more specialised master education, 1-2 years, in another country in a multinational context. Examples:

AUSTRIA

Technical University Graz

- Master degree programme in technical chemistry[69] [70]
- Master degree in Technical Informatics (including battery management systems electronics and Software)[71]

Technical University Graz – Frank Stronach Institute

- Automotive Mechatronics Master (Battery and Electrical Powertrain included) with focus on battery integration in cars[72]

Carinthia University of Applied Sciences

- Master in Electrical Energy and Energy Systems[73]

University of Applied Sciences Joanneum, Graz

- Automotive Engineering Master (Battery and Electrical Powertrain included)[74]

[66] https://www.ntnu.edu/studies/allstudies?admissions=1&search=chemical%20engineering
[67] https://www.ntnu.edu/studies/allstudies?admissions=1&search=enewable
[68] https://www.ntnu.edu/studies/allstudies?admissions=1&search=enewable
[69] https://www.tugraz.at/en/studying-and-teaching/degree-and-certificate-programmes/masters-degree-programmes/technical-chemistry/
[70] https://mibla-archiv.tugraz.at/13_14/Stk_12a/Curriculum_Masterstudium_Technical_Chemistry_deutsch_englisch.pdf
[71] https://www.tugraz.at/studium/studienangebot/masterstudien/information-and-computer-engineering/
[72] https://www.tugraz.at/institute/ftg/home/
[73] https://www.mastersportal.com/studies/25393/electrical-energy-and-mobility-systems.html
[74] https://www.fh-joanneum.at/fahrzeugtechnik/master/en/

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Montanuniversität Leoben (MU Leoben, Montanuni, MUL)

- Waste Management Master (Specialisation possible in Battery Recycling, Pilot Projects with industry)[75]

BELGIUM

Vrije University. Bryssels

- Master of Science in Chemistry[76]

CZECH REPUBLIC

University of Chemistry and Technology, Prague

- Master sub-programme in Hydrogen and Membrane Technologies [77]

Czech Technical University in Prague

- Master programme in Fuel Cells Drives[78]
- Master programme in Electrical Drives[79] (Electrical Engineering, Power Engineering and Management - Electrical Drives)
- Master programme in Electrical Machines, Apparatus and Drives[80]

Technical University of Ostrava

- Master in Applied Electronics[81]
- Master in Automotive Electronic Systems[82]

DENMARK

Danmarks Tekniske Universitet, DTU

[75] https://www.avaw-unileoben.at/en/
[76] https://we.vub.ac.be/en/master-science-chemistry
[77] http://uat.vscht.cz/en/master-sub-programme-hydrogen-and-membrane-technologies/
[78] https://studyinprague.cz/programmes/CTU-2301T052-N2307/
[79] https://www.fel.cvut.cz/en/education/bk/pruchody/pr974240495105.html
[80] https://www.fel.cvut.cz/en/education/bk_peo/obory/obor10105504.N.N.P.10302304.html
[81] https://www.masterstudies.com/Master-in-Applied-Electronics/Czech-Republic/V%C5%A0B-TUO/
[82] https://www.vsb.cz/en/study/degree-students/master-degree/master-degree-detail/?programmeId=819

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- Joint Nordic Master in Innovative Sustainable Energy Engineering[83] together with NTNU, Aalto, Chalmers, DTU

ESTONIA

Tallinn University of Technology, together with the **University of Tartu**

- Master programme Materials and processes of Sustainable Energetics[84]

University of Tartu

- Master in Analytical Chemistry (EACH – joint degree Erasmus Mundus master)[85]
- Master programme Materials and processes of Sustainable Energetics (see above)

FINLAND

Vaasa University

- Master Smart Energy[86]
- Course package with integrated business courses[87]

Aalto University

- Master in energy storage[88] (EIT InnoEnergy master)
- Joint Nordic Master in Innovative Sustainable Energy Engineering[89] together with NTNU, Aalto, Chalmers, DTU.

Åbo Akademi

- Master in Analytical Chemistry (EACH – joint degree Erasmus Mundus Master)[90]

FRANCE

University Claude Bernardh Lyon 1

Master in Analytical Chemistry (EACH – Joint degree Erasmus Mundus master)[91]

[83] https://www.ntnu.edu/studies/msisee
[84] https://new.taltech.ee/en/sustainable-energetics
[85] https://each.ut.ee/EACH/
[86] https://www.univaasa.fi/master/programmes/smart-energy/
[87] https://www.univaasa.fi/en/education/exchange/sustainability_and_energy_business/
[88] https://www.aalto.fi/en/study-options/masters-programme-in-energy-storage-eit-innoenergy
[89] https://www.ntnu.edu/studies/msisee
[90] https://each.ut.ee/EACH/consortium/
[91] https://www.univ-lyon1.fr/news/master-each-excellence-in-analytical-chemistry-768062.kjsp

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GERMANY

Westfaelische Wilhelmsuniversitaet Muenster

- MSc in Chemistry[92]

Ulm University

- Master in Energy Science and Technology[93]

University of Applied Sciences, Ulm

- Electrical Energy Systems and Electromobility[94]

University of Applied Sciences, Kärnten

- Master in Electrical Energy & Mobility Systems[95]

RTWH Aachen University

- Master: Business Administration and Engineering: Electric Energy Technic[96]
- Master: Management and Engineering in Electrical Power Systems[97]

University of Stuttgart

- Master in Electromobility[98]

Technical University Berlin

- Master in IT for Energy[99]

Technical University Munchen

- Master in Energy and Process Engineering[100]

[92] https://www.uni-muenster.de/Chemie/studium/chemie/index.html
[93] https://www.mastersportal.com/studies/280009/energy-science-and-technology.html
[94] https://www.mastersportal.com/studies/280878/electrical-energy-systems-and-electromobility.html
[95] https://www.fh-kaernten.at/en/studium/engineering-it/master/electrical-energy-mobility-systems
[96] https://www.rwth-aachen.de/cms/root/Studium/Vor-dem-Studium/Studiengaenge/Liste-Aktuelle-Studiengaenge/Studiengangbeschreibung/~bjue/Wirtschaftsingenieurwesen-M-Sc-Fachric/?lidx=1
[97] https://www.academy.rwth-aachen.de/en/education-formats/msc-degree-programmes/mme-eps
[98] https://www.uni-stuttgart.de/en/study/study-programs/Electromobility-M.Sc-00001./
[99] https://www.campus-elgouna.tu-berlin.de/energy/v_menu/msc_it_for_energy/
[100] https://www.tum.de/en/studies/degree-programs/detail/energie-und-prozesstechnik-master-of-science-msc/

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ITALY

Politecnico di Torino

- Master in Energy Storage[101] (EIT InnoEnergy master)

LITHUANIA

Vilnius Gediminas Technical University

- Master in Building Energy Engineering[102]

Kaunas Technical University

- Master in Energy Technologies and Economics[103]

THE NETHERLANDS

University of Delft

- Master in Sustainable Energy Technology[104]
- Master in Chemical Engineering[105]

NORWAY

NTNU Norwegian University of Science and technology

- Electric Power Engineering[106] 2-year master
- Material technology 2-year master[107]
- Chemical engineering 2-year master[108]
- Nordic Master in Innovative Sustainable Energy Engineering[109] together with NTNU, Aalto, Chalmers, DTU.

POLAND

[101] https://www.innoenergy.com/for-students-learners/master-school/masters-in-energy-storage/

[102] https://www.vgtu.lt/studies/study-programmes/master-study-programmes/317411?element_id=317413&sp_id=296&f_id=5&qualification=a%3A1%3A%7Bi%3A0%3Bs%3A1%3A%22M%22%3B%7D

[103] https://admissions.ktu.edu/programme/m-energy-technologies-and-economics/

[104] https://www.tudelft.nl/en/education/programmes/masters/sustainable-energy-technology/msc-sustainable-energy-technology/

[105] https://www.tudelft.nl/en/education/programmes/masters/chemical-engineering/msc-chemical-engineering/

[106] https://www.ntnu.no/studier/mselpower

[107] https://www.ntnu.no/studier/alle?admissions=1&search=materialteknologi

[108] https://www.ntnu.edu/studies/allstudies?admissions=1&search=chemical%20engineering

[109] https://www.ntnu.edu/studies/msisee

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University of Warsaw

- MESC multi-university master on Materials Science and Electrochemistry[110]

PORTUGAL

University of Porto

- Master in Chemical Engineering[111]
- Master in Engineering Physics[112]

Instituto Superior Tecnico, Lisbon

- Master of Energy Engineering and Management
- Master in Energy Storage[113] (EIT InnoEnergy)

ROMANIA

The Polytechnic University of Bucharest

- Master in Integrated Electrical Systems Engineering in vehicles[114]

SWITZERLAND

ETH Zurich

- Master's degree programme in Energy Science and Technology (MEST)[115]

SLOVAKIA

University of Žilina

- Master in Electric Power Systems[116]
- Master degree studies Electrical Drives[117]

University of Bratislava

[110] http://www.alistore.eu/education

[111] https://sigarra.up.pt/feup/en/cur_geral.cur_view?pv_ano_lectivo=2019&pv_origem=CUR&pv_tipo_cur_sigla=MI&pv_curso_id=745

[112] https://sigarra.up.pt/fcup/en/cur_geral.cur_view?pv_curso_id=890

[113] https://www.innoenergy.com/for-students-learners/master-school/technical-universities-and-business-schools/ist-instituto-superior-t%C3%A9cnico/

[114] http://www.electro.pub.ro/wp-content/uploads/2012/06/Plan-inv-ISEIA-2018-2020-AFIS.pdf

[115] https://master-energy.ethz.ch/

[116] https://www.uniza.sk/images/pdf/INFOLETAKY-akreditovanych-studijnych-programov/programy-2019-2020/FEIT/FEIT-ING-eng.pdf

[117] https://www.uniza.sk/index.php/en/studijne-programy-info-en?infoid=134&color=rgba(243,%20116,%2041,%201)

- Master in Applied Mechatronics and Electromobility[118]

SLOVENIA

University of Ljubljana

- Master in Chemistry[119]

University of Maribor

- Masters in Chemistry[120] The programme offers many elective possibilities suitable for the battery sector[121].

SPAIN

Universidad de País Vasco

- Master Nuevos materiales[122]

Mondragon Uniberstitatea

- Professional Master in Electric Mobility and Energy Storage[123]

SWITZERLAND

ETH Zurich

- Master's degree programme in Energy Science and Technology (MEST)[124]

SWEDEN

Uppsala University,

- MasterMaster's Programme[125] in Chemical Engineering[126].

[118] https://www.fei.stuba.sk/buxus/docs/2018/okruhy_otazok_AJ.pdf

[119] https://www.uni-lj.si/study/master/fkkt/

[120] https://www.fkkt.uni-lj.si/en/study/second-cycle-study-programmes/university-study-programme-of-chemistry-20192020/

[121] https://www.fkkt.um.si/en/chemical-engineering-education-in-slovenia

[122] https://www.ehu.eus/es/web/master/master-nuevos-materiales

[123] https://www.mondragon.edu/cursos/es/tematicas/electronica-energia/master-profesional-en-movilidad-electrica-almacenamiento-energia

[124] https://master-energy.ethz.ch/ https://master-energy.ethz.ch/

[125] Swedish "civil engineer", EQF 6-7 programme), 5 year program with electrochemistry courses and materials chemistry courses at bachelor level and specified courses in batteries and energy storage materials as well as synthesis at the master level

[126] https://www.uu.se/en/admissions/master/selma/program/?pKod=TKT2Y

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- Master's programme in Analytical Chemistry (EACH – Erasmus Mundus Master)[127]
- Master's Program in Renewable Electricity Production with a course in Batteries and energy storage for non-chemists[128]
- Master's Programme in Chemistry for Renewable Energy[129]
- Master's Programme in Materials Engineering[130]

Royal Academy of Sciences (KTH)

- Joint Nordic Master in Innovative Sustainable Energy Engineering[131] together with NTNU, Aalto, Chalmers, DTU
- Master in Chemical Engineering for Energy and Environment[132]

Chalmers University of Technology, Sweden

- Joint Nordic Master in Innovative Sustainable Energy Engineering[133] together with NTNU, Aalto, Chalmers, DTU
- Master in Electric Power Engineering[134]
- Master in Automotive Engineering[135]
- Master in Systems, Control and Mechatronics[136]

UNITED KINGDOM

United Kingdom is not a part of the EU any longer, but still a part of European development in the broader sense. Here are master educations in the field of batteries and electromobility listed. Many are 1-year educations, not two-year programmes as is more common elsewhere.

University of Southampton

[127] https://www.uu.se/utbildning/utbildningar/selma/program/?pInr=EACH&pKod=TKE2M&lasar=20%2F21
[128] https://www.uu.se/utbildning/utbildningar/selma/kursplan/?kKod=1KB270&lasar=
[129] https://www.uu.se/en/admissions/master/selma/program/?pInr=KEFE&pKod=TKE2M
[130] https://www.uu.se/en/admissions/master/selma/program/?pKod=TTM2Y
[131] https://www.ntnu.edu/studies/msisee
[132] https://www.kth.se/en/studies/master/energyandenvironment/description-1.48518
[133] https://www.ntnu.edu/studies/msisee
[134] https://www.chalmers.se/en/education/programmes/masters-info/Pages/Electric-power-engineering.aspx#second-page
[135] https://www.chalmers.se/en/education/programmes/masters-info/Pages/Automotive-Engineering.aspx
[136] https://www.chalmers.se/en/education/programmes/masters-info/Documents/MPSYS%20Systems%2C%20Control%20and%20Mechatronics_brochure%202018.pdf
https://www.chalmers.se/en/education/programmes/masters-info/Pages/Systems-control-and-mechatronics.aspx

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- Electrochemistry and Battery Technologies[137]
- MScMaritime Technologies [138]
- MSc uncrewed aircrafts systems design [139]

University of Surrey; Batteries, MSc Fuel Cells and Energy Storage Systems[140]

University of Birmingham; MSc Materials Science and Engineering[141]

Coventry University MSc Electrical Automotive Engineering[142]

University of Warwick, MSc Sustainable Energy Technologies[143]

University of Edinburgh, MSc Chemistry[144]

Teesside University MSc Chemical Engineering[145]

WMG University of Warwick (Coventry) MSc Sustainable Automotive Engineering[146]

University of Lincoln, MSc Energy Materials and Battery Science [147]

2.6 Coordinated EQF7 Master concepts

2.6.1 MESC - Erasmus Mundus Joint master

MESC[148] , Master in Materials for Energy Storage and Conversion[149], is an Erasmus-Mundus project with a joint master with several universities, research institutes and labs involved, including other networks (Rs2E, Alistore):

- Warsaw University of Technology
- Université Toulouse III Paul Sabatier
- Université de Picardie Jules Verne (UPJV) in Amiens
- University of Ljubljana, Slovenia
- Universidad del Pais Vasco in Bilbao, Spain

[137] https://www.mastersportal.com/studies/253860/electrochemistry-and-battery-technologies.html
https://www.mastersportal.com/studies/155080/msc-electrochemistry-and-battery-technologies.html
[138] https://www.mastersportal.com/studies/35534/maritime-engineering-science.html
[139] https://www.mastersportal.com/studies/35538/unmanned-aircraft-systems-design.html
[140] https://www.mastersportal.com/studies/272637/batteries-fuel-cells-and-energy-storage-systems.html
[141] https://www.mastersportal.com/studies/117669/materials-science-and-engineering.html
[142] https://www.mastersportal.com/studies/256726/electrical-automotive-engineering.html
[143] https://www.mastersportal.com/studies/134987/sustainable-energy-technologies.html
[144] https://www.mastersportal.com/studies/235076/chemistry.html
[145] https://www.mastersportal.com/studies/235076/chemistry.html
https://www.mastersportal.com/studies/271144/chemical-engineering.html
[146] https://www.mastersportal.com/studies/112865/sustainable-automotive-engineering.html
[147] https://www.lincoln.ac.uk/home/course/eymtbsms/
[148] https://mesc-plus.eu/
[149] http://ecahe.eu/w/index.php/MESC_-_Master_in_Materials_for_Energy_Storage_and_Conversion

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- Drexel University, Philadelphia, USA
- Deakin University, Melbourne, Australia
- ALISTORE – ERI (see below concerning labs as resources)
- RS2E (see below)
- National Institute of Chemistry, Slovenia,

2.6.2 The Nordic joint degree master

Five Nordic universities run four 2-year masters in a concept with the student studying one year at each of two universities depending on the choice of profile. The profiles are

- Environmental Engineering
- Innovative Sustainable Energy Engineering
- Maritime Engineering
- Polymer Technology

The universities are Aalto University in Finland, the Chalmers University of Technology in Sweden, Denmark Technical University (DTU), the Royal Institute of Technology (KTH) in Sweden and the Norwegian University of Science and Technology (NTNU). (Called by themselves together "The Nordic Five Tech")[150]. The master we are thinking of here is mainly the **Innovative Sustainable Energy Engineering Master**[151], but it seems to be possible to specialise in batteries also on other profiles.

2.6.3 The ERASMUS MUNDUS "EACH" Master

Uppsala University in Sweden, the University of Tartu in Estonia, University Claude Bernardh 1 in France and Åbo Akademi, Finland, have a joint degree Master programme "Excellence in Analytical Chemistry" (EACH)[152] with possibilities to combine studies at the four institutions and earn an exam from two of the involved universities. In an Erasmus Mundus master, there are many specialisation possibilities as many institutions, organisations and resources are involved, as Uppsala University's Ångström Advanced Battery Center[153]. The EACH students also have other laboratories available for placements outside these universities.[154] The University of Tartu in Estonia is a coordinator.

[150] https://www.chalmers.se/en/education/programmes/nordic-five-tech/Pages/default.aspx
[151] https://www.ntnu.edu/studies/msisee
[152] https://each.ut.ee/EACH/consortium/
[153] https://www.kemi.uu.se/research/structural-chemistry/aabc/
[154] https://each.ut.ee/EACH/training-placements/

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2.6.4 The EIT InnoEnergy Master in energy storage

EIT InnoEnergy cooperates with universities in the development of programmes, course plans and also in marketing and quality assessment and development. Students spend one year at each of two institutions and end up with a joint degree from two universities[155].

The same 2-year master's programme in **Energy Storage** is offered at

- Aalto University in Helsinki/Espoo, Finland
- Instituto Superior Tecnico in Lisbon, Portugal
- Politecnico de Torino, Torino, Italy

The Eindhoven University of Technology, Eindhoven, Netherlands, is on the way into this concept but does not offer admission for 2020.

2.7 Individual university courses

Besides university programmes, there are also course, offered individually or as part of programmes. Some examples are listed and linked below.

FINLAND

Vaasa University

- Battery energy Storages in Smart Grids[156]
- Business Models for Battery Storages[157]
- Seasonal Energy Storage and Conversion Technologies[158]

University of Oulu

- Small/Medium Power Energy Harvesting and Storage Devices[159]
- Sustainable Urban Energy[160]

[155] https://www.innoenergy.com/for-students-learners/master-school/masters-in-energy-storage/
[156] https://fitech.io/en/studies/battery-energy-storages-in-smart-grids/
[157] https://fitech.io/en/studies/business-models-for-battery-storages/
[158] https://www.univaasa.fi/en/for/student/programmes/master/smart-energy/studies/programme_structure/
[159] https://fitech.io/en/studies/small-medium-power-energy-harvesting-and-storage-devices/
[160] https://fitech.io/en/studies/sustainable-urban-energy/

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- Battery chemistries and components[161]

University of Tampere

- Electrical Energy Storages and Electric Vehicles[162] (Open university course)

NORWAY

NTNU, Norwegian Technical University

- Efficient energy use[163]
- Energy storage[164]
- Electrochemistry[165]
- Power electronics and motor control[166]
- Chemical energy technics/engineering [167]
- Chemical Energy Engineering[168]
- Renewable energy[169]
- Introduction to renewable energy[170]
- Hybrid propulsion systems[171]
- Renewable energy[172]
- Hydrogen, burn fuel, battery and solar technology[173]
- Marine electric power and propulsion systems[174]
- Carbon Materials Technology[175]

PORTUGAL

[161] https://fitech.io/fi/opinnot/battery-chemistries-and-components/
[162] https://www.tuni.fi/en/study-with-us/electrical-energy-storages-and-electric-vehicles
[163] https://www.ntnu.edu/studies/courses/LYFA2002/2019/A#tab=omEmnet
[164] https://www.ntnu.edu/studies/courses/TFNE3006/2019/A#tab=omEmnet
[165] https://www.ntnu.edu/studies/courses/TMT4252/2019/1#tab=omEmnet
[166] https://www.ntnu.edu/studies/courses/TELE2007/2019/A#tab=omEmnet
[167] https://www.ntnu.edu/studies/courses/FENA2011/2019/1#tab=omEmnet
[168] https://www.ntnu.edu/studies/courses/FENT2011/2019/1#tab=omEmnet
[169] https://www.ntnu.edu/studies/allstudies?admissions=1&search=enewable
[170] https://www.ntnu.edu/studies/courses/FENT1001/2019/1#tab=omEmnet
[171] https://www.ntnu.edu/studies/courses/FENA2030/2019/1#tab=omEmnet
[172] https://www.ntnu.edu/studies/allstudies?admissions=1&search=enewable
[173] https://www.ntnu.edu/studies/courses/TMT4285/2019/1#tab=omEmnet
[174] https://www.ntnu.edu/studies/courses/TMR4290/2019/1#tab=omEmnet
[175] https://www.ntnu.edu/studies/courses/TMT4335/2019/1#tab=omEmnet

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University of Porto

- Materials and devices for energy harvesting and storage[176]

SWEDEN

Luleå University of Technology

- Batteries for a sustainable society: from raw materials to battery cells[177] (7,5 ECTS summer course).

The course takes place 10th to 30th of August 2020 in Luleå campus with a visit to the Northvolt battery gigafactory build site in Skellefteå starting in 2021, a period in Västerås where Northvolt Labs is situated[178] and at Uppsala University with its Ångström Advanced Battery Centre[179].

Uppsala University

- Batteries and Storage[180]

2.8 MOOC Courses

The offerings of MOOC courses on Li-Ion batteries and electromobility have multiplied since 2017 when only one course concerning batteries had just started.

A MOOC course is a globally available web-based course from a university with special on-the-edge-research knowledge in an area, scalable from just a few participants to many thousands of synchronous students (current record: 350 000). Universities and other providers do seldom offer MOOC course directly, but through a branded technical platform, such as Coursera, EdX, Futurelearn, MiriadaX, etc. These courses are often available to follow for free – but a smaller fee applies for the participant wanting a certificate. It is today also often possible to buy unlimited access per year for all courses on a platform.

MOOC courses are designed to be short – 4-8 weeks most commonly, and usually demands 4-8 hours studying a week. The design makes it possible to study besides work – but the courses are not at all

[176] https://sigarra.up.pt/feup/en/ucurr_geral.ficha_uc_view?pv_ocorrencia_id=443005

[177] https://www.ltu.se/edu/course/K70/K7006K/K7006K-Batterier-for-ett-hallbart-samhalle-fran-ramaterial-till-battericeller-1.196612?l=en&termin=S20

[178] https://northvolt.com/stories/The-opportunity-of-Northvolt-Labs

[179] https://www.kemi.uu.se/research/structural-chemistry/aabc/

[180] https://www.uu.se/en/admissions/master/selma/kursplan/?kKod=1KB274&lasar=

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"work-free" courses. They are often very professionally made. Some courses start at specific times – other courses are self-paced and starts anytime on demand.

One drawback of MOOC courses is that few students complete them, about 90 % of people registered on a course do not finish. This situation can be helped by arranging a local context as a learner-driven study circle with synchronous meetings.[181] One such project with MOOCs in local learning circles connected to the Northvolt investment in Skellefteå is to start in April 2020.

Here below are listed courses offered globally and accessible in Europe. The MOOC courses are possible to participate in by only having an Internet connection, anywhere.

Available MOOC courses:

Ural Federal University (Russia) offers **Batteries, Fuel Cells and their Role in modern society**[182] on the EdX.org platform (a non-profit platform started by Harvard, Yale, and MIT).

Ecole de Ponts, a French University, offer an orientation course, **Electric Vehicles and Mobility**[183], on Coursera.com, the largest (and commercial) MOOC platform, with an initial emphasis on the universities on the US West coast /Stanford, University of California -system, etc.).

EIT InnoEnergy offers courses on **FutureLearn**[184], which is a European MOOC platform with UK Open University as a central stakeholder. These courses are shorter orientation courses, four weeks, and with less calculated study time per week (2-3h). Courses:

- Energy Storage – understanding the battery revolution[185].
- Battery Storage Technology – Opportunities and uses[186],
- Energy Systems Integration: An introduction.[187]

The Chalmers University of Technology in Gothenburg, Sweden, gives a "**Micro-master**" course package with a certificate on EdX in **Emerging automotive technologies**[188], which also can be studied one by one. These courses have a more massive study load, 10-20 hours per week study time is

[181] See Norberg, A., Händel, Åsa, & Ödling, P. (2015). Using MOOCs at Learning Centers in Northern Sweden. The International Review of Research in Open and Distributed Learning, 16(6). https://doi.org/10.19173/irrodl.v16i6.2035

[182] https://www.edx.org/course/batteries-fuel-cells-and-their-role-in-modern-society-3

[183] https://www.coursera.org/learn/electric-vehicles-mobility

[184] https://www.futurelearn.com/partners/innoenergy

[185] https://www.futurelearn.com/courses/energy-storage

[186] https://www.futurelearn.com/courses/battery-storage-applications

[187] https://www.futurelearn.com/courses/battery-storage-applications

[188] https://www.edx.org/micromasters/chalmersx-emerging-automotive-technologies

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estimated. An innovation is that a person who has earned a Micromaster program certificate is thereby enabled to apply for Chalmers University of Technology's Master of Science in Automotive Engineering or Systems, Control and Mechatronics, and will, if accepted, be accredited 20-22.5 ECTS of 120. Courses:

1. Electric and conventional vehicles[189]
2. Road Traffic Safety in Automotive Engineering[190]
3. Hybrid Vehicles[191]
4. Model-Based Automotive Systems Engineering[192]
5. Sensor Fusion and Non-linear Filtering for Automotive Systems[193]
6. Multi-Object Tracking for Automotive Systems[194]
7. Decision-Making for Autonomous Systems[195]

The University of Colorado gives on the Coursera platform a "**Specialization**" (similar to EdX "Micromaster") course package (with certificate) on **Algorithms for battery management systems[196].** The five courses can be studied one by one as well.

1. Introduction to Battery-management systems[197]
2. Equivalent Circuit Cell Model Simulation[198]
3. Battery State-of-Charge (SOC) Estimation[199]
4. Battery State-of-Health (SOH) Estimation[200]
5. Battery Pack Balancing and Power Estimation[201]

[189] https://www.edx.org/course/electric-and-conventional-vehicles
[190] https://www.edx.org/course/road-traffic-safety-in-automotive-engineering
[191] https://www.edx.org/course/hybrid-vehicles
[192] https://www.edx.org/course/model-based-automotive-systems-engineering
[193] https://www.edx.org/course/sensor-fusion-and-non-linear-filtering-for-automot
[194] https://www.edx.org/course/multi-object-tracking-for-automotive-systems
[195] https://www.edx.org/course/decision-making-for-autonomous-systems
[196] https://www.coursera.org/learn/battery-management-systems?specialization=algorithms-for-battery-management-systems
[197] https://www.coursera.org/learn/battery-management-systems
[198] https://www.coursera.org/learn/equivalent-circuit-cell-model-simulation
[199] https://www.coursera.org/learn/battery-state-of-charge
[200] https://www.coursera.org/learn/battery-state-of-health
[201] https://www.coursera.org/learn/battery-pack-balancing-power-estimation

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The Technical University of Delft offers on **EdX** a course package "**Electric Cars Professional Certificate**"[202] on electric vehicles technology; Courses can be studied individually as well. Observe that there are courses also on **EV business** and **EV policy** issues.

1. Electric Cars: Introduction[203]
2. Electric Cars: Technology[204]
3. Electric Cars: Business[205]
4. Electric Cars: Policy[206]

The ELIC project is ERASMUS+ project (Strategic Partnership for School Education) 2017 – 2019, which developed a MOOC course for natural science teachers "to improve engineering literacy among secondary school pupils".[207]

2.9 Other course offers

There are some courses available, especially on adult- and lifelong learning, which does not easily fit into the above categories:

ATEC offers a **Conditions for Safe Intervention in Electric and Hybrid Vehicles**[208] in-class training course for professionals working in electric and hybrid vehicles, such as mechanics, mechatronics, diagnostic technicians or tugs.

ATEC offers **Advanced maintenance on electric and hybrid vehicles**[209] in-class training course for professionals working in electric and hybrid vehicles, knowledgeable of high voltage system, in parts connected to the same circuit.

ISQ Academy offers a **Renewable Energy Storage** in-class course, 16h, which puts into perspective the applications of the various energy storage solutions in organisations and mobility solutions, providing participants with skills to design and implement energy storage solutions in projects.

[202] https://www.edx.org/professional-certificate/delftx-electric-cars
[203] https://www.edx.org/course/electric-cars-introduction
[204] https://www.edx.org/course/electric-cars-technology
[205] https://www.edx.org/course/electric-cars-business
[206] https://www.edx.org/course/electric-cars-policy
[207] http://elic.fh-joanneum.at/welcome-to-the-elic-mooc/
[208] https://www.atec.pt/cursos-empresas-particulares/mecatronica-automovel.html
[209] https://www.atec.pt/cursos-empresas-particulares/mecatronica-automovel.html

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ECT, European Centre of Technology[210], provides a recurring one-day course F2F in the University of London on **Energy storage**[211] on basic/advanced level. The course leads to a Galileo Master certificate.

Stanford University Online, School of Engineering, offers an asynchronous self-paced online course on **Energy Storage**.[212] For persons without a background in Chemistry or Engineering, there is a 101 guide to help cover individual gaps in pre-knowledge. The course (3 hours of video, 1 hour of course work), leads to an Energy Innovation and Emerging Technologies Certificate.

EEC, **The European Energy Center**, offer a one day "**Energy Storage Course**"[213] at the University of London, alternatively as a distance course with live components. The course leads to a Galileo Certificate.

SEAS, **Estudios Superiores Abiertos,** a Spanish online education provider mostly in the professional sector, offer a 6 ECTS online course in **Hybrid and Electrical Vehicles**[214] (in Spanish only). Depending on the participant's age and previous education, the course can give a certificate or 6 ECTS credits in cooperation with Universidad San Jorge in Zaragoza[215].

IFP Training, a provider of training for oil- and gas industry, offers education on Hybrid and Electric Powertrains.[216]

GREenergy Training arranges 1-day courses in **Battery storage systems**, mostly aimed at installation services.[217]

PDH Online provides a course on **Energy Storage Technology**[218], intended as a learning opportunity for engineers.

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[210] http://theect.org
[211] https://theect.org/energy-storage/
[212] https://online.stanford.edu/programs/energy-innovation-and-emerging-technologies-certificate
[213] https://www.euenergycentre.org/training/energy-storage-course/
[214] https://www.seas.es/energias-renovables/curso-vehiculos-hibridos-electricos
[215] https://www.usj.es/
[216] https://www.ifptraining.com/course/hybrid-electric-powertrains-modelings-simulations-measurements-analysis.html, https://www.ifptraining.com/course/hybrid-electric-powertrains.html https://www.ifptraining.com/course/hybrid-electric-powered-aircraft.html
[217] https://gretraining.co.uk/product/battery-storage-systems
[218] https://pdhonline.com/courses/e320/e320_new.htm

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DNV-GL, an organisation in the field of risk management and quality assurance, offer 2-day training courses in various global locations:

- Energy Storage Essentials[219].
- Solar and Energy Storage
- Grid-connected energy storage

TNEI Services, an energy consultancy, offer a one-day training course in **Energy Storage**[220]

The Energy Delta Institute offers a 3-day Masterclass intensive course in **Flexibility and Energy Storage**[221]

IRTEC offer a course on **Maintenance of storage batteries and the storage of energy**[222]

Ecole Polytechnique Executive Education offers a 2-day course in **Batteries and Electrochemical storage**[223]

IFP Training offer a 5-day course in **Storage of Electrical Energy**[224]

Mondragon Uniberstitatea (University) offers

- Energy Storage Systems[225] (a 24-hour course, spread over one month)
- Stationary Storage course[226]
- Professional Master in Electric Mobility and Energy Storage[227]

ITMD Institute offers a course on **Charging of Electrical Vehicles**[228]

[219] https://www.dnvgl.com/training/training-courses-on-energy-storage-67426
[220] https://www.tneigroup.com/training/energy-storage-training-course
[221] https://www.energydelta.org/programme/flexibility-and-energy-storage/
[222] https://www.cci-formation-bretagne.fr/irtec-ccimbo/quimper/maintenance-des-batteries-daccumulateur-et-stockage-de-lenergie-
[223] https://exed.polytechnique.edu/fr/formations/32537/batteries-et-stockage-electrochimique-de-l-electricite
[224] https://www.ifptraining.fr/formation/module-4-stockage-d-energie-electrique-.html
[225] https://www.mondragon.edu/cursos/es/tematicas/electronica-energia/curso/sistemas-de-almacenamiento-de-energia
[226] https://www.mondragon.edu/cursos/es/tematicas/electronica-energia/curso/almacenamiento-estacionario
[227] https://www.mondragon.edu/cursos/es/tematicas/electronica-energia/master-profesional-en-movilidad-electrica-almacenamiento-energia
[228] https://www.itmasterd.es/curso-vehiculos-electricos

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DEKRA Academy offer, in Germany and all over Europe, several training seminars with different specialisations concerning electromobility[229]: These training opportunities address necessary knowledge, risk management and preventive measures when dealing with high voltage in electric vehicles.

Menschen und Elektromobilität offers on-demand training courses on electromobility both for individuals and teams[230].

Fraunhofer Academy offers continuing technical education and training in all from 1-day seminars with different profiles to 5-months blended courses, as Zertifikatskurs Elektromobilität[231].

Decentralised electrical energy storage systems[232]. Carl von Ossietzky University Oldenburg plans to offer a "Certificate of Advanced Studies" distance study programme for continuing education for professionals.

2.9.1 EIT InnoEnergy education and training

EIT InnoEnergy works with support from the European Commission with innovation and entrepreneurship in the energy sector. A part of this is education and training provision.

Master programmes

InnoEnergy works closely with universities in developing master programmes in different energy-related sectors. For the energy storage sector, see the section above *Multi-university joint degree concepts for master educations.*

Blended professional level courses

EIT InnoEnergy also provides blended courses with fees. They can have a preparation section online, and then 2-3 days synchronous and co-located with teachers and other students. These are presently the professional-level courses in Energy Storage:

- Battery storage masterclass (Sweden) 3 days, blended format.[233]

[229] https://www.dekra.de/de/elektromobilitaet-training/
[230] https://www.menschen-und-elektromobilitaet.at/fuer-unternehmen/training/
[231]
[232] https://uol.de/en/reo/partner/certificate-programme-decentralised-electrical-energy-storage/
[233] https://sea.innoenergy.com/course/battery-storage-masterclass/info

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- Battery Storage Systems (Belgium) 2 days, blended format[234]
- Energy Storage Innovation (Germany) 1 day, blended format[235]
- Flexibility challenges and Energy Storage (France) 2 days, blended format
- Energy Storage for grid application (Spain) 2 days, blended format
- Business Model Innovation in Energy (Storage) Regulation 1 day, blended format
- International Battery Technicians (Belgium) 2 days, blended format

Blended master level programme

EIT InnoEnergy will deliver in 2020 their first master-level programme on battery storage, namely the **Battery Storage Expert Programme**. This programme includes a series of 6 master-level online courses that cover the different aspects of the battery storage value chain, followed by an intensive 2-day face-to-face activity.

Online SPOC courses

EIT InnoEnergy also runs online MOOC-like courses at a (low) cost, sometimes called SPOCs ("Small Private Online Courses"). These run over about four weeks.

- Materials to Electrodes (4 weeks, 2 h per week)[236]
- Electrodes to Cells (4 weeks, 1,5 hour per week)[237]
- Power converters and Efficiency in Battery Applications (4 weeks, 2h per week)[238]
- Battery Management Systems (4 weeks, 2 hours per week)[239]
- Battery testing systems (4 weeks, 2 hours per week)[240]
- Solid-State Batteries (2 weeks, 2 hours per week)
- Energy storage the battery revolution (5.5 weeks, 2 hours per week)[241]

[234] https://sea.innoenergy.com/course/battery-storage-systems-0/info
[235] https://sea.innoenergy.com/course/energy-storage-innovation/info
[236] https://sea.innoenergy.com/course/materials-electrodes/info
[237] https://sea.innoenergy.com/course/electrodes-cells/info
[238] https://sea.innoenergy.com/course/power-converters-and-efficiency-battery-applications/info
[239] https://sea.innoenergy.com/course/battery-management-systems/info
[240] https://sea.innoenergy.com/course/battery-storage-battery-testing-system/info
[241] https://sea.innoenergy.com/course/energy-storage-battery-revolution-0/info

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2.10 Labs as education resources

Many master education and PhD students do periods and internships at laboratories. The Commission, via the Strategic Action Plan for Batteries, recently asked the JRC to open up relevant laboratories[242] [243]for battery education, which they also have done.

Some other battery-related laboratories can from time to time offer access for training, master exam papers and doctoral research. A way to find them can be through some battery-themed networks for Research, Innovation and Development:

ALISTORE-ERI began in 2004 as a 5-year EC-funded FP6 Network of Excellence coordinated by CNRS, France. Today 19 partners are cooperating on battery development and battery materials as a part of ERI, European Research Institute. They have a close connection to the ERASMUS-MUNDUS MESC Battery master.

RS2E in France[244] gather 17 national laboratories (CNRS/Universities), 15 industrial partners and three government-funded organizations (CEA /IFPEN /INERIS) specializing in tech transfer in the battery sector, mainly in France. RS2E is part of MESC master above - these labs are available, at least for MESC Master students.

European Battery Alliance[245] (EBA), gather many stakeholders; universities, businesses, laboratories which are in different value-chain categories.

The Battery2030 partnership organisations[246] are developing European research roadmap on battery research. The partnership contains many labs.

[242] https://ec.europa.eu/info/sites/info/files/organisation_charts/organisation-chart-jrc_en.pdf
[243] https://ec.europa.eu/commission/sites/beta-political/files/report-building-strategic-battery-value-chain-april2019_en.pdf p. 11
[244] https://www.energie-rs2e.com/en
[245] https://www.eba250.com/
[246] https://battery2030.eu/about-us/partners/

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EASE; European Association for Storage of Energy[247] is a Brussels-based organisation with company members in the battery sector[248] and EASE is a partner of several energy-storage projects.

2.11 Open educational resources

Open educational resources are commonly digital resources, used within online courses or in classrooms or for self-directed study. They were earlier called "learning objects". OERs carry some complex issues, for example, version control, compatibility, sudden disappearance and also the question of granularity. A big object – perhaps a whole course, is precious and saves time for a teacher to find if that is precisely what is needed – but often he or she wants smaller objects, to provide possibilities to adaption to student needs and own ideas. However, a small digital item can easy to fabricate on one's own, and hardly worth searching for. Therefore, granularity becomes a question of balancing. This section will be more studied in Task 6:2 for a future deliverable.

Battery University[249] - The Battery University is a free website and not any university, but contains an encyclopaedic reference resource on battery terms and terminology. This resource is connected to a book for sale.

Green Wheels[250] is a Czech project aiming to create open learning materials in the newly emerging field of Operation, repair and service of hybrid and electric vehicles, by using innovative methods and approaches such as Critical thinking, Inquiry-based learning, Collaborative learning, Flipped classroom, Peer Instructions etc. The project focuses on improving and enriching teacher methodology through innovative methods, extensive teacher training courses and mentoring. The project intends to develop a new professional curriculum using EU criteria (ECVET-EQAVET) designing competencies for Operation, repair and service of hybrid and electric vehicles through innovative e-learning materials and work-based learning activities. The projects will create tangible and intangible results such as complex online learning management system (LMS), e-learning modules and worksheets for practical assignments, online picture-based explanatory dictionary in all project languages, blended learning resources, ECVET system in the VET in the automotive industry of hybrid and electric vehicles in the Czech Republic, Slovak Republic, Hungary and the United Kingdom.

[247] https://ease-storage.eu/about-ease/who-we-are/
[248] https://ease-storage.eu/about-ease/members/
[249] https://batteryuniversity.com/
[250] https://www.gwproject.eu/home/

Youtube videos[251] offer an extensive resource for learning. Here can be found all from recorded university lectures to films from individual YouTubers focused on Li-Ion batteries, electric cars or similar. These resources must naturally be used with critical judgement, but are the resources many learners search in the first place for learning something new or challenging. There are some excellent teaching tools to use for making a pedagogical package around a good youtube film or a section of it. One is the TED-ED tool[252], which enables a teacher to package a video in questions to answer, items to reflect on, questions for student assessment, etc. The video stays where it is, but can be used in organised online or blended education and training. A tool with a similar function is the NUITEQ Snowflake[253], which allows to use snippets of videos and to create learning resources around them with the help of templates.

Wikipedia tools are very common in use to search for information for learning. Here we have again the critical quality issues to watch, but many Wikipedia articles can be very up-to-date. They can also be combined into pdf textbooks with Wikipedia tools. There are special wikis, for example, Wikiversity with free course materials and Wikibooks with free book titles for courses and self-directed learning. No battery search hits at the moment. One thing to also look for is special wikis – as an example this wiki specialised on biohydrometallurgy[254], coming from an EC FP6 IP project. No special battery-knowledge wiki has been found, but could perhaps be needed in education and training.

The OERCommons[255] is a European website linking to open educational resources which users have added. A search on "Batteries" gives many hits. Objects are often shared by teachers and labelled with a Creative Commons license.

The Mason Metafinder[256] is a federated search utility linked to many databases of Open Educational Resources for making possible one search instead of many. This metafinder also gives access to free digital textbooks and articles. Battery hits are many.

[251] One example: https://youtu.be/VxMM4g2Sk8U
[252] https://ed.ted.com/educator
[253] https://www.nuiteq.com/snowflake
[254] http://wiki.biomine.skelleftea.se/wiki/index.php/Main_Page
[255] https://www.oercommons.org/
[256] https://mom.gmu.edu

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2.12 OTHER EDUCATIONAL AND TRAINING RESOURCES

Kompetenznetzwerk Litium-Ionen Batterien, KLiB, offer German schools an experiment set for about 50 experiments with Li-Ion batteries, "EnergieExplorer"[257] free of cost, worth about 94€. The network is made possible by donations from companies in the sector.

[257] https://www.klib-org.de/energieexplorer/#c122

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3 Concluding reflections

This report is, as mentioned previously, a first state-of-art review focusing on existing work and initiatives battery and electromobility job roles, education and training. It does not claim to be exhaustive in any way, just to provide an exciting set of examples that enhances our orientation. It does not recommend anything over anything else.

The work with the mapping of stakeholders in the industry, among education providers and in the policy sector is ahead of us in ALBATTS Work Packages 3, 4 and 5, the systematic sectoral intelligence work. This, in turn, will give signals to WP 6 (Training) on what to work with and develop as contributions to the blueprint. Next step in WP6 work will be to look at some modern concepts and tools so the productive work can start when we know in more detail what needs to be done.
To sum up, our experiences when gathering and categorising this data;

- We have found more information than we first imagined, although the work has not included any in-depth content analysis.
- The major part of battery-relevant education has been found in higher levels of the university systems. Universities can have a long perspective on the future and development of both research and industry applications. On the other hand, for applied adult education to start in a region, the right jobs will have to be more or less waiting (which is the situation in Northern Sweden right now with the start of Northvolt production in 2021). EQF4 and EQF5 education are also in more immediate need of detailed input on the curriculum from industry than master educations are. They often rely more on R&D input. Education and training for professionals active in adjacent fields of the work market seem to be already scaling up.
- Concerning readiness by education providers in the battery sector, we find that Europe is better prepared on the masters and doctoral level of education (EQF 7-8) than on the undergraduate and vocational levels (EQF 4-6). Battery technology research generates specialised education at higher levels, and this is supported both by the European understanding of the research-teaching relationship at universities. Furthermore, the education is packaged in the Bologna process pattern for mobility and easy exam recognition in the Bologna signatory countries. It is hard to compare with the readiness in education systems in Asia and the US, but we find it probable that the Bologna system is a useful enabling framework for a fast and flexible future development of education alternatives.

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In short, we now know better what we are dealing with in the ALBATTS project, from which situation we are starting our European-level Blueprint work on Batteries and Electromobility. The education and training map will look a lot different in 2023, and ALBATTS will by then hopefully be an influential part of that change, in cooperation with other initiatives.

This is a Deliverable from the Blueprint under ERASMUS+: Batteries for e-mobility
ALBATTS - ***A**lliance for **B**atteries **T**echnology, **T**raining and **S**kills, 2019-2023*

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