European Commission

BATTERIES EUROPE

EUROPEAN **TECHNOLOGY**
AND **INNOVATION** PLATFORM

DELIVERABLE: TF EDUCATION AND SKILLS POSITION PAPER

Deliverable number	Position Paper
Version Date	18.11.2020 Version n. 1
Issued by	Education & Skills Task Force
Status	Submitted to EC
Deliverable writers	Robert Dominko (National institute of Chemistry/University of Ljubljana/Alistore ERI) Dimitra Maleka (EIT InnoEnergy) Axel Thielmann (Fraunhofer ISI)
Deliverable contributors	Silvia Bodoardo (POLITO) Victor Trapp (Fraunhofer ISC) Henning Lorrmann (Fraunhofer ISC) Mari Lundstrom (Aalto University) Willy Tomboy (Detomserve Gcv) Nieves Gonzalez (CEFIC) Mihaela Buga (ICSI Energy) Thilo Bein (Fraunhofer) Julia Amici (Polito) Bernhard Faessler (UIA) James Copping (EC) Felix Rohn (EC) Andre Richier (EC) Jarkko Vesa (Ministry of Economic Affairs and Employment of Finland) Xavier Montagne (R&I French Ministry) Anja Suknaic (EC) Stefano Arciprete (EIT Raw Materials) Serge Monturet (EIT Raw Materials) Anders Norberg (ALBATTS)

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1 INTRODUCTION AND MOTIVATION

Addressing global challenges of climate change and human and environmental health urges continuous research, development, and innovation. At the same time, it also fuels the urgency to develop a highly skilled workforce, adapted to emerging technologies, whilst also driving the industrial sectors towards adapting to future socioeconomic realities. This should help avoid talent shortages by 2030 and beyond.

The European Commission highlights investment in *education, science, technology, research, innovation, and digitalisation as a prerequisite for achieving a sustainable EU economy* that meets the Sustainable Development Goals of the United Nations[1]. Additionally, Horizon Europe (HE) reflects on education and training for high value skills, productivity, and growth as well as fostering the EU digital transformation.

The global battery demand, driven by electric mobility (xEVs), stationary storage (ESS), and other applications, will dramatically expand the need for battery cells from 250-300 GWh in 2020 to at least 2.5-3 TWh towards 2030 and more than 10 TWh beyond[2]. The European Commission launched the European Battery Alliance[3] in October 2017 to address this industrial challenge. In Europe[4], the demand will increase from currently 30 - 50 GWh to 150 - 300 GWh in 2025, and at least 400 - 1000 GWh around 2030. That will be mainly covered by the setting up of battery production capacities in Europe both by Asian, American but also, increasingly, European cell manufacturers[5]. Developing battery storage and mobility is one of the key pillars of the European Green Deal with strong incentives for the creation of a European Battery Value Chain. The main open question is how successful EU headquartered manufacturers will be and how production will be distributed between European and other world regions.

A **skilled workforce** along the entire Battery Value Chain will therefore be decisive for European companies and industries in order to be competitive and sustainable.[6] It is estimated that the job market impact of the establishment of a 32GWh battery production facility is expected to employ between 2 900 – 5 800 people directly and approximately 3.7 – 7.5 times more indirectly along the Battery Value Chain[7]. Thus, several hundreds of thousands of people with knowledge and skills on different aspects related to batteries will be needed in the next 5 - 10 years and beyond at the European level. [8]

Hence, it is urgent to understand the demand for workforce and required qualifications arising across Europe: along the value chain, across the Member States, in companies, by number, as well as by qualification profiles. Core technical knowledge/skills, wider technical knowledge, and transferrable

[1] Sustainable Development Goals of United Nations
[2] Future Expert Needs in the Battery Sector, Fraunhofer and EIT Raw Materials, 2021
[3] European Battery Alliance
[4] *Europe*: a wide definition for European countries, both EU member countries and candidate countries. Switzerland, Iceland and Norway are also included.
[5] A Vision for a Sustainable Battery Value Chain in 2030 Unlocking the Full Potential to Power Sustainable Development and Climate Change Mitigation (2019)
[6] Batteries Europe Strategic Research Agenda, 2020
[7] Batteries for electric cars: Fact check and need for action. Fraunhofer ISI (2020)
[8] Around 2030 up to 1 million jobs could emerge globally and up to 300,000 jobs in Europe connected only with battery (materials, cells to pack) manufacturing. Beyond 2030, these numbers will at least triple. Taking into account also the downstream value chain including battery based products and a future circular battery economy the direct and indirect jobs might be on a level of up to 5-10 million in the long-term future. (Future Expert Needs in the Battery Sector, Fraunhofer and EIT Raw Materials, 2021)

skills are of high importance. The development and expansion of different educational segments must be rapidly invested in and implemented, including Academic, Professional, Vocational and Public/User segments along with measures that stimulate gender balance in all areas.

SCOPE OF THE DOCUMENT

This Position Paper is a high-level document illustrating the joint view of the Thematic Working Groups (TWGs) of Batteries Europe, on the cross-cutting topic of Education and Skills. The identification of the topics analysed and addressed was performed with input from relevant EU stakeholders. The main purpose of this Position Paper is to identify the current skill gaps and educational needs for different educational segments and across the Battery Value Chain (Figure 1) while considering the capacities for education and existing programs and measures on respective aspects. The educational segments considered are Academic, Professional, Vocational, and Public/User. Proper measures should be done to stimulate gender balance in all areas of education.

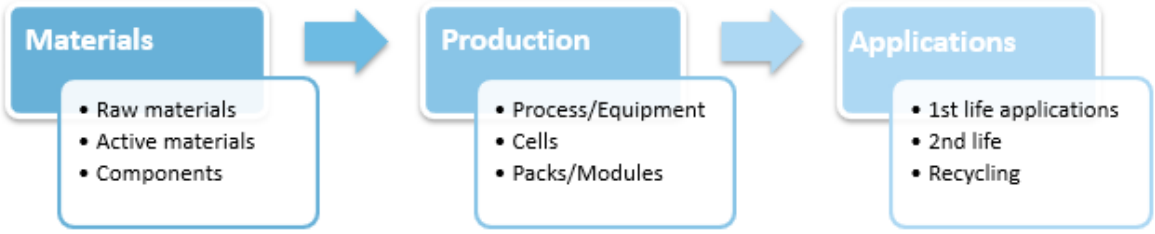

FIGURE 1: BATTERY VALUE CHAIN (SIMPLIFIED) AS CONSIDERED FOR THE ANALYSIS IN THIS POSITION PAPER

Besides scanning the literature and projects running on this topic, inputs were received by the TWGs in the form of open consultation. Lastly, based on the analysis and projections, recommendations are made for the next 5 - 10 years and beyond.

This Position Paper focuses primarily on Lithium Ion Batteries (LIB) as LIB will be the dominating battery type in the next decade and it is estimated that most jobs will be connected to this industry. Nevertheless, skills related to other battery types (e.g. sodium ion batteries, lead acid batteries or any other type of batteries) are not excluded, whenever similar type of skills are required.

2 STATE OF THE ART - 2020

The European Commission's *new industrial policy strategy* goal is making the EU the world leader in digitalisation, decarbonisation, and innovation. Subsequently, battery production is a strategic imperative for the competitiveness of the European automotive sector and for the clean energy transition. Skills are at the heart of industrial policy and in order to create a competitive European Battery Value Chain and enable relevant enterprises to be established in Europe, a significant number of highly skilled and qualified workforce is essential[9].

The EU workforce is generally highly qualified. Nevertheless, sufficient specialised battery-related skills along with all the educational segments and the entire Battery Value Chain are still lacking. This leads to current dependence on Asian competence, especially concerning battery design and large-scale manufacturing. Asia's strength lies in a strong educational system already incorporating elements applicable to the battery industry. At the same time, in Europe, skill gaps have been identified between workforce offer and skills needed for high-tech key enabling technologies[10]. The biggest problem lies in professional and vocational education, as it is increasingly difficult for the battery industry to employ staff with the appropriate qualification profiles. Two main distinctive categories can be identified: knowledge (theoretical orientation) and skills (practical).[11] The skill gaps and future skill needs already identified are existing throughout the battery value chain. They refer in particular to material design, electrode and cell design and manufacturing, product integration, battery management and process design for large-scale manufacturing factories. Such skill gaps raise serious bottlenecks even if several investments and improvements in technology occur. Thus, it is crucial for a significant size of the European workforce to acquire high-level relevant skills with continuous improvement. This is a must for the growth, employability, and competitiveness of the European battery industry. Main needs that have been identified so far are:

- the need for re-/ upskilling of existing workforce (especially in automotive industries),
- the need for mobilising the future workforce (e.g., exchange between industry and academia),
- the need for education on cross-cutting skills (e.g., digital skills), and
- the need for creating knowledge in large-scale (battery cell) production.

In addition, more women should be encouraged or enabled to be more active in the entire Battery Value Chain by combatting gender bias from the earliest stages of education. [12] [13] [14]

Looking into the different educational segments we elaborate further on the current situation (study from 2020). At the same time, we assess measures and programmes available to educate, and train, the workforce. For this purpose, we have examined battery-related education and training programmes as well as other relevant learning resources.

With **academic education,** we refer to Bachelor, Master, Doctoral, and Post-doc education.[15] Strong research and innovation centres and clusters[16] connected with Universities in the European

[9] P. D. TROCH, "European Battery Alliance" Internal Market, Industry, Entrepreneurship and SMEs - European Commission, May 08, 2018. (accessed May 02, 2020).
[10] Skills for industry European Commission
[11] Skills, European Commission
[12] 3 REASONS GENDER DIVERSITY IS CRUCIAL TO SCIENCE
[13] UNESCO Science Report: Towards 2030
[14] She figures 2018
[15] Corresponding to EGF Levels 6-8
[16] RS2E, POLIS, MEET, Fraunhofer Alliance Batteries, ZSW, Ångström Laboratoriet, EnergyVille, VITO, Swedish electromobility center, Polish, Dutch, Italian networks, Alistore ERI, EIT InnoEnergy, among others

landscape[17] are already present and offer capabilities to transfer interdisciplinary skills for current and future battery technologies. Most of them possess the expertise needed for the future generation of battery scientists and engineers in the field of advanced electrochemical techniques, battery monitoring, multiscale modelling, digitalisation, crystal chemistry, advanced characterisation, safety, etc.

Diverse knowledge and expertise available in the research centres and clusters possess most of the required knowledge, but industry needs exceed the number of students. Moreover, the Member States have their own roadmaps on how to implement education on battery technologies, and those roadmaps are not necessarily aligned. In general, certain existing educational solutions on the level of Master and Doctoral degrees enable the education of highly trained students.

Eminent examples are the following European Master programs:

- *MESC – Erasmus Master program,*[18]*a* 2-year programme in Materials Science and Electrochemistry provided in a collaboration of 5 Universities in Amiens, Toulouse, Warsaw, Bilbao, and Ljubljana together with Alistore-European Research Institute (ERI). With the 16th cycle of the programme underway, a significant number of highly skilled specialists have been prepared, most of them working in EU battery industry.[19]
- *Master Program (MSc) in Energy Storage*[20] delivered by EIT InnoEnergy in collaboration with Instituto Superior Técnico (PT), Aalto University (FN) and Politecnico di Torino (IT).
- *Master Program (MSc) in Energy Storage*[21], a newly launched 1-year master from Ulster University, Ireland.

There are several Master programs in the area of Electric Vehicles from University West[22], University of Bologna[23] and INSIA[24]. Additionally, Erasmus Master program - Master in materials science exploring large scale facilities (MaMaSelf[25]) and several other Master programs currently include courses and/or material relevant to batteries. The above programs enable high-level education only to a limited number of students at the moment, but their flexible curricula could be adapted.

EU mechanisms offer possibilities for different Doctoral programmes. These include European Training Networks (ETN) like Polystorage[26], Marie Skłodowska-Curie Actions (MSCA) COFUND projects like Destiny, other H2020 projects,[27] Alistore-ERI co-shared Ph.D. program,[28] etc.) which can provide highly skilled future development engineers, managers, researchers, and professors, but still in limited numbers. All Doctoral programs allow high mobility and secondments at different Universities, industrial partners, and knowledge institutions. These enable students to obtain broader knowledge and additional working experience, due to hands-on practical work in different laboratories.

Education at the Bachelor's level is, in some countries, very general and basic, while in some others more applied and goal-oriented in a specific sector. Lack of specialised studies in the field of

[17] Uppsala University, PoliTo, KIT, TU Delft, VITO, KU Leuven, Aalto, IST, Hasselt University, among others
[18] MESC – Erasmus Mundus Joint Master Degree
[19] Alumni of MESC
[20] EIT InnoEnergy Master's in Energy Storage
[21] Ulster University Master in Energy Storage
[22] Master in Electrical Vehicle Engineering, University West
[23] Master in Electric Vehicle Engineering, University of Bologna
[24] Master's in Hybrid and Electric Vehicle Engineering, University Institute of Automobile Research
[25] Erasmus Master program MaMaSelf
[26] European Training Network POLYSTORAGE
[27] Horizon 2020 Projects
[28] Alistore-ERI

development, production, and use of batteries but also battery applications has been noticed. For students finishing studies after Bachelor's degree, a close connection with companies along with application-oriented research and development is critical to supplement theoretical knowledge.

All educational steps are present at the national level to some extent and at the EU level as presented above. Studies are typically well aligned with on-going research activities and partially cover current the needs of industry. Curricula at Universities are typically connected with the expertise available within their faculty and at times additionally adapted to local needs.

Overall, **academic education** is on a high level within Europe and offers an excellent workforce due to the variety of research centres and innovation facilities. Education solutions at Master and Doctoral levels are the most developed in Europe and exist in almost every member state. Several academics (e.g. Doctoral students) are being prepared and qualified on the subject, but they are mostly focused on research (e.g. in energy, mechanical, and electrical engineering). Further expansion is required e.g. for electrochemistry, material science and technology, process and chemical engineering, and a circular battery economy. For early-career researchers, further efforts are required to cover important scientific topics across the battery value chain. Measures and programmes in academia related to battery technology are available but have been insufficient so far. They may not match the upcoming need for skilled, specialised personnel in the context of ongoing scaling-up of battery production capacities. Considering the fast progress in battery-related fields, the available educational and training programmes are clearly undersized, and a far too small number of professionals benefit from these programs. Thus, it is of high importance to take advantage of the current momentum to invest also in education and training measures.

Regarding **professional education**,[29] currently, along the Battery Value Chain there are difficulties with regards to reskilling and upskilling of personnel or with obtaining already sufficiently skilled personnel. This is especially the case in the automotive industry.

Skilled and specialised personnel exists, however, it is undersized considering the current and expected workforce demand. Due to the lack of skills in certain Member States, in-house education and routines have been developed. The gender gap in the case of professional education is even more exacerbated than in the academic field. Strong measures shall be envisaged to address this problem by the introduction of lead mentoring programs to support women who would like to pursue a career in this field.

Professional education on battery storage related topics is differentiated within the Member States and it can be delivered in the local language. In professional education segment, education can focus on more technical aspects (e.g. for engineers, technical managers, etc.) or business-related aspects (e.g. executives, investment managers, consultants, business analysts, etc.). Some Member States, such as Germany, have set this educational segment as a high priority and have developed a number of training centres and programs relevant to battery storage, while other Member States are less advanced in this sphere. The offerings of trainings and programs on battery storage have increased since 2018. A few free courses are available on online platforms mainly providing a basic level of knowledge on the topic, developed primarily by universities or entities of the European Institute of Technology (EIT),[30] suitable for professionals that might be interested in understanding this field.

There are more specialised paid-for training opportunities. Several online, face-to-face, and blended courses exist in either the local language or in English, from introductory to high expertise levels.

[29] With *professional education* we refer to any non-academic education, of the existing workforce, with a purpose of professional development and acquirement of specific competences for professional practice.
[30] e.g. École de Ponts ParisTech, EIT InnoEnergy, Technical University of Delft. EIT Manufacturing

Current trainings are mainly covering energy storage essentials, technology, and electro-mobility,[31] while trainings on other areas of the Battery Value Chain are rather limited.[32] Many of the above programmes are short trainings with limited online learning hours and on average two days of face-to-face training. EIT InnoEnergy delivered in 2020 the first master-level blended program on battery storage for professionals[33] an extensive 16-weeks programme that covers the entire Battery Value Chain. Europe is lacking in training with a focus on skills on battery production including cell design, electrode engineering, assembly, etc. but also electric drives. These training activities are crucial in order to upskill and reskill the necessary European workforce following a number of battery production facilities.

Vocational education and training (VET)[34] on battery production related areas is in general limited across Europe. Existing trainings are very localised and, in the majority, offered in the local language.[35] There are Member States, such as Sweden, Germany, and France that have taken certain steps to address high need for skilled workforce related to the announced battery production sites. Their vocational education and training programmes are including some battery-related elements[36] or provide Process Technician skills.[37] There are also projects in the field of vocational education that were co-financed by the Erasmus+ program.[38] As for all educational segments, the practical relevance of programmes and measures must be strengthened. Emphasis should be put on materials and battery production, integration, and all cross-cutting aspects around a future circular battery economy. Knowledge in service, aftermarket, and the recycling sector is increasingly needed. For battery manufacturing plants, several-weeks course packages are recommended. They would serve as useful measures to train, for example, machine operators or material handlers. For the existing workforce with a relevant background shorter courses can also be suitable.

Presently, a limited number of the **wider public and users of battery applications** are aware of the daily devices in use that utilise battery technology. There is a lack of knowledge and understanding of basic aspects related to optimal and safe functioning conditions of batteries, leading to reduced lifecycle and in certain circumstances unfortunate situations (e.g. fire, explosion). The same is true for electric cars and electric bikes. Furthermore, there is a lack of knowledge related to the proper disposal of battery waste. Looking at available and qualified offers for Public/User education there is currently a limited number of education options available. The aforementioned free online courses providing a basic level of knowledge on the topic of battery storage are one option. Also, the battery industry progressively engages to provide for free and simple explanations related to batteries and to battery usage[39]. There are several webinars and seminars available on either basic or more specific topics, which became more popular during the COVID-19 pandemic.

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[31] e.g. DNV GL, European Centre of Technology, European Energy Center, PDH Online, TNEI Services, Energy Delta Institute, ATEC, SEAS, IFP Training, Mondragon Uniberstitatea, ITMD, DEKRA Academy, Menschen und Elektromobilität, Fraunhofer Academy, EIT InnoEnergy, Chalmers Professional Education

[32] e.g. GREenergy Training, Mondragon Uniberstitatea, EIT InnoEnergy, Ecole Polytechnique Executive Education, IFP Training, IRTEC, DNV GL, Mondragon Uniberstitatea, ISQ Academy

[33] Battery Storage Expert Programme, EIT InnoEnergy

[34] 'With *vocational education* we refer to both initial and continuing vocational training i.e. either school or work-based.

[35] e.g. Syntra vocational training Battery specialist and Home battery installer

[36] e.g. Soltekniker, TUC Yrkeshögskola

[37] Yrkeshögskolan I Skellefteå

[38] From Combustion Engine Vehicle to Electric Vehicle, Manufacture a Kart with Alternative Energies, Chargers of Electric Vehicles in Learning, AlterDrive and Ready, Steady, Go!

[39] Battery Education Academy by Panasonic and Battery Academy by InoBat

Safety, maintaining and handling issues should be the main focus, together with the issue of acceptance of the technology among the broad public.

3 FUTURE SKILL NEEDS TOWARDS 2030

The needs of the battery industry can differ depending on the area **along the Battery Value Chain**. A cross-disciplinary approach is also recommended to create a large number of highly educated and qualified technicians, engineers, managers, consultants, entrepreneurs, and policy makers. This will call for increasing capacities within existing education platforms and the creation of new specialised courses and programs, which will assist in filling existing vacancies in the value chain. Education should cover five main elements (Figure 2): Science and Technology; Integrations and Applications; Environment and Economics; Processing and Safety; and Social Impact.

Often neglected are also a set of very relevant transferable skills as team-work, collaboration and negotiation skills, interdisciplinary working, diplomacy, multi-cultural sensitivity, decision-making, communication, leadership, critical thinking, curiosity, strategic thinking, commercial awareness, entrepreneurship, project management, planning, and organisation.

FIGURE 2: FIVE MAIN ELEMENTS OF BATTERY-RELATED EDUCATION

Education and knowledge in battery components and production still requires advances. A particular challenge is to increase the workforce and collective knowledge on the large-scale production of batteries. This can be achieved by professional education incorporating all five main elements mentioned, and by vocational training for the specific work within the Battery Value Chain.

Recruiting competence from Asia is currently regarded as a necessity for most of the qualification profiles required to enable large-scale manufacturing mainly for cell production. In this context, **design-to-cost and design-to-manufacturing** aspects are of key importance Advanced **LIB** production capability and flexibility of upgrading and/or renovating the production line for **post-LIB** needs is important to keep pace with the state-of-the-art R&D findings. Close synergies with companies and academia is seen as essential to close the knowledge gaps.

Moreover, the **product integration** on system-level is underdeveloped and requires significant development (e.g. engineers with more applied skills in construction and design at Bachelor and Master levels). For example, in the automotive industry, it is challenging to reskill employees with a mechanical background to electrical applications or to find sufficient personnel e.g. with professional education in the field.

Knowledge and skills in the actual **use phase** of the batteries, their functioning principle, and for the second-life of batteries will become increasingly important in the future. Operating used batteries and re-installing them for a second use application requires a workforce with proper knowledge about ageing processes in the connection with safety. **Safety** is thus a priority issue for all stakeholders throughout the value chain. Knowledge of **battery recycling** (e.g. proper disposal, recycling options, etc.) and cross-cutting topics such as **environmental aspects**, **digitalisation**, **business models**, and **circular economy**, are increasingly important across the value chain.

Consequently, concrete actions are required in **academic education** to build up a trained workforce for the future battery industry with expertise along the battery value chain in the next years. Academia should start already preparing specialised academic education programs for young students. Programs should build curricula based on interdisciplinary educational areas, with some important areas listed below for students of different disciplines:

- Raw materials extraction, and processing
- Materials science and engineering
- Physical chemistry (emphasizing on electrochemistry and characterisation)
- New and emerging battery materials/technologies
- Digitalisation and artificial intelligence
- Engineering and cell design
- Process engineering
- Design of equipment and battery manufacturing
- Module and pack assembly including Battery Management Systems (BMS)
- Battery control and system integration
- Battery testing (safety tests, lifetime tests, simulation tests, etc.)
- Battery applications
- Handling of batteries and safety
- Re-use and Recycling.

Different funding schemes and measures (e.g. EU wide pilot lines[40], Just Transition Fund (JTF) sources[41], Recovery and Resilience Facility funds[42] the Forschungsfabrik Batteriezellen FFB in Germany[43], the CoLabs[44] in Portugal) are only a few possible initiatives which should support educational training and courses with providing access to their infrastructures (e.g. demonstrators). Graduates should have a possibility to gain practical experience and skills, for example, on battery manufacturing. It is important to develop specific courses and master programmes' curricula on specific subjects relevant to battery industries[45] since a large number of trained personnel will be required around production sites (mainly Master and Doctoral level). In addition, a close connection with companies and application-oriented R&D is necessary to enable early practical work in addition to theoretical knowledge. In this respect,

[40] LiPLANET Project, Launch of LiPLANET project
[41] Just Transition funding sources
[42] Recovery and Resilience Facility
[43] Forschungsfabrik Batteriezellen FFB
[44] Collaborative Laboratories (CoLabs)
[45] e.g. operators, technicians, process engineers, maintenance engineers with respect to the battery/cell manufacturing industry as well as electrical drive technology

Battery2030+ coordination and support action (CSA) includes a Work Package dedicated to developing European curricula in future battery technologies (WP3)[46].

Professional education is essential in order to have highly qualified professionals in battery production, system integration of battery-based products, and also monitoring, collecting, and recycling. Evidently, educational measures should be developed and implemented jointly with industrial partners, to reduce time, effort, and financial resources for industries on training new employees. Two important cross-cutting needs appearing along the value chain from the raw materials to production, applications, and recycling are digital skills and a digital mind-set, as well as holistic battery system understanding. All five main elements (Figure 2) should be considered for professional education. With respect to large and complex projects and large scale production facilities there is a special need for highly experienced battery experts in the upper management. They should be able to understand the technical aspects and at the same time to make decisions on strategies, investment, etc.

Vocational training is critical for specific areas of the Battery Value Chain, especially with regards to increasing manufacturing capacities. Special attention should be given to education on handling and transport of batteries, their installation, and testing with emphasis on safety. Such training can be offered to people with solid industrial understanding and interest in batteries, battery technology and production.

Acceleration in technology transfer is needed for all educational segments and along the value chain including the education of the **wider public** and **policymakers**. For example, acceptance from the Public/User is an important contribution to the opening of markets and removing barriers to the uptake of batteries /EVs. As today's awareness of the advantages of using batteries is relatively low and concerns about safety issues are high, the wider public should be properly educated about all aspects of battery technologies, their maintenance and proper use. Predominant focus should be on generations of kids and young adults.

[46] WP3 of Battery2030+ is participated by Uppsala University, PoLiTo, CEA, CNRS, CIDETEC, CIC Energigune, KIT, NIC, DTU, VUB, MEET, WUT, AIT, TU DELFT, Aalto, NTU

4 GAPS AND CHALLENGES

With the challenge to strengthen and expand a Battery Value Chain and to create a European battery circular economy, huge investments are required that will pay off after a long period of time. Taking the right steps in the right scope in a coordinated way across all EU stakeholders will be a key challenge. Actions are required especially in the next few years, while the battery industry is expanding globally, and the production of batteries and battery-based applications is ramping up. Education and training of a skilled workforce should be at the forefront of this process in order to create a critical mass of motivated researchers all around Europe, which could compete with China, Japan, Korea, and the United States. This needs to be done swiftly and in close collaboration between industry, academics, and governments with supporting measures from policies.

One of the most important challenges at the **academic level** is sector attractiveness. Notably, many young people recognise battery production as an activity in Asia and not as an opportunity for their future. An existing program attracts students mainly from other parts of the world.[47] A positive conception of the Battery Value Chain is the most important factor and pre-condition for the broad expansion of a skilled workforce. Europe is building the educational sector practically from scratch.

While the expertise on the different areas of the value chain is available, it is dispersed through different Universities, with a limited teaching capacity. Furthermore, the level of education is different between the Member States. Therefore, standardised curricula at a Master level for different areas of the value chain could be a valuable solution, to support early-career researchers, while basic STEM[48] skills are still of great importance. The barriers that can arise at this point are the reluctance of University rectors and deans to changes, together with the laborious process of approving new curricula. Recommendations and incentives should come from the public sector, while the private sector should provide a clear message about future needs and demand.

Another main barrier is the lack of equipment and training labs where students would be able to carry out real-life hands-on experiments, in addition to theory studies. Facilities for research at Technology Readiness Levels (TRL) 5 - 6 should be preferred rather than facilities for research at TRL 2 - 3. Such an approach would lead to a much smaller separation between industry and academia, which is of the highest importance in this field. Building up (pilot lines, demonstration centres, etc.), renewing old laboratory equipment, and accessing to public and private production facilities for young students, will be of crucial in the next years. Thus, the challenge would be how to create interdisciplinary research strongly connected with education through the entire Battery Value Chain.

Another challenge is the mobility possibilities for students and scholars. Mobility possibilities can at least partially enable well-equilibrated education of students through the whole value chain at different Universities.

Lastly, mechanisms which will attract students to study battery production and battery exploitation-related subjects are required early enough.

On the **professional and vocational level,** the main barrier is seen in the still existing separation between industry, academia, and training schools/centres. This is due to competing interests between researchers and companies (e.g. with respect to knowledge transfer, IP issues, confidentiality, and sensitive information) and may complicate the development of joint educational measures between academia and industry. Interdisciplinary research and value chain-based training could increase the skilled workforce and remove barriers for academic personnel to exchange with and move to the

[47] MESC program received 314 high quality applications for 30 places in the academic year 2021/22
[48] STEM: Science, Technology, Engineering and Mathematics

industry environment (e.g. isolated, specialised academic knowledge with low practical relevance). A key challenge is, therefore, to provide solid specialised knowledge and simultaneously facilitate knowledge transfer as well as cross-cutting knowledge (e.g. the understanding of environmental, recycling, and safety aspects). Strategies need to be studied for the dissemination of knowledge and continuous interaction between industry and academia. Building up competencies in large-scale cell manufacturing is a specific gap and challenge as stated above. This will then drive the need for knowledge on battery components, battery materials, process equipment, connected factory, and automation concept for battery production facilities etc. Lastly, existing programs from Universities, organisations, and innovation centres shall be used as a stepping stone to ensure successful new training programs and learning paths for each function.

For the **public education** level, raising awareness around batteries as a key component for a sustainable future should be predominant direction of education. Short battery life, differences between batteries, the possibility of fire or explosion, disposal of used batteries, proper use, CO_2 footprint are the most frequently asked questions by users. Informing the wider public on the progress and achievements in the last decade, safety improvements, and battery waste management can enable them to overcome hesitations related to battery uptake.

5 RECOMMENDATIONS

The first actions are already being taken at the EU level and by many Member States. They aim at minimising the skills gap and making Europe an attractive location for world-class experts in batteries development and production.

In line with the European Pillar of Social Rights, this requires collaborative efforts between education and training establishments, social partners, and the Battery Value Chain stakeholders. This should lead to design and implementation of coordinated training, reskilling, and upskilling programmes.

Therefore, the Commission has included batteries as a key topic for funding as part of the Blueprint for Sectoral Cooperation on Skills under Erasmus+. This four-year project[49] was started in December 2019.

In parallel, EIT InnoEnergy, Alistore-ERI, and some national networks are working with a network of competent Universities to develop robust Master-level energy transition-related curricula, together with executive training for professionals.[50] The Strategic Action Plan on Batteries foresees support to universities and other education/training institutions to build new degree courses in cooperation with industry.[51]

The following recommendations summarise the insights from those activities as well as the most recent expert consultation analysed in the context of this Position Paper:

In order to **build up a European Battery Economy**, collaboration between relevant stakeholders and systematic synergies will be essential to integrate education and skills throughout the complete Battery Value Chain.

For **academia**, the current education measures include own learning experiences (theoretical and practical from research laboratories) and the exchange between working groups and networks. Knowledge and lectures are constantly complemented by novelties from conferences and workshops on batteries. Several aspects are recommended to develop academic education in the field of batteries on a much better EU-wide/international level with adequate content for the needs of the industry:

- Universities and research institutions should establish more **research groups for early-career** (tenure track positions) researchers with diverse research directions to prepare for the future increasing demand for a skilled workforce in the battery industry.
- Education specialised on/along the Battery Value Chain and the **adaptation of the curricula** is recommended, to match industry-relevant qualification profiles. This should include **specialised courses**/lectures/programmes and **specific degrees** on dedicated subjects/ topics, linking to industry needs.
- The introduction to electrochemistry, characterisation methodology, battery manufacturing, battery management and control, as well as battery system integration in education blocks in the field of engineering and materials science (i.e. other disciplines) would be a measure supporting **cross-disciplinary knowledge transfer**.
- **Platforms, R&D centres, and infrastructures** (pilot lines) should be integrated and functionalised in the academic and professional education network, recognising their

[49] Project ALBATTS
[50] REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK on the Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe COM/2019/176 final
[51] Sustainable Mobility for Europe: safe, connected and clean

educational role, acting as a **nucleus** for exchange between academia and industry. To do so, monetary contributions, materials, and dedicated infrastructure build-up as well as joint educational concepts between academia and industries will be needed.

- Academia should be targeted and advised on the requirements of the industry. The **industry should, in turn, provide necessary training** to academic personnel. This would help to achieve a practical knowledge/skill transfer between industry and academia already at an early stage of the academic or professional careers of researchers.
- Equally important is the Interaction between various institutes and training centres, by encouraging the **mobility of personnel** across Europe, inter alia through education programmes.
- **Attractive grants** should be conditional upon compulsory employment for a certain period of time in the field of the training.
- **Information and communications technology (ICT) use for enhancing the education process**: Digital education and learning, especially following the COVID-19 era, is and will be of increasing importance. A lot of educational materials and concepts could be shared between European universities and other education providers. Digital education could be an alternative for exchange across EU R&D centres (especially if mobility is limited), and to train a larger number of people. The next step should be adaptive learning - together with learning analytics - to optimise the individuals learning flow and education/training time.

There is a **real lack of courses and training programmes in certain areas/topics which should be developed** and implemented in the future. For example:

- Educational topics are often related to lower TRL levels and only a few of them include **hands-on training related to cell manufacturing**. Close connection between **material science and electrochemistry** with deep **characterisation techniques** is currently underestimated in importance.
- Training on **cells and battery packs** behaviour, **testing** and measures towards **safety precautions and risk-management**, use of correct tooling, **equipment**, and safety wear, for both employers and employees are largely based on available standards and norms. It is important to provide education on steps to be taken in case of emergencies (e.g. fire, damaged or defective batteries etc.) but also on the logistics requirements in terms of **handling, storing, packaging and transportation of batteries.**
- Tailor-made courses in **Circular Economy** are needed, as today's courses are far too general.
- Courses with focus on **digitalisation, artificial intelligence, Internet of Things,** and **robotics** to boost development of a competitive EV auto industry.
- Knowledge transfer and **IP protection** together with **project management**, skills for future policymakers and entrepreneurs are very rarely scheduled as teaching modules in courses.

Industry should be involved more actively in the academic process by means of seminars and training of the academic staff, but also training of own personnel. Recommended measures include:

- **Tackling unemployment by reskilling and upskilling**: Courses, webinars, and seminars are relevant for **reskilling** (re-orientation) of **professionals and for vocational education** already in a profession. This is essential in order to secure a trained and qualified workforce in this field for the near future. Activities such as battery-specific courses, are still rather private or localised and come at a higher cost and limited length. Seminars provided under (EU/ national) funding projects are

still too limited and focused on certain aspects of the value chain as well in terms of quantitative offers and length.

  - **Private training**: Companies in need of a workforce with certain specialisations should receive or develop training in collaboration with academia in the respective fields. It is very important to keep up in this field in connection to Industry 4.0.
  - **Public training offers**: To improve the offer of publicly funded education tools, it could be more efficient to combine forces across already funded project consortia and research activities on national or transnational level to develop and offer multi-disciplinary seminars and training sessions.
  - **Use of digital tools**: With current digital communication technologies, universities and innovation centres can develop flexible and practical study programs to offer the possibility to pursue an academic degree and professional education in this field. These include online-lessons and virtual seminars, with limited or no physical attendance on-site since employees have very limited time to upskill in parallel to the current job.

- **Educational testbeds:** Setting up industrial education centres across Europe to fast-track battery production competence and skills, in order to meet the upcoming demand. This could be a measure on the industry side, complementary to the public R&D centres and infrastructure. Such industry-led educational testbeds with small pilot plants and battery testing equipment would enable training unemployed workers from other industries with suitable skills.
- **Cross-sectoral transfer:** There are different sectors, which could diversify their activities to battery manufacturing. The education about the technical aspects of batteries and about the legal issues could help this kind of companies to accelerate their progress to this new business model. Educational instruments would have to be developed with such sectors and industries.

Policy stakeholders need to support both industry and academia in order to coordinate the adaptation of educational systems to the upcoming needs. Firstly, the EU should declare the battery sector as key for the industrialisation in EU and provide recommendations for the Member States to implement in their educational systems. Smaller Member States should consider cross-regional education possibilities or introduce specific modules into existing courses, which will motivate students for mobility. Recommendations and actions should include:

- **Specific funding programmes supported by industries and government**: Funding of existing educational authorities and stakeholders who should identify best practices in educational concepts, provide a full overview about existing offers, analyse the concrete needs for **adoption and expansion of educational systems** in Europe and the MS with respect to the battery ecosystem. The implementation and roll-out of such measures should be the target of the funding program and thus needs to be equipped with the required budget.
- In parallel, an **information and monitoring platform (e.g. virtual web-platform)** on educational offers and possibilities should be established to keep young people as well as professionals informed. Such a platform should monitor the knowledge transfer, balancing the interests of researchers and companies and assure that academia, industry, and policy effectively work together.
- **Acceptance and attractiveness:** Information campaigns and education of the wider public will be required in order to achieve acceptance and trust in battery technologies and their applications. Thus, efforts should be done to involve users and the wider public. Also, a European approach towards raising the image of vocational education and training in this field is essential.
- The acceleration of **regulatory aspects** related to battery production, recycling, and battery use in the different applications are critical to implement battery manufacturing and boost relevant

education skills in Europe. Potential actions would be a change in legislation in order to tilt the balance towards the applications of batteries in a day-to-day life (e.g. tax advantages for zero emission vehicles, subsidies to make them affordable, proper rewarding salary packages for workers, etc.).

- On the occasion of the European Battery Alliance Ministerial meeting on 12th March 2021[52], the need to bridge the skills gap in the European Battery Value chain was unanimously acknowledged. As a result, the European Commission has *asked EIT InnoEnergy to prepare country specific re-/up-skilling projects for interested Member States*. EIT InnoEnergy will soon launch a so-called EBA Academy, developing curricula and training content based on the industry's skills needs and in partnership with local training professionals. The objective of the EBA Academy, a platform of training resources and services operated by EIT InnoEnergy made accessible to training professionals, is to ensure that workers in the battery value chain are skilled, up-skilled, or re-skilled at the speed and scale required by the industry.

[52] Meeting between the European Commission, the EIB and 14 Member States represented

6 Conclusions and Roadmap

To conclude, a number of actions must be taken in the next few years to educate an increasing number of people with qualification profiles tailored for the industry needs along the value chain. With proper coordination between individual Member States and by expanding current programmes the impact can be rather swift. In order to implement and coordinate all actions and skills and education level, co-ordination and support actions would be required to homogenise activities at all levels in different places. Subsequent actions for the broader roll-out will have to follow in the years after 2025.

	Short-term (<2025)	Mid-term (2025-2030)	Long-term (2030+)
Academic level	• Establish more research groups for early-career researchers • Attractive grants for early-stage researchers • Adaptation of curricula (specific degrees) and creation of new courses • Cross-disciplinary knowledge transfer • R&D infrastructures (e.g. pilot lines) as the nucleus for networking between industry and academia (joint programs) • Initial development of trainings based on digital tools • Internships offered within industry • Mobilise workforce to locations with battery production facilities	• EU wide standards for adapted curricula • Increase number and capacity of courses/programs • Increase mobility of researchers across Europe, with an increasing number of R&D centers and infrastructures • Broader roll-out and use of digital tools (create a digital mind-set)	• EU wide established educational network/systems (Battery Value Chain and ecosystem) • Large number of young people interested in studying along the value chain and trained/ available for industry • Adapt curricula based on changing needs
Professional / vocational level	• React to industry needs and expand to provide the right skills • EU-wide re/upskilling programs (digital and onsite) to tackle unemployment (Industry supported by Academia) • Industry to express detailed needs towards academia (concrete qualification profiles need and number/gap of staff) • Set up educational testbeds (e.g. linked to public and private infrastructures) • Mobilise workforce to locations with battery production facilities • Highly skilled and experienced battery experts for upper management of complex projects/ large scale production infrastructures	• Broader roll-out of qualification programs • EU wide accepted standardised curricula/programs/trainings for taking up educated/skilled staff in industries • Review any changing needs within industry and increase in demand	• Re/upskilling programs fully developed • High capacities for training and personnel available for industries • Digital tools for training broadly used and effective • Review any changing needs within industry
Public/User & Policy	• Increase acceptance, awareness, and attractiveness (e.g. information, battery safety, handling to recycling etc.) • Specific funding programs for adaptation and expansion of educational systems • Implement EU wide information and monitoring platform on educational offers • Accelerate regulatory aspects	• Support expansion of adapted educational systems across Europe	• Broad acceptance and awareness of public • Understanding of users achieved • No regulatory barriers

TABLE 1 **Conclusions and roadmap <2025 to 2030+**