SKILLS

IN THE RENEWABLE ENERGY SECTOR

Visions from the European Technology and Innovation Platforms

Authors/Editors

The report was compiled and edited by Nathalie Richet and Anna Spoden of EUREC, the Association of European Renewable Energy Research Centres.

Acknowledgements

This report features input from ETIP Batteries, ETIP Bioenergy, ETIP Hydropower, ETIP PV, RHC ETIP, ETIP Geothermal, ETIP SNET and ETIP Wind, compiled through surveys of stakeholders.

European Technology and Innovation Platforms and the Large-Scale Renewable Energy Skills Partnership

The European Technology and Innovation Platforms (ETIPs) and the Large-Scale Renewable Energy Skills Partnership have joined together to present this overview of skills in the renewable energy sector.

Glossary

4GDH: 4th Generation District Heating

AI: Artificial Intelligence

ATJ: Alcohol-to-Jet

CAPEX: Capital expenditure

CO2: Carbon Dioxide

DHC: District Heating and Cooling

DSO: Distribution system operator

ECTS: European Credit Transfer and Accumulation System

EU: European Union

GWh: Gigawatt hours

HTL: Hydrothermal liquefaction

ICT: Information and Communication Technology

IEA: International Energy Agency

O&M: Operations and Maintenance

PtX: Power-to-x

PV: Photovoltaic

R&D: Research and Development

R&I: Research and Innovation

R&D&I: Research, Development, and Innovation

RES: Renewable Energy Sources

RHC: Renewable Heating and Cooling

TSO: Transmission system operator

VET: Vocational Education and Training

Table of Contents

1. INTRODUCTION

The ambitious plan for the European energy transition towards becoming carbon-neutral by 2050 is the greatest endeavour of our generation. The uptake of Renewable Energy Sources (RES) is consistently growing in most European countries, proliferated by the mandatory fossil fuel phase-out. This uptake of RES also creates obstacles, such as difficulty in aligning electricity generation with demand.

The growing need for decarbonisation and electrification requires a stark growth of the renewables industry. With this growth, however, is a heightened need for a skilled workforce and researchers in the field, including white-collar, blue-collar, and other supporting roles. Complementary to this need is a need to re-skill workers to equip them for future roles in the renewables industry.

This report on jobs and skills in the renewables industry is meant to be an aid in identifying the emerging skills needs of the renewable energy sector, R&D&I needs, and concrete policy measures to overcome the gaps between the current workforce and identified needs. The report is divided into three sections:

- Future and emerging skills and job profiles
- Jobs and skills needs in R&D&I
- Measures to overcome skills shortages

Each section features input from involved renewable energy ETIPs: ETIP Batteries, ETIP Bioenergy, ETIP Hydropower, ETIP PV, RHC ETIP, ETIP Geothermal, ETIP SNET, and ETIP Wind. Each ETIP surveyed and interviewed relevant sector stakeholders to gain greater insights on the current status of jobs and skills for the sector as well as future needs and policy recommendations.

2. FUTURE AND EMERGING SKILLS AND JOB PROFILES

2.1 BATTERIES

The global momentum toward decarbonisation and electrification is rapidly gaining speed, driving the exponential growth of the battery sector. The growing need for batteries in electric vehicles is a main reason for such growth and in this dynamic landscape, battery cell production is rapidly growing in Europe. However, ensuring a skilled workforce and researchers for this field is a big challenge, requiring expertise for white-collar, blue-collar and other supporting jobs.

Battery cell and module production in Europe is estimated to create between 150,000 to 300,000 jobs by 2030, and even more when considering indirect jobs. Gigafactories, which are major job hubs, are expected to generate 90-180 direct jobs per GWh and approximately 300-1400 indirect jobs per GWh. Taking the downstream value chain into account, this could multiply jobs by 5-10 times[1,2]. This rapid growth highlights the pressing need for a highly skilled workforce capable of specialised tasks as well as the importance of investing in training and education to develop a skilled workforce.

> **Education and training are fundamental for expanding Europe's battery sector and achieving competitive functionality of the whole value chain of batteries and electromobility in Europe.**

Europe is now facing a critical phase of expansion of the battery ecosystem. Batteries are a multidisciplinary field, and therefore requires education on 1) raw materials extraction; 2) new active materials development and processing; 3) cell and battery pack production, integration, and assessment for both mobility and stationary applications; 4) Sustainability/circular economy/Life Cycle Assessment; 5) Safety; 6) Processes digitalisation and 7) recycling and second life. In the future, there may very well be other needs to be addressed in relevant policies and regulations.

Addressing the skills gap requires tackling issues of attractiveness, geography and timing to ensure a competent workforce. One critical concept to meet these needs is "Train-the-Trainers," ensuring skilled individuals teach the future workforce and scientists (some examples may be seen here[3]). The quality of training should also be certified and recognised by relevant organisation in the sector.

Many educational activities are already ongoing in Europe and important progress has already been completed: mapping of the existing education activities as of 2022, researching European needs and new job roles and identifying and recommending learning objectives and education concepts for the sector. While updating education activities, the skilling and re-skilling of workers must include consideration for all levels, from blue-collars and vocational levels to professionals to master and PhD students and post-doc professionals. Initiatives like Battery2030+,[4] ETIP Batteries Europe's position paper,[5] Fraunhofer and EIT Raw Materials reports,[6] ALBATTS' skills intelligence updates,[7] Automotive Skills Alliance (ASA), and EIT InnoEnergy's research contribute to this effort.[8]

---

[1] Fraunhofer, EITRawMaterials, 2021 (https://eitrawmaterials.eu/eit-rawmaterials-and-fraunhofer-publish-a-report-on-future-expert-needs-in-the-battery-sector/)
[2] Batteries Europe, 2021 (https://batterieseurope.eu/wp-content/uploads/2022/09/education_and_skills_task_force_position_paper_0.pdf)
[3] Project ALBATTS, Preparatory development of the education and training framework and choice of tools, 2021 (https://www.project-albatts.eu/Media/Publications/34/Publications_34_20211201_8120.pdf#page=132)
[4] Battery 2030+ (https://battery2030.eu/)
[5] Batteries Europe, 2021 (https://batterieseurope.eu/wp-content/uploads/2022/09/education_and_skills_task_force_position_paper_0.pdf)
[6] Fraunhofer, EITRawMaterials, 2021 (https://eitrawmaterials.eu/eit-rawmaterials-and-fraunhofer-publish-a-report-on-future-expert-needs-in-the-battery-sector/)
[7] ALBATTS project research (https://www.project-albatts.eu/en/publications)
[8] InnoEnergy Skills Institute research (https://www.innoenergy.com/skillsinstitute/)

While the EU workforce is generally well-qualified, there's still a lack of specialised electric vehicle and battery-related knowledge and skills across educational segments. Skill scarcity is a major challenge for both research and industry, particularly considering the technological developments. Cross educational segment skills are also required in other areas such as fuel cells.

The battery industry's needs vary across the value chain. A cross-disciplinary approach is advised to educate technicians, engineers, scientists, managers, users and policy makers. Educational capacity should grow in existing platforms/institutions to fill identified gaps and collaboration between academia and industry is vital. Necessary transferable skills such as teamwork, leadership and critical thinking should not be overlooked. Battery related education should cover five main elements (See Figure 1): Science and Technology; Integrations and Applications; Digitalisation, Environment and Economics; Processing and Safety; and Social Impact.

Figure 1: Battery education elements

2.2 BIOENERGY

Bioenergy and renewable fuels are an essential part of an integrated energy system. They contribute a clean and reliable form of energy and provide benefits including supporting decentralised and flexible energy production, contributing to energy security, and constituting part of the bioeconomy. Bioenergy is needed to replace the massive amount of fossil fuel energy that is currently consumed. Bioenergy and renewable fuels will support the decarbonisation (in the sense of defossilisation) of Europe and in particular of its transport system.

Biomass is already widely used in the EU for energy applications; it provides more than 10% of EU total primary energy supply and contributes to the block’s climate and energy security objectives. Bioenergy alone exceeds the contribution of all other renewables together, such as wind, solar, and hydropower.[9] Nevertheless, critical to the future of the bioenergy sector is a large and sufficiently skilled workforce to manage the needs of bioenergy facilities. It takes a large number of workers to sufficiently run a facility: according to the industry, it can take approximately 1,700 workers to run a bioenergy plant (for co-processing, hydrotreatment/deoxygenation, gasification/biomethanol, bioDME synthesis, fermentation, transesterification, and saccharification – in order of the largest number of workers to the least).

[9] ETIP BIOENERGY SRIA 2023, ETIP-B2022-2025, https://www.etipbioenergy.eu/images/SRIA_2023.pdf

The first step to building a skilled workforce is identifying the skills necessary for the future of the sector – and ensuring that education and training programmes reflect those skills. When looking at the current state of the workforce in the bioenergy industry, there is a clear lack of sufficient young engineers with a solid technical educational background who can bring new life and energy into the sector.

There are two broad categories of skills that are important to the manufacture and deployment of bioenergy technologies in the next five to seven years. First and foremost, **engineering skills** are critical. This broad term encompasses a wide range of engineering skills necessary to the bioenergy sector, including mechanical engineering, chemical engineering, and biotechnological engineering. But beyond engineering focus areas, further technical competencies and hands-on experiences are needed for those entering the bioenergy sector. Stakeholders spoke about the need for craftsmen and skilled welders to lead technical installations as well as experts in analytics, knowledge integration, and sustainability assessments.

Within the technical engineering needs of the bioenergy sector, certain specific skills or experiences are valuable. For the bioenergy sector, this can include **laboratory skills** and microbiology processes and techniques. For example, an engineer specialised in fermentation processes, in the biorefining of lignocellulose or in sustainable biomass procurement. Furthermore, specialties such as bioinformatics and the digital industry will become more prevalent in the near future, as digitalisation is incorporated into energy systems to a greater extent. **Digital skills** will also necessitate advanced analytics skills and data analysis.

The second broad category of skills needed are so-called "soft" skills in **sustainability, communication, and commercialisation**. Good communicators are vitally important to explain the needs of the bioenergy sector as well as the importance of bioenergy as a renewable energy source and part of the future carbon neutral system. Creative or lateral thinking is also advantageous to be able to adapt to circumstances or uncertainty, as is a sense of teamwork and collaboration to creatively problem solve and think critically about solutions. To scale up the sector in the future, **project development and management** experience will be vital. This can include management in public affairs, regulatory updates and marketing.

All these skills are valuable in the short and medium term to build up the industry and scale up manufacturing processes, but certain skills are more important than others in the long term – at least according to stakeholders in the bioenergy industry. For the most part, this is the broad categories of skills mentioned above. Engineering and technical expertise are paramount – especially engineers with commercialisation experience who can bring and hold all the required complex technologies in operation. Craftspeople, specialists in bioinformatics and the digital industry, and specialists in process design and scaling up will also be vital to the future of the sector. Finally, innovation is key to the development of any sector.

> **Ensuring that innovation thrives in bioenergy research will be critical to addressing the future needs of the industry – including challenges of availability of supply, production capacity, and evolving regulatory landscapes.**

2.3 HYDROPOWER

Photo by American Public Power Association on Unsplash

Hydropower is considered one of the most sustainable renewable energy sources; it already supports the integration of electricity from intermittent RES into the supply grid through flexibility in generation as well as its potential for storage capacity. It can also provide additional services and benefits for civil society (e.g. water supply for drinking and irrigation, flood protection, drought prevention, sustainable transport, tourism, recreation, sport, fisheries and floating solar PV). The recent energy crisis reveals the important and vital role of hydropower in ensuring a safe supply of electricity during the winter in Europe. The hydropower industry will be a major sector in the EU's transformation towards net zero carbon emissions and an energy system based on renewable sources. However, like many of the renewable energy sectors, it requires adequate financial, political and regulatory support to establish itself more securely in the future energy system. Intrinsic to the future success of the hydropower sector, however, are people. People – employees, managers, operators, certifiers, maintenance workers, and innovators – are the foundation of the sector. Without proper skills and training, it will be impossible to scale up hydropower to the level necessary for Europe's energy future. It is therefore important to take stock of the industry and its skills and job profiles and to look towards future needs – and how policymakers can help support and address those needs and cultivate support for hydropower.

It is first important to analyse the current and emerging skills and job profiles of the hydropower industry. For the most part, job profiles begin on a fundamental level with engineering. Civil, mechanical or electrical engineers are the most typical profiles for the industry. Basic knowledge of hydraulic machines (machine type selection, hydraulic design, operating regimes etc.), hydraulic structures as well as a good understanding of electrical design and grid stability are also important aspects of an educational background. Adaptability is also key for project implementation – engineers should be able to develop programmes that take into account parameters from existing equipment for future design and calculation tools. In view of uprating with concession renewal, issues of environmental engineering will become more important.

Technical skills including welding are also vital – one expert noted that having sufficient simple grinders and welders could become an issue in the future as there are fewer people going into manual jobs and automation processes are difficult and expensive. Other skills necessary for the hydropower sector are those related to project management – contracts, asset management, energy design, supervision for installation as well as operations and maintenance (O&M).

Skills that will become more important over time include data and digitalisation specialists who can incorporate digitalisation practices into hydropower system designs. Electrical engineers with a high voltage background are also decreasing over time, so this skill set must be fostered. Additionally, it will be even more important in the future to encourage multidisciplinary approaches to engineering, as hydropower is incorporated into the grid and new developments will have multi-purpose use. Finally, although digitalisation is important for innovation, innovation can also be cultivated on the side of machinery design and functionality, so design specialists are also key to the future of the hydropower sector.

As the table below illustrates, hydropower is a dynamic sector which encompasses a wide variety of job profiles and skill sets – all of which are necessary to the manufacture and deployment of hydropower technologies in the next 5 to 7 years. The renewable energy sector is dynamic, so it is important to stay up to date with industry trends and emerging technologies. On a long-term level, the table shows the need for educated generalists but also specialists in the field. Hydropower will continue to develop and become more complex as it deals with multi-purpose use, climate adaption, environmental impact, digitalisation, and so on. To bring all these aspects together and maintain an overview of the system is a challenge. Therefore, it is necessary to have multidisciplinary teams working together, both with in-depth knowledge of all aspects of the technology but also a wider scope of the project landscape. Success in this regard requires time and education, including gaining experience in several fields and being part of different projects.

Table 1: Job needs in the hydropower sector

Job Title	Job Description
Renewable Energy Engineer	These professionals will be responsible for designing, developing, and improving hydropower systems. They will need expertise in hydraulics, complex system analysis, power generation, turbine design, and renewable energy technologies.
Project Manager	As hydropower projects become more complex, skilled project managers with multidisciplinary knowledge will be required to oversee the entire development process. They will need strong leadership, organisational, and communication skills to ensure successful project implementation.
Environmental Specialist	Hydropower projects must adhere to environmental regulations and mitigate potential ecological impacts. Environmental specialists, often environmental engineers, will play a crucial role in conducting impact assessments, designing fish passage systems, biotope restoration and ensuring compliance with environmental standards.
Civil Engineer	These professionals will be involved in the construction and maintenance of hydropower infrastructure, such as dams, reservoirs, and water conveyance systems. They will require expertise in hydraulic engineering, structural design, geotechnical engineering, and construction management.
Hydrologist	Understanding water resources and managing water flow is vital for hydropower operations. Hydrologists, often specialised civil or environmental engineers, will be responsible for analysing rainfall patterns, river flows, flood forecast and optimising water resource management strategies.
Automation and Control Engineer	With the increasing integration of digital technologies, automation, and control systems in hydropower plants, engineers with expertise in industrial automation, control systems, and cybersecurity will be needed to ensure efficient and secure operations.

Data Analyst	The collection and analysis of data from sensors and monitoring systems are becoming integral to optimise hydropower plant performance. Data analysts skilled in statistical analysis, machine learning, and programming will help extract insights and improve operational efficiency.
Maintenance Technician	Skilled technicians will be required to inspect, maintain, and repair hydropower equipment, including turbines, generators, and electrical systems. They will need knowledge of mechanical and electrical systems, troubleshooting skills, and adherence to safety protocols.
Renewable Energy Policy Analyst	Professionals specialising in energy policy and regulations will be instrumental in shaping favourable policies, incentives, and frameworks for hydropower development. They will analyse market trends, assess policy implications, and contribute to the growth of the industry.
Safety and Risk Management Specialist	Ensuring the safety of personnel, infrastructure, and surrounding communities is paramount in hydropower projects. Safety and risk management specialists will develop and implement safety protocols, conduct risk assessments, and maintain compliance with safety regulations.

2.4 PHOTOVOLTAICS

The photovoltaic (PV) sector will contribute an important share of the total renewable energy deployed capacity to deliver on the EU's objective of carbon neutrality by 2050. Recent years have witnessed a surge in investments in new PV capacity, driven by factors such as the COVID-19 crisis and energy security concerns arising from the conflict in Ukraine. PV deployment rates in Europe grew by 47% in 2022 compared to 2021, to more than 41 GW of newly installed capacity. This trend is expected to continue in the coming years, contributing significantly to the European Union's broader energy and climate objectives.

Simultaneously to this rapid growth of PV installations, the PV industry – motivated by tensions across global supply chains and renewed political support – is intensifying investments to build up its manufacturing capacity in Europe to increase the energy security of the EU on photovoltaic energy.

However, a critical challenge lies ahead: attracting a larger workforce to the PV industry. This becomes crucial for addressing issues such as delivering a growing number of projects and limiting the lengthening of delays for delivery – most notably in the residential PV segment. Indeed, PV projects tend to have the highest job intensity per million dollars of CAPEX according to the IEA, which means that the PV sector will deliver a large number of high-quality jobs. However, a central challenge to the PV industry and policy makers in coming years is to guarantee the skill levels of workers to deliver PV systems at a high level of quality, reliability and efficiency.

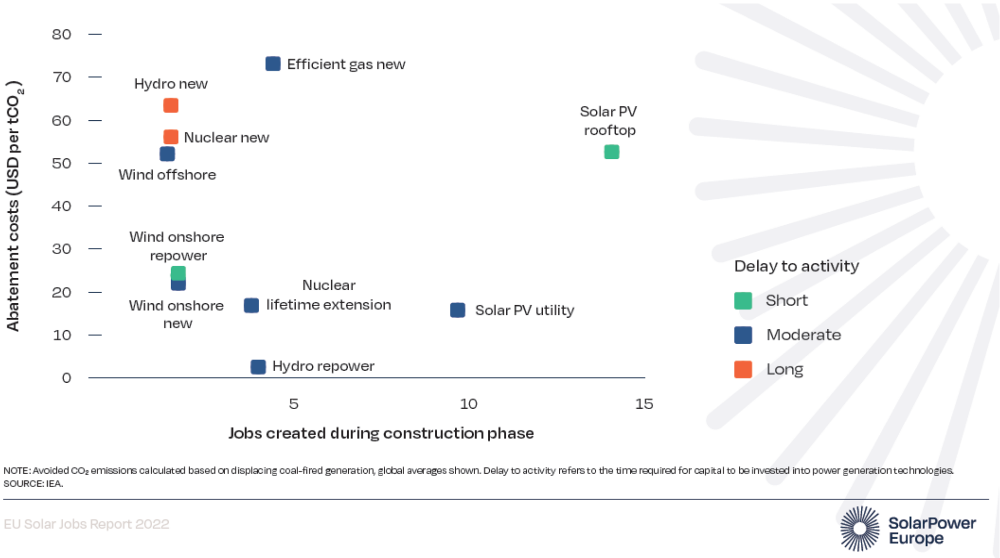

Figure 2: Job creation per million dollars of capital investment in power generation technologies and average CO_2 abatement costs

The PV value chain encompasses a wide landscape of skills and a range of jobs across all levels of qualifications. The dominant segment of employment of the PV sector is in deployment – e.g. the installation of panels on roofs or in utility scale projects – with over 360 thousand workers in Europe. Workers in the deployment of PV systems correspond to different qualifications levels, from transportation to engineering and planning of systems, including the technicians and electricians that are vital to the success of the industry and delivering reliable PV systems.

The manufacturing for the PV value chain is another important segment, representing around 9% of the total employment in PV. These jobs highly depend on current European manufacturing capacities in polysilicon, inverters, and modules. The level of job intensity is greatest in the production of cells and modules, followed by a lower level in the manufacturing of inverters and ingots/wafers, and a significantly lower level in polysilicon production.

O&M is another segment within the PV value chain that accounts, similar to manufacturing, for 9 percent of the total PV workforce in the EU. In the context of the PV industry, O&M refers to the ongoing activities required to ensure the proper functioning and efficiency of solar installations after they have been deployed. O&M professionals play a critical role in ensuring that PV systems continue to generate clean and reliable electricity over their operational lifespan, which can span several decades. Their work helps maximise the return on investment for PV installations and contributes to the overall sustainability and success of the solar energy industry.

Additionally, decommissioning and recycling are essential aspects of the PV value chain, although they currently represent a smaller component of PV employment, their significance is expected to grow rapidly in the coming years, especially as more PV systems reach the end of their operational life. This trend is expected to drive increased demand for skilled professionals and specialised companies involved in decommissioning and recycling within the PV sector.

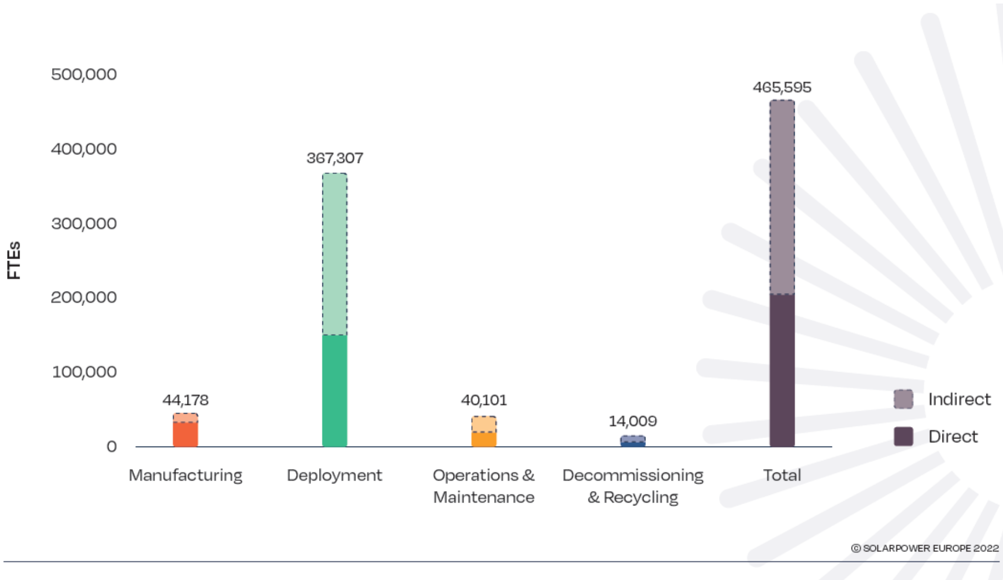

Figure 3: EU-27 Solar Job Market in 2021

Employment in the PV sector is expected to grow rapidly in coming years, with estimates ranging from 540 thousand to over 1 million workers in PV in 2026 in Europe. Doubling the number of professionals in the PV sector will be a major challenge to guarantee the skill levels of the industry, requiring a robust framework for training, reskilling and standards.

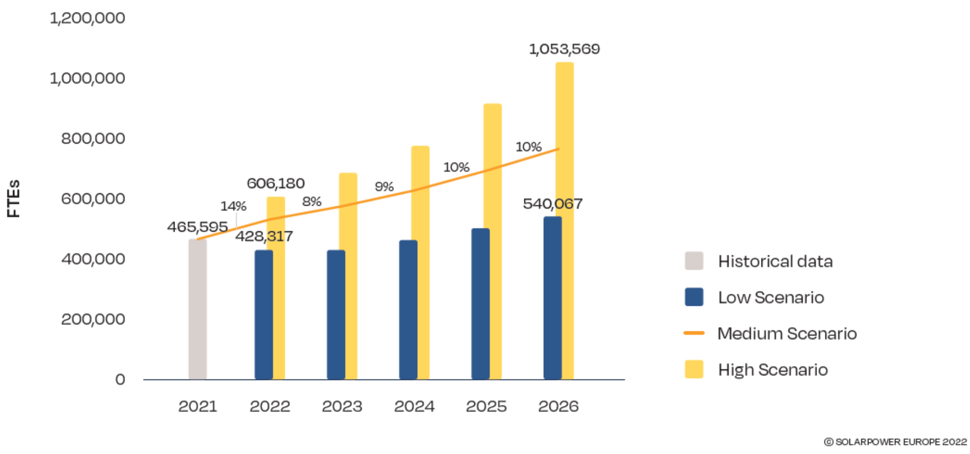

Figure 4: EU-27 Solar PV FTE scenarios 2022-2026

Among the specific skills needed for PV include:

Skills requirements for solar panel manufacturing

- **Knowledge of solar technology**: A strong understanding of the technology and science behind solar PV manufacturing is essential. This includes knowledge of semiconductor materials, photovoltaic cell design, solar panel assembly, and related concepts in physics.
- **Technical skills** are essential for working in the solar manufacturing industry, as they require individuals who are skilled in electrical and mechanical engineering. This includes

being familiar with complex solar panel manufacturing processes, troubleshooting systems, and performing maintenance on machinery and equipment.

- **Quality assurance** is a critical component of the manufacturing process, and solar panel quality can impact the effectiveness and reliability of a solar power system. Individuals who work in the solar manufacturing industry must be skilled in inspection and testing to ensure that solar panels are meeting the required quality, performance standards and safety.
- Managing manufacturing operations involves a wide range of skills, including **organisational and leadership skills**. Effective communication is necessary for ensuring that everyone is working in accordance with the company's values and goals. The solar manufacturing industry requires individuals who can supervise production teams, coordinate schedules, optimise processes, and create new innovative strategies to improve the manufacturing process.
- **Data analysis and statistical analysis** are essential parts of quality assurance, testing, and inspection of making solar panels. To ensure that the products are meeting the desired quality, it is important to be able to analyse data and create insights from data. Individuals who work in the solar manufacturing industry must be skilled in data analysis to make better decisions, reduce costs and enhance production efficiently.
- **Safety awareness**: Solar PV manufacturing involves working with potentially hazardous materials/products and equipment, so safety awareness is critical. You should be able to identify potential safety hazards and take appropriate precautions to prevent accidents.

Skills requirements for solar power plant construction

- **Knowledge of PV technology and installation**: Individuals who work in solar power plant construction must be familiar with photovoltaic technology and installation processes. This includes knowledge of the electrical wiring and design of solar power systems.
- **Understanding of electricity and electrical systems**: A strong understanding of electricity and electrical systems is essential for working in solar power plant construction. This includes knowledge of electrical safety standards and regulations, as well as the ability to read electrical diagrams and blueprints.
- **Project management**: Managing solar power plant construction requires excellent project management skills. Individuals in this field must be skilled in coordinating teams, creating timelines, and ensuring that projects are completed on schedule and within budget.
- **Safety** is a critical concern in solar power plant construction. Individuals working in this field must be knowledgeable about the safety procedures and regulations that apply to solar power systems and construction sites. They must also be able to identify potential safety hazards and take measures to prevent accidents from occurring.
- **Quality assurance** is essential in ensuring the reliability and effectiveness of solar power systems. Individuals working in solar power plant construction must be skilled in inspection and testing to ensure that the systems are meeting safety and performance standards.

Overall, a combination of technical knowledge, problem-solving skills, attention to detail, teamwork, quality assurance, safety awareness and a willingness to learn and adapt are essential to succeed in solar PV manufacturing and deployment.

To fill the skills gaps in the solar industry, educational programmes and training opportunities are essential. Educational programmes can provide individuals with the necessary knowledge and skills to work in the solar industry. This can include vocational training, technical schools and universities. The training opportunities can allow individuals to develop new skills and keep up to date with the latest technologies. Additionally, individuals with skills from other industries can often find synergies in the solar industry, as many of the required skills are transferable. These programmes can range from on-the-job training to formal apprenticeships and educational programmes.

Overall, filling the skills gaps in the solar industry will require a collaborative effort between companies and educational institutions. By developing targeted training programmes, partnerships, and recruitment strategies, the industry can attract and retain the skilled workers needed to support its growth and meet the demand for renewable energy.

2.5 RENEWABLE HEATING AND COOLING

The renewable heating and cooling sector covers a diverse assortment of technologies and systems, including solar thermal, geothermal, biomass, heat pumps, thermal energy storage and district heating and cooling (DHC). Each technology has specific characteristics and requires different job profiles and skills, although there are many skills and needs which overlap across the sector. To achieve climate neutrality, a combination of different solutions is essential and would lead to greater cost-efficiency and effectiveness.

Heat pumps

Heat pumps are rapidly growing; over 3 million heat pumps were installed across Europe in 2022, employing around 162,000 full-time equivalent workers. Doubling deployment by 2030 will require more skilled workers – particularly engineers and installers. Announcing the end of sales of stand-alone fossil fuel boilers would allow installers of fossil fuel boilers to become heat pump installers. While some boiler installers have already reskilled to move into the heat pump sector, heat pumps are more time-consuming to install and appropriate training will be required for additional skills, such as the ability to recover and safely handle refrigerants. The EU is working on a heat pump skills partnership to empower workers with the skills needed for the manufacturing, installation and maintenance of heat pumps, and to establish cooperation between relevant national authorities, vocational education, training institutions and training platforms.

According to the work done in the EU funded Horizon2020 project HP4All (which consolidates data from EHPA and its consortium partners as well as other EU funded projects), three main segments exist – though a professional would need most of these skills to participate in a competitive market:

Segment	Installers/Technicians	Chief Installers	Corporate/Management
Description	Technical and customer focused competencies; focus on company services	Organisational and customer-focused competencies; focus on adaptability and improvement	Business and organisational competencies; focus on growth

The sector also needs the following competences:

Technical	Business/Organisational	Customer-oriented
• Problem solving • Digital • Preventative maintenance • Calibration and testing • RES Integration • Health and safety	• Financial management • Resource management • Commercial awareness • Innovation and entrepreneurship • Negotiation and decision making	• Communication • Customer management

District Heating and Cooling

The current skills associated with the combustion of fuels will not be needed in the future as the DHC sector evolves. The next 5-7 years will create a demand for professionals with skills in heat recovery, new-generation processes, and heat pump technologies. Understanding fourth generation district heating (4GDH) principles and the benefits of lower temperature networks will be important. Additionally, the sector's digital transformation will necessitate data scientists, experts in sector coupling and professionals capable of assessing and communicating the value of new solutions. Technical profiles with engineering skills, such as network design and construction management, will also be sought after. Finally, individuals who understand the sector's transition and possess business development skills will play a pivotal role in its growth. Communicating the value of DHC networks within Smart Energy Systems is essential, along with fostering long-term energy planning skills in universities.

Proficiency in data science, a holistic digital mindset, and the ability to innovate are becoming increasingly important and crucial for the sector's long-term growth. Foundational engineering knowledge remains vital, and interdisciplinary collaboration is gaining prominence. Operational expertise and business development acumen are also emphasised as essential for managing networks effectively and driving new opportunities. As the DHC sector progresses, a blend of technical proficiency, adaptability, and forward-thinking will shape its future trajectory.

Biomass

Biomass has by far been the oldest renewable energy source used throughout history and is the largest employer in the renewable energy sector on the continent, second only (3.44 million in 2021, biofuels account for 2.4 million) to the solar sector (4.29 million in 2021) worldwide.[10] This is also due to the fact that it can be easily used in isolated areas without a grid connection. Many job profiles exist along the value chain, starting from the production of biomass to equipment manufacture and distribution, construction and installation, O&M, and extending to project development and cross-cutting activities like policy making, training, financing and IT. The following skills and occupational needs are valuable to the bioenergy value chain:[11]

[10] Renewable energy and Jobs: Annual review 2022 (ilo.org)
[11] wcms_166823.pdf (ilo.org)

Equipment Manufacture and Distribution	Project Development	Construction and Installation	O&M	Biomass Production	Cross-cutting/ Enabling activities
-R&D -Design -Quality assurance -Marketing -Sales -Delivery	-Design -Resource assessment -Environmental assessment -Financing -Land agreements -Permitting	-Plant construction -Processing -Quality assurance -Conversion (heat, power, or fuel)	-O&M	-Cultivating -Harvesting -Transport	-Training -Policy making -Management and administration -Insurance -IT -Health and safety -Financing -Communication -Biopower transmission and distribution

In addition to the more traditional jobs related to the value chain, such as scientists and engineers conducting research and development, construction workers building plants and updating infrastructure, agricultural workers growing and harvesting feedstocks, and plant workers processing feedstocks into fuel while sales workers sell the biofuels, there are also emerging jobs with new skills.

With the increase in the renewable energy share in the EU and worldwide, it is becoming more popular to use hybrid technologies to maximise renewable energy production, therefore skills must be transferrable across the renewable energy sector.

Targeted short-term programmes, such as retraining electricians to become installers of biomass boilers, present a practical solution to address the skills gap. The greatest job and skills needs are therefore installers who can build boilers and set up hybrid systems that incorporate biomass boilers along with heat pumps, solar panels, and other energy technologies. The new competences required for installers include digitalisation, hybridisation, electrification, system optimisation, refrigerants, and the use of decarbonised gases.[12] Although technical skills related to renewable energy technology remain important, other skill sets related to business skills, environmental knowledge, and especially soft skills are gaining importance due to the ever-changing environment and advancements in technology and digitalisation.

Solar Thermal

For solar thermal systems, needs differ between small-scale (buildings, either residential or commercial) and large-scale (industrial process heat or district heating) deployment. Regarding the deployment of small scale solar thermal systems, the top priority is installers. They require competences on hydronic heating systems and metal working. Installers of small scale also need skills with roofing (working on different types of roofs, weather proofing, security). For large scale systems the needs range from the design and planning phase to the installation, and subsequently to O&M. These include management roles (project managers, project designers, site supervisors) and engineers

[12] EHI-report-Heating-systems-installers-Expanding-and-upskilling-the-workforce-to-deliver-the-energy-transition.pdf

(i.e. hydraulic, electrical, process, automation/controls). For solar thermal manufacturing, the biggest needs are for engineers, R&D specialists and software developers.

One of the most relevant trends in the future will be the hybridisation of systems. This trend will require installers of small-scale systems to have multiple roles, such as electrician, roofer and plumber, in order to install solar thermal, heat pumps or solar PV (either individually or combined in one system). These multiple roles require multiple related competences. Digitalisation will become more relevant, particularly in terms of software engineering and aspects related to connectivity and interoperability of heating systems as well as system performance. For larger scale systems, these requirements will also reflect the development of predictive models, digital twins and other software tools to help on the design, fault-proofing, performance prediction and operational integrity of such large systems. Overall, IT technologies offer a powerful toolkit for researchers, engineers and operators in the solar thermal industry. They enhance system efficiency, reliability, and integration with broader energy systems, ultimately advancing the development and adoption of solar thermal heating systems as a sustainable energy solution.

Geothermal

In the geothermal sector, the rapid development of the market of both geothermal heat pumps and larger-scale geothermal applications will require substantial efforts in terms of the training of new designers and skilling of installers in the next 5 to 7 years. An estimated 15,000 designers and 30,000 installers will need to be trained to handle the approximately 10 million cumulative units of geothermal heat pumps over the next 5 years. An additional 10,000 designers and 20,000 installers will be needed for larger-scale geothermal applications, which will provide baseload electricity, heating and cooling for district heating and cooling systems, renewable cogeneration systems, and industrial and agricultural installations. More specifically, the following main categories of skills are necessary:

- Skills for the installation and maintenance of heat pump systems for heating and cooling, including their connection to and integration with the electric grid as well as 4th/5th generation district heating and cooling systems;
- Skills for the exploration, prospection, drilling, installation, control and maintenance of geothermal energy plants.

2.6 ENERGY SYSTEM INTEGRATION

New renewable energy skills should be promoted and developed through all levels 1-8 of the Education Qualification Framework.[13] Vocational education and training (VET) covers the pre-university education in levels 1-4 and the Higher Education Area or universities educate in levels 5-8.

VET is oriented to prepare specialised technicians (i.e. electricians and plumbers) with a continuous learning process, including additional professional certification. VET's crucial importance in facilitating the green transition was highlighted in June 2023 with the EC's Compendium of Inspiring Practices publication. The Working Group on VET is focused on the implementation of the principles of the Council Recommendation on VET and of the Osnabrück Declaration, with a particular focus on the green transition.

VET is complementary to the university degrees that should be adapted to the profiles requested by the green and digital transition. It is estimated that several tens of thousands of workers will be newly trained, upskilled or reskilled in different sectors for address renewable energies, grid integration and

[13] Europass European Union, Description of the eight EQF levels. https://europa.eu/europass/en/description-eight-eqf-levels

sector coupling. The main skills that should be covered are technical (with particular attention to electrical skills covering installation, O&M), data science, ICT, control and automation, health and safety and business profiles.[14,15]

Universities are oriented to prepare cognitive and practical skills required to develop creative solutions to abstract problems and to solve complex and unpredictable problems in a specialised field of work or study.

ETIP SNET has identified two main areas where there is an urgent need for new training and skills for a safe, resilient and clean energy system: ***Sector Coupling*** and ***Digitalisation***.

The large-scale integration of renewable and decentralised energy resources, the efficiency and flexibility of the energy systems and their reliability and adequacy can be significantly improved through ***Sector Coupling***. It increases the integration of end-user and energy vectors, such as electricity, gas and heating and cooling, with each other.

Analysis showed a discrepancy between current and future demand of abilities for multiple working domains, while digitalisation and technological changes are transforming the way of living and working. ***Digitalisation*** of the energy sector requests rapid transitions from levels of knowledge and from occupations, forcing people to upskill and reskill continuously.

Sector Coupling

The *Energy Systems Integration Skills* refer to the ability to combine energy grids, making it possible to combine electricity with gas grids, electricity with heating and cooling grids or electricity with gas and heating and cooling grids to work together optimally. There is currently a lack of energy system integration capabilities due to the historically siloed development of energy systems. Experts and professionals use different terminology and often use the same language to understand different things. In addition, knowledge of other energy systems is very superficial, which is insufficient for practical joint integration work. All these factors make the practical implementation of sector coupling difficult. Training integration skills in energy systems are essential to implement sector coupling in practice and drive the energy transition forward.

Job profile for the **integrated electricity and gas (bio-methane or hydrogen) systems**:

- Integrate electricity with the gas system in the entire transmission and distribution structure;
- Optimally plan the extension or reinforcement of the gas or power grids by considering their integration and the protection environment issues;
- Developing scenarios for the normal and abnormal operation conditions of integrated power and gas systems;
- Analysing and adapting processes necessary for the reliable and safe operation of the integrated electricity and gas systems;

[14] Green Deal Industrial Plan - plugging the skills gap (europa.eu)

[1] EPSU-EURELECTRIC-INDUSTRIALL. Skills needs developments, vocational education and training systems in the changing electricity sector & EDDIE project (Erasmus+ project) D2.2 Current and future skill needs in the Energy Sector

[2] H2EXCELLENCE – Erasmus+ project https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/how-to-participate/org-details/999999999/project/101104447/program/43353764/details

[3] Identify Occupational Profiles and Urgent Skills Needs. Green Skills for hydrogen. Erasmus+ project - https://greenskillsforhydrogen.eu/wp-content/uploads/2023/10/Green-Skills-for-Hydrogen-European-Hydrogen-Skills-Strategy-last-update-24102023.pdf

[4] Energy Saving Trust. Skills requirements for heat pumps. Sustainable Energy Supply Chain 22 March 2022

[5] Dan Stefanica D3.4 - HP Skills and Competency Framework. HPAll Project.

- Developing coordinated market structures for electricity and gas;
- Operating the integrated power and gas systems.

Job profile for the **integrated electricity and heating and cooling systems**:

- Integrate electricity with heating and cooling systems in their entire transmission and distribution structure;
- Optimally plan the extension or reinforcement of the heating and cooling or power grids by considering their integration and potential protection environment issues;
- Developing scenarios for the normal and abnormal operation conditions of integrated power and heating and cooling systems;
- Analysing and adapting processes necessary for the reliable and safe operation of the integrated electricity and heating and cooling systems;
- Developing coordinated market structures for electricity and gas;
- Operating the integrated power and gas systems.

Job profile for **smart power systems**: the main new professions related to the smart grid systems could be classified in four categories:[1]

- Operation and maintenance technician covering network-electrician, household metering and facility technician (including storage);
- Professions on ICT: specialists on electronics, electrical devices, information technology, data science, cybersecurity;
- Mechatronics and automation technology;
- Support system technicians: energy efficiency advisors, back-office employees, renewable energy installers.

Job profile for **hydrogen**: installation, operation, maintenance, storage, transport and safety trainings, including different specialisation technologies such as electroliers and fuel cells.[2] Specifically, the following profiles are highly requested:[3]

- Maintenance or service technicians;
- Production technicians;
- Testing technicians;
- Higher technical degree in ship machinery systems;
- Administrative staff from public institutions.

Job profile for **heat pumps:** the heat pump installers usually are required to complement their education and training on:

- Domestic plumbing and heating;
- Installation and commission fuel systems;
- Water byelaws/regulations;
- Domestic vented and unvented hot water storage;
- Electrical connections.[4]

Moreover, ground source Heat Pump Installers require additional specialisation:[5]

- Handling of glycol;
- Fusion welding;
- Purging air from brine ground loops.

Other important aspects related to F-Gas connections are that the technician is required to connect the outdoor unit and the indoor unit as well as charge, refill, maintain and certify the refrigerant system.

Digitalisation

An ERASMUS-funded project, the EDDIE project,[16] has dealt intensively with the skills required and newly emerging jobs in the field of digitalisation of the energy system. A dedicated survey to obtain feedback from stakeholders across the whole energy system (all vectors), with diversity in terms of geographic location, size, type of organisation and operational focus (DSOs, TSOs, suppliers, service providers etc) was performed.

Digitalisation is generally regarded as a key factor for enabling new and green technologies with reduced costs as the most impactful added value. All sectors face similar challenges regarding digitalisation, as shown by the answers in Figure 5. Technology integration, data management and IT security issues are important technical challenges.

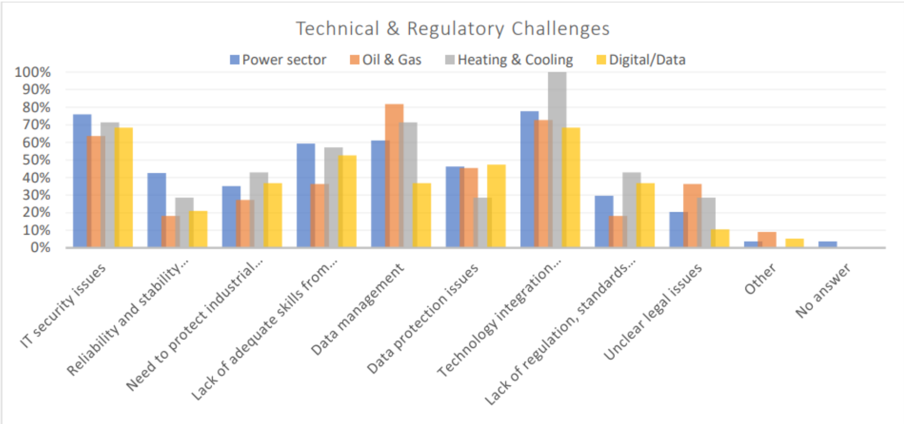

Figure 5: Example of technical and regulatory challenges analysed by sector

2.7 WIND

The energy landscape has been changing – evolving into one emphasising the power of clean, renewable energy – and wind energy will play a pivotal role in Europe's energy future. However, it is necessary to maintain Europe's global leadership in wind energy technology to deliver on the EU's climate and energy objectives.

Europe is the "technology leader in research, technology development and seamless operation of wind energy in highly integrated and complex power systems." Research and innovation are key to strengthen the sector's competitiveness but require a skilled workforce. The current need is clear: the SET Plan Implementation Working Group on wind energy noted their target for at least 100,000 workers to be trained on wind energy at an EU level by 2025. To reach this goal, it is first important to understand the current state of the wind energy workforce, the future needs of the sector in terms of skills and what steps policymakers can take to address these needs.

The wind industry has a number of areas that require an increase in training and skilled workers. One of the most important areas is skilled labour for installation – specifically mechanics, welders, and

[16] The information in this section is based on the results of the EDDIE project (funded by the EC under the ERASMUS+ programme), an industry-driven activity.

electricians/electrical engineers. There is already a shortage in this area (such as with HV electrical engineers) as manufacturing and installations increase in line with European targets. Engineers – in any shape or form – are vital to the future of wind energy. The expansion of renewable energy systems and renewable technologies will be multi-disciplinary, ensuring that all engineering disciplines will be crucial. This includes chemical engineers who would work on Power-to-X (PtX) of the energy system – converting renewable electricity from wind and other renewable sources to a wide variety of end products. In addition to a skills shortage for installation, there are also signs of a large shortcoming in skilled labour for the manufacturing of components.

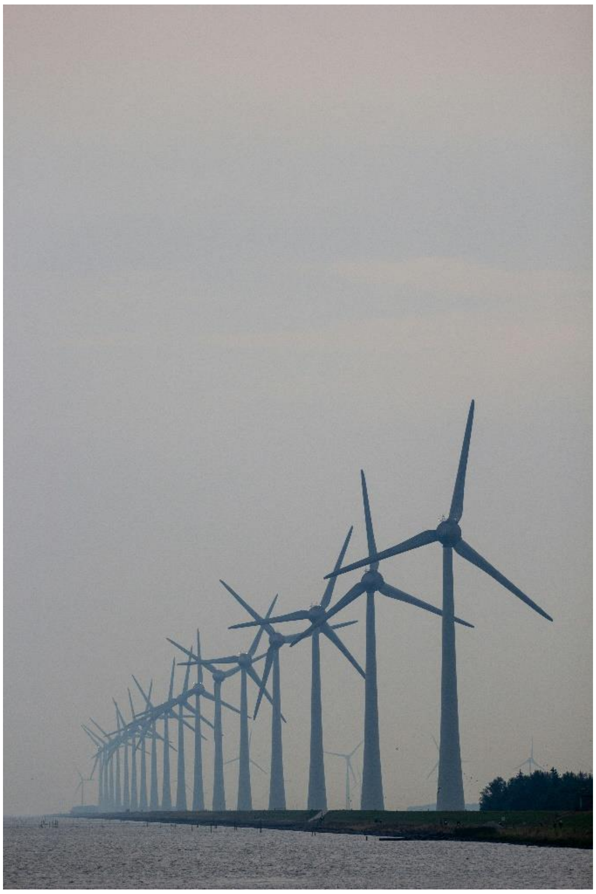

Photo by Muhammed Zafer Yahsia on Unsplash

There are also other jobs that will be highly demanded as both manufacturing and installation increases, namely project managers, IT specialists for digital technologies, consenting specialists, legal advisors, health and safety officers, quality control officers and environmental specialists. Financing is also an important aspect of a project, so financial specialists also need to be involved in the wind energy industry. Offshore wind energy projects add a number of emerging skills that will be necessary for the energy transition, including environmental specialists and marine specialists to monitor the impact of the installation and collect evidence. Met-ocean specialists, geophysicists, geotechnicians, naval architects and marine warranty surveyors are all jobs needed to successfully install and maintain an offshore wind system.

After projects have been completed, skilled workers are still needed to operate and maintain installations; O&M technicians will be a key sector to focus training.

3. JOBS AND SKILLS NEEDS IN R&D&I

3.1 BATTERIES

When looking at **academia**, immediate action is required to increase the number of relevant programmes, flexibility and educational capacity, to equip young engineers, researchers and scientists with high level knowledge and experience for the future battery industry. Areas of focus could include Materials Science, Surface Chemistry and Surface Engineering, Electrochemistry, Characterisation, Emerging Battery Technologies, Digitalisation in Battery Production, Cell Design Engineering, Module/Pack Design Engineering, Design of Equipment and Battery Manufacturing, Battery Control and System Integration, Battery Testing, Safety Aspects, Circular Economy, Life Cycle Assessment, Sustainability, Battery End of Life Pathways, and Engineering. On overall level, the educational system needs to respond to the fast-changing ecosystem in the context of the current and upcoming trends in the future.

Creating highly skilled **professionals** across the battery value chain is equally vital through collaborative professional education with industry partners. Battery components, battery production (large-scale), system integration, functionality, control and monitoring, safety, mechanical design, thermal management, sustainability issues, as well as applications and recycling are areas in need of focus. Critical across the value chain are also the digital skills (AI, cybersecurity, data analysis, data processing and data management, etc.). Reskilling employees and finding specialised professionals is already a challenge for this fast-growing industry and it is now clear that enhancing workforce knowledge is pivotal to meet evolving battery industry demands.

Similarly, **vocational training** is essential for specific segments of the battery industry. It is yet another area that finding specialised workers is already a challenge and training capacity needs improvement. Training expansion is required in the areas of manufacturing machinery and infrastructure, module and pack assembly, safe handling, testing, repair, transport, and installation, amongst others.

Lastly, **public and policymaker education** and acceptance play a pivotal role in market access for battery applications and electric vehicle uptake. This spans from primary schools to even retired citizens. Awareness level education is required to tackle areas such as regulations, safe use, fire safety, recycling, and general battery knowledge. Additionally, driver behaviour and user practices especially regarding charging are important.

3.2 BIOENERGY

Having identified the job profiles and skills needed for the bioenergy industry, it is also important to describe the jobs and education needs in research, development and innovation (R&D&I). Stakeholders certainly overwhelmingly agree that there is a shortage of skilled workers in the bioenergy sector, and this shortage will only continue over time as projects develop.

> **The greatest needs in the sector lie in the areas with the greatest shortage of skilled workers. Highest on this list are people with an engineering or technical background (processes, automation, electrical issues, etc.) to build and operate bioenergy/biorefinery plants. In the bioenergy R&D&I field, there is also a particular lack of skilled workers in applied research and innovation – particularly when it comes to integrating digitalisation into the sector. Finally, hands-on craftsmen and -women in electrical operations, welding and certification are also areas where bioenergy has the greatest needs.**

Gaps in the sector also mean gaps in current education measures. Without proper education, future bioenergy engineers will lack the skills needed for success. According to experts in the bioenergy industry, there are a number of gaps in education. One gap is insufficient exposure to a variety of different technologies, including digital opportunities. Bioenergy itself is often not offered as a course in universities, and there are insufficient PhD programmes relevant to bioenergy. Finally, students are not introduced enough to applied, industry-relevant research or allowed to delve into practical experience and training at the field level. University courses combined with practical experience would give the most well-rounded education to future engineers. However, higher-level education is not the only area where education for the bioenergy sector is lacking. As previously noted, hands-on craftsmen in electrical operations, welding and certification are important skills areas for the industry. It is therefore also necessary to address training gaps beyond universities – namely through apprenticeships where individuals can receive hands-on training in the necessary skills for working at bioenergy plants. Companies should be motivated to hire apprentices – not only university graduates – and train them directly at the plants to fulfill the wide array of jobs needed for a plant to function. This know-how transfer would ensure sufficient skilled workers for the long-term future.

There are also different needs with respect to different technologies within the bioenergy sector. The list below reflects some of these separate needs and particularly where skills gaps are most prominent:

- Biorefineries can be dangerous and therefore require petrochemical skilled workers. They are often located in the countryside, making them less attractive for workers. However, there is great potential in shifting skilled workers from the oil industry to the biorefinery sector.
- In the future, there could also be a lack of workers in combustion R&D.
- A few very skilled workers are required to run a biodiesel facility – approximately five workers per plant. Operating the plants requires some further workers without specific skill requirements. This sector is less of a concern, however, and is expected to get enough skilled workers since biodiesel plants hire on a European level.
- A fossil refinery employs about 2,000 workers, plus a similar number of workers for maintenance. There is potential to keep a similar amount in biorefineries as petrochemical skilled workers can be retained.
- Bioethanol, biodiesel and biogas plants are well-developed, and so are their workers. But new/emerging technologies, such as pyrolysis, gasification, alcohol-to-jet (ATJ), and hydrothermal liquefaction (HTL) will require new skills. There are particularly prominent skills gaps in the bioenergy field when it comes to specialisations in aviation and maritime.

3.3 HYDROPOWER

Most stakeholders agree that there is a shortage of skilled workers in the hydropower sector, especially in applied research and innovation. This links back to the education needs of the sector, and an inherent lack of engineers with sufficient practical experience in renewable energy systems, particularly those with experience in hydraulics and fluid mechanics.

Photo by ThisisEngineering RAEnga on Unsplash

In terms of educational needs for the sector, there is a need for specific Masters and PhD programmes related to the hydropower sector, such as at least a minor in civil, mechanical or electrical engineering programmes. Most of the advanced research in digitalisation, predictive maintenance, tools for O&M, benchmarking and best practice evaluation are focused on other renewable energy industries, such as wind. While there generally seems to be less of an interest in technical studies, without specific exposure to different renewable energy engineering sectors it will be impossible to generate enough interest in those industries.

Those students who do study engineering – and the fewer who specialise in mechanical/civil/electrical studies – will still lack the necessary education for the hydropower industry, as hydropower and dam engineering is not often specifically taught in courses, except in regions which have hydropower heritage. Therefore, it is imperative to incorporate a type of dual study or apprenticeship system where students gain hands-on experience in the field.

On the EU level, the EU can fund more research projects to support renewable energy research in universities. Nationally, Member States should also support new education programmes (e.g. Masters or PhDs) in select technological universities.

3.4 PHOTOVOLTAICS

- **Innovation & new business models create new needs for expertise: circularity is imperative**

In the upcoming years, the PV sector faces a set of challenges and opportunities. One significant challenge is managing the expected rapid growth of the PV industry which is expected to create numerous employment opportunities and drive the emergence of a substantial PV end-of-life and circularity industry. These developments will demand additional research and innovation efforts across the entire value chain. Meanwhile, the requirements for sustainability, reliability and performance of PV systems are already changing the standards for the installation of systems and leading to a rapid evolution of the O&M sector with a growing digitalisation of processes and monitoring.

The PV sector, education bodies and training providers need to proactively address these demands by incorporating forward-looking curricula, training programmes and certification initiatives. This preparation should encompass both immediate and future industry needs. In that regard, challenges related to the circularity of the PV value chain are an outstanding point, considering the prevailing need for significant R&I investments before the industrialisation of many emerging processes for recycling or materials recovery in the PV value chain. However, regulatory certainty on circularity imperatives, as well as steady investments in that sector – although to a varying degree across Member States – present a clear signal to prepare workers for jobs in the circularity of PV.

- **A robust PV manufacturing sector in Europe**

Although in coming years deployment will continue to dominate the PV sector, major investments in new manufacturing capacity will also require a large number of workers to operate factories and deliver "made in Europe" PV systems. Skills required for manufacturing comprise a wide range of qualifications, from machine operators to specialised engineers. As Europe accelerates investments in manufacturing, looking to expand the domestic PV value chain from 5-10 GW/year to 30 GW/year as part of the European Solar Strategy, there will be a pressing need for workers across qualification levels in the PV industry. According to estimates from the ETIP PV, the operation of 10GW of PV manufacturing requires at least 1,000 highly qualified engineers, 1,000 trained technicians, and potentially up to 7,500 operators of industrial machinery, all of whom require specific training and expertise.

Table 2 Estimates of Full Time Equivalent needs per employee categories for different steps of the PV manufacturing process for a model integrated 10 GW TOPCon manufacturing plant (Source: RCT Solutions, ETIP PV, 2023)

	mgSi	Polysilicon	Ingot & Brick	Wafer	Cell	Module
Net capacity	39 MTY	30 MTY	10 GW	10 GW	10 GW	10 GW
Operator	106	520	1047	1531	1052	3014
Technician	28	76	209	156	389	129
Engineer	10	176	459	121	134	36

The PV sector shows a strong connection between R&I and the industry. These ties are particularly evident in ongoing European industrial projects, where the active participation of leading PV research institutions is essential. These institutions play a pivotal role in providing guidance for various processes and actively contribute to the development of robust and advanced PV technologies. In the highly innovative PV field, where newly developed PV cells are posting 1 percentage point per year in efficiency improvement, the EU will also need to significantly expand its R&I capacity to support the competitiveness of the PV industry that is at the core of the European Solar Strategy priorities and the focal point of the European Solar PV industry Alliance.

- **Guaranteeing quality of PV systems**

A priority of the PV industry across all segments of the value chain is to deliver high quality products and high-quality systems. This requires well trained staff that are able to adapt to the rapidly changing PV technology, where modules evolve physically (for instance becoming heavier and larger as bigger glass-glass modules become the norm for utility scale systems),but also to the advancing technology level (a typical module put on the market in 2023 is 400 W, compared to 300 W in 2016, and the technology for manufacturing has evolved dramatically). Moreover, digitalisation plays an increasingly important role throughout the value chain. This includes for example the use of digital twins in manufacturing and operations for predictive maintenance, as well as aerial imaging for project monitoring. Given the rapid pace of innovation, and the growing role of digitalisation, professionals in the PV industry need to engage in regular training and upskilling to maintain a high quality of work despite the evolution of technology solutions.

3.5 RENEWABLE HEATING AND COOLING

Applied research will always be key to advancing energy systems, particularly with new and innovative technologies. The DHC sector, for example, reportedly needs to at least double applied research, with a focus on innovation close to the product level. Other RHC technologies, such as heat pumps, are established and proven, and ready for mass production and deployment on a greater scale. So, while there are still needs in applied research and innovation (i.e. innovative components and configurations to increase efficiency), most of the job needs lie in installation and maintenance. Other needs are a result of a lack of standardisation or clear certification criteria for installers which decreases the transferability of skills across Member States. In the geothermal sector, for example, driller certification passports to standardise certification across the internal market would greatly reduce the time costs for installation.

There are clear gaps in education which then appear as gaps in the workforce. There is a lack of specialised programming – such as for DHC systems – and accordingly few specialised courses and textbooks. These specialised programmes would better allow for collaboration between renewable energy disciplines and would bridge gaps between sectors. More crosscutting programmes where specific technologies are part of renewable energy, sustainable energy, sustainable resource management, energy and environmental master programmes are a good introduction to different aspects of the renewable energy system and can lead students to specialise in Masters/PhD/Postdoctoral courses.

> **The job needs in the RHC sector are driven by the need for sustainable, efficient, cost-effective, and deployable renewable energy solutions. Engineers are essential to all parts of the RHC sector – biochemical, mechanical and electrical engineering can all feed into energy-related jobs. Researchers, data analysts, and environmental/material scientists are also needed for innovation. For installation and maintenance, the sector requires technicians and system design or system integration specialists.**

To support uptake and deployment, policy analysts and advocates are vital, as are regulatory and compliance experts. Educational programmes could offer insights into legal and policy aspects of RHC energy to better understand the complex regulatory landscape surrounding this sector. Additionally, interdisciplinary training, technological advancements, environmental impacts, sustainability, global perspective and hands-on experience are essential areas for gaining expertise, with the goal of closing gaps and ensuring a more comprehensive education. Finally, project managers are necessary to keep the whole project running smoothly and effectively.

3.6 ENERGY SYSTEM INTEGRATION

Concerning **System Integration Skills**, university education can set the foundation for revolutionising the energy landscape. Almost all technical universities that have joined the Bologna Process have incorporated streamlined electricity, fluid and thermal engineering education into their master's degree programmes with 120 European Credit Transfer and Accumulation System (ECTS).

One possibility to integrate skills in energy systems would be creating an interdisciplinary joint master programme, e.g. an "Electricity, fluid and thermal engineering" master. However, the available credits would be insufficient to include the necessary in-depth knowledge of the sector. Thus, the best solution to educate *Integration Skills in Energy Vectors* would be setting up an *International Continuing Education Programme* for graduates having completed the two-year master’s in electrical or fluid-thermal engineering. This type of programme is typically assigned with 60 ECTS and may be structured as shown in 3: graduates are awarded the title *Master of Continuing Education (MCE)*.

The biggest problem for universities – and the reason these programmes do not yet exist – lies in the uncertainty about the number of interested and willing students. To what extent the energy industry is willing to specialise employees in integration is unclear; incentive programmes will initially be needed until sector coupling becomes a popular and viable career path.

Setting up the *International Continuing Education Programme* should help to reach the minimal number of required students. In this case, the ERASMUS programme could be expanded to facilitate mobility for participants in the continuing education programme.

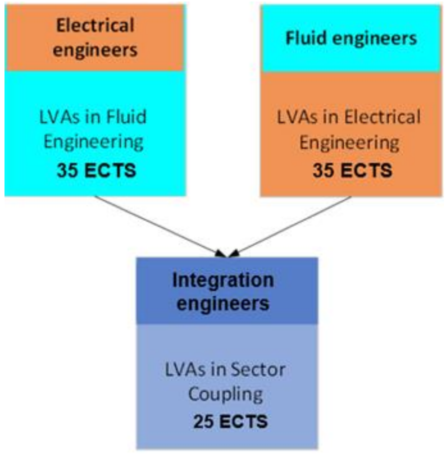

Figure 6: Proposal for a Continuing Education master programme for system integration

The analysis of the EDDIE project (see pg. 27) showed a discrepancy between current and future demand of abilities for multiple working domains, while **digitalisation and technological changes** are transforming the way of living and working. Digitalisation of the energy sector in particular requires rapid transitions in knowledge levels and from one occupation to another, forcing people to continuously upskill and reskill.

'Cybersecurity' is of utmost importance for creating a sustainable energy sector and providing a common ground based on trust between industrial companies and consumers. The ability to easily learn new technical innovations, combined with logical thinking and the ability to quickly analyse data, are important qualities for employees. Although technical skills are especially important, green skills, transversal skills, resilience and adaptability techniques need to find a place in the curricula of the education institutions and on the agenda of the training providers. Alignment of academia with the labour market is needed to teach students both theoretical and practical, hands-on skills directly applicable in the work environment.

To this end, significant effort is being made by some European universities and initiatives. Areas such as Smart Grids, Information & Communication Technology, Innovative methods of simulation & analysis (machine learning, artificial intelligence, big data analytics) appear more and more in European academic programmes.

Given the importance of an organisation's human capital to business success, aligning training and competence development with business needs has become a key challenge. Thus, in the last 10 years, many companies created corporate universities (CU) to educate their employees as part of a strategic instrument for competitiveness as well as an overall support of corporate strategy and culture. They are generally dedicated units acting as partners with senior leadership to develop strategic skills and capabilities. Online training platforms are another useful source of education and training, as indicated by the rising interest in online courses in the last few years.

The EDDIE survey indicated that the energy sector demands high level of expertise in many of the digitalisation related skill sets. The highest expertise needs are observed in engineers and researchers' positions, with technicians and specialists following in the expertise demand. Data capture, management and analysis skills are highly requested in the industry for all staff categories, while skills related to computing tools and programming & development are mostly requested for engineers and technicians in expert and intermediate levels. Moreover, a combination of hard and soft skills is important for the growth of the employees and company achievements since many of the addressed stakeholders pointed out the importance of transversal and green skills.

The analysis of the survey results addressed different staff categories (managers, engineers, technicians), while also addressing different energy sectors, countries, and types of operation. The analysis includes the following skill sets in the field of ***digitalisation***, each consisting of specific skills:

- Data capture and management;
- Analytical methods;
- Computing tools and platforms;
- Programming, development, and technology-related skills;
- Transversal skills;
- Green skills

The results of the analysis show several gaps as a mismatch of demand by the industry and offer by providers, or lack of coverage by already employed personnel. The mitigation of these mismatches can be achieved by enriching the education and training curricula with new topics or by re-skilling employees through several channels, such as corporate universities and industrial training programmes. Apart from the technical skills that will play an important role in the digital transformation of the energy sector, the interdisciplinary transversal, green and business skills will also be crucial during the transformation.

The key skill gaps towards digitalisation are identified in the areas of ***data management and analysis, big data, cybersecurity*** and ***programming & development*** competences. More detailed results of the analysis are shown in 4.

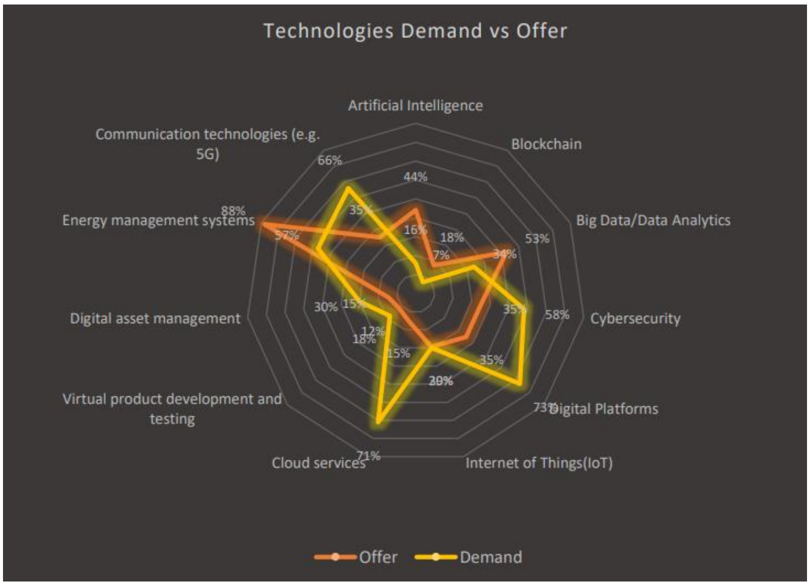

Figure 7: Technologies demand versus offer.

3.7 WIND

To address skills shortages in the wind industry, education and training are required. According to stakeholders, there is a need for more PhDs to fill in the research gap in many disciplines (such as materials, loads and asset management). Unfortunately, there is currently almost a competitive atmosphere between industry and academia, where it is difficult to get new researchers on certain topics (including offshore foundations design, asset management, O&M). Instead, industry and education should be working together to foster skills development such as through combining university courses with practical experience in industry (i.e. in internships). There is a need to champion a diverse workforce, fostering equitable opportunities within the industry and promoting representation of underserved groups and minorities. There is also a clear gender gap in the wind energy sector. As a result, it is important to introduce STEM education at younger ages to encourage students to study wind energy-related topics and eventually work for wind energy-related jobs.

Finally, higher-level education is not the only way to enter the wind energy industry; technical and vocational education and training offers various pathways into the industry. Jobs such as electricians and technicians are essential to the sector and are considered as the roles in most need in wind projects. Therefore, it is also necessary to promote apprenticeships where individuals can receive direct training and hands-on, practical experience and to ensure that apprentices can secure jobs afterwards. These measures are vital to ensure sufficient skilled workers for the long-term future.

On a more detailed level, specific skills for the wind energy sector include aspects related to environmental and sustainability assessments, data analysis, project management, and public engagement. In terms of environmental research and sustainability, each wind energy project will require specialists to conduct assessments and monitor the environmental impact of an installation. This is especially true for offshore wind systems.

Data analysis is also key for future research and development in the wind sector, as well as monitoring operational performance. These skills include data-driven methods, digital literacy (including big data analysis, artificial intelligence, and robotics) and digital security expertise. Project management skills also have an interdisciplinary focus, with skills including project design expertise, health and safety knowledge, public and stakeholder engagement expertise and also often foreign language proficiency. Finally, the wind sector will remain in need of policy advisors who can serve as a communication link between the industry and lawmakers.

4. MEASURES TO OVERCOME SKILLS SHORTAGES

This report has identified the future skills and jobs needs for the renewable energy sector as well as the current skills gap. However, identification of needs is merely the first step. Policy recommendations must bridge the gap between needs and results. The current state of the renewables sector requires adequate policy measures to address the skills needs and meet the REPowerEU targets. A blend of educational incentives, regulatory mandates, and financial support is needed to address the imminent skills shortage and boost the workforce. Vitally, collaboration between policymakers at various levels, industry players, educational institutions, and labour groups is key. Policy recommendations for the renewable energy sector can fall into three main categories: education, financing and regulatory support.

4.1 EDUCATION

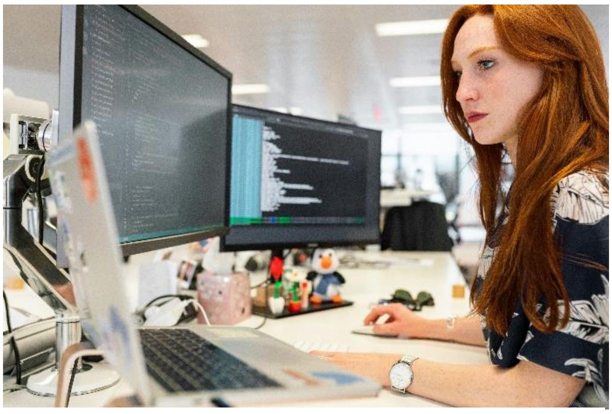

Photo byThisisEngineering RAEnga on Unsplash

In general, education needs are similar across renewable energy disciplines. Several steps need to be implemented over the upcoming years to educate a growing number of people to meet the demands of the renewables industry across the European value chain. Common educational requirements such as standards and accreditation should be pursued about Member States (for different levels of education). A modular approach to training would also better handle overlapping competences (as well as synergies/complementary skills) in renewable energy technologies and reduce the time spent on training, particularly when it comes to reskilling. Upskilling and reskilling will also be essential to reducing the skills shortage and tapping into the potential and skills of the existing workforce.

To support students on the path to joining the renewable energy industry, there should be enhanced links between higher education programmes and industry. European programmes for students in relevant fields and partnering universities with producers would also increase enrollment and appeal, as well as a clear path for employment. Many of the new cutting-edge technologies are not taught in all universities; therefore, centres of excellence should be established at the regional level in multiple countries to stimulate specialties. Higher-level education programmes – such as engineering disciplines – should also include practical training and exposure to different renewable energy system applications. Even non-engineering disciplines such as architecture or design could introduce energy systems such as heat pumps which would need to be integrated into the building and connected to existing systems. Refer to Annex 1 for a roadmap that outlines a necessary progression up to and beyond 2030, for all educational profiles in the batteries industry specifically.

Additionally, education does not always entail university studies. As stated in earlier sections, craftspeople are vitally important to the industry and are currently lacking – and will only continue to be an issue for the sector in the long term as craftspeople retire. Therefore, study plans should be remodeled to reflect the practical needs of the industry. There should be more support and advertising for young people to join apprenticeships (or dual study apprenticeships) and learn hands-on skills such as welding and electrical operations to lead technical installations. Craftspeople in the workforce may also require reskilling efforts. Encouraging and supporting ongoing professional development is vital to keep the workforce up to date with the latest technologies and practices. This entails training and certification programmes for professionals (installers, electricians); policy support and engagement are crucial in delivering successful training and schemes to reach a sufficient number of people. Replicating successful programmes in different Members States and regions is a key focus. The adoption of clear, harmonised certification programmes across Europe also facilitates the movement of workers and the operation of companies across borders, removing some impediments to deployments. Governments can provide grants, subsidies, or tax incentives to individuals and organisations for participating in relevant training courses, workshops, conferences, and certifications.

This last aspect reflects another important measure – financing. With modern infrastructure at technological universities and more promotion of technical education, the skills and education gaps can be addressed. EU regional or national grants for engineering students could be offered and then be matched by companies in the relevant sector. This would also provide a link between university learning and hands-on, practical engineering skills. Governments can allocate funding and grants to support universities, vocational training institutions, and other organisations that provide training programmes specifically tailored to the clean energy sector. This can help develop a skilled workforce by providing accessible and quality education and training opportunities.

Like the engineers, policymakers also need a certain level of education when it comes to making the best decisions for the industry. Only by understanding industry can policies be applied to target specific needs and strengths. EU-wide marketing campaigns should also advertise the renewable energy industry and related career opportunities. This should include clearly defined responsibilities and skill requirements to attract new profiles to the sector and could be incorporated into the training academies outlined in the Net Zero Industry Act.

4.2 FINANCING

All renewable sectors would benefit from additional funding for more investment-intensive competence areas. Stakeholders also suggested EU grants for real training experiences and a reduced tax for industrial companies employing young graduates or apprentices.

Financial incentives – such as ones targeted at installers – can support education and training programmes and can accelerate the adoption of renewable technologies. For example, providing financial aid for textbooks and offering financial incentives to students who choose DHC-related paths could increase the interest among students and the quality of their studies. The LIFE Programme – and EU funding instrument for the environment and climate action – can also be a useful instrument to further support training, certification standardisation, and training criteria in various RHC sectors. Integrating financial expertise into the RHC sector is crucial. There are also currently insufficient EU funding opportunities for educational materials.

Private investment will also be necessary, so it is important to educate investors about the unique dynamics of long-term investment in the RHC industry and other renewable energy industries – cross-border cooperation is essential across sectors.

4.3 REGULATIONS

Some regulatory changes should align with education measures. For example, simplifying and standardising the certification and licensing processes for professionals can help attract and retain talent as well as ensure transferable skills and stable work conditions. Governments can work with industry stakeholders and education institutions to establish clear qualification requirements, streamline certification procedures, and provide guidance on the recognition of qualifications obtained in different jurisdictions. New approvals for hydropower stations, for example, would raise market demand for recruitment. Standardisation and digitalisation will also reduce red tape; the geothermal sector's needs in skilling and certification systems for drillers and installers are directly linked to slow installation times.

There already are certification schemes on a Member State level which should be established across the EU – and there should be mutual recognition of already existing certification schemes with a minimum standard. In geothermal energy, for example, there is a Spanish certification scheme for geothermal heat pump installers (governed by Instituto Nacional de las Cualificaciones - National Institute for Qualifications - INCUAL). Additionally, the GeoTrainet project established a European training and certification programme for shallow geothermal installers, specifically designers (who carry out feasibility and design studies, including geology) and drillers (who make the boreholes and insert the tubes).

> **Long-term planning is key for regulation. This includes socio-economic evaluations, knowledge exchange, and transparent communications. National associations can be a valuable tool to advocate for the renewables sector, focusing on the labour shortage and promoting specialised education programmes. These evaluations and programmes should be continuously assessed and adapted to keep up with changing industry dynamics and technological advancements.** [17]

Governments can facilitate partnerships between industry stakeholders and educational institutions. Industry-academia collaboration can take the form of joint research projects, internships, apprenticeships, or knowledge-sharing initiatives. Incentives such as tax credits or grants can encourage industry players to actively participate in the development of training programmes and curricula. Other skills development programmes could include vocational training, apprenticeships, on-the-job training, and retraining initiatives to upskill or reskill workers from other industries. Additionally, policies that promote diversity and inclusion can help address skills shortages by tapping into a larger talent pool. Governments can encourage initiatives that promote gender equality, minority representation, and inclusive recruitment practices in the industry.

Collaboration with international organisations like the International Renewable Energy Agency (IRENA) – or sector-specific ones like the International Hydropower Association (IHA), International Commission of Large Dams or the European Hydropower Alliance (EHA) (for the hydropower industry) –can also be useful to leverage their expertise and resources in developing training programmes, guidelines, and best practices for the sector.

These policy measures and regulations, when implemented effectively, can help bridge the skills gap by supporting education, training, industry collaboration, and professional development. It is important for policymakers to consider the specific needs and challenges of their respective regions and tailor the measures accordingly.

[17] ETIP SNET WG3, and WG1, paper published in Nov 2022 "Coupling of heating/cooling and electricity sectors in a renewable energy-driven Europe" : coupling-of-heatingcooling-and-electricity-sectors-MJ0922659ENN.pdf (rhc-platform.org)

5. CONCLUSIONS

To increase the production and capacity of renewables, there is certainly a skills gap that must be addressed by European policy initiatives. The outbuild of renewables over the coming decades will require far more skilled personnel than can be educated in the corresponding time frame. Therefore, moving competencies from other areas to renewables will be necessary.

Policymakers – either on a regional, national, or EU level – can take several steps to manage this skills gap. Firstly, awareness of the renewable energy sector is imperative. Raising awareness of the strengths, weaknesses, and needs of different renewable energy sectors among EU institutions and Member States is the first step to address those aspects. The green transition and the role of renewable energy in that transition should be highlighted in policy and in society.

In terms of reducing the skills gap, education is imperative. Programmes to develop skills for renewable energy sectors (including engineering) and energy system integration should be supported, such as through Erasmus programmes. There are also existing best practices – in terms of established energy education programmes – which should be endorsed and emulated. There is also a clear gender gap in the renewable energy industry; there should be a concerted effort to attract women to the industry. There should also be more funding for online education and training initiatives, as well as standardisation. There should be a defined, common set of minimum knowledge, skills and competences for each energy sector, as well as a standardised framework for workers.

All these aspects are vital for the future success of the European renewable energy sector as a whole. The need for education programmes, a smaller gender gap, adequate apprenticeships and funding for education and training are essential for all renewable energy sectors. As previously noted, the expansion of renewable energy systems, their integration and renewable technologies will be multi-disciplinary. This means that as the skills noted here are developed, they will be applicable across disciplines. And with training programmes specific to renewable industries, skilled personnel can transfer across sectors. This manoeuvrability and applicability should be underlined as a positive element of the renewables industry.

Synergy among energy vectors and industries is essential to provide flexibility and enhance resilience for the efficient and secure operation of the energy system, requiring sustainable cross-sector regulation and innovative financial mechanisms. Industry skills should anticipate and actively enable sector integration.

Digitalisation will enable companies and customer operations and processes to unlock a highly dynamic energy system at all layers and timescales; therefore, data intelligence and digital customer services will exponentially increase.

ANNEX 1: Batteries Roadmap 2023-2030+

***Batteries Europe**: Roadmap 2023 – 2030+*

Baseline (2023-2025)

Academic level

- Attractive and competitive grants for early-stage researchers.
- Systematic adoption of curricula (specific degrees) based on the upcoming and current trends.
- Cross-disciplinary knowledge transfer R&D infrastructures (e.g., pilot lines) as the nucleus for networking between industry and academia (joint programmes) - e.g., industry supported university programmes, thesis, and internships.
- Training of the academic staff through specific workshops and course
- Realise specific infrastructure to skilling and reskilling fully dedicated to education scopes

Professional/vocational level

- Initial work in place for identifying industry needs (surveys, expert interviews, job posting crawling, desktop research).
- Some work has been done in curriculum development, with few national curricula still in IVET and some EU wide curricula available for professional re/upskilling.
- Public learning labs are under construction in a few places; few training simulation tools available and certain lab trainings available for hands-on practice.
- Vocational programmes started around rising gigafactories or Fraunhofer Battery Facility (FBF); limited capacity, or regional or national clusters under development or in implementation based on the availability of local resources.
- On professional re/upskilling InnoEnergy Skills Institute (former EBA Academy) and other projects (e.g., European Battery Business Club) and initiatives started; some national development projects; Automotive Skills Alliance (ASA) as a Pact for Skills partnership with education and training supporting tools.
- Gigafactories have more onboarding experiences for filling skills gaps but still largely confidential; younger gigafactories still rely on support.
- Some work started on sector attractiveness, mostly by gigafactories recruiting; additional work has been done by Batteries Europe, Battery 2030+ and BEPA.
- Onsite, online, blended teaching methods used, but mostly in the form of static programmes.
- Modular approach under development and followed by certain content providers; constructivism.
- Train the trainers' events

Public/user level

- Increase acceptance, awareness, and attractiveness of this sector to the general public (e.g., information, battery safety, handling to recycling etc.).
- Specific funding programmes for adaptation and expansion of educational systems.
- Programmes targeted for awareness for battery users, also for people that might be affected by battery production e.g., localities near gigafactories.
- Implement EU wide information and monitoring platform on educational offers available for different audiences. Accelerate regulatory aspects.

Mid-term (<2030)

Academic level

- EU wide standards for adapted curricula and creation of interdisciplinary courses covering the whole value chain of battery production/usage and recycling, available for all interested students.
- Encourage establishment of new groups based on early career researchers in the Member States with lower academic activity in the field of battery research.
- Development of trainings based on digital tools.
- Internships offered within industry to mobilise workforce to locations with battery production facilities with dedicated fundings.
- Increase the number and capacity of courses/programmes available for all interested students.
- Increase mobility of researchers across Europe, with an increasing number of R&D centres and infrastructures.
- Create fundings for students to increase mobility and attendance to specific courses.
- Possibility for more Erasmus Mundus master programmes based on industry needs.

Professional/vocational level

- Continued work to analyse future skill and workforce requirements based on empirical data and in closer collaboration with the industry; assist industry to express detailed needs towards educational providers.
- Internships offered in industry mobilising workforce to battery production facilities locations with dedicated fundings.
- Progressed work in curriculum development, with EU wide acceptance and local adaptations covering the entire battery value chain and multiple European Qualification Framework levels.
- Public learning Labs in most EU countries and dedicated facilities ideally integrated into academic (e.g., FBF) or industrial battery sites (national and EU-wide access).
- Vocational programmes benchmarked and developed into continuous offerings in most EU countries.
- Roll-out of standardised qualification programmes based on industry needs and wider accessibility; Pact for Skills model established; collaboration among industry, training providers, academia, vocational schools, and lab facilities.
- Methods developed for in-house industry training in collaboration with CVET and re/upskilling training providers.
- Train-the-trainer concept developed EU-wide in collaboration with the industry.
- Battery value chain becoming very attractive, mobilising the workforce to relevant locations (e.g., gigafactories).
- More established adaptive and flexible learning for individual needs; Initial VR-based courses/ trainings to complement traditional methods; balance constructivism/constructionism.

Public/user level

- Support expansion of adapted educational systems across Europe.
- Provide additional opportunities (digital or onsite) for the public to receive information and training in terms of awareness, safety, and regulatory aspects (if possible, in multiple languages).
- Disseminate knowledge through social media, newspaper, broadcasts

Long-term (2030+)

Academic level

- 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.
- Long-life learning courses and Massive Open Online Courses available.
- Use of specific fundings for the mobility of master, PhD students.

Professional/vocational level

- European collaborative work model (education – industry) in place with review of changing needs and increase in demand; Needs well represented in vocational/professional education.
- Collaborative models between industry – schools are mainstream, and a high number of relevant curricula are available.
- Learning labs, both physical and virtual, are widespread.
- Continuous and flexible IVET accessibility for the sector.
- Continuing education is normal, frequent and flexible for the entire workforce based on industry needs.
- Validated and flexible pathways for learning, career development at the workplace, and beyond.
- Training trainers/teachers continuously is part of the mainstream sector practice.
- Battery industry is known for its clean and interesting workplaces, with many career opportunities.
- Digital tools for training are used and effective with modular and adaptive trainings; constructionism more dominating.
- Additional Train the Trainers' events with relevant certification.

Public/user level

- Broad acceptance and awareness of the topic by the public.
- Understanding of battery usage and safe handling for users achieved.
- No regulatory barriers.