European Commission

Upskilling needs for the Energy System to support the Energy Transition with a focus on digital skills

ETIP SNET WG4 – Digitalisation of the Electricity System

ETIP SNET

European Technology and Innovation Platform
Smart Networks for Energy Transition

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Contributions from external organisations

EU Pact for Skills – Large Scale Partnership on the Digitalisation of the Energy System

Erasmus+ project EDDIE, Net-Zero Industry Act (NZIA)

SET Plan cross cutting Task Force on Skills

BRIDGE

IEEE PES Task Force on Innovative teaching methods for modern power and energy systems

Large Partnership for renewable energy,

ESCO framework

CEDEFOP (Skills Intelligence), Competence frameworks (DigComp, GreenComp)

EPRI GridED initiative (US Department of Energy)

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with a focus on digital skills

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1 EXECUTIVE SUMMARY

This document analyses the status and future of the skills needed to support the energy system during its transition to achieve the decarbonisation objectives. The digital transformation in the energy sector, as is any other part of the economy, affects especially the requested skills, therefore the main focus of this document targets the digital skills. However, other skills are also considered opening the opportunity to analyse them in more detail in other future related documents.

The document is introduced with a reminder of the European energy policy targeted goals and within it, main documents that highlight skills as the priority in the EU to ensure the competitiveness of its industry. Quite recently, the EU has committed in detail to reskilling and upskilling in the broadest sense the European industrial labour force to acquire and retain the needed talent, within the Union of Skills [1]. Besides that, a reference is being made to the impacts on the workforce as expected through the social observations being made by the World Economic Forum taking into account relevant considerations related to the energy companies.

The core part of the document is the analysis of the answers to a detailed questionnaire distributed to 132 organisations representing stakeholders across the energy value chain. Its main result is a list of skill gaps and anticipated needs in the energy industry categorised with their criticality to bridge them. It also considers digital skills needed specifically for smart grids as they are becoming the backbone of the integrated energy system. As a result, a list of digital technologies to support the skills needs is suggested, also categorised by the importance assigned to each of them within the questionnaire, including a more easy-understandable result with a colour code table. As said earlier, a reference is made to other, non-digital, skills which are important for the energy system.

From the skills gaps and needs identified, the document recommends a series of actions to bridge them through education and collaboration. Beyond the obvious way of adapting higher education and VET programmes to rapidly cover the gaps and needs, the document introduces a more holistic view and mentions approaches and best practices proven as examples to follow. It reaches several conclusions before recommending ways to continue this needed reinforcement of skills in the energy sector.

2 INTRODUCTION

The technologies used in the energy system are complex and understanding them requires much education and training. As they develop and improve, the need to equip people with the appropriate skills grows too. The scope is huge, and it requires an analysis of the different disciplines and technologies involved. Digital skills are particularly in demand within the energy system at a time of "digital revolution".

This document explores the digital skills needed for digitalising the energy system. It also looks at some of the other, non-digital, skills that support this digitalisation.

2.1 Background and importance of upskilling in the energy sector for the energy transition

Europe is at the forefront of decarbonisation as a principal contributor to the fight against climate change. The European Green Deal [2], the "Fit for 55" targets [3], and the Repower EU plan [4], the latter being a response to the energy crisis exacerbated by the invasion of Ukraine, confirm the resolve to proceed with a rapid clean energy transition in Europe.

In parallel, the digitalisation of our society is set on its course, and all economic sectors are being impacted in one way or another. In most cases, digitalisation represents a leverage for efficiency improvements, and, in the particular case of the energy sector, it could become a clear opportunity to speed up its transition in the right way. For example, the integration of renewables and demand-response through flexibility will be faster and more resilient with the appropriate digitalisation of networks.

The transition to a digitalised system is driving significant changes in the skills required by the workforce, the latter defined as all those involved in the different activities across the energy system value chain.

Published in October 2022, the EU action plan "Digitalising the energy system" [5] confirms the need for a skilled workforce to accelerate the digital transition "minimising the risk that the new data-driven services and innovative technology solutions would not be implemented fast enough if there were not enough skilled workers and trained professionals to help deploy them". In this regard, action 4.4 of the Plan has been adopted to support the establishment of a Large-Partnership on the digitalisation of the energy value chain as part of the EU's Pact for Skills, announced in 2020 [6].

By 2023, the EC had published the Green Deal Industrial Plan [7] to address the opportunity that the green transition will represent for the European industry. One of its four pillars is about enhancing skills in green and digital at all levels and for all people, with inclusiveness of women and youth at the heart of the Plan". The Plan states that the Commission proposed a Net-Zero Industry Act, which was adopted in March 2023 and contains a Chapter V entitled "Enhancing skills for quality job creation in net-zero technologies". Recently, the EC has published the Clean Industrial Deal [8], where skills are assigned as one of the six business drivers for industry to decarbonise within Europe in the framework of leveraging our competitiveness.

At the end of 2023, the EC DGENERGY issued the EU Action Plan for Grids [9], where, in its area VII (strengthening supply chains) ,it recognises the following: "Finally, the lack of skilled workers affects the increasing staffing needs of transmission and distribution system operators, HVDC cable manufacturers and other power system suppliers. This includes the need to acquire further advanced digital and technological skills, such as automation, controlling, big data and advanced analytics, to detect and control network challenges as well as develop the necessary technologies."

As a summary for this introduction, education, training and skills are recognised as fundamental in the European energy transition where digitalisation will play a key role.

ETIP SNET has become a highly appreciated forum with its focus on the innovation in the energy system along with its transition. Innovation is related to technology evolution and, nowadays, specially to digitalisation. Since its beginning, ETIP SNET has identified and recognised the importance of skills to ensure that innovation is well implemented and used.

Many R&I projects have found that the identification and right coverage of the skills needed by the industry is an area of special attention. This is also confirmed by BRIDGE project analysis.

ETIP SNET has contributed to highlight the role of skills in the energy transition and the associated innovation, as it is now being addressed by different EC organisations: mainly DG Energy, in its own activity area, DG Connect, very much related to digital technologies and uses and DG Growth and DG Employment with their direct involvement in education.

In 2019, using its ERASMUS+ programme, the EC addressed the opportunity of setting up a Sector Skills Alliance, through the appropriate call for projects, in the area of Digitalisation of the Energy Sector. In 2020, the project EDDIE [10] kicked off with the support of the funding offered in the call, with the main objective of establishing a strategy, or blueprint, to address education for the energy sector under its transition and digitalisation.

During the first three years of the project, EDDIE confronted the industry's demand for skills with the offers from education and training institutions (from VET to university, including informal education), learning how to detect skill gaps. EDDIE also analysed in detail the education and training systems of five European countries, and it considered the surveys performed by European education systems like CEDEFOP on all European countries. The project also designed and implemented a database to support a strategic map of stakeholders.

The EDDIE project finished in 2023 and its results establish a base for further work and research on this specific topic of skills for energy digitalisation. Besides this, many members of EDDIE are also very active in ETIP SNET, with a special mention to ENTSOE and EDSO.

Finally, to update the scenario, the EC is supporting the idea of having the aforementioned Large Scale Partnership follows the EDDIE designed blueprint and use the originated documentation and the structure created like the web and database.

2.2 Objectives and scope

This document will identify, through a survey, the skills gaps with special attention to the industry, which is the main actor on the demand side for jobs and for confirmation of the skills needed. As confirmed in EDDIE, the energy industry is facing significant skill gaps, particularly in areas such as data management and analysis, big data, cybersecurity, and programming and development. These gaps are even more pronounced in the power sector, where the shift towards distributed energy resources and smart grids poses significant challenges, creating new demands for specialised skills.

In addition, the document will also anticipate, through the same survey, the skill needs foreseen in the future, with special attention to the technologies that are rapidly being adopted as edge computing and AI (artificial intelligence) as well as those that will likely impact the industry in the medium-long term future such as quantum computing.

As a response to the identified skill gaps, this document will recommend the education and training to eliminate them. The involvement of education and training providers, at all levels, is therefore a must as they are the main actors in the offer side. Technological advancements can revolutionise education by providing a variety of tools such as e-learning tools (webinars, MOOCs, interactive notebooks, and animations), laboratory education (scaled down hardware models, hardware in the loop simulation, co-simulation, augmented/virtual reality, remote labs, and virtual labs), and classroom education (which can be enhanced with e-learning tools).

Finally, collaboration with the different key stakeholders, not only industry and education providers, but others like policy makers, regional energy hubs, digital hubs, etc. will be addressed.

2.3 Impacts on the workforce and skills requirements

The World Economic Forum has recently published its Report on the Future of Jobs [11] which provides updated its analysis and predictions for the next five-year period (2025-2030). As in previous editions, the applied methodology has been a vast survey of employers and employees of companies for a big variety of sectors around the world, keeping their distinctions for sectors and geographical locations. Among the key findings, we can highlight the following:

Green and energy transition roles are one of the technology-related ones with the fastest growing rates in percentage terms.

Skill gaps are categorically considered the biggest barrier to business transformation by the Future of Jobs Survey respondents, with 63% of employers identifying them as a major barrier over the 2025-2030 period.

Five macrotrends have been carefully considered in the report: Technological change, economic uncertainty, geoeconomic fragmentation, green transition and demographic shifts.

For the general topic of the last macrotrend, demographic shifts, it is important to highlight the following: *“The world is currently experiencing two fundamental demographic shifts: an ageing and declining working-age population predominantly in higher-income economies, due to declining birth rates and longer life expectancy, and a growing working-age population in many lower-income economies, where younger populations are progressively entering the labour market. In higher-income nations, ageing populations are increasing dependency ratios, potentially putting greater pressure on a smaller pool of working-age individuals and raising concerns about long-term labour availability.”* This has been quite clearly detected in the survey results where employers more subjected to the effects of ageing population are more pessimistic about talent availability and expect to face bigger challenges in attracting industry talent.

In general, for all sectors, technological skills are projected to grow in importance more rapidly than any other type of skills. Among these, AI and big data top the list as the fastest-growing skills, followed closely by networks and cybersecurity and technological literacy.

Besides that, in general for all sectors, skill gaps in the labour market are the primary barrier to business transformation while the second most significant perceived barrier is organisational culture and resistance to change. Based on these, workforce strategies have to be established to properly address the business transformations to adapt to the macrotrends.

With regard to our sector of interest in this document, over the next five years, climate mitigation is expected to be at the centre of the energy technology and utilities sector, as companies plan to invest in greener technologies for energy generation, storage and distribution. As a result, environmental engineers, AI and machine learning specialists and renewable / sustainable energy systems engineers are among the expected top-growing job roles in the sector. As employers aim to transform their business, industry players are particularly concerned about skills gaps in the labour market (81%, compared to 63% across all industries), alongside outdated or inflexible regulations (44%), organisational culture and resistance to change, and the industry's capacity to attract talent (37%). To improve talent availability and industry attractiveness, businesses plan to improve talent progression and promotion processes and invest in reskilling and upskilling programmes, for which respondents see a role for increased financial support from the public sector.

While geographically within Europe, the above conclusions are somehow reinforced, the report contains specific characteristics for each of the EU countries.

As it can be seen in the next chapters, our conclusions about skills gaps for the energy sector are aligned with the general conclusions of the WEF report, taking into account the taxonomy adopted and the large differences in geoeconomics and green transition speed. As the latter is a top priority in the EU, we can foresee the urgency for better upskilling and reskilling policies as a basic strategy to adopt.

3 IDENTIFICATION OF SKILL GAPS AND ANTICIPATION OF SKILL NEEDS

The digital transformation of the energy sector necessitates equipping both new professionals and the existing workforce with the necessary skills. Education and training providers play a pivotal role here.

The European Commission is actively fostering this transformation through various initiatives. The Strategic Energy Technology (SET) Plan and the SET Plan Roadmap for Education and Training support higher education institutions and businesses in developing cooperative education, training schemes, and learning systems tailored to the energy transition's challenges. Additionally, funding mechanisms such as Horizon 2020 R&I programmes and Erasmus+ Blueprint Strategy projects are instrumental in identifying skill needs and creating strategic plans to address mismatches across multiple industrial sectors.

3.1.1 The Erasmus+ EDDIE Project

The Erasmus+ EDDIE project exemplifies an industry-driven approach to addressing skill needs. Its objective was to establish a sector skills alliance that would develop strategies for education and training in the energy sector. This initiative focused on anticipating and meeting the skill demands for the sector's sustainable growth and digitalisation.

Recognising the importance of industry consultation, the project developed surveys to collect feedback from key stakeholders across the energy value chain. These stakeholders represented diverse geographic locations, organisational sizes and operational focuses, including distribution system operators (DSOs), transmission system operators (TSOs), suppliers and service providers. The surveys aimed to:

- Address challenges related to energy system digitalisation.
- Identify the new skills required in the digital era.
- Assess the current coverage of these skills among professionals.

The surveys were distributed to 132 key organisations, including EU bodies, multinational corporations, DSOs, TSOs and other prominent entities. Many of these organisations operate across multiple sectors, ensuring broad representation. The findings highlighted several critical challenges, with the lack of adequate employee skills emerging as a significant issue.

To address these challenges, a multidimensional, industry-driven methodology was developed. This approach aligns with "Skills Intelligence" as defined by CEDEFOP and focuses on identifying skill mismatches between industry requirements and the offerings of education and training providers. Key steps in this process included:

- Reviewing relevant frameworks, such as the ESCO framework and CEDEFOP reviews.
- Conducting surveys and interviews to assess the demand for skills, the availability of current skills, and the readiness of education and training systems to address these needs.
- Categorising identified skill gaps by sector, country, operation type and professional role (e.g., managers, engineers, technicians).

The comparison of skill demand and supply revealed specific gaps in areas critical to digital transformation. For example, machine learning emerged as a high-demand skill inadequately covered by existing education and training programmes or workforce expertise. These gaps were further analysed to determine the level of expertise required to address them. The comprehensive analysis is detailed in the report "Current and Future Skill Needs in the Energy Sector" [12], which serves as the foundation for this report.

Building on the outcomes of the EDDIE project, an updated survey was developed to refine, expand and validate previous findings. The results of this updated analysis provide actionable insights into addressing skill gaps and fostering a workforce capable of driving the energy sector's digital transition.

3.2 Analysis of skill gaps in the industry

3.2.1 Digital skills

In today's rapidly evolving technological landscape, digital skills have become fundamental across all industries, including the energy sector. These skills encompass a broad range of competencies, from basic digital literacy and software proficiency to advanced capabilities in data science, artificial intelligence and cybersecurity. As digital transformation accelerates, professionals must adapt to new tools, platforms, and methodologies that enhance efficiency, automation, and decision-making processes.

In the energy sector, the greatest need for digital expertise is observed among engineers and researchers, followed by technicians and specialists. Data capture, management, and analysis are critical competencies required across all staff categories, while computing tools, programming, and software development are primarily needed at expert and intermediate levels for engineers and technicians. Analysis of skill gaps reveals both specific deficiencies and broader categories of missing competencies, which can be attributed to either a mismatch between industry demand and educational offerings or a lack of upskilling opportunities for the current workforce. Beyond technical skills, the digital transformation of the energy sector also depends on interdisciplinary, transversal, green and business skills to ensure a holistic and sustainable transition. The findings from the EDDIE project indicate that data management and analysis, big data, cybersecurity and software development are among the most critical areas for digital upskilling. The following figure illustrates an example of the analysis conducted in EDDIE.

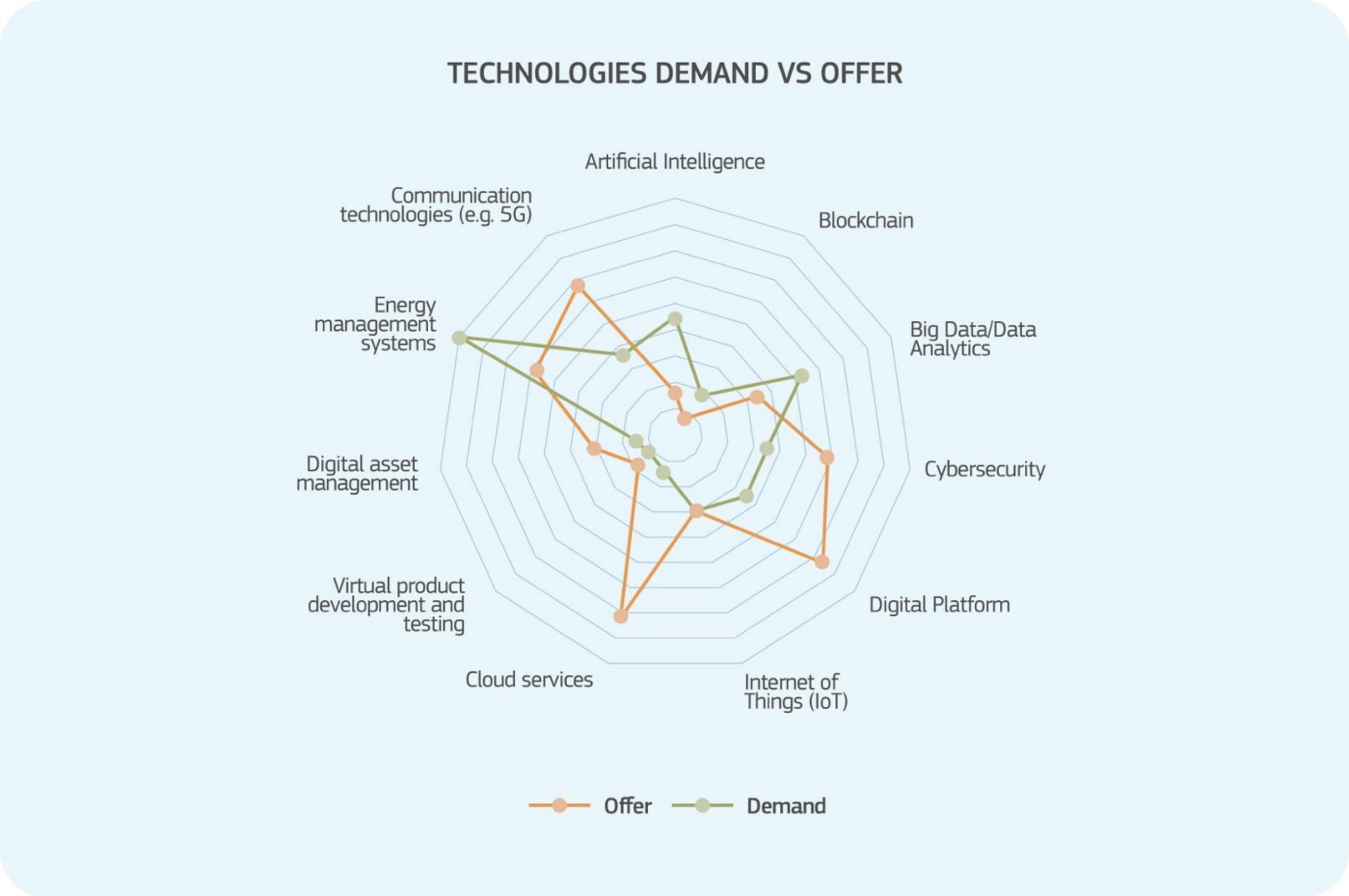

Figure 1 – Skills Demand & Offer comparison (spider chart) across the different energy technologies

3.2.2 Management and soft skills

The complexity of modern energy systems, combined with the increasing role of digitalisation, sustainability, and cross-sector collaboration, requires professionals to develop strong leadership, communication, adaptability and problem-solving abilities. These skills ensure that technical innovations can be effectively implemented, strategic goals can be met, and multidisciplinary teams can work efficiently in a dynamic environment.

According to insights from the EDDIE project, the demand for management and soft skills is particularly high among executives, project managers, and technical leaders, though they are also essential for engineers, technicians, and operational staff. Key competencies include strategic decision-making, project management, stakeholder engagement and change management. Additionally, as collaboration across disciplines and industries becomes more frequent, teamwork, negotiation, and intercultural communication skills are increasingly vital.

A notable gap exists between the industry's need for these skills and their coverage in traditional education and training programmes. In many cases, professionals enter the workforce with strong technical knowledge but lack essential managerial and interpersonal skills, which can hinder innovation and productivity. Addressing these gaps requires targeted upskilling initiatives, including corporate training, mentorship programmes, leadership development courses, and experiential learning opportunities.

3.2.3 Technical skills related to energy production, transmission and distribution

With respect to energy production, transmission and distribution, the EDDIE project findings indicate that the highest technical skill demands are observed among engineers, technicians and system operators. The following categories are potentially the most critical:

- Energy Generation: Expertise in conventional and renewable energy technologies, including solar PV, wind power, hydropower, biomass, and emerging solutions like hydrogen and energy storage. This includes proficiency in system design, maintenance, and performance optimisation.

- Transmission and Distribution Networks: Understanding of grid infrastructure, load balancing, voltage regulation and grid modernisation techniques, including the implementation of smart grids, demand response mechanisms and distributed energy resources (DERs).

- Electrification and System Integration: Knowledge of direct current systems and technologies" which includes both HVDC systems and LVDC and MVDC mircogrids and distribution systems, microgrids, hybrid energy systems, and sector coupling (e.g., Power-to-X technologies) to improve flexibility and resilience in energy networks.

- Power Systems Analysis and Control: Competencies in grid stability, fault detection, protection systems and automation, ensuring operational safety and efficiency. Advanced digital tools, such as SCADA (Supervisory control and data acquisition) systems, digital twins, and AI-driven predictive maintenance, are becoming increasingly important.

3.2.4 Green skills

Furthermore, as the energy sector places greater emphasis on sustainability and green transition, professionals must develop systems thinking, resilience, and ethical decision-making skills to navigate evolving regulatory frameworks and business models. The EDDIE project found that future workforce preparedness depends not only on technical expertise but also on well-rounded skill sets that integrate management, soft skills and sector-specific knowledge.

3.2.5 Hard skills in electrical and mechanical engineering

Electrical and mechanical engineering play a fundamental role in the energy sector, requiring a strong foundation in technical design, system optimisation, and operational maintenance. Key hard skills in electrical engineering include power system design and analysis, electrical machine operation, high-voltage engineering, control and automation systems such as PLCs, SCADAs, protection, and power electronics and renewable integration. In mechanical engineering critical hard skills involve thermodynamics and fluid dynamics (steam cycles, heat exchangers, cooling systems), structural and materials engineering (load-bearing analysis, corrosion prevention), mechanical system design and maintenance (rotating machinery, turbines, compressors) and HVAC and energy efficiency optimisation (industrial applications, building systems).

3.3 Results of the Questionnaire

In order to enhance the quality of insights and broaden the geographical and sectoral representation of skill gaps and emerging competences, a new survey was designed, targeting key stakeholders, mainly from industry. The analysis of their responses aimed to validate the findings of the EDDIE project while identifying additional skill gaps.

To develop the survey questions, the key findings from the EDDIE project were extracted and critically evaluated by experts in the energy sector. A Likert scale was employed, requiring participants to rate the significance of each identified skill gap on a five-point scale. This ensured a structured assessment of industry needs.

Most responses were from the industry, followed by a substantial share from the education and training sector. Additionally, several responses came from research institutes, with a smaller number from service providers. In terms of areas of operation, the power sector was the most represented, while a significant number of participants also came from other sectors.

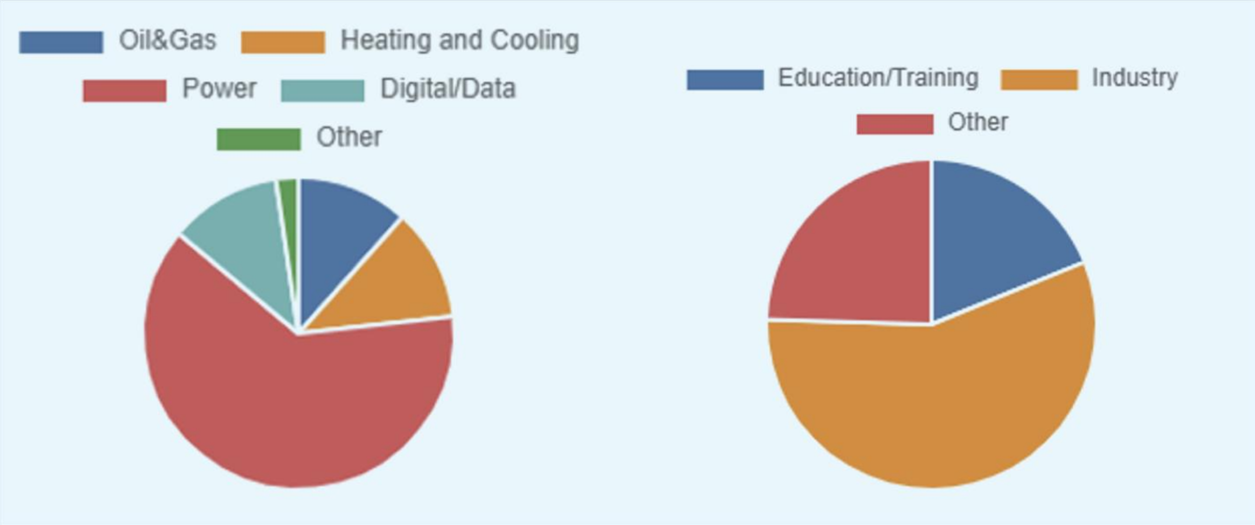

Figure 2 – Likert Scale questionnaire analysis – Areas of operation of the respondents (left) and sector (right)

The areas of activity range from system operators, technology vendors, ESCOs, energy generation companies, while several of the respondents indicated that their organisation is active in more than one area of operation.

Please select the role which best describes your organisation? (You can choose more than one if applicable)

	Answers	Ratio
System operator	10	19.23 %
Energy services company (ESCO)	4	7.69 %
Generation company (GENCO)	2	3.85 %
Energy retailer	2	3.85 %
Consumer	0	0.00 %
Regulator	0	0.00 %
Technology vendor	15	28.85 %
Other	5	9.62 %
No Answer	23	44.23 %

Figure 3 – Analysis of the Likert scale questionnaire

The results of the Likert scale questionnaire provide valuable insights into how respondents perceive the importance of skill gaps across various competencies related to data analysis, digital technologies and system management.

Concerning the assessment of skill gaps in a list of selected digital skills gaps in the energy sector, the key findings are described next and presented in summary in tables and figures.

Most Critical Skill Gaps:

- Perform big data analysis (Mean: 3.62, SD: 1.18)
- Application of data-driven methods (e.g., supervised learning, deep learning) (Mean: 3.58, SD: 1.12)
- Evaluate data, information and digital content (Mean: 3.48, SD: 1.28)
- Development of prototypes and new analysis algorithms (Mean: 3.37, SD: 1.08)

These results suggest that respondents consider gaps in handling large datasets, applying machine learning techniques and evaluating digital content as particularly significant. The median values of 4 indicate that the majority perceive these as crucial areas requiring attention.

Less Critical Skill Gaps:

- Administration of hardware infrastructure (web servers, workstations, etc.) (Mean: 2.58, SD 1.17)
- Expertise and proficiency in programming languages (Mean: 2.83, SD: 1.09)

- Query data from databases (Mean: 2.85, SD: 1.26)

The administration of hardware infrastructure received the lowest ratings, indicating that respondents do not perceive a significant skill gap in this area. Similarly, gaps in programming languages and database querying are seen as less pressing than other competencies.

Moderately Important Skill Gaps:

- Application of statistical methods (Mean: 3.08, SD: 1.21)
- Mathematical optimisation (Mean: 3.19, SD: 1.16)
- System design competence (Mean: 3.19, SD: 1.19)
- Accessing, analysis, and visualisation of data (Mean: 3.29, SD: 1.36)
- Understanding of cybersecurity (Mean: 3.42, SD: 1.23)

These skills have mean scores clustered around 3, suggesting a moderate perception of importance regarding existing skill gaps.

The standard deviation values suggest that there is a notable spread in responses across most skills. Report analysis results (SD: 1.43), Evaluate data, information and digital content (SD: 1.28), and Managing security and privacy issues on digital platforms (SD: 1.30) show relatively high dispersion, suggesting differing opinions on the significance of gaps in these areas. This indicates a need for targeted discussions to align understanding of their importance.

Table 1 – Assessment of digital skill gaps in the energy sector

Skill	Mean	Median	Standard Deviation
Evaluate Data, Information and Digital Content	3,48	4,00	1,28
Application of statistical methods	3,08	3,00	1,21
Mathematical optimisation	3,19	3,00	1,16
Application of data mining approaches	3,37	3,50	1,21
Perform Big Data analysis	3,62	4,00	1,18
Report analysis results	3,21	3,00	1,43
Predictive modelling/analysis	3,38	3,00	1,21
Accessing, analysis and visualisation of data	3,29	3,00	1,36
Managing security and privacy issues on digital platforms	3,27	3,50	1,30
Administration of hardware infrastructure (web servers, workstations, etc.)	2,58	2,00	1,17
Creative use of digital technologies	3,31	3,00	1,08

Development of prototypes and new analysis algorithms	3,37	4,00	1,08
Use specific data analysis software	3,15	3,00	1,10
Requirement's analysis	3,13	3,00	1,07
Development of applications	3,02	3,00	1,18
Query data from database	2,85	3,00	1,26
System design competence	3,19	3,00	1,19
Understanding of cybersecurity	3,42	3,00	1,23
Understanding and usage of comm. Technologies	3,00	3,00	1,09
Application of data-driven methods (e.g., supervised learning, deep learning)	3,58	4,00	1,12
Expertise and proficiency in programming languages	2,83	3,00	1,09

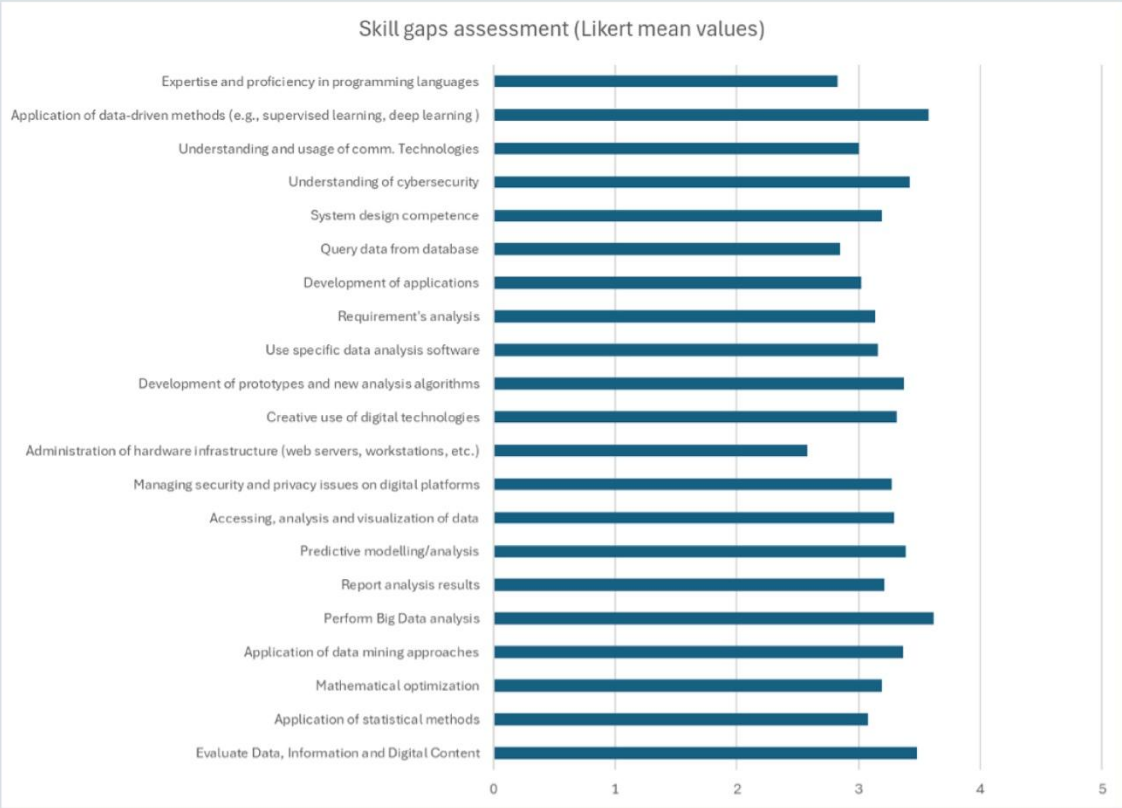

Figure 4 – Graphical representation of Likert mean values for skill gaps

In order to better understand the gaps in knowledge and competences, a list of the most prominent digital technologies that pertain to the energy sector was set against the experience of the participating stakeholders. The key findings for these digital technologies are the following:

Most Critical Technology Gaps:

- Artificial intelligence (Mean: 3.90, SD: 1.04)
- Big data/data analytics (Mean: 3.73, SD: 1.13)
- Cybersecurity (Mean: 3.58, SD: 1.12)
- Energy management systems (Mean: 3.50, SD: 1.29)

Respondents identified artificial intelligence, big data, and cybersecurity as the most critical technology gaps. The median values of 4 suggest that these areas are widely regarded as requiring further development and investment.

Less Critical Technology Gaps:

- Cloud services (Mean: 2.96, SD: 1.04)
- Communication technologies (e.g., 5G) (Mean: 2.98, SD: 1.07)

These technologies received relatively lower importance ratings, indicating that respondents do not perceive substantial gaps in these areas compared to others.

Moderately Important Technology Gaps:

- Digital asset management (Mean: 3.40, SD: 1.08)
- Virtual product development and testing (Mean: 3.31, SD: 1.01)
- Blockchain (Mean: 3.21, SD: 1.23)
- Digital platforms (Mean: 3.27, SD: 1.13)
- Internet of Things (IoT) (Mean: 3.25, SD: 0.92)

These technologies have mean scores around 3, reflecting a moderate level of perceived skill gap importance.

The standard deviation values suggest that there is a notable spread in responses across most skills. Report analysis results (SD: 1.43), Evaluate data, information and digital content (SD: 1.28), and Managing security and privacy issues on digital platforms (SD: 1.30) show relatively high dispersion, suggesting differing opinions on the significance of gaps in these areas. This also indicates a need for targeted analysis and assessment to align understanding of their importance.

Table 2 - Assessment of skill gaps in the most relevant digital technologies within the energy sector

Digital Technologies	Mean	Median	Standard Deviation
Artificial Intelligence	3,90	4,00	1,04
Big Data/Data Analytics	3,73	4,00	1,13
Cybersecurity	3,58	4,00	1,12
Digital Platforms	3,27	3,00	1,13
Internet of things (IoT)	3,25	3,00	0,92
Cloud services	2,96	3,00	1,04
Virtual product development and testing	3,31	3,00	1,01
Blockchain	3,21	3,00	1,23
Digital asset management	3,40	3,00	1,08
Energy management systems	3,50	3,50	1,29
Communication technologies (e.g. 5G)	2,98	3,00	1,07

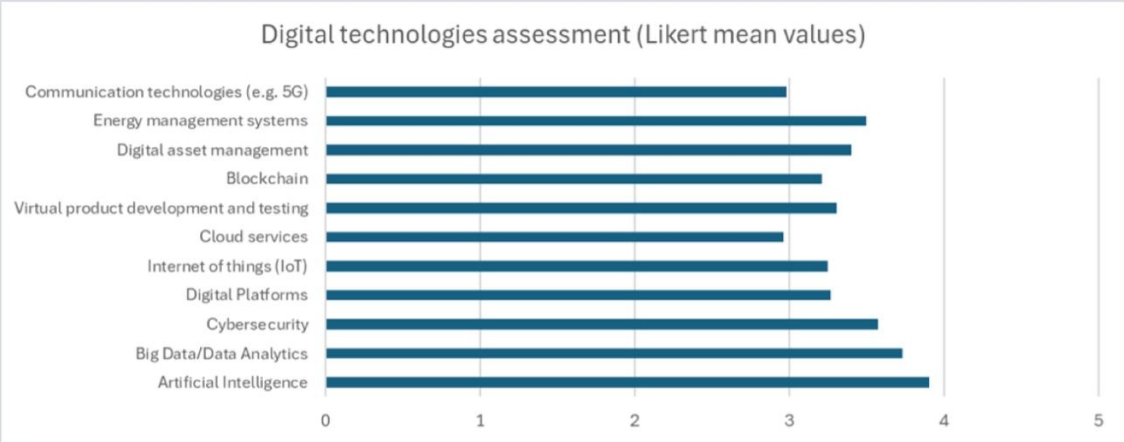

Figure 5 – Graphical representation of Likert mean values for digital technologies skill gaps

3.3.1 Presentation of the analysis results using a colour scale

An analysis using a different perspective than the one described above yields consistent results. The results are presented in the following table. The colour scale ranges from areas with larger skill gaps in red, to areas with moderate skill gaps in white, to areas with small skill gaps in green. The results can be sorted by organisation, sector or role. This makes the skill gaps in the various areas very easy to read and compare. The following figure is for visualisation purposes only, for a readable version please see the attachment.

Figure 6 – Visualisation of skill gaps across different areas, with a colour scale from red (large gaps) to green (small gaps).

The overall average shows the highest skill gaps in artificial intelligence, data-driven methods of learning , big data analysis and cybersecurity, followed by predictive modelling and energy management systems. Lowest skill gaps can be seen in hardware infrastructure, programming languages, communication technologies, accessing data in databases and cloud services. When looking at the complete table, some outliers can be identified in the example below: The heating and cooling sector sees skill gaps in system design competence and the oil and gas sector sees issues in digital asset management.

Skill Area	Overall Average	Organisation Average	Sector Average	Sector: (not specified	Sector: Power	Sector: Heating and Cooling	Sector: Oil & Gas	Sector: Digital/Dat	Role Average
Artificial	3,93	3,99	3,80	4,00	3,73	4,00	4,00	3,25	4,23
Application of data-driven methods (e.g., supervised learning, deep learning)	3,81	3,88	3,88	3,83	3,55	4,33	4,00	3,67	3,99
Big Data / Data Analytics	3,70	3,79	3,54	3,63	3,65	4,00	3,67	2,75	4,04
Perform Big Data analysis	3,67	3,78	3,62	3,57	3,64	4,25	3,33	3,33	3,83
Cybersecurity	3,57	3,71	3,44	3,67	3,26	4,00	3,00	3,25	3,70
Predictive modelling / analysis	3,57	3,70	3,51	3,52	3,52	3,50	3,67	3,33	4,00
Understanding of cybersecurity	3,55	3,62	3,50	3,70	3,24	4,25	2,67	3,67	3,36
Evaluate Data, Information and Digital Content	3,55	3,55	3,45	3,39	3,52	4,00	3,33	3,00	3,70
Energy management systems	3,53	3,68	3,40	3,71	3,13	3,50	3,67	3,00	3,70
Application of data mining approaches	3,52	3,60	3,40	3,65	3,29	3,75	3,00	3,33	3,51
Accessing, analysis and visualization of data	3,47	3,53	3,72	3,22	3,65	3,75	4,00	4,00	3,81
Development of prototypes and new analysis algorithms	3,45	3,50	3,68	3,09	3,64	4,00	[illegible]	3,67	3,83
Digital asset management	3,41	3,41	3,86	3,25	3,36	4,25	4,67	[illegible]	3,53
Creative use of digital technologies	3,34	3,33	3,48	3,13	3,43	3,50	3,67	[illegible]	3,65
Digital Platforms	3,33	3,46	3,48	3,42	3,09	3,75	3,67	3,50	3,60
Virtual product development and testing	3,33	3,38	3,43	3,38	3,09	3,75	3,67	3,25	3,41
Managing security and privacy issues on digital platforms	3,31	3,43	3,14	3,35	3,09	4,25	2,33	2,67	3,38
Mathematical optimization	3,30	3,37	2,88	3,26	3,24	[illegible]	2,00	2,67	3,02
System design competence	3,30	3,37	3,24	3,22	3,14	4,50	[illegible]	2,67	3,48
Internet of things (IoT)	3,28	3,39	3,10	3,38	3,04	3,00	[illegible]	2,75	3,31
Report analysis results	3,27	3,33	3,25	3,26	3,14	3,50	3,00	3,33	3,34
Use specific data analysis software	3,27	3,31	3,31	3,13	3,24	3,50	3,00	3,67	3,37
Blockchain	3,22	3,18	3,40	3,00	3,32	3,50	3,67	3,50	3,13
Understanding and usage of comm. technologies	3,21	3,35	3,14	3,39	2,79	3,50	3,00	3,00	3,10
Requirement's analysis	3,18	3,25	3,04	3,22	3,00	3,00	3,33	2,67	3,29
Application of statistical methods	3,18	3,24	2,97	3,13	3,14	3,25	2,33	3,00	2,97
Development of applications	3,16	3,19	3,36	3,04	3,10	4,00	3,67	3,00	2,99
Cloud services	3,07	3,17	2,86	3,08	2,90	3,00	3,00	2,33	3,21
Query data from database	3,00	3,12	2,79	2,95	2,90	3,75	2,00	2,33	3,05
Communication technologies (e.g. 5G)	2,98	3,08	2,94	3,13	2,64	3,50	2,67	2,75	3,04
Expertise and proficiency in programming languages	2,91	2,94	2,67	2,96	2,67	2,75	2,67	2,33	2,46
Administration of hardware infrastructure (web servers, workstations, etc.)	2,64	2,80	2,41	2,74	2,33	3,00	1,67	2,33	2,71

Figure 7 – Overview of skill gaps by technological area and sector, with a colour scale from red (large gaps) to green (small gaps).

3.3.2 Inclusion of other relevant skills

In addition to the predefined digital skill gaps identified in the survey, respondents highlighted several critical areas requiring further attention. They emphasise both emerging technological competencies and the practical challenges of implementing digital solutions effectively within the energy sector.

Key areas of concern include a growing need for expertise in large language models (LLMs), quantum computing, and post-quantum cryptography, particularly as these technologies begin to intersect with energy system operations and cybersecurity. Competencies in functional and architectural requirements for digital equipment deployed in field installations are essential. Respondents stressed the importance of understanding the relationships between digital equipment and central systems, ensuring seamless integration and interoperability. A significant gap in data engineering skills was noted, with an urgent need for expertise in data by design—a proactive approach similar to the cybersecurity by design framework. This applies not only to IT professionals but also to business roles involved in commissioning digital developments. Several responses pointed to difficulties in implementing digital technologies (DT) efficiently and reliably. Many solutions are overly complex, lack clarity and lead to unsafe operations with high failure rates. There is a need for professionals who can apply the principle of "as simple as possible, but not simpler," ensuring usability without unnecessary complexity. Skills in digital regulation, data management, identification and governance are increasingly important. Respondents emphasised the need for seamless data interoperability, ensuring that data can move freely across applications and cloud platforms without compatibility issues. The industry faces challenges in legacy data readiness, requiring expertise in integrating older digital solutions with modern systems while maintaining operational efficiency. Additionally, edge computing skills are becoming critical for decentralised and real-time data processing in energy infrastructure. There is a recognised need for skills in data quality assessment, digital use cases and business models in the energy sector. Professionals must understand how to optimally integrate different digital technologies to maximise efficiency and scaleability.

4 RECOMMENDATION OF EDUCATION AND TRAINING FOR THE SKILLS GAP

4.1 Digital skills

Digital skills are crucial in the energy sector, particularly in the context of smart grid technologies. Smart grids represent a significant evolution in how electricity is generated, distributed and consumed, integrating digital technology into the traditional energy infrastructure. The following list provides a range of required skills in the energy sector with a focus on smart grid technologies.

1. Understanding Smart Grid Components

- **Digital Infrastructure:** Smart grids rely on a complex network of sensors, meters and communication technologies. Professionals need digital skills to understand and manage these components effectively.

- **Integration of Renewable Energy:** Digital skills are essential for integrating renewable energy sources into the grid, enabling real-time monitoring and management of energy flows from diverse sources.

2. Data Management and Analytics

- **Big Data Utilisation:** Smart grids generate vast amounts of data from various sources, including smart meters and IoT devices. Professionals with data analytics skills can analyse this data to optimise grid performance, forecast demand and identify patterns in energy consumption.

- **Predictive Analytics:** Digital skills enable the use of predictive analytics to anticipate energy demand fluctuations, allowing for proactive management of resources and improved reliability.

3. Real-Time Monitoring and Control

- **Advanced Metering Infrastructure (AMI):** Understanding AMI systems is crucial for managing real-time data on energy consumption. Digital skills allow professionals to interpret this data and make informed decisions about energy distribution.

- **Dynamic Load Management:** Digital skills are necessary for implementing dynamic load management strategies that adjust energy distribution based on real-time demand, enhancing grid stability.

4. Cybersecurity Awareness

- **Protecting Critical Infrastructure:** As smart grids become more interconnected, they also become more vulnerable to cyber threats. Digital skills in cybersecurity are essential for protecting the grid from attacks that could disrupt service or compromise safety.

- **Incident Response:** Professionals need to be trained in cybersecurity protocols and incident response strategies to quickly address potential breaches and mitigate risks.

5. User Engagement and Customer Interaction

- **Smart Metering and Customer Interfaces:** Digital skills are vital for developing and managing customer-facing technologies, such as smart meters and mobile applications that allow consumers to monitor their energy usage and manage their consumption more effectively.

- **Demand Response Programs:** Knowledge of digital tools enables the design and implementation of demand response programs that incentivise consumers to adjust their energy usage during peak times, contributing to grid stability.

6. Interoperability and Standards

- **Understanding Protocols:** Smart grids require interoperability between various devices and systems. Professionals must be familiar with communication protocols and standards (e.g., IEC 61850, IEEE 2030) to ensure seamless integration and operation.

- **Collaboration Across Disciplines:** Digital skills facilitate collaboration among engineers, IT professionals and regulatory bodies to develop and implement interoperable solutions.

7. Regulatory Compliance and Reporting

- **Data-Driven Compliance:** Digital skills are necessary for managing data related to regulatory compliance, ensuring that smart grid operations meet local and international standards for safety, reliability and environmental impact.

- **Transparent Reporting:** Professionals must be adept at using digital tools to generate reports and documentation required by regulatory agencies, enhancing transparency and accountability.

8. Innovation and Continuous Improvement

- **Adopting Emerging Technologies:** Digital skills enable professionals to explore and implement emerging technologies, such as artificial intelligence and machine learning, in order to enhance smart grid functionalities and improve operational efficiency.

- **Research and Development:** A workforce equipped with digital skills can contribute to R&D efforts aimed at developing innovative solutions for energy management, grid resilience and sustainability.

9. Sustainability and Environmental Impact

- **Energy Efficiency Initiatives:** Digital skills enable professionals to implement energy efficiency measures and sustainability initiatives within smart grid frameworks, contributing to reduced carbon footprints and promoting environmental stewardship.

- **Life Cycle Assessment:** Knowledge of digital tools for life cycle assessment helps organisations evaluate the environmental impact of their smart grid projects and make informed decisions that align with sustainability goals.

Conclusion

In summary, digital skills are essential for the successful implementation and operation of smart grid technologies in the energy sector. As the industry continues to evolve, the demand for a skilled workforce proficient in digital technologies will only increase. By investing in training and development in these areas, energy companies can enhance their operational efficiency, improve customer engagement, ensure cybersecurity and drive innovation, ultimately positioning themselves for success in a rapidly changing energy landscape. The integration of smart grid technologies not only enhances the reliability and efficiency of energy systems but also plays a critical role in the transition to a more sustainable and resilient energy future.

4.2 Other skills

The energy transition has a very broad spectrum aiming to make the energy more clean, affordable and reliable. Digitalisation is only one of the key elements of energy transition, enabling broadband communications, sensors, artificial intelligence, smart maintenance and diagnostics and so on.

Making energy cleaner 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 and re-skill workers to equip them for future roles in the renewables industry.

PV sector

Although in the 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. The 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 10 GW 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.

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 increase demand for skilled professionals and companies specialised in decommissioning and recycling within the PV sector.

Battery sector

The battery sector is growing rapidly, as the global shift towards decarbonisation and electrification gains ever more momentum. The main reason for this level of growth is the need for electric vehicle batteries and PV deployment. **Recycling is an essential aspect of the battery value chain**.

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

The large-scale deployment of renewable, distributed and centralised energy resources requires large storage capacities. Since the gas infrastructure has very large storage capacities, sector coupling is essential for a cleaner energy. The creation of clean molecules from electrons (electricity surplus), such as hydrogen, synthetic gas, etc. becomes relevant and requires new skills. Additionally integration skills are necessary. These refer to the ability to combine electricity with gas grids, electricity with heating and cooling grids or electricity with gas and heating and cooling grids, so that they work together optimally. There is currently a lack of energy system integration capabilities due to their historically siloed development. Experts and professionals use different terminology and often use the same language to mean different things. In addition, knowledge of other energy systems is very superficial, which is insufficient for practical integration work. All these factors make the practical implementation of sector coupling difficult. Training in energy systems integration is essential to implement sector coupling in practice and drive the energy transition forward.

5 BRIDGING SKILL GAPS THROUGH EDUCATION AND COLLABORATION

5.1 Methodological approach for education and training

Closing the skill gaps identified in this document will require a combination of established and innovative education and training methods. Traditional learning paths offered by universities and other educational centres will remain at the forefront of preparing the next generation of digitally skilled professionals to support the energy transition. However, innovative approaches will also be needed to support this endeavour, given the rapid pace at which digital technologies evolve and the urgency of having skilled professionals who can apply them.

In this section, we present a list of methods and tools that are shaping the future of learning and have great potential to contribute to the digital upskilling of energy professionals based on industry trends and relevant case studies. These approaches include e-learning, bootcamps, laboratory education and advanced educational tools. We discuss the use of tools such as massive open online courses (MOOCs), virtual labs, living labs, interactive notebooks and generative AI chatbots, and we their advantages and potential caveats. Moreover, we discuss how these tools can be used to engage younger generations. Our findings suggest that the listed innovative approaches can contribute to creating a robust framework for digital upskilling as they not only enhance learning flexibility and accessibility but also foster engagement and practical experiences. However, it is also critical that other resources are put in place to ensure the associated technological tools are properly accessed and used by potential learners.

5.1.1 e-learning

The widespread adoption of personal computers, mobile devices and the internet have revolutionised how we acquire new skills and knowledge, offering unprecedented flexibility and accessibility. Now, students can access online resources anywhere at any time as long as they have an internet connection. The social distancing measure imposed during the Covid-19 pandemic further promoted the adoption of e-learning resources. In fact, people are increasingly used to relying on online resources to learn new skills. Data from Europe 2023 shows that 30% of internet users aged 16 to 74 had done an online course or used online learning material in the past three months, a 2% increase compared with 2022 [13]. Typical e-learning resources include online training courses, webinars, tutorials, e-books, audiovisual material, learning apps and software.

The use of e-learning resources to train professionals in digital and ICT skills, green skills (e.g., sustainability or climate change theory), management and soft skills has been trending for a while. On the contrary, the use for technical and hard skills is more recent but is now gaining more traction recently thanks to the advancements in educational tools such as remote or virtual laboratories. Diverse stakeholders such as universities, research institutes, companies or governments have made countless online resources available to students willing to dive into energy and digital topics. Many of these resources are made available to learners via Youtube, a widely used platform that can be accessed anywhere and used free of charge. For example, Denmark Technical University, in collaboration with EIT InnoEnergy and KU Leuven, has made available on Youtube a series of lessons on forecasting methods and its implications for the digitisation of the grids and energy markets [14].In other cases, those resources are shared using the creator´s own platforms. An outstanding case is the Massachusetts Institute of Technology (MIT) that owns and maintains an OpenCourseWare repository as part of the MIT Open Learning initiative. Through this platform, the university offers more than 2,500 MIT on-campus coursed and supplemental resources, all available under a Creative Commons license.

Private companies and individuals are also active creators of e-learning material. A Google search using the keywords “apps to learn coding” shows 35 options. The first option in the list, Mimo coding app, was created by the company Mimo GmbH, and offers learners free coding lessons and exercises for Python, JavaScript, HTM and SQL languages, although advanced features are subjected to a paywall. It offers full-stack, front-end, Python Artificial Intelligence, and backend web development as learning paths. The app has over 10 million downloads and can be used in both mobile and PC devices. Github, a popular platform for developers, is full of public examples and tutorials posted by seasoned or junior coders to share their work and help others learn. Open knowledge communities are common among digital professionals, and there are several platforms – e.g., Stack Overflow – where learners can look for or post questions and receive answers from more advanced users. As we discuss later, the arrival of AI-based chatbots also presents new opportunities for users to enhance their online learning experience.

Massive Online Open Courses (MOOCs)

MOOCs are online educational programmes designed to be accessible to a large number of participants, often for free or at a low cost, although personalised tutoring and other optional features are often offered with additional cost. They cover a wide range of subjects and are created and hosted by universities, colleges, educational platforms, companies, governments, among others. MOOCs aim to provide flexible, affordable, and democratic education by lifting financial and geographical barriers while fostering a continuous learning culture. To do so, they apply digital technologies – e.g., videos, quizzes, discussion forums, peer-reviewed assignments – to offer interactive and engaging learning experiences to diverse audiences. The main downside of MOOCs is that they have high dropout and low reoccurrence rates despite being free. Studies show that MOOC competition rates are below 13% and the vast majority of learners never return after their first year [15][16]. Nonetheless, the implementation of virtual and remote labs or other advanced educational tools such as interactive notebooks or AI chatbots might increase these numbers by enhancing interactivity, thus improving students’ experience.

MOOCs can be accessed through dedicated platforms such as Coursera, edX, FutureLearn, Udemy, Saylor and Khan Academy [17]. On these platforms it is possible to find standalone courses, full programmes or certified learning paths. Popular topics include energy and sustainability, digital skills as well as management and soft skills. For example, on Coursera, the keyword “energy” leads to 218 courses, 28 specialisations, 2 degrees, 3 certificates and 4 project-based learning experiences. Similarly, the keyword “digital” shows 958 courses, 178 specialisations, 20 degrees, 18 certificates, and 232 project-based offers. These courses are offered by universities from all around the world, but also by companies like IBM, Google, Adobe, Microsoft or Siemens, or by organisations like the World Wildlife Fund or the Inter-American Development Bank.

MOOCs can also be specifically developed to fill an identified skill gap. For example, after passing an ambitious energy reform in 2013, Mexico’s Energy Ministry in collaboration, with public research bodies and public and private higher education institutions from the U.S. and Mexico, created the Binational Laboratory project for the Smart Management of the Energy Sustainability and the Technological Formation. The objective was to foster technological and knowledge development around energy and sustainability to support the transformation of the energy industry transformation [18]. As part of this platform, a set of 12 MOOCs was developed by the Tecnológico de Monterrey with the purpose of training Spanish speakers in energy and sustainability matters. The courses included topics such as basic concepts of electricity, business opportunities in energy markets, energy efficiency, smart grids, and carbon markets. During its two editions – 2018 and 2019 – more than 100,000 participants enrolled in the MOOCs, 14% of which successfully completed them. The typical learner profile was a person over 17 years old, who had at least completed high school education and wanted to learn about energy sustainability and improve job opportunities. Most were based in Latin America and were employees of the Mexican state utility or worked in an energy-related job. The course design included several innovative features such as gamification (e.g. badges were assigned to learners who solved questions based on the time and opportunities they used), virtual and augmented reality, an open educational resources repository and remote labs (with limited seats requiring reservation beforehand). The MOOCs were offered through the open learning platform MexicoX and participants could follow them as standalone courses or as part of a certification path [19].

The vast number of e-learning resources available to learners presents great opportunities for accelerating digital upskilling for the energy transition. However, it requires filtering useful and accurate material from low-quality resources to ensure learners become truly proficient in their field of interest. For this reason, the effective use of e-learning resources for upskilling the workforce in the energy transition needs to be accompanied by other strategies. These include providing resources that help learners find the right e-learning material and tools that ensure they successfully acquire the needed skill set. An example could be a check list of skills needed for highly demanded positions next to a virtual library with a curated list of resources that people can access to learn those skills. Furthermore, an optional skill certification that is recognised by potential employers might also be offered as an incentive for learners to go through the material available. This could be done through a micro-credential scheme, which is a tool supported by the European Skills Agenda. Micro-credentials can be defined as documented statements that acknowledge a person's learning outcomes, which are related to small volumes of learning and that, for the user, are made visible on a certificate, badge or endorsement (issued in a digital or paper format) [20].

Finally, successful use of online resources also demands the use of self-learning skills acquired during basic education levels, such as critical and logical thinking or reading proficiency. Thus, an upskilling strategy based on e-learning must not neglect the importance of reinforcing basic skills in younger generations – e.g., logic, critical thinking, reading proficiency, writing proficiency – so they can eventually tap into the potential of endless e-learning resources they will likely encounter in the future.

5.1.2 Bootcamps

A bootcamp can be defined as short-term training programmes designed to equip training participants with employment-ready programming skills for entry-level tech positions. Usually, they follow a structured process based on three main characteristics: intense rapid-skills training (lasting usually less than six months) with competitive selection processes, project-based, experiential learning approach; and a curriculum continuously adapting to industry demand. Given these characteristics, bootcamps are particularly attractive to working professionals willing to reskill and change to a new labour sector, to talented unemployed people with lack of formal training or with previous training in a low-demand field, or in vulnerable sectors with access barriers to formal educational channels such as university degrees.

This model originated in technology hubs in the U.S., but it has rapidly expanded globally (World Bank, 2017). Moreover, the bootcamp model has evolved to cover other skills in addition to coding, including cybersecurity, data science, game design and user experience design (Hamilton, 2024). Currently, there are several providers of in-person, online or hybrid bootcamps with average costs between 7,000 EUR and 18,000 EUR depending on the bootcamp length and location. The lack of standardisation, however, means that the quality of training may vary considerably from one provider to another. Furthermore, market saturation means that it is becoming harder for bootcamp graduates to find entry-level jobs, although market analysts still report 80-90% employment rates.

Despite its shortcomings, the bootcamp format is an attractive educational model to fill skill shortages, which is why it is not only driven by private educational providers but also by regional governments. For example, the It Academy, set up in 2017 by the municipality of Barcelona, Spain, through its Barcelona Activa initiative, offers students an 18-week free training programme to learn entry-level skills for front-end, back-end or full stack developer, data analytics, business intelligence, big data or machine learning. According to the organisation, the programme has trained over 3,200 students with an employment rate of 83% (measured 18 months after completing the programme) and a mean satisfaction punctuation of 9.4 out of 10 (REF). Another example is the UK's Skills Bootcamps programme, which delivered free courses in digital skills across six areas of England including cyber security, coding, software development and engineering, data analysis and digital marketing. Technical skills bootcamps in other priority areas such as construction or heavy goods vehicle driving – with huge demand in England – were also offered as part of this initiative. Between April 2021 and March 2022, this programme managed to recruit 18,110 students, with a 62% completion rate, from which 58% reported a positive outcome.

5.1.3 Laboratory education

Laboratories provide students with a link between theoretical lessons and real-world experiences. Traditional laboratories are controlled physical setups that emulate real-life conditions, allowing students to experiment and test actions in a safe environment. While traditional laboratories remain valuable, two new approaches offer added value for programmes aiming to upskill professionals for the energy transition: virtual or remote laboratories and living labs. Although these approaches may seem contradictory, they complement each other by offering different advantages to professors and students.

Virtual and remote laboratories

Virtual laboratories are purely based on simulations, whereas remote laboratories involve at least one physical component that students interact with in real time through another person (via streaming devices) or through an interface and remote controllers. The use of virtual and remote laboratories skyrocketed during the Covid-19 pandemic due to the constraints for in-person gatherings. Universities transformed in-person laboratory courses to virtual or remote settings or fine-tuned existing ones. Some of these new setups were so successful that universities decided to maintain them even after pandemic restrictions had ended. Some advantages of using virtual or remote laboratories digital upskilling are improved accessibility by eliminating geographical barriers, cost effectiveness for education providers, realistic simulation setups for students to acquire and practice new skills, and fostered collaboration across teams and institutions. Examples of remote or virtual laboratory setups are:

- *Instructor-led remote laboratory in Scotland.* At the University of Strathclyde, Scotland, the Department of Electronic and

Electrical Engineering's Undergraduate Programme proposed a setup where the instructor ras the experiments wearing a head mounted or hand-held camera. This allowed students to see what the instructor was seeing, emulating an in-person experience. Students could record observations for later analysis and use an online chat to discuss findings or raise issues. Now, the university is considering further automation and replicating these remote labs in their dual master programme with the Hong Kong University of Science and Technology [21].

- *Automated remote laboratory in Germany.* At RWTH Aachen University, the Institute for Automation of Complex Power Systems offers a remote laboratory for graduate students in electrical engineering. Students receive materials in advance (flipped classroom) and conduct lectures online. Experiments are carried out using a web-based methodology connected to real-time simulators and actual devices via an Ethernet network. Physical connections between power equipment and control devices, real time simulator and virtual machines are set up in advance. Students access virtual machines using a stable internet connection and interact with simulators and intelligent electronic devices to perform tasks. Teams develop joint scripts, extend power system components and configure control components and intelligent devices. One student at the time takes the lead in running the experiments; care is put on rotating the student in charge of different tasks [21].

- *Virtual laboratories with virtual and augmented reality in the Netherlands.* TU Delft, Netherlands, offers a virtual PV lab course as part of a summer school hosted by the faculty of Electrical Engineering, Mathematics and Computer Science. Initially designed for on-campus hands-on experience, the course was shifted to a virtual setting to accommodate increasing demand, allowing more students to join even those with mobility restrictions. The virtual lab closely resembles real equipment as its first edition was improved with beta testers who had taken the in-person summer school. This resulted in a successful learning experience that has now been expanded to other courses. The PV lab is currently offered as part of the PV conversion, systems and components virtual lab and the solar and chemical energy conversions for green hydrogen courses.

Further examples of remote or virtual lab can be consulted at the Innovative Teaching Methods for Modern Power and Energy Systems report published by the IEEE Power & Energy Society [21].

Living labs

Living laboratories represent a learning and research and development concept for a user-centric, iterative, open innovation environment that allows sensing, prototyping, validating and refining complex solutions in multiple and evolving real-life contexts [22][23][24][25][26].

Living labs can be broadly defined as open innovation ecosystems in real-life environments based on a systematic user co-creation approach that integrates research and innovation activities in communities and/or multi-stakeholder environments, placing citizens and/or end users at the centre of the innovation process. They offer real-life experiences and foster innovation among the actors in the Quadruple Helix Model (citizens, government, industry and academia) [27], which is making them increasingly popular across universities and industry aiming to produce knowledge and technologies to address real-life challenges.

University-led living labs can take various forms. They can be power system element or subsystem such as microgrid, power plant, building, campus or other that is used for research purposes. This is the case of the Urban Sciences Building (USB) at Newcastle University, which use renewable energy and over 4,000 digital sensors that provide data for research purposes [28]. In other cases, living labs can consist of experimental buildings located within the campus and that emulate real-life settings. One example is the Living Lab Energy Campus at Karlsruhe Institute of Technology, which consists of three identical detached houses and two office buildings, each with different technological setups that are closely monitored via sensors. These sensors allow researchers to test adaptive and predictive control strategies per each individual building or together as a smart neighbourhood community [29]. Living labs can also be wider-scope projects that encompass a set of initiatives that is implemented at the university or in close partnership with it. For instance, the UPV Living Lab, at the Universitat Politècnica de València, encompasses various innovative projects and sandboxes aimed at accelerating the path towards carbon neutrality at the university and in the city of Valencia. These initiatives would be first be tested in one of the university's campuses and later replicated in the city's neighbourhoods [30].

Although other educational tools can try to replicate real-life situations, none can mimic perfectly what happens during real-life projects. This is the added value that living labs provide to students. They can learn and practice negotiation skills to navigate conflicts among stakeholders within a data-driven project, technical skills to deal with the common problems associated with working with real data (installation of needed equipment, addressing privacy or security concerns, structuring databases to fit project requirements, etcetera), or the ability to work in interdisciplinary teams, for instance, by cooperating with social science and humanities professionals to gather socioeconomic data needed to interpret or build energy data models. The downside of living labs is their limited participation to a reduced number of students, often restricted to developing thesis work in the living lab facilities.

5.1.4 Advanced educational tools

New technologies with the potential to optimise and enhance learning processes are emerging and becoming accessible to all through the internet. In this section, we present two that we have identified as particularly promising for their applications in digital skill training: interactive notebooks and generative AI chatbots. The first are browser-based tools designed for interactive coding or data analysis. They enable users to create and share documents, including live code, equations, visualisations and explanatory text. Moreover, interactive notebooks support multiple users and servers, thus facilitating collaboration [31]. Generative AI chatbots are technologies that generate context such as text, images, audio and video, interacting with users via chatbots, i.e., computer programs that use large language models to emulate human conversations, typically through typed text in a software application [32].

Interactive notebooks

The use of interactive notebooks that allow students to programme in real time while following a teacher's instructions or collaborating with each other has become a useful tool for teaching digital skills with languages such as Python, R, SQL, Scala, or Julia. Examples of platforms that support these applications are Amazon SageMaker Notebooks, CoCalc, Databricks, Deepnote, Google Colab, JetBrains Datalore, Jupyter Notebook, Kaggle Notebooks, Microsoft Azure Notebooks Notebooks and Visual Studio Code.

An example of the use of these tools for the upskilling of digital skills in the energy sector is the Data Science & AI for Energy Engineers course offered by EIT InnoEnergy. It introduces students to exploratory data analysis, forecasting and optimal decision making. By using interactive notebooks, participants can reinforce the theoretical concepts previously seen in class and do practical programming exercises on their own, with the option to receive tutoring during out-of-class hours. The latest version of this course is taught using Deepnote, a cloud platform tool for Jupyter Notebook collaboration. Previously, instructors used a custom-built cloud platform based on JupyterHub, but Deepnote was easier and cheaper to maintain and provided more functionalities. Both solutions provided students with several advantages: all needed pre-installed Python packages, allowing students to focus directly on developing their own algorithms; the platform grants students with greater computational resources enabling the development of more complex algorithms; and the cloud setting gives instructors greater control over content. The notebooks created as part of these courses are released to the public under an AGPL-3.0. This is an increasingly common practice that allows collaboration and knowledge building. In fact, the EIT Innoenergy course, provides students with an introductory lesson on Python programming using Jupyter Notebooks created and released by the University of Cambridge [33].

Generative AI chatbots

The recent release of generative AI chatbots such as ChatGPT, Mistral, Gemini and Copilot is changing how different processes are conducted across several sectors, and education is no exception. Their use is expected to become even more disruptive as their capabilities continue to evolve, but there are already some ways in which chatbots can be used in educational settings. For instance, a 2023 review states that students prefer to use AI chatbots for homework and study assistance, personalised learning experience and the development of various skills, whereas educators tend to use it to save time and improve pedagogy [34]. Moreover, Stanford University [35] has identified at least seven approaches in which AI chatbots can be used in educational settings, all of which can be used to support digital skills training alone or in conjunction with some of the other methods and tools listed in this section (Table 3).

Table 3 - Applications of generative AI chatbots in digital skills training based on the seven approaches identified by Stanford University [34].

Approach	Description	Use case example in digital skill training.
Mentor	Provides students with frequent, immediate, and adaptative feedback.	Provides immediate feedback on how a junior coder can improve a given energy model.
Tutor	Skill building in small groups or one-on-one settings.	Helps students understand the basics of a statistical method they want to use to analyse a large dataset.
Coach	Metacognitive skill development.	Helps students reflect on how to improve personal learning methods after a failure experience.
Teammate	The chatbot plays different team roles, helping to synthesise ideas, developing a timeline of action items, or giving different perspectives or critiques of the team's ideas.	The chatbot plays the role of a teammate with social science background, adding its perspectives on a new energy management app, helping engineering students to think about its potential societal impacts.
Student	The chatbot can play a student, supporting through this role the organisation of knowledge required to teach another person and, in	The learner explains to the chatbot the critical points about Europe's data privacy and security policies. The chatbot plays the role of a curious engineering student and asks the learner follow-up questions, deepening

	this way, reinforcing the teacher's own learning on the topic.	their knowledge on the topic.
Simulator	Development of scenarios and role play activities to practice new skills.	The chatbot plays the role of various stakeholders that provide students with a list of insights each expects to get from a given dataset,
Versatile tool	The chatbot is used as a tool to aid thinking (brainstorming, concept mapping, collaborative writing), day-to-day (summarising, cleaning data, tracking progress) or designing processes (content personalisation, accessibility, curriculum mapping).	The chatbot can help a learner put together a list of online resources they need to acquire a certain digital skill.

Despite the benefits and advantages offered by generative AI chatbots, they also have some risks that need to be considered when implementing them in training or educational programmes. For example, they sometimes present false or erroneous answers as true, which may be difficult to identify by a beginner. In the Data Analysis course at Yale, the instructor asks students to identify two errors that ChatGPT makes when explaining the appropriate uses of Poisson regression [36]. Although this is a valuable learning experience for attendees, a learner without the guidance of a more knowledgeable tutor may take the chatbot's answers as factual. Similarly, in the paper *Analysing ChatGPT's Aptitude in an Introductory Computer Engineering Course*, the authors state that the chatbot performs well on quizzes and short-answer questions, but does not have the capability to handle questions with diagrams or figures, and it can confuse students with incorrect answers that sound plausible and human-like [37]. These outcomes highlight the importance of reinforcing basic skills such as critical thinking in younger generations and of providing safeguards and tools to guide current learners towards appropriate usage of AI tools for digital upskilling. An example of these resources is prompt libraries that include a list of high-quality prompts that learners can use as a starting point to build their own prompts and obtain their desired outcomes. In this respect, Maastricht University, Netherlands, has created a prompt library that students can use in applications such as learning, preparing exams, writing or getting feedback. It not only includes the example prompt but also associated tips and disclaimers that help students use generative AI chatbots appropriately [38][39].

5.1.5 Engagement strategies for younger generations

All the above methods and tools can be used to engage younger generations with modifications to adapt them to the target age range such as introducing gamified learning experiences and age-appropriate tools. To successfully reach younger audiences, it is also critical to engage parents, educators and other role models in the process. In some cases, for generative AI chatbots, it is imperative to target tutors as there are age restrictions for direct technology use (e.g., some generative AI chatbots have a minimum age limit of 13-years old and suggests users under 18 should have a guardian or tutor's permission to use).

Examples of adapted e-learning resources are available on the MOOC platform edX, which offers an online coding course for kids, applying coding principles to game-style activities, making the content fun and engaging for younger learners. It uses Scratch, software developed by MIT's Media Lab that allows students to code by dragging and dropping graphical blocks that resemble puzzle pieces instead of typing out text [40]. Scratch has also been used by TU Delft (Netherlands) to develop a MOOC that teaches 8+ year olds to code by creating different games [41]. edX also offers a catalogue of courses for pre-school and primary school educators looking to develop their own plugged and unplugged activities to introduce coding concepts to their pupils [42]. The option to learn code skills through unplugged activities is valuable for the youngest learners as health experts such as the World Health Organization increasingly recommend limiting screen time for young children [43].

Laboratory education also presents a great opportunity for young students to have hands on experience with cutting-edge technologies. Several initiatives run by governments, companies or universities to engage kids and teenagers with laboratory work can be found in the energy and digital fields. Ericsson's Digital Lab programme provides a platform for students aged 11-16 years to have their first encounters with programming, robotics and automation. It includes five separate foundation level courses where attendees can learn about basic robotics, artificial intelligence, electronics, and how to create games and programme their own LED charm. The course also promotes the development of soft skills such as the ability to solve problems, communicate and work effectively with others. The course is run by volunteers from the company and local universities and is offered to students through partnerships with local schools or other educational platforms [44].

For older students (16-18 years), the Mad for Science programme run by the Catalunya La Pedrera Foundation – an ONG based in Catalonia, Spain – in partnership with local research centres and institutions of international excellence offers an interesting case. The programme consists of theory and practical sessions that students follow in-person by attending a research centre specialised in their field of interest during a series of Saturdays throughout the year. Among the 13 courses students can select, the following energy and digital topics can be found: artificial intelligence, energy, supercomputing and new technologies. To enter the course, students must show a good academic record and previous interest in science, as the programme's primary goal is to guide students towards a possible research career and provide them with some of the skills they would need to succeed in the future [45].

Virtual labs can also be used to engage and teach younger students and offer a great resource for teachers and educators to reinforce energy and digital concepts and skills. The U.S. National Oceanic and Atmospheric Administration offers a series of open learning resources for different school levels, including an Energy Lab. Through this virtual platform, students (aged 6-12 years old) can conduct a series of activities to design a renewable energy system for one of five different cities, each with its own energy resources and constrains. Moreover, they can test their designs using real-time weather data that is retrieved by the platform for each of the available cities [46]. In this way, students can not only reinforce concepts associated to energy systems but also experience how data analysis can support decision-making processes in energy planning.

5.1.6 Training strategies for employees

Companies can help their employees gain the required skills in the clean energy sector, including digital skills, by providing in-house training opportunities or by helping them access external educational programmes. For external training, bootcamps and MOOCs are two interesting options as they can be adapted to working schedules. To develop their own training programmes, companies require a set of tools and resources to ensure an effective training environment. In-person training entails adequate training facilities that can accommodate various group sizes, including classrooms, workshops, and simulation areas, as well as access to relevant equipment that employees will use in their roles. Technological infrastructure such as learning management systems (e.g., to track students' progress), simulation tools, e-learning and communication platforms (e.g., videoconferencing tools) are also required. Companies also need to allocate specialised human resources to its training efforts. In addition to qualified trainers, companies can also put together mentorship programmes and feedback mechanisms to enhance learning effectiveness. When putting together the curricula, it is critical to develop material that is up-to-date and relevant to the specific roles and responsibilities of employees and aligned to industry standards. Similarly, it is important to ensure training promotes diversity and inclusion in the existing workforce, for instance by accommodating various learning styles (visual, auditory, kinaesthetic).

The project "Smart Grids Academy" in Spain, very much supported by Iberdrola, part of the "Bizkaia with talent" initiative developed by the Bizkaia Provincial Council and Iberdrola's Global Smart Grids Innovation HUB, managed by GAIA the Euskadi ICTA Cluster, seeks to address the urgent need for specific talent for the energy transformation towards smart grids, and its requirements for technological and digital skills.

UK Power Networks – a utility operating in London, Southeast and East of England – launched in 2023 its Digital Skills Academy. The initiative was created to facilitate the development of grassroots digital capabilities and upskilling of existing staff, increasing digital and data competency and literacy across the company. Through this programme, staff, including seasoned employees and new hires, could access a range of standard digital apprenticeship programmes [47]. Staff participating in the programme were given time to study during the week and committed to study at home. The courses were offered by an in-house training team in partnership with experienced training providers. The topics offered ranged from business analysis to cybersecurity and cover different expertise levels [48].

Government support can also be a catalyser for upskilling existing energy staff. An example is the cybersecurity training offered by the U.S. Department of Energy in collaboration with Idaho National Laboratory. It consisted of a 3-day in-person course that provided a mixture of lectures and hands-on training to improve the attendees' knowledge and skills needed to respond effectively to cyber threats. The course curriculum was designed for utility staff that require a hybrid set of skills across information technologies (IT), industrial control systems and operational technology, cybersecurity and grid operations. The programme was offered for free to utility workers and trained more than 600 personnel from utilities in seven different states [49].

5.2 Ensuring collaboration with required stakeholders (Miguel)

Addressing the skill gaps in the energy sector requires collaboration between industry, education and training providers, and policymakers. Partnerships can help to ensure that training programmes are aligned with industry needs, while providing opportunities for work-based learning and apprenticeships.

ETIP SNET is a member of the Large Partnership for Skills in the Energy System (LSP in Energy) created in December 2023 as part of the EU Pact for Skills, complying with the requirement established under the EU Digital Action Plan for Energy.

The main question when starting up the LSP in Energy is how to better contribute to education for the required digitalisation of the energy sector. This is answered during the course of the LSP activities with the long-term vision of contributing to the digital skills required by the European energy sector during its transition. Current members of this LSP are:

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas

CESI

DAFNI KEK

EDDIE ASBL: Education for Digitalisation of Energy Association

EIT InnoEnergy

ElectriCITY Innovation

Escuelas Profesionales Padre Piquer

ETIP SNET

Eurogas

European Biogas Association

European Distributed Energy Resources Laboratories (DERlab)

European Distribution System Operators (E.DSO)

European Network of Transmission System Operators for Electricity (ENTSO-E)

Fundación Montemadrid

Iberdrola

Institute of Energy Economics, University of Cologne

NOVEL Group

NTTDATA SPAIN

POLITECNICO DI MILANO (Department of Energy)

AnciLab

Romanian Energy Center - CRE

RWTH Aachen University

School of Electrical and Computer Engineering of the National Technical University of Athens (NTUA)

SyntraPXL vzw

Universidad Pontificia Comillas

University of Cyprus

Zabala Innovation

ICERT ANONYMI ETAIREIA

And more members will come. As it can be seen, industry and training providers are well represented and the continuous understanding for detecting new skills gaps, and their provisioning is granted.

To successfully implement this strategy, it is necessary to cooperate with other related initiatives and/or groups, such as the following ones:

- Large Skills Partnership for renewable energy. The Partnership on Digitalisation of the Energy System should explore the possibility to cooperate with it on common issues, in accordance with the Pact for Skills [6]

- The Large Skills Partnership for the digital ecosystem. The Partnership on Digitalisation of the Energy System should explore the possibility to cooperate with it on common issues and involve digital stakeholders that could take an interest.

- Heat Pumps Skills Partnership, exploring the possibility to cooperate with it on common issues.

- The European Digital Innovation Hubs (EDIHS), regionally oriented and acting as one-stop shops supporting companies to respond to digital challenges and become more competitive. EDIHS are well organised within the Digital Europe Strategy [50], funded through their programme [51] and properly catalogued [52] so as to focus on the hubs that are related to the energy sector that will be part of the upcoming GEDI-EU Platform. The 'Gathering Energy and Digital Innovators from Across the EU' (GEDI-EU) platform will gather: on the one hand, the **European Digital Innovation Hubs (EDIHs)** and the **Artificial Intelligence Testing and Experimentation Facilities (AI TEFs)** that focus on energy; on the other hand, the EU network of innovators and research institutions in the Energy Sector set up under the **SET Plan** for increased interaction among these players.

Finally, it is important to mention here the Horizontal Task Force on Skills which has been recently created within the strategic revision of the SET Plan, aiming to create a collaborative forum among all ETIPS.

6 CONCLUSIONS

The energy sector is undergoing dramatic changes mainly due to the pressing need to reduce GHG emissions and combat climate change. All sectors of the energy chain are critically affected, including generation, transmission and consumption. Alongside technological progress, the energy transition needs the appropriate skills in the workforce. This fundamental lack of adequate knowledge is frequently confirmed by the industry, including power system operators, RES stations investors and owners, energy market participants, public authorities and active citizens. This dictates the urgent need for workforce upskilling and reskilling without, of course, neglecting the basic knowledge in science and social studies for the necessary specialisation. Upskilling and reskilling concern a wide range of skills, i.e. management and soft skills, green skills, technical skills related to energy production, transmission, and distribution, hard skills in electrical and mechanical engineering, and digitalisation skills. Among these, the latter are of primary importance due to the rapid changes in digital technologies that drive developments in many fields of human activities.

The transmission and distribution grids are the backbone for the integrated energy system, therefore the successful implementation and operation of smart grid technologies in the energy sector is of vital importance. As the industry continues to evolve, the demand for a skilled workforce proficient in digital technologies will only increase. By investing in training and development in these areas, energy companies can enhance their operational efficiency, improve customer engagement, ensure cybersecurity, and drive innovation, ultimately positioning themselves for success in a rapidly changing energy landscape. The integration of smart grid technologies not only enhances the reliability and efficiency of energy systems but also plays a critical role in the transition to a more sustainable and resilient energy future.

6.1 Future directions and recommendations for upskilling in the energy sector

Upskilling and reskilling of the workforce in the energy sector should be considered as a matter of utmost importance and urgency. This concerns, in particular, the digital skills due to the ongoing rapid advancements in these technologies. Support is needed for further investigations in order to identify more precisely the skill gaps.

The curricula offered by higher education and vocational training institutions need to adopt the necessary changes in education and training for new digital technologies, without neglecting the basic engineering and science. The derivation of a "model" curriculum-framework, easily adaptable to regional and national needs would be helpful.

Research in designing and applying modern educational methods can fill gaps faster. Modern educational methods including application of AI, can be helpful, provided they are used with much care.

Collaboration between industry, education and policymakers should be strongly encouraged and supported. This will ensure that training programmes are aligned with industry needs, while providing opportunities for work-based learning and apprenticeships.

INDEX OF REFERENCES

[1] COM (2025) 90, The Union of Skills.

[2] COM (2019)640. The European Green Deal.

[3] COM (2021)550. “Fit for 55: Delivering the EU’s Climate Target and the way to climate neutrality”.

[4] COM (2022)108. REPowerEU: Joint European action for more affordable, secure and sustainable Energy.

[5] COM (2022)552. Digitalising the energy system – EU action plan.

[6] pact-for-skills.ec.europa.eu

[7] COM (2023)62 “A Green Deal Industrial Plan for Net-Zero Age”

[8] COM (2025) 85 The Clean Industrial Deal: A joint roadmap for competitiveness and decarbonisation.

[9] COM (2023) 757 “Grids, the missing link - An EU Action Plan for Grids”

[10] https.//www.eddie-erasmus.eu

[11] World Economic Forum, The future of jobs report 2025 (https://www.weforum.org/publications/the-future-of-jobs-report-2025/digest/)

[12] https://www.eddie-erasmus.eu/wp-content/uploads/2021/01/D2.2-Current-and-future-skill-needs-in-the-Energy-Sector-v.2.0.pdf

[13] https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20240124-2

[14] https://www.youtube.com/watch?v=RZi5RjDKAH0

[15] https://wrap.warwick.ac.uk/id/eprint/65543/

[16] https://www.science.org/doi/10.1126/science.aav7958

[17] https://eures.europa.eu/top-6-free-platforms-online-courses-2020-05-11_en

[18] https://energialab.tec.mx/en/about-us

[19] https://educate.gast.it.uc3m.es/wp-content/uploads/2019/03/pres_marisol.pdf

[20] https://migrant-integration.ec.europa.eu/sites/default/files/2020-07/SkillsAgenda.pdf

[21] https://resourcecenter.ieee-pes.org/publications/technical-reports/pes_tp_tr120_peec_032624

[22] P. Kotsampopoulos, N. Hatziargyriou, J. Ponocko et al., “Innovative Teaching Methods for Modern Power and Energy Systems”,IEEE PES-TR120, March 2024. [Online] https://resourcecenter.ieee.org/publications/technical-reports/pes_tp_tr120_peec_032624 (accessed Dec. 19, 2024)

[23] Directorate-General for the Information Society and Media (European Commission), Living Labs for user-driven open innovation: an overview of the Living Labs methodology, activities and achievements, 2009.

[24] M. Boronowsky, O. Herzog, P. Knackfuss and M. Lawo, "Wearable Computing - an Approach for Living Labs," 3rd International Forum on Applied Wearable Computing, 2006, pp. 1–8.

[25] https://op.europa.eu/en/publication-detail/-/publication/3f36ebab-4aaf-4cb0-aada-fe315a935eed (accessed Dec. 17, 2024)

[26] MIT, Defining Living Labs, 2021. https://sustainability.mit.edu/defining-living-labs (accessed Dec. 10, 2024)

[27] https://enoll.org/living-labs/#living-labs

[28] https://www.ncl.ac.uk/sustainable-campus/play-your-part/living-lab/

[29] https://www.elab2.kit.edu/english/livinglab.php

[30] https://www.upv.es/entidades/vcampus/en/living-lab-call-for-projects/

[31] https://open-science-cloud.ec.europa.eu/services/interactive-notebooks

[32] https://teachingcommons.stanford.edu/teaching-guides/artificial-intelligence-teaching-guide/defining-ai-and-chatbots

[33] https://hdsr.mitpress.mit.edu/pub/pn3w0aes/release/4

[34] https://educationaltechnologyjournal.springeropen.com/articles/10.1186/s41239-023-00426-1

[35] https://teachingcommons.stanford.edu/teaching-guides/artificial-intelligence-teaching-guide/exploring-pedagogical-uses-ai-chatbots

[36] https://poorvucenter.yale.edu/ai-teaching-examples

[37] https://arxiv.org/abs/2304.06122

[38] https://www.maastrichtuniversity.nl/prompt-library/prompt-library-prompt-templates

[39] https://www.maastrichtuniversity.nl/about-um/education-at-um/edlab/ai-education-maastricht-university/prompt-library

[40] https://www.edx.org/learn/scratch-programming/harvard-university-cs50-s-introduction-to-programming-with-scratch

[41] https://ocw.tudelft.nl/courses/scratch-programming-kids-8/

[42] https://www.edx.org/learn/kids-coding-language

[43] https://iris.who.int/bitstream/handle/10665/325147/WHO-NMH-PND-2019.4-eng.pdf

[44] https://www.ericsson.com/en/about-us/sustainability-and-corporate-responsibility/digital-inclusion/access-to-education/improving-digital-learning-in-schools

[45] https://www.fundaciocatalunya-lapedrera.com/en/mad-science

[46] https://www.climate.gov/teaching/resources/energy-lab-29435

[47] https://digitalisation.ukpowernetworks.co.uk/project/digital-skills-academy

[48] https://www.ukpowernetworks.co.uk/news/digital-jobs-fit-for-the-future

[49] https://www.energy.gov/ceser/cybersecurity-training-utility-workforce

[50] digital-strategy.ec.europa.eu/en/activities/edihs

[51] COM (2021)7911. DIGITAL EUROPE. European Digital Innovation Hubs. Work Programme 2021-2023

[52] JRC catalogue of EDIHS. S3platform.jrc.europa.eu/digital-innovation-hubs-tool

ABBREVIATIONS / GLOSSARY

AI	Artificial Intelligence	
BRIDGE	Project: BRIDGE is a collaborative initiative involving various stakeholders dedicated to addressing four key areas: Smart Grid, Energy Storage, Islands, and Digitalisation Projects	https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/
CEDEFOP	European Centre for the Development of Vocational Training	https://www.cedefop.europa.eu/de
DSO	Distribution System Operator	
DT	Digital Technologies	
EC DG ENER	European Commission Directorate General for Energy	https://commission.europa.eu/about/departments-and-executive-agencies/energy_en
EDDIE	Project: Education for Digitalisation of Energy	https://www.cedefop.europa.eu/en/project-fiches/education-digitalisation-energy-eddie
EDSO	European Distribution System Operators	https://www.edsoforsmartgrids.eu/
ENTSOe	European Network of Transmission System Operators	https://www.entsoe.eu/
ERASMUS+	EU programme for education, training, youth and sport	https://erasmus-plus.ec.europa.eu/
ESCO Framework	European Skills, Competences, Qualifications and Occupations	https://esco.ec.europa.eu/en
ETIP SNET	European Technology and Innovation Platform – Smart Networks for Energy Transition	https://smart-networks-energy-transition.ec.europa.eu/
HVDC	High-Voltage Direct Current	
LLMs	Large Language Models	https://en.wikipedia.org/wiki/Large_language_model
LSP	Large Scale Partnership: Pact for Skills	https://pact-for-skills.ec.europa.eu/index_en
PLC	Programmable Logic Controller	A Programmable Logic Controller (PLC) is a computer that controls electrical systems in industrial settings. PLCs are used to automate processes

R&I	Research and Innovation	
SCADA	Supervisory Control and Data Acquisition	https://en.wikipedia.org/wiki/SCADA
SET Plan	Strategic Energy Technology Plan	https://energy.ec.europa.eu/topics/research-and-technology/strategic-energy-technology-plan_en
TSO	Transmission System Operator	
VET	Vocational Education and Training	
WEF	World Economic Forum	https://www.weforum.org/

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