WP7

D7.2: Skills Trends and Future Skills Gap

Co-funded by
the European Union

101144027 — SEBCoVE — ERASMUS-EDU-2023-PEX-COVE

SEBCoVE
SMART ELECTRICITY FOR BUILDINGS

D7.2: Skills Trends and Identifying Future Skills Gaps

SEBCoVE

SMART ELECTRICITY FOR BUILDINGS

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

Table of Contents

REVISION HISTORY

Rev.	Date	Author	Document Sponsor	Revision Summary
0	28/08/2024	FC, BC, DA	IPP	First Edition
1	29/08/2024	FC, BC, DA	IPP	Corrections

REVIEWERS

Rev.	Date	Author	Document Sponsor	Reviewed
0	09/08/2024	Evaggelos Pomboudakis External reviewer	Digital Mende	YES
1	20/08/2024	Constantinos Andronis Reviewer	Digital Mende	YES

Co-funded by
the European Union

"Skills Trends and Identifying Future Skills Gaps"

Summary

This task aims to address the future skills gaps in the Smart Electricity for Buildings (SEB) sector, ensuring the sustainability of the project beyond its completion by fostering a strong partnership between education and industry. The project will systematically utilize workshops, desk research, brainstorming sessions, and expert interviews to identify and study the emerging roles and training requirements driven by advancements in Internet of Things (IoT), automation, and renewable energy technologies. Part of the focus will be on optimizing photovoltaic and wind energy production, integrating monitoring and storage systems, and enhancing the interaction with electric vehicle charging and energy communities. The outcomes are documented in this report to guide the SEBCoVE curriculum, with updates provided as new trends emerge. The current circumstances in the countries of the project's participants (Greece, Spain, Portugal, Italy, North Macedonia, Germany, and Netherlands) are also emphasized in addition to a comprehensive general analysis.

Introduction

- Background: The SEBCoVE project aims to develop hubs for vocational excellence in smart electricity for buildings, supporting regional specialization and establishing international knowledge hubs for vocational education and training (VET) systems.
- Objectives: The project seeks to create resilient and future-proof VET systems, develop regional centres of vocational excellence (CoVEs), support smart specialization, and establish a curriculum based on EU VET standards.
- Purpose of the Report: To address the future skills gaps in the SEB sector, ensuring the sustainability of the project beyond its completion by fostering a strong partnership between education and industry.

Research Methodology

- Thorough Analysis of Previous Reports and Deliverables: Identification of potential interest points of reports such as D2.2.
- Topics of Interest Definition: Initial scoping of the topic and selection of relevant topics and subtopics.
- Selection of Relevant Literature: Starting by conducting a thorough search for pertinent literature in the field of study. Making use of search engines and databases to locate pertinent sources, such as review articles and essential papers. Review articles have the potential to contextualize other publications in the field and offer a more comprehensive perspective on the subject matter. Some relevant websites and law decrees were also analysed.
- Analysis of Selected Relevant Literature: After selecting the corpus of literature, there is an analysis of each, individually, and then it is decided if that literature is relevant to each of the initially defined topics.
- Writing and Citing: After defining if the literature is relevant to any of the defined topics it is written and properly cited, at all times.

Key Findings

- Technological Impact: Emerging technologies like IoT, building automation, and renewable energy systems are transforming the SEB sector, necessitating new skills and roles for professionals.
- Skills Gaps: There is a critical need for upskilling and reskilling within the SEB sector to meet the demands of these technological advancements, particularly in the areas of smart building systems, energy management, and cybersecurity.
- Regional Differences: Different regions exhibit varying levels of progress and challenges in adopting these technologies, influencing the specific skills required locally.
- Educational Needs: The report emphasizes the importance of updating VET curricula to reflect these changes, ensuring that the workforce is adequately prepared.
- Industry-Education Partnership: Strong collaboration between industry and educational institutions is crucial for addressing the evolving skills needs and ensuring the sector's long-term sustainability.

Implications and Recommendations

- Implications: The scoping of the gaps in skills helps in analyzing the current field of smart electricity in buildings and finding potential points of interest that should be worked on moving forward.
- Recommendations: Periodically scope new potential changes, especially since technology and laws surrounding it are constantly changing.

Connection with Other Activities

Defining Potential Skills and Trades: Establish a base structure in which some specific professions need to collaborate to form a complete and functional building automation system.

Regional Scenario Analysis

Apart from a generalized global analysis, each partner’s regional structure for smart electricity in buildings is individually highlighted.

Conclusion

The SEB sector is undergoing rapid technological evolution, driven by advancements in IoT, building automation, and renewable energy systems. These changes are creating significant skill gaps that must be addressed to ensure the sector’s sustainable growth. Strong partnerships between industry and educational institutions are critical for developing targeted training programs that will equip the workforce with the necessary skills for the future.

Abstract

This document, "Skills Trends and Identifying Future Skills Gaps," explores the evolving field of skills required in the SEB sector. It examines the impact of emerging technologies such as the IoT, building automation, and renewable energy systems on the roles of industry professionals. The report highlights the necessity of addressing these skill gaps through targeted training programs and strong partnerships between education and industry. By identifying future skills needs, the SEBCoVE project aims to ensure the sector's sustainable development and provide insights into curriculum updates necessary for maintaining a competitive workforce in the SEB industry.

1. Introduction to the topic

The SEB sector is undergoing significant transformations driven by rapidly evolving technologies such as the IoT, building automation, and renewable energy systems [1]. These advancements are causing substantial changes in the skills required by industry professionals, particularly electricians, who are now faced with increasingly complex, multidisciplinary tasks. Addressing these skills gaps through targeted training programs and fostering strong partnerships between education and industry is essential for the sector's sustainable development and long-term viability [2], [3].

This report aims to identify and analyze future skills gaps in the SEB sector, focusing on the impact of emerging technologies like IoT, automation, and renewable energy systems. The SEBCoVE project adopts a systematic approach involving workshops, desk research, brainstorming sessions, and interviews with experts from academia, industry, and end-users. By providing practical insights into the new roles and training needed to meet these challenges, the project seeks to equip the workforce with the necessary skills to ensure the successful integration of smart technologies, energy optimization, and advanced monitoring solutions in buildings.

The ultimate goal is to establish a perfect partnership between education and industry, contributing to the sustainability of the SEB sector beyond the project's completion. The outcomes of this study will support the development of updated curricula that address these skill gaps, keeping the SEB workforce at the forefront of innovation.

2. Technological Advancements and Impact on Roles

Technological developments in the construction and manufacturing sectors—such as Building Information Modelling (BIM) and smart sensors—are driving significant changes in the skills required for electro-engineering workers. These advancements, along with initiatives for greater sustainability and circularity, pledges for increasing renewable energy production, and the need to improve the repair of electronic devices, are reshaping the landscape of the SEB sector. In Portugal, for instance, the integration of IoT, automation, and renewable energy systems is not only evolving existing roles but also necessitating the creation of new positions (BIM manager/specialist, IoT integration engineer, RES engineer, circular economy specialist, among others), requiring a comprehensive understanding of these changes to properly educate the workforce [4].

Electro-engineering workers, who install and maintain electronic equipment and systems, are increasingly engaged with digital tools like BIM [5], which allows all participants in a construction project—architects, engineers, contractors, and owners—to collaborate more effectively by sharing and coordinating information in real-time. This technology is already impacting the construction sector, including the electrical field, where workers need to interact with BIM to access information about the installation of electrical equipment such as cables and wiring [6]. Furthermore, the IoT is influencing future electro-engineering work, particularly in the construction sector, where smart sensors are used to monitor and control building systems [7], [8].

As the global energy system undergoes rapid transformation, significant effects are expected in the coming decades. The new EU energy strategy calls for major changes and technological innovations in businesses, further emphasizing the need for upskilling within the SEB sector to keep pace with these developments [9]. The high demand for digital skills among electro-engineering workers, coupled with their frequent need for consultation and technical support roles, underscores the urgency of adapting educational and training programs to meet these evolving needs.

2.1. Impact of IoT, Automation, and Renewable Energy on SEB Sector Roles

Technological advancements, such as the IoT, automation, and renewable energy systems, are rapidly reshaping the SEB sector. These changes necessitate new skills and roles for electricians and other professionals involved in the sector, as the integration of smart technologies into buildings requires proficiency in installing and maintaining interconnected systems, including smart sensors, energy management systems, and automated controls.

This transformation is occurring within a complex EU framework designed to promote the adoption of smart technologies and support the growth of the smart building sector. Central to this framework are initiatives like the European Green Deal (EGD), which aims to achieve a climate-neutral economy and society [10]. The twin transition emphasizes digitalization and sustainability in various sectors, including construction and building management [11]. Supporting these goals, technological standard tools such as BIM [12] and specific regulations like the new Energy Performance of Buildings Directive (EPBD) emphasize energy efficiency while promoting smart building technologies to optimize energy use and enhance occupant comfort [13].

Countries like Spain have leveraged EU funds and national strategies to advance the adoption of smart technologies across all building types, including offices, residential, and industrial buildings [14], [15]. Spain has made significant progress in creating the technological, regulatory, and economic conditions necessary for this transition. Building Automation Systems (BAS) and their advanced counterparts, Building Automation and Control Systems (BACS), along with IoT technology and Renewable Energy Systems (RES), are central to this progress. These systems, often referred to as the "brain" and "nervous system" of smart buildings, have evolved significantly with advancements in open protocols, cloud computing, machine learning, AI, and IoT integration [16]. These advancements are crucial for achieving the performance standards mandated by the EPBD [17].

IoT integration is a significant technological driver for the progress in building automation. For example, IoT enables enhanced data collection and real-time monitoring through BAS, allowing for more interconnected and responsive building environments [18]. This integration of IoT devices within buildings not only facilitates advanced automation routines but also contributes to the broader sustainability goals outlined in the European Green Deal by enhancing energy efficiency and occupant comfort.

The integration of Renewable Energy Systems (RES) into buildings is another critical trend, contributing to the sustainability and efficiency of the built environment, while aligning with the EU's broader goals of achieving Zero-Emission Buildings (ZEB) as stipulated in the EPBD [19]. Technologies like solar photovoltaic (PV) systems, geothermal, wind, and biomass energy are becoming more common, while emerging technologies such as hydrogen fuel cells and energy storage systems (ESS) are beginning to gain traction, depending on geographic and resource availability.

The Netherlands and Germany are also at the forefront of this transformation. The Netherlands, known for its innovation in the buildings and services sector, effectively uses IoT, automation, and renewable energy to drive excellence. IoT enables precise monitoring of various building parameters, such as temperature, humidity, and air quality, which is crucial for system optimization and creating comfortable environments [20]. Automation technologies further enable the creation of intelligent buildings that adjust their systems autonomously, responding to different contexts without human intervention. Renewable energy integration in the Netherlands, particularly through solar and wind technologies, requires professionals with expertise in inverters, batteries, and energy management systems to ensure efficient energy use [20].

In Germany, the integration of IoT with energy networks is revolutionizing the energy sector. With a strong emphasis on innovation, Germany has emerged as a leader in adopting IoT technologies to enhance real-time data monitoring and control, improving efficiency and reducing costs in the energy sector. The adoption of IoT by German companies has increased significantly, from 19% in 2018 to 66% in 2022, reflecting the country's commitment to integrating cutting-edge technologies into its industrial processes [21].

Portugal is also experiencing significant shifts in the SEB sector, driven by the adoption of IoT, automation, and renewable energy technologies. The increasing integration of IoT devices in smart buildings allows for real-time monitoring and control of energy systems, shifting the responsibilities of electricians and energy managers towards more strategic roles that require skills in data analysis, network management, and cybersecurity [22]. Automation technologies streamline building management, reducing the need for manual interventions and transforming traditional maintenance roles into positions focused on overseeing automated systems and optimizing performance using advanced software tools [2], [3], [22] .

The deployment of renewable energy systems, particularly PV and wind energy, further drives the demand for specialized skills in system design, implementation, and maintenance [23], [24], [25].

The workforce in the emerging smart building sector is rapidly evolving in response to these technological advancements. The integration of digital technologies and sustainability practices throughout the building lifecycle—from design and development to operation and management—has led to a shift in occupational roles. Professionals now require interdisciplinary skills, cross-disciplinary collaboration, and a commitment to continuous learning to keep up with the increasingly sophisticated building systems [26], [27]. Training and education are essential to equip the workforce with the necessary knowledge to thrive in this evolving landscape. This need is underscored by the persistent labor shortages in fields like ICT and construction, which are likely to be exacerbated by the twin transition [28].

2.2. New Role Sets Emerging Due to Technological Advancements

The rapid technological advancements in the SEB sector are driving the emergence of new roles, reshaping existing ones, and highlighting evolving skills trends. These changes are creating a dynamic job market characterized by the introduction of both high-level and low/medium-level professional roles, each requiring distinct educational and training pathways.

In Spain, education and training for these roles can be found in universities [29], the VET system [30], and non-formal training offerings. While some of this education is structured as comprehensive study programs, much of it remains dispersed, reflecting the emergent nature of the industry and the lack of more dedicated policies from education and training institutions.

High-Level Professionals (EQF 6 and Above)

- Design Phase:
    - Architect: Overall design of smart buildings in architectural plans.
    - Smart Building Systems Engineer: Designs integrated smart systems.
    - Sustainability Consultant: Advises on the environmental impact of designs.
    - IoT Solutions Architect: Designs the architecture for IoT integration.

- Development Phase:
  - Software Engineer: Develops software for controlling smart systems.
  - Electrical Engineer: Implements electrical systems within buildings.
  - Network Engineer: Installs communication networks.
- Operation & Maintenance Phase:
  - Facility Manager: Oversees the day-to-day operation of buildings.
  - BAS/BACS Specialist: Monitors and maintains Building Automation Systems (BAS).
  - Energy Manager: Optimizes the building's energy usage.
  - IT Systems Administrator: Manages IT infrastructure.
- Management Phase:
  - Building Operations Manager: Ensures all systems meet operational goals.
  - Data Analyst/Building Performance Analyst: Analyzes data to improve efficiency.
  - Cybersecurity Specialist: Secures digital infrastructure.
  - Sustainability Manager: Ensures environmentally responsible operation.

Low to Medium-Level Professionals (EQF 3 to 5)

- Design Phase:
  - Drafting Technician (CAD): Creates drawings for building systems.
  - Electrical Design Technician: Assists in designing electrical systems.
  - HVAC Design Technician: Works on HVAC specifications.
- Development Phase:
  - Electrical Installer: Installs wiring, circuits, and devices.
  - HVAC Installer and Maintenance Technician: Sets up and tests HVAC systems.
  - Low Voltage Technician: Installs and maintains low voltage systems.

    - Smart Systems Installer: Configures smart building technologies [31].
- Operation & Maintenance Phase:
    - Building Maintenance Technician: Performs inspections, repairs, and servicing.
    - BAS Technician: Monitors and maintains BAS.
    - Energy Technician: Monitors energy consumption.
    - IT Support Technician: Manages IT infrastructure.
    - Renewable Energy Technician: Installs and maintains renewable energy systems [32].
    - Smart Lighting Technician: Installs and configures automated lighting.
    - Plumbing Technician: Installs and maintains plumbing systems.
- Management Phase:
    - Facility Coordinator: Assists in day-to-day operational tasks.
    - Energy Management Assistant: Collects and analyzes energy data.
    - Security Systems Operator: Monitors and manages security systems.

Across Europe, other countries are also experiencing similar shifts in the SEB sector. The Netherlands, recognized for its technological avant-garde, has emerged as a pioneer in creating new roles driven by artificial intelligence (AI) and automation. Professionals specializing in cybersecurity, data science, and software development are increasingly in demand, driven by the country's investment in achieving a more sustainable economy. This commitment to innovation is reflected in the Netherlands' ranking as fourth in the European Innovation Scoreboard published by the European Union in 2023 [33]. One other important factor here are Energy Storage Systems (more on chapter 5.).

In Portugal, the convergence of innovative technologies is similarly giving rise to new specialized positions. For instance, the Smart Building Systems Integrator plays a critical role in integrating IoT devices, automation systems, and renewable energy sources into efficient smart building ecosystems [3]. Another emerging role is the Renewable Energy Systems Specialist, who is responsible for designing, installing, and optimizing PV and wind energy systems, with a particular focus on integrating these with storage solutions and electric vehicle charging infrastructure [2], [3]. Moreover, the Energy Data Analyst is becoming increasingly important, analyzing data from IoT devices and automated systems to optimize energy consumption and uncover trends that lead to cost savings and efficiency gains. Cybersecurity Specialists for Energy Systems are also in high demand, ensuring the security of interconnected SEB systems against cyber threats [34].

Germany, a leader in the energy transition and Industry 4.0, is also witnessing the emergence of new roles such as energy consultants specializing in digitalization and sustainability. Additionally, cybersecurity experts are crucial in protecting Germany's increasingly interconnected energy infrastructure. The rise of electric mobility is creating opportunities for professionals skilled in charging infrastructure, battery technologies, and network integration [35]. Despite the global trend towards AI-driven roles, Germans remain cautious, with only 33% of the population using AI, compared to 74% in India and 53% in China [36].

The global movement towards renewable energy and the depletion of fossil fuels are driving the need for innovative algorithms and technologies that enable household appliances to transition from conventional utility networks to renewable energy sources [37]. This transition, essential for addressing the energy crisis and combating global warming, requires a workforce proficient in digital technologies. Workers in the renewable energy sector must retrain and upskill to adapt to the rapid changes brought about by Industry 4.0 [38]. Key competencies for these roles include critical thinking, effective communication, data interpretation from IoT devices, problem-solving, and systems thinking, all of which are essential for optimizing energy production, distribution, and consumption [39].

Advanced communication technologies like 5G require sophisticated skills in areas such as network architecture, radio frequency engineering, cybersecurity, data analytics, and software development, as these technologies involve complex systems for managing high-speed data transmission, low latency, and massive connectivity across diverse devices and applications.

In conclusion, the SEB sector across Europe is evolving rapidly, with new professional roles emerging to meet the demands of a more sustainable, connected, and digitally driven world. From high-level architects and engineers to skilled technicians and energy specialists, the need for a multidisciplinary approach is evident. This approach combines technical expertise, analytical skills, and an understanding of new and evolving technologies, underscoring the importance of education, training, and continuous learning in this dynamic industry.

2.3. Region-specific advancements and their impact

Spain has been making significant progress in creating a facilitating framework to make buildings smarter, focusing on satisfying technological, regulatory, economic, social, environmental, and institutional conditions. For instance, Technological Conditions encompass the development of Digital Infrastructure, adoption of Interoperability Standards, and ensuring Data Security and Privacy. Similarly, Regulatory and Legal Conditions include Supportive Legal Frameworks, Incentives and Subsidies, and the establishment of Building Codes and Standards. However, the implementation of these conditions varies significantly across the country, with disparities evident between urban and rural areas and among different regions, driven by factors such as economic resources, policy focus, climate considerations, and cultural and social priorities [40].

Urban areas and economically advanced regions like Catalonia, Madrid, and the Basque Country lead the way in adopting smart building technologies. These regions benefit from strong infrastructure, significant investment, and proactive policy initiatives. In contrast, rural areas and less industrialized regions, such as Galicia and Extremadura, face challenges related to connectivity, limited economic resources, and a lack of policy focus. Addressing these disparities requires targeted policies that cater to the unique needs and circumstances of different regions. Enhancing digital infrastructure, providing financial incentives, and promoting awareness and training are crucial steps to ensure that the benefits of smart building technologies are equitably distributed across the country.

Globally, other countries have made significant strides in smart building technologies by leveraging regional strengths. The Netherlands, known for its constant innovation, has implemented various technological advances across different regions. The Eindhoven region, for example, is recognized for its concentration of high-tech companies, start-ups, and research centers. Amsterdam serves as a key financial and technological hub, while cities like Delft and Groningen boast excellent research centers. The Dutch excel in online connectivity, with 98% of households having broadband access, ranking second globally in this area [41].

In Portugal, the drive for energy independence and sustainability is transforming the SEB industry with the adoption of new technologies. The country's favorable conditions for renewable energy production, particularly solar and wind, have led to widespread adoption of these technologies, significantly impacting the labor market [42]. Government support for renewable energy and EU initiatives have spurred the implementation of smart grids and energy communities. Advanced technologies in these areas require professionals skilled in integrating distributed energy resources (DERs) with grid infrastructure, managing energy flows within communities, and ensuring regulatory compliance. Furthermore, Portugal's emphasis on energy efficiency in building construction and retrofitting is creating a demand for professionals knowledgeable in energy-efficient technologies and sustainable building practices, including modern HVAC systems, energy-efficient lighting, and eco-friendly materials. These regional successes underscore the need to tailor training and education to the specific demands of the local SEB sector to prepare the workforce for Portugal's energy challenges and opportunities [43].

Germany, with its robust investment in research and development, has created a favorable ecosystem for technological innovation, particularly in smart grid technologies, energy storage solutions, and hydrogen production. The country is a global leader in these areas, supported by agencies like DENA, the German federal agency promoting energy efficiency and renewable energy [44]. Germany also boasts one of the largest technology markets in Europe, particularly in software, with around 100,000 IT companies employing approximately 1.189 million people in 2023 [45].

3. Skills Optimization Areas

3.1. Optimization of PV and Wind Generation

The massive integration of solar power into low voltage networks introduces complex technical challenges like overvoltage, overloading, and interactions with protective equipment, requiring electrical engineers to possess sophisticated knowledge in areas such as dynamic voltage control, load flow analysis, protection coordination, grid stability, power quality, and smart grid technologies to ensure network reliability, stability, and safety.

To increase overall energy output and efficiency in Portugal, PV and wind energy generation must be optimized. Strategies for PV systems include routine maintenance, such cleaning the panels to guarantee optimal absorption of sunlight, and replacing the inverters with new, more energy-efficient versions [46], [47]. Real-time recordings of energy production are made possible by sophisticated monitoring systems, and predictive analytics assists in spotting possible problems before they have an influence on output. Similar to this, wind energy optimization depends on sophisticated turbine control systems that maximize energy capture by modifying rotor speeds and blade angles in response to wind conditions. For wind turbines, predictive maintenance—powered by IoT sensors—is essential because it enables operators to keep an eye on the turbines' condition and take preventative measures to fix problems before they arise [48], [49]. Furthermore, placing PV panels and wind turbines as optimally as possible thanks to thorough environmental study greatly increases the amount of energy produced by both technologies [46], [47], [48], [49].

A broad range of abilities bridging technical and financial knowledge are required for the integration of intelligent systems in the PV and wind energy sectors. To analyze performance indicators and optimize system operations for both technologies, professionals require good data analysis skills. It is crucial to comprehend financial modeling and the workings of the energy market in order to spot chances for boosting profitability through well-considered energy pricing and incentives [50]. Furthermore, optimizing financial gains requires proficiency with smart technology, especially for real-time efficiency tracking and predictive maintenance. Professionals need to be skilled in handling these technologies to maintain top performance and guarantee cost-effectiveness, whether they are overseeing wind turbines or PV systems[46], [49], [50].

Portugal's varied topography and climate need for region-specific approaches to PV and wind energy system optimization. To maximize solar energy year-round in regions with strong solar insolation, like southern Portugal, PV panel orientation and tilt optimization is essential. It's also crucial to integrate PV systems with local energy storage options in areas where grid stability may be an issue [51]. Strong, steady winds along the coast necessitate expertise in wind energy turbine siting and design in order to efficiently capture these wind patterns [52]. Because wind patterns are more changeable in inland regions, turbine response and flexibility must be prioritized. For all technologies, maintaining compliance while reaching the highest levels of sustainability and energy efficiency requires familiarity with regional environmental laws and proficiency with the permitting procedure.

Spain's renewable energy landscape is diverse and dynamic, encompassing solar PV, wind power, hydropower, and emerging technologies like green hydrogen and marine energy [14], [15]. The country benefits from favorable natural conditions and robust policy support, driving a relatively rapid expansion of renewable energy technologies. This transformation varies regionally, with different areas leading in specific technologies. For example, Spain stands out in Europe for Solar PV generation, particularly in the southern regions such as Andalucía, Extremadura, and Murcia, due to their high levels of sunshine [53].

Solar PV generation is exploited in various forms depending on the scale, application, and installation type. Primary forms include residential PV systems, commercial and industrial PV systems, and utility-scale solar PV farms. Integrating solar PV systems into smart buildings enhances energy efficiency, reduces operational costs, and supports environmental sustainability. Recent advancements in the solar PV industry have significantly impacted the efficiency, cost-effectiveness, and versatility of solar energy systems. Notable innovations include Perovskite Solar Cells, Bifacial Solar Panels, improved Solar Tracking Systems, Building-Integrated Photovoltaics (BIPV), High-Efficiency Solar Inverters, Energy Storage Solutions (ESS), AI and Machine Learning for performance optimization, and Recycling Initiatives.

These technological advancements are reshaping the skills required in the solar PV workforce. Workers need to adapt to new technologies and processes, acquiring technical skills in the installation of new solar panels and BIPV systems, digital and data skills for working with smart inverters and grid interactions, ESS skills for installation and maintenance, and sustainability and recycling competencies. Proficiency in digital tools and automation, cross-disciplinary collaboration, customer interaction and education, safety and risk management, and project management are also increasingly important.

Wind power is another major renewable energy source in Spain, with the country being the second-largest producer of wind energy in Europe, after Germany. The northern regions, particularly Galicia, Castilla y León, and Aragón, are rich in wind resources, especially in mountain ranges and coastal areas, making them ideal for wind farm development. Offshore wind power is also gaining attention as a new focus area.

Wind power is utilized in various forms, including onshore and offshore wind farms, distributed wind power projects, hybrid systems (wind-solar, wind-hydro), Vertical Axis Wind Turbines (VAWT), and wind-powered water pumping. VAWTs, in particular, are well-suited for urban environments due to their ability to operate in turbulent wind conditions and their compact design, which allows integration into built environments where traditional turbines might not be feasible.

Advancements in wind power technology are driving improvements in efficiency, cost-effectiveness, and adoption. Key innovations include larger and more efficient turbines, AI for predictive maintenance and performance optimization, wind energy storage solutions (battery integration, compressed air, hydrogen storage), smart grid integration (virtual power plants), renewed interest in VAWTs, digital twins for planning and control, and complex projects such as floating offshore wind turbines.

These advancements are influencing the skillsets required in the wind power sector, creating demand for expertise in installing larger turbines and VAWTs, specialized maintenance for floating turbines, advanced simulation tools, AI for adaptive control systems, management of hybrid systems, environmental and sustainability practices, smart grid technologies, and regulatory compliance. Cross-disciplinary collaboration, advanced project management, health and safety protocols, and adherence to regulatory standards are also increasingly vital.

Significant investments in renewable energy have focused on optimizing both PV and wind energy systems to enhance efficiency and profitability. For PV generation, real-time monitoring systems are crucial for quickly identifying and addressing issues, while maintaining system cleanliness is also essential for optimal performance [54].

Successful integration of intelligent systems in PV plants demands expertise in power electronics, programming, and systems engineering, which helps increase energy production and reduce maintenance costs. The use of solar tracking and energy storage systems further boosts efficiency [55]. Similarly, in the Netherlands, wind energy optimization involves advanced turbine control systems with intelligent algorithms that adjust rotation speed according to wind conditions, thereby maximizing energy output and minimizing turbine wear. AI algorithms play a vital role in forecasting wind conditions more accurately, leading to more efficient energy production. This approach requires skills in wind engineering, data science, programming, and software engineering. The dense electrical grid and high penetration of wind energy in the Netherlands facilitate effective grid management and adaptation to variable weather conditions due to its proximity to the sea [56], [57]. Germany is actively engaged in optimizing its renewable energy systems, focusing on both PV and wind energy. In the realm of PV systems, Germany employs techniques such as performance monitoring, regular panel cleaning, and the integration of advanced technologies. A case study in southern Germany highlights that significant energy autonomy can be achieved, with the most favorable cost-benefit ratio reaching 44%. However, this energy autonomy results in higher supply costs in urban areas and is economically viable primarily in regions with substantial wind energy contributions [58]. Simultaneously, Germany capitalizes on its coastal winds to enhance wind energy generation. The country is dedicated to optimizing wind energy production by selecting ideal locations and performing rigorous maintenance. A 2020 report from Germany reveals that many wind turbines have suffered from inadequate management, leading to increased wear and reduced efficiency. To address these issues, the Fraunhofer Institute for Energy Economics and Power Systems Technology in Kassel has collaborated on the KORVA project. This initiative aims to improve the profitability and efficiency of wind turbines by considering factors such as wear, operational variables, wind conditions, and fluctuating market prices [59].

3.2. Other technologies

Germany, the Netherlands, and Portugal are each leveraging a diverse mix of renewable energy sources to enhance their energy portfolios. In Germany, the focus is on optimizing hydroelectric power and biomass. Although hydroelectric potential is constrained by the country's flat terrain, Germany has adapted water mills for electricity

Co-funded by the European Union

generation and is investing in wave and tidal energy projects along its maritime coastline. Additionally, biomass, supported by the Bundesverband Bioenergie, is used extensively in energy production through large-scale cultivation and operational integration in bioenergy plants [59].

Similarly, in the Netherlands, hydroelectric power is limited but the country has capitalized on wave and tidal energy due to its extensive coastline. Biomass plays a crucial role, with agricultural, forestry, and industrial waste converted into thermal and electrical energy. In 2023, renewable sources such as solar, wind, and hydroelectric power are projected to contribute 48% of the country's electricity, reflecting the Netherlands' substantial commitment to renewable energy [60], [61].

In Portugal, renewable energy sources, including hydroelectricity and biomass, are vital components of the national energy strategy alongside solar and wind energy. Expertise in hydrology, dam operation, and turbine optimization is crucial for maximizing the output of hydroelectric power while maintaining environmental sustainability. Biomass energy also requires proficiency in feedstock management, combustion technology, and emissions control. Integrating these technologies with smart grids demands skills in hybrid system design and management, highlighting Portugal's comprehensive approach to optimizing its diverse renewable energy portfolio [62].

4. Implementation of Monitoring Systems

4.1. Technologies and Methods for Monitoring Energy Systems

Smart technologies—such as actuators, sensors, and artificial intelligence (AI)—are essential for enhancing home and building safety, well-being, productivity, and energy efficiency. Smart homes that use AI can make better decisions and integrate IoT devices for more uses, which will accelerate the adoption of these devices. Precise real-time data gathering is necessary for system monitoring and dynamic adjustment. Future studies should concentrate on creating instruments to record the activity of occupants and improving AI systems for data analysis and dynamic navigation. Geographic Information Systems (GIS) can support data mining with AI by helping to visualize and track actions [63]. AI is essential in the energy sector for managing complicated systems and vast amounts of data, particularly in renewable energy, and for enhancing monitoring, operation, maintenance, storage, and control [64].

Holland in its buildings uses advanced technologies and methods to monitor energy systems. The implementations of these systems are crucial to ensure the optimization of energy production and distribution, thus guaranteeing grid stability. The country uses smart sensors in order to efficiently collect data. It uses advanced data platforms that process and analyze data, plus the benefits of artificial intelligence and machine learning to predict data and make decisions [65].

In Portugal's SEB sector, energy system performance and efficiency depend on sophisticated monitoring systems. Monitoring energy generation, distribution, and consumption with IoT sensors, real-time data analytics platforms, and smart meters is common. These systems monitor energy flow, identify inefficiencies, and enable predictive maintenance [66]. IoT sensors measure voltage, current, and temperature to reveal system performance. Real-time data analytics tools provide actionable insights for dynamic operations. Smart meters in these monitoring systems allow consumers and providers to trace energy usage precisely, which helps manage energy demand and optimize distribution networks [66], [67].

Germany has invested significantly in advanced technologies and methods for monitoring energy systems. Energy sector coupling enables an efficient transition path to achieve climate goals, using a multi-modal energy systems planning approach to support decision-making. The use of synthetic fuels and electrification of the heating

Co-funded by the European Union

sectors allows a high impact on the exchange of electrical energy on the operation and costs of the system [68].

4.2. Skills Needed for Implementing and Maintaining Monitoring Systems

Smart grids driven by big data analytics and the Internet of Things are essential to increasing the dependability and efficiency of electricity generation in the energy industry. They give access to real-time usage data, which helps them streamline processes and save waste. By utilizing AI and machine learning to predict system faults and enable preventative interventions, predictive maintenance may increase the lifespan and efficiency of infrastructure. Employees must be adept at utilizing new technology, deciphering data, and coming to conclusions based on that data. Digital literacy, data analysis, systemic thinking, user-centered design, cross-disciplinary cooperation, and comprehension of societal and cultural ramifications are among the fundamental competencies. In addition to utilizing digital technologies, digital literacy also entails content creation, comprehension of digital ethics, and protection of cybersecurity and data privacy. Future efforts in education and training can be better directed by identifying skill shortages [69].

Currently, it is very important to have qualified people in the respective areas so that the project has a good chance of success. To implement these technologies, professionals in the field of electrical engineering, computer science and industrial automation are needed. Furthermore, understanding data analysis tools and visualization platforms is essential. Given the complexity of these systems, it is essential to implement system security through knowledge of communication networks and cybersecurity [70]. Technical skills and experience are needed to implement and maintain SEB monitoring systems. Installing and configuring IoT sensors and devices to collect energy system data requires expertise. Making educated judgments and increasing system performance requires data analytics abilities to evaluate and comprehend vast datasets. Understanding real-time monitoring and data visualization software is essential for managing and changing energy systems using live data. Cybersecurity abilities are also needed to keep monitoring systems running smoothly and safeguard data [71], [72].

4.3. Region-specific skills and technologies

With the growing evolution in the world of buildings, a new era of intelligent buildings has entered, capable of optimizing energy consumption, as well as improving occupant comfort, thus improving the overall performance of the entire building. Monitoring systems are part of this growth, in which they are crucial in collecting precious data and its subsequent analysis. A project called SMARTeeSTORY will be implemented in historic buildings, not residences, in the Netherlands. This project consists of a system capable of autonomously detecting, interacting with users through specific technologies, the psychological capabilities of users in the building [73].

Monitoring technologies and expertise in Portugal vary by location and energy infrastructure. In locations with a high concentration of renewable energy sources, like the Alentejo region with its many solar energy installations, monitoring systems that can handle fluctuating and decentralized renewable energy production are prioritized. Professionals in these places must be skilled in managing DERs and integrating them with local grids [74]. Advanced turbine monitoring technology that can resist harsh marine conditions may be prioritized in wind-heavy coastal areas. Knowledge of robust sensor technology and experience maintaining systems in harsh settings are needed. Portugal's diversified energy landscape requires monitoring systems to be adapted to area particular for optimal energy management [74].

IoT plays a fundamental role, allowing the collection of important data in real time for subsequent analysis and in search of improvements and correction of faults, thus allowing more efficient energy management and the optimization of production and consumption. German EDGE CLOUD is a system that records energy data for in-depth analysis and assessments and is easy to view through your system [75].

5. Integration with Energy Storage Systems

5.1. Strategies for optimizing generation-consumption

More buffer capacity for electrical systems is required due to growing electricity consumption and growing usage of renewable energy. Systems for storing energy in batteries are efficient and scalable, which makes them useful. With almost 80% of their capacity left, discarded electric car batteries provide an affordable and environmentally friendly storage option. High-energy, high-power, and hybrid applications can be made of these batteries, which will help to promote the expanding use of renewable energy sources [76].

Energy storage systems are important for balancing production from renewable sources with energy demand. Strategies such as price selection, support of auxiliary services for the network and the reduction of demand peaks are prioritized, with greater support from the country in order to guarantee a more efficient optimization of energy generation and consumption. Energy management in Germany through ENERGIEWENDE with an energy transition policy, with the goal of generating electricity using renewable energy sources without resorting to nuclear energy. Alem said he intends to lead the country to a low-cab energy system by 2050 [77].

The Netherlands is one of the European and even global countries that most create optimization strategies, having implemented them with the intention of optimizing the relationship between energy generation and consumption. One of the strategies is the use of energy storage systems, such as batteries or green hydrogen, aiming to be fundamental in balancing electricity supply and demand. Other techniques are for example intelligent energy load management and participation in flexible energy markets. A model studied by the Dutch regional energy strategies program allows the incorporation of indirect costs, allowing the model to have a more complete assessment of the impacts of different investment options and thus help in choosing sustainable solutions [78].

Integrating energy storage technologies in Portugal's SEB sector requires optimizing energy generation and use. Innovative energy management systems (EMS) that dynamically regulate energy flows based on real-time generation and consumption data are key [79], [80]. These systems can store excess solar electricity generated at midday and release it during high demand, leveling energy supply and demand. Demand response programs adjust user consumption to grid needs, optimizing stored energy utilization. Integrating predictive analytics improves energy generation and consumption predictions, maximizing storage capacity [79], [80], [81], [82].

5.2. Skills required for Integrating Energy Storage Systems, Electric Vehicles, and Energy Communities

Portugal's SEB sector needs interdisciplinary skills to integrate energy storage systems, EV charging infrastructure, and energy communities [83], [84]. Professionals must grasp lithium-ion and flow battery technologies and how they optimize renewable energy storage and utilization. This includes competence in EMS, which regulate storage system charging and discharging to balance generation and consumption.

Integration of EV charging systems requires knowledge of smart charging technologies, which modify charging rates based on grid circumstances and renewable energy availability. Vehicle-to-grid (V2G) technology lets EVs consume and return energy to the grid, improving grid stability and energy efficiency [85].

Energy communities require coordination and management abilities. This includes designing systems to share energy storage resources and optimize stored and renewable energy distribution to satisfy community demands. Reducing grid strain during peak usage times requires understanding grid integration, especially in urban areas with dense EV populations. Professionals must also manage regulatory frameworks and incentives to combine storage systems, EV chargers, and energy communities for economic and environmental goals [83], [84]. The ability to repair key components of electric and hydrogen vehicles, such as batteries, charging stations, inverters, fuel cells, and electric motors, is crucial for the future of sustainable transportation, and addressing the current shortage of skilled technicians is essential to support the widespread adoption and reliability of these vehicles, making it imperative that education on these repair skills is prioritized in training programs for future electrical engineers and technicians [86].

Effective integration of energy storage systems in the Netherlands requires a specific set of skills, that is, in each project it is crucial to obtain a group of people qualified for that type of work. Therefore, these professionals need to have in-depth knowledge in electrical engineering, data science and control systems. The ability to model energy systems, optimizing charging and discharging processes is also required, in addition to a full understanding of energy markets and their regulations [87]. The development of charging systems for electric vehicles and energy communities also requires specific skills. Professionals must understand charging infrastructure, intelligent load management, integration with storage systems. More than 50% of people who own electric vehicles charge at home. And in the Netherlands, 4 to 5% of people charge their vehicles at external charging stations [88].

5.3. Region-specific strategies

With the large population living in the Netherlands and the high penetration of renewable energies, they lead to unique challenges and opportunities. Regional strategies focus on distributed storage solutions, such as batteries in residential and commercial buildings. Proximity to the sea enables large-scale energy storage, such as green hydrogen [89].

Local energy supplies and consumption trends must inform Portugal-specific storage system integration options. Energy storage devices are essential for grid stability and energy supply in Madeira [24] and the Azores, which have limited grid connectivity with the mainland. These regions require microgrid management abilities, which use storage systems to balance supply and demand. In EV-heavy cities like Lisbon and Porto, improving EV charging station deployment and connecting them with local storage systems may reduce grid strain during peak charging hours [90]. Understanding the local regulatory context and incentives for energy storage and EV integration is essential for customizing plans to regional demands and guaranteeing efficient and sustainable energy systems across Portugal.

In the integration of energy storage systems, Germany includes promotions of energy communities, so that communities share energy among themselves, optimizing the use of storage systems and reducing dependence on the electrical grid. On the other hand, the country invests in research and development of new technologies, such as long-lasting batteries or thermal storage systems in order to confront the challenges of the energy transition [91].

6. Integration with Existing Information Systems

6.1. Methods for Seamless Integrations

Energy management and SEB operating efficiency require seamless connection with existing information systems. Standardized communication protocols and APIs help new systems and legacy platforms share data. Middleware ensures system compatibility and data flow. Modular and scalable integration frameworks allow incremental legacy system updates without affecting operations. Data normalization and transformation ensures consistency and correctness across interconnected systems by reconciling data formats and structures [92], [93].

Optimal integration of existing monitoring systems and information systems is crucial to avoid redundancy and ensure data consistency. The Netherlands adopts APIS and web services for communicating different services. Furthermore, service-oriented architectures are used to create a flexible and scalable structure. The integration standard facilitates communication between systems when exchanging data. Furthermore, it is important to ensure semantic interoperability in Industry 4.0, such as device lifecycle management and the implementation of flexibility, adaptability and, finally, cybersecurity [94].

Germany faces challenges when integrating new devices, due to the need to find methods to deal with emerging device dynamics and potential failures. These methods, such as the use of open communication standards, application of service-oriented architectures and the implementation of self-configuration mechanisms, are fundamental to ensuring perfect and efficient integration [94].

6.2. Skills Required for Integrating with Existing Information Systems

Integrating new technology with current information systems demands varied technical expertise. Systems analysis and design skills are needed to understand how new components will interact with legacy systems. Communicating with systems requires expertise in data integration techniques like APIs and middleware [95]. Database management and data transformation skills are also needed to synchronize and use data from different sources. The integration process requires project management and change management abilities to avoid disruptions and ensure a smooth transition.

When integrating monitoring systems with existing information systems in the Netherlands, a group of qualified professionals is required. These professionals need solid knowledge in software engineering, systems architecture and databases, as well as skills in programming languages and tools to integrate different systems. It is also essential to understand the business and processes involved [96].

The integration of information systems requires a set of technical skills such as professionals with knowledge in databases, programming languages, systems architecture and software engineering. On the other hand, skills in business analysis, project management and communication are crucial to ensuring the success of system integration [97]. Germany achieved 52% coverage of basic digital skills, compared to the EU average of 55.6%. This puts Germany at 65.3% of the global EU 2030 target, aiming for 80% of the population to have basic digital skills [98].

6.3. Benefits and Challenges of Using Previously Established Information Systems

Using existing information systems reduces deployment costs and time by leveraging infrastructure and data. These systems frequently have established workflows and user familiarity, making technology adoption easier. New system integration may be hindered by scalability and technology compatibility issues. Legacy systems may not be flexible enough for additional functions and real-time data processing, causing performance difficulties. Supporting and updating older systems requires resources and adaptability to changing technology [92], [93], [95].

The use of pre-established information systems in the integration of monitoring systems in smart buildings presents a series of benefits. These benefits are economies of scale, that is, taking advantage of previous investments in IT infrastructure. Reuse of components, reducing development time and cost. Simplified integration, through the existence of interfaces. Access to historical data, making it possible to analyze trends and behaviors. On the other hand, there are challenges such as data compatibility, adaptation of functionalities, security risks and the difficulty in integrating old systems with modern technologies [99].

The use of these pre-established information systems offers advantages such as cost reduction, since we are reusing the system's functionalities. However, not everything is good, as there may be problems with data compatibility, process adaptation and system maintenance [100].

6.4. Regional-specific integration methods and skills

Regional concerns can affect new system integration with information infrastructures in Portugal. In the Alentejo region, where renewable energy projects are abundant, integration approaches may need to accommodate their unique data and communication needs. Professionals in these regions should know renewable energy data formats and procedures. Cities like Lisbon and Porto have considerable smart building and energy management infrastructure; therefore, integration methods may involve harmonizing new technology with complex current systems, requiring urban data management and smart grid knowledge. Regional regulatory restrictions and local standards may affect integration methods, requiring knowledge of local compliance issues and best practices [101].

In the Netherlands there is a high level of digitalization, featuring a robust IT infrastructure facilitating system integration. Cloud integration platforms are common, offering scalability and flexibility. On the other hand, data management and data science skills are essential for ensuring information quality and security, as well as extracting valuable insights [96].

Germany stands out for its systematic approach to information systems integration, as it has an ecosystem of highly developed software providers and integration services. One example is Bitkom, which represents the German IT industry and offers insights into trends and challenges in the sector [102].

7. Future skills and training needs

7.1. Identification of Future Skills

7.1.1. Analysis of Emerging Skills due to Technological Changes

Professionals with a wide range of skills are needed to modernize the electric grid and move toward a smart grid (SG), which uses automation, digital systems, controls, and communication to adapt to the ever-changing needs for electricity. This transition calls for curriculum modifications that put an emphasis on developing students' skills rather than imparting traditional knowledge in order to prepare them for the demands of SGs in the future. Research skills and critical thinking are vital because many new problems don't have established answers. As part of a research-focused strategy, future engineers must be critical, propositional, and objective in order to properly examine and develop technical inquiries. As a result, it is important to introduce students to a methodological framework that places an emphasis on critical analysis, efficient review, and ongoing skill and knowledge development [103].

The Netherlands, as one of the leaders in technological innovation, manages to emerge many skills through the rapid evolution of technologies such as artificial intelligence, big data, internet of things and digitalization. The demand for professionals with skills in data analysis, machine learning, data science and software development is constantly growing. On the other hand, it increasingly requires greater importance in systems modeling, simulation and optimization, due to their increasing complexity. TNO's ambition for 2030 is that 80% of the population of the Netherlands will have a job corresponding to their capabilities, since rapid evolution or the emergence of new technologies leads to constant updating and professionals who do not take this precaution disappear. and young people emerge [104].

Technology is changing the SEB industry, creating new skills. IoT, building automation, and renewable energy technologies require a full review of the skills needed to operate and manage them. This involves comprehending the challenges of integrating new technologies with existing infrastructure and adjusting to rapid energy production and consumption changes [105], [106].

Germany invests significantly in identifying emerging skills and pursuing innovative developments. Digitalization is accelerating the energy sector, driven by technologies such as artificial intelligence, big data and IoT. Training is important to adapt workers' skills to the use of technology. Companies in Germany invest a lot in IT training for their employees, which reflects success in the quality of work [107].

7.1.2. Identification of Role-Specific Skills and Training Needs

The workforce will need to adjust to new skill needs as Industry 4.0 technologies are adopted and the renewable energy sector develops. The demand for supplemental skills will expand as a result of the integration of smart sensors, robots, and automation, which will replace regular activities while increasing the value of non-automated tasks. For remote operations and automation, people with medium- to high-level skills—especially those with ICT and STEM backgrounds—will be crucial. Proficiency in entrepreneurship, business awareness, finance, economics, legal literacy, self-management, problem-solving, and cooperation are also essential multidisciplinary skills. To undertake historically dangerous duties properly and avoid risks, even lower-skilled roles will need digital literacy and ICT capabilities [108].

In the energy system, the future smart grid structure will necessitate core skills in computer programming, advanced mathematics, data management, and software development. The transformation brought by Industry 4.0 will also require professionals to develop problem-solving abilities and soft skills such as proactive attitudes, communication, adaptability, systematic thinking, leadership, and ethical responsibility. Specific skills will vary by subsector; for example, wind power professionals will need expertise in using drones for inspection and specialized skills for offshore environments. Cybersecurity skills will be crucial for managing data on cloud-based platforms. These evolving skill trends provide opportunities for reskilling workers from conventional energy sectors and other industries like construction, military, and manufacturing [108].

Industry 4.0 requires new skills, considering the influence of geographic distance and type of product. In Germany, the metallurgical sector company revealed the need for a hybrid professional profile, combining technical and interpersonal skills. Other important aspects are communication skills, teamwork, product knowledge and command of languages and cultural understanding [22]. A study carried out by McKinsey in Germany predicts that 46% of jobs will be automated by 2025, as it is estimated that 6 million low-skilled jobs will disappear. However, it estimates that 15 million well-qualified roles will be created over the same period [23].

To stay up with technology, SEB positions will need different talents. Smart Building Systems Integrator and Renewable Energy Systems Specialist require system design and optimization skills, while Energy Data Analysts need data interpretation and analytics skills. Targeted training programs for current and future demands require identifying role-specific competencies [106], [109].

7.1.3. Skills Needed for Key Areas

A directory known as the ESCO database is used to identify and classify vocations, skills, competencies, and certifications that are pertinent to the education and labor markets of the European Union [110]:

Technical Future Skills: IoT, Big Data, Artificial intelligence (AI), Sensors technology, Machine learning, Business intelligence (BI), Cloud computing, Collaborative/autonomous robotics, Agile human-machine interfaces (HM), Cyber-physical systems (CPS), Augmented reality (AR), Digital twin, Post-processing, Reverse engineering, ERP systems, Communication among components, equipment (M2M), and environment, Online inspection and monitoring systems, Equipment and process monitoring and its implementation, Traceability, Blockchain, Predictive and proactive maintenance, Computerized maintenance management, Basic digital skills, Basic data input and processing, Advanced IT skills and programming, Advanced data analysis and modelization, Data management-safe storage, Cybersecurity, Use of digital communication tools, E-commerce, Financial literacy, Knowledge and understanding of quality procedures related to digital transformation, Use of drones, Working in confined spaces/heights, Advanced first aid and rescue.

Transversal Future Skills: Advanced communication skills, Negotiation skills, Customer relationship management, Interpersonal skills and empathy, Leadership and managing others, Entrepreneurship and initiative-taking, Risk management, Opportunity Assessment, Adaptability and adapting to change, Continuous learning, Teaching and training others, Critical thinking and decision-making, Cross-functional process know-how, Interdisciplinary thinking and acting, Personal experience, Ethical skills, Cultural empathy, Work autonomously, Active listening, Teamwork skills, Basic numeracy and communication, Advanced literacy, Quantitative and statistical skills, Complex information processing and interpretation, Process analysis, Appropriate linguistic skills, Creativity, Conflict Resolution, Complex problem solving

Co-funded by the European Union

Green Future Skills: Environmental awareness, Energy efficiency, Platforms for energy management of equipment and plants, Monitoring systems of energy consumption, Sustainable resource management, Waste reduction and waste management, Water conservation, Resource reuse/recycling, Knowledge and understanding of international and national standards and legislation, Product life cycle impact assessment, Circular economy, Climate change risk management.

There are numerous skills necessary for the development and maintenance of a smart building. Data analysis and interpretation is important to be thorough in order to collect all the data and be able to analyze it for possible improvements or fault detection. It is extremely necessary these days to use cybersecurity measures to protect data. In these buildings, energy management and optimization with various innovative technologies is crucial. There is a strong integration of renewable sources in the Netherlands, such as wind, hydroelectric and marine energy, among others. Finally, the development of automation systems is also essential, as well as the maintenance of sensors and IoT devices [111].

Germany emphasizes the importance of digital and technical skills for the energy sector. The ability to analyze and interpret large volumes of data is crucial for optimizing energy systems. On the other hand, cybersecurity is increasingly a priority due to the increasing digitalization of the area and possible cyber-attacks. In addition, skills in energy management, integration of renewable energy, building automation and development of smart sensors and IoT are valued [112].

The expanding SEB industry requires several essential skill areas [105], [106], [109], [113], [114]:

- Data Analysis and Interpretation: Actionable insights require expertise in massive dataset analysis. This incorporates data analytics and energy consumption knowledge.
- Cybersecurity: As digital technologies become more integrated, good cybersecurity abilities are needed to secure systems and data. This requires security, threat detection, and response skills.
- Energy management and optimization: Expertise is essential. This involves energy forecasting, efficiency enhancement, and advanced energy management system installation.

- Renewable Energy Integration: Installing renewable energy sources into networks and systems requires skills. This requires understanding solar, wind, and other renewable technology technical needs.
- Implementing Building Automation Systems: Energy efficiency and operational performance demand building automation knowledge. Skills in system design, installation, and management.
- Monitoring and regulating energy systems requires expertise in creating, implementing, and maintaining smart sensors and IoT devices. This covers hardware and software integration and troubleshooting.

7.1.4. Region-specific Skills

Regional energy landscape in Portugal affects required capabilities. Large solar energy installations may require additional solar technology and energy storage integration experts. Areas with many wind farms need wind turbine management and optimization knowledge. Knowing geographical variances helps tailor training programs to local needs [115].

The Netherlands, with its strong tradition in hydraulic engineering and sustainability, presents specific needs such as professionals with knowledge in offshore wind energy, hybrid resource management and adaptation to climate change. Furthermore, knowledge in the circular economy and sustainability is highly valued. In the Netherlands there is one of the most sustainable buildings in the world, THE EDGE. With a multitude of sensors and automated features, the building offers a highly personalized and efficient work environment, using 100% renewable energy, combining intelligent design with advanced technologies. The building is used as a model for future constructions, due to its sustainability, energy efficiency and focus on the well-being of users [116].

Germany has regions with a strong industrial presence, which have skills in industrial automation, digitalization and industry 4.0. Meanwhile, there are regions with a greater concentration of renewable energy, such as the north of the country due to the seacoast, requiring specific skills in solar and wind energy. With increasing digitalization, it is important to get people qualified in artificial intelligence or robotics, as well as digital interaction, adaptability and entrepreneurial thinking. Over the next 5 years, Germany will need at least 700,000 more people with high qualifications in a variety of advanced technologies. On the other hand, many current workers will have to be retrained for current skills [117].

7.1.5. Development of Training Programs

Developing effective training programs is crucial for addressing emerging skills gaps and preparing the workforce for future demands. This involves creating curricula that incorporate the latest technologies and industry practices to ensure that graduates possess relevant, up-to-date knowledge. Upskilling and reskilling initiatives are also vital, with strategies such as specialized training courses, certification programs, and workshops focused on new technologies and methodologies. Collaboration between educational institutions and companies plays a key role in this process, helping to align training with industry needs. Such partnerships can aid in curriculum development, provide practical experience through internships, and ensure that training programs are adaptable to the evolving requirements of the SEB sector. Region-specific partnerships can further enhance this alignment by tailoring training programs to address local industry needs and technological advancements [2], [3], [92], [106], [109], [115].

Students need to be analytical, propositional, and impartial because current and modern subjects will soon be the focus of many modifications and ideas. Standard, well-known solutions, such as those for basic physics or electric circuits, cannot be used to address ongoing topics; instead, teachers must encourage students' critical thinking and research skills rather than providing a traditional method of problem-solving because, in this case, many issues have not yet been identified or have no "standard" solution [118].

Involved Disciplines:

Electrical Engineering: System Theory, System Modeling, Automatic control, Digital Control, Industrial integration, Energy conversion, Power electronics, Signal procession, Transmission and distribution, Three-phase physics, Sensors and actuators, Instrumentation, Numerical methods, Protective relaying, Power Quality, Energy storage, Integration of AC and CD systems, Circuit design.

Computer engineering: Algorithms, System modeling, Information technologies, Information management, Communication and networks, Graph theory and dependence analysis, Asset management applications, Decision making, Database design and management, Machine learning, Pattern recognition, Wireless sensors network, Web design

Other: Standards, Management, Public policy, Marketing, Economics, Maintenance, Ethics, Environmental awareness.

Innovations in IoT, AI, and big data analytics—all key components of Industry 4.0—have the potential to boost productivity, sustainability, and efficiency in the energy industry. The implementation of smart grids and predictive maintenance, facilitated by AI and IoT, has the potential to significantly enhance the dependability and effectiveness of power generation [119].

To meet industry expectations, new cross-disciplinary skill sets are needed for the development and integration of developing Smart Grid technologies. Key goals for undergraduate students to better assist the Smart Grid business have been identified by research. Developing strong software programming skills, gaining practical experience in designing smart grid solutions, creating mathematical models and simulations for smart grid systems, understanding the smart grid business model, and developing cybersecurity skills to guard against cyberattacks are a few of these [120]. Other abilities include managing industrial projects both individually and in teams.

Recommended Smart-Grid curriculum by [118]:

Electric circuits: Passive elements in electric circuits, Type of connection of passive elements, Frequency-domain analysis, AC power analysis, Polyphase circuits, Harmonics

Electric machinery: Main electric machinery, Rotational motion, Newton's law, power relationships, The magnetic field, Electromechanical energy conversion, Machine windings, Winding inductances, Synchronous machine, Asynchronous machine

Hydroelectricity: Overall characteristics and operation

Wind energy: Wind turbine basic structure, Variable speed wind turbine, The back-to-back converters

Photovoltaic: Grid-connected PV systems, Stand-alone PV systems, Inverter power electronics

Electric power: Transmission line parameters

Transmission parameters: Transmission line mathematical model

Renewables' integration: Types of storage systems, Advantages and disadvantages of renewables' integration

Power distribution system, Unsymmetrical failures, and Power system protections: Types of distribution systems, Electric protections, Power line carrier

Smart-Grid: Economic factors, Environmental conditions, Cyber-security, Contribution of solar energy, Contribution of hydropower, Contribution of wind plant

The Netherlands, constantly monitoring rapid technological developments, has invested significantly in the development of training programs in order to become increasingly superior. Higher education institutions, in partnership with companies, are adapting curricula to offer interdisciplinary programs and courses that cover areas such as engineering, computer science and sustainability. On the other hand, the Dutch government supports professional qualification initiatives and encourages continuous learning [111], [121].

Germany has a highly developed professional training system, with strong collaboration between companies and educational institutions. The country invests in continuous training programs to update the skills of professionals. CVs are regularly adapted to meet new job market demands [122].

8. Security and Privacy Concerns

8.1. Cybersecurity Challenges and Solutions for Smart Building Systems

Cybersecurity is difficult with smart building systems with IoT devices, automation, and data analytics. These systems have many interconnected devices and networks, generating several vulnerabilities. Unauthorized access, data breaches, and malicious assaults can interrupt building operations. These issues can be solved with encryption, multi-factor authentication, and software updates. Network segmentation can also mitigate breaches by isolating vital systems from less secure ones. Intrusion detection systems (IDS) and continuous monitoring help identify and respond to attacks in real time [123], [124].

For smart energy systems, IoT offers a new paradigm with substantial advantages like enhanced performance, instantaneous decision-making, and creative experiences. However, interoperability, fragmentation, and security become more difficult as devices become more connected. It's challenging to create IoT devices that can handle data securely, learn intricate patterns, and maintain accuracy [125].

Cyberattacks can affect smart home energy management systems, posing a risk of denial of service and integrity and confidentiality breaches. The likelihood of these attacks is increased by the absence of strong infrastructure and security measures [126].

The Netherlands, as one of the world leaders in technology and innovation, implements security measures in its various systems. The increasing interconnectivity of systems, including IoT, building automation, exposes them to a major cyber threat. There are attacks such as: ransomware, phishing and social engineering that could compromise the operation of the building, causing financial data and possibly in extreme situations, putting the physical safety of the occupants at risk. The Netherlands to combat these attacks uses intrusive detection, advanced cryptographic, and identity and access management systems [127].

The increasing interconnection of devices and systems increases the attack surface, making buildings vulnerable to cyberattacks. In order to reduce these risks, the country invests in research and development of advanced security solutions, which subsequently results in the use of advanced encryption protocols, intrusion detection systems and the use of firewalls. In 2019, nearly 40% of computing systems that were used to control smart buildings were subject to malicious attacks [128].

8.2. Consideration of Data Privacy Regulations and Measures to Protect Occupants' Personal Information

Personal data in smart buildings is protected by data privacy laws like the GDPR [129] in Europe. These laws necessitate strict protection of smart system-collected occupant data. Transparent data gathering, clear consent, and data anonymization to safeguard identities are important. Access controls should limit data access to authorized workers, and data retention regulations should limit personal data storage. To maintain privacy compliance and mitigate vulnerabilities, audits and compliance checks are needed regularly.

Residents' vital signs, including blood pressure, heart rate, body temperature, and sleep duration, are monitored by smart meters and connected appliances. This data is processed in real-time and shared with energy providers and other services. Because of current methods, personal data is frequently exposed without sufficient privacy measures, leaving it open to identification by cybercriminals or unauthorized parties. Residents' security and privacy are seriously threatened by this, underscoring the need for stronger data privacy laws and safeguards for private information [130].

8.3. Regional Perspectives on Security and Privacy Regulations

Smart building systems in Portugal must comply with national and European data protection laws. The GDPR [129] sets strong data privacy standards across the EU, but regional differences can affect implementation These geographical differences must be understood to ensure smart building systems comply with all legislation and manage privacy issues.

The Netherlands, being one of the world's pioneers in the area of smart buildings, has to implement high security standards and regulations. How the Dutch Data Protection Authority plays an active role in supervising and enforcing its rules, this facet being one of the priorities for the Netherlands [131].

There are regions, such as Bavaria, that have a strong automotive industry, posing challenges related to protecting data from electric vehicles in smart parking [132]. Regions with a higher concentration of technology industries experience faster adoption of advanced security standards. On the other hand, regions with historic buildings face challenges with the integration of smart technologies [133].

Co-funded by the European Union

9. Conclusions

The SEB sector is at the forefront of a technological revolution, with innovations such as the IoT, advanced building automation, and renewable energy systems reshaping industry practices. These advancements are not only altering the nature of jobs within the sector but also demanding a new set of skills from professionals. The SEBCoVE project has identified critical skills gaps, particularly in smart building systems, energy management, and cybersecurity, which need to be addressed to ensure the sector's competitiveness and sustainability.

The challenge is compounded by regional disparities in the adoption of these technologies, which result in varying local skills demands. For instance, regions more advanced in implementing smart technologies require a workforce proficient in the latest digital tools and techniques, while other areas may need foundational training to catch up. This variability underscores the need for a tailored approach to skills development across different regions.

Educational institutions, particularly those involved in VET play a pivotal role in bridging these skills gaps. The report highlights the necessity of updating VET curricula to reflect the emerging needs of the SEB sector. This includes incorporating new modules on advanced digital technologies, energy efficiency, and cybersecurity, among others. However, updating curricula alone is not sufficient; there must be a strong, ongoing collaboration between industry and education providers to ensure that training programs remain relevant and responsive to the evolving demands of the workplace.

Moreover, the SEBCoVE project emphasizes that the development of new skills is not just a one-time effort but an ongoing process. As technologies continue to evolve, so too will the skills required by the workforce. Continuous professional development and lifelong learning opportunities will be crucial for keeping the workforce updated and adaptable. Therefore, fostering a culture of learning within the sector, supported by robust industry-education partnerships, is essential for maintaining a skilled, adaptable, and future-ready workforce.

In conclusion, the future of the SEB sector depends on its ability to anticipate and respond to emerging skill needs driven by technological advancements. By addressing the identified skills gaps through targeted education and training initiatives, and by nurturing strong collaborations between industry and educational institutions, the SEB

Co-funded by the European Union

sector can ensure its long-term sustainability and competitiveness in a rapidly changing global field.

References

[1] H. Lund, P. A. Østergaard, D. Connolly, and B. V. Mathiesen, "Smart energy and smart energy systems," *Energy*, vol. 137, pp. 556–565, Oct. 2017, doi: 10.1016/j.energy.2017.05.123.

[2] EU, "New skills for the construction sector to achieve European energy targets," 2021, [Online]. Available: http://www.buildup.eu/en/skills

[3] Visuna, "Power Industry Jobs of the Future: Skills and Career Opportunities." Accessed: Aug. 09, 2024. [Online]. Available: https://visuna.com/power-industry-jobs-of-the-future/

[4] ANACOM, "Utilização da Internet das Coisas (IoT - Internet of Things) 2022." Accessed: Aug. 09, 2024. [Online]. Available: https://www.anacom.pt/render.jsp?contentId=1737942

[5] Autodesk, "BIM Website." Accessed: Aug. 29, 2024. [Online]. Available: https://www.autodesk.com/solutions/aec/bim

[6] Schop, "What products do European electrical installers use BIM for." Accessed: Aug. 27, 2024. [Online]. Available: https://tinyurl.com/26m2llm6

[7] CEDEFOP, "Electro engineering works: skills opportunities and challenges," 2023.

[8] "Construction Blueprint." Accessed: Aug. 27, 2024. [Online]. Available: https://tinyurl.com/2a9wqe63

[9] O. Pilipczuk, "Sustainable Smart Cities and Energy Management: The Labor Market Perspective," *Energies (Basel)*, vol. 13, no. 22, p. 6084, Nov. 2020, doi: 10.3390/en13226084.

[10] European Commission, "Delivering the European Green Deal." Accessed: Aug. 27, 2024. [Online]. Available: https://tinyurl.com/3fwa3fc6

[11] European Comission, "What we do. Together, we can turn your reform agenda into a success. ," 2024, Accessed: Aug. 27, 2024. [Online]. Available: https://reform-support.ec.europa.eu/what-we-do_en

[12] European Comission, “Building Information Modelling (BIM) standardization. ,” 2024, Accessed: Aug. 27, 2024. [Online]. Available: https://publications.jrc.ec.europa.eu/repository/handle/JRC109656

[13] Eur-Lex, “Directive (EU) 2024/1275 on the energy performance of buildings – EPBD. ,” 2024, Accessed: Aug. 27, 2024. [Online]. Available: https://tinyurl.com/bdhtxwxe

[14] Gobierno de España, “Plan de Recuperación, Transformación y Resiliencia (PRTR). .” Accessed: Aug. 27, 2024. [Online]. Available: https://planderecuperacion.gob.es/politicas-y-componentes

[15] Gobierno de España, “Plan Nacional Integrado de Energía y Clima 2021-2030. .” Accessed: Aug. 27, 2024. [Online]. Available: https://tinyurl.com/3xcb75yk

[16] EUBAC, “What are BACS?” Accessed: Aug. 27, 2024. [Online]. Available: https://eubac.org/about/what-are-bacs/

[17] EUBAC, “ La liste de contrôle de conformité BACS avec EPBD en français. .” Accessed: Aug. 27, 2024. [Online]. Available: https://eubac.org/publications/#

[18] H. Smeenk and M. Petock, *Internet of Things for Smart Buildings: Leverage IoT for smarter insights for buildings in the new and built environments* , 1st ed. 2023.

[19] D. Gerring, *Renewable Energy Systems for Building Designers*. New York: Routledge, 2022. doi: 10.1201/9781003297819.

[20] van der Veen, K. Kok, A. van der Veen, S. Doumen, P. Loonen, and C. J. dr Kok, “Transactive Energy in the Dutch Context Citation for published version (APA): Transactive Energy in the Dutch Context.” [Online]. Available: www.tue.nl/taverne

[21] Caburn Telecom, “How IoT in Germany is Driving Innovation.” Accessed: Aug. 27, 2024. [Online]. Available: https://caburntelecom.com/iot-in-germany/

[22] NobleProg, “Internet of Things (IoT) Training in Portugal.” Accessed: Aug. 09, 2024. [Online]. Available: https://www.nobleprog.pt/en/internet-of-things-iot-training

[23] A. Castillo and D. F. Gayme, “Grid-scale energy storage applications in renewable energy integration: A survey,” *Energy Convers Manag*, vol. 87, pp. 885–894, Nov. 2014, doi: 10.1016/j.enconman.2014.07.063.

[24] M. Miguel, T. Nogueira, and F. Martins, “Energy storage for renewable energy integration: the case of Madeira Island, Portugal,” *Energy Procedia*, vol. 136, pp. 251–257, Oct. 2017, doi: 10.1016/j.egypro.2017.10.277.

[25] D. P. Macedo, A. C. Marques, and O. Damette, “The impact of the integration of renewable energy sources in the electricity price formation: is the Merit-Order Effect

occurring in Portugal?," *Util Policy*, vol. 66, p. 101080, Oct. 2020, doi: 10.1016/j.jup.2020.101080.

[26] Verdantix, "The Future Of Smart Building Success Depends On Technology Talent." Accessed: Aug. 27, 2024. [Online]. Available: https://tinyurl.com/4vp6jssx

[27] Buildings, "Help wanted: Tech-savvy talent to lead smart buildings into the future. ." Accessed: Aug. 27, 2024. [Online]. Available: https://tinyurl.com/3y7k7xp8

[28] European Comission, "Employment and Social Developments in Europe (ESDE). Addressing labour shortages and skills gaps in the EU. ." Accessed: Aug. 27, 2024. [Online]. Available: https://tinyurl.com/rt6v77rz

[29] Gobierno de Espanã - ANECA, "Registro de Universidades, Centros y Títulos (RUCT). ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.educacion.gob.es/ruct/consultaestudios?actual=estudios

[30] Gobierno de España - MEFPD, "Títulos de FP por Familias Profesionales. ." Accessed: Aug. 27, 2024. [Online]. Available: https://todofp.es/que-estudiar/loe.html

[31] International Society of Automations (ISA), "Skills for the future: IoT and Smart Sensors ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.isa.org/

[32] P. Barman *et al.*, "Renewable energy integration with electric vehicle technology: A review of the existing smart charging approaches," *Renewable and Sustainable Energy Reviews*, vol. 183, p. 113518, Sep. 2023, doi: 10.1016/j.rser.2023.113518.

[33] InvestInHolland, "The Netherlands is top innovators in EU Innovation Scoreboard. ." Accessed: Aug. 27, 2024. [Online]. Available: https://investinholland.com/news/the-netherlands-ranks-among-top-innovators-in-the-european-innovation-scoreboard/

[34] M. binti Mohamad Noor and W. H. Hassan, "Current research on Internet of Things (IoT) security: A survey," *Computer Networks*, vol. 148, pp. 283–294, Jan. 2019, doi: 10.1016/j.comnet.2018.11.025.

[35] E. Prodi, M. Tassinari, A. Ferrannini, and L. Rubini, "Industry 4.0 policy from a sociotechnical perspective: The case of German competence centres," *Technol Forecast Soc Change*, vol. 175, p. 121341, Feb. 2022, doi: 10.1016/j.techfore.2021.121341.

[36] The Stepstone Group, "Against the Global Trend: Germans View Job Changes Due to Artificial Intelligence with More Calm." Accessed: Aug. 27, 2024. [Online]. Available: https://www.thestepstonegroup.com/english/newsroom/press-releases/against-the-global-trend-germans-view-job-changes-due-to-artificial-intelligence-with-more-calm/

[37] M. S. Aliero, K. N. Qureshi, M. F. Pasha, and G. Jeon, "Smart Home Energy Management Systems in Internet of Things networks for green cities demands and services," *Environ Technol Innov*, vol. 22, p. 101443, May 2021, doi: 10.1016/j.eti.2021.101443.

[38] I. Arcelay, A. Goti, A. Oyarbide-Zubillaga, T. Akyazi, E. Alberdi, and P. Garcia-Bringas, "Definition of the Future Skills Needs of Job Profiles in the Renewable Energy Sector," *Energies (Basel)*, vol. 14, no. 9, p. 2609, May 2021, doi: 10.3390/en14092609.

[39] O. Adepoju, O. Akinyomi, and O. Esan, "Integrating Human-Computer Interactions in Nigerian Energy System: A Skills Requirement Analysis," *Journal of Digital Food, Energy & Water Systems*, vol. 4, no. 2, Dec. 2023, doi: 10.36615/digital_food_energy_water_systems.v4i2.2933.

[40] Gobierno de España, "Ejecución del PRTR." Accessed: Aug. 27, 2024. [Online]. Available: https://planderecuperacion.gob.es/ejecucion

[41] InvestInHolland, "The Netherlands: One of the Best Countries for IT & Tech. ." Accessed: Aug. 27, 2024. [Online]. Available: https://investinholland.com/doing-business-here/industries/it-tech/

[42] T. S. Adebayo, S. D. Oladipupo, I. Adeshola, and H. Rjoub, "Wavelet analysis of impact of renewable energy consumption and technological innovation on CO2 emissions: evidence from Portugal," *Environmental Science and Pollution Research*, vol. 29, no. 16, pp. 23887–23904, Apr. 2022, doi: 10.1007/s11356-021-17708-8.

[43] F. Ribeiro, P. Ferreira, M. Araújo, and A. C. Braga, "Public opinion on renewable energy technologies in Portugal," *Energy*, vol. 69, pp. 39–50, May 2014, doi: 10.1016/j.energy.2013.10.074.

[44] Dena Home, "Deutsche Energie-Agentur ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.dena.de/en/home/

[45] Germany GOV, "Germany - Information and Communications Technology (ICT." Accessed: Aug. 27, 2024. [Online]. Available: https://www.trade.gov/country-commercial-guides/germany-information-and-communications-technology-ict

[46] A. Singh, A. Sharma, S. Rajput, A. Bose, and X. Hu, "An Investigation on Hybrid Particle Swarm Optimization Algorithms for Parameter Optimization of PV Cells," *Electronics (Basel)*, vol. 11, no. 6, p. 909, Mar. 2022, doi: 10.3390/electronics11060909.

[47] T. E. K. Zidane *et al.*, "Grid-Connected Solar PV Power Plants Optimization: A Review," *IEEE Access*, vol. 11, pp. 79588–79608, 2023, doi: 10.1109/ACCESS.2023.3299815.

[48] A. Chehouri, R. Younes, A. Ilinca, and J. Perron, "Review of performance optimization techniques applied to wind turbines," *Appl Energy*, vol. 142, pp. 361–388, Mar. 2015, doi: 10.1016/j.apenergy.2014.12.043.

[49] J. Herbert-Acero, O. Probst, P.-E. Réthoré, G. Larsen, and K. Castillo-Villar, "A Review of Methodological Approaches for the Design and Optimization of Wind Farms," *Energies (Basel)*, vol. 7, no. 11, pp. 6930–7016, Oct. 2014, doi: 10.3390/en7116930.

[50] E. S. Vorm and D. J. Y. Combs, "Integrating Transparency, Trust, and Acceptance: The Intelligent Systems Technology Acceptance Model (ISTAM)," *Int J Hum Comput Interact*, vol. 38, no. 18–20, pp. 1828–1845, Dec. 2022, doi: 10.1080/10447318.2022.2070107.

[51] A. F. A. Castanheira, J. F. P. Fernandes, and P. J. C. Branco, "Demonstration project of a cooling system for existing PV power plants in Portugal," *Appl Energy*, vol. 211, pp. 1297–1307, Feb. 2018, doi: 10.1016/j.apenergy.2017.11.086.

[52] F. M. Camilo, P. J. Santos, P. J. Lobato, and S. B. Moreira, "Optimization of Offshore Wind Power Generation in Response to the 2022 Extreme Drought in Portugal," *Energies (Basel)*, vol. 16, no. 22, p. 7542, Nov. 2023, doi: 10.3390/en16227542.

[53] Red Eléctrica Española, "Las renovables en el sistema eléctrico español. ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.sistemaelectrico-ree.es/informe-de-energias-renovables

[54] Dutch PV Portal, "Electrical Sustainable Energy ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.tudelft.nl/en/ewi/over-de-faculteit/afdelingen/electrical-sustainable-energy/photovoltaic-materials-and-devices/dutch-pv-portal

[55] V. Schepel, A. Tozzi, M. Klement, H. Ziar, O. Isabella, and M. Zeman, "The Dutch PV portal 2.0: An online photovoltaic performance modeling environment for the Netherlands," *Renew Energy*, vol. 154, pp. 175–186, Jul. 2020, doi: 10.1016/j.renene.2019.11.033.

[56] TenneT, "Lighting the way ahead together. ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.tennet.eu/

[57] C. El Mokhi and A. Addaim, "Optimization of Wind Turbine Interconnections in an Offshore Wind Farm Using Metaheuristic Algorithms," *Sustainability*, vol. 12, no. 14, p. 5761, Jul. 2020, doi: 10.3390/su12145761.

[58] M. Kühnbach, S. Pisula, A. Bekk, and A. Weidlich, "How much energy autonomy can decentralised photovoltaic generation provide? A case study for Southern Germany," *Appl Energy*, vol. 280, p. 115947, Dec. 2020, doi: 10.1016/j.apenergy.2020.115947.

[59] German Energy Solutions, "Optimizing the operation and control of wind turbines. ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.german-energy-solutions.de/GES/Redaktion/EN/News/2020/20201215-optimizing-wind-turbines.html

[60] P. W. Gerbens-Leenes, A. Y. Hoekstra, and Th. van der Meer, "The water footprint of energy from biomass: A quantitative assessment and consequences of an increasing share of bio-energy in energy supply," *Ecological Economics*, vol. 68, no. 4, pp. 1052–1060, Feb. 2009, doi: 10.1016/j.ecolecon.2008.07.013.

[61] CBS, "Nearly half the electricity produced in the Netherlands is now renewable ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.cbs.nl/en-gb/news/2024/10/nearly-half-the-electricity-produced-in-the-netherlands-is-now-renewable

[62] J. P. S. Catalão, H. M. I. Pousinho, and V. M. F. Mendes, "Hydro energy systems management in Portugal: Profit-based evaluation of a mixed-integer nonlinear approach," *Energy*, vol. 36, no. 1, pp. 500–507, Jan. 2011, doi: 10.1016/j.energy.2010.10.014.

[63] S. Sepasgozar *et al.*, "A Systematic Content Review of Artificial Intelligence and the Internet of Things Applications in Smart Home," *Applied Sciences*, vol. 10, no. 9, p. 3074, Apr. 2020, doi: 10.3390/app10093074.

[64] A. C. Serban and M. D. Lytras, "Artificial Intelligence for Smart Renewable Energy Sector in Europe—Smart Energy Infrastructures for Next Generation Smart Cities," *IEEE Access*, vol. 8, pp. 77364–77377, 2020, doi: 10.1109/ACCESS.2020.2990123.

[65] L. F. M. van Summeren, A. J. Wieczorek, G. J. T. Bombaerts, and G. P. J. Verbong, "Community energy meets smart grids: Reviewing goals, structure, and roles in Virtual Power Plants in Ireland, Belgium and the Netherlands," *Energy Res Soc Sci*, vol. 63, p. 101415, May 2020, doi: 10.1016/j.erss.2019.101415.

[66] M. Manfren, P. Caputo, and G. Costa, "Paradigm shift in urban energy systems through distributed generation: Methods and models," *Appl Energy*, vol. 88, no. 4, pp. 1032–1048, Apr. 2011, doi: 10.1016/j.apenergy.2010.10.018.

[67] Y. He *et al.*, "An overview of acoustic emission inspection and monitoring technology in the key components of renewable energy systems," *Mech Syst Signal Process*, vol. 148, p. 107146, Feb. 2021, doi: 10.1016/j.ymssp.2020.107146.

[68] C. Müller *et al.*, "Modeling framework for planning and operation of multi-modal energy systems in the case of Germany," *Appl Energy*, vol. 250, pp. 1132–1146, Sep. 2019, doi: 10.1016/j.apenergy.2019.05.094.

[69] O. Adepoju, O. Akinyomi, and O. Esan, “Integrating Human-Computer Interactions in Nigerian Energy System: A Skills Requirement Analysis,” *Journal of Digital Food, Energy & Water Systems*, vol. 4, no. 2, Dec. 2023, doi: 10.36615/digital_food_energy_water_systems.v4i2.2933.

[70] N. Verkade and J. Höffken, “The design and development of domestic smart grid interventions: Insights from the Netherlands,” *J Clean Prod*, vol. 202, pp. 799–805, Nov. 2018, doi: 10.1016/j.jclepro.2018.08.185.

[71] S. O. Duffuaa and A. Raouf, *Planning and Control of Maintenance Systems*. Cham: Springer International Publishing, 2015. doi: 10.1007/978-3-319-19803-3.

[72] nubiral, “Best practices for implementation of IT monitoring systems.” Accessed: Aug. 09, 2024. [Online]. Available: https://nubiral.com/successful-implementation-of-it-monitoring-systems/

[73] BUILD UP, “SMARTeeSTORY Project.” Accessed: Aug. 27, 2024. [Online]. Available: https://build-up.ec.europa.eu/en/resources-and-tools/links/smarteestory-project

[74] Infocontrol, “Monitorização de consumos de energia.” Accessed: Aug. 09, 2024. [Online]. Available: https://www.infocontrol.pt/gestao-de-energia-e-eficiencia-energetica/monitorizacao-consumos-energia/

[75] GEC, “Energy Management.” Accessed: Aug. 27, 2024. [Online]. Available: https://gec.io/en/industrial-solutions/oncite-digital-production-system/energy-management/

[76] B. Faessler, “Stationary, Second Use Battery Energy Storage Systems and Their Applications: A Research Review,” *Energies (Basel)*, vol. 14, no. 8, p. 2335, Apr. 2021, doi: 10.3390/en14082335.

[77] Metron, “Energiewende: The Energy Transition of German Industry .” Accessed: Aug. 27, 2024. [Online]. Available: https://www.metron.energy/blog/energiewende-energy-transition-german-industry/

[78] N. Wang, R. A. Verzijlbergh, P. W. Heijnen, and P. M. Herder, “Incorporating indirect costs into energy system optimization models: Application to the Dutch national program Regional Energy Strategies,” *Energy*, vol. 276, p. 127558, Aug. 2023, doi: 10.1016/j.energy.2023.127558.

[79] C. Tan, S. Geng, Z. Tan, G. Wang, L. Pu, and X. Guo, “Integrated energy system–Hydrogen natural gas hybrid energy storage system optimization model based on cooperative game under carbon neutrality,” *J Energy Storage*, vol. 38, p. 102539, Jun. 2021, doi: 10.1016/j.est.2021.102539.

[80] M. A. Hannan *et al.*, “Battery energy-storage system: A review of technologies, optimization objectives, constraints, approaches, and outstanding issues,” *J Energy Storage*, vol. 42, p. 103023, Oct. 2021, doi: 10.1016/j.est.2021.103023.

[81] F. Castro, J. Soares, B. Canizes, and Z. Vale, “A Brief Review on Optimal Network Planning Considering Energy Storage Systems and Uncertainty,” in *2023 International Conference on Future Energy Solutions (FES)*, IEEE, Jun. 2023, pp. 1–6. doi: 10.1109/FES57669.2023.10182511.

[82] F. Castro, B. Canizes, J. Soares, J. Almeida, and Z. Vale, “Comprehensive Framework for Distribution Network Multi-Investment Expansion Planning: Emissions, Uncertainty, and Resource Remuneration Integration,” *Energy Convers Manag*, vol. 316, p. 118734, Sep. 2024, doi: 10.1016/j.enconman.2024.118734.

[83] C. Srithapon and D. Månsson, “Predictive control and coordination for energy community flexibility with electric vehicles, heat pumps and thermal energy storage,” *Appl Energy*, vol. 347, p. 121500, Oct. 2023, doi: 10.1016/j.apenergy.2023.121500.

[84] Z. Liu *et al.*, “Two-phase collaborative optimization and operation strategy for a new distributed energy system that combines multi-energy storage for a nearly zero energy community,” *Energy Convers Manag*, vol. 230, p. 113800, Feb. 2021, doi: 10.1016/j.enconman.2020.113800.

[85] B. K. Sovacool, L. Noel, J. Axsen, and W. Kempton, “The neglected social dimensions to a vehicle-to-grid (V2G) transition: a critical and systematic review,” *Environmental Research Letters*, vol. 13, no. 1, p. 013001, Jan. 2018, doi: 10.1088/1748-9326/aa9c6d.

[86] I. Komlósi, T. Z. Varga, J. Menyhárt, P. V. De Souza Araujo, and P. Araújo, “Maintenance of Electric and Hybrid Vehicles,” *International Journal of Engineering and Management Sciences*, vol. 5, no. 3, pp. 37–46, Dec. 2020, doi: 10.21791/IJEMS.2020.3.5.

[87] EWT, “Power Systems Engineer.” Accessed: Aug. 27, 2024. [Online]. Available: https://ewtdirectwind.com/vacancies/power-systems-engineer/

[88] T. Unterluggauer, J. Rich, P. B. Andersen, and S. Hashemi, “Electric vehicle charging infrastructure planning for integrated transportation and power distribution networks: A review,” *eTransportation*, vol. 12, p. 100163, May 2022, doi: 10.1016/j.etran.2022.100163.

[89] rijkswaterstaat, “Home.” Accessed: Aug. 27, 2024. [Online]. Available: https://www.rijkswaterstaat.nl/

[90] T. Theodoropoulos *et al.*, "Impact of dynamic EV wireless charging on the grid," in *2014 IEEE International Electric Vehicle Conference (IEVC)*, IEEE, Dec. 2014, pp. 1–7. doi: 10.1109/IEVC.2014.7056234.

[91] BMWK, "Electricity Storage Strategy Fields of action and measures to ensure a persistent and dynamic expansion of electricity storage facilities and their optimal systems integration. ." Accessed: Aug. 27, 2024. [Online]. Available: www.bmwk.de

[92] ACER EU, "Energy Systems Integrations." Accessed: Aug. 09, 2024. [Online]. Available: https://www.acer.europa.eu/green-deal/energy-system-integration

[93] C. Nayanatara, S. Divya, and E. K. Mahalakshmi, "Micro-Grid Management Strategy with the Integration of Renewable Energy Using IoT," in *2018 Internat2018 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC)ional conference on computation of power, energy, Information and Communication (ICCPEIC)*, IEEE, Mar. 2018, pp. 160–165. doi: 10.1109/ICCPEIC.2018.8525205.

[94] D. Del Gaudio and P. Hirmer, "Seamless integration of devices in industry 4.0 environments," *Internet of Things*, vol. 12, p. 100321, Dec. 2020, doi: 10.1016/j.iot.2020.100321.

[95] V. M. Tabim, N. F. Ayala, and A. G. Frank, "Implementing Vertical Integration in the Industry 4.0 Journey: Which Factors Influence the Process of Information Systems Adoption?," *Information Systems Frontiers*, Nov. 2021, doi: 10.1007/s10796-021-10220-x.

[96] *Towards an Integrated Health Information System in the Netherlands*. OECD, 2022. doi: 10.1787/a1568975-en.

[97] Ferdinand-Braun-Institut, "IT Specialist for Systems Integration ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.fbh-berlin.de/en/career/apprenticeship/it-specialist

[98] Digital Skills and Jobs Platform., "Germany: a snapshot of digital skills ." Accessed: Aug. 27, 2024. [Online]. Available: https://digital-skills-jobs.europa.eu/en/latest/briefs/germany-snapshot-digital-skills

[99] C. Marnewick, "Benefits of information system projects: The tale of two countries," *International Journal of Project Management*, vol. 34, no. 4, pp. 748–760, May 2016, doi: 10.1016/j.ijproman.2015.03.016.

[100] J. L. Hernández, I. de Miguel, F. Vélez, and A. Vasallo, "Challenges and opportunities in European smart buildings energy management: A critical review," *Renewable and*

Sustainable Energy Reviews, vol. 199, p. 114472, Jul. 2024, doi: 10.1016/j.rser.2024.114472.

[101] INESCTEC, "Portugal contributed to the digitalisation of the European electricity sector with interoperable solutions that connect homes and buildings to the grid." Accessed: Aug. 09, 2024. [Online]. Available: https://www.inesctec.pt/en/press-releases/portugal-contributed-to-the-digitalisation-of-the-european-electricity-sector-with-interoperable-solutions-that-connect-homes-and-buildings-to-the-grid#content

[102] Wissenschaftsregion Bonn, "Fraunhofer Institute for Applied Information Technology FIT. ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.wissenschaftsregion-bonn.de/en/wissenschaftseinrichtungen/forschungseinrichtungen/fraunhofer-institut-fuer-angewan/

[103] P. Ponce, L. Ibarra, O. Mata, and A. Molina, "How to develop research skills among undergraduate engineering students to tackle current ongoing topics? A Smart-Grid case study," *The International Journal of Electrical Engineering & Education*, vol. 58, no. 2, pp. 113–141, Apr. 2021, doi: 10.1177/0020720918816004.

[104] TNO, "80% of Dutch working people to have a job that matches their skills." Accessed: Aug. 27, 2024. [Online]. Available: https://www.tno.nl/en/newsroom/insights/2024/05/ambition-2030-dutch-working/

[105] I. Arcelay, A. Goti, A. Oyarbide-Zubillaga, T. Akyazi, E. Alberdi, and P. Garcia-Bringas, "Definition of the Future Skills Needs of Job Profiles in the Renewable Energy Sector," *Energies (Basel)*, vol. 14, no. 9, p. 2609, May 2021, doi: 10.3390/en14092609.

[106] opito, "Future Skills." Accessed: Aug. 09, 2024. [Online]. Available: https://opito.com/future-skills

[107] F. Lukowski, M. Baum, and S. Mohr, "Technology, tasks and training – evidence on the provision of employer-provided training in times of technological change in Germany," *Studies in Continuing Education*, vol. 43, no. 2, pp. 174–195, May 2021, doi: 10.1080/0158037X.2020.1759525.

[108] I. Arcelay, A. Goti, A. Oyarbide-Zubillaga, T. Akyazi, E. Alberdi, and P. Garcia-Bringas, "Definition of the Future Skills Needs of Job Profiles in the Renewable Energy Sector," *Energies (Basel)*, vol. 14, no. 9, p. 2609, May 2021, doi: 10.3390/en14092609.

[109] futureenergyskills, "Future Energy Skills." Accessed: Aug. 09, 2024. [Online]. Available: https://futureenergyskills.com.au

[110] I. Arcelay, A. Goti, A. Oyarbide-Zubillaga, T. Akyazi, E. Alberdi, and P. Garcia-Bringas, "Definition of the Future Skills Needs of Job Profiles in the Renewable Energy Sector," *Energies (Basel)*, vol. 14, no. 9, p. 2609, May 2021, doi: 10.3390/en14092609.

[111] EngD, “Smart Buildings & Cities”, Accessed: Aug. 27, 2024. [Online]. Available: https://www.4tu.nl/bouw/Education/SBC/

[112] O. Ogunleye *et al.*, “Improving resilience and efficiency in the energy sector: A perspective on cybersecurity and renewable energy storage.,” *International Journal of Scientific Research and Management (IJSRM)*, vol. 12, no. 05, pp. 502–513, May 2024, doi: 10.18535/ijsrm/v12i05.m01.

[113] G. U. Aliagha, A. P. T. Goh, M. N. Abdullah, N. M. Jaafar, and S. E. Eluwa, “Investigating Skill Gaps in Green Building Skills for Energy Efficiency,” *Adv Mat Res*, vol. 1073–1076, pp. 1282–1287, Dec. 2014, doi: 10.4028/www.scientific.net/AMR.1073-1076.1282.

[114] T. A. Branca *et al.*, “Skills Demand in Energy Intensive Industries Targeting Industrial Symbiosis and Energy Efficiency,” *Sustainability*, vol. 14, no. 23, p. 15615, Nov. 2022, doi: 10.3390/su142315615.

[115] EDP, “Skills for Future.” Accessed: Aug. 09, 2024. [Online]. Available: https://www.edp.com/pt-pt/yes-areas/skills-future

[116] The Edge, “EDGE.” Accessed: Aug. 27, 2024. [Online]. Available: https://edge.tech/buildings/the-edge

[117] Stiferverband, “Future skills: Which skills are lacking in Germany.” Accessed: Aug. 27, 2024. [Online]. Available: https://www.stifterverband.org/medien/which-skills-are-lacking-in-germany

[118] P. Ponce, L. Ibarra, O. Mata, and A. Molina, “How to develop research skills among undergraduate engineering students to tackle current ongoing topics? A Smart-Grid case study,” *The International Journal of Electrical Engineering & Education*, vol. 58, no. 2, pp. 113–141, Apr. 2021, doi: 10.1177/0020720918816004.

[119] O. Adepoju, O. Akinyomi, and O. Esan, “Integrating Human-Computer Interactions in Nigerian Energy System: A Skills Requirement Analysis,” *Journal of Digital Food, Energy & Water Systems*, vol. 4, no. 2, Dec. 2023, doi: 10.36615/digital_food_energy_water_systems.v4i2.2933.

[120] N. Elatky, J. Hoang, M. Elwell, R. Harkins, J. Cruz, and J. Li, “Developing Power Engineering Education and Learning for Next-generation Smart Grid Workforce,” in *2023 ASEE Annual Conference & Exposition Proceedings*, ASEE Conferences. doi: 10.18260/1-2--42280.

[121] Government NL, “Encouraging Innovation.” Accessed: Aug. 27, 2024. [Online]. Available: https://www.government.nl/topics/enterprise-and-innovation/encouraging-innovation

[122] CEDEFOP, "New study-integrated training programmes in Germany ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.cedefop.europa.eu/en/news/new-study-integrated-training-programmes-germany

[123] S. Wendzel, J. Tonejc, J. Kaur, and A. Kobekova, "Cyber Security of Smart Buildings," in *Security and Privacy in Cyber-Physical Systems*, Wiley, 2017, pp. 327–351. doi: 10.1002/9781119226079.ch16.

[124] I. Lee, "Internet of Things (IoT) Cybersecurity: Literature Review and IoT Cyber Risk Management," *Future Internet*, vol. 12, no. 9, p. 157, Sep. 2020, doi: 10.3390/fi12090157.

[125] T. Ahmad and D. Zhang, "Using the internet of things in smart energy systems and networks," *Sustain Cities Soc*, vol. 68, p. 102783, May 2021, doi: 10.1016/j.scs.2021.102783.

[126] M. S. Aliero, K. N. Qureshi, M. F. Pasha, and G. Jeon, "Smart Home Energy Management Systems in Internet of Things networks for green cities demands and services," *Environ Technol Innov*, vol. 22, p. 101443, May 2021, doi: 10.1016/j.eti.2021.101443.

[127] S. Dong, J. Cao, D. Flynn, and Z. Fan, "Cybersecurity in smart local energy systems: requirements, challenges, and standards," *Energy Informatics*, vol. 5, no. 1, p. 9, Dec. 2022, doi: 10.1186/s42162-022-00195-7.

[128] Marsh, "Smart and intelligent buildings: Cybersecurity considerations ." Accessed: Aug. 27, 2024. [Online]. Available: https://www.marsh.com/en-gb/services/risk-consulting/insights/smart-intelligent-buildings-cyber-security-considerations.html

[129] GDPR.EU, "What is GDPR, the EU's new data protection law?" Accessed: May 14, 2024. [Online]. Available: https://gdpr.eu/what-is-gdpr/

[130] M. S. Aliero, K. N. Qureshi, M. F. Pasha, and G. Jeon, "Smart Home Energy Management Systems in Internet of Things networks for green cities demands and services," *Environ Technol Innov*, vol. 22, p. 101443, May 2021, doi: 10.1016/j.eti.2021.101443.

[131] Home, "Autoriteit Persoonsgegevens. ." Accessed: Aug. 27, 2024. [Online]. Available: https://autoriteitpersoonsgegevens.nl/

[132] B. F. G. Fabrègue and A. Bogoni, "Privacy and Security Concerns in the Smart City," *Smart Cities*, vol. 6, no. 1, pp. 586–613, Feb. 2023, doi: 10.3390/smartcities6010027.

[133] DKE, "DKE/ DINROADMAP." Accessed: Aug. 27, 2024. [Online]. Available: www.dke.de

Co-funded by the European Union

GERMANY

GREECE

ITALY

NETHERLANDS

NORTH MACEDONIA

PORTUGAL

SPAIN

Co-funded by
the European Union

101144027 — SEBCoVE — ERASMUS-EDU-2023-PEX-COVE

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Education and Culture Executive Agency (EACEA). Neither the European Union nor EACEA can be held responsible for them.

SEBCoVE.eu

LinkedIn

Facebook