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Definition of the Future Skills Needs of Job Profiles in the Renewable Energy Sector

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Abstract: The growth of the renewable energy industry is happening at a swift pace pushed, by the emergence of Industry 4.0. Smart technologies like artificial intelligence (AI), Big Data, the Internet of Things (IoT), Digital Twin (DT), etc. enable companies within the sector of renewable energies to drastically improve their operations. In this sectoral context, where upgraded sustainability standards also play a vital role, it is necessary to fulfil the human capital requirements of the imminent technological advances. This article aims to determine the current skills of the renewable energy industry workforce and to predict the upcoming skill requirements linked to a digital transition by creating a unified database that contains both types of skills. This will serve as a tool for renewable energy businesses, education centers, and policymakers to plan the training itinerary necessary to close the skills gap, as part of the sectoral strategy to achieve a competent future workforce.

Keywords: renewable energy; skills; Industry 4.0; jobs; digitalization; future

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1. Introduction

The renewable energy sector includes all sorts of technologies that obtain energy from renewable resources: wind power, solar power, hydro power, geothermal power, marine power, and biofuels [1]. Renewable energies are major actors in the transition towards a climate-neutral economy, as they outpace conventional energy sources, contributing to the decarbonization needed to counter climate change [2]. The sector has gained significance over the last decades, as proven by the increasing share of renewable energies in the global energy market [3].

The evolution of renewable energies is partly driven by the digitalization of industry, also known as Industry 4.0. It can be defined as the fourth industrial revolution and it consists of the adoption of advanced digital technologies, namely IoT, Big Data analytics, and cyber-physical systems, that enhance the productivity and performance of the industry [4].

Achieving sustainability is also a key aim of Industry 4.0, which enables the efficient consumption of material and energy resources [5]. Therefore, the renewable energy sector benefits from industry-wide digital transformation, as the changes led by Industry 4.0 in most sectors will presumably favor the use of renewable energy resources, thus increasing their presence and share in the energy system [6].

Moreover, digitalization within the renewable energy sector can help boost its development prospects and competitiveness as it will improve the flexibility, generation, and efficiency of renewable energy supply [7]. Digital technologies such as IoT, AI, and blockchain allow the optimization of renewable assets as well as enabling the creation of smart grids, new energy transfer modes, improvement of the system operation, eased integration of electric vehicles and energy storage technologies into the grid, stimulation of

energy trade interactions without the need of a central authority, and decentralized storage systems [8–10].

Overall, the benefits provided by digitalization include supporting decarbonization by increasing the share of renewable energy sources; providing new business model opportunities within the future decentralized energy system; enhancing the efficiency of energy generation, distribution, and consumption; and ensuring a reliable, cost-competitive, and secure energy supply for end-users [11].

To accommodate the renewable energy sector to Industry 4.0 development, human resources need to be competent in digital technologies and capable of overcoming the challenges associated with the rapid evolution of the sector. For that purpose, the creation of a suitable workforce for the future renewable energy sector involves the upskilling and reskilling of current workers of the sector and akin industries [12]. For the sector to successfully introduce digital technologies, transition to new systems, and change internal processes, a sufficiently updated workforce is needed, regarding its competences, skills, and knowledge.

Achieving the desired pool of professionals must be the goal of a sectoral level strategy that effectively provides the skills demanded by the market for the 2025–2030 period, bridging the gap between present and future skills. This strategy focuses on determining the future requirements for renewable energy sector professionals, as well as evaluating the current state of the workforce in order to align industry efforts into obtaining the desired future skills. To do so, renewable energy sector companies, training centers, and policymakers should collaborate in the creation of training programs that ensure the acquisition of such competences by the future workers of the sector.

This research responds to the renewable energy sector's need to define a skills strategy for the 2025–2030 period, by generating a job profile database that incorporates future skills needs for the selected professionals linked to the sector. Eventually, it will serve as a tool for the creation of such educational itineraries as a baseline that outlines the mismatch between current and future skills in the renewable energy sector.

The article is divided into the following sections: Section 2 shows a literature review of the latest evolutions of the renewable energy sector and changes coming from the digitalization of industry. These trends lead to a change in the skill needs of the renewable energy sector, as discussed in Section 3.1. Then, Section 3.2 introduces the proposed procedure shown for deploying the skill needs onto specific profiles of the renewable energy sector by means of a sector-wide skills strategy; followed by, in Section 3.3, detailing the development of the database that contains current and future skills needs for professional profiles of the renewable energy sector. Finally, in Section 4, main conclusions of the research are discussed and future research pathways are suggested.

2. The Effect of Digitalization on the Renewable Energy Sector

The conventional power system is rapidly experimenting transformation due to digitalization, electrification, and decentralization, which unlock opportunities for the inclusion of renewable energy sources into the energy system. Digitalization allows controlling great amounts of data to provide additional functionalities such as the optimization of operations, new business models, the improvement of performance, and closer control to real-time [8]. This section presents the latest evolutions of the renewable energy sector, mainly coming from the digitalization of industry. For this aim, we carried out an extensive desktop research on these digital technologies as well as on their effect on the sector, focusing on the most relevant literature.

Due to the decentralized, variable, and unpredictable nature of renewable energy sources [13], a smart system that controls and solves intermittency [14] as well as allowing a highly distributed grid [15] is needed. A smart grid is the result of digitalizing the traditional electric power system to facilitate the integration of renewable energy sources [15]. The smart grid infrastructure is based on IoT: it connects energy generation to consumption with bidirectional devices such as sensors and smart meters [16].

In addition to renewable energy source integration, with the inclusion of distributed energy resources, the appearance of prosumers, and the connection of dynamic mobile loads like electric vehicles, the power flow will increase in complexity, both on the supply and demand side, which will bring additional challenges to the smart grid [17].

The structure of the conventional, unidirectional, and centralized grid is already being transformed by the inclusion of distributed energy resources, which are defined as multi-input and multi-output energy systems powered by small-scale technologies and with IT platform integration potential [8,18,19].

Prosumers, defined as consumers that either produce energy from renewable energy sources to cover their power needs or generate surplus energy to transfer to the grid, are emerging agents on the energy market [20–22]. Energy storage applications such as Power-to-X will gain importance as enablers of renewable energy integration while decoupling energy generation from demand [8].

Hence, coordinated management of the electric grid is needed in order to effectively control bidirectional energy transactions between supply and demand [23]. For that purpose, virtual power plants allow grouping nearby generators and controlling them according to energy demand, electricity market prices, and distance to the generators among other parameters.

Ultimately, the conventional centralized power grid will become the IoE (Internet of Energy) [17]. Benefits of the smart grid include flexible electricity distribution, a permanently controlled system, reduction of losses, improved efficiency, balanced supply and demand, and the integration of renewable energy sources and energy storage technologies [16]. Consequently, smart grids ought to be a crucial infrastructure to foster the energy transition by increasing the use of renewable energy [7].

However, due to Internet-based protocols and inherent security risks in the general IT environment, smart grid possesses a high vulnerability to cyber-attacks. Thus, it is necessary to consider cyber-security by appropriately constructing the network and applying sufficient countermeasures [16]. Blockchain is a technology that guarantees security for peer-to-peer (P2P) transactions in the energy field. This technology enables the creation of P2P networks that do not need trusted controller or centralized processing units, so it can become a key tool for a decentralized energy system [10]. Additionally, blockchain applications for energy systems include carbon tracking, smart device connections, distributed energy systems transactions, energy trading platform enabler, electric vehicle charging, and energy production source certificates [24].

A digital twin is a virtual replica of a physical component or system that accurately depicts the status of the element empowered by data and simulation [25]. Energy suppliers can use the obtained data from digital twins for failure detection at the grid [13]. Therefore, digital twins are key enablers for the integration of renewable energy sources in smart grids, as they can predict, monitor, control, and diagnose energy supply [26]. Another application of digital twins is the monitorization of renewable energy generators as both physical damage and performance can be forecasted and modeled [27–31].

Renewable energy technologies can improve performance supported by better maintenance of the equipment through its lifespan [32]. For that purpose, predictive maintenance is an ever-growing strategy within the renewable energy sector to minimize O&M (operations and maintenance) cost [33]. In addition to DT, AI, Big Data, machine learning, and IoT are used in the renewable energy sector to analyze and monitor real-time data gathered by sensors [33–36]. Modeling equipment behavior leads to early detection of damage, performance tracking, operation optimization, and the prevention of failures and inefficiencies [33].

Forecasting is essential to avoid the uncertainty and variability of renewable power generation, particularly for wind and solar energies. Solutions based on cloud computing, machine learning, and AI can improve the detail and accuracy of such kinds of renewable energy sources [8].

Essentially, Industry 4.0 possesses several energy sustainability applications such as smart energy management, energy sector transformation, and new business models among others [5], which means it fosters great opportunities for renewable energy sector development. Industry 4.0 can technically contribute to the adoption of a renewable energy system by providing flexibility, improving traceability, enhancing efficiency and reducing consumption [13].

Nevertheless, the digitalization of the renewable energy sector has several drawbacks brought by the issues associated with Industry 4.0 such as cyber-security risks, the shortage of skilled workers, the need for substantial investment, and resistance to change from workers [37]. The digital evolution of the sector will also limit job creation [38], whereas highly qualified workers with the knowledge of digital technologies will always be needed by the sector [39].

3. Identification of the Skills Needs of the Renewable Energy Sector Job Profiles

In this section, current and future skills requirements for the renewable energy sector are identified. For this aim, a literature review was performed on the skills trends influencing the renewable energy sector and the obtained findings are presented in Section 3.1, regarding the impact of the digitalization of the industry in Section 2. Afterwards, a sectoral long-term skill strategy is proposed in Section 3.2, with the aim of fulfilling future skills requirements. Lastly, in Section 3.3, the methodology and results of our research are presented: the development of a database of skills for the renewable energy sector.

The aim of this paper is precisely to generate the sectoral database that contains job profiles from the renewable energy sector containing both current and forthcoming skills. To do so, future skills requirements were forecasted, regarding industry's upcoming digitalization and transformation. Eventually, this database will serve as a framework for designing the necessary training programs to obtain the required skills by the future workforce of the renewable energy sector, as part of the sectoral skill strategy. Stakeholders such as education centers, renewable energy companies, and policymakers will benefit from the use of the database to ease the creation of the aforementioned training programs.

3.1. Renewable Energy Sector Skills Trends

Envisioning the evolution of the renewable energy sector is essential for future skills requirements to be identified, as they accommodate the changes undergone by the sector, fueled by the adoption of Industry 4.0. The inclusion of smart sensors, robots, and automation entailed by Industry 4.0 will demand change in the skills of the workforce [40].

Automation and robots will substitute certain aspects of tasks that are routine; organized in a standardized, discrete, and predictable manner; with no need for social interaction and low-level education requirements, whereas work that involves creativity, sociability, and full autonomy exceeds the capabilities of advanced AI [41,42]. Furthermore, automation increases productivity, and higher productivity augments the value of non-automated tasks performed by workers. Hence, the demand for supplementary skills to automation is rising [43].

In the renewable energy sector, the demand for medium-skilled (supervisory/ technician/skilled crafts) and high-skilled (professional/managerial) [44] professionals will increase, as the growth of remote operation and automation requests ICT (information and communications technology) skills and STEM (science, technology, engineering, and mathematics) skills for these profiles.

Moreover, interdisciplinary knowledge linked to social initiatives and new business models will be required: entrepreneurship, business and customer awareness, finance, economics, legal literacy, self-management, problem-solving, and team working [45–47]. However, ICT skills and digital literacy will also be demanded for lower-skilled profiles such as technicians, to substitute traditionally hazardous tasks and therefore contribute to the reduction of risks [42,48].

As for the energy system, regarding the future smart grid structure that will foster renewable energy sources, skill needs for future professionals on the field are described thereupon. Despite its high level of automation, the smart grid based on IoT and cloud computing will require professionals managing the grid to acquire core computer programming skills, higher mathematical knowledge, data management skills, and software hard skills. Additionally, the adoption of such Industry 4.0 elements will result in a transformation of roles such as operators becoming employees with problem-solving skills [10].

Soft skills will also be a key factor for the successful development of the smart grid, such as a proactive and dynamic attitude, advanced communication skills, adaptability to change, systematic thinking, leadership skills, and the ability to assume social and ethical responsibility [49].

In addition, the smart grid embedded in a web-based platform allows other operating agents such as renewable energy sales agents to create, manage, and publish content regarding smart grid application services for end-users without the necessity of specific web programming [49].

The technology differs depending on the renewable energy source; thus, some subsectors require specific skills linked to the sectoral-particular evolution of technology. Within the wind power subsector, onshore wind power and offshore wind power share the specific skill need use of ROVs (remotely operated vehicles) such as drones [45,50,51] for remote inspection, surveillance, and damage detection of wind turbines. Furthermore, offshore wind future professionals will require particular skills regarding the marine environment where activities will take place: deep-sea exploration skills [45], advanced first aid and rescue [51], working in confined spaces/at heights [42], and team living skills [42,51].

Cyber-security skills and related knowledge will be needed to properly manage potential safety risks linked to the use of data on cloud-based platforms, as well as for maintaining the security of sensible information [52,53].

As the literature proposes, the skills mentioned above will have to be developed so that the sector achieves a relevant level of domain in them. Complementarily, other mainly digital and sustainability-oriented skills must be included, as these skills are already targeted in other sectors, such as the food sector [54], the oil and gas sector [55], the civil engineering sector [56], and the machine tool sector [57].

Meeting these skill trends in the future brings the opportunity for reskilling and upskilling workers from conventional energy industries, namely coal, gas, and oil sectors [42], but skill transfer can also come from sectors like construction, military, or industry [45].

3.2. Long-Term Skills Strategy Proposal

Developing a sectoral strategy is decisive to achieve a competent workforce with the skills required by the future renewable energy sector. This will serve as a guide to address and close the breach between the skills expected by the industry and the actual capabilities of the professionals.

For that purpose, the proposed long-term strategy for the renewable energy sector is to incorporate several phases described hereafter. The long-term strategy proposal of the renewable energy sector is based on an already tested procedure. This procedure is the one that the ESSA (European Steel Skills Alliance) project is following [58] to upgrade the steel job profiles to the future needs of the sector. This procedure is considered valid as, among others, it has been honored by a Social Impact award [59].

3.2.1. Assessment of the State of the Digitalization of the Renewable Energy Sector

Firstly, the state of the art of the renewable energy sector with regards to its digitalization needs to be comprehensively analyzed. From this evaluation, the direction the sector moves towards can be extracted, regarding technology and innovation, as well as sustainability and the economic factor [58], in addition to the changes to be undergone by professional profiles and internal operations in the renewable energy sector.

The obtained results will be the upcoming sectoral technological advances and their associated required skills, and they will portray the immediate future of the sector.

3.2.2. Determination of Future Skill Requirements of the Sector

Once the future scenario of the renewable energy sector is obtained, job profiles, and future skills demanded by the sector are defined, considering the changes undergone by the digitalization and development of Industry 4.0. Then, the skills gap between the current and upcoming industry requirements is identified.

The creation of the database that contains skills requirements of the future for professional profiles within the renewable energy sector collects the findings from all the previous research work on skills and the digitalization of the sector. This automated database will consider skills shortages and construct future skills need accordingly. Eventually, the database will serve as a benchmark for job profiles and skills to be demanded in the renewable energy sector.

3.2.3. Creation of Training Programs to Obtain the Required Skills

For future professionals to acquire the skills demanded by the enterprises from the renewable energy sector, universities and education centers should offer the proper itinerary of training [60]. This includes adapting not only training content but also the methodology used to educate. For example, synergies between dual education pathway students and industry veterans are proposed, as the former lack knowledge of internal processes but excel at IT (information technology) skills, whereas the latter present the opposite.

In addition, training programs should cover internal workplace training as it is a major enabler for Industry 4.0 [61] and could promote its development within the renewable energy sector. Furthermore, training programs both for educational and business frameworks should be kept up to date according to the evolution of skills requirements as the renewable energy sector transitions promoted by the digitalization of industry.

If this phase is successfully performed, the renewable energy sector will achieve a highly competent workforce that will meet industry expectations and procure a shared benchmark for sectoral skills requirements.

3.2.4. Acquisition of Talent

The final stage of the strategy aims to engage a highly valuable workforce that fulfils renewable energy sector demands. Promoting optimal talent acquisition and recruitment will result in the inclusion of professionals suited for the challenges brought by digitalization in the industry.

3.3. Development of the Database for the Renewable Energy Sector

This section consists of the creation of a database that integrates professional profiles from the renewable energy sector that contain both current and future skill needs per job position. The database will be used as a guide for the later design of training programs, as stated by the second phase of the strategic plan presented in the previous section.

3.3.1. Methodology

This work was developed following the procedures employed by our research team in the elaboration of studies [54–57]: findings from the literature review in Sections 2 and 3.1 and European skills/competences, qualifications, and occupations (ESCO) framework were collated with experts on the matter in order to validate the identified future skills requirements of the renewable energy sector. Figure 1 shows the summary of the methodology of this research.

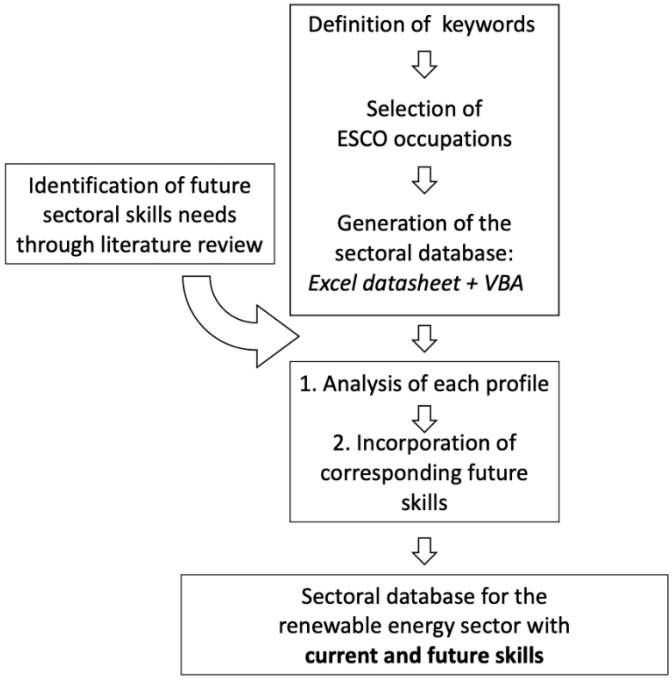

Figure 1. Summary of the methodology.

The ESCO database, which is an initiative managed by the European Commission, is the starting point from which this work emerges. It is a directory that identifies and categorizes skills, competences, qualifications, and occupations relevant for the European Union labor market and education and training, as well as showing the relationships between the different concepts [62]. The skills pillar of ESCO involves 13,485 concepts structured in a hierarchy that contains four sub-classifications. Each sub-classification targets different types of knowledge and skill/competence concepts: (a) knowledge, (b) skills, (c) attitudes and values, and (d) language skills and knowledge. In addition to the hierarchy, subsets of skills can be accessed through: (a) a transversal skill hierarchy, (b) a collection of languages, or (c) a collection of digital skills. In our research, the ESCO database was the main source for the selection of job profiles and their current skill needs.

In order to identify the renewable energy sector related professional profiles, we determined the keywords ("renewable", "solar", "wind", "hydro", "geothermal", "bio", "power", and "energy") directly connected with the sector, which the title of the profile should include.

Then, keywords were introduced as search terms in the ESCO database; among the resulting 67 occupations obtained from keyword searches, we identified 19 sector-related ones through a detailed analysis. Occupations labeled as "engineer", "technician", "plant operator", or "consultant" were considered, as well as occupations including "renewable energy" or "sustainable" in their description and/or in their corresponding skills/competences. Table 1 demonstrates the keywords and the ESCO occupations selected from the search.

After identifying the relevant profiles, we used ESCO database to define the current skills needs. Then, the ESCO profiles along with solely current skills and knowledge, were inserted into an Excel spreadsheet. Next, through Excel's VBA (visual basic for applications) automated process, the initial database containing current skills for the identified job profiles of the renewable energy sector was generated.

Table 1. The key terms related to "renewable energy" and 19 ESCO occupations identified after the analysis.

Key Term	Id.	Identified Occupation	ESCO Description
Renewable	1	Renewable energy consultant	Renewable energy consultants advise clients on the advantages and disadvantages of different renewable energy sources. They conduct surveys and interviews to research demand of and opinions on renewable energy, and strive to advise clients on the most advantageous source of renewable energy for their purpose.
	2	Renewable energy engineer	Renewable energy engineers research alternative sources of energy in order to design systems for renewable energy production. They strive to optimize energy production from renewable sources and reduce production expenses and environmental strain. They design systems that focus on energy sustainability and efficiency.
	3	Renewable energy sales representative	Renewable energy sales representatives assess clients' energy supply needs and attempt to secure sales of renewable energy methods. They promote renewable energy suppliers and the use of renewable energy products and liaise with consumers to increase sales.
Solar	4	Solar energy technician	Solar energy technicians install and maintain systems that collect solar energy. They prepare the necessary fixtures, often on roofs, install solar panels, and plug them into an electronic system including an inverter to connect the solar energy systems to the electricity lines.
	5	Solar energy sales consultant	Solar energy sales consultants provide advice on solar energy for domestic or industrial purposes, and aim to promote the use of solar energy as an alternative and more sustainable source of energy. They communicate with prospective clients and attend networking events to ensure increased sales of solar energy products.
	6	Solar energy engineer	Solar energy engineers design systems that generate electrical energy from sunlight, such as photovoltaic systems. They design and construct systems that optimize the energy output from solar power and the sustainability of the production process of solar systems.
	7	Solar power plant operator	Solar power plant operators operate and maintain equipment that produces electrical energy from solar power. They monitor measuring equipment to ensure the safety of operations and that the production needs are met. They also react to system problems, and repair faults.
Wind	8	Wind turbine technician	Wind turbine technicians maintain and repair wind turbines by performing diagnostic inspections, analyzing faults, and performing repair duties. They ensure the wind turbines operate in compliance with regulations, and assist the wind engineers in the construction of wind turbines. Wind turbine technicians may also test and install hardware and software components of wind turbines.
	9	Wind energy engineer	Wind energy engineers design and install wind energy farms and equipment. They research and test locations to find the most productive location, test equipment such as wind-turbine blades, and develop strategies for more efficient energy production and environmental sustainability.
Geothermal	10	Geothermal power plant operator	Geothermal power plant operators operate and maintain equipment, often steam-driven turbines, which produce electrical energy. They monitor measuring equipment to ensure the safety of operations, and that the production needs are met. They also react to system problems and repair faults. They may regulate the generators to control the flow of electricity to the power lines.
Hydro	11	Hydropower engineer	Hydropower engineers research, design, and plan the building of facilities that generate electricity from the movement of water. They search optimal locations, conduct trials, and try different materials to achieve the best result. Hydropower engineers develop strategies for more efficient energy production and analyze environmental consequences.
	12	Hydropower technician	Hydropower technicians install and maintain systems in hydropower plants. They perform inspections, analyze problems, and carry out repairs. They ensure that the turbines operate in compliance with regulations and assist the hydropower engineers in the construction of turbines.
	13	Hydroelectric plant operator	Hydroelectric plant operators operate and maintain the equipment used in the production of energy from the movement of water. They monitor the measuring equipment, assess the production needs, and adapt the water flow to meet these needs. They also perform repairs and maintenance duties.
Bio	14	Biochemical engineer	Biochemical engineers research in the field of life science striving for new discoveries. They convert those findings into chemical solutions that can improve the wellbeing of society such as vaccines, tissue repair, crops improvement, and green technologies.

Table 1. *Cont.*

Key Term	Id.	Identified Occupation	ESCO Description
Power	15	Biogas technician	Biogas technicians work in the derivation of gas from organic matter and produced as landfill gas or digested gas. They operate equipment in biogas plants, perform tests and maintenance tasks, and take action in the event of a failure.
	16	Power production plant operator	Power production plant operators maintain and operate the equipment in power stations and other energy production plants. They repair faults, operate machinery directly or from a control room, and handle materials related to electricity production in compliance with safety and environmental procedures. They facilitate interaction between electrical energy facilities, ensuring that distribution occurs safely.
Energy	17	Electric power generation engineer	Electric power generation engineers design and develop systems that generate electrical power, and develop strategies for the improvement of existing electricity generation systems. They strive to conciliate sustainable solutions with efficient and affordable solutions. They engage in projects where the supply of electrical energy is required.
	18	Energy engineer	Energy engineers design new, efficient, and clean ways to produce, transform, and distribute energy to improve environmental sustainability and energy efficiency. They extract energy through natural resources, such as oil or gas, or renewable and sustainable sources, such as wind or solar power.
	19	Energy systems engineer	Energy systems engineers supervise energy conversion and distribution processes. They analyze the energy supply and consumption efficiency developing new ways to improve the existing processes, taking into account both the technical and the financial aspects. They also study the environmental impact of energy usage and combine the production of renewable energy in the current power systems.

Subsequently, we needed to determine the future skills needs. Since ESCO's content did not involve future skills demands particularly about digitalization, we carried out a research based on literature review about the forthcoming skills requirements of the selected profiles. As a result, we utilized other references dealing with the future skills requirements of the machine tool sector. For this reason, an expanded literature review was executed (Section 3.1), associated with the research on the digitalization and diffusion of Industry 4.0 in the renewable energy sector (Section 2). Furthermore, the other main reference of future skills was the work on the machine tool sector elaborated by this research team [57].

The following step was to analyze each professional profile to identify whether it would transform due to digitalization and technology advances in the sector, based on desktop research findings. The future skills requirements demanded by the renewable energy sector must be guaranteed by these professional profiles. We assume that future profiles will correspond to the selected current professional profiles, and although we presume there will be new occupations in the future that do not currently exist, the design and definition of those goes beyond the scope of this research. Thus, we consider that the existing professional profiles will cover the future skills requirements of the sector, noting that proficiency for each skill will differ among profiles.

After the analysis, identified skills were fed to the initial database manually. The decision-making was backed up by expert opinions on the matter as part of the process of introducing specific future skills for the selected profiles. Moreover, the identified skills were only deemed future skills if they were not already in the ESCO database. The incorporation of future skills to the professional profiles ended with the verification of the professional profiles meeting the future skills demand of the renewable energy sector. Lastly, the automated sectoral database was finalized, containing both current and future skills needs.

3.3.2. Results and Discussion

The aim of this research was to generate a sectoral database incorporating the renewable energy-related professional profiles along with their current and future skill needs.

As described in the methodology, Section 3.3.1, we extracted the professional profiles and their skill requirements from ESCO's content to generate the database. Therefore, our main desktop research focused on identifying the specific and general skills that will be needed by the renewable energy sector workforce in the near future. The defined future skills can be divided into three main categories: technical skills, transversal skills, and green skills, as shown in Tables 2–4.

Table 2. List of selected future technical skills for the renewable energy sector workforce. Reprinted from Akyazi, T.; Goti, A.; Oyarbide-Zubillaga, A.; Alberdi, E.; Carballedo, R.; Ibeas, R.; and Garcia-Bringas, P. 2020.

Technical Future Skills for the Renewable Energy Sector
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
Deep-sea exploration skills
Use of drones
Working in confined spaces/heights
Advanced first aid and rescue

Then, we identified the future skill need of each selected profile. The database, which is the main outcome of the methodology, was completed. It integrated all the current skills included in the ESCO database and the identified additional future skills.

As an example, the "renewable energy engineer" job profile (Table 5) shows the appearance of the database and the information displayed for every tab corresponding to each professional profile. The top four rows of the table make up the occupational group classification in a graded order: "Renewable energy engineer" is a professional profile part of the "engineering professionals not elsewhere classified" group, which belongs to the "engineering professionals (excluding electrotechnology)" upper group, included in the "science and engineering professionals" group. Each professional profile is provided with a

URL to the profile on the ESCO website, alternative labels for naming the job, a description of the profile, and a unique number that is the international occupation code for the ISCO (International Standard Classification of Occupations). The skills and knowledge required for the professional profile are listed consecutively, both current and future.

Table 3. List of selected future transversal skills for the renewable energy sector workforce. Reprinted from Akyazi, T.; Goti, A.; Oyarbide-Zubillaga, A.; Alberdi, E.; Carballedo, R.; Ibeas, R.; and Garcia-Bringas, P. 2020.

Transversal Future Skills for the Renewable Energy Sector
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 adapt 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

Table 4. List of selected future green skills for the renewable energy sector workforce. Reprinted from Akyazi, T.; Goti, A.; Oyarbide-Zubillaga, A.; Alberdi, E.; Carballedo, R.; Ibeas, R.; and Garcia-Bringas, P. 2020.

Green Future Skills for the Renewable Energy Sector
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

Table 5. Sample job profile tab from the database.

Professionals
Science and engineering professionals
Engineering professionals (excluding electrotechnology)
Engineering professionals not elsewhere classified
Renewable energy engineer
ESCO URL: http://data.europa.eu/esco/occupation/ab7bccb2-6f81-4a3d-a0c0-fca5d47d2775 (accessed on 30 January 2021)
renewables engineer//project engineer, PV array//project engineer, renewables//renewable energy technology engineering specialist//renewable energy engineering specialist//renewable energy technology engineer//renewable energy systems engineer//asset engineer, renewable power//project engineer, offshore wind//renewable energy engineering adviser//renewable power engineer//renewable energy technology engineering adviser//turbine engineer//renewable energy engineering expert//renewable energy engineering consultant//renewable energy technology engineering expert//industrial energy engineer//wind turbine project engineer//renewable energies engineer//renewable energy technology engineering consultant//project engineer, energy efficiency.
Renewable energy engineers research alternative sources of energy in order to design systems for renewable energy production. They strive to optimize energy production from renewable sources, and reduce production expenses and environmental strain. They design systems that focus on energy sustainability and efficiency.
ISCO number: 2149
Essential
Knowledge
Civil engineering Electrical engineering Engineering processes Environmental engineering Fluid mechanics Industrial heating systems Mechanical engineering Mining, construction, and civil engineering machinery products Power engineering Renewable energy technologies Solar energy Technical drawings
Adapt energy distribution schedules Adjust engineering designs Approve engineering design Carry out energy management of facilities Design wind turbines Ensure compliance with safety legislation Inform on government funding Make electrical calculations Manage engineering project Perform project management Perform scientific research Promote sustainable energy Provide information on geothermal heat pumps Provide information on solar panels Provide information on wind turbines Research locations for wind farms Use CAD software Use technical drawing software Use thermal management

Table 5. *Cont.*

Optional
Knowledge
Electric generators Electrical power safety regulations energy market Energy performance of buildings engineering principles Power electronics
Skill/Competence
Analyze energy consumption Assess project resource needs Coordinate electricity generation Create AutoCAD drawings Develop material testing procedures examine engineering principles Identify energy needs Inspect facility sites Inspect wind turbines Maintain photovoltaic systems Manage contracts Oversee quality control Prepare technical reports Report test findings Troubleshoot Use software tools for site modeling
Future skills
Essential
IoT Big Data Artificial intelligence (AI) Augmented reality Knowledge and understanding of quality procedures related to digital transformation Sensors technology Machine learning Cloud computing Digital twin Communication among components, equipment (M2M), and environment Traceability Advanced IT skills and programming Advanced data analysis and modelization Data management-safe storage Cybersecurity Use of digital communication tools Risk management Opportunity assessment Adaptability and adapt to change Critical thinking and decision-making Cross-functional process know-how Interdisciplinary thinking and acting Advanced literacy Quantitative and statistical skills Appropriate linguistic skills Complex problem solving Environmental awareness Energy efficiency

Table 5. *Cont.*

Platforms for energy management of equipment and plants
Climate change risk management
Knowledge and understanding of international and national standards and legislation
Monitoring systems of energy consumption
Entrepreneurship and initiative taking
Continuous learning
Complex information processing and interpretation
Waste reduction and waste management
Sustainable resource management
Water conservation
Circular economy
Risk management

Table 5 is described as a smart table because changing the name of the job profile will return the tab with the information associated with the introduced term. This feature turns the database into a very useful and easy to use tool, as it allows instant access to the searched professional profile.

A sample of the resulting database from this research is provided in Table 6, which displays 4 tabs of job profiles from the renewable energy sector. Each profile contains the information from ESCO and the selected future skills, our contribution to the database and the product of this research. The future skills are retrieved from the identified skills as shown in Tables 2–4. The complete database that contains all the selected professional profiles for the renewable energy sector is available as Supplementary Materials.

The generated database is very significant for the sector since it involves all the information about the sector-related job profiles. Since it is an automated database and also a smart table; training providers, companies, and universities have very quick access to the data related to the profile that they want to work with. Our main contribution to the database is the identification of the future skills for each profile through a detailed analysis. These addressed skill demands will be the fundamental part of the next generation training programs.

The database generated through this research may contribute to the evolution and upgrade of the ESCO database, which would result in improved usability for users.

Moreover, findings from this research were endorsed by industry insiders and experts on the matter. Selected profiles and future skills requirements for the renewable energy sector were reviewed and validated, proving the generated database to become a key tool in the development of a sectoral strategy for the successful development of the sector in the Industry 4.0 context.

Table 6. Preview of some tabs from the generated database of job profiles from the renewable energy sector.

Job Profile	**Renewable Energy Sales Representative**	**Wind Turbine Technician**	**Solar Energy Engineer**	**Electric Power Generation Engineer**
ESCO URL	http://data.europa.eu/esco/occupation/ff3a164d-4045-4511-a472-49093dabf9fc (accessed on 30 January 2021)	http://data.europa.eu/esco/occupation/98562ce3-9632-4226-b129-c67eb9c54f0f (accessed on 30 January 2021)	http://data.europa.eu/esco/occupation/42dbb769-4c91-47dc-bd16-ec8e70c4180f (accessed on 30 January 2021)	http://data.europa.eu/esco/occupation/58db3ac6-5217-4d46-8a4c-126598be1d13 (accessed on 30 January 2021)

Table 6. *Cont.*

Job Profile	**Renewable Energy Sales Representative**	**Wind Turbine Technician**	**Solar Energy Engineer**	**Electric Power Generation Engineer**
Alternative labels	renewable energy sales consultant//residential alternative energy sales representa-tive//renewable energy sales promoter//residential renewable energy sales representa-tive//alternative energy sales consultant//alternative energy salesman//alternative energy sales negotiator//renewable energy sales negotiator//renewable energy seller//renewable energy salesperson//alternative energy saleswoman//alternative energy sales rep//renewable energy saleswoman//renewable energy sales rep//alternative energy salesperson//alternative energy seller//renewable energy salesman//alternative energy sales promoter	wind plant technician//off-shore wind turbine maintenance technician//wind turbine maintenance technician//wind turbine repair technician//off-shore wind turbine repair technician//wind farm worker//on-shore wind turbine inspection technician//wind turbine inspection technician//wind turbine service technician//off-shore wind turbine inspection technician//on-shore wind turbine maintenance technician//offshore wind turbine worker//on-shore wind turbine repair technician//windfarm worker m,f,n)//wind turbine array worker//wind energy installer//wind turbine worker//onshore wind turbine worker	solar energy technology engineering specialist//solar energy engineering expert//solar energies engineer//solar energy engineering specialist//solar energy systems engineer//solar engineer//solar energy technology engineering adviser//solar energy engineering adviser//solar power engineer//solar energy technology engineer//solar energy technology engineering consultant//solar energy technology engineering expert//solar energy engineering consultant	power station engineer//electricity generation engineer//power plant project engineer//power supply engineer//electric power station engineer//power generation networks engineer//power plant engineer//gas generation engineer//electric power plant engineer//electric power plant project engineer//quality and electric power engineer//production and electric power engineer//electric power supply engineer//energy generation engineer//control and electric power engineer//power generation systems engineer
Description	Renewable energy sales representatives assess clients' energy supply needs, and attempt to secure sales of renewable energy methods. They promote renewable energy suppliers and the use of renewable energy products, and liaise with consumers to increase sales.	Wind turbine technicians maintain and repair wind turbines by performing diagnostic inspections, analyzing faults, and performing repair duties. They ensure the wind turbines operate in compliance with regulations, and assist the wind engineers in the construction of wind turbines. Wind turbine technicians may also test and install hardware and software components of wind turbines.	Solar energy engineers design systems which generate electrical energy from sunlight, such as photovoltaic systems. They design and construct systems which optimize the energy output from solar power, and the sustainability of the production process of solar systems.	Electric power generation engineers design and develop systems which generate electrical power, and develop strategies for the improvement of existing electricity generation systems. They strive to conciliate sustainable solutions with efficient and affordable solutions. They engage in projects where supply of electrical energy is required.
ISCO number	3322	7412	2149	2151
	Essential	Essential	Essential	Essential
	Knowledge	Knowledge	Knowledge	Knowledge

Table 6. *Cont.*

Job Profile	Renewable Energy Sales Representative	Wind Turbine Technician	Solar Energy Engineer	Electric Power Generation Engineer
	Characteristics of products Characteristics of services Renewable energy technologies Sales argumentation Sales strategies Solar energy	Electrical power safety regulations Electricity Electronics Mechanics Types of wind turbines	Electrical engineering Energy Energy market Engineering principles Engineering processes Power engineering Solar energy Technical drawings Thermodynamics Types of photovoltaic panels	Electric current Electric generators Electrical engineering Electrical power safety regulations Electricity Energy Engineering principles Engineering processes Renewable energy technologies Technical drawings
	Skill/competence	Skill/competence	Skill/competence	Skill/competence
	Advise on heating systems energy efficiency Answer requests for quotation Assess customers Carry out sales analysis Identify customer's needs Identify energy needs Inform customers on energy consumption fees Inform on government funding Manage contracts Promote sustainable energy Provide information on geothermal heat pumps Provide information on solar panels Provide information on wind turbines	Arrange equipment repairs Ensure equipment maintenance Follow safety procedures when working at heights Inspect wind turbines Install electrical and electronic equipment Maintain electrical equipment Maintain electronic equipment Maintain hydraulic systems Maintain records of maintenance interventions Wear appropriate protective gear	Adjust engineering designs Adjust voltage Approve engineering design Conduct engineering site audits Create AutoCAD drawings Design solar energy systems Examine engineering principles Maintain concentrated solar power systems Maintain solar energy systems Manage engineering project Perform scientific research Promote sustainable energy Provide information on solar panels Use technical drawing software Use thermal analysis	Adjust engineering designs Approve engineering design Design electric power systems Develop strategies for electricity contingencies Ensure compliance with electricity distribution schedule Ensure safety in electrical power operations Perform scientific research Promote sustainable energy Respond to electrical power contingencies Shift energy demands Use technical drawing software
	Optional	Optional	Optional	Optional
	Knowledge	Knowledge	Knowledge	Knowledge

Table 6. *Cont.*

Job Profile	Renewable Energy Sales Representative	Wind Turbine Technician	Solar Energy Engineer	Electric Power Generation Engineer
	Domestic heating systems Electricity market Energy performance of buildings Industrial heating systems	Aerodynamics Hardware components Hardware testing methods Hydraulics Renewable energy technologies Technical drawings	Electricity market Fluid mechanics Industrial heating systems Quality standards Renewable energy technologies	CAD software Design drawings Design principles Electricity consumption Electricity market Energy market Quality standards
	Skill/competence	Skill/competence	Skill/competence	Skill/competence
	Achieve sales targets Advise on utility consumption Assess supplier risks Attend trade fairs Deliver a sales pitch Implement marketing strategies Implement sales strategies Liaise with advertising agencies Manage contract disputes Manage development of promotional material Monitor after sales records Negotiate improvement with suppliers Negotiate terms with suppliers Perform market research Plan customers' sales visits Plan event marketing for promotional campaigns Prepare sales checks Promote environmental awareness Prospect new customers Review completed contracts	Assemble electrical components Ensure compliance with electricity distribution schedule Execute software tests Inspect underground power cables Install hydraulic systems Liaise with engineers Oversee pre-assembly operations Provide advice to technicians Provide information on wind turbines Read engineering drawings Repair underground power cables Replace large components Report test findings Resolve equipment malfunctions Write inspection reports	Assess financial viability Calculate solar panel orientation Design thermal equipment Draw blueprints Inspect facility sites Maintain photovoltaic systems Perform project management Read engineering drawings Run simulations Test procedures in electricity transmission Troubleshoot Use CAD software Wear appropriate protective gear	Analyze energy market trends Assess financial viability Coordinate electricity generation Design utility equipment Develop electricity distribution schedule Ensure equipment maintenance Inspect industrial equipment Maintain electrical equipment Monitor electric generators Monitor nuclear power plant systems Monitor utility equipment Resolve equipment malfunctions Supervise crew Wear appropriate protective gear
	Future skills	Future skills	Future skills	Future skills
	Essential	Essential	Essential	Essential

Table 6. *Cont.*

Job Profile	Renewable Energy Sales Representative	Wind Turbine Technician	Solar Energy Engineer	Electric Power Generation Engineer
	ERP	IoT	IoT	IoT
	Big Data	Big Data	Big Data	Big Data
	Basic digital skills	Artificial intelligence	Artificial intelligence (AI)	Artificial intelligence (AI)
	Basic data input and processing	Collaborative/ autonomous robotics	Augmented reality (AR)	Sensors technology
	Use of digital communication tools	Agile human-machine interfaces (HM)	Sensors technology	Augmented reality (AR)
	Financial literacy	Augmented reality (AR)	Machine learning	Machine learning
	Advanced communication skills	Online inspection and monitoring systems	Collaborative/ autonomous robotics	Cloud computing
	Negotiation skills	Predictive and proactive maintenance	Agile human-machine interfaces (HM)	Agile human-machine interfaces (HM)
	Customer relationship management	Computerized maintenance management	Cyber-physical systems (CBS)	Cyber-physical systems (CBS)
	Entrepreneurship and initiative taking	Advanced IT skills and programming	Augmented reality (AR)	Digital twin
	Risk management	Basic data input and processing	Post-processing	ERP
	Opportunity assessment	Use of digital communication tools	Communication among components, equipment (M2M), and environment	Communication among components, equipment (M2M), and environment
	Critical thinking and decision making	Basic numeracy and communication	Online inspection and monitoring systems	Online inspection and monitoring systems
	Advanced literacy	Quantitative and statistical skills	Equipment and process monitoring and its implementation	Traceability
	Environmental awareness	Environmental awareness	Predictive and proactive maintenance	Computerized maintenance management
	Energy efficiency	Energy efficiency	Computerized maintenance management	Advanced IT skills and programming
	Knowledge and understanding of international and national standards and legislation	Platforms for energy management of equipment and plants	Advanced IT skills and programming	Advanced data analysis and modelization
	Business intelligence (BI)	Use of drones	Advanced data analysis and modelization	Data management-safe storage
	E-commerce	Monitoring systems of energy consumption	Quantitative and statistical skills	Cybersecurity
	Conflict resolution	Knowledge and understanding of international and national standards and legislation	Complex information processing and interpretation	Use of digital communication tools
	Interpersonal skills and empathy	Complex problem solving	Complex problem solving	Adaptability and adapt to change
	Active listening	Advanced literacy	Environmental awareness	Continuous learning
	Appropriate linguistic skills	Process analysis	Energy efficiency	Complex information processing and interpretation
	Cultural empathy	Critical thinking and decision making	Sustainable resource management	Complex problem solving

Table 6. *Cont.*

Job Profile	Renewable Energy Sales Representative	Wind Turbine Technician	Solar Energy Engineer	Electric Power Generation Engineer
		Risk management	Climate change risk management	Sustainable resource management
		Cross-functional process know-how	Monitoring systems of energy consumption	Environmental awareness
		Continuous learning	Platforms for energy management of equipment and plants	Energy efficiency
		Complex information processing and interpretation	Critical thinking and decision making	Sustainable resource management
			Product life cycle impact assessment	Climate change risk management
			Process analysis	Monitoring systems of energy consumption
			Risk management	Platforms for energy management of equipment and plants
			Continuous learning	Critical thinking and decision making
			Adaptability and adapt to change	Product life cycle impact assessment
			Use of digital communication tools	Quantitative and statistical skills
				Process analysis
				Cross-functional process know-how
				Risk management
	Optional	Optional	Optional	Optional
	Complex information processing and interpretation	Teamwork skills	Business intelligence (BI)	Financial literacy
	Process analysis	Active listening	Knowledge and understanding of quality procedures related to digital transformation	Advanced communication skills
	Creativity	Appropriate linguistic skills	Leadership and managing others	Teaching and training others
	Personal experience	Data management-safe storage	Financial literacy	Leadership and managing others
	Ethical skills	Sustainable resource management	Interpersonal skills and empathy	Knowledge and understanding of quality procedures related to digital transformation
	Teaching and training others	Resource reuse/recycling	Adaptability and adapt to change	Conflict resolution
	Cross-functional process know-how	Deep-sea exploration skills	Resource reuse/recycling	Waste reduction and waste management
	Knowledge and understanding of quality procedures related to digital transformation	Working in confined spaces/heights	Sustainable resource management	Teaching and training others
	Continuous learning	Team living	Teamwork skills	
	Interdisciplinary thinking and acting	Advanced first aid and rescue	ERP	
	Basic numeracy and communication	Teaching and training others	Conflict resolution	

Table 6. *Cont.*

Job Profile	Renewable Energy Sales Representative	Wind Turbine Technician	Solar Energy Engineer	Electric Power Generation Engineer
	Quantitative and statistical skills	Knowledge and understanding of quality procedures related to digital transformation	Active listening	
	Circular economy	Adaptability and adapt to change	Ethical skills	
	Climate change risk management	Teaching and training others	Advanced communication skills	
	Product life cycle impact assessment		Waste reduction and waste management	
	Adaptability and adapt to change		Teaching and training others	
	Teaching and training others			

4. Conclusions

Shifting towards a clean energy system demands an increased presence of renewable energy sources that effectively substitute conventional energies. The ever-growing renewable energy sector can benefit from emerging technologies to support its integration within the current energy system. Digitalization can also achieve a more efficient, flexible, reliable, and competitive generation and distribution of renewable energy. Thus, Industry 4.0 unfolds as a key enabler for boosting renewable energy sector prospects.

The opportunity, however, raises issues regarding the workforce's ability to satisfactorily deliver industry needs. The sector evolves at the swift pace of technology advances which the human resources' skills should keep up with. For that purpose, it is proposed to elaborate a long-term skill strategy based on the assessment of the current state of the digitalization of the renewable energy sector and the determination of future skills requirements. The strategy aims to create training programs regarding the findings from the evaluation of current and future state of the renewable energy sector, for the workforce to obtain the required skills. For that purpose, renewable energy sector–academia cooperation is essential to design appropriate education that will close the breach between industry needs and human resources' actual capabilities. Eventually, once the skills requirements are met, the focus will shift towards the attraction and acquisition of talent. The renewable energy sector is in need of a skills guideline leading the sector through industrial changes. This study responds to the need and fills the void in the sector by analyzing future skills requirements of job profiles of the renewable energy sector through its digital evolution.

Therefore, the object of this research was to examine the evolution of the renewable energy sector job profiles and their skill demands through the adoption of Industry 4.0 technologies. Based on the ESCO database, the future skills obtained from desktop research were incorporated into the selected professional profiles of the sector. Thus, an integrated database was created, which includes both current and future skills for the selected jobs at the renewable energy sector.

As stated before, we believe the database will be a fundamental guideline for the renewable energy sector companies, educational centers, and policymakers to design training programs as part of the sectoral long-term skill strategy. By providing a common framework of future skills requirements, the database will guide and serve as a benchmark to create appropriate itineraries that will achieve trained professionals with the capabilities expected by the industry. Thus, the database is a very functional tool to increase the competitiveness of the sector if the sector addresses the skill needs correctly. It can be utilized actively during the development of training programs for reskilling and upskilling the workforce and lead to the generation of a highly qualified workforce for the sector.

Moreover, the findings of the research have the potential to be evaluated by the ESCO experts and be used for the updating process of the ESCO. Hence, it could be used more effectively by the end-users since ESCO is a European framework commonly used by the European labor market and training centers.

Future research is needed on the development of skills linked to the changes brought by the digitalization and implementation of Industry 4.0 in the renewable energy sector, particularly in the steps of the skills strategy that follow with this work's research: the development of training programs and the recruitment of professionals. Hence, this research can be a guide for upcoming investigations on the matter.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/en14092609/s1, Figure S1: a sample of the database (in excel format) with the renewable energy sector job profiles including current and future skills needs.

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References

1. OECD. Energy-Renewable Energy-OECD Data. Available online: https://data.oecd.org/energy/renewable-energy.htm (accessed on 24 March 2021).
2. Ilzarbe, J.M.B.; Gonzalez, J.C.R. Energy and climate change in the post-covid-19 scenario. *DYNA Ing. E Ind.* **2020**, *95*, 570–571. [CrossRef]
3. Khanna, M. COVID-19: A cloud with a silver lining for renewable energy. *Appl. Econ. Perspect. Policy* **2021**, *43*, 73–85. [CrossRef] [PubMed]
4. Hernandez, D.M.; Peralta, G.; Manero, L.; Gomez, R.; Bilbao, J.; Zubia, C. Energy and coverage study of LPWAN schemes for Industry 4.0. In Proceedings of the 2017 IEEE International Workshop of Electronics, Control, Measurement, Signals and Their Application to Mechatronics (ECMSM), Donostia, Spain, 24–26 May 2017; pp. 1–6.
5. Ng, T.C.; Ghobakhloo, M. Energy sustainability and industry 4.0. *IOP Conf. Ser. Earth Environ. Sci.* **2020**, *463*, 012090. [CrossRef]
6. Dogaru, L. The main goals of the fourth industrial revolution. renewable energy perspectives. *Procedia Manuf.* **2020**, *46*, 397–401. [CrossRef]
7. Renewable Energy Agency International. *World Energy Transitions Outlook 1.5 °C Pathway*; IRENA: Abu Dhabi, United Arab Emirates, 2021; ISBN 978-92-9260-334-2.
8. Renewable Energy Agency International. *Innovation Landscape for a Renewable-Powered Future: Solutions to Integrate Variable Renewables*; IRENA: Abu Dhabi, United Arab Emirates, 2019.
9. da Silva, F.S.T.; da Costa, C.A.; Crovato, C.D.P.; Righi, R.D.R. Looking at energy through the lens of Industry 4.0: A systematic literature review of concerns and challenges. *Comput. Ind. Eng.* **2020**, *143*, 106426. [CrossRef]
10. Borowski, P. Digitization, digital twins, blockchain, and industry 4.0 as elements of management process in enterprises in the energy sector. *Energies* **2021**, *14*, 1885. [CrossRef]

11. Verma, P.; Savickas, R.; Buettner, S.M.; Strüker, J.; Kjeldsen, O.; Wang, X. *Enabling the New Phase of Energy Efficiency*; Group of Experts on Energy Efficiency Digitalization: Geneva, Switzerland, 2020.
12. Jennings, P. New directions in renewable energy education. *Renew. Energy* **2009**, *34*, 435–439. [CrossRef]
13. Scharl, S.; Praktiknjo, A. The role of a digital industry 4.0 in a renewable energy system. *Int. J. Energy Res.* **2019**, *43*, 3891–3904. [CrossRef]
14. Ramakrishna, S.; Ngowi, A.; De Jager, H.; Awuzie, B.O. Emerging industrial revolution: Symbiosis of industry 4.0 and circular economy: The role of universities. *Sci. Technol. Soc.* **2020**, *25*, 505–525. [CrossRef]
15. Dileep, G. A survey on smart grid technologies and applications. *Renew. Energy* **2020**, *146*, 2589–2625. [CrossRef]
16. Gunduz, M.Z.; Das, R. Cyber-security on smart grid: Threats and potential solutions. *Comput. Netw.* **2020**, *169*, 107094. [CrossRef]
17. Mahmud, K.; Khan, B.; Ravishankar, J.; Ahmadi, A.; Siano, P. An internet of energy framework with distributed energy resources, prosumers and small-scale virtual power plants: An overview. *Renew. Sustain. Energy Rev.* **2020**, *127*, 109840. [CrossRef]
18. Di Somma, M.; Graditi, G.; Heydarian-Forushani, E.; Shafie-Khah, M.; Siano, P. Stochastic optimal scheduling of distributed energy resources with renewables considering economic and environmental aspects. *Renew. Energy* **2018**, *116*, 272–287. [CrossRef]
19. Howell, S.; Rezgui, Y.; Hippolyte, J.-L.; Jayan, B.; Li, H. Towards the next generation of smart grids: Semantic and holonic multi-agent management of distributed energy resources. *Renew. Sustain. Energy Rev.* **2017**, *77*, 193–214. [CrossRef]
20. UNIDO. *Industrial Prosumers of Renewable Energy, Contribution to Inclusive and Sustainable Industrial Development*; UNIDO: Vienna, Austria, 2015.
21. Milčiuvienė, S.; Kiršienė, J.; Doheijo, E.; Urbonas, R.; Milčius, D. The role of renewable energy prosumers in implementing energy justice theory. *Sustainability* **2019**, *11*, 5286. [CrossRef]
22. Borowski, P.F. Zonal and nodal models of energy market in european union. *Energies* **2020**, *13*, 4182. [CrossRef]
23. Zhang, W.; Xu, Y.; Liu, W.; Zang, C.; Yu, H. Distributed online optimal energy management for smart grids. *IEEE Trans. Ind. Inform.* **2015**, *11*, 717–727. [CrossRef]
24. Wang, Q.; Su, M. Integrating blockchain technology into the energy sector—From theory of blockchain to research and application of energy blockchain. *Comput. Sci. Rev.* **2020**, *37*, 100275. [CrossRef]
25. Rasheed, A.; San, O.; Kvamsdal, T. Digital twin: Values, challenges and enablers from a modeling perspective. *IEEE Access* **2020**, *8*, 21980–22012. [CrossRef]
26. Steindl, G.; Stagl, M.; Kasper, L.; Kastner, W.; Hofmann, R. Generic digital twin architecture for industrial energy systems. *Appl. Sci.* **2020**, *10*, 8903. [CrossRef]
27. Zierath, J.; Rosenow, S.-E.; Luthe, J.; Schulze, A.; Saalbach, C.; Sander, M.; Woernle, C. A structural fatigue monitoring concept for wind turbines by means of digital twins. *Rotating Mach. Hybrid Test Methods Vibro-Acoust. Laser Vibrometry* **2020**, *8*, 139–142.
28. Pimenta, F.; Pacheco, J.; Branco, C.M.; Teixeira, C.M.; Magalhães, F. Development of a digital twin of an onshore wind turbine using monitoring data. *J. Phys. Conf. Ser.* **2020**, *1618*. [CrossRef]
29. A Smirnov, A.; Lunenko, V.S.; A Boldyrev, I. Application of digital twins of equipment for managing complex renewable energy. *IOP Conf. Series: Mater. Sci. Eng.* **2021**, *1035*, 012023. [CrossRef]
30. Errandonea, I.; Beltrán, S.; Arrizabalaga, S. Digital twin for maintenance: A literature review. *Comput. Ind.* **2020**, *123*, 103316. [CrossRef]
31. Onederra, O.; Asensio, F.J.; Eguia, P.; Perea, E.; Pujana, A.; Martinez, L. MV cable modeling for application in the digital twin of a windfarm. In Proceedings of the 2019 International Conference on Clean Electrical Power (ICCEP), Otranto, Italy, 2–4 July 2019; pp. 617–622. [CrossRef]
32. IEA. *Digitalization & Energy*; IEA: Paris, France, 2017.
33. Shin, W.; Han, J.; Rhee, W. AI-assistance for predictive maintenance of renewable energy systems. *Energy* **2021**, *221*, 119775. [CrossRef]
34. Bosman, L.B.; Leon-Salas, W.D.; Hutzel, W.; Soto, E.A. PV System predictive maintenance: Challenges, current approaches, and opportunities. *Energies* **2020**, *13*, 1398. [CrossRef]
35. Canizo, M.; Onieva, E.; Conde, A.; Charramendieta, S.; Trujillo, S. Real-time predictive maintenance for wind turbines using Big Data frameworks. In Proceedings of the 2017 IEEE International Conference on Prognostics and Health Management (ICPHM), Dallas, TX, USA, 19–21 June 2017; pp. 70–77. [CrossRef]
36. Hsu, J.-Y.; Wang, Y.-F.; Lin, K.-C.; Chen, M.-Y.; Hsu, J.H.-Y. Wind turbine fault diagnosis and predictive maintenance through statistical process control and machine learning. *IEEE Access* **2020**, *8*, 23427–23439. [CrossRef]
37. Sony, M. Pros and cons of implementing Industry 4.0 for the organizations: A review and synthesis of evidence. *Prod. Manuf. Res.* **2020**, *8*, 244–272. [CrossRef]
38. Aldieri, L.; Grafström, J.; Sundström, K.; Vinci, C.P. Wind power and job creation. *Sustainability* **2019**, *12*, 45. [CrossRef]
39. Bughin, J.; Hazan, E.; Lund, S.; Dahlstrom, P. *Skill Shift: Automation and the Future of the Workforce*; McKinsey &Company: Hong Kong, China, 2018; pp. 3–84.
40. Bongomin, O.; Ocen, G.G.; Nganyi, E.O.; Musinguzi, A.; Omara, T. Exponential disruptive technologies and the required skills of industry 4.0. *J. Eng.* **2020**, *2020*, 1–17. [CrossRef]
41. Gonzalez Vazquez, I.; Milasi, S.; Carretero Gomez, S.; Napierala, J.; Robledo Bottcher, N. *The Changing Nature of Work and Skills in the Digital Age*; Publications Office of the EU: Brussels, Belgium, 2019; ISBN 978-92-76-09206-3.
42. CISL. *CLG Europe Working towards a Climate Neutral Europe: Jobs and Skills in a Changing World*; CISL: Hong Kong, China, 2020.

43. Autor, D.H. Why Are there still so many jobs? the history and future of workplace automation. *J. Econ. Perspect.* **2015**, *29*, 3–30. [CrossRef]
44. ISCO. *International Standard Classification of Occupations: Structure, Group Definitions and Correspondence Tables*; International Labour Office: Geneva, Switzerland, 2012.
45. Czako, V. *Employment in the Energy Sector Status Report 2020*; Publications Office of the European Union: Brussels, Belgium, 2020. [CrossRef]
46. LMI. Humber Skills for Employment. Available online: https://lmihumber.co.uk/skills-for-employment/ (accessed on 23 March 2021).
47. European Comission. *JRC SETIS Magazine*; European Comission: Brussels, Belgium; Luxembourg; Carquefou, France, 2018.
48. Fong, T. *Robotics and Autonomous Systems in O&M: Removing the Barriers to BVLOS Operations*; Offshore Renewable Energy Catapult: Glasgow, UK, 2019.
49. Faheem, M.; Shah, S.; Butt, R.; Raza, B.; Anwar, M.; Ashraf, M.; Ngadi, A.; Gungor, V. Smart grid communication and information technologies in the perspective of Industry 4.0: Opportunities and challenges. *Comput. Sci. Rev.* **2018**, *30*, 1–30. [CrossRef]
50. Shihavuddin, A.; Chen, X.; Fedorov, V.; Christensen, A.N.; Riis, N.A.B.; Branner, K.; Dahl, A.B.; Paulsen, R.R. Wind turbine surface damage detection by deep learning aided drone inspection analysis. *Energies* **2019**, *12*, 676. [CrossRef]
51. Energy & Utility Skills. *Skills and Labour Requirements of the UK Offshore Wind Industry*; Energy & Utility Skills: Solihull, UK, 2018; pp. 1–143.
52. Accenture. *Building Greater Cyber Resilience in Renewables*; Accenture: Hong Kong, China, 2020.
53. Negreiro, M.; Belluomini, A. *The New European Cybersecurity Competence Centre and Network*; European Commission: Brussels, Belgium; Luxembourg; Carquefou, France, 2020.
54. Akyazi, T.; Goti, A.; Oyarbide, A.; Alberdi, E.; Bayon, F. A guide for the food industry to meet the future skills requirements emerging with industry 4.0. *Foods* **2020**, *9*, 492. [CrossRef]
55. Akyazi, T.; Oyarbide, A.; Goti, A.; Gaviria, J.; Bayon, F. Creating a roadmap for professional skills in industry 4.0. *Hydrocarb. Process.* **2020**, *99*, 11.
56. Akyazi, T.; Alvarez, I.; Alberdi, E.; Oyarbide-Zubillaga, A.; Goti, A.; Bayon, F. Skills needs of the civil engineering sector in the european union countries: Current situation and future trends. *Appl. Sci.* **2020**, *10*, 7226. [CrossRef]
57. Akyazi, T.; Goti, A.; Oyarbide-Zubillaga, A.; Alberdi, E.; Carballedo, R.; Ibeas, R.; Garcia-Bringas, P. Skills requirements for the european machine tool sector emerging from its digitalization. *Metals* **2020**, *10*, 1665. [CrossRef]
58. ESSA. ESTEP-European Steel Skills Agenda (ESSA). Available online: https://www.estep.eu/essa/ (accessed on 24 March 2021).
59. University of Deusto Label. Deusto Research Social Impact. Available online: https://www.deusto.es/cs/Satellite/deustoresearch/en/home/dissemination-and-transfer/label-deusto-research-social-impact?cambioidioma=si&_ga=2.184954729.1348305076.1616511738-1234147669.1606250526 (accessed on 24 March 2021).
60. Lucchi, E.; Lopez, C.S.P.; Franco, G. *A Conceptual Framework on the Integration of Solar Energy Systems in Heritage Sites and Buildings*; IOP Conference Series: Materials science and engineering; IOP Publishing: Bristol, UK, 2020; Volume 949.
61. Acatech. *Skills for Industrie 4.0 Training Requirements and Solutions*; Acatech Position Paper: Munich, Germany, 2017; pp. 1–14.
62. ESCO. ESCO-European Commission. Available online: https://ec.europa.eu/esco/portal/home?resetLanguage=true&newLanguage=en (accessed on 22 March 2021).