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Identifying the Future Skills Requirements of the Job Profiles Related to Sustainability in the Engineering Sector

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Abstract

The field of engineering has undergone significant evolution over the time. With the advent of new industrial revolutions and the growing importance of sustainability, the skills necessary to excel as an engineer have changed drastically. To be a competent engineer in the future, and to achieve the psychological wellbeing of a qualified and up-to-date professional, it is necessary to analyze potential changes that may occur in the field and adapt one's skills accordingly. Engineers can stay ahead of the curve and remain relevant in an ever-changing landscape, only by anticipating and preparing for future developments as well as foreseeing the future skills needs. In order to address the need of identifying the future skill requirements for engineers, in this work, we created a skills database with a strong focus on sustainability. This database not only integrates current skills, but also foresees and establishes the skills related to sustainability, which will be needed in the future. For this aim, we benefited from the ESCO database for selecting the engineering job profiles related to sustainability as well as the current skills needs of the engineers. On the other hand, we conducted a detailed desk research in order to analyse and identify the future skills needs for the selected engineering job profiles. The aim of our work is to address the lack of a skills database specifically designed for the engineering field in relation to sustainability. The database is intended to provide end -users with information on new skill requirements that may arise from future changes, such as industrial and sustainable shifts.

Keywords*:* Engineering, Sustainability, Skills, skilling for wellbeing.

Introduction

Engineering is a discipline that encompasses several areas which human beings are in contact with, in their day to day. This instruction has had several meanings over the time. Originally, its meaning goes back to the art of driving engines. At present this concept has come to develop into something deeper, since it is said to be related to the word ingenuity, which has some relationship with talent and intelligence [1]. Engineering focuses on solving problems by using scientific knowledge as mathematics, resulting in technologies or solutions that satisfy the various problems that can be encountered in society [2].

Throughout the first industrial revolution, it was seen how the revolution of technology increasingly permeated the industries of that time. This technology was mostly developed by the engineers of the time, who helped in different areas such as agriculture, energy and metallurgy. [3] Due to this industrial change, different engineering specializations were formed for different industrial areas or systems. This specialization is responsible for designing, improving and installing integrated systems of people, materials, information, equipment and energy. The engineering sector has a very important responsibility in the industrial revolution that has and is currently being experienced [4].

In recent years, industries have been involved in another new term that has invaded them throughout their value chain. This term is sustainability. Although it is a new term in the industry, it is a thought that comes from forestry, where the thought of not harvesting more than the land can produce was followed [5]. Today, this term has changed somewhat and now focuses more on production by meeting the present needs of consumers without jeopardising the prosperity of future generations [6]. It can be said that the current terminology consists of three important aspects; On the one hand, there is the social sphere, on the other hand, there is the economic and, finally, the environmental one [5]. Thus, the skilling level of an engineer in the future affects , without shadow of doubt, the psychological wellbeing of a professional of the field.

The shift towards sustainable industry began at the moment the European Union focused on European industries. This change was mainly due to the seriousness of environmental pollution and the lack of natural resources [7]. Consequently, the European Commission focused on targeted policies for industry [8]. Thanks to this policy, you can see how progressively sustainability has been taking on greater importance in European industries. In 2008, the European Commission launched the Action Plan on Sustainable Consumption and Production and a Sustainable Industrial Policy. The main purpose of this plan was to integrate sustainability into the evolution of European industry at that time [9]. Two years later, along with the crisis that was experienced, the European Commission gave a statement, where it indicated that they were going to establish a strategy for European economic growth in an intelligent way. This strategy was called Europe 2020. Throughout the intervention they indicated what the objectives of this strategy would be. Among these objectives were ideas such as climate change or energy [10]. In 2015 the United Nations signed the well-known 2030 agenda, which focuses on the sustainable development of the world, where three main dimensions are taken into account: the economy, society and the environment [11]. Along with this new decision, the importance of sustainability spread, impacting the entire industry and society. In 2019, a study was carried out on the state of the environment in Europe, which concludes that if urgent action is not carried out, it will not be possible to meet the proposed objectives [12]. It is worth mentioning that so far, very important progress has been made in the area of climate change mitigation, since greenhouse gas emissions have been reduced to some extent [13]. Likewise, large European companies which have an impact on waste generation and on the European economy are currently investigating innovative strategies so that their own companies can grow sustainably [7]. As an example, one of the trends that the industrial sector has opted for is the energy area, where the use of renewable energies and the use of much more efficient technologies have prevailed [7].

As indicated by UNESCO, engineering has always played an important role in evolving the citizens of the world thanks to the development of new technological elements, which is why, its role in the conversion towards a sustainable era is very important, since its innovation impacts the whole society [14].

The implementation of this new mentality in the area of engineering has not only come to contribute to the environment, but, in the same way, has helped to make economic savings in the different industries. This is because the interaction between the industry and sustainability within the company is of vital importance [7, 15]. To achieve this transition in the industry it is very important to make use of the different digital technologies available [7].

One of the digital concepts that have been established in different industries is industry 4.0, since this new tool provides an immense capacity to implement the sustainability plan [15].

Industry 4.0 is a paradigm that comprises technological, social and organizational properties. This is possible due to the use of digital technologies. The main objectives of this type of industry are to transform the design methods used, manufacturing and service delivery [16]. As a result, the use of intelligent systems in industries has led to new perspectives and management powers [15]. In addition, industries are currently involved in requirements related to sustainability and thanks to this umbrella they are able to be agile and fast in the face of these demands. However, within the purposes of the United Nations 2030 Agenda, the development of the technological field means that traditional technology becomes obsolete and gives way to new intelligent machines without harming the sustainability of the industry itself [17]. This is because through the use of these advanced technologies it is possible to reduce pollution. That is, it helps to reduce the emission of greenhouse gases from industries, and it also reduces their energy consumption [17].

As a result of the changes which are provoked by the sustainability needs and digitalisation in the field of engineering, it is essential to analyse the skills needs of the job profiles related to engineering in detail. Because the key to create a highly competent and versatile workforce, capable of facing technological and green transformation is to identify the skills needs and then to continuously update of qualifications and knowledge of this workforce [7].

To this end, it is essential to look at the skills of the people who hold these positions today and how their skills needs will be transformed in the future. The main focus of this study is to analyse and determine the future skills needs of the job profiles related to sustainability in the engineering area. For this aim, the current skills needs of these job profiles will be also identified.

Therefore, throughout this research, the sustainability related skills demands of engineering will be established. This will be carried out through generating a database of the different professional profiles, which will be based on the ESCO database, and then, the identified future skills needs for these job profiles will be integrated into the database. Ultimately, the tool will make it possible to create well-developed training programs that deliver the skills demanded by the workforce.

For an ease of understanding, the article has been divided into the following sections.

In the first, introduction, section, the current and future changes that engineering is facing with are presented.

In the second section, in-depth information about the planned industrial revolutions and the shift towards a more sustainable society is provided. This information has been collected from different articles, regulations of the European Union and communications of the Commission of the EU.

The third section shows the development of the database, which is the final outcome of our research. It shows, in detail, the steps followed to create the skills database for the engineering job profiles related to sustainability. The first step to generate the database, which is to select the transversal engineering job profiles connected with sustainability is detailed. Then, as the next step the information about the future skills needs obtained in the second section, is analysed. After, the skills needed for each profile in the future are determined.

Finally, the forth section presents the main conclusions of our study.

IDENTIFYING THE FUTURE SKILL REQUIREMENTS RELATED TO SUSTAINABILITY FOR THE ENGINEERING SECTOR

The objective of this section is to show the requirements that will be demanded in the future of engineers working in the sustainability area. To achieve this, it is essential to detect the trends in skills related to sustainability and energy efficiency. To this end, a thorough investigation of documentary sources, such as scientific articles, reports, guidelines and relevant projects are carried out. It also considers previous studies of the research team [7, 18-22] and the work developed by the experts of the SPIRE-SAIS project (this is a team of experienced academics and industrial professionals) [23].

In section 2.1. the general future trends and development of engineering skills in the field of sustainability is analysed. While in section 2.2. the future needs of the completed database is discussed.

General trends and development in qualifications for sustainability-related engineering

Engineering is a vast field with various branches and specializations. To better understand the changing requirements of this discipline, it is necessary to carry out a more general analysis.

Looking to the future, a fundamental element that all specializations and industrial areas will have to share is sustainability. Which, itself, focuses on meeting the needs of the present, without compromising the ability of future generations to meet their own needs. With new sustainable thinking engineers are demanded to have certain competences that are pillars of sustainability itself [24].

One of the main competences related to sustainability is the reduction of waste generation and the efficiency of the resources used [25]. Engineers, when designing products, must take into account that at all times they should make the most of the resources, since it benefits to reduce environmental impacts.

Another primary competence to be sustainable is the production and design of the different elements of which recycling is very simple [25, 26]. Likewise, the production capacity of elements through industrial symbiosis recycled resources will be highly valued.

An additional significant competence environmental protection awareness [25, 27]. An engineer should be aware that their actions have an environmental impact, so they must bear in mind that the processes that they develop should help preserve biodiversity and mitigate climate change.

To achieve these outcomes, it is crucial to have knowledge about the environmental legislation and regulations in the related working field. This is because the developed products and processes should comply with the regulations in force at that time. Currently, there are several regulations about sustainability, but the one most talked about in the European Union is the Green Deal. This pact has as its main objective to transform the European Union into climate neutral by 2050 [28]. In order to achieve the objective set, certain guidelines have been determined within different engineering areas.

The first guideline of the Green Deal corresponds to the transport and automotive sector. This sector plays a key role in reducing the total CO2 emissions generated in the European Union. To achieve the targets set for 2035, all cars and vans marketed in the region must operate without diesel or gasoline engines [29]. Due to this change, the near future engineers should have broader and more developed knowledge about electric motors, or engines that consume other types of green fuels (H2, BIO fuels ..) leaving aside the importance of combustion engines with fossil fuels (oil, coal, gas ..) since the use of these second will not be so high [29].

Another specialization that engineers will focus on is the development of energy storage, as in batteries, ammonia, etc... So, the development and evolution of the elements is going to be momentous. In this line, there is a lot of work to do as regards innovation such a solar energy storage, green hydrogen,.etc. [29].

One of the areas that will also undergo significant changes is fuels used in heavy transport, including aircraft and shipping. This shift will require engineers to possess a broader knowledge of sustainable fuels that can be used in these sectors in the future [28].

Therefore, energy is an area where significant changes are expected. By optimising energy efficiency, the European Union can reduce CO_2 emissions and promote the use of biofuels. These offer a promising alternative to fossil fuels and can significantly reduce CO_2 production. Currently, many projects are being subsidized for the development of biofuels with the aim of being sustainable with the planet. In addition, with the consumption of biofuels the European Union would make an economic saving of resource import for the energy sector of around 330,000 million euros, to achieve this saving a reduction in consumption of around 40% has been planned [28, 30, 31]. Consequently, innovation in the biofuel generation sector will be another competence to be taken into account in the engineering field.

In the future, one of the most important qualities for engineers will be the inventive ability to develop processes or elements that maximize energy efficiency. At the same time, the design of processes in which the minimization of energy consumption is considered will have the same importance. In other words, the focus will be on using a smaller amount of energy to produce the same result. Therefore, engineers should not only focus on providing solutions to energy-related problems, but should also strive to ensure that these solutions are as efficient as possible, both in terms of their production and use [31].

Continuing with the energy field, by 2030 the final consumption of renewable energies is expected to increase by 45% [30, 32]. Therefore, it is assumed that engineers have a deeper knowledge about this sector. In addition, to generate more renewable energy, such knowledge is being expanded into new ways of obtaining energy, such as through hydrogen and ocean sources, which include tidal and wave energy, floating solar energy and the use of algae as biofuel [33]. Therefore, the entrepreneurship specialized in the generation of new ways of obtaining renewable energies will be considered as a necessary skill for future engineers.

Furthermore, engineers in the future are expected to show investigative skills in the product reuse. But also, they should be able to establish the best techniques for the recycling and reuse so that through the reuse of products, an outcome with high quality can be obtained [34-37].

It can be concluded that in the future, eco-design will play a very important role in all these sectors, where aspects related to sustainability will be taken into account [38]. During product development, different factors will be taken into account, which the engineer must take into consideration, so they must be aware of them. Some examples are product durability, potential reuse, upgradeability, product repair, resource efficiency, remanufacturing, recycling and the carbon footprint generated by your production [38].

One of the points in the industrial field that the European Commission intends to change, or influence is the development of different industrial projects. What is intended is to carry out joint projects among the states that make up the European Commission. So, for engineers it will be essential to have a great ability to relate to other individuals from different cultures and languages. That is, they must have some skills for an effective communication, and be able to have an interdisciplinary collaboration [37].

As it has been observed, most of the competences imply having some creativity in different areas that make up engineering. This is because an important aspect that the European Union intends to promote in the industry is the spirit of entrepreneurship. As a consequence, future engineers must possess innovative skills to succeed. By developing a culture of innovation, engineers can keep up with changing industry demands and drive growth and progress [39-42].

That is why digitalization has become a key tool for innovation, allowing companies to access more information and create new products... The COVID-19 pandemic has highlighted the importance of digitization, leading to an increased demand of IT in businesses. As a result, digital capability has become an essential requirement for engineers [43].

The European Commission in turn intends to introduce digitalization in different industries, so they promote the installation of industry 4.0 and the industry 5.0 is planned to be installed on the future [44].

Industry 4.0 has caused some of the engineering sectors linked to the industry to be affected, because the requirements for these jobs have been modified. This leads to the digitalization of companies. As a consequence, on the basis of this idea, different engineers must have characteristics in this area [42, 45]. In particular, engineers should focus on developing their skills in the area of the use of key enabling technologies (KETs) which are the following: artificial intelligence, connectivity, cybersecurity and advanced digital capabilities (advanced manufacturing, advanced materials and micro/nanoelectronics). By mastering these areas, engineers can stay competitive and contribute to the success of their companies [40, 43, 46-48].

Gaining deeper knowledge in the field of artificial intelligence will help in the interpretation of the calculations obtained by the different development programs. So, engineers must be able to understand the result obtained. In addition, thanks to artificial intelligence, the generated designs can assume different factors that have previously been stored, and that the user has forgotten. Therefore, it will help the engineer to generate optimal designs. To achieve this end, the engineer must be able to use design programs in which artificial intelligence is implemented and learn simulation and testing of the elements to be designed [49].

On the other hand, the field of cybersecurity is going to be fundamental in all industries. Communicative between different workers must have an environment where secure interaction is offered. This is going to be done using quantum encryption. That is why future engineers will be advised to have skills related to quantum encryption [50].

Engineers must also control over Big Data, since the quality control of the different products will be carried out digitally. This technology is going to capture data from the elements and then the engineer must be able to use Big Data techniques and determine if the product is good or not, and at the same time avoid overproduction of elements that do not meet the production requirements, causing the amount of waste generated to decrease [42, 45].

Along with all this digitalization that is driven by Industry 4.0, sustainability awareness among engineers is expected to become a core competence [40, 42, 45-47].

When analyzing the future of the industrial revolution, we come across the concept of Industry 5.0, which combines the key features of Industry 4.0 – sustainability and digitalization – with a crucial difference. In this case, the central focus of industrial production shifts to the welfare of workers, placing human needs and aspirations at the heart of the revolution [51-54].

This shift means that the engineers of the future must adapt to certain new skills that generate sustainable, resilient and human-centered outcomes [51, 52]. Consequently, it is necessary to think about giving a technological result in a way that serves and adapts to the needs and diversity of workers in the industry [51]. In order to achieve these goals, future engineers must also have certain social skills that are indispensable. To begin with, they must have critical thinking, that is, they must be able to evaluate information critically, so that there are no environmental or social impacts [55].

Since Industry 5.0 is about focusing on the human being, some essential skills for this to be achieved are effective communication and teamwork. These skills will help the company's goal to focus in a simpler way [56]. In addition, the spirit of leadership will be a skill to take into account since this will drive the project forward [56].

Likewise, so, this will help to foster respect among all workers and promote a good work environment that all engineers must have emotional intelligence [57].

As with Industry 4.0, together with Industry 5.0 it is also intended to bring about a shift towards sustainability. In this case, it is expected that the new industrialization will bring about the development of circular processes. In these processes, engineers must keep in mind waste reduction, reuse of materials, recycling and minimization of the possible impact on the environment [51, 52, 54]. Engineers will need to design products in ways that help promote the circular economy [51, 52].

Identification of the future skills needs of the sector

After analyzing the general trends and future scenarios of the engineering field, we propose the necessary skill requirements to prepare for possible changes that may arise from the various aspects mentioned in section 2.1. Then, we group these skills which are related to sustainability into three categories: technological skills, green skills, and social skills. These findings have been brought together in a database covering the future skills requirements for the aforementioned professional profiles. This database, in turn, will serve as a useful guide to identify both the needed occupations and competencies related to sustainability in the field of engineering.

Once all the skills needed for the future are defined, the gaps between the skills required today and those that will be needed in the future will be identified. By identifying and addressing these skill gaps, engineers can remain competitive and adaptable in an ever-changing industry. After, the last phase will consist of recruiting and training a highly competent workforce, capable of meeting the needs of potential emerging sectors of the engineering field.

DEVELOPMENT OF SECTORIAL SKILLS DATABASE

This section describes the creation of a database, which contains information about professional profiles on engineering related to sustainability, including their requirements, current and future skills. This database is designed with the purpose of serving as a guide for the creation of educational courses and talent recruitment. In addition, the development of the methodology is addressed and the findings of the research carried out in this area are presented.

Materials and methods

During the creation of the database, the ESCO (European Classification of Skills, Competences, Qualifications and Occupations, developed by the European Commission) is used as the main reference to identify transversal occupations related to sustainability in the engineering field, and also to define their current skills needs.

The ESCO database provides the user with the possibility to search for occupations, skills, competences or qualifications relevant to the European Union labour market. This database has a total of 2942 occupations and 13,485 skills [58]. During the study, ESCO is used as the primary source for defining and selecting job profiles, as well as identifying their current skill requirements. Our research team established a set of keywords to identify transversal engineering occupational profiles related directly to sustainability. The keywords were selected based on a word cloud [59], are shown in Table 1. They are used to search in title of the job profiles in the ESCO database.

Table 1. The keywords to identify transversal job profiles related to engineering and sustainability

Defined Keywords for the Occupations
Sustainability
Environmental
Renewable energy
Green
Ecology
Recycling
Resource
Waste
Conservation

After analysing the job profiles that contained the aforementioned keywords, only the most relevant and representative profiles in the engineering area are selected, with the aim of maintaining a reduced number of profiles, and improving the quality of the research.

Following the selection of the most significant profiles, the ESCO database is used to define their current skill requirements. ESCO occupational profiles are added to an Excel spreadsheet, incorporating their descriptions and skills that are currently required to perform those profiles.

The ESCO database classifies the skill needs of each profile into two categories: essential and optional. This classification is maintained in the new spreadsheet.

After inputting all the data into the spreadsheet, the next key step in developing the automated database for selected engineering profiles in the manufacturing industry was to apply Excel's automated VBA (Visual Basic for Applications) method to the document. This enables us to streamline and automate the process of organizing and analyzing the data, making it more efficient and accurate. The next step is to determine the future competence needs of the jobs that have been selected. To achieve this, detailed desk research is conducted, which is presented throughout Section 2. The objective of this step is to analyse and identify the future skills requirements about sustainability in the field of engineering. With the results of this research, a database is created that includes the necessary information to determine the future needs of the selected jobs.

The development of future skills requirements is achieved by carrying out an exhaustive study of the literature on the subject. This study consists on a detailed review of the existing literature. After reviewing the literature, we identify the general skills needs expected from engineers, which are related to sustainability taking into account ongoing technological changes and sustainability needs.

These skills related to sustainability are then divided into three categories; technical skills, green skills and social skills, in order to make it easier. Once categorized, we proceed to carry out the analysis of how the job profiles will evolve in the future taking into account the three categories.

A posteriori, we proceed to analyze and decree the future skills that each profile will demand. When a future need for the profile is identified, it is evaluated if this is an essential or optional skill, and then, it is categorized.

Throughout this study it is observed that many of the current skills will be maintained but the level of mastery that is required will evolve over time. Also, many other new skills related to sustainability and the impact of the new industrial revolutions fostered in the European Union are included in the study.

It is true that as a result of these changes new areas of engineering may be created, but this possibility is not considered throughout this research. That is, it is assumed that the selected profiles will be able to meet future needs.

Results and discussion

The goal of our research is to develop a database that covers the current and future skills requirements for engineering profiles related to sustainability.

In order to identify cross-cutting jobs in the engineering sector that impact sustainability, we enter relevant keywords into the ESCO database and collected information on different occupations in the field of engineering. We then analyzed the job profiles to determine if they were transversal or not, resulting in a total of 27 jobs. From these, we select four jobs for a more detailed and accurate analysis. The job profiles are listed in the image 1 for reference (please note that images and large tables are placed at the end of the article for a better visualization of their contents).

In our work, we use the research conducted by ESCO as the key source of information to identify current relevant job profiles for engineering and the competences required for each profile.

In order to develop the database, the descriptions of the 4 profiles and the current skills needs of each selected profile, which were obtained directly from ESCO, are first incorporated to our database.

Table 2 and 3 shows the aforementioned description of each chosen profile, also, the link to the ESCO website, the alternative tags it has and the corresponding ISCO number.

We utilized ESCO's efficient classification system for skills, competencies, qualifications, and occupations to develop the current skills requirements for selected occupations in the engineering field. However, since ESCO does not provide us future skills needs, our study aims to identify these. We identify the general skills connected with sustainability that will be needed in the field of engineering due to the industrial revolutions and the shift towards a more sustainable era. In addition, we conduct an in-depth study of the four selected occupations to further identify the skills that will be needed in the future.

Future skills related to sustainability are identified and classified into 3 categories: technological, social and green. In the following table 4 you can see the classification of the skills.

Our research aims to identify the future skills required for a sustainable engineering sector, and its primary contribution has been the identification process. With this information, we analyse the future skills needed for each profile and determined their importance, both essential and optional, to add them to the database. This last step can be seen in the following table 5 and 6. Where the words in pink are the current skills that are maintained, yellow indicates skills that will be necessary in the future, which are selected from Table 4, and finally blue denotes currently classified optional skills that will be classified as essential.

The results obtained in the tables shown, i.e., the result of the work carried out, the automated database and the data related to this elaboration, were validated by the SPIRE-SAIS project partners.

Table 7 presents an example of a database sheet created for the job profile of a "Material Engineer." The initial rows of the table show the hierarchical order of occupation groups according to ESCO's classification. Additionally, the table includes a direct link to ESCO where all the data related to the job profile can be accessed. Other relevant information added to the table includes alternative names of each job position and the corresponding ISCO number. Lastly, the table displays both current skills required and those predicted to be necessary in the future, which are based on the findings of this study.

CONCLUSION

The change of thinking, towards a more sustainable era brings with it changes that affect the area of engineering. Sustainability has become very important around the world, and engineering is a key sector to achieve a successful transition, as it is the key tool to generate a transition towards a low-carbon and environmentally friendly economy.

The importance of this area is because it will have a fundamental role in the design and implementation of clean and renewable technologies. Likewise, tomorrow’s engineers must be aware of including the concept of sustainability in the planning, designs, production, operation and maintenance of the systems of the products develop. Industry 4.0, due to, the digitalization of the production chain, contributes to the implementation of sustainable thinking, since through the digitalization of the production chain it is possible to optimize resources and generate less waste.

Making a more futuristic analysis, you can see how also in the future in the industry sustainability will be a fundamental pillar. This is because, in the Industry 5.0, one of the pillar will be sustainability, along with resilience and social welfare. This new trend will lead to greater collaboration between engineers, in order to create innovative and sustainable solutions.

To meet the demands of the future, the engineering field needs to adapt in certain ways, primarily in terms of the skills needed to be a successful engineer. In order to, address this, we have developed a database for the most representative engineering occupations with a focus on sustainability.

The database is designed to identify current and future skill needs for the selected engineering job profiles. To establish the current skill needs and descriptions, we used the ESCO database. However, since there is no database available to determine future skill needs, we conducted detailed research to identify the required skills (as described in Section 2) and added them to the database. Once the database was generated, SPIRE-SAIS experts validated the results obtained.

The key feature of the database is the identification of future skills required for each job profile, something that the ESCO database needs to improve given the constant evolution of job profiles. Our research aims to provide a tool for tomorrow's users to obtain this information, such as educational institutions, to help them teach in ways that best align with the skills needed by their students in the future.

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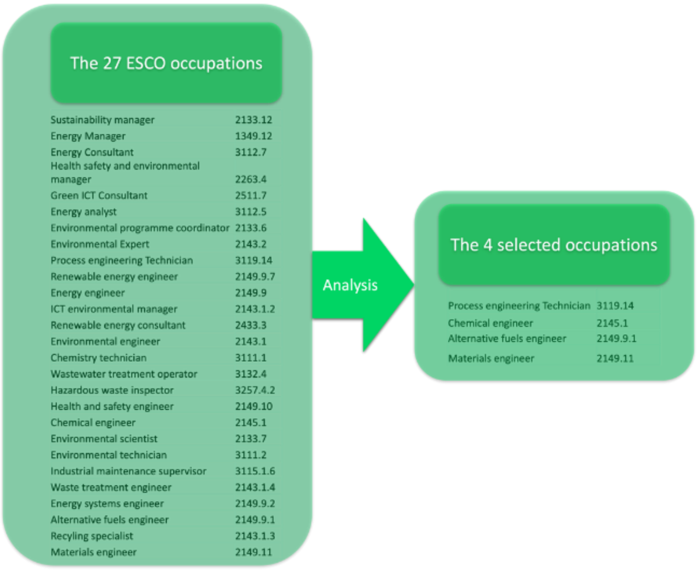

Image 1. Lists of selected occupations

Table 2. Description of the four selected occupations (I)

	Professionals	Professionals
	Science and engineering professionals	Science and engineering professionals
	Engineering professionals (excluding electrotechnology)	Engineering professionals (excluding electrotechnology)
	Engineering professionals not elsewhere classified	Engineering professionals not elsewhere classified
		Energy engineer
ESCO Occupation	Material engineer	Alternative fuels engineer
Web link	https://esco.ec.europa.eu/en/classification/occupation_main#overlayspin	https://esco.ec.europa.eu/en/classification/occupation_main#overlayspin
Alternative labels	Advanced materials engineer Building materials engineer Building materials engineering adviser Building materials engineering consultant Building materials engineering expert Building materials engineering specialist Ceramic engineer Construction materials engineer Construction materials engineering adviser Construction materials engineering consultant Construction materials engineering expert Construction materials engineering specialist Material engineer Materials engineer Materials engineering adviser Materials engineering consultant Materials engineering expert Materials engineering specialist	Fuel cell engineer Hydrogen engineer
Description	Materials engineers research and design new or improved materials for a diverse number of applications. They analyse the composition of materials, conduct experiments, and develop new materials for industry-specific use that can range from rubber, to textiles, glass, metals, and chemicals. They advise companies in damage assessments, quality assurance of materials, and recycling of materials.	Alternative fuels engineers design and develop systems, components, motors, and equipment which replace the use of conventional fossil fuels as main power source for propulsion and power generation with the feature of using renewable energies and non-fossil fuels. They strive to optimise energy production from renewable sources and reduce production expenses and environmental strain. The alternative fuels employed mainly include Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG), biodiesel, bio-alcohol as well as electricity (i.e., batteries and fuel cells), hydrogen and fuels produced from biomass.
Code	2149.11	2149.9.1

Table 3. Description of the four selected occupations (II)

	Professionals	Technicians and associate professionals
	Science and engineering professionals	Science and engineering associate professionals
	Engineering professionals (excluding electrotechnology)	Physical and engineering science technicians
		Physical and engineering science technicians not elsewhere classified
		Process engineering technician
ESCO Occupation	Chemical engineers	Process engineering technician
Web link	https://esco.ec.europa.eu/en/classification/occupation_main#overlayspin	https://esco.ec.europa.eu/en/classification/occupation_main#overlayspin
Alternative labels	Ceramics chemical engineer Chemical engineer Chemical engineering adviser Chemical engineering consultant Chemical engineering expert Chemical engineering specialist Chemicals engineer Chemical technology engineer Chemical technology engineering adviser Chemical technology engineering consultant Chemical technology engineering expert Chemical technology engineering specialist Glass chemical engineer Pyrotechnics chemical engineer Refinery process engineer Water purification chemical engineer	Engineering operational inspector Engineering operations inspector Manufacturing engineering operations supervisor Manufacturing engineering supervisor Manufacturing processing engineer Manufacturing processing supervisor Process engineering supervisor Process engineering technician Production inspector Production supervisor Resident inspector Resident technical support
Description	Chemical engineers design and develop large-scale chemical and physical production processes and are involved in the entire industrial process required for transforming raw materials into products.	Process engineering technicians work closely with engineers to evaluate the existing processes and configure manufacturing systems to reduce cost, improve sustainability and develop best practices within the production process.
Code	2145.1	3119.14

Table 2. Future skill requirements related to sustainability in the engineering area and their classification

Technical Skills	Social Skills	Green Skills
Artificial intelligence	Social responsability	Material reutilisation
Cybersecurity	Ethical responsability	Resource efficiency
Digital Twin	Cooperation	Environmental awarness
Cyber-physical systems (CPS)	Networking	Develop waste reduction
Preventive and predictive maintenance	Critical thinking	Waste Management
Quality Assurance	Teamwork	Energy conservation
Remote control and smart sensoring	Adaptability to change	Sustainable resource management
Monitoring systems of energy consumption	Well-connected	Rs, reuse, recycle, reduce
Cloud technologies	Show empathy	Energy storage systems
IoT	Leadership principles	Adjust engineering sustainable design
Smart factory and intelligent factory Internet of Services	Flexibility and adaptability	Carbon management
Advanced simulation	Emotional intelligence	Sustainable supply chain management
Circular business models	Demonstrate intercultural competence	Assess environmental impact
Big data analytics and interpretation skills	Protect the psychological wellbeing	Climate change mitigation and adaptation
Entrepreneurship	Interdisciplinary skills	Natural resources management
Innovation	Understanding of the social and political factors	Awareness of the importance of gas mitigation
Digital capability	Ability to communicate technical information	Awareness of gravity of climate change
Green fuels	Maintain working relationships	Energy efficiency
Biofuels	Create a work atmosphere of continuous improvement	Assessment of the carbon footprint generated
Knowledge of obtaining high-quality recycled products		Ensure compliance with environmental legislation
Adjust engineering ecological design		Renewable energy
Design for durability		Advise on sustainable management policies
Designing products for reusability		
Knowledge of advanced manufacturing		
Resilient results		
Emerging technologies related with the carbon capture		
Knowledge of regulations and standards of alternative fuels		
Carry out research on hydrogen		
Process optimization		
Solving problems		
Test material with digital application		
Advanced materials		
Emerging materials		
Electronics and automation		
Robotics		

Table 5. Future skills needs related to sustainability for four selected engineering job profiles (I).

Material engineer	Alternative fuels engineer	Chemical engineers	Process engineering technician
Current essential skills and competences			
Analyse production processes for improvement	Analyse energy consumption	Apply health and safety standards	Advise on manufacturing problemsa
Apply health and safety standards	Approve engineering design	Approve engineering design	Analyse test data
Approve engineering design	Assess hydrogen production technologies	Assess environmental impact	Collaborate with engineers
Assess environmental impact	Conduct energy Audit	Forecast organisational risks	Conduct routine machinery checks
Create solutions to problems	Design electric power systems	Perform chemical experiments	Create solutions to problems
Develop advanced materials	Design electrical systems	Perform scientific research	Perform maintenance on installed equipment
Develop material testing procedures	Dispose of hazardous waste	Test chemical samples	Read engineering drawings
Forecast organisational risks	Ensure compliance with environmental legislation	Work with chemicals	Record test data
Integrate new products in manufacturing	Ensure compliance with safety legislation	IoT	Resolve equipment malfunctions
Cybersecurity	Execute feasibility study on hydrogen	Entrepreneurship	Troubleshoot
IoT	Identify energy needs	Innovation	Cyber-physical systems (CPS)
Entrepreneurship	Perform scientific research	Adjust engineering ecological design	Preventive and predictive maintenance
Innovation	Plan maintenance activities	Design for durability	Quality Assurance
Adjust engineering ecological design	Promote innovative infrastructure design	Designing products for reusability	Cybersecurity
Knowledge of obtainig high-quality recycled products	Promote sustainable energy	Critical thinking	IoT
Design for durability	Provide information on hydrogen	Teamwork	Smart factory and intelligent factory Internet of Services
Designing products for reusability	Use sustainable materials and components	Show empathy	Circular business models
Critical thinking	Use technical drawing software	Solving problems	Adjust engineering ecological design
Teamwork	Use thermal management	Protect the psychological wellbeing	Process optimization
Show empathy	Green fuels	Resource efficiency	Cooperation
Solving problems	Energy storage systems	Environmental awareness	Networking
Protect the psychological wellbeing	Biofuels	Rs, reuse, recycle, reduce	Critical thinking
Material reutilisation	Adjust engineering ecological design	Adjust engineering sustainable design	Demonstrate intercultural competence
Resource efficiency	Design for durability	Assess environmental impact	Solving problems
Environmental awareness	Desingning products for reusability	Climate change mitigation and adaptation	Protect the psychological wellbeing
Rs, reuse, recycle, reduce	Carry out research on hydrogen	Awareness of gravity of climate change	Ability to communicate technical information
Adjust engineering sustainable design	Knowledge of regulations and standards of alternative fuels	Ensure compliance with environmental legislation	Resource efficiency
Assess environmental impact	Social responsability	Ensure compliance with safety legislation	Environmental awareness
Climate change mitigation and adaptation	Ethical responsability	Execute feasibility study on hydrogen	Develop waste reduction
Ensure compliance with environmental legislation	Critical thinking	Improve chemical processes	Adjust engineering sustainable design
Assessment of the carbon footprint generated	Teamwork	Monitor plant production	Sustainable supply chain management
Test materials with digital applications	Show empathy	Provide information on hydrogen	Waste management
Advanced materials	Solving problems	Use technical drawing software	Carbon management
Emerging materials	Protect the psychological wellbeing		Awareness of gravity of climate change
Awareness of gravity of climate change	Resource efficiency		Use CAD software
Ensure compliance with environmental legislation	Environmental awareness		Use computer-aided engineering systems
Advise on pollution prevention	Rs, reuse, recycle, reduce		
Advise on waste management procedure	Renewable energy		
	Adjust engineering sustainable design		
	Assess environmental impact		
	Climate change mitigation and adaptation		
	Awareness of gravity of climate change		
	Ensure compliance with environmental legislation		
	Prevent sea pollution		

Table 6. Future skills needs related to sustainability for four selected engineering job profiles (II).

Current optional skills and competences			
Assess the feasibility of implementing developments	Analyse production processes for improvement	Advise on pollution prevention	Analyse production processes for improvement
Define quality standards	Analyses stress resistance of materials	Advise on waste management procedures	Assess operating cost
Design prototypes	Conduct performance tests	Analyse production processes for improvement	Create technical plans
Develop chemical products	Control compliance of railway vehicles regulations	Analyse test data	Manage supplies
Perform laboratory tests	Control production	Conduct public presentations	Order supplies
Artificial intelligence	Create technical plans	Contribute to registration of pharmaceutical products	Oversee quality control
Cloud technologies	Design prototypes	Create solutions to problems	Perform test run
Advanced simulation	Draft design specifications	Define quality standards	Read standard blueprints
Big data analytics and interpretation skills	Ensure aircraft compliance with regulation	Design optical systems	Secure working area
Digital capability	Ensure vessel compliance with regulations	Design pharmaceutical manufacturing systems	Use testing equipment
Energy efficiency	Execute feasibility study	Design prototypes	Remote control and smart sensoring
Electronics and automation	Operate battery test equipment	Develop chemical products	Artificial intelligence
Emerging technologies related with the carbon capture	Record test data	Develop material testing procedures	Monitoring systems of energy consumption
Digital Twin	Train employees	Develop pharmaceutical drugs	Cloud technologies
Social responsability	Artificial intelligence	Draft design specifications	Big data analytics and interpretation skills
Ethical responsability	Cloud technologies	Establish collaborative relations	Entrepreneurship
Adapt to change	Advanced simulation	Evaluate pharmaceutical manufacturing process	Digital capability
Well-connected	Big data analytics and interpretation skills	Integrate new products in manufacturing	Knowledge of advanced manufacturing
Maintain working relationships	Digital capability	Manage chemical testing procedures	Electronics and automation
Leadership principles	Energy efficiency	Manage pharmaceutical production facilities construction	Teamwork
Demonstrate intercultural competence	Emerging technologies related with the carbon capture	Record test data	Adapt to change
Interdisciplinary skills	Adapt to change	Test materials	Well-connected
Understanding of the social and political factors	Well-connected	Test pharmaceutical process	Show empathy
Develop waste reduction	Maintain working relationships	Test production input materials	Maintain working relationships
Sustainable resource management	Leadership principles	Use chemical analysis equipment	Leadership principles
Renewable energy	Demonstrate intercultural competence	Write batch record documentation	Flexibility and adaptability
Natural resource management	Interdisciplinary skills	Write technical reports	Understanding of the social and political factors
Awareness of the importance of gas mitigation	Understanding of the social and political factors	Artificial intelligence	Create a work atmosphere of continuous improvement
Energy efficiency	Ability to communicate technical information	Cloud technologies	Assess environmental impact
Robotics	Develop waste reduction	Advanced simulation	Robotics
Advise on sustainable management policies	Sustainable resource management	Big data analytics and interpretation skills	Emotional intelligence
Energy storage systems	Natural resource management	Digital capability	
Resilient results	Awareness of the importance of gas mitigation	Energy efficiency	
	Energy efficiency	Emerging technologies related with the carbon capture	
	Assessment of the carbon footprint generated	Carry out research on hydrogen	
	Advise on sustainable management policies	Social responsability	
	Advanced materials	Ethical responsability	
	Emerging materials	Adapt to change	
	Resilient results	Well-connected	
		Maintain working relationships	
		Leadership principles	
		Demonstrate intercultural competence	
		Interdisciplinary skills	
		Undestanding of the social and political factors	
		Ability to communicate technical information	
		Develop waste reduction	
		Energy conservation and energy efficiency	
		Sustainable resource management	
		Renewable energy	
		Natural resources management	
		Awareness of the importance of gas mitigation	
		Energy efficiency	
		Assessment of the carbon footprint generated	
		Advise on sustainable management policies	
		Energy storage systems	
		Advanced materials	
		Emerging materials	
		Resilient results	

Table 5. Example of how the information will be delivered to the database

ESCO Occupation	Professionals Science and engineering professionals Engineering professionals (excluding electrotechnology) Engineering professionals not elsewhere classified Material engineer
Web link	https://esco.ec.europa.eu/en/classification/occupation_main#overlayspin
Alternative labels	Advanced materials engineer Building materials engineer Building materials engineering adviser Building materials engineering consultant Building materials engineering expert Building materials engineering specialist Ceramic engineer Construction materials engineer Construction materials engineering adviser Construction materials engineering consultant Construction materials engineering expert Construction materials engineering specialist Material engineer Materials engineer Materials engineering adviser Materials engineering consultant Materials engineering expert Materials engineering specialist
Description	Materials engineers research and design new or improved materials for a diverse number of applications. They analyse the composition of materials, conduct experiments, and develop new materials for industry-specific use that can range from rubber, to textiles, glass, metals, and chemicals. They advise companies in damage assessments, quality assurance of materials, and recycling of materials.
Code	2149.11
Current essential skills	Adjust engineering designs Analyse production processes for improvement Apply health and safety standards Approve engineering design Assess environmental impact Create solutions to problems Develop advanced materials Develop material testing procedures Forecast organisational risks Integrate new products in manufacturing Perform chemical experiments Perform scientific research Test chemical samples Test materials Work with chemicals
Current optional skills	Advise on pollution prevention Advise on waste management procedures Assess the feasibility of implementing developments Define quality standards Design prototypes Develop chemical products Perform laboratory tests
Essential skills for the future	Cybersecurity IoT Entrepreneurship Innovation Adjust engineering ecological design Knowledge of obtaining high-quality recycled products Design for durability Designing products for reusability Critical thinking Teamwork Show empathy Solving problems Protect the psychological wellbeing Material reutilisation Resource efficiency Environmental awareness Rs, reuse, recycle, reduce Adjust engineering sustainable design Assess environmental impact Climate change mitigation and adaptation Ensure compliance with environmental legislation Assessment of the carbon footprint generated Test materials with digital applications Advanced materials Emerging materials Awareness of gravity of climate change
Optional skills for the future	Artificial intelligence Cloud technologies Advanced simulation Big data analytics and interpretation skills Digital capability Energy efficiency Electronics and automation Emerging technologies related with the carbon capture Digital Twin Social responsability Ethical responsability Adapt to change Well-connected Maintain working relationships Leadership principles Demonstrate intercultural competence Interdisciplinary skills Understanding of the social and political factors Develop waste reduction Sustainable resource management Renewable energy Natural resource management Awareness of the importance of gas mitigation Energy efficiency Robotics Advise on sustainable management policies Energy storage systems Resilient results

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