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Book

Mapping green and digital energy jobs : trends and insights from online job posting

Mapping Green and Digital Energy Jobs

Trends and insights from online job posting

International Energy Agency

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Abstract

The global energy sector has experienced significant changes in recent years, driven by the dual forces of the climate emergency and the accelerating energy transition. As the world shifts towards cleaner technologies and renewable sources, the demand for specialised workforces in energy efficiency and clean energy technologies such as solar, wind, batteries and electric vehicles, and heat pumps has surged. Digitalisation – a key driver of the energy transition – has also created a demand for a skilled digital workforce capable of modernising existing infrastructure and developing innovative tools for a cleaner, more efficient energy future. This report delves into the evolution of online job postings in these fields, analysing trends in the number of jobs advertised online, advertised salaries, hiring industries and required skills, using data from the comprehensive Lightcast dataset. By exploring this dataset, the report uncovers how workforce demands have adapted to the energy transition, reflecting both technological advancements and policy shifts aimed at decarbonising the global economy. This analysis not only highlights the growing opportunities in clean energy jobs but also demonstrates the rich potential for further exploration of advertised vacancies trends in the sector. This report ultimately underscores the dataset's utility in analysing evolving workforce dynamics and supports broader discussions about the role of clean energy jobs in the transition to a sustainable future.

Acknowledgements, contributors and credits

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Executive summary

In the context of the ongoing climate change, governments and private companies are implementing efforts towards the necessary energy transition. This has resulted in a growing focus on clean energy, energy efficiency and other sustainability initiatives. Consequently, clean energy sectors are experiencing a surge in demand for skilled workers, as emphasised in the World Energy Employment 2024 report. The transition to a low-carbon economy is creating numerous job opportunities.

This report focuses on online job postings (OJPs) and provides analysis of trends of vacancies posted online in various countries, sectors or occupational categories. Examining online job postings to understand labour market trends has the advantage of providing valuable real-time data and detailed insights and can be used as a proxy for labour demand, though it is important to consider their limitations, such as potential biases in representation and coverage. The analysis is twofold: a first chapter is dedicated to investigating job trends on energy efficiency and some key technologies related to the clean energy transition, such as solar, wind, heat pumps, and batteries and electric vehicles (EVs). A second chapter is focused on digital jobs and skills in the energy sector.

From 2021 to 2023, the share of online job postings in the clean energy technologies analysed (solar, wind, heat pumps, energy efficiency, and batteries and electric vehicles) increased for most countries under study. In 2023, Spain achieved a record high 0.3% of its total OJPs dedicated to solar positions, **a level never achieved in any previous years, or by any other technology**. Germany stood out with wind- and battery- and EV-related OJPs reaching around 0.08% of the total. Heat pump OJPs reached around 0.03% of the total online postings in Austria, and energy efficiency OJPs reached the same in France.

Across all the clean energy technologies analysed, the share of online job postings related to clean technologies is on average higher in European countries than in Australia, Canada, New Zealand, Singapore and the United States.

The number of online job postings also increased in almost every country, for every technology, between 2021 and 2023. The number of Italian wind-related OJPs multiplied by 4.5 in only three years. Over the same period, in Ireland, wind OJPs multiplied by 4, and Spanish ones by about 3 for heat pumps and batteries and electric vehicles. However, four countries decreased their number of online job postings regarding energy efficiency-related positions: Australia, Belgium, Switzerland and the United States.

Utilities and *Manufacturing* sectors consistently play a critical role in recruitment across solar, wind, heat pumps, and batteries and EV sectors, accounting for 25% to 67% of the technologies' OJPs. For energy efficiency, the percentage is lower, ranging from 8% to 48%.

Analyses of the occupational categories show that *Technicians, Associate Professionals, and Skilled Trades Workers* are often the most advertised positions in terms of share of clean technology OJPs. This category is closely followed by *Professionals*, emphasising the ongoing demand for technical skills in the clean energy workforce.

In terms of salaries (PPP adjusted), anglophone countries, particularly the United States, offer higher wages across clean energy technologies, on average. However, it should be pointed out that anglophone countries offer a better coverage in terms of advertised salary information available in the postings and this may influence the results.

When examining individual countries' dynamics (in Australia, France, Germany, the United Kingdom and the United States), solar consistently emerges as the most dominant technology in terms of share of OJPs. This highlights solar energy's significant contribution to clean technology employment across the world.

The data also allow more detailed geographical analysis. In the United States, vacancies posted online for solar positions are heavily concentrated in California (25% of solar OJPs), with additional concentrations in Texas, Florida, Arizona, Nevada and the East Coast. On the other hand, wind jobs are predominantly based in Texas (20%) and the Midwest's "wind corridor". In the United Kingdom, London is the major publisher of OJPs for both solar (16%) and wind (24%), with Bristol, Manchester, Sheffield and Glasgow also emerging as key hubs for both technologies. While the United Kingdom has similar hubs for both sectors, the United States shows distinct geographical differences between solar and wind job locations due to the way that both resources and state incentives are spread.

Focusing on digital jobs, the share of digital OJPs in power utilities is generally lower than in other sectors and has not shown significant growth, even as the sector undergoes digital transformation through technologies such as smart grids, underscoring a lag in digital hiring practices within power utilities.

In the United States, cybersecurity-related OJPs in the power utility sector have not been rising since 2018 despite an increasing number of cyberattacks. The data indicate that while job postings surge immediately following major cyber incidents, there is no sustained hiring trend, suggesting a reactive rather than proactive recruitment approach. Recruitment challenges are compounded by comparatively low salaries and the highly specialised skill sets needed within power utilities.

Finally, smart grid-related jobs in the United Kingdom and the United States have also been minimally advertised since 2018. In these markets, *Professional, Scientific and Technical Activities*, along with *Utilities*, remain the primary industries driving recruitment in this area. *Professionals* account for approximately two-fifths of OJPs, highlighting a demand for advanced expertise, while *Technicians, Associate Professionals and Skilled Trades Workers* make up about 30% of postings. These findings demonstrate the ongoing needs for both specialised and technical roles in this evolving energy landscape.

Analysing digital skills in more detail shows that smart grids, and battery and EV OJPs exhibit the highest shares of roles that require at least one specialised digital skill in both the United Kingdom and the United States, indicating their strong reliance on advanced digital expertise. In contrast, a lower share of solar OJPs requires digital skills, highlighting a disparity in digital skills demand across clean energy sectors. In the United Kingdom, energy efficiency OJPs require most digital skills among Automation, Big Data, Scripting Languages, Internet of Things, AI and Machine Learning, Cloud Computing, Storage and Solutions, Telecommunications, SQL, Data Science and Analysis, and Cybersecurity, while in the United States smart grid OJPs are still the ones with the highest share. When analysing all technologies collectively, *Data Analysis* emerges as the most sought-after digital skill in both countries, underscoring the critical role of data proficiency in the clean energy transition.

Understanding online job postings

Lightcast dataset

Lightcast collects information on vacancies using a web crawling algorithm and then performs pre-processing on the data to infer job title, date of the posting, industry, occupation, salary and job requirements. Data are obtained from many different websites to make sure that as many postings as possible are collected. Checks are in place to remove eventual duplicates of the same job posted on different platforms.

The **industry classification** is extracted either from the company name or from the job posting's text (for non-anglophone countries) and follows the official classification used in a country (Australian and New Zealand Standard Industrial Classification, Nomenclature of Economic Activities [Europe], North American Industry Classification System, Singapore Standard Industrial Classification, UK Standard Industrial Classification – more details in the methodology annex). If the company posting the job is not disclosed or is a recruitment agency, no information on the industry classification is available.

The **occupational classification** is extracted from the job title and follows the national occupational codes (Australian and New Zealand Standard Classification of Occupations; European Skills, Competences, Qualifications and Occupations; International Standard Classification of Occupations; Standard Occupational Classification [United States]; Singapore Standard Occupational Classification – more details in the methodology annex). If the quality of the job title is low, this may result in no availability of the occupational classification.

In the report, both industry and occupational classifications used are custom-made, created to enable the comparison of sector and occupation across countries. The detailed mapping between the available taxonomies and the custom classifications used is available in the methodology annex.

The **advertised minimum annual salary** of the position, if available, is displayed in the local currency. To ensure comparability across region, the values have been adjusted using purchasing power parity (PPP) conversion rates for the respective year and country.

Job requirements include the **years of education** and **skills**. The years of education, if available, are also inferred from the text of the posting and start from primary school, so that 5 years means primary education only and 12-13 years corresponds to high school. Skills are broadly defined in Lightcast and can also

include competencies and abilities mentioned in the ad, such as “Public Speaking”, “Teamwork” or “Problem Solving”. Information technology (IT) skills are also marked as specialised or not, where baseline skills include everyday abilities such as Microsoft Word or Microsoft Windows.

The job postings also contain **location** variables, such as region, city and geographical co-ordinates, when available, that are based on the finest location details specified in the job advertisement.

Advantages and limitations of the data

Online job postings (OJPs) are different from job openings, and cannot be directly compared to employment data. However, they remain valuable for gaining insight into trends in labour demand and requested skills. It is important, though, that the user is mindful of their limitations when interpreting the report’s findings.

First, the dataset contains only vacancies that are posted online, so all those that are filled through other means (such as internal recruitment, employee referrals or word of mouth) are not contained in the dataset. In addition, jobs advertised through newspapers or physical offices will not be captured by this dataset. Even though the propensity to use the web as the main mean for job advertisement increased during and after the Covid-19 pandemic, it still varies greatly by sector and occupation, so that certain categories may be under- or overrepresented.

Second, even if the online postings could be good representatives of the available vacancies, there are many different websites collecting job advertisements, and Lightcast’s capacity to reflect the reality differs by location, industry and occupation. More consolidated countries such as the United States are likely to better capture the totality of online postings compared with countries that were added more recently, such as Mexico.

In addition, job postings cannot be directly compared to vacancies, since a job may be advertised online but never filled, or a single advertisement could be used to hire multiple people.

Another consideration concerns the tenure and turnover rates, which are very heterogeneous by occupations, sectors and even by companies within the same sector and may result in disparities among occupation representation. As an example, Davis, Faberman and Haltiwanger (2013) found that growing firms tend to be overrepresented compared with the average firm.

The coverage of the various job information is also a non-negligible topic, which entails some limitations when using the data. Industry and occupational classification have a heterogeneous coverage, and their availability may not overlap, since occupation is inferred from the job title while industry is mostly

extracted from the employer. Advertised salaries, on the other hand, are retrieved from the text so that when comparing salaries, a few jobs are first discarded because no salary information is available; then – when analysing salaries by occupation and/or industry – additional postings are removed because no occupational and/or industry information is available. In big countries, with overall good job coverage, this may not pose a problem. However, in smaller countries or when analysing niche jobs, such as those in smart grids, these limitations may significantly reduce the sample size, rendering any attempt at analysis futile.

Filtering process

The report provides an overview of the evolution of OJPs between 2018 and 2023.

The first chapter, **Online job postings related to the energy transition**, offers a descriptive analysis of online job postings on energy efficiency and some key technologies related to the clean energy transition, such as solar, wind, heat pumps, and batteries and electric vehicles. These jobs have been identified using 1) a combined search of keywords in the job titles and occupational codes for wind and solar jobs; and 2) only keywords for heat pumps, battery and electric vehicle, and energy efficiency jobs.

The second chapter, **Digital jobs and skills in the energy sector**, delves into digital online job postings and skills in the energy sector. Some jobs have been extracted using a mix of occupational and industry codes, and smart grid jobs were identified using keywords.

All the details are outlined in the methodology annex.

Throughout the report, to ensure the robustness of the results, a minimum **threshold of 50 observations** was required before performing data aggregation. This criterion was implemented to mitigate the risks of random variability influencing the results and to ensure that the aggregated data reflect meaningful trends. Observations below this threshold were excluded to maintain the reliability and validity of the findings.

Throughout the report, the notion of “share of OJPs in a given country X, for the technology Y” refers to number of Y-related OJPs in X over the total number of online job postings in X (not limited to the selected technologies from this report). For example, the share of solar jobs in Australia in 2020 is computed as the total number of solar OJPs in Australia in 2020 over the total number of online job postings collected by Lightcast in Australia during 2020.

Online job postings related to the energy transition

This chapter provides insights into trends and distributions of online job postings related to the energy transition. For details about what jobs are covered in each section, please refer to the methodology annex.

Solar online job postings

The solar energy industry has experienced remarkable growth over the past decade, driven by technological advancements, decreasing costs and a global push towards clean energy. This surge has not only transformed the energy landscape but also created a substantial demand for professionals – as solar creates more jobs per megawatt than any other renewable technology – across various industries who contribute to the research and development, manufacturing, installation, and operation of solar panels. This chapter explores the dynamics of online job demand in Australia, Austria, Belgium, Canada, France, Germany, Ireland, Italy, New Zealand, Singapore, Spain, Switzerland, the United Kingdom and the United States. Solar postings used for the analysis in this chapter have been identified using a combination of filtering using keywords in the job title and occupational categories. More details are available in the methodology annex.

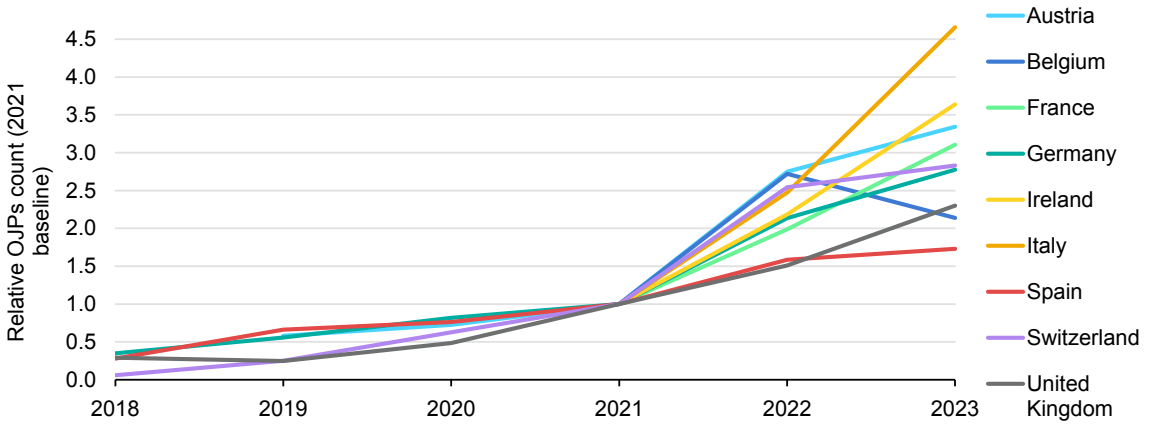
Total online job postings

The job demand in the solar sector experienced an increase across most of the analysed countries.

Among the countries in Europe (Austria, Belgium, France, Germany, Ireland, Italy, Spain, Switzerland, the United Kingdom), Spain holds the record for the highest share of solar OJPs, reaching 0.3% in 2021 and 2023, followed by Austria (0.21% in 2023) and Italy (0.18% in 2023). In terms of absolute numbers, the largest relative increase in OJPs between 2021 and 2023 happened in Italy, Ireland and Austria, where the number of ads rose by a over factor of three (in Austria) and over 4.5 times the values of 2021 in Italy.

According to the EU Market Outlook for Solar Power 2023-2027, the solar sector, including both direct and indirect jobs, should reach 1 million employees by 2025 and 1.2 million by 2027 to achieve the European Union's 2030 solar deployment targets. In 2023, direct employment opportunities in Europe accounted for around 380 000 people.

Relative count of solar online job postings (2021 baseline) in selected countries, 2018-2023



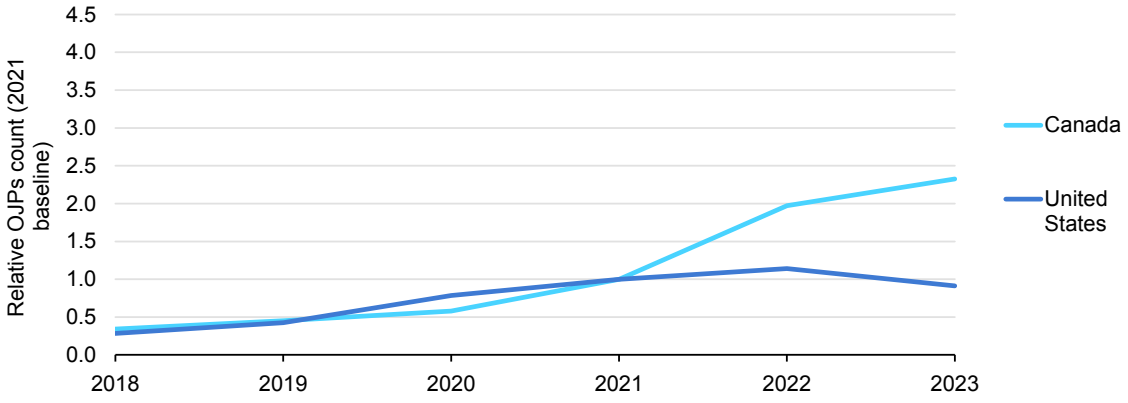
IEA. CC BY 4.0.

Notes: Data for 2023 are available only until the end of the third quarter for all countries except the United Kingdom (for which they are available until 30 November 2023). The total number of OJPs for 2023 has been estimated by multiplying by 12 (number of available months) the count of jobs for 2023. More details in the methodology annex.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

In North America, the share of solar OJPs in the United States fluctuates and peaks in 2021, reaching 0.11%, after which it continues to stay above 0.1%. When looking at the absolute number of OJPs, though, the rise is steady, with numbers starting to decrease again in 2023. In Canada, the share is now slowly picking up, reaching 0.03% in 2023. This is not surprising considering that the installed capacity for photovoltaic (PV) systems in Canada has gone from 3.1 gigawatts (GW) in 2018 to 6 GW in 2023, while in the United States it has skyrocketed from 62.5 GW to 169.8 GW in the same period.

Relative count of solar online job postings (2021 baseline) in Canada and United States, 2018-2023



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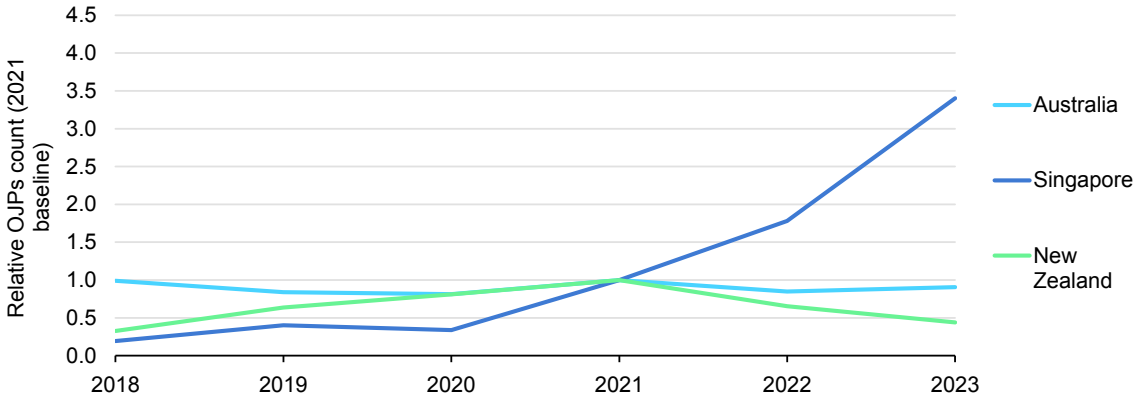
Notes: Data for 2023 are available only until the end of November for Canada and the end of October for the United States. The total number of OJPs for 2023 has been estimated by multiplying by 12/(number of available months) the count of jobs for 2023. More details in the methodology annex.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

Singapore follows the trend of the above countries with an increase in solar OJPs, especially in recent years. The increase in installed solar capacity is slow but steady, and the rise in OJPs may reflect the engagement to actively shift from the current early stage of integration of variable renewable energy (VRE) to more integrated power system operations. The trend in Australia and New Zealand is fluctuating, despite a ramping increase of solar capacity in Australia.

Relative count of solar online job postings (2021 baseline) in Australia, New Zealand and Singapore, 2018-2023



IEA. CC BY 4.0.

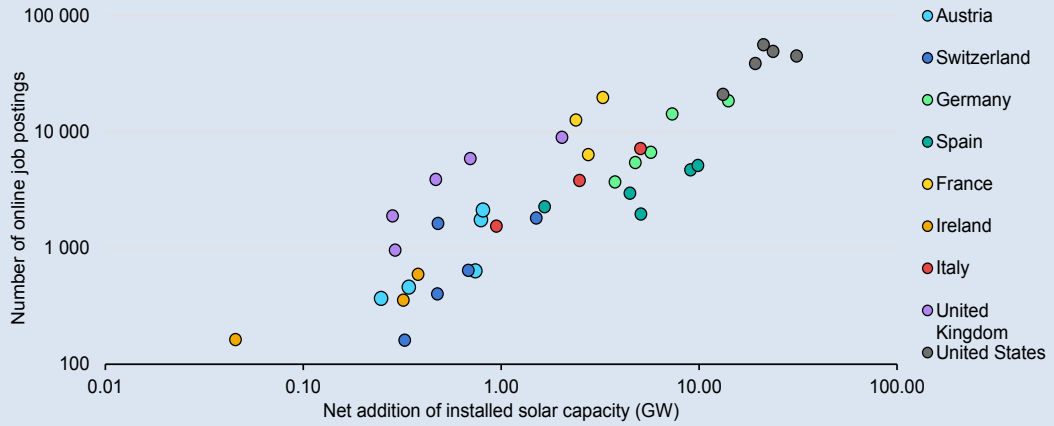
Notes: Data for 2023 are available only until the end of November 2023 for Singapore, so the total number of OJPs for 2023 has been estimated by multiplying by 12/11 the count of jobs for 2023. More details in the methodology annex.
Source: IEA analysis based on data from Lightcast (accessed July 2024).

Relationship between net annual addition of installed solar capacity and number of online job postings

All the countries display a moderate to steep increase in demand for solar positions, which reflects the expansion of the installed capacity, as reported by the Renewable Energy Progress Tracker. For most countries, when looking at the last five available years, from 2019 to 2023, there is also a clear relationship between net addition installed solar capacity and number of OJPs. The relationship is clearly visible even without any time lag, probably because of the upward trend over time for both jobs and annual additional capacity.

In the scatter plot, each dot marks the relationship (by country and year) between annual net addition of solar capacity and total number of online solar jobs.

Net annual addition of installed solar capacity versus number of solar online job postings by country and year, 2019-2023



Notes: Both x and y axes are represented in the log form. Data for 2023 are available only until end of the third quarter for Austria, Switzerland, Germany, France, Ireland, Italy; until the end of November for the United Kingdom; and until the end of October for the United States. The total number of OJPs for 2023 has been estimated by multiplying by 12/(number of available months) the count of jobs for 2023. More details in the methodology annex.

Sources: IEA analysis based on data from Lightcast and the Renewable Energy Progress Tracker.

Online job postings distribution by industry

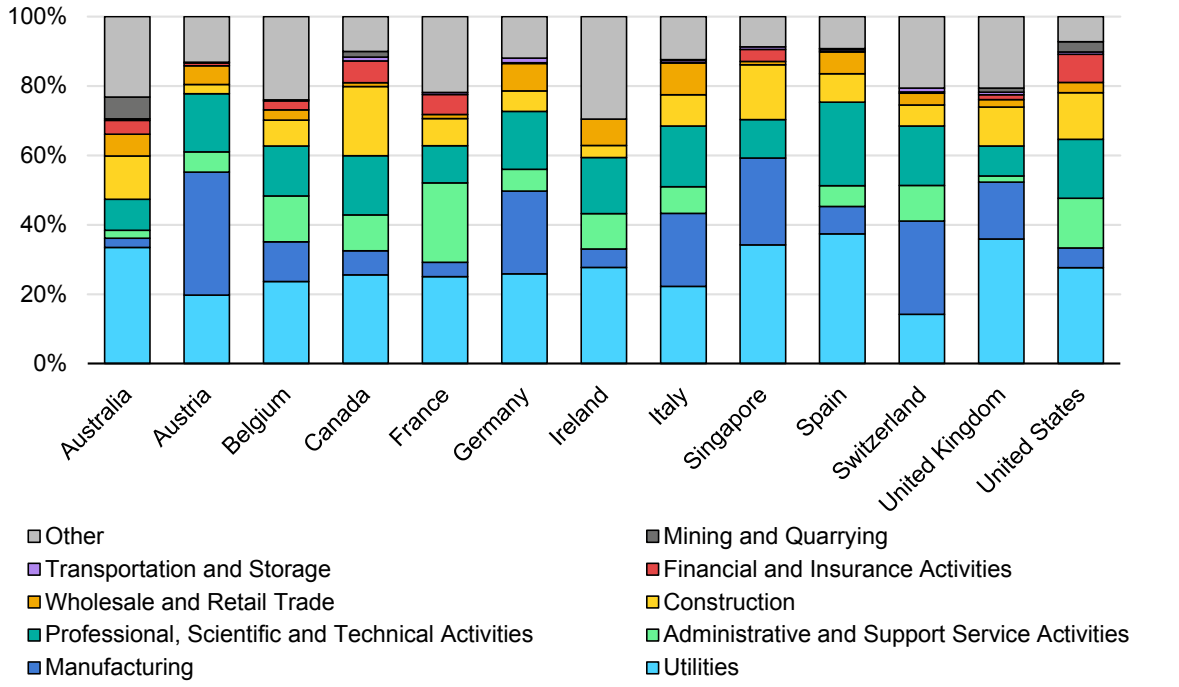
The distribution of job demand across industries varies greatly among countries. In 2023, *Utilities*, *Manufacturing*, and *Administrative and Support Service Activities* accounted for at least 50% of the online vacancies in most of the analysed European countries (Austria, France, Germany, Italy, Spain, Switzerland and the United Kingdom). The *Utilities* online postings make up the largest sector share in all European countries except for Austria and Switzerland, where *Manufacturing* takes the lead.

In the United States, *Utilities* has a share of 28% and *Manufacturing* of 6%. The United States Energy and Employment Report 2024 shows a different picture, where Solar Employment in *Utilities* accounts for only 4% and the biggest share of jobs is in the *Construction* industry (50%, while its share among OJPs is only 13%). This may be due to different ways to advertise jobs between industries, where jobs in *Construction* are not posted online as much as jobs in *Utilities*. Therefore, Lightcast data may underrepresent the number of vacancies in this sector.

Canada follows the trend of European countries but has a rather larger share of *Construction* online positions (20%).

In Australia, *Utilities* jobs represent a high share of solar positions, like most of the other countries, but jobs in *Manufacturing* and *Administrative and Support Service Activities* account for only 5% of the total share. Singapore, on the other hand, displays a high share of both *Utilities* and *Manufacturing* jobs (34% and 25%, respectively).

Solar online job postings distribution by industry in selected countries, 2023



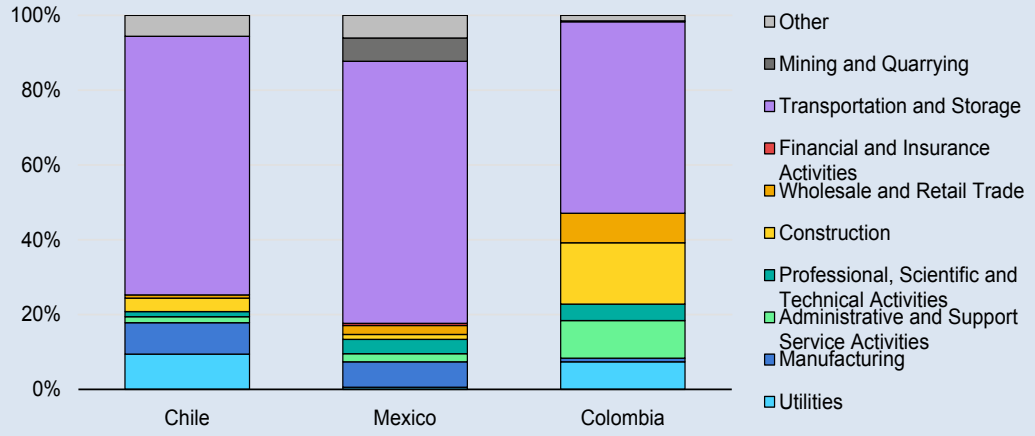
Note: "Other" includes the following industries: *Accommodation and Food Service Activities*, *Agriculture, Forestry and Fishing*, *Arts, Entertainment and Recreation*, *Education*, *Human Health and Social Work Activities*, *Information and Communications*, *Other Service Activities*, *Public Administration and Defence*, *Real Estate Activities*.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

Solar online job postings by industry in Latin American countries

In Chile, Mexico and Colombia, data from 2022 show a different tendency, where the greatest part of online solar jobs belongs to the *Transportation and Storage* industry. This may be due to the way that Lightcast infers industry from job postings, when the company is not available, creating this big difference with other countries.

Solar online job postings distribution by industry in Chile, Mexico, Colombia, 2022



Note: "Other" includes the following industries: *Accommodation and Food Service Activities*, *Agriculture, Forestry and Fishing*, *Arts, Entertainment and Recreation*, *Education*, *Human Health and Social Work Activities*, *Information and Communications*, *Other Service Activities*, *Public Administration and Defence*, *Real Estate Activities*.

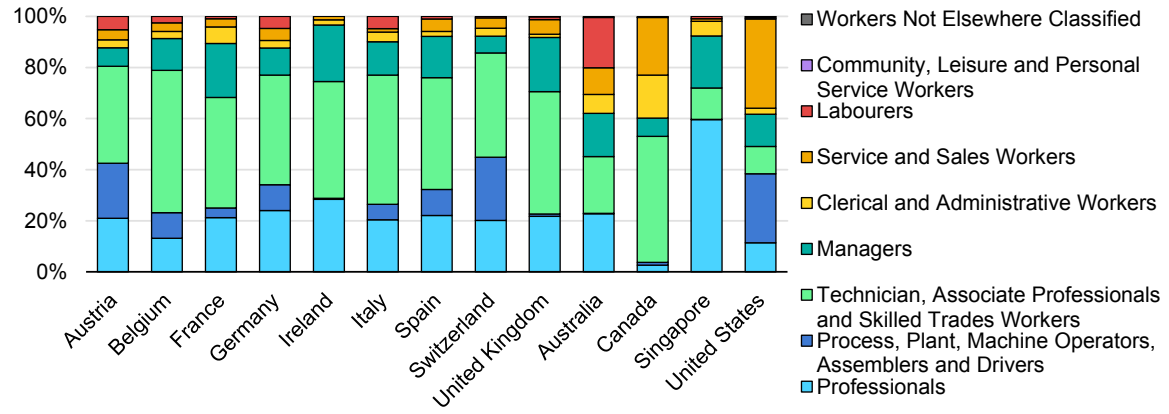
Source: IEA analysis based on data from Lightcast (accessed July 2024).

Online job postings distribution by occupation

In 2023, occupation patterns across Europe (Austria, Belgium, France, Germany, Ireland, Italy, Spain, Switzerland, the United Kingdom) reveal a consistent trend among countries, whereas the other analysed countries exhibit unique distributions of job postings.

In Europe, *Technicians, Associate Professionals and Skilled Trades Workers* (such as PV Installation Technicians, Solar Panel Maintenance Technicians) represent the most demanded OJPs position for all analysed countries (around or above 40% for all countries except Australia, Singapore and the United States), followed by *Professionals* (around 20% of the postings for most countries, including positions such as Solar Engineers and Photovoltaic [PV] Design Specialists) and *Managers* (for example, Solar Project Managers and Solar Farm Operations Managers). *Process, Plant, Machine Operators, Assemblers and Drivers* (such as Solar Panel Manufacturing Machine Operators) have a variable share but take up a relatively bigger chunk of jobs in Switzerland and Austria (25% and 22%, respectively).

Solar online job postings distribution by occupation in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

The postings in Australia are quite well spread across *Professionals*, *Technicians, Associate Professionals and Skilled Trades Workers*; *Managers*; and *Labourers* (an example of labourers could be Solar Panel Installers' Assistants and Construction Labourers for Solar Farms). This last occupation covers 20% of the ads, while in all other countries it is only 5% or less.

In Canada, *Technicians, Associate Professionals and Skilled Trades Workers* account for almost half of the online jobs. Compared with the other countries, far more *Service and Sales* and *Clerical and Administrative Workers* are sought. Non-exhaustive sample positions for *Service and Sales* might be Solar Sales Consultants and Customer Support Representatives for Solar Systems, and for *Clerical and Administrative*, Solar Project Coordinators and Permit Administrators for Solar Projects.

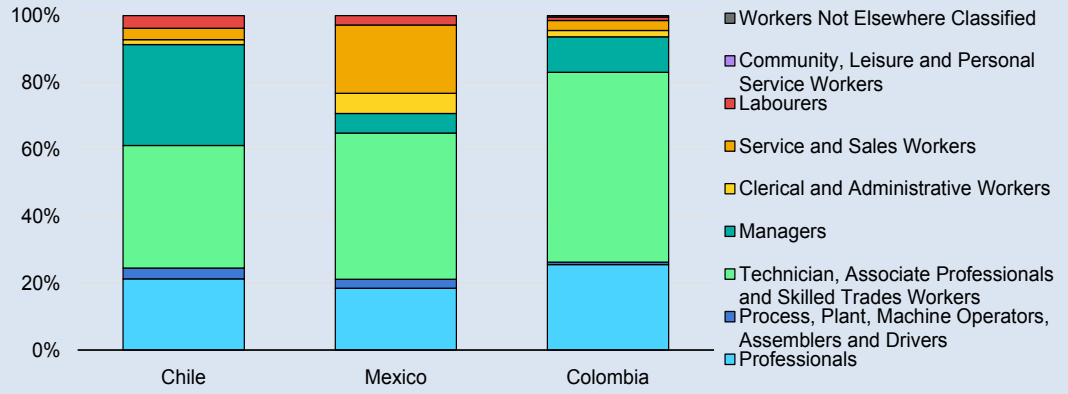
Sixty percent of Singapore online jobs are *Professionals*, followed by *Managers* (20%) and *Technicians, Associate Professionals and Skilled Trades Workers* (12%).

In the United States, *Service and Sales Workers* encompass 35% of the postings, followed by *Process, Plant, Machine Operators, Assemblers and Drivers* (27%) and *Managers; Professionals*; and *Technicians, Associate Professionals and Skilled Trades Workers* with a similar share (11-13%).

Solar online job postings by occupation in Latin American countries.

In 2022 (the full time series for 2023 is not available for these countries), occupation distribution in Chile, Mexico and Colombia was similar to the one in Europe, with *Technicians, Associate Professionals and Skilled Trades Workers* making up between 37% and 57% of the jobs, followed by *Professionals* (18-26%). In Chile, *Managers* represent a higher share of postings (30%) compared with Mexico (6%) and Colombia (11%). On the other hand, Mexico displays a larger share of *Service and Sales Workers* (20%) compared with Chile and Colombia, where they represent only 3% of the online job ads.

Solar online job postings distribution by occupation in Chile, Mexico, Colombia, 2022

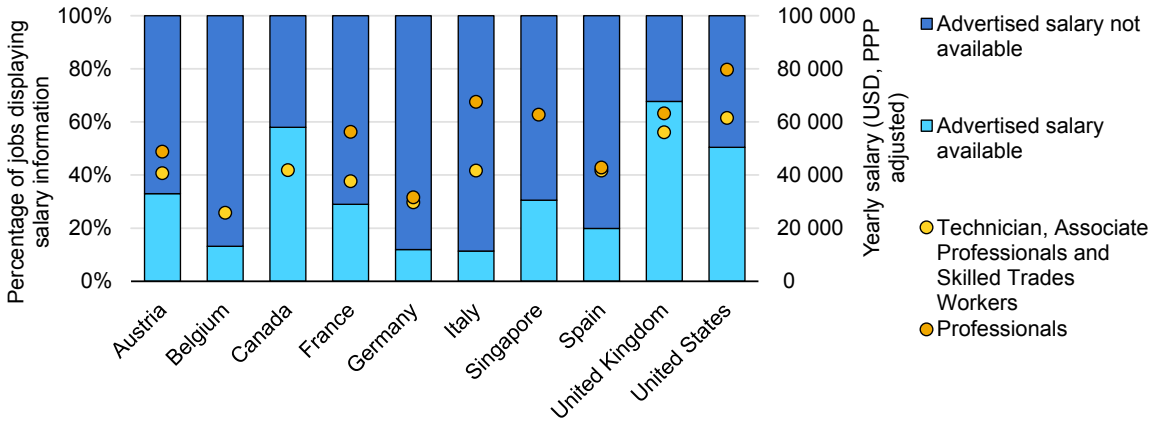


Source: IEA analysis based on data from Lightcast (accessed July 2024).

Advertised salaries

Data availability for advertised salaries varies greatly across countries (from less than 12% of OJPs displaying salary information in Germany and Italy to over 60% in the United Kingdom), with generally better coverage in anglophone countries (except for Singapore). The aggregated data in Europe (Austria, Belgium, France, Germany, Italy, Spain, the United Kingdom), covering 33% of OJPs, shows that in 2023 the yearly average salary offered online for solar jobs was in the range of USD 26 000 to USD 80 000. When looking at the salary average by country, the highest salaries (which also display the greatest variability) are in the United States, followed by the United Kingdom and Italy.

Average minimum advertised annual salary (PPP adjusted) for solar Professionals and Technician, Associate Professionals and Skilled Trades Workers versus share of solar online job postings displaying an advertised salary, in selected countries, 2023

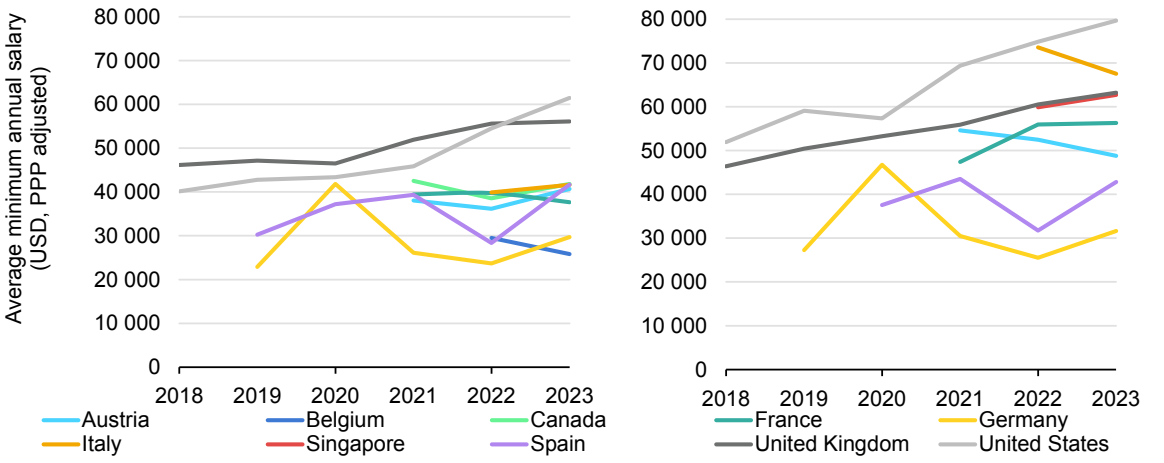


Notes: PPP= purchasing power parity. Not enough OJPs with advertised salary for *Professionals* are available for Singapore. Not enough OJPs with advertised salary for *Technician, Associate Professionals and Skilled Trade Workers* are available for Belgium and Canada.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

When looking at the aggregated data by country and year, the average offered salary (PPP adjusted) for *Technician, Associate Professionals and Skilled Trades Workers* and *Professionals* has remained mostly constant or decreasing over time, for most countries. This trend may pose a problem for recruitment. The United Kingdom and the United States, however, display clear increasing trends over the whole period analysed.

Average minimum yearly salary (PPP adjusted) advertised for solar Technician, Associate Professionals and Skilled Trades Workers (left) versus solar Professionals (right) in selected countries, 2018-2023

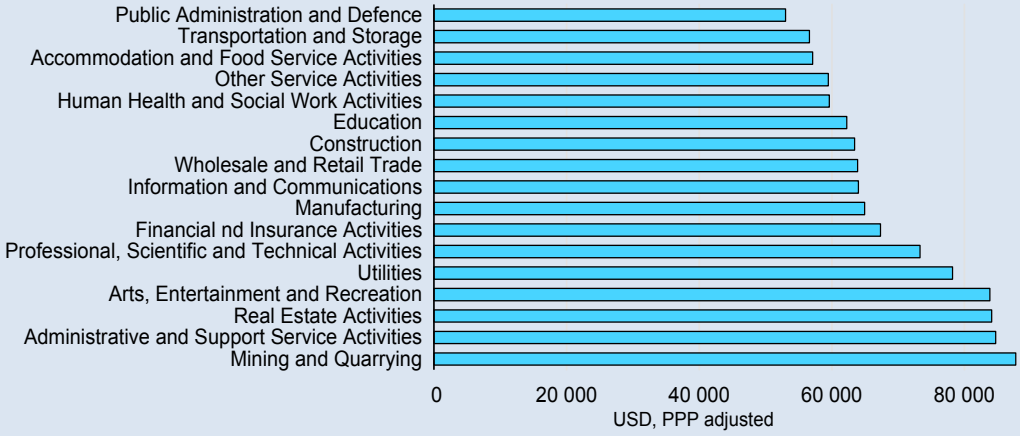


Source: IEA analysis based on data from Lightcast (accessed July 2024).

Focus: Salary breakdown by industry and occupation in the United Kingdom and the United States

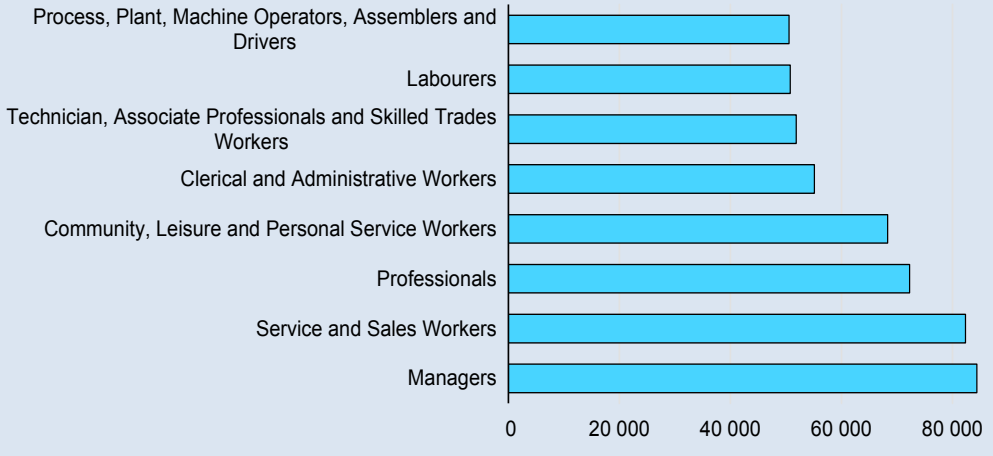
As mentioned above, coverage of the various indicators such as salary, industry and occupation vary greatly across countries. It is interesting, however, to have a look at the salary distribution by both industry and occupation, in the United States and the United Kingdom, where there is abundance of data available for the most recent years.

Average annual advertised minimum salary (USD, PPP adjusted) in solar online job postings by industry in the United States, 2019-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Average annual advertised minimum salary (USD, PPP adjusted) in solar online job postings by occupation in the United States, 2019-2023



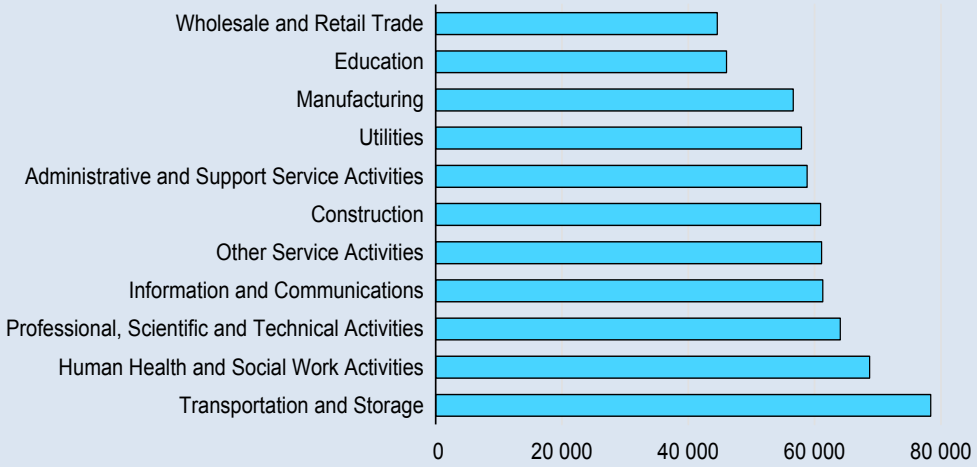
Source: IEA analysis based on data from Lightcast (accessed July 2024).

In the United States, the industries offering the highest salaries are *Mining and Quarrying*; *Administrative and Support Service Activities*; *Real Estate Activities*; *Arts, Entertainment and Recreation*; and *Utilities*, with an average advertised minimum yearly salary between USD 75 000 and USD 90 000. Jobs in *Public Administration and Defence*, on the other hand, offer a minimum yearly salary lower than USD 55 000.

As for occupation categories, *Managers* and *Service and Sales Workers* have on average the higher advertised minimum yearly salary (between USD 80 000 and USD 85 000) while position advertised in *Process, Plant, Machine Operators, Assemblers and Drivers*; *Labourers*; and *Technician, Associate Professionals and Skilled Trades Workers* propose a salary starting at around USD 50 000 per year.

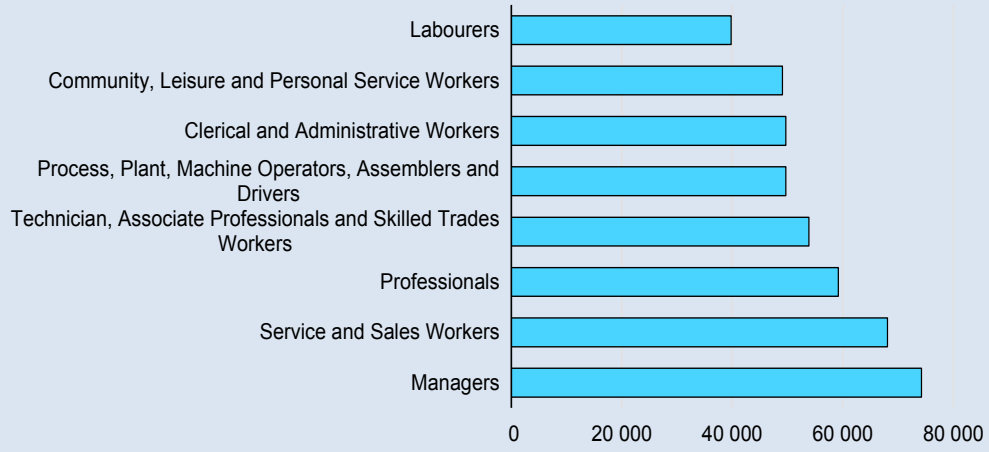
In the United Kingdom the situation is different, with a lower average minimum salary overall. When looking at sectors, workers hired in *Transportation and Storage* and *Human Health and Social Work Activities* belong to the best-paid industries, but in the United States those figure among the five lowest-paying ones. *Professional, Scientific and Technical Activities Workers* have a relative high salary, similarly to what happens in the United States. Workers in *Utilities* also seem to belong to the lower-paid sectors compared with the United States. Despite all the differences in salaries by industry between the two countries, it is worth noting that the gaps between the lowest- and highest-paid industry in the United Kingdom and the United States are similar (around USD 34 000).

Average annual advertised minimum salary (USD, PPP adjusted) in solar online job postings by industry in the United Kingdom, 2019-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Average annual advertised minimum salary (USD, PPP adjusted) in solar online job postings by occupation in the United Kingdom, 2019-2023



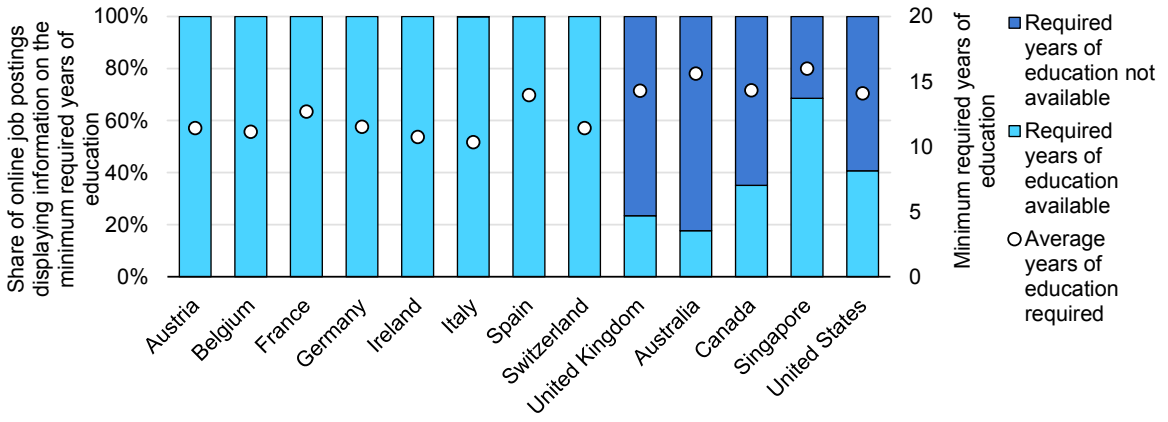
Source: IEA analysis based on data from Lightcast (accessed July 2024).

The comparison among occupations shows that *Service and Sales Workers* and *Managers* are the best-paid workers in the United Kingdom as well (USD 65 000 to USD 75 000), while *Labourers* are offered the lowest salary (USD 40 000). In the United Kingdom there is a bigger share of occupations with a medium salary (*Community, Leisure and Personal Service Workers*; *Clerical and Administrative Workers*; *Process, Plant, Machine Operators, Assemblers and Drivers*; and *Technician, Associate Professionals and Skilled Trades Workers*), while in the United States most of the occupations belong to the high or low end of the salary scale.

Required education

In Europe (Austria, Belgium, France, Germany, Ireland, Italy, Spain, Switzerland and the United Kingdom), the average minimum education requirement for solar jobs in 2023 is 11.9 years (which roughly corresponds to compulsory education). The highest requirement is in the United Kingdom with 14.3 years, followed by Spain (14) and France (12.7), with Ireland (10.7) and Italy (10.3) having the lowest requirements.

Average minimum years of education required for solar jobs in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Over the same year, solar jobs posted online in the United States and Canada require around 14 years of education. Schooling requirements are the highest in Australia and Singapore, where on average at least 15.6 and 16 years of education are necessary, corresponding to obtaining a college degree.

Wind online job postings

The wind energy sector, much like its solar counterpart, has witnessed significant expansion in recent years. Driven by technological advancements, favourable policies and an increasing emphasis on renewable energy sources, the wind market has become a key element of the global energy portfolio. This section examines how, in selected countries (Australia, Austria, Belgium, Canada, France, Germany, Ireland, Italy, New Zealand, Singapore, Spain, Switzerland, the United Kingdom, the United States), this growth has generated a robust demand for a skilled workforce across various domains, including manufacturing, research and development, engineering, and wind turbine services.

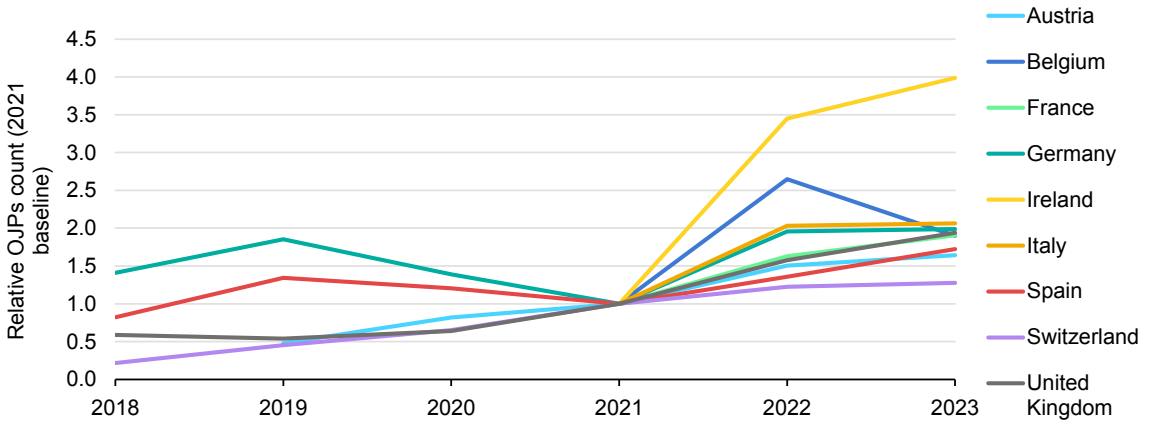
Total online job postings

In 2022, on average, wind-related OJPs accounted for 0.03% of all offers posted online in the analysed countries, which is below the 0.087% observed for solar jobs over the same period. Dynamics and evolution of this share varied a lot depending on countries or regions.

Between 2021 and 2023, European countries (namely Austria, Belgium, France, Germany, Ireland, Italy, Spain, Switzerland, and the United Kingdom for the remainder of this section) displayed an overall increase in the share of wind-

related OJPs, growing by 11% on average. Absolute numbers also increased for all analysed countries. However, when looking at each country-specific case, two distinct groups can be distinguished. On one hand, Austria, Belgium, Germany, Ireland and the United Kingdom saw their share increasing between 12% and 122%, between 2021 and 2023. On the other hand, France, Italy, Spain and Switzerland all had a decreasing share of wind OJPs during the same period of time. Germany was the country with the highest share in 2023: 0.08% of German OJPs were dedicated to wind-related positions. In terms of absolute numbers, between 2021 and 2023 the number of OJPs increased in all countries, exceptionally by four times for Ireland, while for all other countries the growth was up to two times the original value.

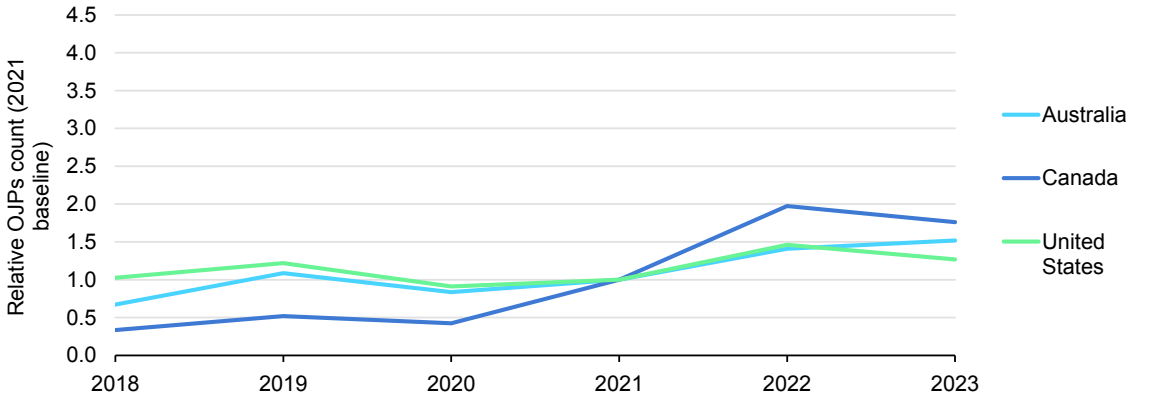
Relative count of wind online job postings (2021 baseline) in selected countries, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Like the European countries, Canada also increased its share of wind jobs posted online. In 2023, the share was more than twice as big as the 2018 level. On the other hand, the trend for the United States is fluctuating but is picking up in the last years. It is important to note that temporary drops in the wind OJP shares can be observed around the Covid-19 pandemic, before getting back to increasing trends, in most cases. The growing tendency of the wind job market is confirmed by the Land-Based Wind Market Report: 2023 Edition, which claims a 4.5% increase in the number of wind jobs between 2021 and 2022, and the World Energy Employment 2024 report showing a 4% growth of wind jobs between 2022 and 2023. However, this tendency is nuanced, especially in Europe, with several firms announcing job cuts starting in 2024.

Relative count of wind online job postings (2021 baseline) in Australia, Canada and the United States, 2018-2023



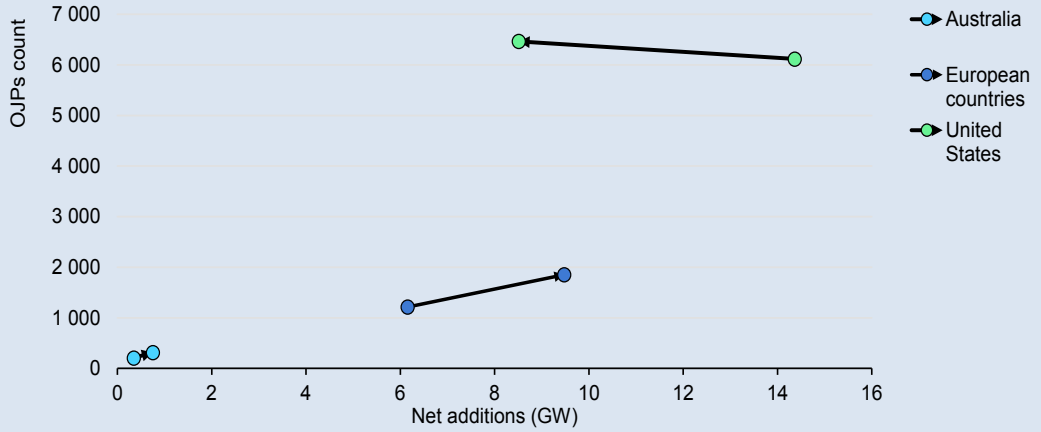
Source: IEA analysis based on data from Lightcast (accessed July 2024).

Finally, the share of wind OJPs increased in Australia as well. Despite a drop for the three countries in 2021, 2023 shares were significantly higher than the 2018 ones. In 2023, Australia's share was as high as Canada's, and higher than in the United States. Absolute numbers also show a slow rise in wind online job postings.

Relationship between net installed yearly wind capacity and number of online job postings

As emphasised in Wind Energy in Europe: 2023 Statistics and the Outlook for 2024-2030, analysed European countries decreased the net additional capacity installed during the Covid-19 pandemic, before increasing it again in 2021 and 2022, and stabilising it at a higher level in 2023. Consequently, the number of wind OJPs also increased over the same period. However, in the case of the United States, while more online vacances were posted, the net additional capacity installed was reduced between 2021 and 2023, going from more than 14 GW in 2021 to 8.5 GW in 2023.

Number of wind online job postings versus net installed additional yearly wind capacity, in Australia, European countries and the United States, 2021 versus 2023



Note: European countries are Austria, Belgium, France, Germany, Ireland, Italy, Spain, Switzerland, and the United Kingdom.

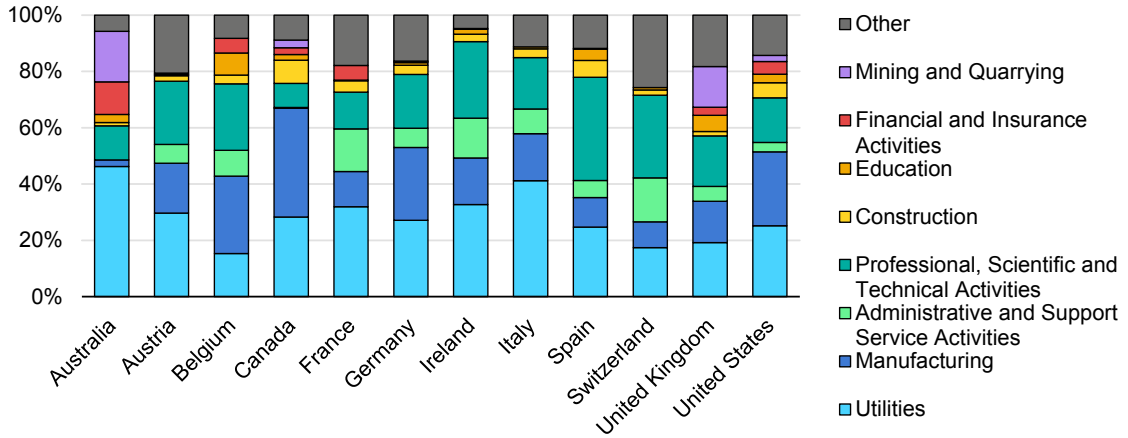
Sources: IEA analysis based on data from Lightcast and the Renewable Energy Progress Tracker.

Similar to Europe, Australia more than doubled its net additional capacity between 2021 and 2023, while the number of wind OJPs increased by more than 50%.

Online job postings distribution by industry

In 2023, as with solar jobs, wind OJPs were distributed across industries in very different ways, depending on the country under study.

Wind online job postings distribution by industry, in selected countries, 2023



Note: "Other" includes the following industries: *Accommodation and Food Service Activities*, *Agriculture, Forestry and Fishing*, *Arts, Entertainment and Recreation, Human Health and Social Work Activities*, *Information and Communications*, *Other Service Activities*, *Public Administration and Defence*, *Real Estate Activities*, *Transportation and Storage*, and *Wholesale and Retail Trade*.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

Utilities, *Manufacturing*, and *Administrative and Support Service Activities* accounted for around 50% of wind jobs posted online for most analysed countries. Only Spain, Switzerland and the United Kingdom differ. While 36.7% of Spanish wind OJPs are attributed to the *Professional, Scientific and Technical Activities*, 30% of the Swiss ones and 17.9% of the UK ones are. In addition, other industries, such as *Public Administration and Defence; Information and Communications; Transportation and Storage*; and *Arts, Entertainment and Recreation* represent 26% of the Swiss wind-related online job offers and 18.3% of those in the United Kingdom.

Contrary to solar jobs, the United States Energy and Employment Report 2024 shows a partially similar picture. According to the report, wind employment in *Utilities* represents 28% of wind jobs created in 2023, and this report finds that 25% of the US OJPs for wind-related positions were posted by companies from the *Utilities* sector. In addition, 5.4% of the newly created wind positions are related to the *Construction* sector, the same as its share of OJPs. More generally, the United States Energy and Employment Report 2024 found that the five industries hiring the most in 2023 were professional and business services industry, utilities, wholesale trade, manufacturing, and construction, which are also the industries with the most OJPs according to this report, except from *Wholesale and Retail Trade*.

The difference in share might be due to different ways of posting jobs (online versus on paper) depending on the industry, creating a bias in the market analysis through online job postings only, which might explain the gap between this report's findings and the United States Energy and Employment Report's ones. One can nevertheless observe that the biggest industries are the same, even if the magnitude is not.

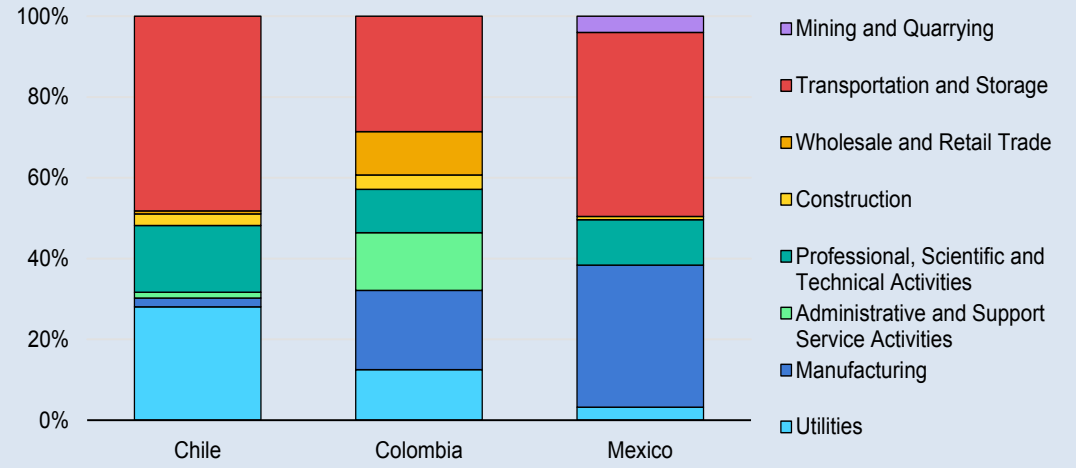
Wind online job postings by industry in Latin American countries

Similar to solar jobs, in 2022 *Transportation and Storage* was the most dynamic industry in wind jobs in countries from Latin America (Chile, Colombia and Mexico), representing 48.2% of wind OJPs in Chile, 45.6% in Mexico, and 28.6% in Colombia. This may be due to the way that Lightcast infers industry from job postings, when the company is not available, creating this big difference with other countries.

After *Transportation and Storage*, companies from the *Manufacturing* sector are the second-most-important recruiters in these Latin American countries, accounting for more than 35% of Mexican OJPs and almost 20% of the Colombian ones.

Finally, 28% of the Chilean wind OJPs came from *Utilities*-related companies in 2022.

Wind online job postings distribution by industry, in Chile, Colombia and Mexico, 2022

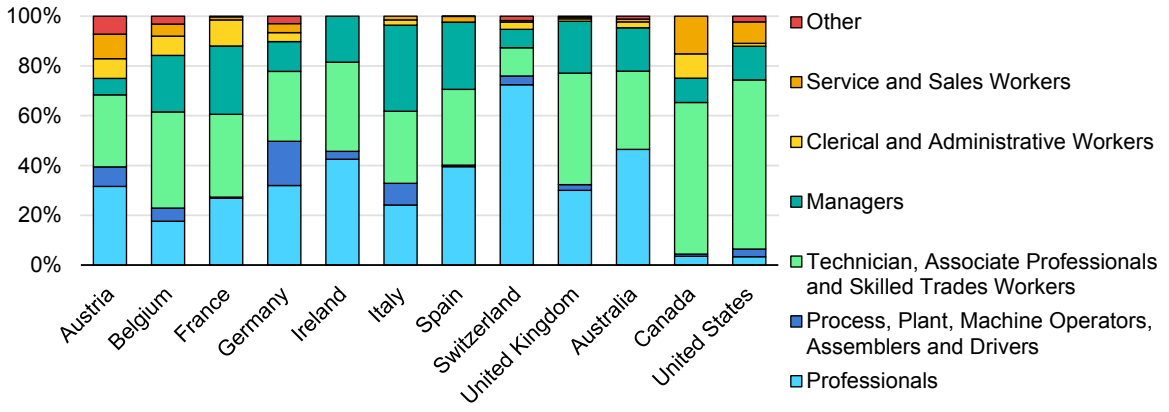


Source: IEA analysis based on data from Lightcast (accessed July 2024).

Online job postings distribution by occupation

Analysing wind OJPs from an occupation perspective distinguishes two countries, Canada and the United States, versus the rest. *Technician, Associate Professionals and Skilled Trades Workers* such as Wind Turbine Technicians or Wind Farm Maintenance Workers represent more than half the wind jobs advertised in Canada (60.9%) and two-thirds in the United States (67.9%). Jobs belonging to the same occupation family represent around 30% of wind OJPs for the remaining analysed countries, except in the United Kingdom, where it accounts for 45% of them. *Managers* positions (for example Offshore Wind Site Managers) as well as *Professionals* (such as Wind Turbine Design Engineers, Wind Resource Analysts) are much more advertised in European countries and in Australia. They represent on average 55.8% of these countries' wind OJPs, but only 15.1% in Canada and the United States. *Professionals* were particularly sought-after by companies: 72.4% of Swiss OJPs were *Professionals*-related positions as well as between 40% and 47% of the Australian, Irish and Spanish ones.

Wind online job postings distribution by occupation, in selected countries, 2023

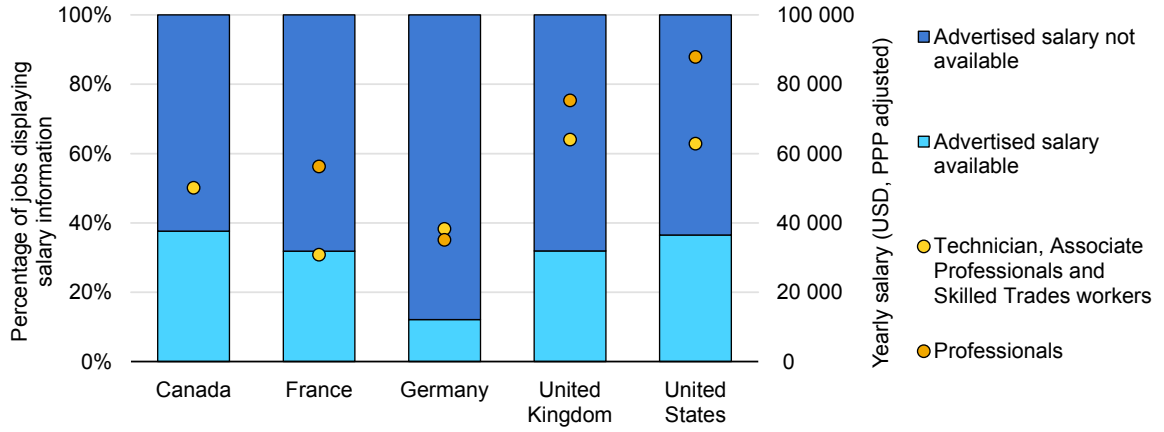


Note: "Other" includes the following occupations: *Community, Leisure and Personal Service Workers* and *Workers not Elsewhere Classified*.
Source: IEA analysis based on data from Lightcast (accessed July 2024).

Advertised salaries

Unlike the results for solar OJPs, the availability of advertised salary information in wind OJPs is low for all countries and quite similar, except Germany, where it is even lower. In 2023, only 12% of German OJPs for *Professionals* and *Technician, Associate Professionals and Skilled Trades Workers* provide information on salaries, compared with 38% coverage in Canada. On average, wind-related OJPs display a similar amount of information regarding salaries, compared with solar, in 2023. The reader should be mindful of the poor salary coverage when interpreting the results.

Average minimum advertised annual salary (PPP adjusted) for wind Professionals and Technician, Associate Professionals and Skilled Trades Workers versus share of wind online job postings displaying an advertised salary, in selected countries, 2023



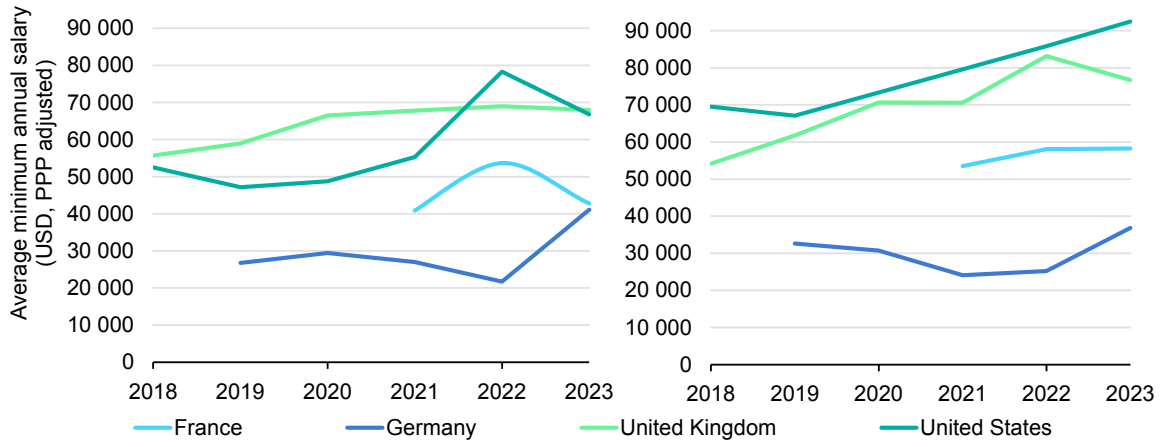
Note: Not enough OJPs with advertised salary for *Professionals* are available for Canada.
Source: IEA analysis based on data from Lightcast (accessed July 2024).

For *Professionals* workers, in 2023, the average minimum advertised annual salary was highest in the United States at around USD 87 900. This is around 10.5% more than what a worker could make in the solar sector, in a similar position, in the United States. In the United Kingdom, job postings for the same occupation offer an average minimum salary of USD 75 000 (PPP adjusted).

Concerning *Technician, Associate Professionals and Skilled Trades Workers*, salaries are much higher in anglophone countries than in France and Germany, in some cases even being more than two times larger (e.g. United Kingdom or United States versus France). Such positions are, on average, advertising salaries of at least USD 64 000 in the United Kingdom, USD 63 000 in the United States, and USD 50 000 in Canada. Both German and French OJPs for *Technician, Associate Professionals and Skilled Trades Workers* propose minimum salaries bellow USD 40 000 per year, on average. It is important to keep in mind that, depending on the country, availability of information about advertised salary in the OJPs is very different. It could happen that in some countries, high-paid OJPs do not display salaries while low-paid ones do, or vice versa. Thus, the information on salaries displayed here does not represent the actual salary level in each country, but a snapshot of some salaries offered, for some positions.

Salary evolutions across time are also very different between anglophone countries and France and Germany. Wind jobs advertised salaries for *Professionals* and *Technician, Associate Professionals and Skilled Trades Workers* in the United States and the United Kingdom increased between 2018 and 2023 – by between USD 12 000 and USD 23 000. *Technician, Associate Professionals and Skilled Trades Workers*' OJPs display a lower proposed salary growth than *Professionals* ones.

Average minimum yearly salary (PPP adjusted) advertised for Technician, Associate Professionals and Skilled Trades Workers (left) versus Professionals (right) in the wind sector, in selected countries, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

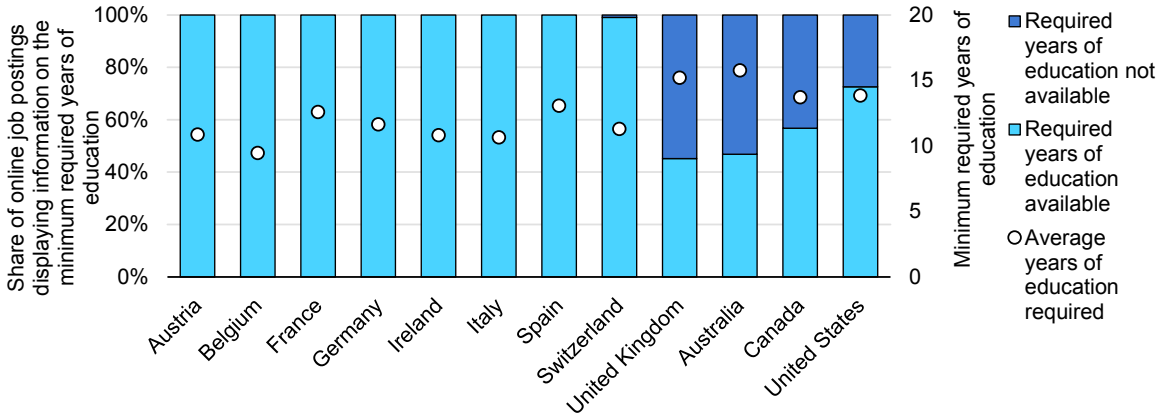
German and French salaries increased more slowly, on average. While in France, the average minimum salary displayed in online vacancies grew by 8.86% for *Professionals*, and by 4.6% for *Technician, Associate Professionals and Skilled Trades Workers* between 2021 and 2023, German salaries proposed to *Professionals* increased by 13%, which is much lower than what happened in the United States and the United Kingdom. However, *Technician, Associate, Professionals and Skilled Trades Workers* in Germany experienced the largest proposed salary increase between 2019 and 2021, growing by more than 53%; they went from less than USD 27 000 in 2019 to USD 41 100 in 2023.

Required education

In 2023, Australia was asking for the highest number of years of education (with a mean value of 15.78 years).

In Europe and for the countries analysed, the average minimum number of years of education required is 12.42 years. After Australia, the United Kingdom (15.21 years), and the United States (13.85 years) are the countries demanding the most years of education, while Belgium has the lowest average requirement of 9.47 years.

Average minimum number of years of education required in wind online job postings, in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Heat pump online job postings

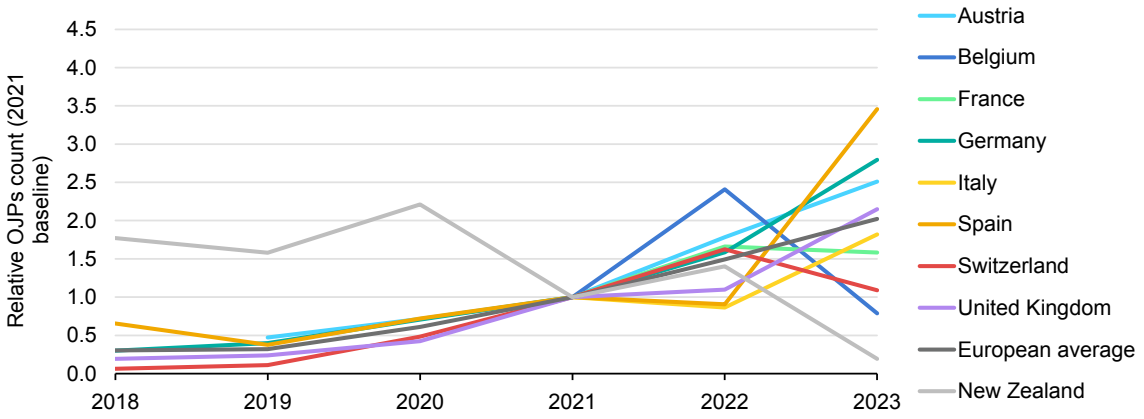
The heat pump industry has experienced significant growth over the past decade, fuelled by advancements in energy-efficient technology, rising environmental awareness and supportive government policies. This growth is transforming the HVAC (heating, ventilation, and air-conditioning) sector, offering an efficient

alternative to traditional heating and cooling systems. The increasing adoption of heat pumps has led to a surge in demand for professionals skilled in areas such as system design, installation, maintenance and energy optimisation. This section explores the evolving job market in the heat pump sector in selected countries (Austria, Belgium, France, Germany, Italy, New Zealand, Spain, Switzerland, the United Kingdom, the United States), highlighting how industry expansion translates into new employment opportunities and the specific skills that are in demand.

Total online job postings

The number of heat pump online vacancies varies greatly across the examined countries. Although in most countries the tendency shows an increased number of advertised online jobs in the past years, in a few countries (Belgium, France, Switzerland, New Zealand) the industry is still not actively recruiting.

Relative count of heat pump online job postings (2021 baseline) in selected European countries and New Zealand, 2018-2023



Notes: Data for 2023 are available only until the end of November for the United Kingdom and the end of the third quarter for Austria, Belgium, France, Germany, Italy, Spain, Switzerland. For those countries, the total number of OJPs for 2023 has been estimated by multiplying by 12/(number of available months) the count of jobs. More details in the methodology annex.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

In Europe (Austria, Belgium, France, Germany, Italy, Spain, Switzerland, the United Kingdom) the average share of heat pump OJPs reached 0.011% in 2021, remained stable in 2022 and increased to 0.13% in 2023. Austria, Germany, Spain and the United Kingdom show a moderate to steep increase in share, while the demand in Belgium, Italy, France and Switzerland sank in 2023. Austria (0.029%), Switzerland (0.024%), Germany (0.019%) and the United Kingdom (0.016%) all reached a share above 0.01% in 2023. Spain, Germany and Austria showed the greatest increase in OJP numbers between 2021 and 2023.

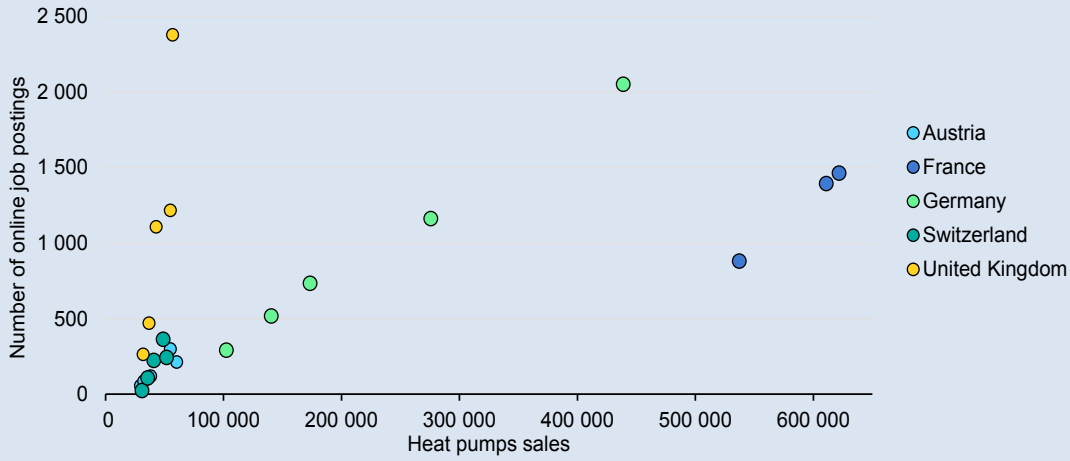
Heat pump sales in Europe

When considering the last decade, heat pump sales have been steadily increasing in all the analysed countries, except for 2023, which inverted the trend with a drop of around 5% overall in 14 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, and Switzerland). However, when looking at individual countries, the sales increased in Belgium, Spain and Germany, and dropped in France, Italy, Austria and Switzerland.

In the United Kingdom, the Boiler Upgrade Scheme (BUS) grant was introduced in 2022 to support the decarbonisation of homes and small non-domestic buildings in England and Wales. At the end of 2023 the grant levels for heat pumps were increased, which could explain the rise of both share and number of OJPs in the United Kingdom between 2022 and 2023.

When analysing the correlation between heat pumps sales and OJPs in the past five available years (2019-2023), for countries having at least 50 ads per year and country for all years, different patterns emerge.

Heat pump sales versus yearly number of heat pump online job postings in selected countries, 2019-2023



Notes: Data for 2023 are available only until the end of November for the United Kingdom and the end of the third quarter for Austria, France, Germany, Switzerland. The yearly number of OJPs for 2023 has been estimated by multiplying by 12/(number of available months) the count of jobs. More details in the methodology annex.

Sources: IEA analysis based on data from Lightcast, European Heat Pump Association, and national associations.

First of all, all countries show some correlation between these measures. Germany and France display similar gradients between points, indicating that the growth in heat pump sales corresponds to a similar growth of online job postings. The gradients between points for Austria, Switzerland and United Kingdom are steeper, meaning that, despite a relatively small increase in heat pumps sales, those

countries experienced a greater increase in heat pumps OJPs. This can be due to several factors, including a larger manufacturing capacity focused on serving export markets, the presence of research centres that drive job growth independently of the local market, or the evolution of the dominant heat pump technology selected by countries, which necessitates a newly skilled workforce, as observed in the United Kingdom.

Heat pump OJPs only started to appear in Australia in 2021.[1] This could be explained by the recent introductions of new financial incentives to install heat pumps in Victoria, New South Wales and Southern Australia, which resulted in installations of hot water heat pumps increasing more than fourfold from 2019 to an estimated 100 000 units sold in 2021, and 117 000 in 2022. On the contrary, New Zealand shows a fluctuating trend with a peak in 2020 (0.041%), after which it seems that the demand for heat pump workers is slowly decreasing. Despite this, the number of heat pumps sales has been slowly rising since 2013, but experienced a drop in 2023.

Compared with the average European share of heat pump jobs, the United States displays much lower ones and are therefore not shown. This contrasts with heat pump sales in the United States, which outsold gas furnaces in 2022, also thanks to the Inflation Reduction Act. The vast majority of heat pumps installed in the United States use the existing air-conditioning systems that are present in more than 90% of US households. As a result, most heat pump installations may be carried out by incumbent installers already established in the market, reducing the need for new job postings.

Trends for Canada are not shown because fewer than 50 OJPs were found for every year of the time series. Although the number of heat pumps installed has doubled in the past two decades, Canadian households are already largely equipped with air conditioning, which reduces the need for a new workforce, similarly to the United States. Even though the increase in heat pumps sales has been ongoing, the spike witnessed in the last year can be attributed to the Oil to Heat Pump Affordability (OHPA) Program, introduced in November 2022 and updated in 2023 to allow eligible homeowners to obtain up to USD 5 000 in additional federal support.

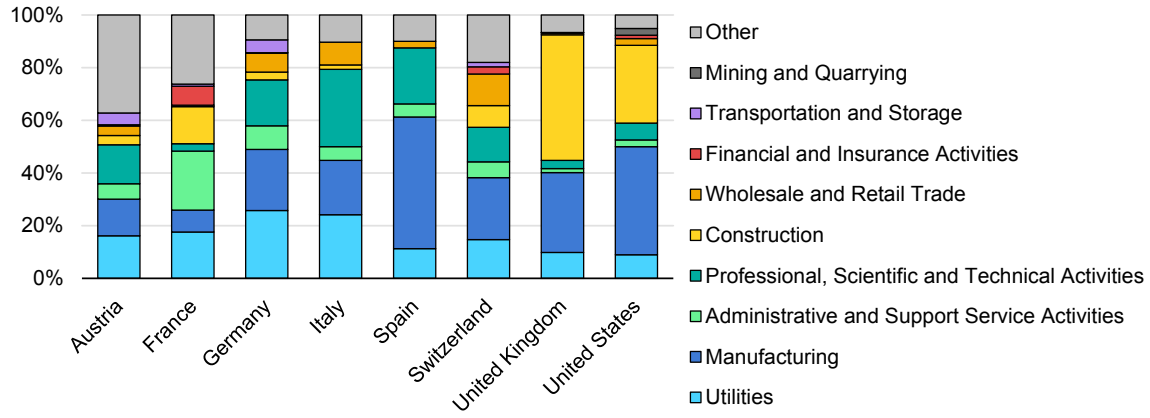
[1] However, fewer than 50 observations are available for each year, which is why data are not shown.

The big difference between the sales number in the United States and Canada and the low number in OJPs may be due to the way heat pump jobs are advertised (as part of the bigger HVAC category, without specifying heat pump, which is used as keyword to select ads).[2]

Online job postings distribution by industry

The data coverage on industry classification is not equally available across countries, and the distribution is quite heterogeneous.

Heat pump online job postings distribution by industry in selected countries, 2023



Note: "Other" includes the following industries: *Accommodation and Food Service Activities*, *Agriculture, Forestry and Fishing*, *Arts, Entertainment and Recreation*, *Education, Human Health and Social Work Activities*, *Information and Communications*, *Other Service Activities*, *Public Administration and Defence*, *Real Estate Activities*.
Source: IEA analysis based on data from Lightcast (accessed July 2024).

In the United States, *Manufacturing* – encompassing over 40% of all OJPs – was by far the largest industry looking for heat pump workers in 2023. Its share was only bound to increase in 2024 after the Biden-Harris administration announcement of a pledge of USD 63 million to accelerate electric heat pump manufacturing and nearly USD 85 million across four heat pump manufacturers to accelerate the manufacturing of electric heat pumps, heat pump water heaters, and heat pump components at five factories in New York, Tennessee, Texas and Rhode Island. *Construction* workers make up much of the rest of the share (29%).

The United Kingdom also displays a large share of OJPs belonging to the *Manufacturing* industry (30%), but an even higher one in *Construction* (48%). In the other European countries (Austria, France, Germany, Italy, Spain and

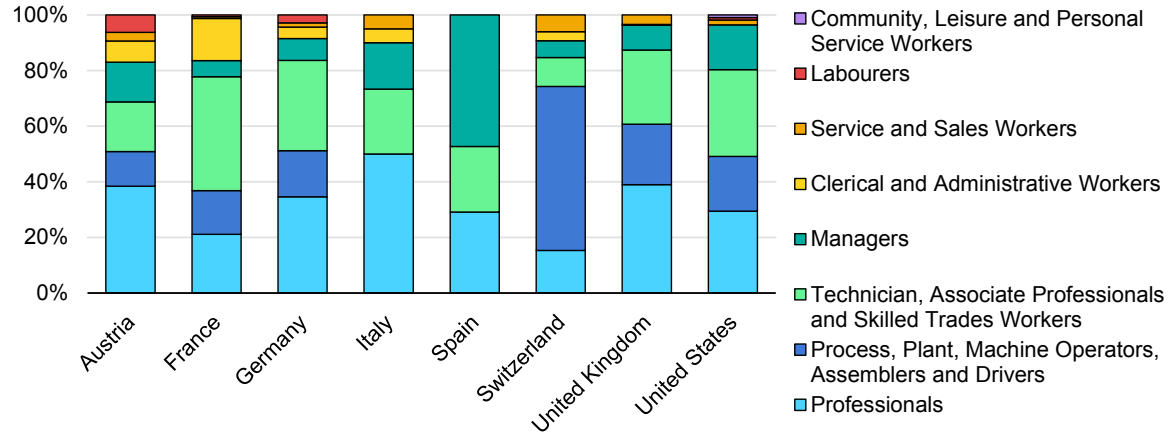
[2] Please consult the methodology annex for more details on the filters used to extract the data.

Switzerland), the share of *Manufacturing* is variable (from 8% in France to 50% in Spain), while the share of *Utilities* is a bit higher, ranging from 11% to 26%. France is looking for a relatively high share (22%) of jobs in the *Administrative and Support Service Activities* sector compared with the other countries, while Italy, Spain, Germany, Austria and Switzerland are searching for slightly more workers in the *Professional, Scientific and Technical Activities* industry (13-29%).

Online job postings distribution by occupation

The distribution of OJPs across occupations shows great variety in the analysed countries.

Heat pump online job postings distribution by occupation in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

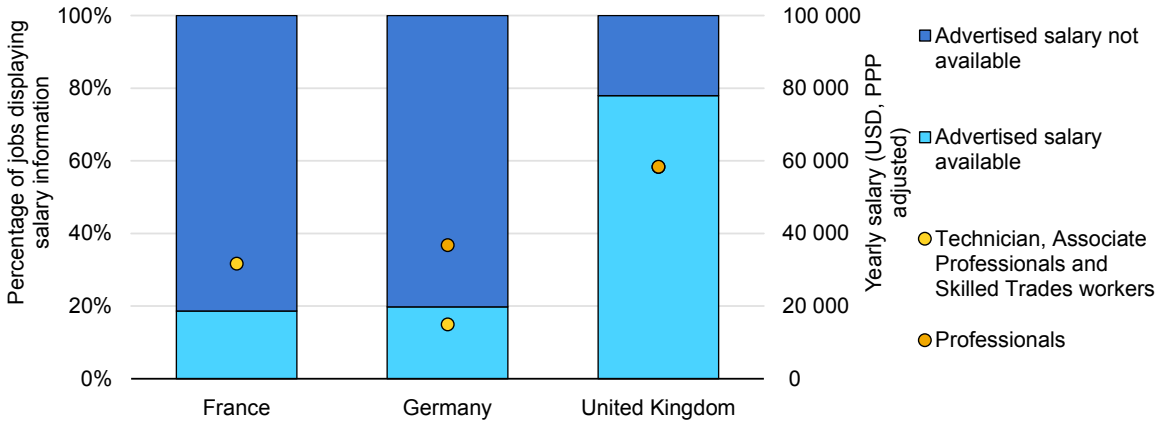
In 2023, *Professionals* (such as Heat Pump Engineers) make up a big portion of heat pump OJPs in Italy, the United Kingdom, Austria and Germany (35-50%), followed by *Technician, Associate Professionals and Skilled Trades Workers* (such as Heat Pump Installers), which compose between 31% and 41% of the jobs in France, Germany and the United States. *Process, Plant, Machine Operators, Assemblers and Drivers* (59%) are the most-sought heat pump employees in Switzerland. A job title example for this occupation could be Heat Pump Component Assembly Line Worker. In the other countries this category of workers constitutes between 12% and 21%, except for Italy and Spain where it is absent. *Managers* (for example Heat Pump Installation Managers) cover 47% of jobs in Spain and oscillate between 6% and 17% in the other countries. Heat pump *Clerical and Administrative Workers*; *Service and Sales Workers*; *Labourers*; and *Community, Leisure and Personal Service Workers* make up a minimal part of the share in all the analysed countries (less than 10%) and include, among others, Scheduling Coordinators for Heat Pump Installations, Heat Pump Sales

Representatives, Heat Pump Marketing Specialists, Residential Heat Pump Advisers and Heat Pump Transport Workers.

Advertised salaries

Advertised salary information on heat pump OJPs is very scarce and, even for countries with enough data, covers over half of them for only one out of three available countries (78% of OJPs from the United Kingdom display salary information, compared with a coverage of only 20% and 19% for Germany and France). On average, the highest yearly salaries are advertised in the United Kingdom for heat pump *Professionals* (USD 58 000), followed by German *Professionals* (USD 36 800), and French *Technician, Associate Professionals and Skilled Trades Workers* (USD 31 700).

Average minimum advertised annual salary (PPP adjusted) for heat pumps Professionals and Technician, Associate Professionals and Skilled Trades Workers versus share of heat pump online job postings displaying an advertised salary, in selected countries, 2023



Notes: Not enough OJPs with advertised salary for *Professionals* are available for France. In the United Kingdom, both *Professionals* and *Technician, Associate Professionals and Skilled Trade Workers* have similar average minimum salaries, resulting in overlapping dots.

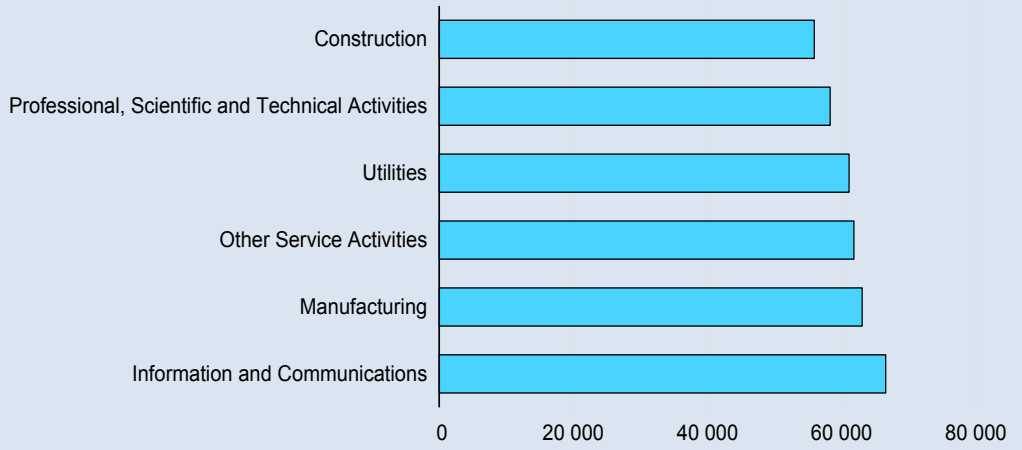
Source: IEA analysis based on data from Lightcast (accessed July 2024).

Concerning OJPs' salaries evolution over the past few years, they increased in the United Kingdom, by 20% to 34%, between 2018 and 2022, before slightly decreasing in 2023. Overall, the average minimum salary displayed in the United Kingdom's OJPs increased by almost USD 10 000 between 2018 and 2023. On the contrary, in France, salaries for *Technician, Associate Professionals and Skilled Trades Workers* decreased from USD 36 800 in 2021 to USD 31 700 in 2023.

Focus: Heat pump advertised minimum salaries (PPP adjusted) in the United Kingdom

Considering that the United Kingdom is the country for which the largest dataset for heat pumps jobs is available in terms of years, it is interesting to compare the difference of advertised salaries by industry and occupation between 2019 and 2023.

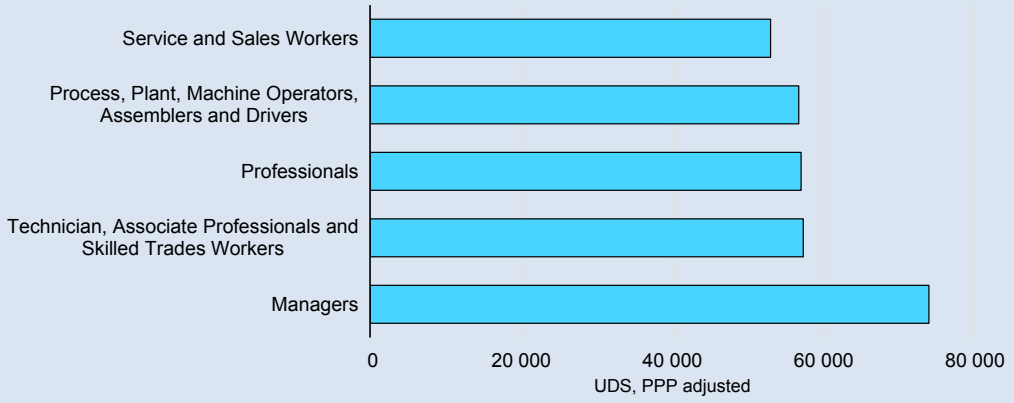
Average advertised minimum annual salary (USD, PPP adjusted) in heat pump online job postings by industry in the United Kingdom, 2019-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

The advertised salary gap between industries is not too pronounced. *Information and Communications* and *Manufacturing* advertise the highest minimum salary, with an average of around USD 65 000, followed by *Other Service Activities* (USD 62 000), and *Utilities* (USD 61 000). *Construction* is the sector advertising the lowest wage (USD 56 000).

Average advertised minimum annual salary (USD, PPP adjusted) in heat pump online job postings by occupational category in the United Kingdom, 2019-2023



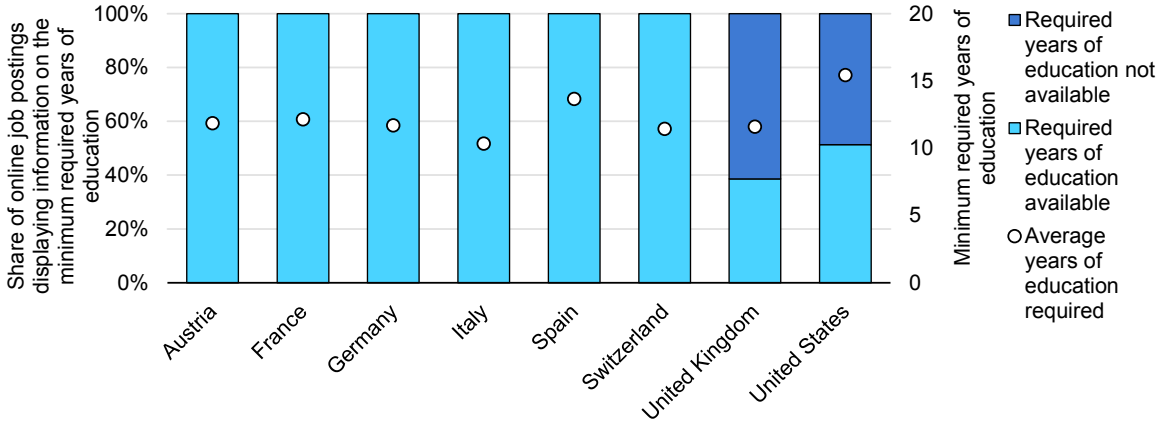
Source: IEA analysis based on data from Lightcast (accessed July 2024).

When looking at occupations, the gap expands significantly, particularly between *Managers* (USD 74 000) and the other categories. The occupations offering the lowest salary are *Service and Sales Workers* (USD 53 000) and *Process, Plant, Machine Operators, Assemblers and Drivers* (USD 57 000).

Required education

All the analysed countries, except the United Kingdom and the United States, provide information on the minimum required education on all heat pumps OJPs in 2023.

Required minimum years of education for heat pump online job postings in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Workers recruited in Spain are typically required to have studied for a minimum of 13.7 years, which is slightly less than what is needed for a bachelor's degree and represents the highest educational requirement among all countries in Europe. The highest requirement of 15.4 years of formal education (corresponding to the completion of a bachelor's degree) belongs to the United States, while all the other countries vary slightly between 10.3 years requested in Italy and 12.1 in France (corresponding to the completion of secondary education).

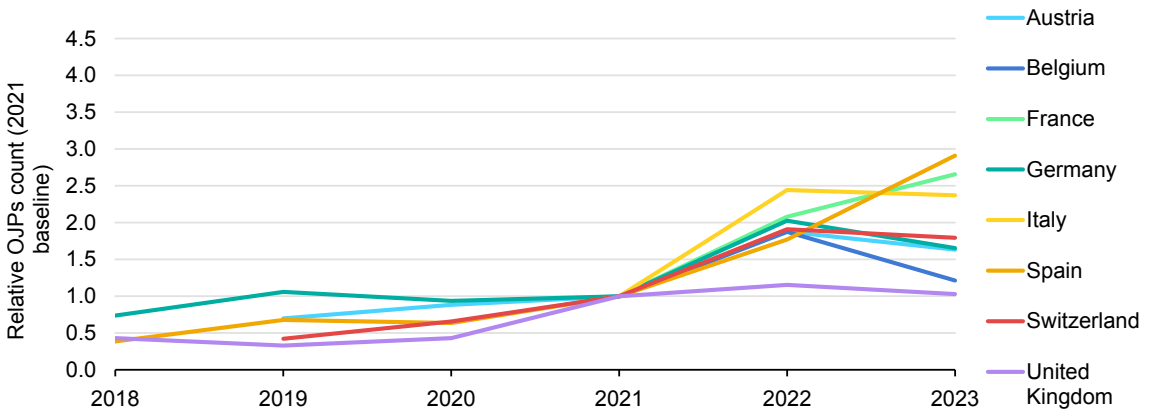
Battery and electric vehicle online job postings

In the past few years, the increasing number of tax credits in several countries as well as the increasing popularity of car leasing led to an increasing demand for electric vehicles and, indirectly, batteries to produce them. In order to face the increasing demand, manufacturers had to adjust their production and thus, look for more workers. This section explores the dynamics of online postings related to battery and EV jobs in Austria, Australia, Belgium, Canada, France, Germany, Ireland, Italy, Singapore, Spain, Switzerland, the United Kingdom and the United States.

Total online job postings

European car manufacturer and related activities' adjustment to the increasing demand is observable on every European job market. Indeed, between 2018 and 2023 the share of batteries and EV OJPs (and their absolute number) grew or remained constant in all the analysed countries, except Belgium, and the United Kingdom, to some extent. Between 2021 and 2023, shares increased variably from 10% (for Austria) to 63% (for Spain). In France, the share went up by a third, while in Germany it grew by 11% and in Switzerland by 19%, and it remained constant in Ireland and Italy. Belgium and the United Kingdom saw their share decreasing over the same period, by 14% and 33%, respectively. On average, the European share increased by 12% between 2021 and 2023. In 2023, German batteries and EV vacancies accounted for 0.083% of the total amount of jobs posted online, a record in European analysed countries, where batteries and EV job postings represent on average 0.031% of the total OJPs. In terms of absolute numbers, Spain, France and Italy were the countries experiencing the largest increase in online postings over the same period.

Relative count of batteries and electric vehicle online job postings (2021 baseline) in selected countries, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

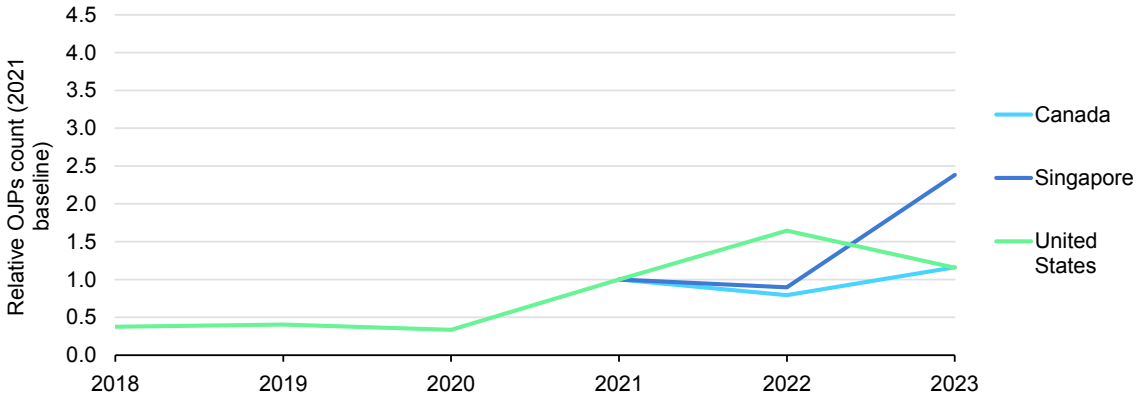
The increase in online job postings between 2021 and 2023 coincides with the discussions at the European Parliament regarding the new EU regulatory framework for batteries. First proposed in December 2020, the new framework was designed to modernise the European Union's regulations with requirements on sustainability, safety, labelling and end-of-life management of batteries in Europe. The European Parliament and the Council reached a first agreement in 2022, and fully adopted the text in 2023. Industries might have anticipated this adoption and new rules by adapting their research and development (R&D), production, marketing and sales, leading to new hirings. However, the slowdown observed between 2022 and 2023 can be attributed to a number of factors such as the financial difficulties observed by a number of key players in the field, resulting in less demand for manufacturing jobs

In Canada and the United States, the job market for batteries and electric vehicles is also becoming more dynamic with time. After the Covid-19 pandemic, the share of OJPs skyrocketed for both countries, despite a not-so-pronounced increase in absolute numbers. Between 2018 and 2023, the share of OJPs increased by over 150% for the United States, going from 0.003% to 0.008%. It is, however, important to note that Canadian shares experienced an important drop in 2022, before getting almost back to their 2021 level in 2023 (0.006%). Despite such increasing rates, the share of batteries and EV OJPs remained far below the European average of 0.031% in 2023.

The US Bureau of Labor Statistics predicted a 5.3% increase in EV-related jobs between 2021 and 2031. OJPs data seem to go in the same direction as US batteries, and EV OJPs have sharply increased since 2021. This corresponds to some policies implemented at the same time, such as the 2021 Biden-Harris Electric Vehicle Charging Action Plan, planning to build 500 000 chargers across the country to make EVs accessible to everyone, for local and long-distance trips,

and the 2022 USD 2.8 billion grant from the Bipartisan Infrastructure Law to Boost Domestic Manufacturing and the American Battery Materials Initiative, which aimed at boosting US battery manufacturing through investments and policies on one side, and on the other hand reducing reliance on foreign supply chains, and creating good-paying jobs in the clean energy sector.

Relative count of batteries and electric vehicle online job postings (2021 baseline) in Canada, Singapore and the United States, 2018-2023



IEA. CC BY 4.0.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

Singapore's share and absolute number of OJPs increased strongly from 2021 to 2023, reaching 0.011% and almost 2.5 the number of postings compared with 2021.

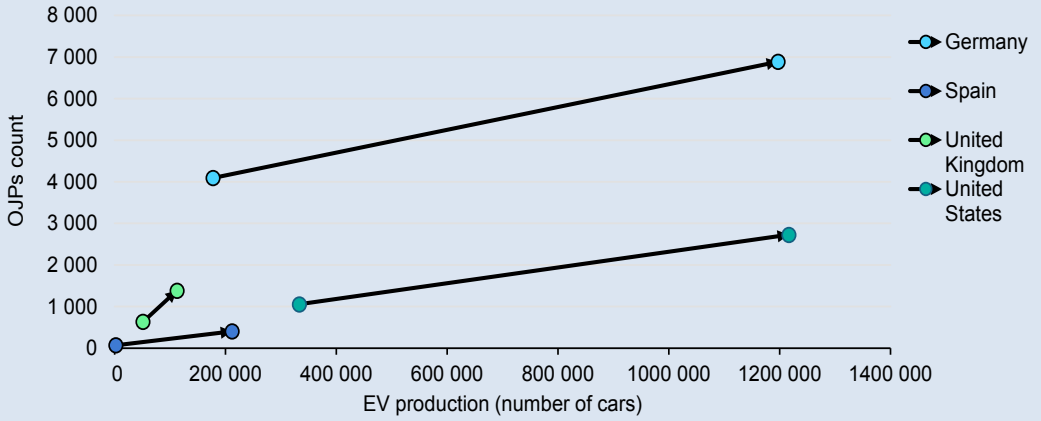
Electric car production and number of EV and battery online job postings

As emphasised by the Global EV Outlook 2024, EV production and sales increased strongly worldwide. Electric car sales increased by 3.5 million between 2022 and 2023, representing a 35% year-on-year increase. Sales went from 1 million to more than 13 million in only six years, between 2017 and 2023. This fast growth is obviously correlated to trends observed in every analysed country's job markets. In Europe, EV sales increased by 20% between 2022 and 2023. Previously, they grew by 15% between 2021 and 2022, 65% between 2020 and 2021 and by 40% every year over 2017-2019. This strong increasing trend, especially in 2021, follows the adjusted corporate strategies put in place by European manufacturer to comply with the carbon dioxide emission standards passed in 2019, according to the Global EV Outlook 2023.

Electric car production and number of battery and EV OJPs are positively correlated. In Germany, the OJP yearly count went from 4 092 to 6 886 between 2018 and 2023. In the meantime, electric car production increased from 0.2 million

to 1.2 million vehicles. The same trends can be observed in the United Kingdom, in Spain, and even in the United States where the number of online job postings is lower.

Number of battery and electric vehicle online job postings versus electric cars production in selected countries, 2018 versus 2023

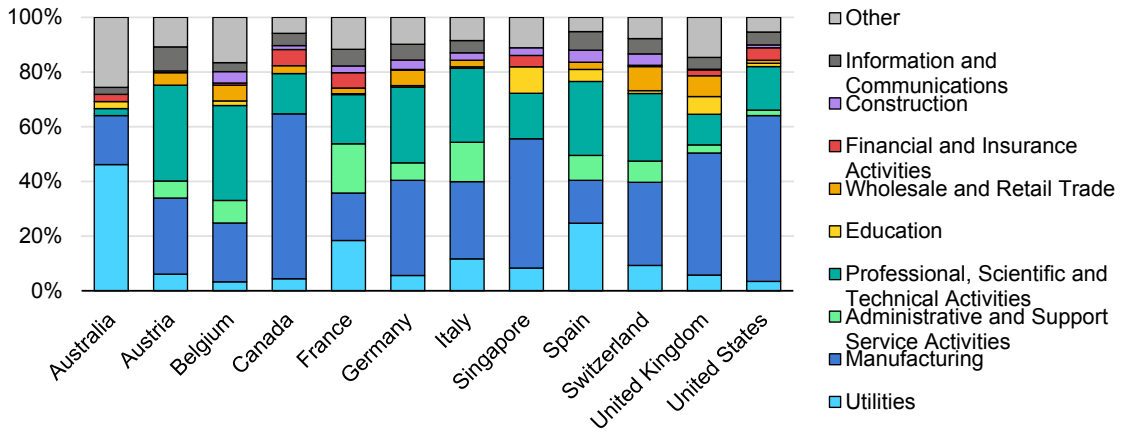


Sources: IEA analysis based on data from Lightcast and EV volumes.

Online job posting distribution by industry

In 2023, OJP distribution across industries varied significantly depending on the country. Among all industries, two of them stand out: *Manufacturing* and *Professional, Scientific and Technical Activities*. In every country except Australia and France, one of them is the biggest provider when it comes to battery and EV OJPs.

Share of battery and electric vehicle online job postings by industry in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Manufacturing companies publish vast online job postings; it is the industry putting out the biggest number of battery and EV OJPs in Canada, Germany, Italy, Singapore, Switzerland, the United Kingdom, and the United States, with shares ranging from 28% to 61% in 2023. It is the second-biggest one in Australia, Austria and Belgium, with shares of 18%, 28% and 21%, respectively. Only France and Spain do not have *Manufacturing* in their top two industries, even though it represents 17% of French OJPs, and 16% of Spanish ones. This relatively high number of *Manufacturing* OJPs for batteries and EV is not surprising when considering the increasing production in recent years.

Professional, Scientific and Technical Activities is the second-largest industry. It is the number one industry in most of the countries for which *Manufacturing* is not first: Austria, Belgium and Spain, where it accounts for 27% to 35% of the online job postings. When *Professional, Scientific and Technical Activities* companies are not the first OJPs' providers, they are the second one. In Canada, Germany, Italy, Singapore, Switzerland, the United Kingdom and the United States, *Professional, Scientific and Technical Activities* gathers between 11% and 28% of the battery and EV OJPs. Only in Australia and France, this industry is not among the top two. This follows the trend started in 2017 with the launch of the European Battery Alliance (EBA) by the European Commission. The purpose of this alliance is to make battery manufacturing one of the strategic parts of Europe's clean and digital transition. The Commission aims to make Europe a global leader in sustainable battery production and use, and thus, to increase the number of battery original equipment manufacturers, gathering manufacturing but also R&D-related positions.

In 2023, *Manufacturing* and *Professional, Scientific and Technical Activities* publishes together 61% of the countries' online vacancies, on average, excluding Australia and France from this computation.

Australia's case is different from countries above. Indeed, in 2023, 46% of its OJPs come from *Utilities* companies. It is the only country for which this is the most important industry, together with France, as it usually accounts for no more than 10% of online job postings in other countries, except in Italy and Spain. *Manufacturing* is the second-most-important industry (18%) and *Professional, Scientific and Technical Activities* accounts for only 3% of the vacancies posted online.

Finally, France is the most homogeneous country as it is the only one for which shares of four industries were above 15% in 2023. In France, *Administrative and Support Service Activities*; *Professional, Scientific and Technical Activities*; and *Utilities* each accounted for 18% of the OJPs. *Manufacturing* gathers 17% of them. *Administrative and Support Service Activities* and *Utilities* are the two main industries in terms of OJPs, by a short lead.

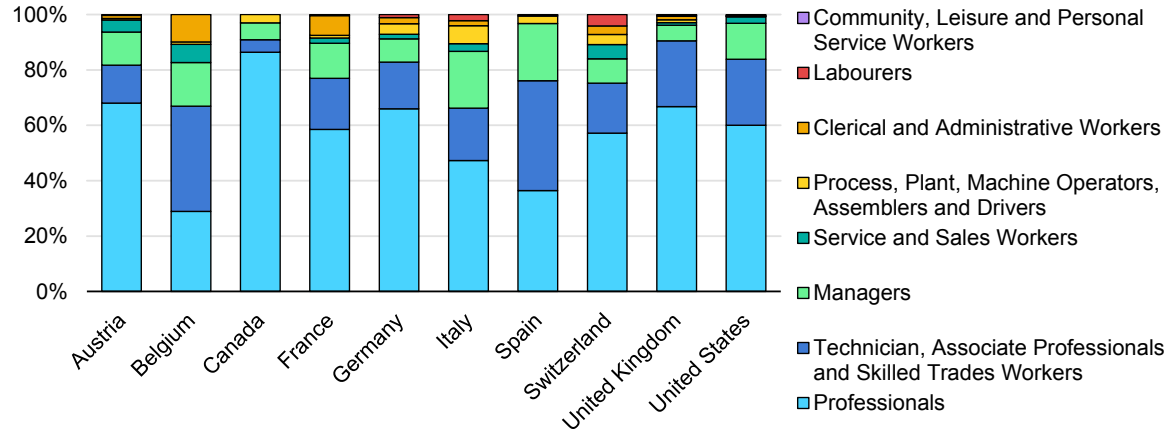
Online job postings distribution by occupation

Among occupational categories, *Professionals* positions, including but not limited to Battery Chemists and EV Powertrain Specialists, make up most of the online vacancies in most countries. Indeed, in 2023, *Professionals* are the most wanted positions for companies in Austria, Canada, France, Germany, Italy, Switzerland, the United Kingdom, and the United States, accounting for 45% to over 80% of the batteries and EV online vacancies. It is the second-largest occupation in terms of OJPs in Spain and Belgium, with 36% and 29%, respectively.

In Spain and Belgium, *Technician, Associate Professionals and Skilled Trades Workers* represent the majority of the job offers posted online, overcoming *Professionals'* general dominance. Examples from this occupation include Battery Assembly Technicians, Battery Recycling Technicians, EV Charging Station Technicians and Electric Vehicle Maintenance Technicians. Almost 40% of Spanish and Belgium offers belong to the same occupation. In the other countries (excluding Canada), this category accounts for 13% to 24% of the OJPs. In Canada, such positions represent less than 5% of the online job postings.

Finally, *Clerical and Administrative Workers* make up 10% of Belgians' battery and EV OJPs and 7% of French ones. Otherwise, only 3% or less of other countries' OJPs belong to this occupation, which includes for example EV Sales Support Specialists and Charging Network Coordinators.

Share of battery and electric vehicle online job postings by occupation category in selected countries, 2023

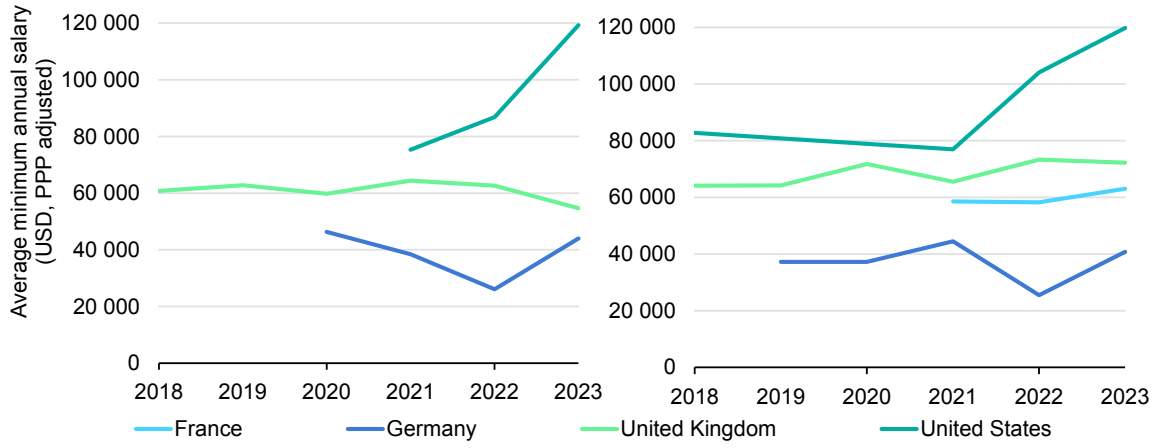


Source: IEA analysis based on data from Lightcast (accessed July 2024).

Advertised salaries

Advertised salaries in European countries (France, Germany and the United Kingdom) did not show an increase in the last years. Indeed, they all saw the average of their proposed minimum salary remaining almost constant.

Average minimum yearly salary (USD, PPP adjusted) advertised for Technician, Associate Professionals and Skilled Trades Workers (left) versus Professionals (right) in the battery and electric vehicle sector, in selected countries, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

When analysing *Technician, Associate Professionals and Skilled Trades Workers*, advertised minimum annual salaries slightly decrease in the United Kingdom (2018-2023) and Germany (2020-2023). German advertised minimum salaries even experienced an important drop in 2022 before recovering their 2021 level in 2023.

On the other hand, French and British advertised salaries for *Professionals* vacancies displayed a slight increase between 2021 and 2023: 7.7% and 10.3%, respectively. German salaries, however, drop strongly in 2022 and, despite recovering in 2023, decrease by 8.3% between 2021 and 2023. It is important to note the massive drop in German salaries for both occupational categories in 2022. However, salaries returned to their higher level in 2023.

Finally, minimum salaries in the United States grew by 55% to 58% between 2021 and 2023, reaching almost USD 120 000 in 2023 for both kind of occupations.

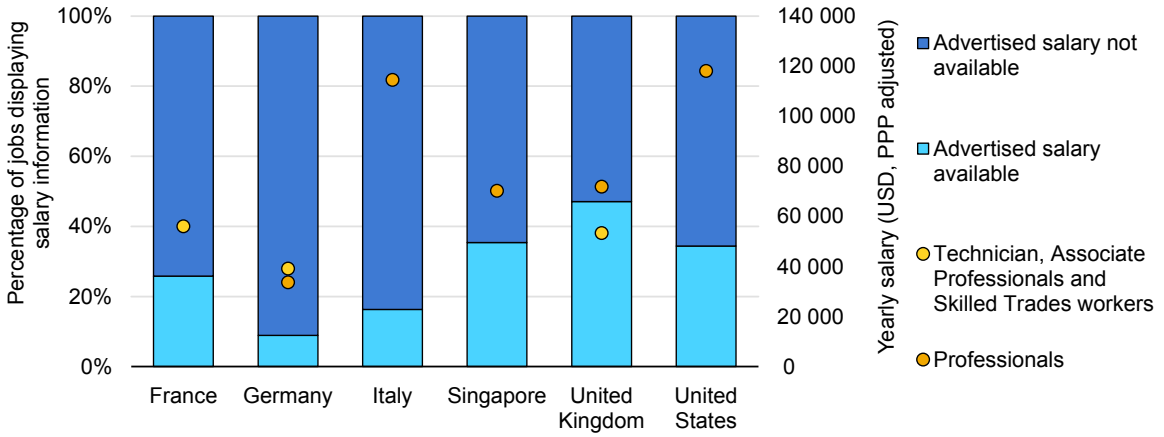
In 2023, the United States' battery and EV online job postings for *Professionals* workers had the highest advertised minimum yearly salaries: USD 118 000, on average, followed by Italy (USD 114 000 PPP adjusted), and the United Kingdom (USD 72 000). Germany is the only country with average minimum advertised yearly salaries below USD 40 000. However, it is important to note that for Germany, less than 10% of online postings for battery and EV jobs contain information on salaries, which probably heavily influences the result.

Technician, Associate Professionals and Skilled Trades Workers online vacancies display on average lower advertised salaries than *Professionals*. OJPs' advertised

annual salaries for *Technician, Associate Professionals and Skilled Trades Workers* are the highest in France (USD 56 000).

Overall, the advertised salary coverage is very low for all countries, meaning that for the occupations in question (*Professionals* and *Technician, Associate Professionals and Skilled Trades Workers*) fewer than one in two postings provides an advertised salary. The reader should be mindful of this when reading the results.

Average minimum advertised annual salary (USD, PPP adjusted) for battery and electric vehicle Professionals and Technician, Associate Professionals and Skilled Trades Workers versus share of battery and electric vehicles online job postings displaying an advertised salary, in selected countries, 2023



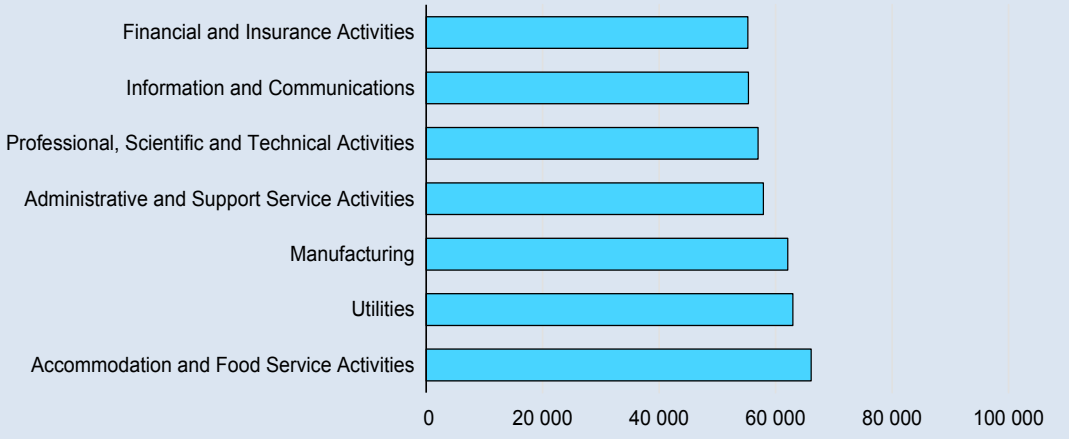
Note: Not enough OJPs with advertised salary for *Professionals* are available for France. Not enough OJPs with advertised salary for *Technician, Associate Professionals and Skilled Trade Workers* are available for Italy, Singapore and the United States.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

Focus: Battery and electric vehicle online job postings minimum salary (PPP adjusted) by industry, 2019-2023

Analysing the average minimum annual advertised salary by industry, for each country for which enough data are available (France, Germany, the United Kingdom, and the United States are the countries with the best cross-coverage of industry and salary information), shows that no one single industry advertises the highest salaries.

Average of the advertised minimum salary (USD, PPP adjusted) in battery and electric vehicle online job postings by industry in France, 2019-2023

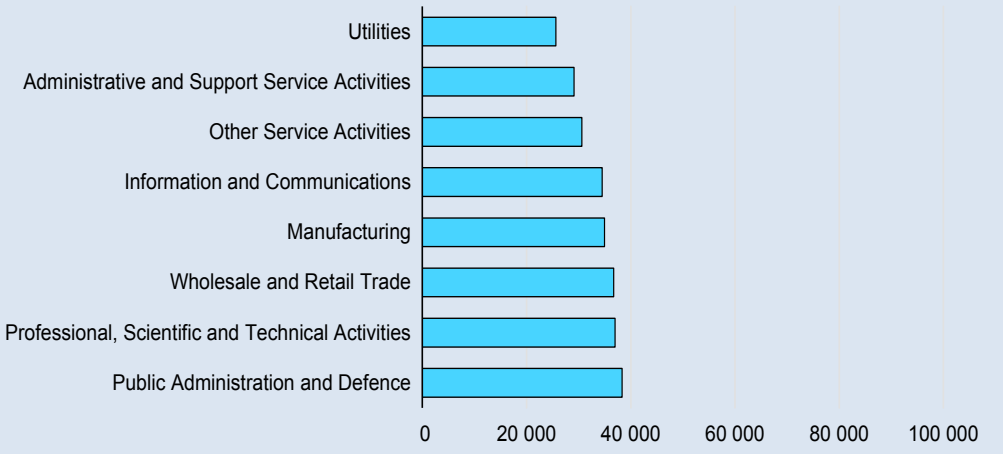


Note: Industries for which fewer than 50 OJPs display information on salaries are removed from this analysis.

Source: IEA analysis (2024), based on data from Lightcast (accessed July 2024).

French salaries are higher for *Accommodation and Food Service Activities** related positions (USD 66 000), as are German salaries for *Public Administration and Defence* jobs (USD 38 000). *Utilities* is the second industry in France in terms of advertised salaries (USD 63 000) but is the bottom one in Germany (USD 25 600).

Average of the advertised minimum salary (USD, PPP adjusted) in battery and electric vehicle online job postings by industry in Germany, 2019-2023



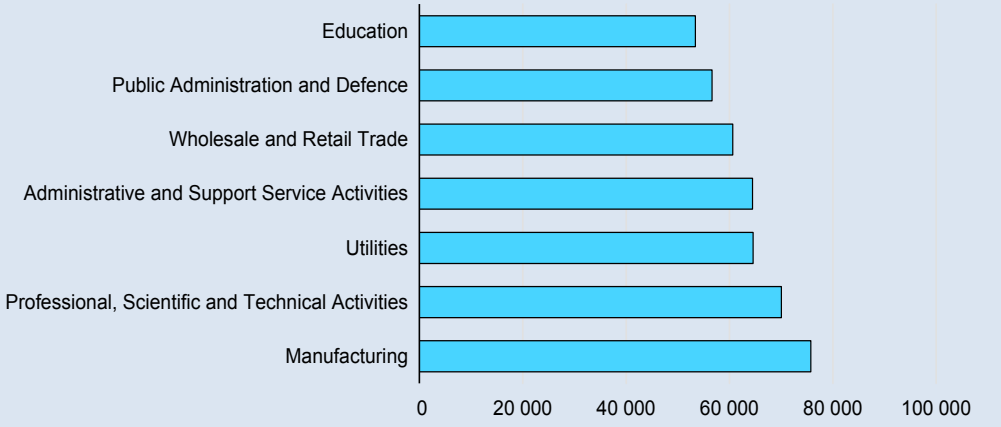
Note: Industries for which fewer than 50 OJPs display information on salaries are removed from this analysis.

Source: IEA analysis (2024), based on data from Lightcast (accessed July 2024).

The United Kingdom offers relatively high salaries for *Manufacturing* jobs, with an average of USD 75 700, as well as in the United States, where such positions are advertised at a minimum of almost a USD 100 000, on average. *Professional, Scientific and Technical Activities* is the second-highest-paying industry in both

countries, with salaries starting at USD 70 000 in the United Kingdom and USD 89 000 in the United States, as well as in Germany (USD 37 000).

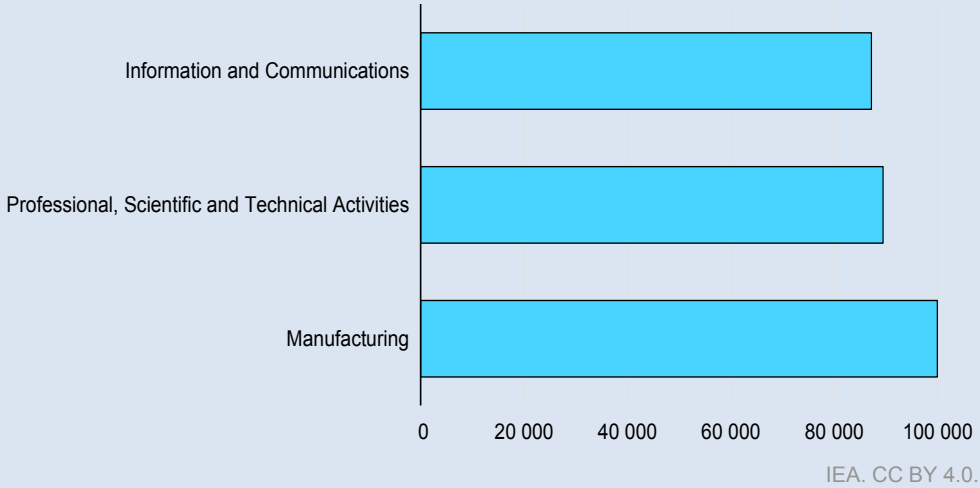
Average of the advertised minimum salary (USD, PPP adjusted) in battery and electric vehicle online job postings by industry in the United Kingdom, 2019-2023



Note: Industries for which fewer than 50 OJPs display information on salaries are removed from this analysis.

Source: IEA analysis (2024), based on data from Lightcast (accessed July 2024).

Average of the advertised minimum salary (USD, PPP adjusted) in battery and electric vehicle online job postings by industry in the United States, 2019-2023



Note: Industries for which fewer than 50 OJPs display information on salaries are removed from this analysis.

Source: IEA analysis (2024), based on data from Lightcast (accessed July 2024).

Some industries pay relatively well in every country, such as *Manufacturing* and *Professional, Scientific and Technical Activities*, which are in the five best-paying industries for all countries.

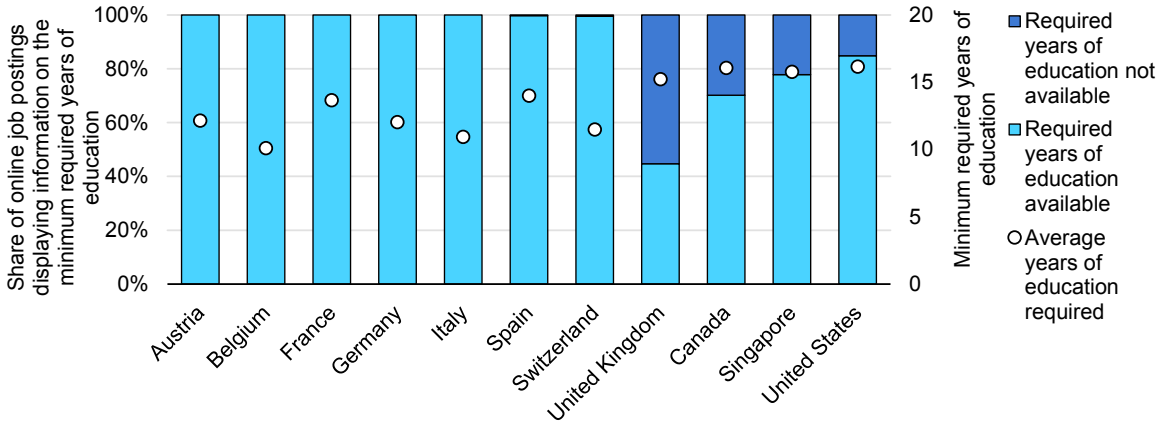
Overall, the United States offer the highest salaries in every industry, with average industry salaries always above USD 85 000, while German ones are always below USD 40 000.

* There might be a mislabelling in the Lightcast database as all jobs from this industry refer to engineering positions, while the industry does not seem related to batteries and EV. See the first section of the report for more details on limitations of the dataset.

Required education

For battery and EV vacancies posted online, the United States and Canada requires on average a minimum of over 16 years of education, corresponding to a college degree. These are the most demanding requirements, followed closely by Singapore and the United Kingdom between 15 and 16 years). Belgium, on the other hand, requires 6 fewer years, with a minimum required education of 10 years, on average, roughly corresponding to a high school diploma. Italy and Switzerland demand a similar level of education as Belgium, with 11 and 11.5 years required, respectively.

Average minimum number of years of education required in battery and electric vehicle online job postings, in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

The 16 years required by Singapore is also what is asked for solar-related positions and is lower than what is necessary to work in energy efficiency positions, still in Singapore. However, it is more than what the most demanding countries require for heat pumps and wind jobs.

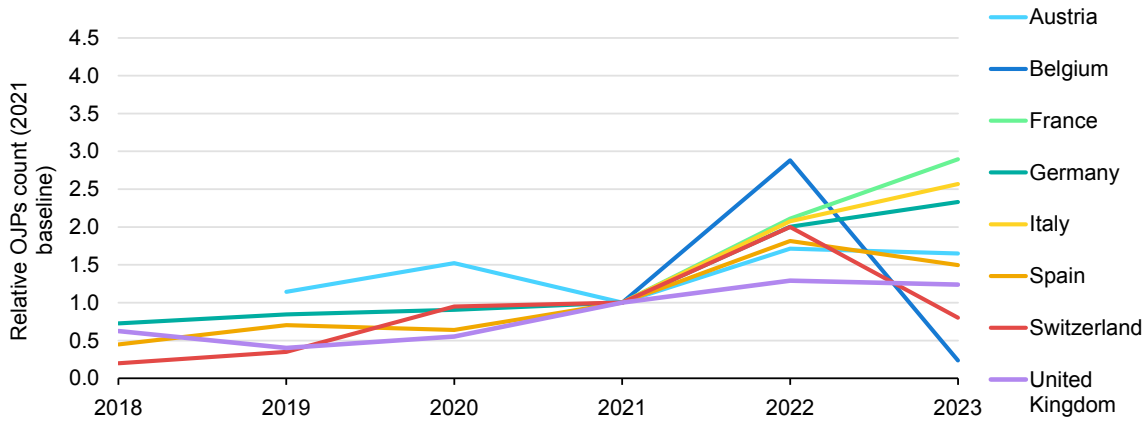
Energy efficiency online job postings

The energy efficiency sector has seen remarkable growth globally, propelled by advancements in technology, supportive policies and a heightened focus on sustainable practices. As nations strive to reduce their carbon footprints and optimise energy use, the demand for energy-efficient solutions has surged. However, this expansion does not seem to translate in robust hiring increasing trends, as employing dynamics differ strongly depending on analysed countries (Australia, Austria, Belgium, Canada, France, Germany, Italy, New Zealand, Singapore, Spain, Switzerland, the United Kingdom, the United States). In European countries, numbers of online job postings respond to this increasing demand, with salaries growing too. In non-European anglophone countries, the number of online job postings is mostly decreasing or remaining constant, while salaries adjust differently depending on countries.

Total online job postings

Energy efficiency job markets' dynamics are very different across countries. While over 22 000 energy efficiency OJPs were advertised in the United States between 2012 and 2023, fewer than 500 were posted in Australia over the same period. The gap across countries is also important in Europe. France has the most dynamic online job market for energy efficiency positions with over 8 000 offers posted online between 2021 and 2023, more than twice as many as in any other European country.

Relative count of energy efficiency online job postings (2021 baseline) in selected countries, 2018-2023



IEA. CC BY 4.0.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

In 2023, the most dynamic energy efficiency job markets were France (0.032%), Italy (0.03%) and Spain (0.025%), with share of OJPs above the rest of the

analysed European countries, which were all below 0.01%. When looking at absolute numbers, however, Germany's job postings surpass the ones in Spain. Belgium, the United Kingdom and Switzerland had the lowest shares of both postings and relative growth compared with 2021. Despite this variance, on average, the share of energy efficiency OJPs in the selected European countries increased by 8% between 2021 and 2023. This increasing trend corresponds to the discussions surrounding the EU revised Energy Efficiency Directive as well as its publication. After a first proposal to review the directive in 2021, as part of the EU Green Deal package, the proposal was further enhanced and finally published in September 2023. The revised directive more than doubles the annual energy savings obligation by 2028, putting more pressure on governments and industries to reach the 2030 targets, with intermediary milestones to achieve.

Moreover, European selected countries are, on average, above other countries in terms of OJP share. With an average of 0.013% in 2023, the European share of OJPs for energy efficiency is more than four times bigger than the Canadian one, and more than twice those in Singapore and the United States.

In the last years, the share of energy efficiency OJPs in Canada and the United States has fluctuated, but always remained below 0.01%. In the United States, it increased in 2023 to reach 0.005%, following the passage of the 2022 Inflation Reduction Act, including USD 86 billion for energy efficiency actions. According to the 2024 US Energy & Employment Jobs Report (USEER), US energy efficiency jobs increased by 3.4% between 2022 and 2023. The Lightcast data, despite the increase in share, show a decrease in absolute number of online job postings by 29% in 2023, compared with 2022. This difference could be explained by the way that Lightcast collects information (only online postings, leaving out jobs advertised through newspapers or physical offices), as explained in the first chapter and/or may be related to the way used to identify energy efficiency postings, which may exclude other positions that are still relevant but whose job title does not match the utilised filter.

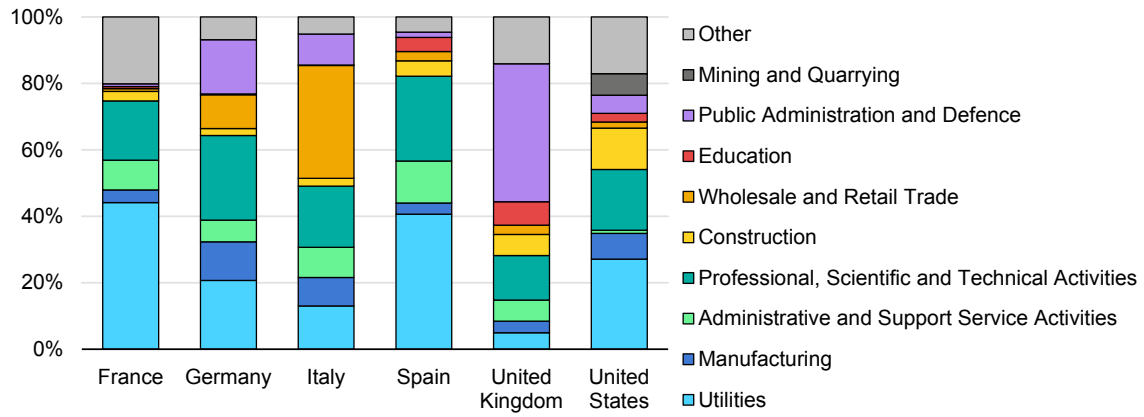
Between 2018 and 2023, Australia experienced a decrease in the number of energy efficiency jobs advertised online, first in 2020 and then again in 2023. On the other hand, New Zealand and Singapore saw their share increase, on average, despite unstable levels after 2020. For both Australia and New Zealand, however, absolute numbers are below the threshold for all the years. In Singapore, the number of energy efficiency jobs surpasses 50 observations only starting from 2022.

Online job postings distribution by industry

The distribution of online job postings across industry varies a lot depending on the country analysed. In 2023, the largest employing industries in terms of OJPs were *Public Administration and Defence* (United Kingdom), *Utilities* (France,

Spain, United States), *Wholesale and Retail Trade* (Italy) and *Professional, Scientific and Technical Activities* (Germany).

Share of energy efficiency online job postings by industry in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

In 2023, *Utilities* was responsible for 44% of the energy efficiency vacancies posted online in France, 41% in Spain and 27% in the United States, being larger than the second-ranking industry by 10 to 24 percentage points in these three countries. It is the second-largest industry in terms of share of energy efficiency OJPs in Germany. This is the only industry gathering more than 20% of jobs advertised online in four countries out of the six analysed. No other industry dominates in other countries as *Utilities* does in France, where it represents almost half of French energy efficiency OJPs.

Professional, Scientific and Technical Activities is the second-largest industry in every country, except Germany, where it is the first one, considering that *Other* groups a certain number of very small industries and is not an industry by itself. Its shares oscillate between 13% and 26% of the energy efficiency OJPs.

When looking at the individual countries, *Public Administration and Defence* is by far the industry advertising the most online in the United Kingdom. In 2023, nearly 42% of the energy efficiency online vacancies come from this industry. It follows a series of bills and policies introduced in the United Kingdom in 2022 and 2023, such as the Energy Bill 2022-2023, which promotes energy efficiency and the decarbonisation of buildings, or the update of the National Energy Category Strategy for Local Government, leading to hirings of energy efficiency experts in local and regional councils. However, *Public Administration and Defence* is not represented a lot in other countries: it accounts for 16% of energy efficiency OJPs in Germany, 9% in Italy, and 5% or less in France, Spain, and the United States.

In Italy, in 2023, a third of energy efficiency job offers were posted online by companies from the *Wholesale and Retail Trade* sector. It is by far the biggest

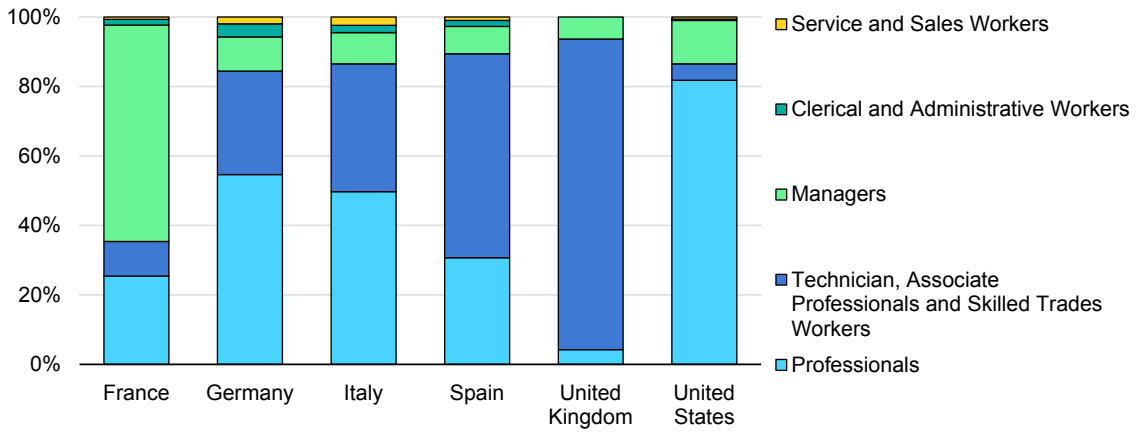
industry concerning OJPs, as the second one is more than 15 percentage points behind. *Wholesale and Retail Trade* accounts for as many OJPs as the second- and third-largest industries in Italy (*Professional, Scientific and Technical Activities* and *Utilities* respectively). This industry represents 10% of the online vacancies in Germany, and less than 3% in France, Spain, the United Kingdom and the United States.

Germany is different from other countries for two reasons. First, its energy efficiency online job postings are not mainly published by companies from the *Public Administration and Defence*, *Utilities*, or *Wholesale and Retail Trade* sectors, but by companies from *Professional, Scientific and Technical Activities*. Indeed, this industry publishes one out of four offers posted online for energy efficiency-related positions, mainly due to Enercity AG, one of the largest municipal energy service providers in Germany, or ENGIE Deutschland. Second, unlike other countries, Germany does not have a strictly dominant industry but is more balanced. The second-largest sector, *Utilities*, represents 21% of the energy efficiency OJPs, followed by *Public Administration and Defence* (16%), *Manufacturing* (11%), and *Wholesale and Retail Trade* (10%). Other industries are all below 10%.

Online job postings distribution by occupation

In 2023, three occupational categories are mainly advertised online for energy efficiency positions: *Professionals, Technicians, Associate Professionals and Skilled Trades Workers* and *Managers*. In every country, one of them gathers at least 50% of the country's energy efficiency OJPs, with different intensity.

Share of energy efficiency online job postings by occupation in selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Positions for *Professionals* including Energy Efficiency Auditors and Heat Pump Engineers are largely advertised in almost every country, accounting for 25% to

82% of the energy efficiency OJPs, except in the United Kingdom, where they represent only 4%. Four out of five energy efficiency positions posted online concern the *Professionals* occupational category in the United States. The second category, *Managers*, accounts for less than 13% of the OJPs. In Germany and Italy also, *Professionals* are the most wanted positions online, generating 55% and 50% of the online offers, respectively. In Spain, *Professionals*-related positions make up one-third of the energy efficiency jobs advertised online, and they are a quarter of French ones.

Technicians, Associate Professionals and Skilled Trades Workers such as Energy Efficiency Analysts and Heat Pump Installers represent the second-largest occupational category overall, in terms of share of energy efficiency OJPs. However, it is the category that dominates the most in a country, accounting for almost 90% of the UK online job postings. No other occupational categories are as big as this one in any of the analysed countries. It is also the main one in Spain, generating almost 60% of its energy efficiency OJPs. It is the second OJP source in Germany and Italy, responsible for 30% and 37% of them.

Finally, *Manager* positions including Energy Efficiency Managers and Heat Pump Installation Managers generally do not account for a large share of online job postings, representing between 6% and 13% of energy efficiency-related positions advertised online, in 2023. However, in France the situation is different, with more than 60% *Manager* positions, followed by *Professionals*, accounting for less than half of the managerial jobs. This high share of managers is due to an overrepresentation of project manager job ads in France in the database.

In all selected countries, except for France, *Professionals* and *Technicians, Associate Professionals and Skilled Trades Workers* account for 84-94% of energy efficiency online job postings. In France, they make up 35% of them. On the other hand, *Service and Sales Workers* as well as *Clerical and Administrative Workers* represent at most 4% or less of each country's OJPs for energy efficiency positions.

To conclude, while United States, Germany and Italy are mainly looking for *Professionals*, the United Kingdom and Spain are mostly looking to hire *Technicians, Associate Professionals and Skilled Trades Workers*, and France is the only country for which *Managers* is the most wanted occupation.

Such differences among countries could be due to the way the same positions are advertised.

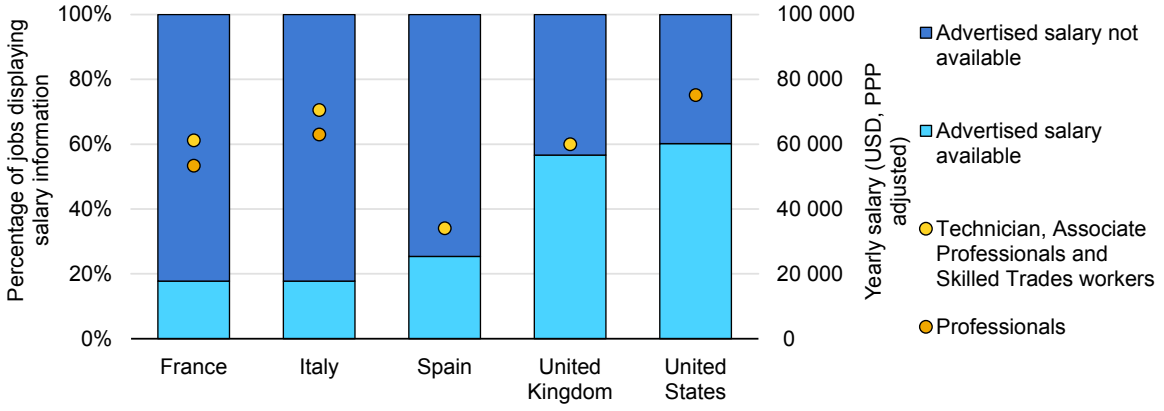
Advertised salaries

Energy efficiency job markets are subject to diverse dynamics depending on the country analysed. Thus, advertised salaries also vary from one country to the other.

On average, between 2021 and 2023, the minimum salary advertised for *Professionals* workers increased by 16.8% in France, and by 35% for similar positions in the United States. Over the same period, advertised salaries for *Technicians, Associate Professionals and Skilled Trades Workers* remained constant in the United Kingdom.

When focusing on 2023, anglophone countries provide more information on salaries than other countries. An advertised salary was included in 57% of the United Kingdom's online jobs postings and 60% of those in the United States, against 18% for France and Italy, and 25% for Spain. It is good to keep this in mind as the coverage may of course impact the results.

Average minimum advertised annual salary (PPP adjusted) for energy efficiency Professionals and Technician, Associate Professionals and Skilled Trades Workers versus share of energy efficiency online job postings displaying an advertised salary, in selected countries, 2023



Notes: Not enough OJPs with advertised salary for *Professionals* are available for Spain and the United Kingdom. Not enough OJPs with advertised salary for *Technician, Associate Professionals and Skilled Trade Workers* are available for the United States.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

In 2023, the United States was the most profitable job market for energy efficiency *Professionals*. The advertised annual US salaries were, on average, USD 12 000 above Italy's (USD 75 000 in the United States and USD 63 000 in Italy) and 41% higher than in France. Spain had the lowest average of minimum advertised annual salary: almost four times lower than the US one: USD 25 000.

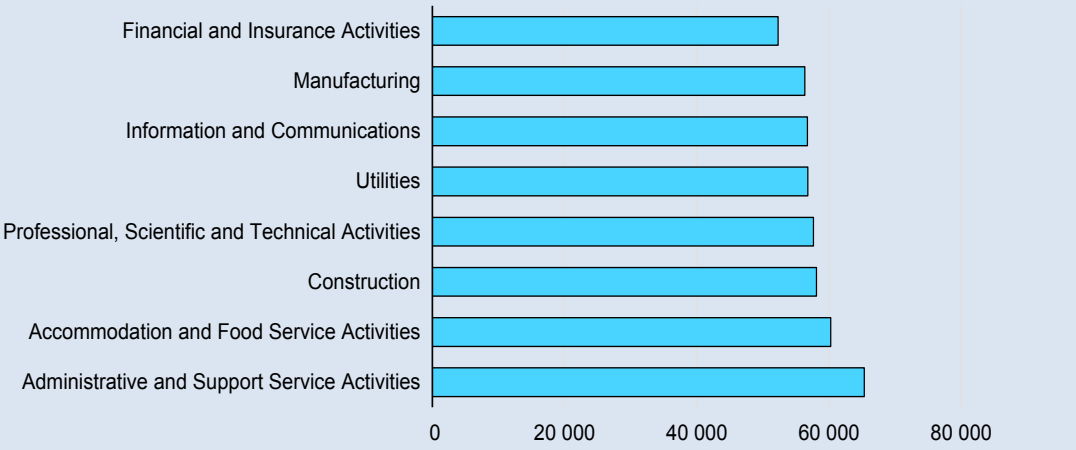
Italian OJPs for *Technician, Associate Professionals and Skilled Trades Workers* display the highest average advertised minimum salary: USD 70 500 per year.

France and the United Kingdom follow with around USD 60 000 proposed for similar positions. Finally, Spain tends to offer much lower compensations, with average minimum annual salaries below USD 35 000 in their OJPs.

Focus: Energy efficiency online job postings advertised minimum salary (PPP adjusted) by industry in France and United States

When comparing salaries by industry in France and the United States, which have enough data when cross-filtering by available salary and industry, differences are easily observable.

Energy efficiency online job posting average of minimum advertised salaries (USD, PPP adjusted) by industry in France, 2019-2023

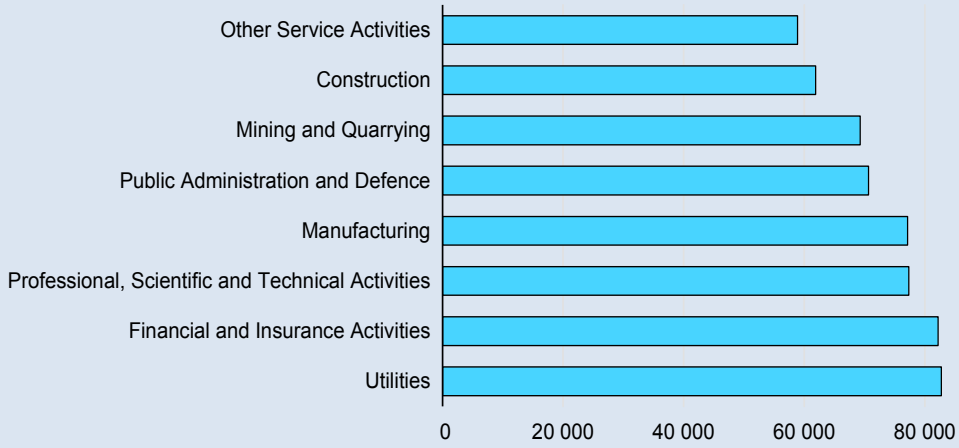


Note: Industries for which fewer than 50 OJPs displayed information on salaries are removed from this analysis: *Human Health and Social Work Activities*; *Real Estate Activities*; *Transportation and Storage*; and *Arts, Entertainment and Recreation*.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

Between 2019 and 2023, the industry advertising the highest salary was different in France and in the United States. In France the highest average of minimum annual salaries was advertised for *Administrative and Support Service Activities* (USD 65 300) while *Utilities* was the industry with the highest average of advertised minimum salaries in the United States, for energy efficiency-related positions, and proposed salaries starting at USD 82 700. Despite being the highest advertised salaries in the United States, *Utilities*' advertised salaries in France fall into the industries of the lower end (USD 56 700). *Financial and Insurance* activities, *Professional, Scientific and Technical Activities*, and *Manufacturing* complete the US top four industries with advertised salaries between USD 77 000 and USD 82 000, all above the French sector with the highest advertised salary.

Energy efficiency online job posting average of minimum advertised salaries (USD, PPP adjusted) by industry in the United States, 2019-2023



Note: Industries for which fewer than 50 OJPs displayed information on salaries are removed from this analysis: *Human Health and Social Work Activities*; *Real Estate Activities*; *Transportation and Storage*; and *Arts, Entertainment and Recreation*.

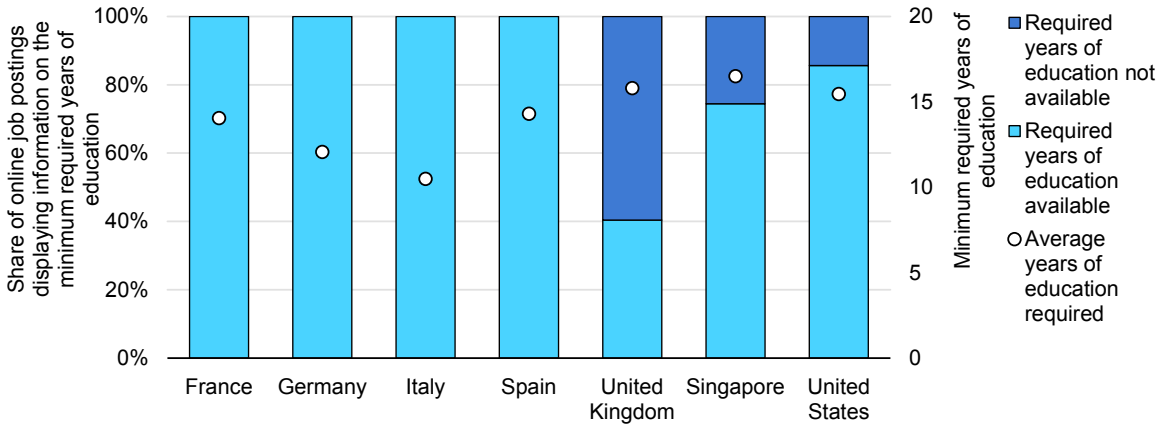
Source: IEA analysis based on data from Lightcast (accessed July 2024).

The variance in wage is also very different between the two countries. In France, *Administrative and Support Service Activities* is the industry advertising the highest average salary, while *Financial and Insurance Activities* has the lowest one (USD 52 300). The average salary difference between these two industries in France (USD 13 000) is almost two times lower than the difference between the industries advertising the highest and lowest average minimum annual salary in the United States: *Other Service Activities* (USD 58 900) and *Utilities* (USD 82 700), with a difference of almost USD 24 000.

Required education

Among the analysed countries, in 2023 Singapore required the highest minimum number of years of education for energy efficiency-related positions (more than 16 years, which include primary education). The United Kingdom and the United States follow closely by requesting on average a bit less than 16 years while Spain requires 14 years of education on average. Italy is less demanding, with an average of around 10 years of education required. Both Singapore, the United Kingdom and the United States have long prioritised the development of highly skilled professionals through their advanced education systems, which might explain the difference between these two countries and the others.

Average minimum number of years of education required for energy efficiency online job postings for selected countries, 2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Online job demand comparison across key energy sectors

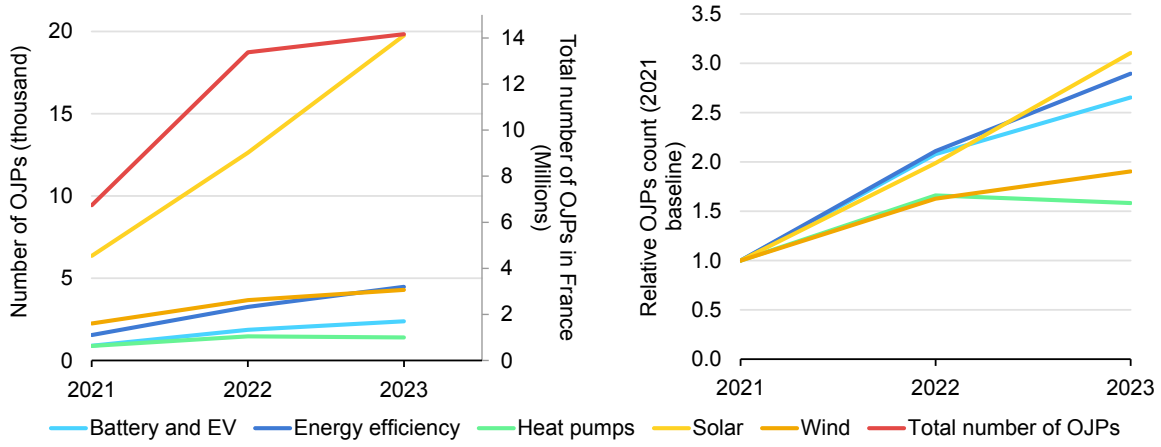
This section delves into how the online job postings for solar, wind, heat pumps, batteries and electric vehicles, and energy efficiency have evolved within each country's specific job market. While technologies' analyses showed significant variation across countries, understanding the unique dynamics of each one of them within a nation's job market, and comparing it with other technologies, offers deeper insights. This section compares the evolution of online job vacancies for these technologies in selected countries across different continents: France, Germany, and the United Kingdom in Europe, the United States for the Americas, and Australia representing Oceania.

France

In France, among the technologies analysed in 2023, the majority of online postings were related to solar jobs. Even if their share[3] grew only from 0.09% to 0.14%, their absolute number tripled in two years. This increase follows the introduction of the Renewable Energy Acceleration Bill (*Projet de loi relatif à l'accélération de la production d'énergies renouvelables*) discussed in 2022 and adopted in 2023 prioritising renewable energy projects, with a focus on solar power. The law places particular emphasis on increasing solar power production, including mandates to install solar PV on large parking lots and along highways.

[3] Computed as the ratio between online solar postings over total number of online postings.

Job demand comparison across key energy sectors in France, 2021-2023



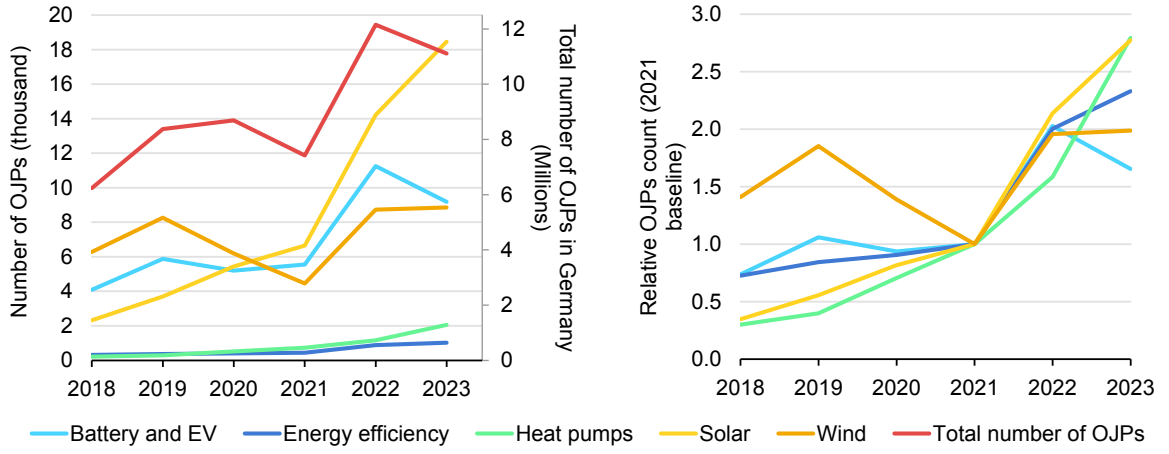
Note: Data for 2023 are available only until the end of the third quarter. The total number of OJPs for 2023 has been estimated by multiplying by 4/3 the count of jobs for 2023. More details in the methodology annex.
Source: IEA analysis based on data from Lightcast (accessed July 2024).

Battery- and EV-related positions, as well as energy efficiency ones, also experienced an increase, in 2023 reaching between 250% and 300% of their 2021 level. Their share in the total number of French OJPs also increased over the same period, but only slightly.

Germany

In Germany, wind and batteries and EV workers were the most wanted profiles in 2018-2020. The number of solar OJPs displayed a steep increase throughout the years, so that solar jobs make up the most advertised positions online from 2021, representing 0.17% of all German online job postings in 2023. This increasing share is a direct consequence of the massively growing number of offers posted online. In 2023, there were eight times more solar-related positions advertised online than in 2018.

Job demand comparison across key energy sectors in Germany, 2018-2023



Note: Data for 2023 are available only until the end of the third quarter. The total number of OJPs for 2023 has been estimated by multiplying by 4/3 the count of jobs for 2023. More details in the methodology annex.
Source: IEA analysis based on data from Lightcast (accessed July 2024).

This strong increase in solar OJPs follows the introduction of the Renewable Energy Act in July 2022, which became mostly effective in January 2023. This act aims at increasing the share of renewable energies in German electricity consumption, planning to reach 80% by 2030. Among the various measures proposed, higher remuneration for new solar systems installed on rooftops, as well as simpler administrative processes for solar projects run by citizens' energy co-operatives, might have contributed to boosting the solar employment dynamics in the most recent years.

On the other hand, wind positions are the only ones whose share decreased below the 2018 level, despite the growth in absolute numbers. However, wind remained the third-most-prevalent technology in terms of vacancies advertised online, accounting for 0.08% of the German OJPs in 2023.

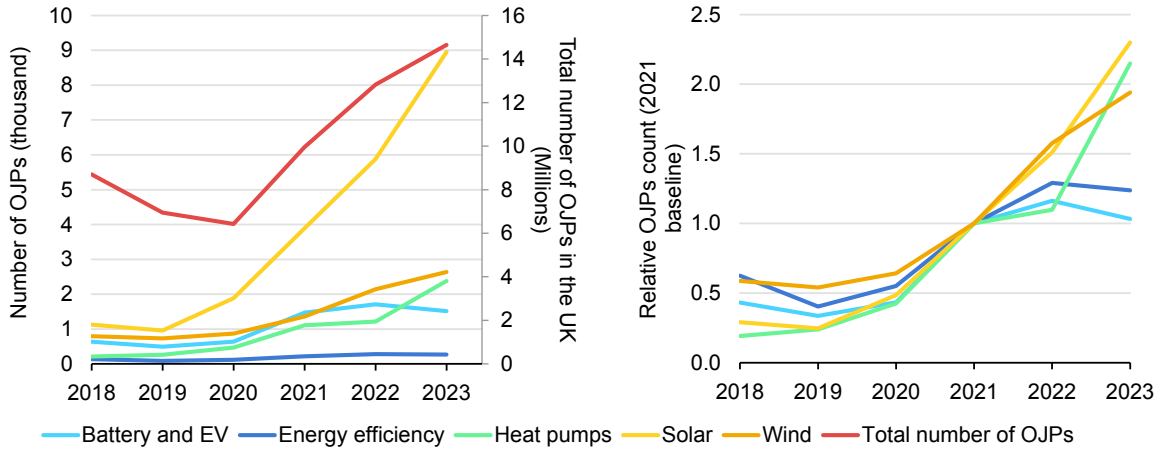
It is also important to notice the strong increase in the publication of heat pump-related positions. Even if the number of offers remains low (with a share of 0.02% in 2023) compared with other technologies, the number of heat pump OJPs increased strongly, reaching in 2023 a level more than nine times higher than in 2018, mostly due to the 2023 massive increase.

In Germany, the five technologies combined represented 0.36% of total OJPs in 2023, a record level for Germany. It was 0.21% in 2018. This general trend might be a consequence of the Renewable Energy Act introduction, as it "lays the foundations for Germany to become climate neutral", providing guidance to "increase the share of gross electricity consumption that is covered by renewables to at least 80% by 2030".

The United Kingdom

In the United Kingdom, the share of solar OJPs started to increase in 2020, ending up in 2023 at a record level of 0.06%. There are also more solar vacancies posted online since 2020. In 2023, the number of solar vacancies advertised online was eight times higher than in 2019. As highlighted in the Lighting the way report, the UK solar industry is positioned as a crucial component of the country's green recovery from the Covid-19 pandemic. By transitioning to renewable energy sources, the United Kingdom aims to create new jobs in the renewable sector by 2030, explaining this increasing trend in solar OJPs since 2020.

Job demand comparison across key energy sectors in the United Kingdom, 2018-2023



Note: Data for 2023 are available only until the end of November. The total number of OJPs for 2023 has been estimated by multiplying by 12/11 the count of jobs for 2023. More details in the methodology annex.
Source: IEA analysis based on data from Lightcast (accessed July 2024).

In the United Kingdom, contrary to France and Germany, the share of wind-related positions increased after 2018, reaching 0.03% in 2023.

As in Germany, the number of heat pump OJPs skyrocketed from 2018 onwards. In 2023, the number of heat pumps OJPs grew tenfold compared with the 2018 value. Heat pump OJPs' share increased too, by over 500%, from 0.002% in 2018 to 0.016% in 2023. As part of its target to reach net zero emissions, the United Kingdom plans to invest and develop massively in heat pump deployment by 2028.

Finally, even if the relative count of OJPs did not increase as much as those for heat pumps, EV and battery online job postings' share also increased over the period. Starting from 0.007% in 2018, it constantly grew to reach 0.01% in 2023.

The five technologies' OJPs put together represented 0.12% of the United Kingdom total online job postings in 2023.

Geographical distribution of solar and wind online job postings in the United Kingdom

The solar and wind energy sectors have created thousands of jobs across the United Kingdom, though their geographical distribution varies significantly due to resource availability, regional policies and the strategic direction of investments. OJPs for solar and wind energy jobs in the United Kingdom show a clear concentration in regions with supportive policies, infrastructure development and urban populations driving demand for residential and commercial installations. Regions in the south of the country, particularly around London, and areas of Scotland have emerged as significant employment hubs for solar and wind energy.

The London area dominates solar job postings, representing approximately 16.2% of total OJPs between 2019 and 2023. This may be related to the widespread adoption of rooftop solar installations, driven by the combination of urban demand and local government incentives such as the Mayor's Solar Action Plan.

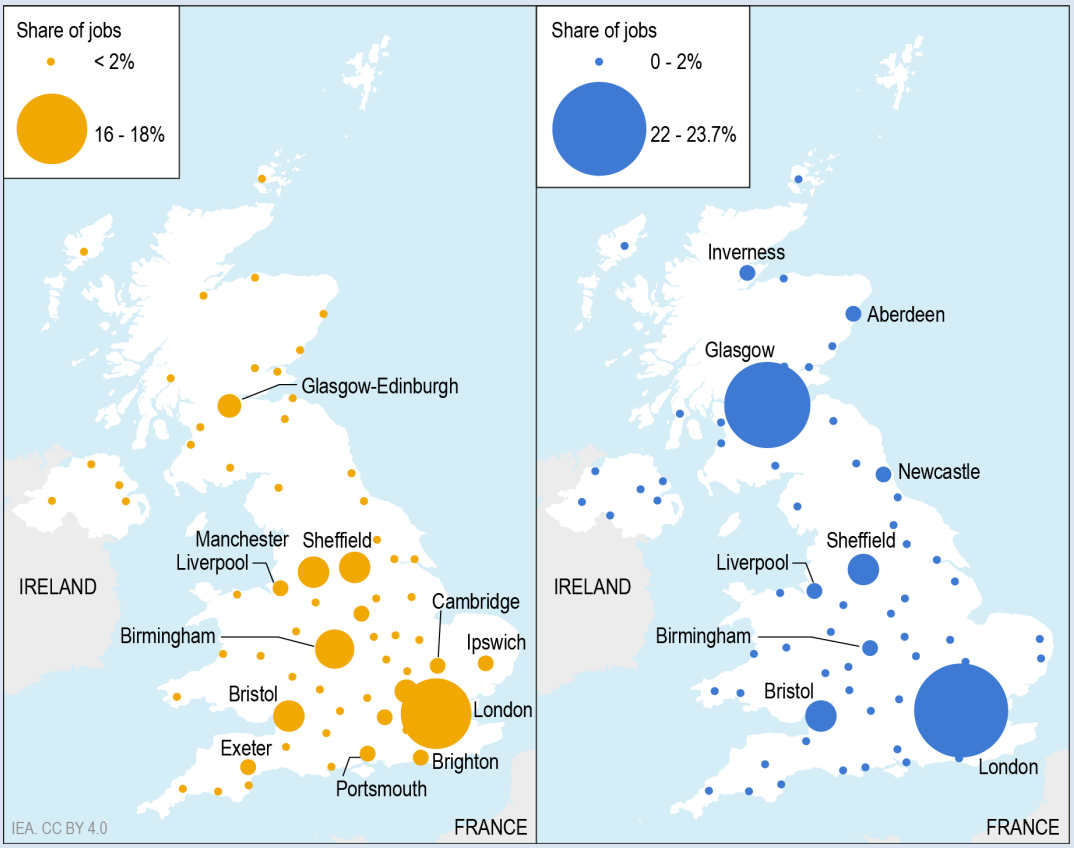
Bristol is a key hub for solar employment in the southeast of the United Kingdom, accounting for 7.9% of the United Kingdom's OJPs for solar over this time window. This region has benefited from large-scale solar farms and robust policy support from local authorities promoting solar energy as part of their broader renewable energy strategy, such as Bristol's One City Climate Strategy or the Solar Together scheme.

Across the Midlands, cities such as Birmingham, Sheffield and Manchester have become significant hubs for solar energy online vacancies. Birmingham, the largest city in the region, accounts for approximately 8.6% of solar job postings, driven by urban regeneration projects and incentives for solar installations on commercial and residential buildings, which have been supported by the Birmingham City Council Net Zero Plan. Manchester represents 7.2% of solar OJPs, supported by large-scale solar projects and initiatives led by local councils aimed at reaching net zero targets.

Central Scotland accounts for almost 6% of solar OJPs, particularly around Glasgow. While Scotland's solar potential is not as strong as in southern regions, investments in solar technology and government support for clean energy transitions have helped foster job growth in both residential and commercial installations. The Scottish government's Draft Energy Strategy and Just Transition Plan, published in January 2022, lays out an ambitious target of developing 4 GW to 6 GW of solar capacity by 2030, which Solar Industry Scotland projects will support nearly 9 000 full-time jobs in manufacturing, construction and business management.

Other regions, such as Northern Ireland and parts of Wales, show moderate concentrations of online solar job postings, albeit on a smaller scale compared with Central and Southern England.

Geographical distribution of solar (top) and wind (bottom) online job postings in the United Kingdom, 2019-2023



Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IEA analysis (2024), based on data from Lightcast (accessed July 2024).

Wind energy OJPs in the United Kingdom exhibit a clear geographical concentration in regions with substantial onshore and offshore wind energy projects, notably in Scotland, as well as in London and its surrounding regions. The postings' distribution reflects both natural resource availability and significant policy support for renewable energy expansion, such as the Contracts for Difference (CfD) scheme. London alone represents almost 24% of OJPs in the wind sector. Despite its distance from major wind farms, the concentration of OJPs in London can be attributed to its role as a headquarters for many leading renewable energy companies and project development firms. Additionally, the region plays a key role in the financial and administrative aspects of large wind projects, particularly offshore wind farms in the North Sea. London's proximity to several coastal wind

projects, as well as its capacity to attract skilled professionals in finance, project management and engineering, make it a major centre for wind energy employment.

Scotland contributes to almost one-third of the total OJPs for wind. Key cities such as Glasgow, Edinburgh and Aberdeen have become major centres for wind energy, driven by Scotland's abundant wind resources, supportive policy environment for both onshore and offshore wind projects, and experience in offshore oil and gas development providing transferable knowledge base. Scotland's leadership on floating offshore wind in particular is being leveraged to catalyse job creation in manufacturing, operations and maintenance, supported by the Scottish government's ambitious renewable energy goals.

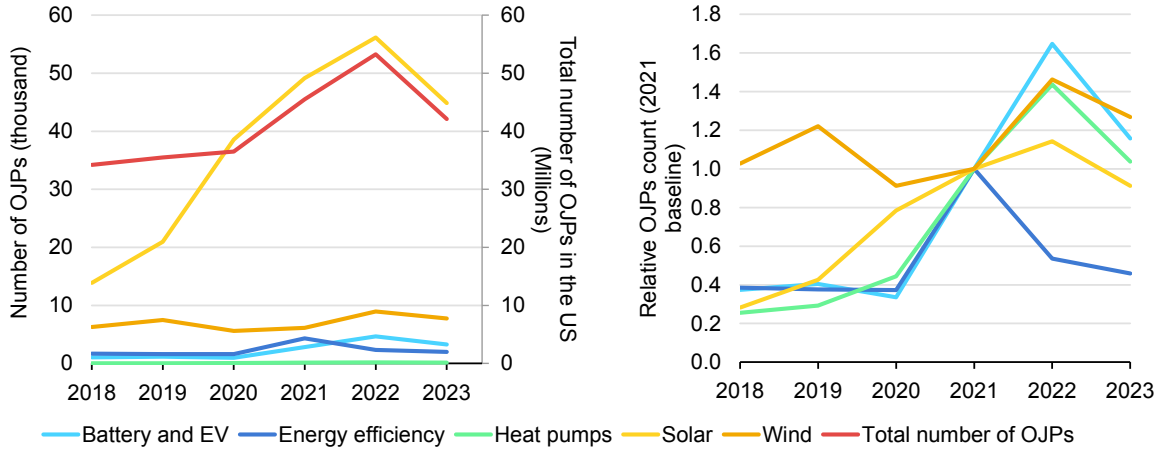
Cities such as Bristol, Sheffield and Liverpool also stand out as significant hubs for wind energy recruitment in the United Kingdom. These urban centres benefit from their proximity to key coastal and offshore wind projects, while also serving as locations for engineering and renewable energy firms. This concentration supports regional economic growth and aligns with the United Kingdom's broader strategy to expand renewable energy employment beyond London and the southeast.

Looking ahead, employment in wind energy in England is expected to benefit from the repeal of a de facto ban on new onshore wind development. Originally implemented in 2015 by the addition of two footnotes to the National Planning Policy Framework, which applied only to onshore wind, this ban allowed a single objection to block approval of a project.

The United States

As with Germany, France and the United Kingdom, solar workers are by far the most in demand in the US job market. Since 2020, solar-related OJPs represent more than 0.1% of the total number of OJPs in the United States. Solar-related OJPs' share displays similar patterns in the United States as in the United Kingdom. Their share really started to skyrocket between 2018 and 2020, before stabilising, compared with the total number of OJPs. The relative OJP count presents a similar pattern. There were four times more solar-related vacancies posted online in 2022 than in 2018.

Job demand comparison across key energy sectors in the United States, 2018-2023



Note: Data for 2023 are available until only the end of October. The total number of OJPs for 2023 has been estimated by multiplying by 12/10 the count of jobs for 2023. More details in the methodology annex.
Source: IEA analysis based on data from Lightcast

The particular increase between 2018 and 2020 could be due to the Investment Tax Credit (ITC) timeline phaseout. It provided a 30% tax credit for residential, commercial and utility-scale solar energy installations, and 2019 was the last year of the full 30% ITC, leading to a rush for solar installations to take advantage of the full credit. That might have explained the increase in the number and share of solar OJPs during this period. The ITC was reduced to 26% in 2020, and 22% in 2021. It was supposed to decrease to 10% in 2022 onwards, but the Inflation Reduction Act passed in 2022 extended the 30% ITC until 2032, explaining why the OJP share plateaued from 2021 onwards.

Wind positions are the second-most-advertised. However, their share among all OJPs remained almost constant, oscillating around 0.015%. The relative count of wind OJPs also remained almost constant since 2018.

Heat pumps and EV and battery positions are particularly liked by recruiters since 2020, when the relative count of OJPs exploded. In 2022, there were four to six times more vacancies advertised online for these fields than there were in 2018. These are the highest increases, even more than solar-related positions. The strong increase in heat pumps is the result of several policies encouraging the deployment, distribution and manufacture of heat pumps in the United States. It is particularly the case of the 2021 Japan-US Clean Energy Partnership and the 2022 Installing Clean Efficient Energy Hastens Our Transition Act and Heating Efficiency and Affordability through Tax Relief Act. Concerning EV and battery jobs, it might be partially due to the Inflation Reduction Act which also aims at driving investments towards American EV battery manufacturing.

Geographical distribution of solar and wind online job postings in the United States

Solar energy online job postings exhibit regional concentration in areas with abundant solar resources, strong energy demand growth and conducive policy environments. California, Texas and Florida emerge as the states with the highest number of online solar vacancies, supported by unique combinations of natural resources and ambitious renewable portfolio standards.

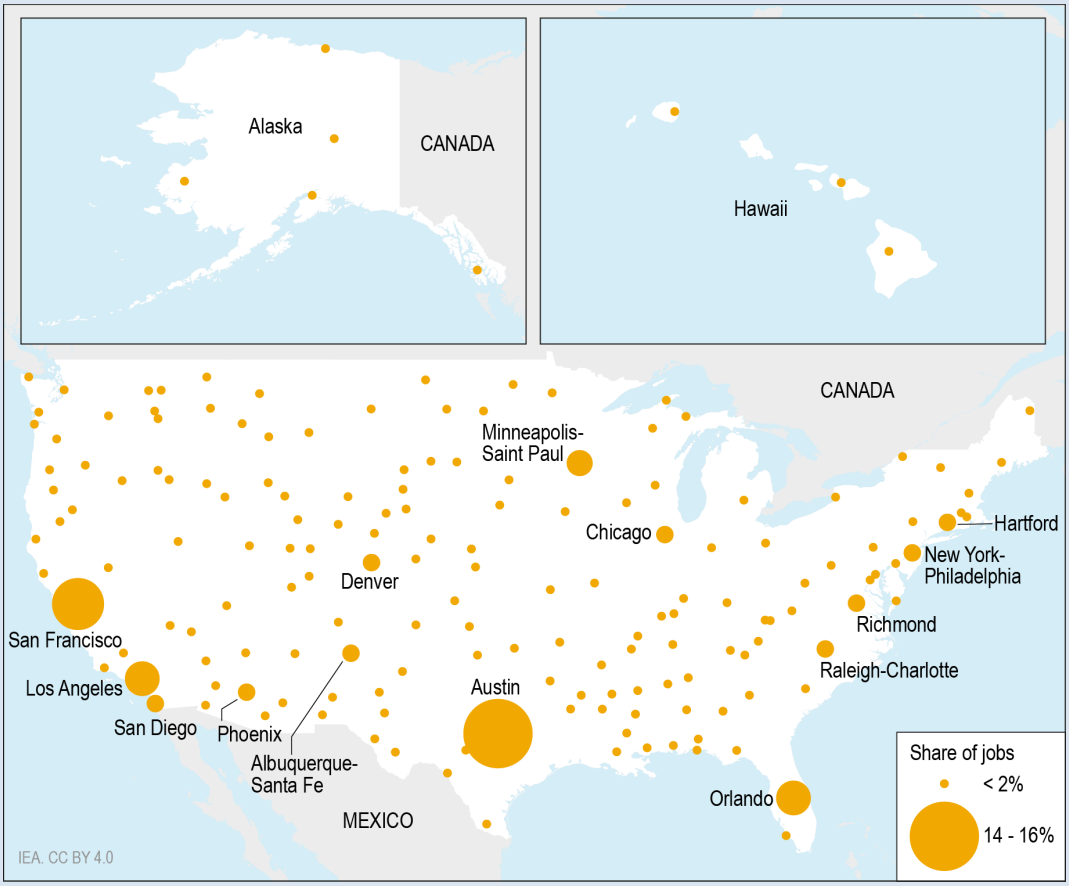
California hosts a few major clusters, such as the Bay Area around San Francisco (which combined represent 11.1% of the country's solar online job postings) and Los Angeles (representing 7.8%). As a whole, California accounted for almost one-fourth of the US online solar vacancies between 2019 and 2024, bolstered by aggressive state-level renewable energy targets and the expansion of both utility-scale solar farms and residential installations, supported by incentives such as the Disadvantaged Communities – Single-Family Solar Homes (DAC-SASH) programme

Texas is also a significant region for online solar job postings, particularly among cities in the Texas Triangle, namely Austin, Houston and Dallas, whose share of vacancies in the past five years amounts to almost 15% of the country's total. While Texas is traditionally known for its fossil fuel industry, the state's deregulated electricity market and expedited processing of new grid connections has supported the rapid diversification of its energy mix. Strong electricity demand growth, illustrated by the state regularly breaking peak-demand records, coupled with corporate demand for clean energy, particularly from the tech sector, and the availability of vast land suitable for solar farms all contribute to the state's strong growth in solar jobs.

Despite providing little policy support for solar, **Florida** ranks third in terms of online solar job vacancies concentration, with Orlando emerging as a key hub for online recruitment. With approximately 7% of OJPs for solar in the United States, Florida has leveraged its abundant solar resource to develop a robust solar market. Utilities such as Florida Power & Light have invested heavily in expanding solar capacity, supporting job growth across installation, maintenance and project development.

Other states in the Southwest, including **Arizona** and **Nevada**, also display notable hubs of online solar job postings due to their high solar potential and ongoing investments in utility-scale solar farms. These states benefit from consistent solar insolation, making them ideal for expanding solar infrastructure and related job markets.

Geographical distribution of solar online job postings in the United States, 2019-2023



Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IEA analysis (2024), based on data from Lightcast (accessed July 2024).

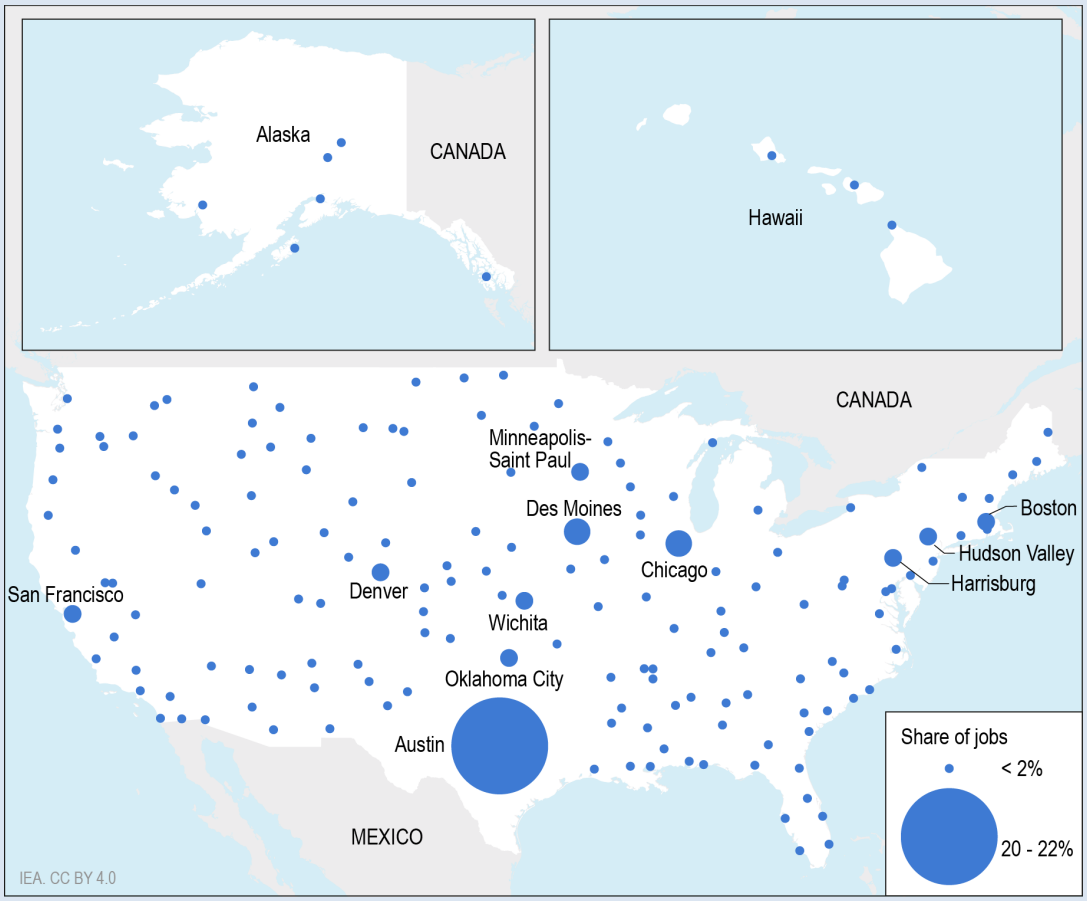
The geographical distribution of online wind energy job postings presents a different pattern compared with solar, with hubs concentrated primarily in the Midwest, the Great Plains and Texas. These regions have become pivotal in the growth of the wind energy sector, driven by the development of large-scale wind farms and robust investment in transmission infrastructure supported by the US Department of Energy's Production Tax Credit.

Texas stands as the largest hub for wind energy jobs, accounting for more than one-fifth of OJPs for wind. Wind energy jobs are concentrated around cities such as Amarillo, Lubbock and Houston, which have benefited from Texas' vast wind resources and the development of extensive transmission systems supported by the Competitive Renewable Energy Zones (CREZ) initiative. This infrastructure has enabled efficient transport of wind-generated electricity from rural areas to urban demand centres, further stimulating job growth in the state.

In the Midwest and Great Plains, states such as **Iowa**, **Kansas** and **Oklahoma** represent a sizeable share of online wind energy job postings (from 3% in Wichita to 5% in Des Moines). Known as the "wind corridor", these states are characterised by high average wind speeds, which have attracted large-scale investments in onshore wind farms. Wind energy jobs in these regions span across turbine manufacturing, installation and maintenance, contributing significantly to local economies in predominantly rural areas.

Other notable wind energy hubs include the Great Lakes region, particularly Chicago on the coast of Lake Michigan, where the potential for offshore wind is being explored, and along the **Eastern Seaboard**, where the country's first offshore wind farms are beginning to come online.

Geographical distribution of wind online job postings in the United States, 2019-2023



Notes: This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries, and to the name of any territory, city or area.

Source: IEA analysis (2024), based on data from Lightcast (accessed July 2024).

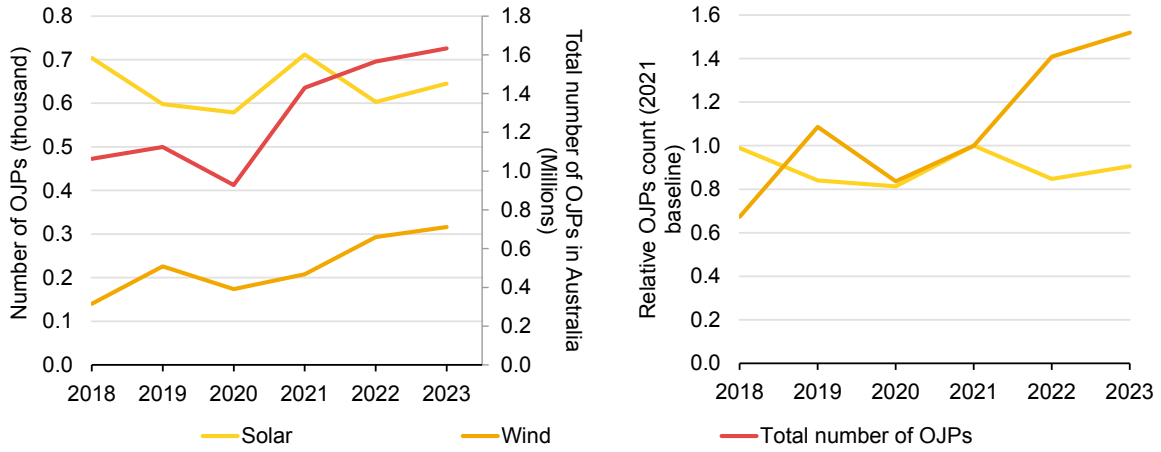
The concentration of solar and wind jobs reflects their technological demands: solar jobs are urban-centred, driven by residential and commercial installations, especially in states such as California and Florida. Wind jobs, however, are rural-

focused, benefiting local economies in states such as Texas, Iowa and Oklahoma, where large-scale wind farms require substantial land and support construction, maintenance and operations far from cities.

Australia

The share of solar jobs in Australia does not show a pronounced increase as in other countries. While for most of them the share is strongly increasing from 2018 onwards, it is oscillating in Australia. Since 2018, the number of solar-related OJPs has slightly decreased.

Job demand comparison across key energy sectors in Australia, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

On the contrary, the number of wind OJPs slowly increased, starting from less than 200 in 2018, to over 300 in 2023, despite a small drop in 2020. In 2023, the number of wind OJPs doubled compared with 2018.

Results for batteries and EV, energy efficiency, and heat pump postings are not shown since the number of observations per year is not above the threshold for all years. However, the number of battery and EV job postings is increasing since 2021, going from less than 50 postings to over 150 in 2023. Australia being the world's largest producer of lithium (a fundamental material used in most rechargeable batteries, particularly those used in electric vehicles), the increasing demand in EVs worldwide led to an increasing activity in Australia. In order to benefit more from this dynamic, investments are currently made to build large-scale battery-material factories locally, generating even more employment opportunities.

Digital jobs and skills in the energy sector

Digital jobs in power utilities

Digital technologies[1] are set to play a key role in the transition to more secure and sustainable energy systems, fostering greater connectivity, efficiency, reliability and emissions reductions. New digital tools – such as those that can help match power supply with demand, predict and detect faults in networks, or give greater control to consumers – will enable the faster integration of renewables, improve grid stability and unlock greater energy savings. However, the pace of digitalisation will depend heavily on the energy sector's ability to build a workforce with the right skills.

The number of digital roles across the energy sector has picked up globally. Yet there is growing evidence that it remains broadly insufficient, inhibiting greater investment in digitalisation; in a survey of energy professionals conducted by EY, 89% identified skills gaps as the main challenge to accelerating the adoption of digital technologies.

Total online job postings

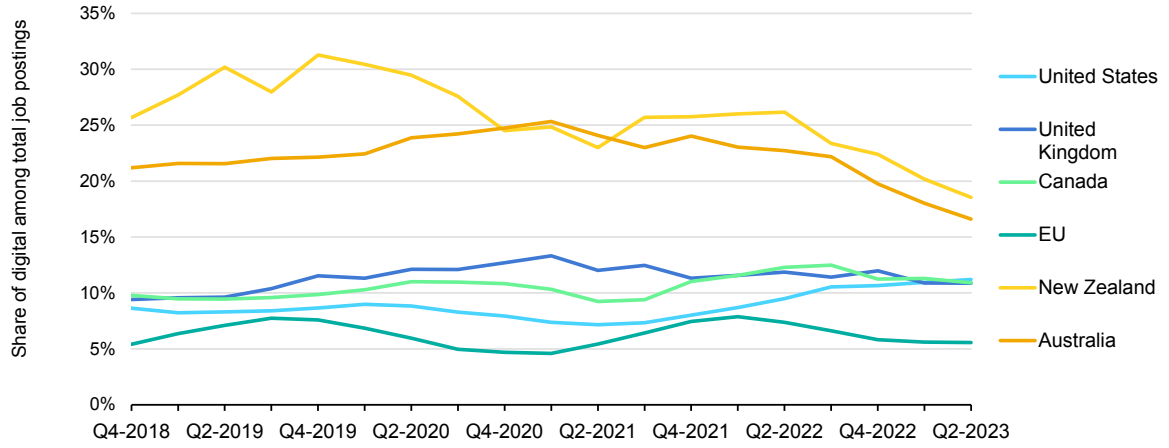
Analysing regional differences over time highlights the various stages of the digitalisation of the power sector. Between the fourth quarter of 2018 and the second quarter of 2023, Australia and New Zealand had high shares of digital job postings, though they declined recently. The United States, Canada and the United Kingdom had lower shares, but they are now rising. Europe (Austria, Belgium, Bulgaria, Croatia, Cyprus[2], the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland) has consistently had a low share

[1] The content of this section has been adapted from the commentary: Power utilities need digital talent – but not all are searching for it.

[2] Footnote by Türkiye: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue".
Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

of digital jobs, especially between 2022 and 2023, indicating that countries in the region may not be fully leveraging their investments in digital equipment.

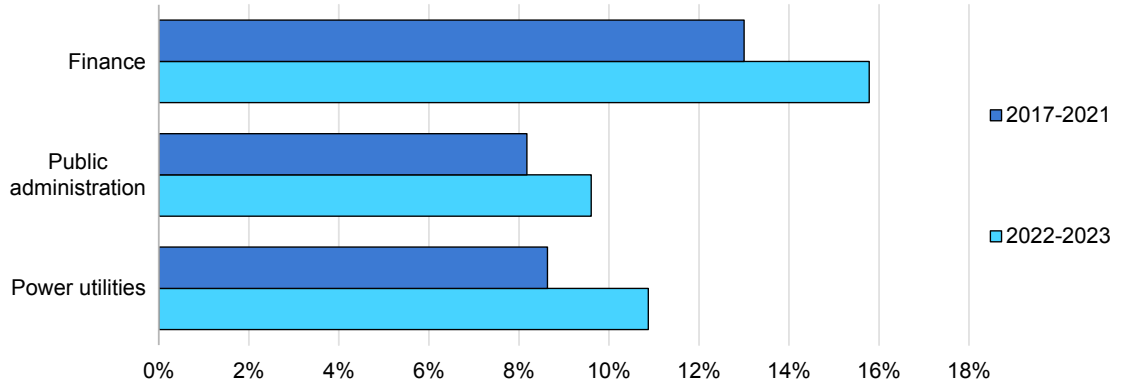
Share of primarily digital job postings in power utilities, per country and region, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

When shifting the focus to the United States only, power utilities have been slower to post significant shares of digital jobs than finance and insurance but slightly more than public administration. In recent years, digital job postings approached 16% of total listings by finance and insurance companies, whereas the share for power utilities stagnated around 11%, with a decline below 9% between 2017 and 2021.

Share of digital job postings among total by sector in the United States

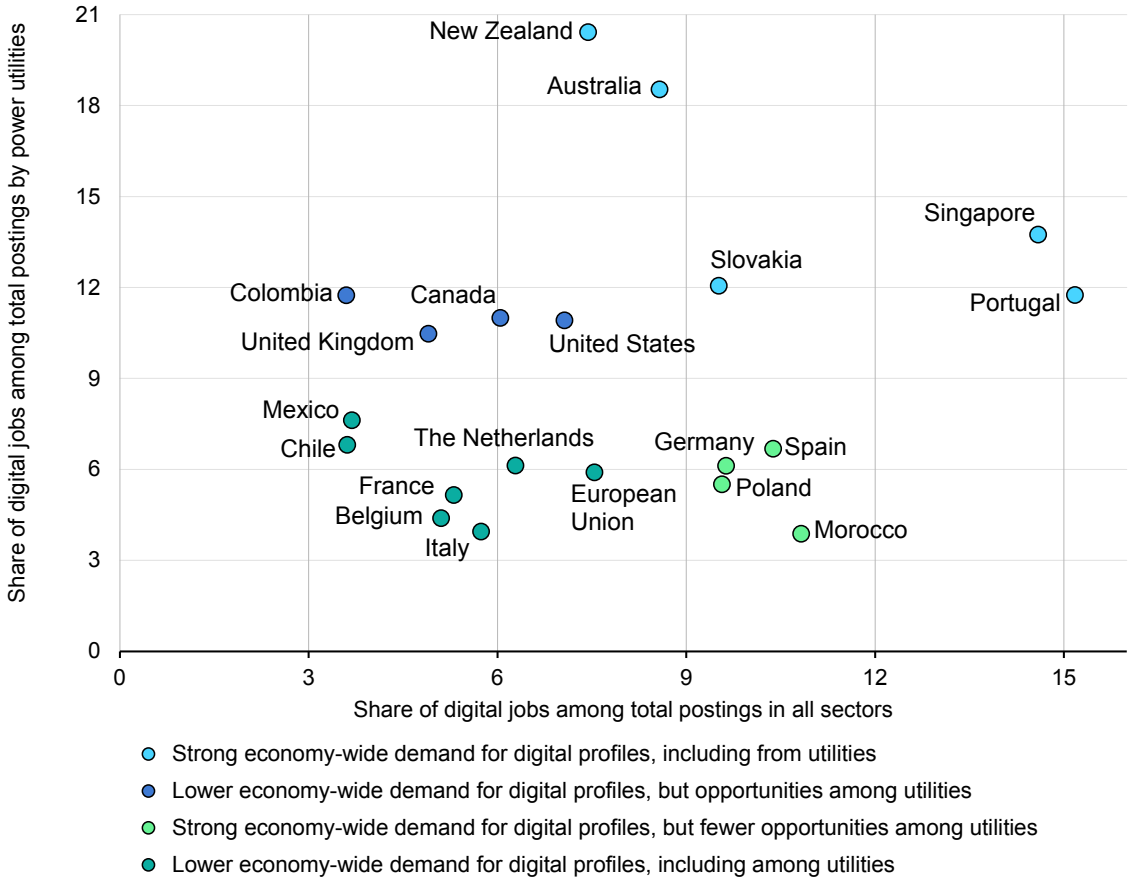


Source: IEA analysis based on data from Lightcast (accessed July 2024).

On the other hand, a cross-comparison of selected countries (Australia, Belgium, Canada, Chile, Colombia, France, Germany, Italy, Mexico, Morocco, the Netherlands, New Zealand, Poland, Portugal, Singapore, Slovakia, Spain, the United Kingdom, the United States) in 2022-2023 finds that nations can be divided into four groups based on interest in hiring workers with digital profiles. The first includes nations such as Singapore, Portugal and Slovakia, where employers are actively hiring workers with digital talents across all sectors, including for roles at power utilities. In a second group, which features countries such as Australia and New Zealand, hiring for digital roles by power utilities is even stronger – outpacing digital hiring across all sectors. This can be explained by several factors, including the identification by the government of certain essential digital skills and their inclusion on a skills priority list – which facilitates visa processing for foreign workers and allows to promote training and education programmes.

Meanwhile, among a third group of countries – including the United States, Canada, the United Kingdom and Colombia – the share of job vacancies that require digital skills posted by power utilities is higher than for the economy as a whole, but overall digital recruitment remains low. Colombia notably maintains a 3-to-1 ratio of digital job postings from utilities compared with all sectors of the economy.

Share of digital job postings among total from power utilities, 2022-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

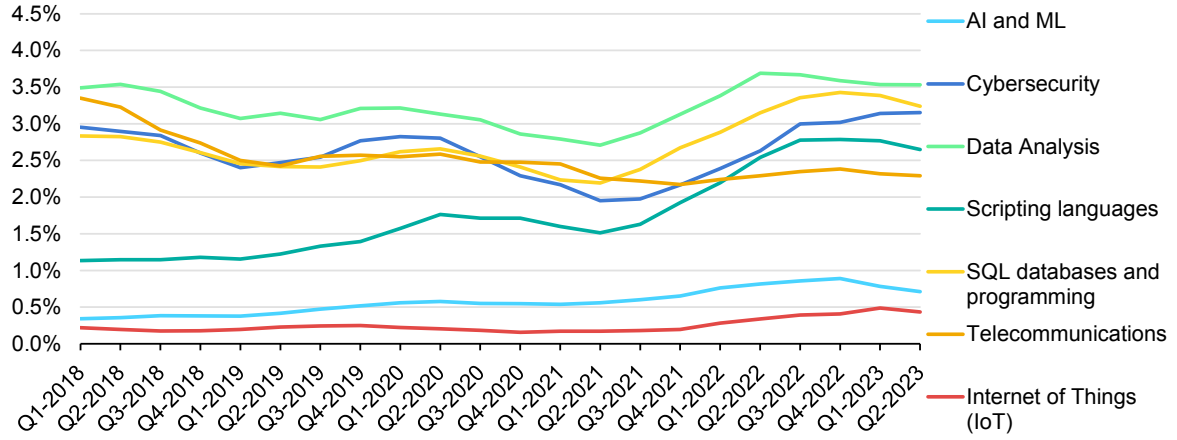
In contrast, the fourth group sees low demand for digital roles overall and in the power sector. It includes the majority of European Union member states, along with certain Latin American and North African nations. This group can be further divided into subgroups: one consisting of Spain, Germany, Poland and Morocco, which display less digital job demand within power utilities compared with their broader national economies, and another that includes Chile, Mexico, Italy and France, which maintain a share of digital job postings within power utilities (between 4% and 7%) that is similar to overall digital job market trends.

Required skills

With most jobs set to require digital skills in the coming years, energy utilities will increasingly be competing for a limited pool of qualified workers to bridge the sector's skills gap. This will require stronger and more cohesive digital hiring strategies and training efforts.

The types of digital skills prioritised by power utilities are shifting. In 2018, expertise in scripting languages was rarely required. However, since mid-2021, demand has grown rapidly for workers with those skills, in addition to data analysis, SQL database skills and cybersecurity expertise. Demand for workers with knowledge of more recent technologies, such as machine learning, artificial intelligence or the Internet of Things, is still at very low levels, even though these are extremely powerful tools for power system management.

Share of digital skills demand among total job postings by US power utilities, 2018-2023



Note: AI = artificial intelligence; ML = machine learning.
Source: IEA analysis (2024), based on data from Lightcast (accessed July 2024).

Cybersecurity jobs in power utilities

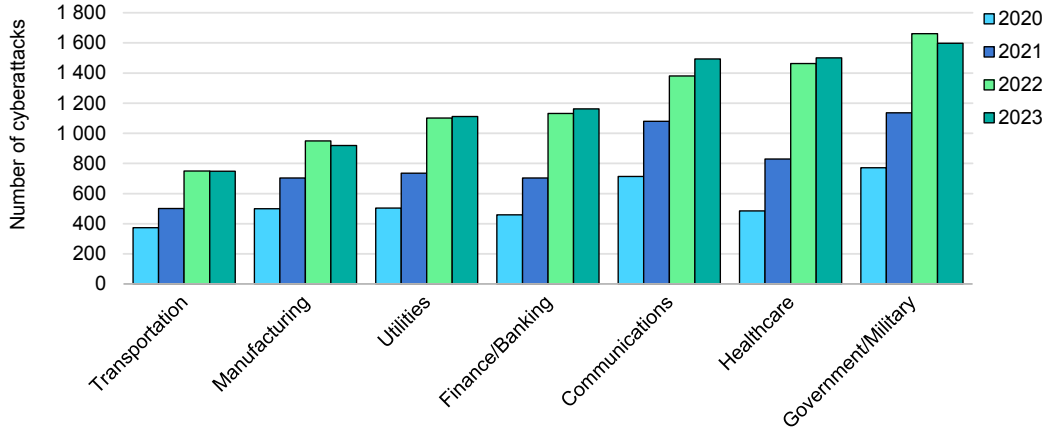
As with most industries, utilities increasingly use digital technologies[3] to better manage plants, grids and business operations, which contributes to energy security by improving quality of supply, providing additional services to customers, and enabling clean energy transitions through the integration of distributed energy resources. However, this progress comes with risks. Digital systems, telecommunication equipment and sensors throughout the grid increase utilities' exposure, as each element provides an additional entry point for cybercriminal organisations.

Publicly available information on significant cybersecurity incidents is limited due to under-reporting and lack of detection. However, there is increasing evidence that cyberattacks on utilities have been growing rapidly since 2018, reaching

[3] The content of this section provides an update of insight highlighted in the commentary: Cybersecurity – is the power system lagging behind?

alarmingly high levels in 2022 following the Russian Federation's invasion of Ukraine. Recent cyberattacks in the electricity sector have disabled remote controls for wind farms, disrupted prepaid meters due to unavailable information technology (IT) systems, and led to recurrent data breaches involving client names, addresses, bank account information and phone numbers. Worldwide, the average cost of a data breach hit a new record high in 2024, reaching USD 5.29 million in the energy sector.

Average number of weekly cyberattacks per organisation in selected industries, 2020-2023



Source: IEA analysis based on data from Checkpoint.

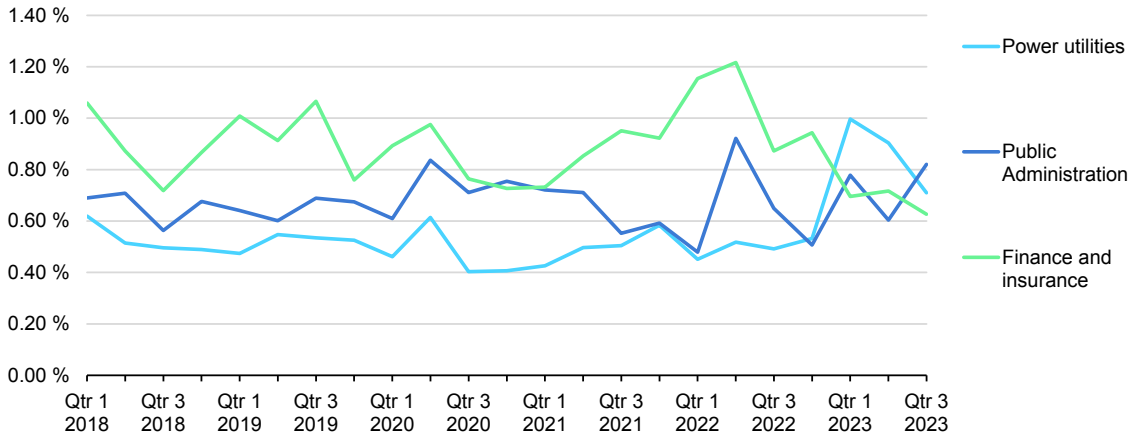
Critical infrastructure*, including gas, water and particularly power utilities, are favoured targets for malicious cyber activity.*

Total online job postings

Data from the United States shows a constant share of online cybersecurity vacancies since 2018, which slightly picked up in 2023. By contrast, the share of cybersecurity job postings in finance and insurance companies in the United States is a bit higher for most of the analysed time frame.

The number of cybersecurity expert job postings in power utilities has not evolved as rapidly as total job posting trends in the sector, despite the increasing digitalisation of power systems and their exposure to cyberattacks. Very similar trends have been observed in Canada and the United Kingdom. Some of the gap may be explained by heterogeneity across sectors, by factors such as diverse propensities to contract external specialised support, and differences in labour turnover (i.e. churn rates). Still, the difference is of some concern.

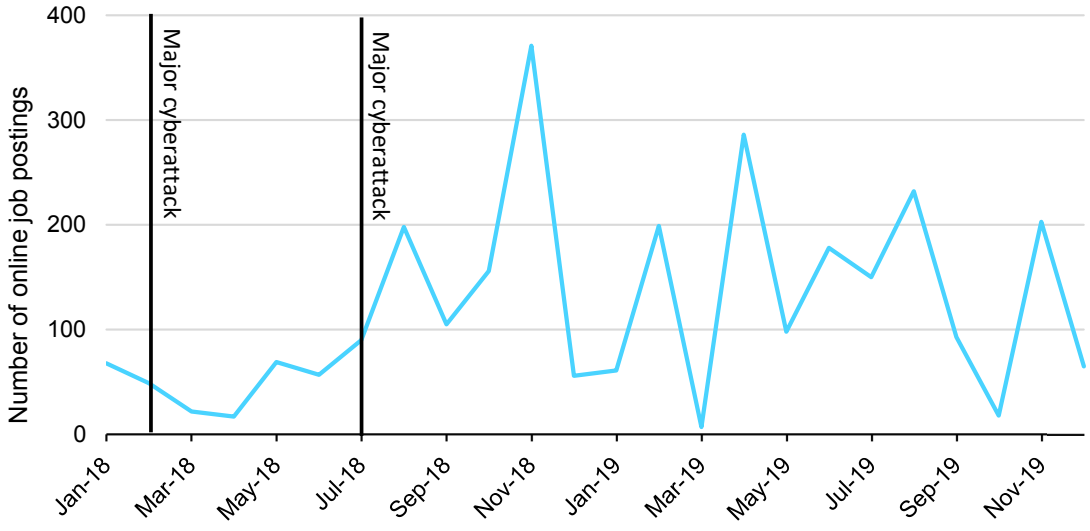
Share of cybersecurity professional job postings among total in selected United States industries, January 2010-September 2022



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Besides, while electric power utilities across the globe already dedicate substantial budgets to cybersecurity – averaging 8% of total IT budgets in the United States and Canada – job posting data from major power utilities in the United States show that cyberattack events trigger sudden increases in demand for cybersecurity professionals, suggesting a lack of long-term strategy or planning in the past. Smaller companies in the United States and others in developing economies could show similar behaviour in the future after suffering preventable attacks.

Cybersecurity professional job postings after a cyberattack in NERC Regional Reliability Entity, 2018-2019

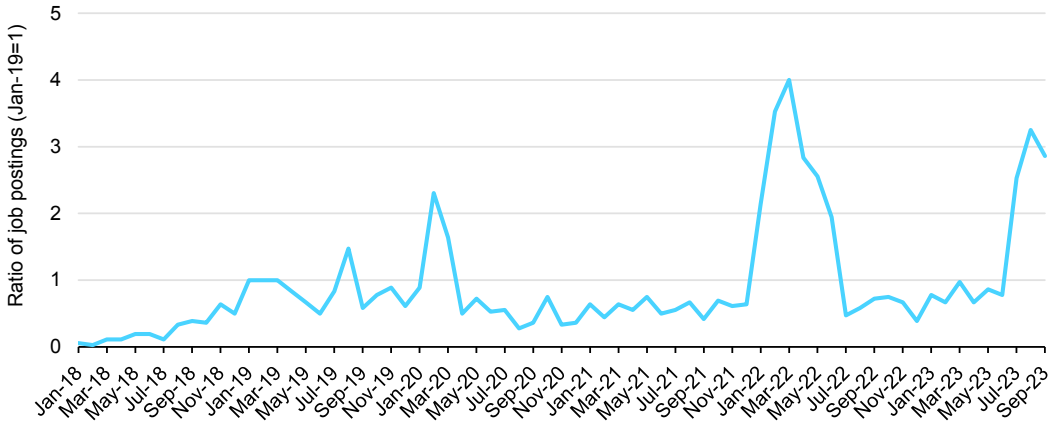


Source: IEA analysis based on data from Lightcast (accessed July 2024).

European Union utilities have also been in reactive mode. While the implementation of secure remote working (both for corporate and industrial

systems) and related cyber risks may explain the job posting peak in February 2020, these trends suggest that European Union utilities were not fully prepared at the time to face critical events such as the Covid-19 pandemic and the Russian invasion of Ukraine. The last available months also show an increase in cybersecurity online job postings that may be due to the political agreement reached in June 2023 between the European Parliament and the Council of the EU, which led to the new Cybersecurity Regulation, which entered into force in January 2024.

Cybersecurity professionals job postings in European Union utilities, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

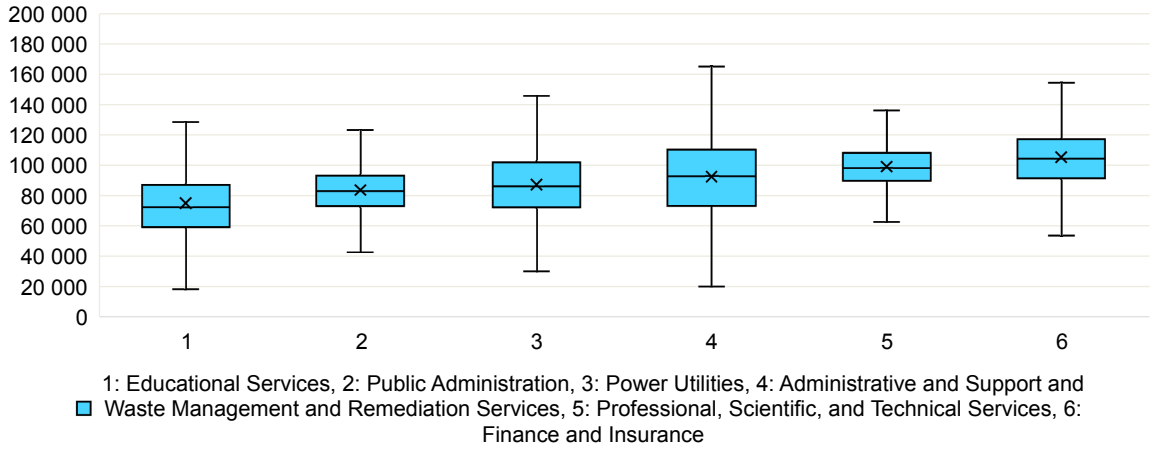
Advertised salaries

In addition to lower rates of job postings, power utilities have difficulties recruiting and retaining cybersecurity employees for three main reasons:

1. A worldwide shortage of cybersecurity workers across all sectors, estimated at 3.4 million people in 2022.
2. Available data for the United States, Canada and the United Kingdom suggests salaries offered by power utilities in cybersecurity job postings are among the lowest for the occupation.
3. Power utilities require specific cybersecurity skills adapted to their regulated technical and operational activities.

Between 2021 and 2023, US *Power Utilities* advertised an average annual salary of USD 87 000, higher than in *Educational Services* and *Public Administration* but substantially lower than top sectors such as *Finance and Insurance*, which offered more than USD 100 000. Given the wide range of job vacancies, cybersecurity experts are likely to prefer sectors offering better conditions, further increasing the shortage of professionals in the power utility sector. Finance and Banking, in particular, is a sector well known for its high levels of investment in cybersecurity.

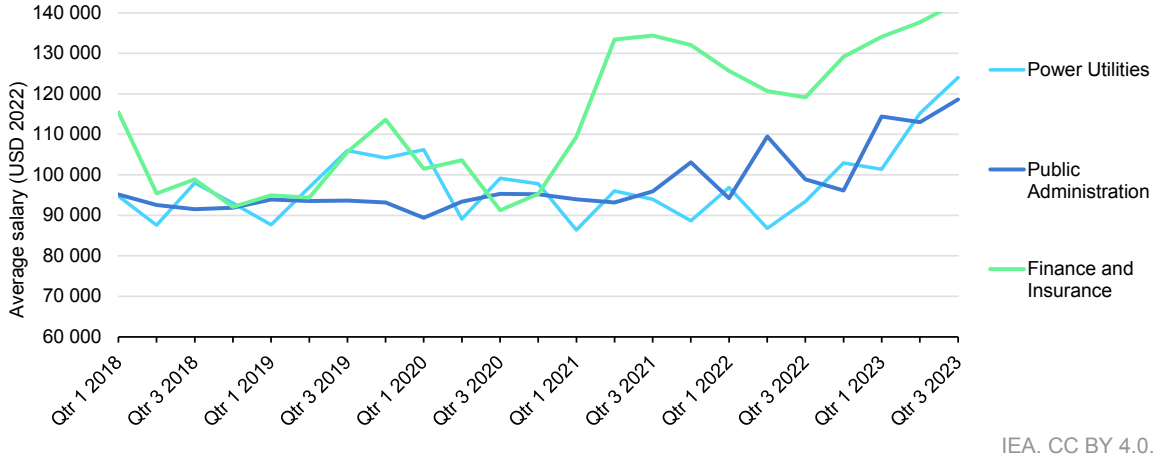
Salaries advertised in cybersecurity professional online job postings by industry in the United States, 2021-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Data starting from 2018 for online cybersecurity job postings in *Power Utilities*, *Finance and Insurance*, and *Public Administration* show that offered cybersecurity salaries in *Power Utilities* were initially competitive until 2020, and not far from top-paying sectors. However, utilities' offered wages have not kept up with competition over the past years, and power utilities have progressively fallen into the lower group along with public administration, but increased by about 25% between third quarter of 2023 and the third quarter of 2024. While this may be explained in part by differences across sectors in wages (and the degree to which firm-level revenue is shared with workers), the relatively low and stagnant salaries for cybersecurity workers within power utilities is a cause for concern in the face of increasing threats.

Average salaries advertised in cybersecurity professionals job postings by United States industry, 2018-2023



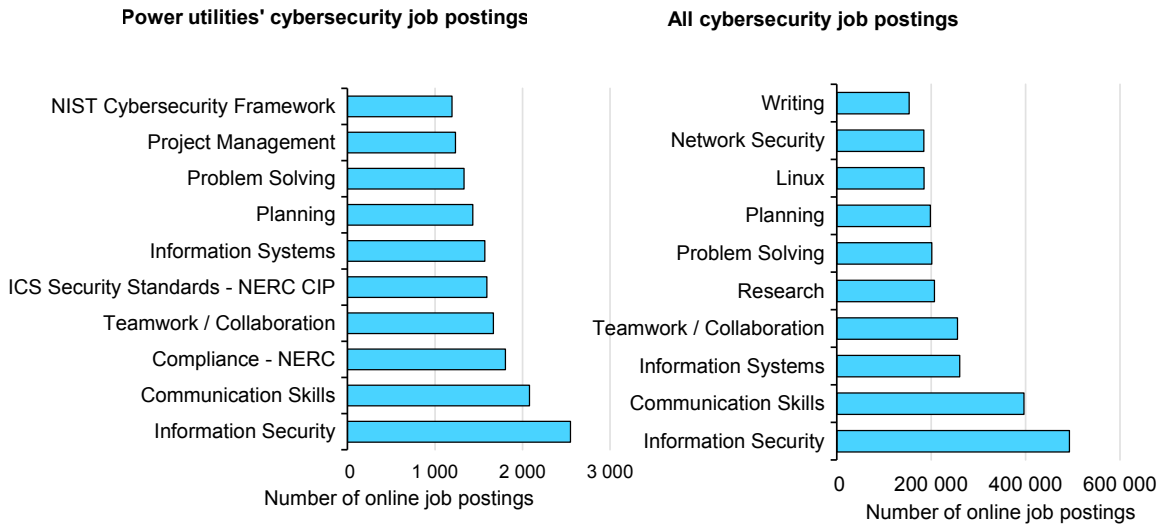
Source: IEA analysis based on data from Lightcast (accessed July 2024).

Required skills

Considering these findings, it is not surprising that power utilities seem to have difficulties finding cybersecurity profiles adapted to their tasks. This is certainly due in part to the very specialised nature of their activities and the high degree of digitalisation in recent years, leading to complex IT and operational technology (OT) systems capable of remote control operation of plants and grids. A recent survey showed that 62% of respondents within utilities either do not know or do not believe that they have the skills and tools in their organisations to protect against cyberthreats.

Regulation in North America and specifically in the United States has been at the forefront in developing cybersecurity standards for the power grid, mainly through the North American Electric Reliability Corporation (NERC) and its Critical Infrastructure Protection (CIP) standards, as well as through the Cybersecurity Framework Smart Grid Profile. As expected, knowledge and experience with NERC standards is one of the top three skills required for cybersecurity profiles in the power utilities sector, closely followed by Industrial Control Systems (ICS) security standards, specifically within the NERC CIP framework.

Top required skills in power utilities' (left) versus all (right) cybersecurity online job postings in the United States, 2018-2023



IEA. CC BY 4.0.

Note: NIST = National Institute of Standards and Technology.
Source: IEA analysis based on data from Lightcast (accessed July 2024).

Responsibility for securing power systems does not rest exclusively with power utilities. Policy makers play a central role in enhancing the cybersecurity of power systems, along with regulators and equipment providers. Without a strategic approach towards ensuring cyber skills, power system stakeholders may not be able to effectively cope with future attacks. The main action areas for achieving

more appropriate electricity security frameworks are institutionalising responsibilities and incentives; identifying, managing and mitigating risks; monitoring progress; and responding to and recovering from disruptions. Smaller utilities may require additional support from policy makers and regulators, as their fixed costs for cybersecurity infrastructure and systems are higher in relative terms.

Although long-term data on job vacancies seem to suggest that demand for skilled cybersecurity personnel at US power utilities is relatively stagnant, the sector has been doing well in terms of business continuity and resiliency, namely absorbing damage and avoiding major impacts to end users. In order to achieve this, many power utilities have relied on external support from specialised companies instead of creating large in-house cybersecurity teams. But internal adaptation to current cyberattack trends across teams is necessary as it involves the whole value chain of power utility companies. Cyberthreats will continue to evolve and become both more frequent and more powerful, given the established business models of cybercriminals and the wide range of advanced technologies at their disposal. It is therefore essential that every power utility, big or small, include cybersecurity as a core element of their business strategy and ensure access to in-house cybersecurity professionals and their skills, continuously updating them and ensuring talent retention.

Smart grid online job postings

In recent years, smart grids are becoming an integral part of energy management across the globe, revolutionising the way electricity is generated, distributed and consumed. These advanced energy systems incorporate digital communication technology to enhance the monitoring and efficiency of electricity flows, allowing for a more resilient and responsive power grid. Indeed, smart grids support a shift towards more sustainable energy consumption patterns, reducing losses and adapting to fluctuating energy demands. In both the United States and the United Kingdom, the development and expansion of smart grid technologies could lead growth in associated job markets, contributing to employment in sectors such as engineering, data analysis and IT.

Total online job postings

The goal of the United Kingdom's Smart Systems and Flexibility Plan 2021 is to spread the use of smart systems across the country in order to optimise national energy use and boost smart systems-related companies' activities. The United Kingdom is already a global leader in these technologies, and the government plans on increasing even more its investments, creating up to 24 000 jobs by 2050. However, since the plan's release, the share of smart grid-related positions advertised online remained on average constant. After a

decrease in 2019, smart grid share in the United Kingdom stabilised. The share even decreased in 2022, one year after the publication of the 2021 Smart Systems and Flexibility Plan.

According to the 2024 US Energy & Employment Jobs Report, smart grid-related jobs increased by 5.8%, representing 1 435 new jobs in the United States between 2022 and 2023. However, the share of online job postings, which slightly increased in 2022, remained constant in 2023. This difference might be due to online versus on-paper job postings, or to the global number of online job postings which might have increased in 2023, keeping the share to a constant level. When looking at the big picture, the share of smart grid OJPs remained on average stable in the US since 2018, decreasing in 2020 and 2021, before getting back to its 2018 level in 2022 and 2023.

Online job distribution by industry

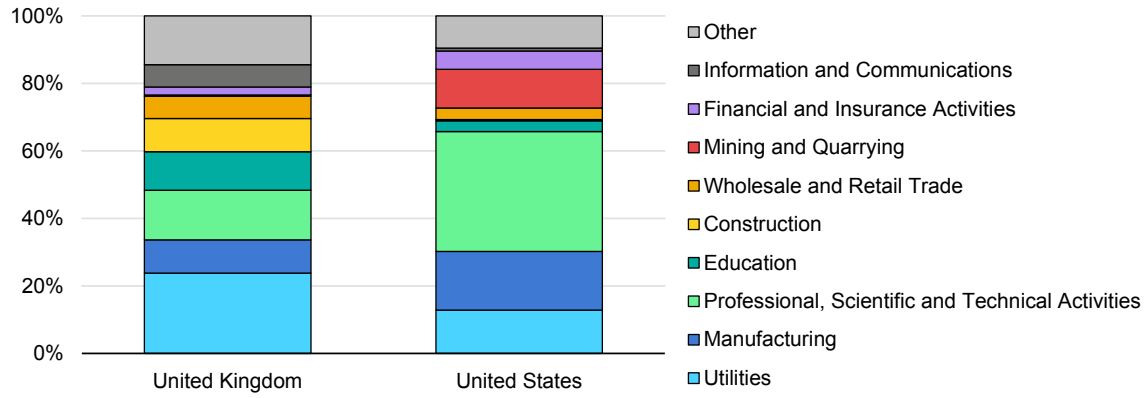
Two industries are mainly responsible for smart grid-related OJPs in the United Kingdom and the United States: *Professional, Scientific and Technical Activities* and *Utilities*.

Between 2018 and 2023, *Professional, Scientific and Technical Activities* published the highest number of online vacancies in the United States, being responsible for 36% of the country's OJPs related to smart grids. It also played a major role in the United Kingdom as it is the second-largest industry in terms of number of job offers posted online, with 15% of the UK smart grids' offers published. This dominance shows that smart grids are a technology that still involve research and development as well as engineering work and is not only in a deployment phase. Smart grids also rely heavily on data collection and real-time monitoring. Thus, the presence of this industry also reflects all jobs related to the collection, treatment and analysis of the data collected by smart grids.

The *Utilities* industry is the largest OJP provider when it comes to smart grids in the United Kingdom, as 24% of the vacancies posted online are for positions related to this sector. It is also significantly present in the United States with a share of 13% of the US smart grids OJPs.

Other important industries are *Manufacturing*, *Mining and Quarrying*, and *Education*. Between 2018 and 2023, *Mining and Quarrying* companies – which include companies working in the entire energy supply chain – published offers only in the United States, where they made up around 11% of the smart grid online job postings. *Education* was responsible for 11% of smart grid OJPs in the United Kingdom, and only accounted for 3% of the US ones. *Manufacturing,* however, is among the biggest online job posters in both countries, with 17% and 10% of the smart grids OJPs published in the United Kingdom and in the United States, respectively.

Share of smart grid OJPs by industry in the United Kingdom and the United States, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Online job distribution by occupation

The United Kingdom and the United States display very similar profiles when it comes to the distribution of smart grid OJPs per occupational category.

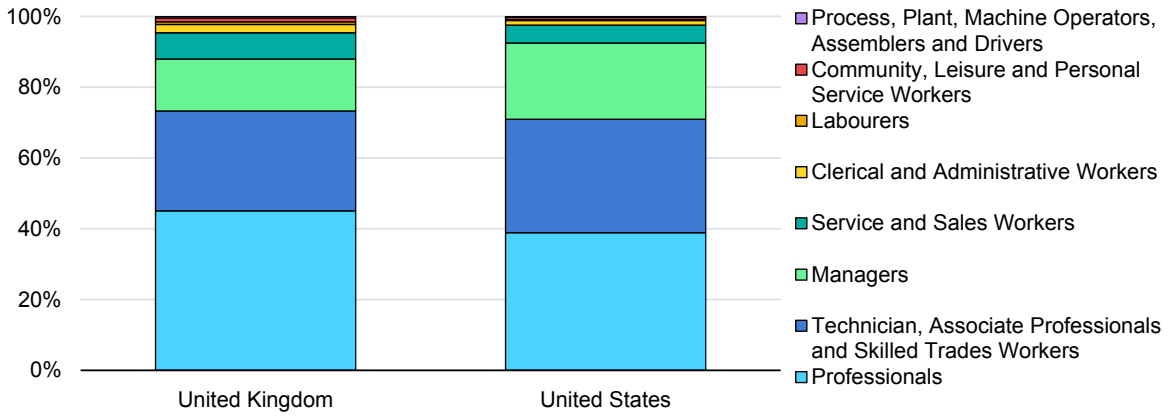
In both countries, *Professionals* (such as Data Scientists for Smart Grids) were the most advertised positions between 2018 and 2023. In the United Kingdom, almost half (45%) of the jobs advertised online for smart grids related positions were for *Professionals*. Those same vacancies represented 39% of the US smart grids OJPs.

The second-most-advertised positions are *Technician, Associate Professionals and Skilled Trades Workers* (for example Smart Meter Installers), in both the United States and the United Kingdom. Such positions accounted for 28% of the UK smart grids OJPs between 2018 and 2023, and 32% of those in the United States.

Managers, such as Smart Grid Program Managers, also gather a significant proportion of the online job postings. Such positions accounted for 22% of the US online vacancies, and 15% of the UK ones.

Together, *Professionals*; *Technician, Associate Professionals and Skilled Trades Workers*; and *Managers* encompass 93% of the smart grids OJPs in the United States and 88% in the United Kingdom. *Service and Sales Workers* (for example Smart Home Technology Sales Representatives) accounted for 5% and 7% of the OJPs in the United States and the United Kingdom, respectively, leaving only between 2% to 5% of the online postings to other occupational categories during the period analysed.

Share of smart grid OJPs by occupational category in the United Kingdom and the United States, 2018-2023

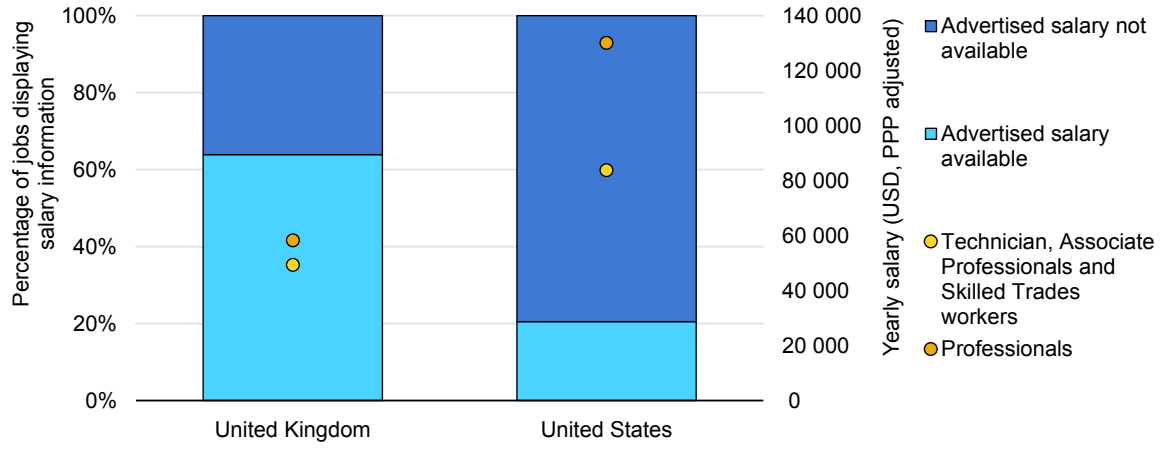


Source: IEA analysis based on data from Lightcast (accessed July 2024).

Advertised salaries

Between 2018 and 2023, advertised minimum salaries for smart grid positions were on average higher in the United States, being more than twice that of United Kingdom (USD 130 000 versus USD 58 000) for *Professionals* and 70% bigger for *Technician, Associate Professionals and Skilled Trades Workers*.

Average minimum advertised annual salary (PPP adjusted) for smart grids Professionals and Technician, Associate Professionals and Skilled Trades Workers versus share of smart grids online job postings displaying an advertised salary, in the United Kingdom and the United States, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

It is nevertheless important to note that smart grid jobs posted online between 2018 and 2023 displayed information on salaries more often in the United Kingdom than in the United States. More than half of the UK OJPs

displayed information on salaries (64%) versus only 20% of the US ones. The different coverage might explain part of the salary difference between the two countries.

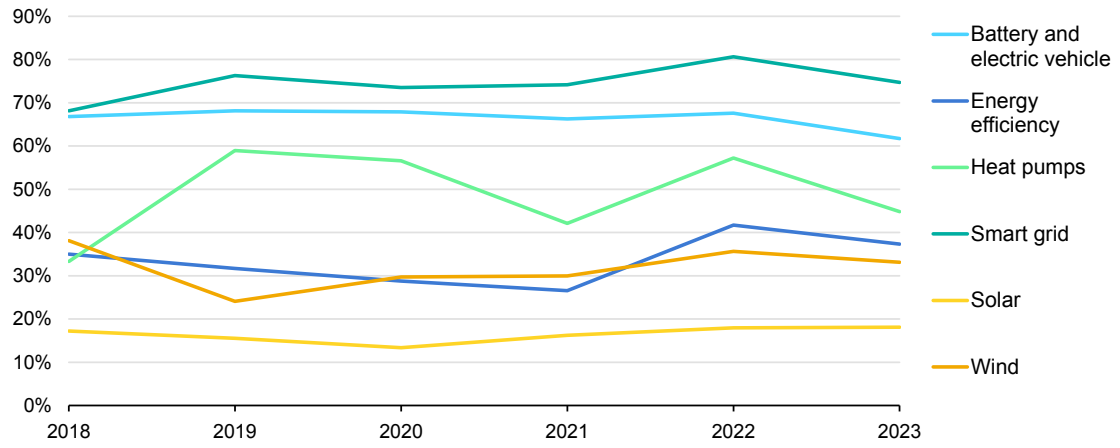
Digital skills in online job postings related to the energy transition

Digital skills are becoming increasingly critical in the renewable energy sector, including jobs in solar, wind, heat pumps, battery storage and EV, energy efficiency, and smart grids. Despite this, the skills listed in online job postings do not adequately reflect the need for the energy industry to become more digital. It is interesting to look at the evolution of digital skills requirement among the OJPs analysed in the previous chapter, in the United States and the United Kingdom.

United States

In the United States, on average, for the years 2018-2023, smart grid online job postings required at least one specialised digital skill[4] for most of the jobs, followed by battery and EV OJPs. The other categories (solar, wind, heat pump and energy efficiency) show that on average 50% or less postings require at least one specialised digital skill. Across all cases, despite a shy increase in 2022, the share does not appear to have significantly increased in recent years, suggesting that companies seeking talents in these specific fields may not be aiming to increase the share of digital workers through external recruitment.

Share of online job postings requiring at least one specialised digital skill in the United States, 2018-2023



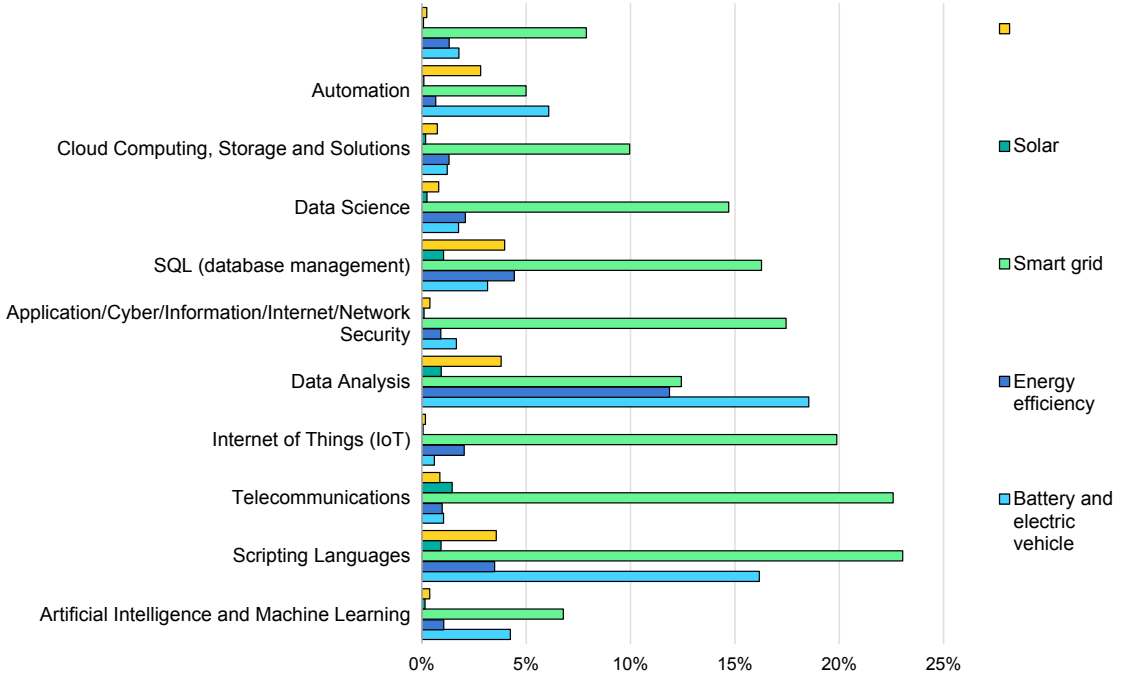
IEA. CC BY 4.0.

Source: IEA analysis based on data from Lightcast (accessed July 2024).

[4] Please see the methodology annex for more details.

Going more into details and considering the full time series between 2018 and 2023, a breakdown of requirement by skill category is available.[5] This paragraph focuses on a specific subset of skills, including some that are key for the digitalisation of the energy sector, such as SQL, Scripting Languages, Automation, Telecommunications, Data Science, Cloud Computing, Storage and Solutions, Application Security, Cybersecurity, Information Security, Internet and Network Security, Artificial Intelligence and Machine Learning, Big Data, Internet of Things (IoT), and Data analysis.

Share of online job postings requiring at least one digital skill from a specific subset by technology, in the United States, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

On average, the share of smart grid postings requiring at least one skill among these categories is higher than for other technologies, with most jobs looking for workers with skills in Scripting Languages, Telecommunications and Internet of Things. Among battery and EV online ads, the digital skills most requested are Data Analysis and again Scripting Languages. Skills in Data Analysis and SQL are the most required in energy efficiency jobs, while skills in each one of the

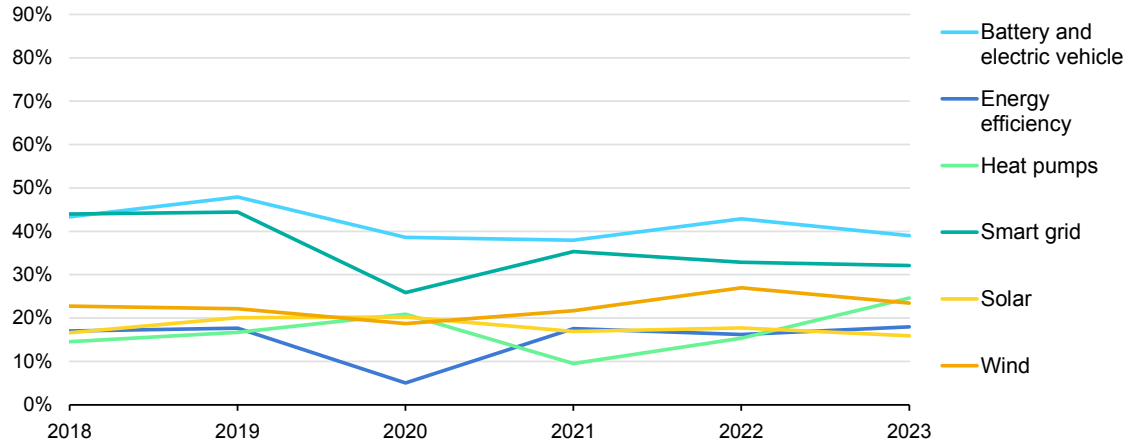
[5] Not enough data on heat pumps was available to perform this analysis.

selected categories are requested in less than 4% of wind (and 2% of solar) jobs. Overall, skills in Scripting Languages and Data Analysis seem to be the most requested digital skills, among the ones analysed.

United Kingdom

In the United Kingdom, shares of online job postings requiring at least one digital skill were much lower than in the United States over the same period of time (2018-2023). Smart grids was also one of the technologies requiring the most people with at least one digital skills, but it was not the largest one. Indeed, in 2023, 39% of battery and EV OJPs required at least one digital skill, while only 32% of the smart grid ones did, and 25% of the heat pump ones. As in the United States, solar-related positions were the least demanding ones in terms of digital skills (16% in 2023).

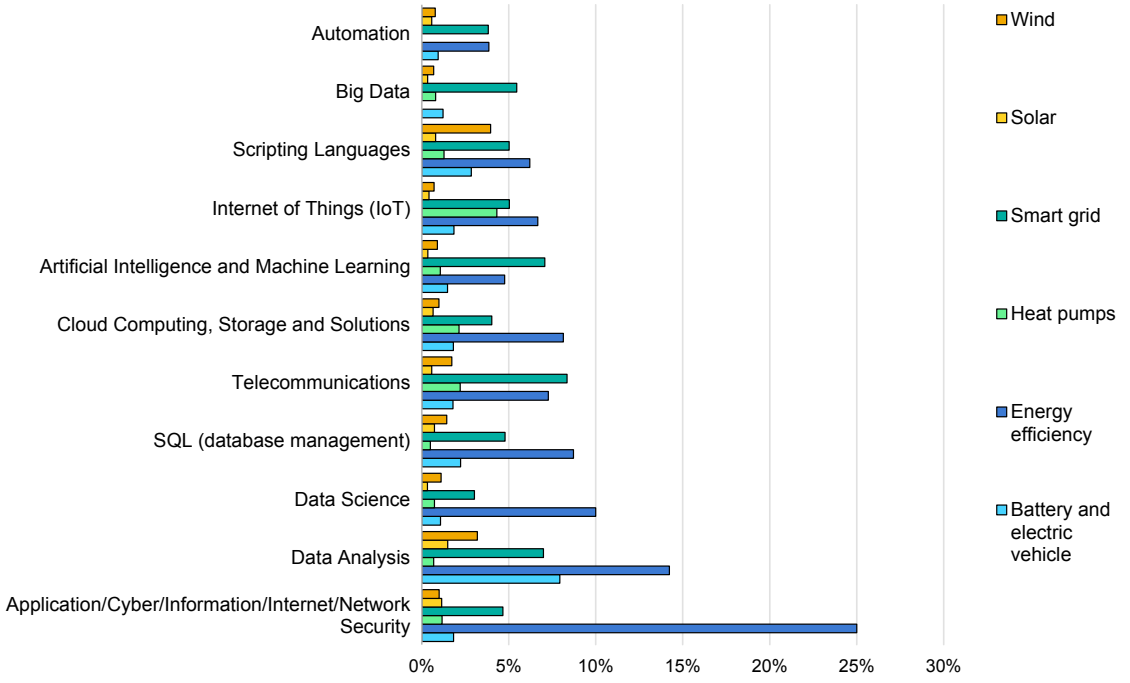
Share of online job postings requiring at least one specialised digital skill in the United Kingdom, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

Since 2018, the top two technologies – batteries and EV and smart grids – both showed a decrease in their share of OJPs requiring at least one digital skill. Solar's share also decreased. Every technology experienced a drop in their share around the Covid-19 pandemic, either in 2020 or in 2021.

Share of online job postings requiring at least one digital skill from a specific subset by technology in the United Kingdom, 2018-2023



Source: IEA analysis based on data from Lightcast (accessed July 2024).

As for the United States, a breakdown of requirement by skill category is available. Energy efficiency online positions require the most digital skills that are among the analysed specific subset of skills. One posting out of four requires skills in *Application/Cyber/information/Internet/Network Security* for this technology, and 14% of them in *Data Analysis*, which is the most wanted skill, all technologies considered together. Batteries and EV, despite being the technology with the highest share of jobs requiring at least one digital skill, are not among the technologies requiring the highest share of skills among this set, indicating that other digital categories not taken into account here are more requested. As seen previously, solar positions do not demand many digital skills.

Methodology annex

Data coverage

Data provided by Lightcast on online job postings are structured in tabular format and contain information such as job title, occupations, industry, salary, required education and skills. Data availability and coverage varies by country. For most of the report, only data starting from 2018 was used, until the last available date.

Data coverage by country and technology

Country	Start date	End date
Australia	1 Jan 2018	31 Dec 2023
Austria	1 Jan 2019	30 Sep 2023
Belgium	1 Jan 2021	30 Sep 2023
Canada	1 Jan 2018	30 Nov 2023
Chile	1 Jan 2020	1 Feb 2023
Colombia	1 Jan 2020	1 Feb 2023
France	1 Jan 2021	30 Sep 2023
Germany	1 Jan 2018	30 Sep 2023
Ireland	1 Jan 2021	30 Sep 2023
Italy	1 Jan 2018	30 Sep 2023
Luxembourg	1 Jan 2019	30 Sep 2023
Mexico	1 Jan 2020	1 Feb 2023
New Zealand	1 Jan 2018	31 Dec 2023
Singapore	1 Jan 2018	30 Nov 2023
Spain	1 Jan 2018	30 Sep 2023
Switzerland	1 Jan 2018	30 Sep 2023
United Kingdom	1 Jan 2018	30 Nov 2023
United States	1 Jan 2018	31 Oct 2023

Filtering process

Solar, wind, heat pumps, battery and EV, energy efficiency, and smart grid online job postings

To identify jobs related to the chosen technologies (Battery, Efficiency, Heat Pumps, Smart Grid, Solar, Wind), data were extracted using a combination of text search in the job title and a filter on the occupational code. The choice of selecting data using the occupational code may seem like a more robust and consistent approach, but 1) not all occupational codes have the granularity necessary to identify only jobs related to the interested technology/category; and 2) some jobs do not have a specific occupational code. Therefore, a combination of text filter and occupational code seemed preferrable.

The filter on the occupational code was applied to extract Wind and Solar jobs only, as there are no specific occupations for the other technologies. The O*NET-SOC Taxonomy was available for both Canada and United States. Standard occupation classifications were provided for Australia and New Zealand (ANZSCO); Canada (NOC); Europe (ESCO–4 digits); Chile, Mexico, Colombia (ISCO); Singapore (SSOC); the United Kingdom (SOC); and the United States (SOC). Lightcast has its own Occupational Taxonomy (LOT), which resembles O*NET and was contained in the data of the core anglophone countries (Australia, Canada, New Zealand, Singapore, the United Kingdom and the United States).

Occupation classifications available by country

Country	Industry classification
Australia, New Zealand	Australia and New Zealand Standard Classification of Occupations (ANZSCO), LOT
Canada	National Occupational Classification (NOC), O*NET, LOT
Chile, Colombia, Mexico	International Standard Classification of Occupations (ISCO)
Europe	European Skills, Competences, Qualifications and Occupations (ESCO)
Singapore	Singapore Standard Occupational Classification (SSOC), LOT
United Kingdom	Standard Occupational Classification (SOC), LOT

Country	Industry classification
United States	Standard Occupational Classification (SOC), O*NET, LOT

Unfortunately, most standard occupation classifications (the US SOC is the only exception) do not have any occupations that refer to only one of the categories of interest. Instead, such jobs are part of a bigger category that encompasses other jobs and were therefore not used for filtering. For example, when looking for solar jobs, the ISCO four-digit code 3131 refers to "Power production plant operators", which encompasses "Operator, solar power plant" but – among others – it also refers to "Operator, nuclear power plant". As a consequence, using this filter would result in extracting more jobs than the desired ones. The table below highlights the taxonomies used to extract wind- and solar-related positions by country and technology.

Occupational codes by taxonomy, technology and country used to filter online job postings

Category	Occupational classification	Countries	Code	Name
Wind	O*NET	Canada, United States	11-9199.09	Wind Energy Operations Managers
Wind	O*NET	Canada, United States	11-9199.10	Wind Energy Development Managers
Wind	O*NET	Canada, United States	17-2199.10	Wind Energy Engineers
Wind	O*NET	Canada, United States	49-9081.00	Wind Turbine Service Technicians
Wind	SOC	United States	49-9081	Wind Turbine Service Technicians
Wind	LOT	Australia, Canada, New Zealand, Singapore, United Kingdom, United States	49-9081.00	Wind Turbine Technician

Category	Occupational classification	Countries	Code	Name
Solar	O*NET	Canada, United States	17-2199.11	Solar Energy Systems Engineers
Solar	O*NET	Canada, United States	41-4011.07	Solar Sales Representatives and Assessors
Solar	O*NET	Canada, United States	47-1011.03	Solar Energy Installation Managers
Solar	O*NET	Canada, United States	47-2231.00	Solar Photovoltaic Installers
Solar	O*NET	Canada, United States	47-4099.02	Solar Thermal Installers and Technicians (old code)
Solar	O*NET	Canada, United States	47-2152.04	Solar Thermal Installers and Technicians
Solar	SOC (2018)	United States	47-2231	Solar Photovoltaic Installer
Solar	LOT	Australia, Canada, New Zealand, Singapore, United Kingdom, United States	17-2199.11	Solar Engineer
Solar	LOT	Australia, Canada, New Zealand, Singapore, United Kingdom, United States	41-4011.07	Solar Sales Representative
Solar	LOT	Australia, Canada, New Zealand, Singapore, United Kingdom, United States	47-2231.00	Solar Installer

As for the text filter, job titles were scraped in the original language for all countries except Australia, Canada, New Zealand, Singapore, the United Kingdom and the United States, so the filter applied is in the country's language(s). Some keywords were identified for each technology and used to include or exclude data. The table below contains the English keywords, which were also translated to the languages used in the countries analysed.

English keywords by technology

Technology	Filter type	Keyword
Battery and electric vehicle	Include	battery engineer (or engineer battery)
Battery and electric vehicle	Include	charging infrastructure engineer
Battery and electric vehicle	Include	electric powertrain
Battery and electric vehicle	Include	e-mobility
Battery and electric vehicle	Include	electric (commercial) vehicle
Battery and electric vehicle	Include	electrical vehicle
Energy efficiency	Include	energy efficiency
Heat pumps	Include	heat pump
Smart grid	Include	smart grid
Smart grid	Include	smart metering
Solar	Include	solar
Solar	Include	photovoltaic
Wind	Include	wind

In addition to filters used to include jobs in the extraction, especially for wind and solar postings, it was necessary to exclude jobs that contained the selected keyword but did not belong to the concerned category. This process was partly manual and partly automated, by identifying occupations or sectors not related to the jobs in question. As an example, some jobs extracted using the word "wind" referred to wind ensemble were removed, similar to many jobs for retirement homes, whose names often contain the word "solar". This procedure was

performed for every language used, since some of these cases were language-/country-specific. As another example, “wind” was also contained in many telecommunication jobs in Italy since it is the name of one of the main telco companies and is contained in the name of a few towns in Germany.

Example of jobs that were removed when they contained certain keywords by technology, English language

Technology	Filter type	Keyword
Solar	Exclude	resort
Solar	Exclude	nanny
Wind	Exclude	wind ensemble
Wind	Exclude	veterinarian
Battery and electric vehicle	Exclude	electric vehicle driver

Power utilities

To identify power utilities jobs in Europe, Canada, Australia, New Zealand, the United Kingdom and the United States, the industry classification was used as a filter, as detailed in the table below.

Industry codes by taxonomy and country used to filter online job postings

Industry classification	Countries	Code	Name
NAICS (2-digit)	Canada, United States	22	Utilities
NAICS (4-digits, where available)	Canada, United States	2211	Electric Power Generation, Transmission and Distribution companies
ANZSIC	Australia, New Zealand	26	Electricity supply
NACE Rev. 2/SIC	Europe, United Kingdom	35 or Section D	Electricity, gas, steam and air conditioning supply

Industry classification	Countries	Code	Name
NACE Rev. 2/SIC (Group, where available)	Europe, United Kingdom	35.1	Electric power generation, transmission and distribution

Notes: NAICS stands for North American Industry Classification System, ANZIC stands for Australia and New Zealand Standard Industrial Classification, and NACE stands for Statistical classification of economic activities. More details in the upcoming 'Industry classification' section.

The industry codes above were used individually or in combination with others in queries, depending on the columns of each dataset. Specifically for United States data and considering four-digit NAICS coverage was substantially lower than two-digit NAICS coverage, an ad hoc methodology was developed in order to filter out gas-only and water-only utilities, using keywords and company names.

In addition to the above, the comparison with other industry done for the United States in the sections "Digital jobs in power utilities" and "Cybersecurity jobs in power utilities" uses some other NAICS (two-digit) industry codes, namely 52 for *Finance and Insurance*; 92 for *Public Administration*; 54 for *Professional, Scientific, and Technical Services*; 56 for *Administrative and Support and Waste Management and Remediation Services*; 61 for *Educational Services*.

Digital and cybersecurity job postings

Digital and cybersecurity job postings were identified using the occupational classification available, as detailed in the table below.

Occupational codes by taxonomy, and country used to filter digital and cybersecurity online job postings

Category	Occupational classification	Countries	Code
Digital jobs	LOT/O*NET	Canada, Australia, New Zealand, United Kingdom, United States	All codes starting with 15-11
Cybersecurity jobs	LOT/O*NET	Canada, Australia, New Zealand, United Kingdom, United States	15-1122.00 (old)

Category	Occupational classification	Countries	Code
Cybersecurity jobs	O*NET	Canada, Australia, New Zealand, United Kingdom, United States	15-1212.10
Digital jobs	ISCO-08/ ESCO (2-digit)	Europe	25
Digital jobs	ISCO-08/ ESCO (4-digit)	Europe	3512
Digital jobs	ISCO-08/ ESCO (4-digit)	Europe	3513
Digital jobs	ISCO-08/ ESCO (4-digit)	Europe	3514
Digital jobs	SOC	United Kingdom	213

Industry classification

A custom industry classification was created to allow comparison across countries. The table below reports the taxonomies available by country.

Industry classifications available by country

Country	Industry classification
Australia, New Zealand	Australia and New Zealand Standard Industrial Classification (ANZSIC)
Canada, Chile, Colombia, Mexico, United States	North American Industry Classification System (NAICS)
Europe	Statistical classification of economic activities (NACE)
Singapore	Singapore Standard Industrial Classification (SSIC)
United Kingdom	Standard Industrial Classification of economic activities (SIC)

The custom classification is done at the most generic level available on the dataset for each one of these classifications, as detailed in the following tables.

Map between ANZSIC and the custom industry classification used in the report

ANZSIC code	ANZSIC title	Custom name
01	Agriculture	Agriculture, Forestry and Fishing
02	Aquaculture	Agriculture, Forestry and Fishing
03	Forestry and Logging	Agriculture, Forestry and Fishing
04	Fishing, Hunting and Trapping	Agriculture, Forestry and Fishing
05	Agriculture, Forestry and Fishing Support Services	Agriculture, Forestry and Fishing
06	Coal Mining	Mining and Quarrying
07	Oil and Gas Extraction	Mining and Quarrying
08	Metal Ore Mining	Mining and Quarrying
09	Non-Metallic Mineral Mining and Quarrying	Mining and Quarrying
10	Exploration and Other Mining Support Services	Mining and Quarrying
11	Food Product Manufacturing	Manufacturing
12	Beverage and Tobacco Product Manufacturing	Manufacturing
13	Textile, Leather, Clothing and Footwear Manufacturing	Manufacturing
14	Wood Product Manufacturing	Manufacturing
15	Pulp, Paper and Converted Paper Product Manufacturing	Manufacturing
16	Printing (including the Reproduction of Recorded Media)	Manufacturing
17	Petroleum and Coal Product Manufacturing	Manufacturing
18	Basic Chemical and Chemical Product Manufacturing	Manufacturing

ANZSIC code	ANZSIC title	Custom name
19	Polymer Product and Rubber Product Manufacturing	Manufacturing
20	Non-Metallic Mineral Product Manufacturing	Manufacturing
21	Primary Metal and Metal Product Manufacturing	Manufacturing
22	Fabricated Metal Product Manufacturing	Manufacturing
23	Transport Equipment Manufacturing	Manufacturing
24	Machinery and Equipment Manufacturing	Manufacturing
25	Furniture and Other Manufacturing	Manufacturing
26	Electricity Supply	Utilities
27	Gas Supply	Utilities
28	Water Supply, Sewerage and Drainage Services	Utilities
29	Waste Collection, Treatment and Disposal Services	Utilities
30	Building Construction	Construction
31	Heavy and Civil Engineering Construction	Construction
32	Construction Services	Construction
33	Basic Material Wholesaling	Wholesale and Retail Trade
34	Machinery and Equipment Wholesaling	Wholesale and Retail Trade
35	Motor Vehicle and Motor Vehicle Parts Wholesaling	Wholesale and Retail Trade
36	Grocery, Liquor and Tobacco Product Wholesaling	Wholesale and Retail Trade
37	Other Goods Wholesaling	Wholesale and Retail Trade
38	Commission-Based Wholesaling	Wholesale and Retail Trade

ANZSIC code	ANZSIC title	Custom name
39	Motor Vehicle and Motor Vehicle Parts Retailing	Wholesale and Retail Trade
40	Fuel Retailing	Wholesale and Retail Trade
41	Food Retailing	Wholesale and Retail Trade
42	Other Store-Based Retailing	Wholesale and Retail Trade
43	Non-Store Retailing and Retail Commission Based Buying and/or Selling	Wholesale and Retail Trade
44	Accommodation	Accommodation and Food Service Activities
45	Food and Beverage Services	Accommodation and Food Service Activities
46	Road Transport	Transportation and Storage
47	Rail Transport	Transportation and Storage
48	Water Transport	Transportation and Storage
49	Air and Space Transport	Transportation and Storage
50	Other Transport	Transportation and Storage
51	Postal and Courier Pick-up and Delivery Services	Transportation and Storage
52	Transport Support Services	Transportation and Storage
53	Warehousing and Storage Services	Transportation and Storage
54	Publishing (except Internet and Music Publishing)	Information and Communications
55	Motion Picture and Sound Recording Activities	Information and Communications
56	Broadcasting (except Internet)	Information and Communications
57	Internet Publishing and Broadcasting	Information and Communications
58	Telecommunications Services	Information and Communications

ANZSIC code	ANZSIC title	Custom name
59	Internet Service Providers, Web Search Portals and Data Processing Services	Information and Communications
60	Library and Other Information Services	Information and Communications
62	Finance	Financial and Insurance Activities
63	Insurance and Superannuation Funds	Financial and Insurance Activities
64	Auxiliary Finance and Insurance Services	Financial and Insurance Activities
66	Rental and Hiring Services (except Real Estate)	Real Estate Activities
67	Property Operators and Real Estate Services	Real Estate Activities
69	Professional, Scientific and Technical Services (except Computer System Design and Related Services)	Professional, Scientific and Technical Activities
70	Computer System Design and Related Services	Professional, Scientific and Technical Activities
72	Administrative Services	Administrative and Support Service Activities
73	Building Cleaning, Pest Control and Other Support Services	Administrative and Support Service Activities
75	Public Administration	Public Administration and Defence
76	Defence	Public Administration and Defence
77	Public Order, Safety and Regulatory Services	Public Administration and Defence
80	Preschool and School Education	Education
81	Tertiary Education	Education
82	Adult, Community and Other Education	Education

ANZSIC code	ANZSIC title	Custom name
84	Hospitals	Human Health and Social Work Activities
85	Medical and Other Health Care Services	Human Health and Social Work Activities
86	Residential Care Services	Human Health and Social Work Activities
87	Social Assistance Services	Human Health and Social Work Activities
89	Heritage Activities	Arts, Entertainment and Recreation
90	Creative and Performing Arts Activities	Arts, Entertainment and Recreation
91	Sports and Recreation Activities	Arts, Entertainment and Recreation
92	Gambling Activities	Arts, Entertainment and Recreation
94	Repair and Maintenance	Other Service Activities
95	Personal and Other Services	Other Service Activities

Map between NAICS and the custom industry classification used in the report

NAICS code	NAICS title	Custom name
11	Agriculture, Forestry, Fishing and Hunting	Agriculture, Forestry and Fishing
21	Mining, Quarrying, and Oil and Gas Extraction	Mining and Quarrying
22	Utilities	Utilities
23	Construction	Construction
31-33	Manufacturing	Manufacturing
42	Wholesale Trade	Wholesale and Retail Trade
44-45	Retail Trade	Wholesale and Retail Trade
48-49	Transportation and Warehousing	Transportation and Storage

NAICS code	NAICS title	Custom name
51	Information	Information and Communications
52	Finance and Insurance	Financial and Insurance Activities
53	Real Estate and Rental and Leasing	Real Estate Activities
54	Professional, Scientific and Technical Services	Professional, Scientific and Technical Activities
55	Management of Companies and Enterprises	Financial and Insurance Activities
56	Administrative and Support and Waste Management and Remediation Services	Administrative and Support Service Activities
61	Educational Services	Education
62	Health Care and Social Assistance	Human Health and Social Work Activities
71	Arts, Entertainment and Recreation	Arts, Entertainment and Recreation
72	Accommodation and Food Services	Accommodation and Food Service Activities
81	Other Services (except Public Administration)	Other Service Activities
92	Public Administration	Public Administration and Defence

Map between NACE and the custom industry classification used in the report

NACE code	NACE title	Custom name
A	Agriculture, Forestry and Fishing	Agriculture, Forestry and Fishing
B	Mining and Quarrying	Mining and Quarrying
C	Manufacturing	Manufacturing

NACE code	NACE title	Custom name
D	Electricity, Gas, Steam and Air Conditioning Supply	Utilities
E	Water Supply; Sewerage, Waste Management and Remediation Activities	Utilities
F	Construction	Construction
G	Wholesale and Retail Trade	Wholesale and Retail Trade
H	Transportation and Storage	Transportation and Storage
I	Accommodation and Food Service Activities	Accommodation and Food Service Activities
J	Publishing, Broadcasting, and Content Production and Distribution Activities	Information and Communications
K	Financial and Insurance Activities	Financial and Insurance Activities
L	Real Estate Activities	Real Estate Activities
M	Professional, Scientific and Technical Activities	Professional, Scientific and Technical Activities
N	Administrative and Support Service Activities	Administrative and Support Service Activities
O	Public Administration and Defence; Compulsory Social Security	Public Administration and Defence
P	Education	Education
Q	Human Health and Social Work Activities	Human Health and Social Work Activities
R	Arts, Sports and Recreation	Arts, Entertainment and Recreation
S	Other Service Activities	Other Service Activities
T	Activities Of Households as Employers and Undifferentiated Goods- and Services-Producing Activities of Households for Own Use	Activities of Households as Employers of Domestic Personnel

NACE code	NACE title	Custom name
U	Activities of Extraterritorial Organisations and Bodies	Activities of Extraterritorial Organisations and Bodies

Map between SSIC and the custom industry classification used in the report

SSIC code	SSIC title	Custom name
A	Agriculture and Fishing	Agriculture, Forestry and Fishing
B	Mining and Quarrying	Mining and Quarrying
C	Manufacturing	Manufacturing
D	Electricity, Gas, Steam and Air-Conditioning Supply	Utilities
E	Water Supply; Sewerage, Waste Management and Remediation Activities	Utilities
F	Construction	Construction
G	Wholesale and Retail Trade	Wholesale and Retail Trade
H	Transportation and Storage	Transportation and Storage
I	Accommodation and Food Service Activities	Accommodation and Food Service Activities
J	Information and Communications	Information and Communications
K	Financial and Insurance Activities	Financial and Insurance Activities
L	Real Estate Activities	Real Estate Activities
M	Professional, Scientific and Technical Activities	Professional, Scientific and Technical Activities
N	Administrative and Support Service Activities	Administrative and Support Service Activities
O	Public Administration and Defence	Public Administration and Defence
P	Education	Education

SSIC code	SSIC title	Custom name
Q	Health and Social Services	Human Health and Social Work Activities
R	Arts, Entertainment and Recreation	Arts, Entertainment and Recreation
S	Other Service Activities	Other Service Activities
T	Activities of Households as Employers of Domestic Personnel	Activities of Households as Employers of Domestic Personnel
U	Activities of Extra-Territorial Organisations and Bodies	Activities of extraterritorial organisations and bodies

Map between SIC and the custom industry classification used in the report

SIC code	SIC title	Custom name
01	Crop and animal production, hunting and related service activities	Agriculture, Forestry and Fishing
02	Forestry and logging	Agriculture, Forestry and Fishing
03	Fishing and aquaculture	Agriculture, Forestry and Fishing
05	Mining of coal and lignite	Mining and Quarrying
06	Extraction of crude petroleum and natural gas	Mining and Quarrying
07	Mining of metal ores	Mining and Quarrying
08	Other mining and quarrying	Mining and Quarrying
09	Mining support service activities	Mining and Quarrying
10	Manufacture of food products	Manufacturing
11	Manufacture of beverages	Manufacturing
12	Manufacture of tobacco products	Manufacturing
13	Manufacture of textiles	Manufacturing
14	Manufacture of wearing apparel	Manufacturing

SIC code	SIC title	Custom name
15	Manufacture of leather and related products	Manufacturing
16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Manufacturing
17	Manufacture of paper and paper products	Manufacturing
18	Printing and reproduction of recorded media	Manufacturing
19	Manufacture of coke and refined petroleum products	Manufacturing
20	Manufacture of chemicals and chemical products	Manufacturing
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	Manufacturing
22	Manufacture of rubber and plastic products	Manufacturing
23	Manufacture of other non-metallic mineral products	Manufacturing
24	Manufacture of basic metals	Manufacturing
25	Manufacture of fabricated metal products, except machinery and equipment	Manufacturing
26	Manufacture of computer, electronic and optical products	Manufacturing
27	Manufacture of electrical equipment	Manufacturing
28	Manufacture of machinery and equipment not elsewhere classified	Manufacturing
29	Manufacture of motor vehicles, trailers and semi-trailers	Manufacturing

SIC code	SIC title	Custom name
30	Manufacture of other transport equipment	Manufacturing
31	Manufacture of furniture	Manufacturing
32	Other manufacturing	Manufacturing
33	Repair and installation of machinery and equipment	Manufacturing
35	Electricity, gas, steam and air conditioning supply	Utilities
36	Water collection, treatment and supply	Utilities
37	Sewerage	Utilities
38	Waste collection, treatment and disposal activities; materials recovery	Utilities
39	Remediation activities and other waste management services	Utilities
41	Construction of buildings	Construction
42	Civil engineering	Construction
43	Specialised construction activities	Construction
45	Wholesale and retail trade and repair of motor vehicles and motorcycles	Wholesale and Retail Trade
46	Wholesale trade, except of motor vehicles and motorcycles	Wholesale and Retail Trade
47	Retail trade, except of motor vehicles and motorcycles	Wholesale and Retail Trade
49	Land transport and transport via pipelines	Transportation and Storage
50	Water transport	Transportation and Storage
51	Air transport	Transportation and Storage
52	Warehousing and support activities for transportation	Transportation and Storage
53	Postal and courier activities	Transportation and Storage

SIC code	SIC title	Custom name
55	Accommodation	Accommodation and Food Service Activities
56	Food and beverage service activities	Accommodation and Food Service Activities
58	Publishing activities	Information and Communications
59	Motion picture, video and television programme production, sound recording and music publishing activities	Information and Communications
60	Programming and broadcasting activities	Information and Communications
61	Telecommunications	Information and Communications
62	Computer programming, consultancy and related activities	Information and Communications
63	Information service activities	Information and Communications
64	Financial service activities, except insurance and pension funding	Financial and Insurance Activities
65	Insurance, reinsurance and pension funding, except compulsory social security	Financial and Insurance Activities
66	Activities auxiliary to financial services and insurance activities	Financial and Insurance Activities
68	Real estate activities	Real Estate Activities
69	Legal and accounting activities	Professional, Scientific and Technical Activities
70	Activities of head offices; management consultancy activities	Professional, Scientific and Technical Activities
71	Architectural and engineering activities; technical testing and analysis	Professional, Scientific and Technical Activities

SIC code	SIC title	Custom name
72	Scientific research and development	Professional, Scientific and Technical Activities
73	Advertising and market research	Professional, Scientific and Technical Activities
74	Other professional, scientific and technical activities	Professional, Scientific and Technical Activities
75	Veterinary activities	Professional, Scientific and Technical Activities
77	Rental and leasing activities	Administrative and Support Service Activities
78	Employment activities	Administrative and Support Service Activities
79	Travel agency, tour operator and other reservation service and related activities	Administrative and Support Service Activities
80	Security and investigation activities	Administrative and Support Service Activities
81	Services to buildings and landscape activities	Administrative and Support Service Activities
82	Office administrative, office support and other business support activities	Administrative and Support Service Activities
84	Public administration and defence; compulsory social security	Public Administration and Defence
85	Education	Education
86	Human health activities	Human Health and Social Work Activities
87	Residential care activities	Human Health and Social Work Activities
88	Social work activities without accommodation	Human Health and Social Work Activities
90	Creative, arts and entertainment activities	Arts, Entertainment and Recreation
91	Libraries, archives, museums and other cultural activities	Arts, Entertainment and Recreation

SIC code	SIC title	Custom name
92	Gambling and betting activities	Arts, Entertainment and Recreation
93	Sports activities and amusement and recreation activities	Arts, Entertainment and Recreation
94	Activities of membership organisations	Other Service Activities
95	Repair of computers and personal and household goods	Other Service Activities
96	Other personal service activities	Other Service Activities
97	Activities of households as employers of domestic personnel	Activities of Households as Employers of Domestic Personnel
98	Undifferentiated goods- and services-producing activities of private households for own use	Activities of Households as Employers of Domestic Personnel
99	Activities of extraterritorial organisations and bodies	Activities of extraterritorial organisations and bodies

Occupation classification

As already mentioned in the “Filtering process” section, the available occupation taxonomies are not the same for all countries analysed, hence the need to come up with a custom classification for comparison. The custom occupation classification was created at the higher possible level available, except for some cases where more granularity was required in order to split some categories into two or more. The occupational titles used in the report are detailed in the table below, together with a few examples.

Custom occupational classification used in the report and some examples

Custom title	Examples
Managers	Solar Project Managers, Solar Farm Operations Managers, Offshore Wind Site Managers, Energy Efficiency Managers, Heat Pump Installation Managers, Smart Grid Program Managers, Battery Manufacturing Operations Managers, EV Charging Infrastructure Managers

Custom title	Examples
Professionals	Solar Engineers, Photovoltaic (PV) Design Specialists, Wind Turbine Design Engineers, Wind Resource Analysts, Energy Efficiency Auditors, Heat Pump Engineers, Data Scientists for Smart Grids, Battery Chemists, EV Powertrain Specialists
Technician, Associate Professionals and Skilled Trades Workers	PV Installation Technicians, Solar Panel Maintenance Technicians, Wind Turbine Technicians, Wind Farm Maintenance Workers, Energy Efficiency Analyst, Heat Pump Installers, Smart Meter Installers, Battery Assembly Technicians, Battery Recycling Technicians, EV Charging Station Technicians, Electric Vehicle Maintenance Technicians
Community, Leisure and Personal Service Workers	Community Solar Advocates, Renewable Energy Outreach Coordinators, Community Engagement Specialists for Wind Projects, Energy Efficiency Educators, Home Energy Advisers, Residential Heat Pumps Advisers, Community Liaison Officers for Smart Grid Projects, Energy Storage Educators for Local Communities, EV Usage Trainers
Clerical and Administrative Workers	Solar Project Coordinators, Permit Administrators for Solar Projects, Wind Farm Administrative Assistants, Energy Efficiency Accountants and Bookkeeping Clerks, Scheduling Coordinators for Heat Pump Installations, Administrative Assistants for Grid Modernisation Projects, EV Sales Support Specialists, Charging Network Coordinators
Service and Sales Workers	Solar Sales Consultants, Customer Support Representatives for Solar Systems, Wind Power Sales Representatives, Energy Efficiency Sales Representatives, Heat Pump Sales Representatives, Heat Pump Marketing Specialists, Smart Home Technology Sales Representatives, Energy Storage Customer Support Specialists, Charging Network Customer Service Reps

Custom title	Examples
Process, Plant, Machine Operators, Assemblers and Drivers	Solar Panel Manufacturing Machine Operators, Wind Turbine Assembly Workers, Offshore Transport Vessel Operators, Energy Efficiency Construction Labourers, Heat Pump Component Assembly Line Workers, Smart Meter Assembly Workers, Lithium-ion Battery Manufacturing Technicians, EV Assembly Line Workers
Labourers	Solar Panel Installers' Assistants, Construction Labourers for Solar Farms, Wind Turbine Construction Workers, Heat Pump Transport Workers, Cable Installation Labourers, Charging Station Construction Labourers, EV Factory Cleaners

The tables below contain the detail on how the existing occupations were mapped to the custom one.

Map between ANZSCO and the custom occupational classification used in the report

ANZSCO code	ANZSCO title	Custom title
1	Managers	Managers
2	Professionals	Professionals
3	Technicians and Trades Workers	Technician, Associate Professionals and Skilled Trades Workers
4	Community and Personal Service Workers	Community, Leisure and Personal Service Workers
5	Clerical and Administrative Workers	Clerical and Administrative Workers
6	Sales Workers	Service and Sales Workers
7	Machinery Operators and Drivers	Process, Plant, Machine Operators, Assemblers and Drivers
8	Labourers	Labourers

Map between NOC and the custom occupational classification used in the report

NOC code	Broad occupational title	Major group title	Custom title
0	Management occupations		Managers
11	Business, finance and administration occupations	Professional occupations in business and finance	Professionals
12	Business, finance and administration occupations	Administrative and financial supervisors and administrative occupations	Clerical and Administrative Workers
13	Business, finance and administration occupations	Finance, insurance and related business administrative occupations	Clerical and Administrative Workers
14	Business, finance and administration occupations	Office support occupations	Clerical and Administrative Workers
15	Business, finance and administration occupations	Distribution, tracking and scheduling coordination occupations	Clerical and Administrative Workers
21	Natural and applied sciences and related occupations	Professional occupations in natural and applied sciences	Professionals
22	Natural and applied sciences and related occupations	Technical occupations related to natural and applied sciences	Technician, Associate Professionals and Skilled Trades Workers
30	Health occupations	Professional occupations in nursing	Professionals

NOC code	Broad occupational title	Major group title	Custom title
31	Health occupations	Professional occupations in health (except nursing)	Professionals
32	Health occupations	Technical occupations in health	Technician, Associate Professionals and Skilled Trades Workers
34	Health occupations	Assisting occupations in support of health services	Labourers
40	Occupations in education, law and social, community and government services	Professional occupations in education services	Professionals
41	Occupations in education, law and social, community and government services	Professional occupations in law and social, community and government services	Professionals
42	Occupations in education, law and social, community and government services	Paraprofessional occupations in legal, social, community and education services	Community, Leisure and Personal Service Workers
43	Occupations in education, law and social, community and government services	Occupations in front-line public protection services	Community, Leisure and Personal Service Workers
44	Occupations in education, law and social, community and government services	Care providers and educational, legal and public protection support occupations	Community, Leisure and Personal Service Workers

NOC code	Broad occupational title	Major group title	Custom title
51	Occupations in art, culture, recreation and sport	Professional occupations in art and culture	Professionals
52	Occupations in art, culture, recreation and sport	Technical occupations in art, culture, recreation and sport	Technician, Associate Professionals and Skilled Trades Workers
6	Sales and service occupations		Service and Sales Workers
72	Trades, transport and equipment operators and related occupations	Industrial, electrical and construction trades	Technician, Associate Professionals and Skilled Trades Workers
73	Trades, transport and equipment operators and related occupations	Maintenance and equipment operation trades	Technician, Associate Professionals and Skilled Trades Workers
74	Trades, transport and equipment operators and related occupations	Other installers, repairers and servicers and material handlers	Technician, Associate Professionals and Skilled Trades Workers
75	Trades, transport and equipment operators and related occupations	Transport and heavy equipment operation and related maintenance occupations	Process, Plant, Machine Operators, Assemblers and Drivers
76	Trades, transport and equipment operators and related occupations	Trades helpers, construction labourers and related occupations	Technician, Associate Professionals and Skilled Trades Workers
82	Natural and applied sciences and related occupations	Supervisors and technical occupations in natural resources, agriculture and related production	Technician, Associate Professionals and Skilled Trades Workers

NOC code	Broad occupational title	Major group title	Custom title
84	Natural resources, agriculture and related production occupations	Workers in natural resources, agriculture and related production	Labourers
86	Natural resources, agriculture and related production occupations	Harvesting, landscaping and natural resources labourers	Technician, Associate Professionals and Skilled Trades Workers
9	Occupations in manufacturing and utilities		Process, Plant, Machine Operators, Assemblers and Drivers

Map between ISCO and the custom occupational classification used in the report

ISCO code	ISCO title	Custom title
0	Armed Forces Occupations	Workers Not Elsewhere Classified
1	Managers	Managers
2	Professionals	Professionals
3	Technicians and Associate Professionals	Technician, Associate Professionals and Skilled Trades Workers
4	Clerical Support Workers	Clerical and Administrative Workers
5	Services and Sales Workers	Service and Sales Workers
6	Skilled Agricultural, Forestry and Fishery Workers	Technician, Associate Professionals and Skilled Trades Workers
7	Craft and Related Trades Workers	Technician, Associate Professionals and Skilled Trades Workers
8	Plant and Machine Operators and Assemblers	Process, Plant, Machine Operators, Assemblers and Drivers
9	Elementary Occupations	Labourers

Map between ESCO and the custom occupational classification used in the report

ESCO code	ESCO title	Custom title
1	Managers	Managers
2	Professionals	Professionals
3	Technicians and associate professionals	Technician, Associate Professionals and Skilled Trades Workers
4	Clerical support workers	Clerical and Administrative Workers
5	Service and sales workers	Service and Sales Workers
6	Skilled agricultural, forestry and fishery workers	Technician, Associate Professionals and Skilled Trades Workers
7	Craft and related trades workers	Technician, Associate Professionals and Skilled Trades Workers
8	Plant and machine operators, and assemblers	Process, Plant, Machine Operators, Assemblers and Drivers
9	Elementary occupations	Labourers

Map between SSOC and the custom occupational classification used in the report

SSOC code	SSOC title	Custom title
1	Legislators, Senior Officials and Managers	Managers
2	Professionals	Professionals
3	Associate Professionals and Technicians	Technician, Associate Professionals and Skilled Trades Workers
4	Clerical Support Workers	Clerical and Administrative Workers
5	Service and Sales Workers	Service and Sales Workers

SSOC code	SSOC title	Custom title
6	Agricultural and Fishery Workers	Technician, Associate Professionals and Skilled Trades Workers
7	Craftsmen and Related Trades Workers	Technician, Associate Professionals and Skilled Trades Workers
8	Plant and Machine Operators and Assemblers	Process, Plant, Machine Operators, Assemblers and Drivers
9	Cleaners, Labourers and Related Workers	Labourers
X	Workers Not Elsewhere Classified	Workers Not Elsewhere Classified

Map between SOC (United Kingdom) and the custom occupational classification used in the report

SOC code (United Kingdom)	SOC title (United Kingdom)	Custom title
1	Managers, Directors and Senior Officials	Managers
2	Professional Occupations	Professionals
3	Associate Professional and Technical Occupations	Technician, Associate Professionals and Skilled Trades Workers
4	Administrative and Secretarial Occupations	Clerical and Administrative Workers
5	Skilled Trades Occupations	Technician, Associate Professionals and Skilled Trades Workers
6	Caring, Leisure and Other Service Occupations	Community, Leisure and Personal Service Workers
7	Sales and Customer Service Occupations	Service and Sales Workers

SOC code (United Kingdom)	SOC title (United Kingdom)	Custom title
8	Process, Plant and Machine Operatives	Process, Plant, Machine Operators, Assemblers and Drivers
9	Elementary Occupations	Labourers

Map between SOC (United States) and the custom occupational classification used in the report

SOC code (Major/Minor group)	Major group title	Minor group title	Custom title
11-	Management Occupations		Managers
13-	Business and Financial Operations Occupations		Professionals
15-	Computer and Mathematical Occupations		Technician, Associate Professionals and Skilled Trades Workers
17-2	Architecture and Engineering Occupations	Aerospace Engineers	Professionals
17-2	Architecture and Engineering Occupations	Agricultural Engineers	Professionals
17-2	Architecture and Engineering Occupations	Biomedical Engineers	Professionals
17-2	Architecture and Engineering Occupations	Chemical Engineers	Professionals
17-2	Architecture and Engineering Occupations	Civil Engineers	Professionals

SOC code (Major/Minor group)	Major group title	Minor group title	Custom title
17-2	Architecture and Engineering Occupations	Computer Hardware Engineers	Professionals
17-2	Architecture and Engineering Occupations	Electrical Engineers	Professionals
17-2	Architecture and Engineering Occupations	Electronics Engineers, Except Computer	Professionals
17-2	Architecture and Engineering Occupations	Environmental Engineers	Professionals
17-2	Architecture and Engineering Occupations	Health and Safety Engineers, Except Mining Safety Engineers and Inspectors	Professionals
17-2	Architecture and Engineering Occupations	Industrial Engineers	Professionals
17-2	Architecture and Engineering Occupations	Marine Engineers and Naval Architects	Professionals
17-2	Architecture and Engineering Occupations	Materials Engineers	Professionals
17-2	Architecture and Engineering Occupations	Mechanical Engineers	Professionals
17-2	Architecture and Engineering Occupations	Mining and Geological Engineers, Including Mining Safety Engineers	Professionals

SOC code (Major/Minor group)	Major group title	Minor group title	Custom title
17-2	Architecture and Engineering Occupations	Nuclear Engineers	Professionals
17-2	Architecture and Engineering Occupations	Petroleum Engineers	Professionals
17-2	Architecture and Engineering Occupations	Engineers, All Other	Professionals
17-3	Architecture and Engineering Occupations	Aerospace Engineering and Operations Technicians	Technician, Associate Professionals and Skilled Trades Workers
17-3	Architecture and Engineering Occupations	Civil Engineering Technicians	Technician, Associate Professionals and Skilled Trades Workers
17-3	Architecture and Engineering Occupations	Electrical and Electronics Engineering Technicians	Technician, Associate Professionals and Skilled Trades Workers
17-3	Architecture and Engineering Occupations	Environmental Engineering Technicians	Technician, Associate Professionals and Skilled Trades Workers
17-3	Architecture and Engineering Occupations	Industrial Engineering Technicians	Technician, Associate Professionals and Skilled Trades Workers
17-3	Architecture and Engineering Occupations	Mechanical Engineering Technicians	Technician, Associate Professionals and Skilled Trades Workers
17-3	Architecture and Engineering Occupations	Engineering Technicians, Except Drafters, All Other	Technician, Associate Professionals and Skilled Trades Workers
19-	Life, Physical and Social Science Occupations		Professionals

SOC code (Major/Minor group)	Major group title	Minor group title	Custom title
21-	Community and Social Service Occupations		Community, Leisure and Personal Service Workers
23-	Legal Occupations		Professionals
25-	Education, Training and Library Occupations		Community, Leisure and Personal Service Workers
27-	Arts, Design, Entertainment, Sports and Media Occupations		Technician, Associate Professionals and Skilled Trades Workers
29-	Healthcare Practitioners and Technical Occupations		Technician, Associate Professionals and Skilled Trades Workers
31-	Healthcare Support Occupations		Labourers
33-	Protective Service Occupations		Workers Not Elsewhere Classified
35-	Food Preparation and Serving Related Occupations		Labourers
37-	Building and Grounds Cleaning and Maintenance Occupations		Labourers
39-	Personal Care and Service Occupations		Community, Leisure and Personal Service Workers
41-	Sales and Related Occupations		Service and Sales Workers
43-	Office and Administrative Support Occupations		Clerical and Administrative Workers

SOC code (Major/Minor group)	Major group title	Minor group title	Custom title
45-	Farming, Fishing and Forestry Occupations		Technician, Associate Professionals and Skilled Trades Workers
47-	Construction and Extraction Occupations		Process, Plant, Machine Operators, Assemblers and Drivers
49-	Installation, Maintenance and Repair Occupations		Technician, Associate Professionals and Skilled Trades Workers
51-	Production Occupations		Technician, Associate Professionals and Skilled Trades Workers
53-	Transportation and Material Moving Occupations		Process, Plant, Machine Operators, Assemblers and Drivers
55-	Military Specific Occupations		Workers Not Elsewhere Classified

Geographical distribution of wind and solar jobs

This analysis examined job postings in the solar and wind energy sectors over the past five years, with a focus on spatial clustering in the United States and the United Kingdom, chosen due to the quality of available data.

The methodology involved a three-step clustering process, using different levels of administrative and spatial grouping to provide insights on the spatial distribution of online job postings.

1. Initial clustering by administrative division

- Job postings were first clustered by administrative boundaries at the county level in both the United States and the United Kingdom. This grouping allowed for an aggregation of job postings within each administrative unit and the calculation of centroids to represent the geographic centres of these clusters.

- The centroid of each cluster was determined by calculating the weighted average latitude and longitude based on OJP counts, creating a balanced geographic centre for each administrative division's job data.
- The output from this stage was used as an input for the next level of clustering, adding a spatial layer to the administrative insights obtained.

2. **Regional clustering using density-based spatial clustering of applications with noise (DBSCAN) by country-specific administrative levels**

- In this step, a spatial clustering technique, DBSCAN, was applied within broader administrative regions (admin level 1). A 100-kilometre radius was used to group job postings within each region while maintaining administrative boundaries.
- This stage included adjustments based on country-specific administrative levels, grouping by regions in the United States and counties in the United Kingdom, reflecting their unique geographical divisions.
- Weighted centroids were recalculated for each cluster at this level, based on the number of job postings, providing a refined spatial distribution within regional boundaries.
- The results from this stage fed into the final step, where clustering transcended administrative borders.

3. **Final clustering across entire dataset**

- In the last stage, DBSCAN clustering was applied across the entire dataset without regard to administrative boundaries, using a 25-kilometre radius to capture finer spatial relationships across regions.
- This clustering focused on purely spatial proximity, providing insights into job concentrations that might not align with formal administrative boundaries but instead reflect functional labour market areas.
- Centroids were again calculated using weighted averages based on job counts within each spatial cluster, with each cluster location representing the barycentre of job postings. This method ensured that clusters appeared closest to cities in proportion to each city's share of job postings within the cluster.

4. **Visualisation**

- The clusters were visualised on maps with bubble markers representing the clusters. Each bubble’s size is proportional to the number of job postings within the cluster over the last five years, enabling an intuitive visual representation of job concentration.
- The cities indicated on the maps serve as reference points for the general location of clusters. However, it is important to note that these clusters often

encompass multiple cities or urban areas, as they reflect job densities within the surrounding regions rather than a single urban centre.

- The cluster location is the barycentre of job post locations, meaning it is positioned relative to the density of job postings across nearby areas, and is not limited to the closest city but rather represents the combined influence of multiple urban centres.

List of acronyms and abbreviations

ANZSCO	Australia and New Zealand Standard Classification of Occupations
ANZSIC	Australia and New Zealand Standard Industrial Classification
CIP	Critical Infrastructure Protection
DBSCAN	Density-based spatial clustering of applications with noise
DDS	Data Development and Support
EDC	Energy Data Centre
ESCO	European Skills, Competences, Qualifications and Occupations
EV	Electric vehicle
HVAC	Heating, ventilation, and air-conditioning
ISCO	International Standard Classification of Occupations
ITC	Investment Tax Credit
LOT	Lightcast Occupation Taxonomy
NACE	Statistical classification of economic activities
NAICS	North American Industry Classification System
NERC	North American Electric Reliability Corporation
NOC	National Occupational Classification
OJP	Online job posting
PPP	Purchasing power parity
PV	Photovoltaic
R&D	Research and development
SOC	Standard Occupational Classification
SIC	Standard industrial classification of economic activities
SSIC	Singapore Standard Industrial Classification
SSOC	Singapore Standard Occupational Classification
BUS	Boiler Upgrade Scheme
CfD	Contracts for Difference
CREZ	Competitive Renewable Energy Zones
EBA	European Battery Alliance
ICS	Industrial Control Systems
IoT	Internet of Things
OHPA	Oil to Heat Pump Affordability
OT	Operational technology
VRE	Variable renewable energy

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