JRC SCIENCE FOR POLICY REPORT

Employment in the Energy Sector

Status Report 2020

Czako, V.

Joint Research Centre

EUR 30186 EN

Contact information
Name: Veronika Czako
Address: European Commission, Joint Research Centre, Westerduinweg 3, 1755 LE, Petten, the Netherlands
Email: veronika.czako@ec.europa.eu
Tel.: +31 (0) 224 56 5136

EU Science Hub
https://ec.europa.eu/jrc

JRC120302

EUR 30186 EN

PDF ISBN 978-92-76-18206-1 ISSN 1831-9424 doi:10.2760/95180

Luxembourg: Publications Office of the European Union, 2020

How to cite this report: Czako, V., *Employment in the Energy Sector Status Report 2020*, EUR 30186 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-18206-1, doi:10.2760/95180, JRC120302.

Contents

Abstract

The green economic and clean energy transition are already underway worldwide and in Europe. This report provides an overview of recent employment trends at the global and EU-28 level related to the greening and decarbonisation of the economy, with a focus on the energy sector. It brings together and presents statistical data and the results of recent employment assessment reports. In addition, the report examines qualitative aspects, including education as well as skills requirements and changing talent profiles in the green transition. It addresses workforce characteristics, including gender and generational aspects. The report concludes by highlighting key figures and providing policy recommendations to overcome labour force related barriers as part of a just transition to a cleaner energy system.

Acknowledgements

This report benefited from valuable discussions and comments provided by Bogdan Atanasiu, Frank Siebern-Thomas, Andreas Uihlein, Faidra Filippidou, Pablo Ruiz Castello, Juan Pablo Jimenez Navarro, Ingrida Murauskaite, Giorgos Koukoufikis and Aura Caramizaru and advice on communication aspects from Carine Nieuweling and Nicola Magnani. Special thanks are extended to Sara Andre for designing the front cover.

Author

Veronika CZAKO

Executive summary

The transition towards a green economy and a low-carbon energy system has profound employment implications worldwide and in Europe. This report provides an overview of employment trends at the global and EU level related to the greening and decarbonisation of the economy, keeping the energy sector in focus. It does so by gathering and presenting available statistical data and the results of recent reports assessing the employment effect of the green economic transition. However, due to the lack of a solid and coherent employment estimation methodology, results of these studies cannot be directly compared.

Policy context

The European Green Deal announced in December 2019 is the European Union's new growth strategy under the von der Leyen Commission. It aims to make Europe climate-neutral by 2050. Parallel to cutting greenhouse gas emissions, creating jobs and making the transition inclusive and just are key elements of the strategy. Accounting for the employment effects of the green economic transition is crucial in order to determine the progress against these goals. The outbreak of the COVID-19 coronavirus crisis in early 2020 puts this in new light, creating opportunity for an accelerated green transition parallel to economic and social recovery.

Key conclusions

Within the context of moving towards a greener economy a solid and coherent method to track employment impacts of the transition is lacking. This report aims to bring together information on employment impacts related to the green economic transition with a focus on energy. It must be kept in mind that figures presented from different sources are not directly comparable due to differences in estimation approaches.

The results of studies estimating employment impacts and initiatives carrying out regular monitoring of employment impacts of particular elements of the green transition suggest that it is delivering positive employment effects. 18 million net jobs can be created by 2030 worldwide by limiting global warming to 2°C by the end of the century (ILO, 2018). The presence of green components is already identifiable in the case of many occupations. Based on the task content of occupations, 87.6 million jobs were green(able) in the EU-28 by 2016, amounting to 40 % of employment that year (European Commission, 2019b).

Global employment in the energy sector reached nearly 58 million in 2017 (IRENA, 2020a). About half of these jobs were in the fossil fuel industries.

The renewable energies sector is an element of the green transition where systematic assessment of employment impacts has been ongoing in the last decade, both at the international and the EU level (however not with uniform methodologies, hindering comparison of results of the different initiatives). Renewable energy employment has been continuously increasing globally, reaching 11 million total jobs in 2018 (IRENA, 2019b). A third of global renewable energy source (RES) industry jobs were in the solar photovoltaic (PV) sector. China is the largest RES employer globally, accounting for 37 % of total RES jobs in the world. More than half of Chinese RES jobs are in the solar PV sector. Parallel to increasing deployment, PV manufacturing has also shifted to China and other Asian countries, while decreasing in Europe.

In the EU-28 the number of total jobs in renewable energy reached over 1.5 million in 2018 (EurObserv'ER, 2019). Direct RES jobs[1] have not increased significantly in the last decade. Underlying factors include the aftermath of the 2008 financial crisis, moving of some renewables manufacturing capacities outside of Europe, as well as the change in the subsidisation of renewables within the EU.

Solid biomass and wind are the largest European RES sectors, together accounting for nearly half of total EU RES jobs. Nearly a fifth of European RES jobs are in Germany. Here the leading renewables industry in terms of employment is by far the wind sector, followed by solar PV and solid biomass. At the same time, the leaders in renewables jobs per capita are less populous Member States, including Latvia, Estonia, Denmark and Finland.

On the energy demand side, similarly to RES, accounting for specifically energy efficiency intervention related employment impacts is hampered by difficulties in isolating the relevant activities within economic sectors as they are currently defined. A net positive employment effect of energy efficiency in the EU-28 until 2030 was estimated by different studies relying on different methodologies and assumptions to be in the range of 0.41 – 4.8 million.

[1] Eurostat [env_ac_egss1]

Skills mismatches inhibit the transition to a low-carbon energy system in Europe and beyond. The workforce in the energy industry, especially in conventional energy sectors is male dominated and is aging. Digital skills and graduates in Science, Technology, Engineering and Mathematics (STEM) fields are in high demand. Parallel to STEM profiles, soft skills including costumer awareness, problem solving, team working, self-management, and communication and literacy are key employability skills in the energy sector.

STEM education, especially Engineering and ICT studies are characterized by gender imbalance. This is an underlying factor of underrepresentation of women in the energy sector.

Private companies have initiated their own training programmes and acted in partnership with the public and education sectors in order to influence education and skills policy in the context of the clean energy transition.

Policy recommendations

Policymakers in the context of a just green transition should

- *develop and implement strategies in an integrated manner* in order to appropriately address complex impacts (e.g. climate, employment, social, education and skills, regional, digital, industrial strategies).
- *ensure the provision of coordinated social and professional reskilling/upskilling support in declining sectors and regions.* This is relevant both in case employees have to leave the active labour force, as well as in the process of entering other, including greening economic sectors.

The public and private sectors should take coordinated action, where appropriate in the form of public-private partnerships to

- *facilitate sub-sector, gender and age disaggregated data collection in the energy industry* in a comparable manner across the EU and globally, in order to better understand labour force characteristics and needs.
- *improve and adapt STEM education profiles* to market demand in the context of the expanding green economy.
- *improve visibility and wider perception, incentivise STEM education* both for men and women already from a young age.
- *increase the availability of apprenticeships, as well as up- and reskilling programmes* to ensure that enough job seekers with the required skill sets are available for the energy industry.

The private sector should take action to

- *better attract underrepresented workforce categories in the energy industry*. These include female and millennial job seekers. This is expected to increase the number of suitable candidates, provide better access to energy jobs for a more diverse population, as well as to help overcome the challenges posed by an aging energy workforce.
- *improve policies to retain knowledge* from workforce leaving the energy industry.

Related and future JRC work

In 2018 the JRC carried out an assessment of opportunities and challenges facing European coal regions in the context of the clean energy transition, estimating employment effects. This work continues and extends to cover other energy intensive sectors. Further research is foreseen on education and skills requirements and changing talent profiles in the context of the green economic and clean energy transition. Finally, to improve the assessment of distributional impacts of climate change policies, new approaches are to be developed in a new DG EMPL - JRC project.

Quick guide

The report is structured as follows: Chapter 1 provides a brief introduction to the policy context and conceptual background of assessing the employment impacts of the clean energy transition. Chapter 2 outlines key transformative trends affecting labour markets. Chapter 3 and Chapter 4 provide an overview of employment development in the green economy, in the energy supply sector, as well as within the renewable energy sector, at the global and EU level respectively, and energy efficiency at the EU level. Chapter 5 explores energy sub-sector specific employment trends at the global and EU level. Chapter 6 provides an overview of changing education and skills requirements in the context of the green economic transition. Chapter 7 provides information on the workforce characteristics of the energy sector, including gender and generational aspects. Chapter 8 concludes by highlighting key figures and providing policy recommendations to overcome labour force related barriers as part of a just transition to a cleaner energy system.

1 Introduction

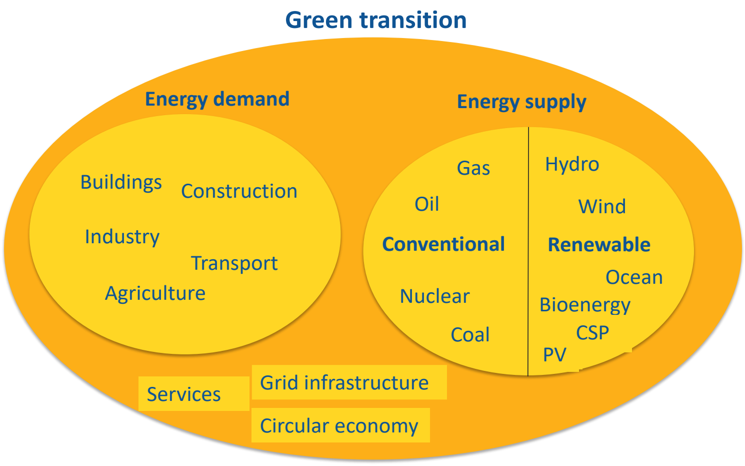
The clean energy and green economic transition is already underway in the EU and in the world. Besides technological and infrastructural aspects, they also have significant implications for employment.

In late 2018, the European Commission presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050, in accordance with the Paris Agreement on climate action (European Commission, 2018b). The EU is implementing its target to reduce GHG emissions by at least 40 % by 2030, integrating the employment and social dimension from the outset. Taking a step further, in December 2019 the European Green Deal was presented by the incoming European Commission (European Commission, 2019d). It is an ambitious package of measures aiming to further ensure a socially just green transition in Europe. It also includes the intention to potentially raise the EU GHG emission reduction target to 50-55 % by 2030. The green transition is also under way in other world regions, especially in Asia and the Americas renewable energy generation is rapidly expanding.

The outbreak of the COVID-19 coronavirus pandemic in early 2020 and the resulting socio-economic crisis puts recent progress of the green transition in a new light. On the one hand the immediate need to revive economic growth and employment may be at odds with the requirements of climate action. At the same time the COVID-19 crisis also presents a historic opportunity to create jobs in clean technologies, as part of longer-term investment plans.

The green transition and resulting employment impacts can be understood broadly, or more narrowly focusing on elements thereof. An early assessment of green employment conducted by the United Nations Environment Programme covered the renewable energy, building and construction, transportation, basic industry, agriculture and forestry sectors (UNEP, 2008). More recently the International Labour Organization (ILO) assessed the employment aspects of a just transition to a green economy, covering the energy and agriculture sectors, as well as the circular economy (ILO, 2018). In its global energy sector employment estimates the International Renewable Energy Agency (IRENA) includes wholly or partly energy demand side activities, including energy efficiency, energy flexibility and grid infrastructure, besides purely energy supply sectors (IRENA, 2019c). Energy efficiency has significant employment effects, mainly in the construction industry. Figure 1 provides an overview of concepts relevant for the discussion of employment aspects in the green transition.

Figure 1 Green transition – conceptual overview



JRC, 2020

Most recurring employment assessments in the broader context of the green transition focus on energy supply[2]. Conventional energy and renewable energy technologies comprise the two main segments of the energy supply sector. Conventional energy technologies, including oil and gas, coal and nuclear have been mature industries and major employers for decades. The spread of renewable energy industries is however more recent and only started to generate significant and increasing employment effects in the last decade.

[2] See Annex 2 for more details.

The renewable energy sector consists of several sub-sectors, including solar photovoltaics, wind energy, hydropower, liquid biofuels, solid biomass, biogas, solar heating and cooling, concentrated solar power, ocean energies, geothermal energy, heat pumps and municipal and industrial waste. Some of these renewables, such as solar PV, wind and bioenergy are already mature industries and significant employers both globally and in the EU. Others, such as geothermal energy and ocean energies still have limited employment impact.

On the demand side of the energy system the buildings sector has substantial energy saving potential and consequently the construction industry energy efficient employment creation potential. Appliances manufacturers have also been focusing on producing energy and resource efficient equipment. At the same time, similarly to RES, accounting for specifically energy efficiency intervention related employment impacts is hampered by difficulties in isolating the relevant activities within economic sectors according to currently used statistical classifications. For RES, systematic assessment of employment impacts has been ongoing in the last decade, both at the international and the EU level, with updates published on an annual basis. For energy efficiency, similar systematic assessment initiatives are missing.

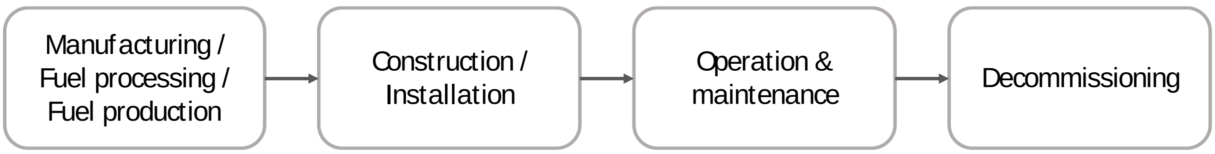
The assessment of the historical development and the estimation of future employment effects of the global energy industry is challenging. Quantitative data on present employment based on actual surveys is difficult to obtain, especially with global coverage. Statistical data collection is limited mainly due to cost considerations. There is no single body conducting job surveys covering all energy sub-sectors and geographical regions to collect and update statistical data on a regular basis. Therefore employment estimation methodologies cannot be calibrated against time series data (Rutovitz et al., 2015).

Furthermore, renewable energy technologies constitute a relatively new and cross-cutting field, encompassing several economic sub-sectors. Renewables are not singled out as a separate sector in national economic, trade or labour statistics. This leads to data gaps for certain countries and for certain technologies.

Renewables may create more jobs than conventional, mostly fossil-based power production due to their larger labour intensity. However, there is no obvious one-to-one relationship between RES expansion and the net change in energy supply jobs. Net employment effects of switching from fossil fuels to low-carbon energy technologies depend on factors including the mix of technologies deployed, the domestic content of alternative energy sources, the time period as well as a series of modelling assumptions (Fragkos et al., 2017).

The relative contribution of value chain segments to employment creation varies according to technology. Figure 2 provides an overview of the basic value chain segments. In the fossil fuel industry the majority of jobs are in fuel processing and operation and maintenance; in the biomass industry in fuel production and processing as well as in operation and maintenance; and in the rest of the renewable energy industry in manufacturing and construction/installation (IRENA, 2019c; Kammen et al., 2004).

Figure 2 Basic value chain of energy technologies



JRC, 2020

This report provides an overview of recent employment trends at the global and EU level related to the greening and decarbonisation of the economy. Within this context it focuses on the energy system, both from the supply and demand side[3]. It presents best available statistical data and results of recent employment assessment reports. Parallel to quantitative employment effects, qualitative aspects affecting jobs in the clean energy transition are highlighted including education and skills requirements and workforce characteristics.

The report is structured as follows: Chapter 2 outlines current transformative trends affecting global and EU labour markets. Chapter 3 and Chapter 4 provide an overview of employment trends related to the expansion of the green economy, in the energy supply sector, as well as within the renewable energy industry at the global and EU level respectively, and energy efficiency at the EU level. Chapter 5 explores sub-sector specific

[3] The majority of recurring data sources focuses on the supply side of the energy system. See Annex 2 for more details.

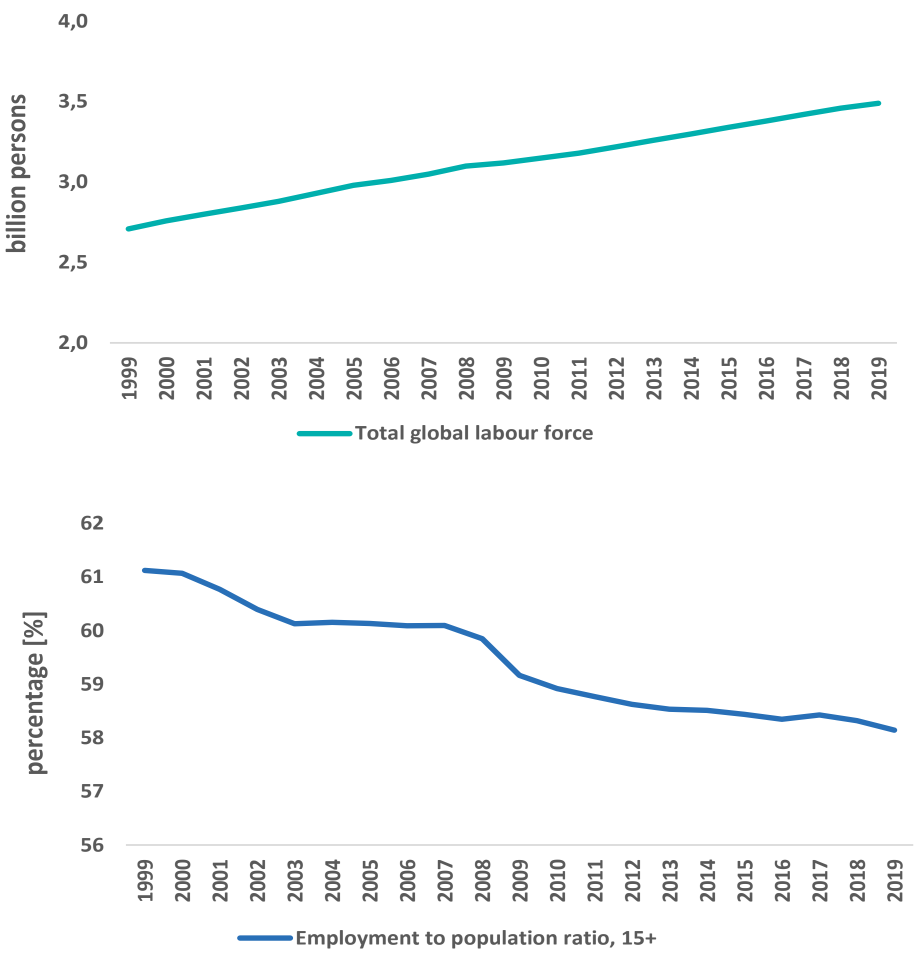
employment trends, covering conventional energy sectors as well as RES sectors at the global and EU level. Chapter 6 provides an overview of changing education and skills requirements in the context of the clean energy and green economic transition. In Chapter 7 workforce characteristics of energy sub-sectors are explored in more detail, including gender and generational aspects. The report concludes by highlighting key figures and providing policy recommendations to overcome labour force related barriers as part of a just transition to a cleaner energy system.

2 Global employment trends

2.1 Employment indicators

The total labour force has been increasing across the globe in the last 20 years, while the employment to population ratio has been following a decreasing trend, reaching 58 % at the end of the period (Figure 3). 3.3 billion people were employed globally in 2018, out of a 5.7 billion working age population. An estimated 172 million workers were unemployed the same year. A further 140 million people were in the “potential labour force” constituting underutilized labour, and 2 billion were outside the extended labour force in 2018 (ILO, 2019). Within this context, industrial jobs were falling in the West and rising in the East (World Bank, 2019).

Figure 3 Total global labour force and employment to population ratio, 1999-2019

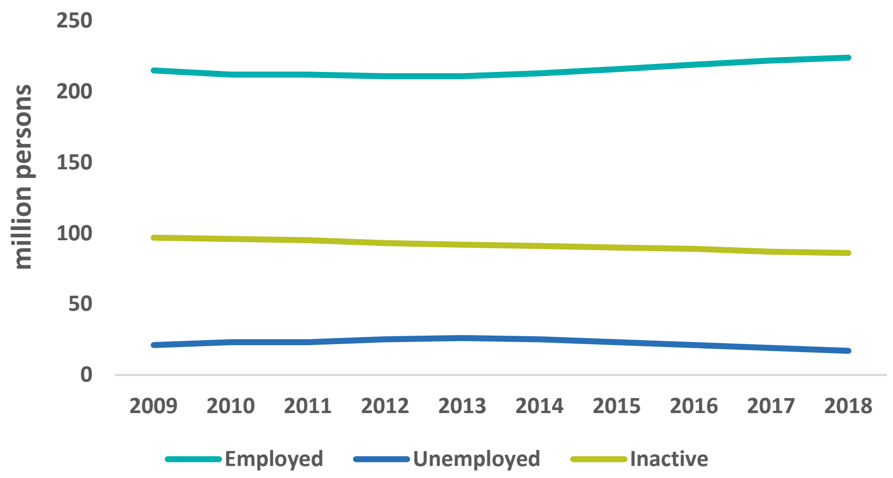


Source: ILOSTAT [SL.TLF.TOTL.IN, SL.EMP.TOTL.SP.ZS]

Until the outbreak of the COVID-19 crisis, the EU’s economy continued to expand, with all-time records for employment (European Commission, 2019b). The number of people at risk of poverty or social exclusion continued to fall below pre-2008 financial crisis levels (European Commission, 2019b). The COVID-19 crisis will lead to millions of people in Europe as well as around the world becoming unemployed. In the dawn of the recovery phase the EU has adopted three safety nets supporting jobs and workers, businesses and Member States (Council of the EU, 2020), keeping the green and digital transitions at the core.

The number of employed persons in the EU-28 reached over 224 million in 2018. Nearly 17 million people were unemployed, and 86 million inactive[4] in the same year, both indicators following a slight downward trend (Figure 4). Nearly 69 % of the total population of the EU-28 aged 15-64 was employed in 2018[5].

Figure 4 Trends in employment, unemployment and inactivity in the EU-28, 2009-2018



Source: Eurostat [lfsa_egan, lfsa_ugan, lfsa_igan]

2.2 Transformative processes

Transformative processes influencing the labour market and reshaping the world today include action against climate change, demographic aging, digitalisation and globalisation (European Commission, 2019b). These influences playing out in combination pose substantial challenges to economies and societies as a whole. Furthermore, the COVID-19 crisis is bound to exacerbate inequality, both within and across countries (Garrotte Sanchez et al., 2020). The combination of these challenges require new approaches and immediate response from policymakers and economic actors alike. A well-designed transition to a climate neutral economy may help make labour markets more resilient to the damaging effects of globalisation, technological change, resource scarcity and demographic changes (University of Cambridge Institute for Sustainability Leadership, 2020).

Demographic ageing and the increase of the old-age dependency ratio poses a challenge to societies and labour markets mainly in the developed world, in view of maintaining and reinforcing social protection systems and social resilience. In terms of employment in the energy sector, this has relevance regarding the general socio-economic context where companies operate. Furthermore, in the energy sector, especially in fossil fuel industries an aging workforce and an increasing demand for employees with more digital skills is the driver of a potential talent crisis.

Globalisation allows firms to respond to cost reduction pressures by relocating rapidly, while contributing to rising returns to skilled workers. It also facilitate the exploitation of increasing market potential with positive employment effects. However, in view of ensuring more autonomy and security of supply, pressures on reshoring and nearshoring are also increasing. In the context of energy technology value chains, globalisation is most relevant for the manufacturing stage. Manufacturing capacities may be relocated to places where production is possible at lower cost. This leads to job losses in energy sub-sectors in countries where production originally took place. For example in the last decade a process of relocation took place from Europe to Asia regarding solar photovoltaic manufacturing capacities.

[4] A person is economically inactive if he or she is not part of the labour force. Inactive people are neither employed or unemployed. Some of the inactive population may be working age, however not working, and not available or looking for work either (ILO definition).

[5] Eurostat [lfse_emp_a]

Digitalisation today creates new types of concerns for firms and for individuals, even though both are normally exposed to the influence of technological progress. Some jobs have been identified as being more susceptible to automation than others (Frey & Osborne, 2017). Another approach emphasizes that automation substitutes or complements certain tasks rather than endangering occupations as a whole (Arntz et al., 2016; World Bank, 2019). Table 1 provides an overview of factors influencing exposure to automation.

Table 1 Factors influencing the exposure of jobs to automation

Characteristics of work that may be more exposed to automation	**Characteristics of work beyond the current capabilities of advanced AI**
Organised in a discrete, standardised and predictable way	Creativity
Relatively low level of education required	Full autonomy
No need for complex social interaction	Sociability
Involvement of routine manual tasks	

Source: (Gonzalez Vazquez, I., Milasi, S., Carretero Gomez, S., Napierala, J., Robledo Bottcher, N., Jonkers, K., Goenaga et al., 2019)

In line with this, power plant operators and service unit operators in oil, gas and mining were found to be highly susceptible to computerization (Frey & Osborne, 2017). High-skilled, specialist roles (e.g. oceanographers, hydrographers and geophysicists developing surveys in offshore wind farm design) are likely to be affected to a significantly lower extent. Some medium-skilled roles may be subject to opposing influences.

Exposure to automation and robots potentially replacing people in jobs is an issue receiving much attention. However, jobs being lost to digitalisation may be less of an issue than what people do on the job, and how they do it (Gonzalez Vazquez, I., Milasi, S., Carretero Gomez, S., Napierala, J., Robledo Bottcher, N., Jonkers, K., Goenaga et al., 2019). Furthermore, automation related jobs created in IT specialist profiles will offset some of the jobs that might be lost.

Climate change as a transformative process and related climate action leads to the emergence of new green jobs and the greening of some existing occupations. In the broadest sense, green jobs can be defined as those impacting the environment in a positive way. Specifically, but not exclusively, this includes jobs that help to protect and restore ecosystems and biodiversity; reduce energy, materials, and water consumption through high-efficiency and avoidance strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution (UNEP, 2008).

The presence of green components is already identifiable in the case of many occupations in Europe (European Commission, 2019b). Table 2 provides an overview of job categories identified in the context of green(able) jobs, according to required changes in tasks, skills and knowledge.

Another approach classifies jobs according to their circularity. Circular jobs focus on preserving and extending what is already made, rethinking business models, using waste as a resource, incorporating digital technology, prioritising renewable sources, as well as collaboration and design (EHERO, 2017).

Table 2 Taxonomy of green(able) jobs

Green Increased Demand Jobs	Existing jobs that are expected to be in high demand due to greening, but do not require significant changes in tasks, skills and knowledge (support green economic activity but no specific green task – e.g. bus drivers in public transport).
Green Enhanced Skills Jobs	Existing jobs that require substantial changes in tasks, skills and knowledge as a result of greening (e.g. electric vehicle electrician).
Green New and Emerging Jobs	Unique jobs created to meet the new needs of the green economy (e.g. fuel cell engineers, sustainable finance experts).
Green Rival jobs	Non-green jobs that are similar to one of the green jobs either because tasks or required skills are similar (e.g. lorry drivers).
Other Non-Green Jobs	Non-green jobs that are less likely to be affected due to lack of similarity to green occupations (e.g. medical doctors).

Source:(European Commission, 2019b) based on (Bowen & Hancke, 2019)

Job growth in the past decade in the EU has been green to some extent, with employment in green(able) jobs increasing in all categories, most strongly in occupations requiring new green skills and retraining in response to new activities and technologies (European Commission, 2019b). Construction, transport, manufacturing, energy and waste management, and professional services activities were the sectors with the highest proportion of green(able) jobs in the EU-28 in 2016 (73 %, 61 %, 52 %, 58 %, 52 % of total jobs respectively in the sectors) (European Commission, 2019b).

Based on the task content of occupations, 87.6 million jobs were green(able) in the EU-28 by 2016, amounting to 40 % of employment that year (European Commission, 2019b).

3 Global energy employment

3.1 Green economy

Moving towards a greener economy can have a net positive employment effect. 18 million net jobs can be created by 2030 worldwide by limiting global warming to 2°C by the end of the century (ILO, 2018). This is achieved by the adoption of sustainable practices, including changes in the energy mix, projected growth in the use of electric vehicles, and improvements in energy efficiency of existing and future buildings.

Parallel to the overall positive influence on global employment levels, the clean energy transition affects regions and sectors differently. Renewables create employment in a more geographically dispersed manner than conventional energy industries, supporting local economic activity and employment. The profound changes in labour patterns can lead to significant misalignments in all world regions, to significant labour reallocation across sectors, and the skills required by new jobs may not match that of the vanishing ones (European Commission, 2019b; IRENA, 2019c). Therefore, policies addressing the distributional impacts of climate change mitigation are necessary to ensure that the transition is fair.

Sectors benefiting in terms of employment from the green transition include construction, electrical machinery manufacturing, copper mining, renewable energy production, biomass crop cultivation, transport and services (European Commission, 2019b; ILO, 2018). At the same time, jobs will be lost in petroleum extraction and refinery, in coal mining and production of electricity from coal (ILO, 2018). The Middle East will be hit the most by job losses and Africa to a lesser extent. The Americas will experience the highest gains in employment during the course of the green transition (ILO, 2018).

3.2 Energy supply

A realignment of labour patterns is taking place among energy sub-sectors in the context of different and changing labour intensities. Some conventional energy industries, for example the extraction of crude oil and gas, are already affected by automation and are characterized by relatively low labour intensity (Table 3). Coal and lignite mining is characterized by higher labour intensity, while automation may lower labour requirement in the future.

The labour intensity of renewable energy sub-sectors is generally higher in all stages of the value chain than that of conventional energy industries (Table 3). This is not likely to change, as the renewables sectors may be less affected by automation. Especially in the installation, and operation and maintenance segments of renewables value chains work tends to take place in confined, harder to access places (maintenance technicians working in the nacelle of wind turbines, installers of rooftop PV panels.) In these contexts replacement by automated solutions is less likely.

A realignment of tasks may occur, however. More routine tasks of technicians that do not require work in confined spaces may be automated: drones may be used to monitor wind turbines while workers can spend more time on problem solving (Bughin et al., 2017; IEA, 2018).

Table 3 OECD employment factors6

Sector	**Construction times (Years)**	**Construction/ Installation (Job years /MW)**	**Manufacturing (Job years /MW)**	**Operation & Maintenance (Jobs/MW)**	**Primary fuel supply (Jobs/PJ)**
Coal	5	11.2	5.4	0.14	39.7 (1)
Oil and gas	2	1.3	0.93	0.14	15.1 (1)
Nuclear	10	11.8	1.3	0.6	0.001 jobs/GWh final demand
Biomass	2	14.0	2.9	1.5	29.9
Hydro-large	2	7.4	3.5	0.2	
Hydro-small	2	15.8	10.9	4.9	
Wind onshore	2	3.2	4.7	0.3	
Wind offshore	4	8.0	15.6	0.2	
Solar PV	1	13.0	6.7	0.7	
Geothermal	2	6.8	3.9	0.4	
Ocean	2	10.2	10.2	0.6	

(1) World average.

Source: (Rutovitz et al., 2015)

Global employment in the energy sector reached nearly 58 million in 2017 (IRENA, 2020a). Parallel to the conventional energy sectors, including coal, gas and oil, and nuclear, these estimates also comprise jobs in renewables, energy efficiency and energy flexibility and grid infrastructure. About half of these jobs were in the fossil fuel industries.

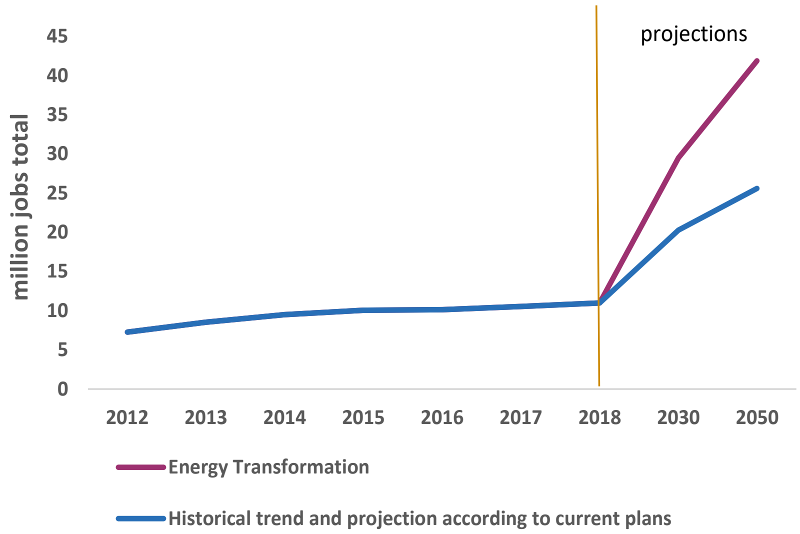
Total jobs in the energy sector can reach nearly 100 million by 2050 in the Energy Transition scenario, with 42 million of these jobs in renewables (IRENA, 2020a). In the case of less ambitious policies (in the Current Plans scenario) energy sector employment will reach over 87 million by 2050, with 25.6 million of these jobs in renewables. Job losses in the fossil fuel sectors are offset by gains in renewables, parallel to the creation of new jobs related to energy flexibility and grid development.

[6] The employment factor overview table is derived from (Rutovitz et al., 2015). It is a consistent set of employment factors covering a wide range of energy technologies. The document serves as the methodological background behind energy employment estimations in the Greenpeace Energy [R]Evolution Scenarios. (Rutovitz et al., 2015) has also been relied on it in the past as a starting point for annual RES employment estimations by IRENA and EurObserv'ER.

3.3 Renewables

Global renewable energy employment has been increasing continuously since 2012, reaching 11 million jobs in 2018 (Figure 5)[7]. Continuation of this trend is expected in the future. In case ambitious policies are implemented, global renewable energy jobs can reach 42 million by 2050 (IRENA, 2019c).

Figure 5 Global renewable energy employment estimates 2012-2018 and projections for 2030 and 2050



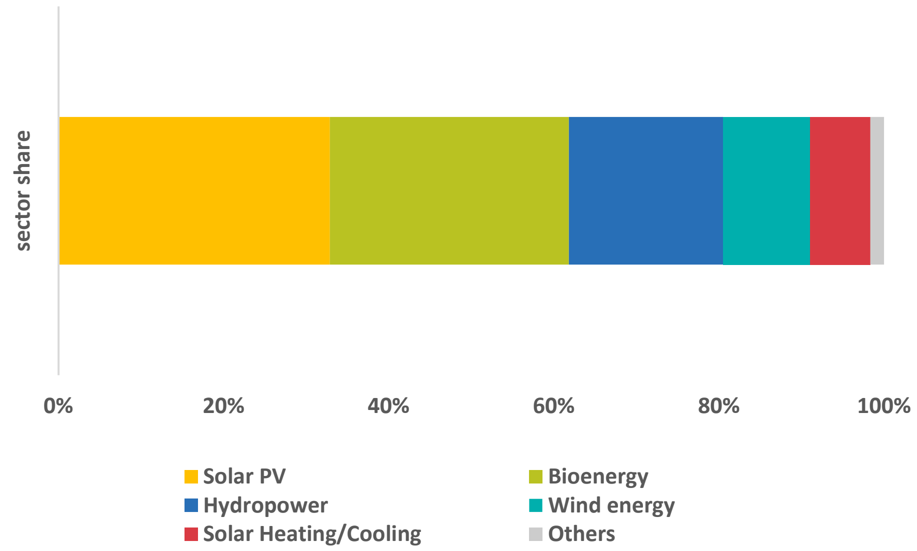
Source: (IRENA, 2018, 2019c)

Solar PV and bioenergy are the largest employers in renewables globally, followed by hydropower (Figure 6). In 2018 a third of the world's renewable energy jobs were in the solar PV sector. It was closely followed by bioenergy representing nearly another third of global RES jobs. Both leading RES sectors accounted for well over 3 million jobs globally. Total global employment in hydropower is 2 million. Wind energy and solar heating and cooling each employ in the range of 1 million people globally.

The relative contribution of value chain segments to employment also has a temporal dimension. As the number of installations increases, so does the share of operation and maintenance related activities and demand for skill sets relevant for this segment. In the European PV industry, by 2011, 75 % of jobs were related to installation and operation and maintenance activities (Jäger-Waldau, 2014). Due to growing operating capacity by 2030 in the EU wind sector the operation and maintenance segment is expected to experience the largest skills shortages relative to other supply chain segments (Fitch-Roy, 2013).

[7] Sections of the report contain information referring to different employment concepts (as indicated throughout), relying on different estimation methodologies. For example, some data sources provide information on direct jobs only, while others on total jobs comprising direct employment and indirect jobs along the industry value chain. Some sources refer to renewable energy employment. Others provide information on employment e.g. in electricity supply related activities, with no further breakdown between conventional and renewable energy sources.

Figure 6 Sector share in total employment in the global renewable energy industry, 2018

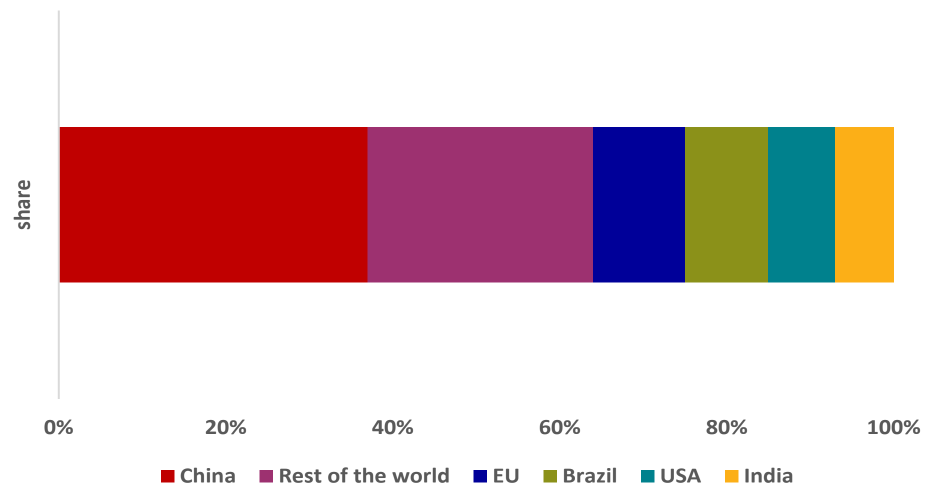


Source: (IRENA, 2019b)

80 % of all global renewable energy jobs are concentrated in the solar PV, bioenergy and hydropower sectors (Figure 6). Wind energy and solar heating and cooling, while significant, are not leading RES sectors in terms of employment. A combination of the remaining technologies, including geothermal energy, concentrated solar power, heat pumps, municipal and industrial waste and ocean energy constitute only 2% of global renewable energy jobs.

China is the largest renewables employer in the world, hosting over 4 million, or 37% of total global RES jobs (Figure 7). The EU-28 as whole is the second largest RES employer with 11% of global RES jobs. Brazil (10%) the USA (8%) and India (7%) follow.

Figure 7 Share in global RES employment by geographic area, 2018



Source: (IRENA, 2019b)

4 EU energy employment

4.1 Green economy

Climate policies and the clean energy transition underway are already having an effect on employment and on the European economy.

The transition to a low-carbon economy is estimated to be positive for the EU as a whole, both in terms of GDP and employment growth. Compared to a business-as-usual baseline, until 2030 GDP and employment show growth of 1.1 % and 0.5 % respectively (Lewney et al., 2019).

Ambitious climate policies are expected to have a positive net impact on employment both in the medium- and in the longer term in the EU-28. In the case of 1.5°C temperature increase scenarios, 1.5-2 million jobs could be created in terms of total employment in 2050, compared to the baseline (European Commission, 2019b).

A full implementation of the Paris agreement would create additional 1.2 million jobs in the EU as a whole by 2030. This job creation is expected to take place mostly in greening sectors, including construction, waste management and sustainable finance (European Commission, 2019b). Conventional energy industries (fossil fuel extraction, processing and generation) and the regions where they are concentrated would at the same time be affected by job losses locally.

4.2 Energy efficiency

More ambitious energy efficiency policies have been found to result in higher benefits in terms of employment creation in the European Union.

In 2030 in the case of a 30 % energy efficiency target 0.405 - 0.434 million additional net jobs may be created in the EU-28[8]. A 40 % energy efficiency target is expected to lead to 1.2 – 4.8 million additional net jobs by that year[9] (European Commission, 2016).

A strengthened Energy Performance of Buildings Directive (EPBD) may lead an increase of up to 568 000 jobs by 2030 compared to the reference case representing no change in EU initiatives related to buildings[10] (Cambridge Econometrics, 2016).

The effects of a very ambitious energy efficiency programme running until 2030, including energy efficiency investment actions across various economic sectors, were found to result in an increased labour demand of 2.3 million job-years in 2030[11]. In the long-term the programme was not found to deliver any significant employment effect[12] (Næss-Schmidt et al., 2018).

[8] E3ME macro-econometric model "no crowding out" and GEM-E3 computable general equilibrium model "loan-based" cases, respectively.

[9] GEM-E3 computable general equilibrium model "loan-based" and E3ME macro-econometric model "no crowding out" cases, respectively.

[10] Estimated with E3ME macro-econometric model.

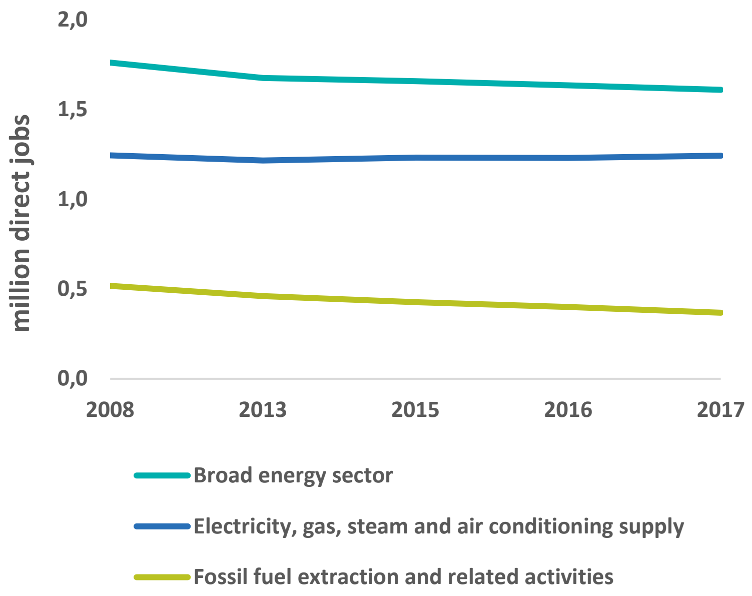
[11] The COMBI project financed under Horizon 2020 explored employment impacts as one of the multiple benefits of energy efficiency, using an Input-Output model and the CE-CEM computable general equilibrium model. The I-O model was used to analyse short-run business cycle effects and the CE-CEM CGE model for long-run, structural effects. While the GEM-E3 and E3ME models uses an assumption of idle resources for its long-run impacts, in CE-CEM there is no output gap or idle resources.

[12] An Input-Output model was used to analyse short-run business cycle effects and the CE-CEM computable general equilibrium model for long-run, structural effects.

4.3 Energy supply

Employment in the energy sector has been decreasing over the past decade in the EU-28, supporting over 1.6 million direct jobs in 2017 (Figure 8). Of the two main components of the broad energy sector, employment in 'Electricity, gas, steam and air conditioning supply' slightly increased in the preceding years. In the other component 'Fossil fuel extraction and related activities', employment decreased in the same time period.

Figure 8. Employment in the energy sector, EU-28, 2008-2017



Source: (European Commission, 2019a) – Eurostat – Structural Business Statistics Survey (SBS)

As a comparison, 'Water supply; sewerage, waste management and remediation activities' is a sector of similar size in terms of employment as the broad energy sector. It supported 1.61 million direct jobs in 2017 in the EU-28[13].

The European construction sector as a whole[14] supported nearly 13 million direct jobs in the EU-28 in the same year[15]. The construction and renovation of buildings within this category has large potential for GHG emission reductions through the implementation of energy efficiency measures. However, current statistical classification of construction related activities does not allow for precise attribution of energy efficiency related employment.

[13] Eurostat – Structural Business Statistics Survey (SBS) [TIN00151]

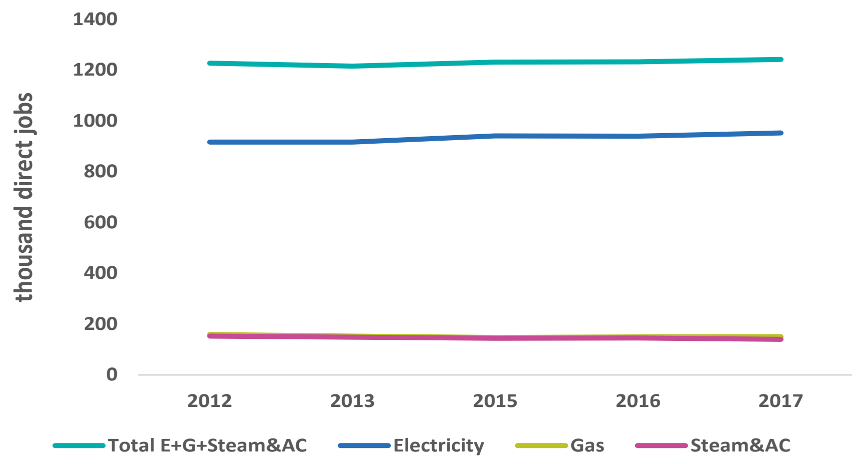
[14] The construction sector as a whole comprises the categories 'specialised construction activities', 'construction of buildings' and 'civil engineering' (approximately 60 %, 26 % and 13 % of construction as a whole, respectively, ranked on value added) (Eurostat, 2015). Energy efficiency related employment may occur in the construction of new buildings and in some specialized construction activities (also known as 'special trades'). 'Specialized construction activities' are usually specialised in one aspect common to different structures, requiring specialized skills. Energy efficiency related activities within this wider category include thermal insulation, and heating and air conditioning installation.

[15] Eurostat – Structural Business Statistics Survey (SBS) [TIN00151]

The largest and relatively most stable employer in the EU energy supply sector is 'Electricity, gas, steam and air conditioning supply'. It supported 1.24 million direct jobs in 2017 (Figure 9). Energy supply jobs from renewable sources are also included here.

From the combined category 'Electricity, gas, steam and air conditioning supply', 'Electricity supply' related activities support more than six times more jobs than the other two categories each. Direct jobs in 'Electricity supply' reached over 953 000 in the EU-28 in 2017. Employment in 'Gas supply' accounted for 150 000 direct jobs, while 'Steam and air conditioning supply' 140 000 direct jobs that year (Figure 9).

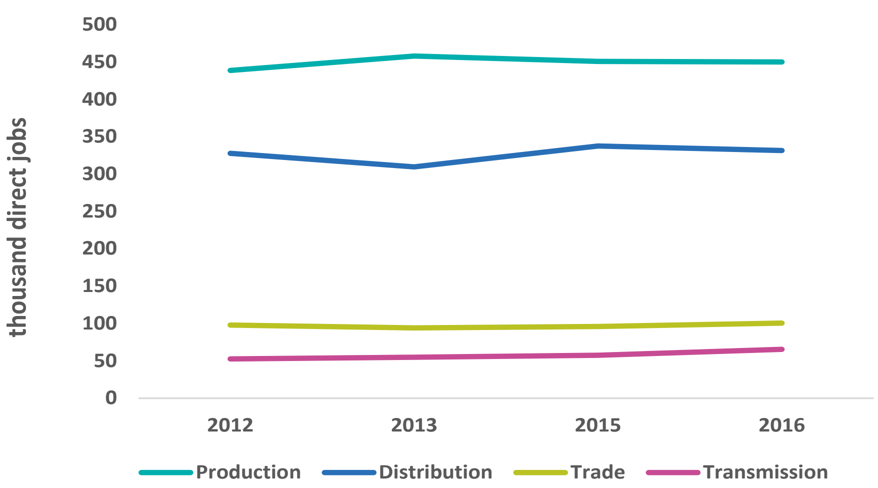
Figure 9. Employment in electricity, gas, steam and air conditioning supply by sub-sector in the EU-28



Source: (European Commission, 2019a) – Eurostat – Structural Business Statistics Survey (SBS)

'Electricity production' and 'Electricity distribution' are the largest sub-sectors in terms of employment within 'Electricity supply'. They support 450 000 and 331 000 direct jobs respectively in the EU-28 (Figure 10).

Figure 10. Employment in electricity supply related activities in the EU-28

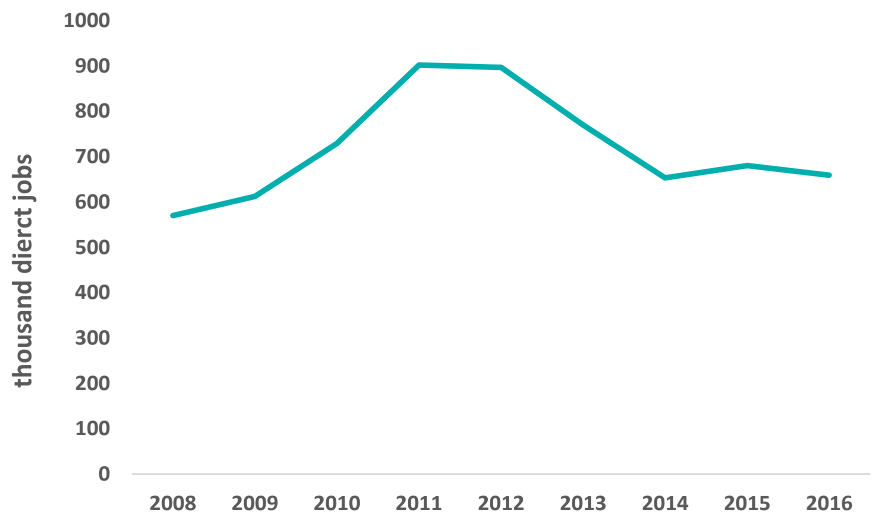


Source: (European Commission, 2019a) – Eurostat – Structural Business Statistics Survey (SBS)

4.4 Renewables

Direct employment in the production of energy from renewable sources reached nearly 660 000 jobs in 2016 in the EU-28 (Figure 11). A downward trend in direct RES jobs occurred from 2011 onwards, turning to stagnation in the following years. Factors behind this development include the aftermath of the 2008 financial crisis, moving of some renewables manufacturing capacities outside of Europe, as well as the change in the subsidisation of renewables within the EU.

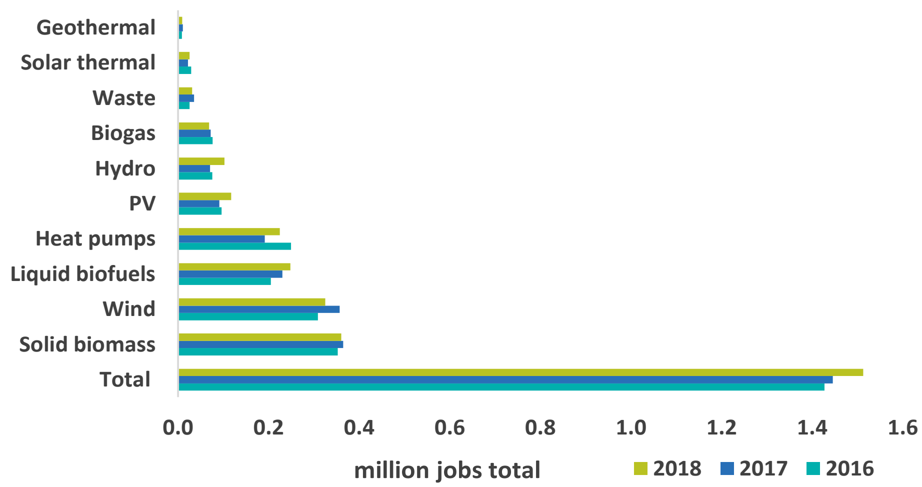
Figure 11. Employment in the production of energy from renewable sources, EU-28, 2008-2016



Source: Eurostat [env_ac_egss1]

With reference to total employment (direct at the establishment and indirect within the value chain), the EU renewables sector accounted for over 1.5 million jobs in 2018 (EurObserv'ER, 2019). This represents a slightly increasing trend over three years (Figure 12). The solid biomass and wind sectors remained in the lead, supporting nearly 361 000 and over 325 000 jobs, respectively. Liquid biofuels was at third place ahead of heat pumps, with employment in the former reaching over 248 000 and the latter nearly 225 000. Employment in the solar PV sector increased compared to the previous year, to over 117 000 total jobs in 2018.

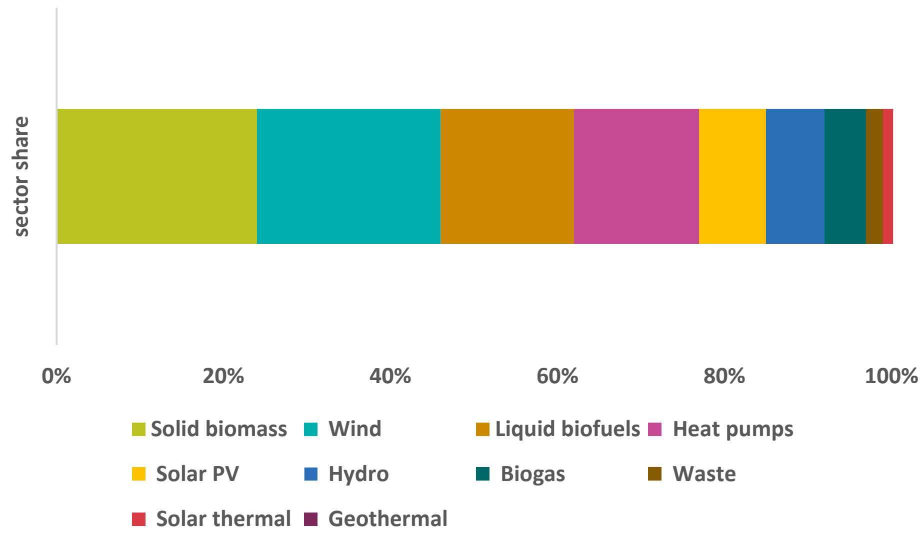
Figure 12. Employment in the renewable energy industry by sector, EU-28, 2016-2018



Source: (EurObserv'ER, 2018) (EurObserv'ER, 2019)

The solid biomass and wind sectors each supported nearly a quarter of total EU renewable energy jobs in 2018 (Figure 13). Over three-fourth of EU renewable energy jobs were in one of the four leading sectors in terms of employment (solid biomass, wind, liquid biofuels and heat pumps).

Figure 13. Sector share in total employment in the renewable energy industry, EU-28, 2018



Source: (EurObserv'ER, 2019)

Over half of all RES jobs in the EU were located in one of the top five countries in terms of RES employment (Figure 14). These include Germany, Spain, France, the United Kingdom and Italy. Germany alone accounted for nearly a fifth of EU RES jobs, amounting to nearly 264 000 in 2018. Most German RES jobs are by far in the wind sector, followed by the solar PV and solid biomass sectors. In Spain heat pumps and wind, while in France and Italy heat pumps and solid biomass are the leading RES employers. Similarly to Germany, in the UK the wind sector leads by far in terms of employment, followed by solid biomass.

Latvia, Estonia, Denmark and Finland are in the lead in Europe in terms of renewables employment per capita population. On the one hand, the overall population level is low in these countries (over 5.7 million in Denmark, the most populous in the group, and over 1.3 million in Estonia, the least populous in the group). On the other hand, they host at least one strong renewables sub-sector. In the case of Latvia, Estonia and Finland the solid biomass industry is the main RES employer. In Denmark the strong wind industry, including the manufacturing segment of the value chain is the responsible for RES jobs in the country.

Among the European leaders in overall RES employment, Germany and Spain perform around the EU average, while France, the United Kingdom and Italy below the EU average in terms of RES employment per capita.

Figure 14. RES employment in the EU-28 by Member State and RES employment per population, 2018

Source: (EurObserv'ER, 2019) Eurostat [TPS00001]

5 Energy sub-sector employment

This chapter explores technology specific employment trends, covering conventional energy sectors (fossil fuels and nuclear power) as well as RES sectors at the global and EU level. From the RES sub-sectors those that generate the most employment globally, in Europe, or both, are explored in more detail. These include solar PV, wind, solid biomass, liquid biofuels, hydropower and heat pumps (Figure 6 and Figure 12). Employment information is provided also for the remaining RES sub-sectors, including solar thermal and concentrated solar power, biogas, waste, geothermal energy and ocean energy.

Employment impacts in connection to the expansion of renewable energy technologies have been monitored, estimated and annually published for nearly a decade by the International Renewable Energy Agency (IRENA) at the global and the EurObserv'ER project at the European level[16]. Eurostat and some national statistical offices publish energy sector and RES employment data. Reports are also published by other organisations focusing on employment in specific energy sub-sectors. Employment data from the mentioned sources is not directly comparable due to differing estimation approaches.

The Annexes provide a overview of key concepts and methodological approaches in estimating employment impacts, as well as of key sources referenced in this report monitoring and estimating transition to a low-carbon economy related employment impacts at the global and EU level.

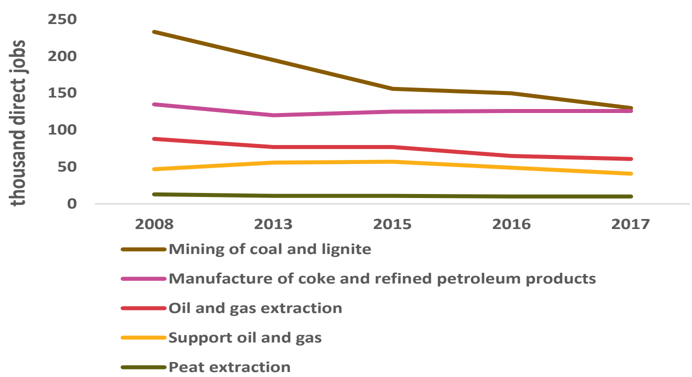
5.1 Fossil fuels

Globally fossil fuel sectors supported approximately 30 million jobs in total while employment in renewables reached over 10.5 million in 2017 (IRENA, 2019c). Both in the medium and the long term the relative weight of employment in the fossil fuel industries is expected to decrease vis-à-vis employment in renewables, energy efficiency, and jobs in energy flexibility and grid (IRENA, 2019c).

In the EU-28 extractive fossil fuel industries supported over 225 000 direct jobs in 2016 (Figure 15). Two-thirds of these jobs were in the mining of coal and lignite, the rest in the extraction of oil and gas, and peat. Support, production and manufacturing activities related to coal, and oil and gas employed a further 175 000. Overall, direct employment in coal as well as oil and gas related extractive and processing activities stood at 400 000 jobs in 2016 in the EU-28.

Direct employment was decreasing in coal and lignite mining and to a lesser extent in the extraction of crude oil and natural gas between 2008 and 2017 in the EU-28 (Figure 15). Drivers of this was the depletion of oil and gas resources in the EU, as well as policies to phase out coal in combination with its loss of profitability. Poland, the Czech Republic, Germany and Bulgaria registered the highest direct employment levels in coal mining, while Romania, the UK and Italy in the extraction of oil and natural gas in 2017 among EU Member States.

Figure 15. Employment in fossil fuel sectors, EU-28, 2008-2017



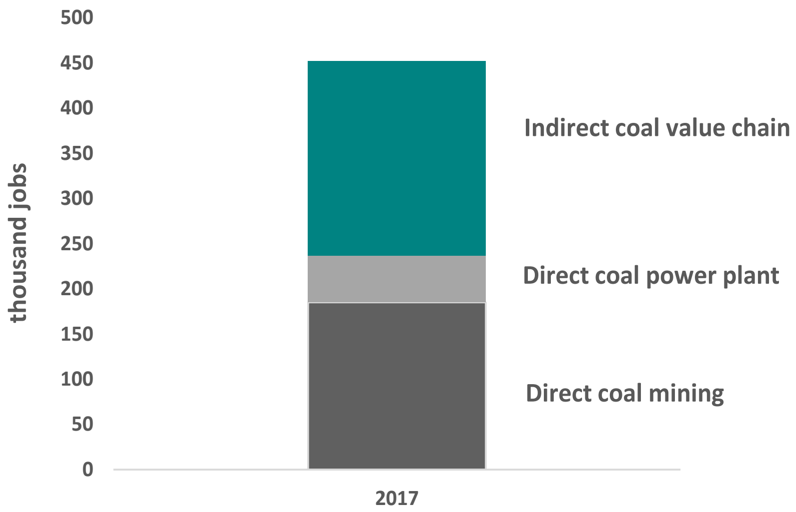
Source: (European Commission, 2019a) – Eurostat - Structural Business Statistics Survey (SBS)

[16] Due to a significant change in methodological approach implemented by EurOsberv'ER affecting data from 2016 onwards, EU Member State level RES sub-sector employment information covers the years 2016-2018. Employment effects are picked up with some delay due to model characteristics.

While there is no direct relationship between the expansion of renewables and the potential decline of fossil fuel industries, connections in the development of employment patterns can be established with modelling methods. The composition of the fossil fuel sector and the type of renewable technology deployed are key influencing factors. Countries that have coal mining activities are more susceptible to job losses as well as those countries where renewables industries are gaining ground that do not use feedstock, as feedstock using technologies generate high amount of jobs per MW (EurObserv'ER, 2018). It is estimated that by 2017 over 258 000 direct jobs were lost in the fossil fuel sector that can be connected to the development of renewables in 18 EU Member States (EurObserv'ER, 2018). The job losses occurred in fuel extraction and production, as well as in operation and maintenance activities. Romania and Germany were among the countries impacted the most.

The EU coal sector as a whole, including mining and power plants, are estimated to have employed about 237 000 people directly in 2017. The vast majority of these were in coal mining, amounting to 185 000 jobs (Figure 16). The number of indirect jobs dependent on coal activities is estimated to reach up to 215 000 throughout the coal value chain in the EU-28 (Alves Dias et al., 2018).

Figure 16. Jobs along the coal value chain in the EU-28



Source: (Alves Dias et al., 2018)

5.2 Nuclear power

With an installed capacity of 118 GW the nuclear industry is estimated to sustain 1.1 million jobs in total in the EU in 2019 (Deloitte, 2019). Nearly half of these jobs are highly skilled. 70 % of the nearly 352 000 direct jobs in the EU nuclear sector are in the operation and maintenance phase of the value chain.

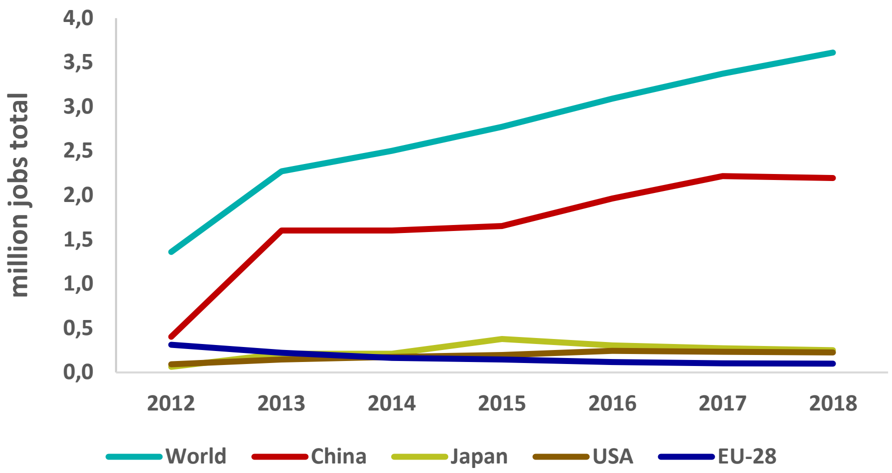
5.3 Solar PV

The solar PV sector is the largest RES employer in the world (Figure 6). It accounts for 3.6 million jobs, or a third of total global RES jobs. 85 % of solar PV jobs are in Asia, mainly in China, Japan, Bangladesh and India. Apart from Asian countries, the United States and Germany are also among the top ten solar PV employers globally (IRENA, 2019b).

PV cell and module manufacturing is transforming into a mass-production industry, and has largely shifted to Asia (Jäger-Waldau, 2017). China remains a dominant employer in PV manufacturing as well as deployment, with nearly 2.2 million total solar PV jobs in 2018 (Figure 17). It is followed by Japan and the United States, with significantly lower employment levels (around 250 000 solar PV jobs each). Parallel to the shift of manufacturing towards Asia, the solar PV industry and related employment experienced a downturn in Europe.

Chinese and other foreign direct investment (FDI) drives the spread of PV manufacturing to other Asian countries, including Malaysia, Thailand and Vietnam. Japan, the Republic of Korea and Taiwan are also among important PV panel producers (IRENA, 2019b).

Figure 17. Solar PV employment, world and selected major players, 2012-2018

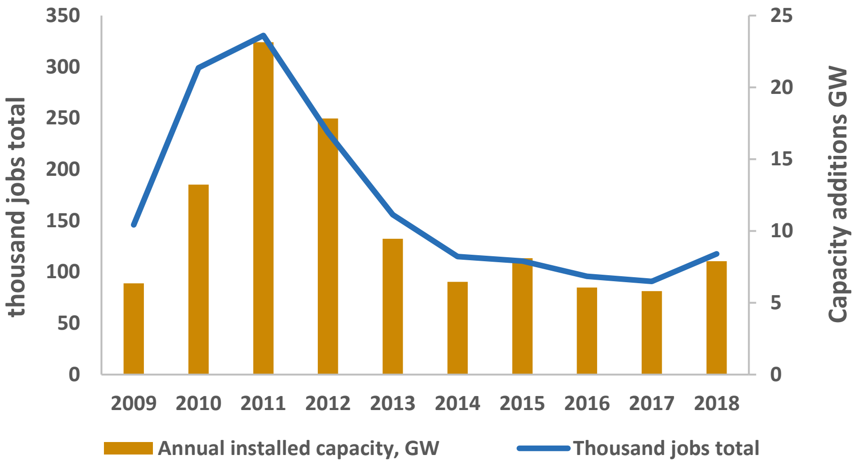


Source: (IRENA, 2013, 2014, 2015, 2016, 2017, 2018, 2019b)

Following a peak in 2011 and parallel to the strengthening of PV manufacturing capacities in Asia, the solar PV sector in the EU-28 has been experiencing a decline both in terms of annual added generation capacity and employment (Figure 18). In 2014, 75 % of solar PV jobs in Europe were local and in the installation, and operation and maintenance of solar PV systems (Jäger-Waldau, 2014).

After a slight recovery in 2015, the decline in solar PV employment in the EU-28 continued until 2017. In 2018, parallel to the increase in annual added generation capacity, employment in the sector also increased to nearly 118 000 total jobs (Figure 18). This made it the fifth largest employer among RES sectors in Europe that year (Figure 12). European PV employment in 2018 was 36 % of the peak seen in 2011, when it was leading in terms of employment among RES sectors (Figure 18).

Figure 18. Solar PV employment and annual capacity additions, EU-28, 2009-2018

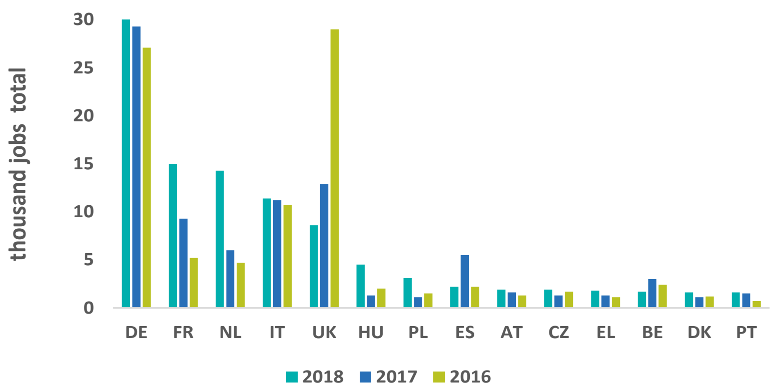


Source: (EurObserv'ER, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019; IRENA, n.d.)

In 2018 over a third of EU PV jobs were located in Germany (Figure 19 and Figure 20). Other countries leading in solar PV employment in Europe include France, the Netherlands, Italy and the UK. The leading countries together accounted for nearly 80 % of solar PV jobs in the EU-28 in 2018.

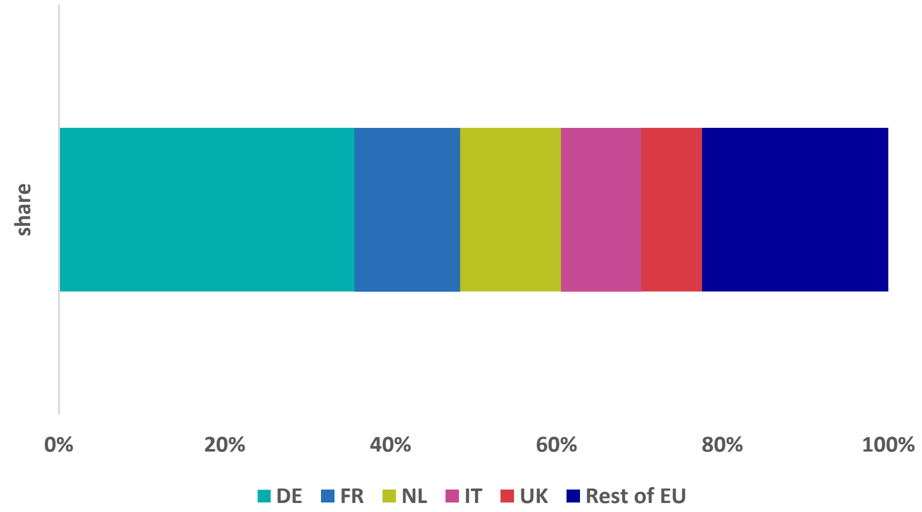
The United Kingdom experienced a 70 % loss in PV employment between 2016 and 2018. This was due to the decline in installations also impacting operation and maintenance jobs. Parallel to this, PV employment increased in most of the Member States leading in deployment, mostly driven by capacity additions. The year-on-year increase in solar PV employment between 2017 and 2018 was notable in France and the Netherlands, in connection to domestic policies driving renewables deployment.

Figure 19. Solar PV employment in selected EU Member States, 2016-2018



Source: (EurObserv'ER, 2018) (EurObserv'ER, 2019)

Figure 20. Member States' share in EU solar PV employment, 2018

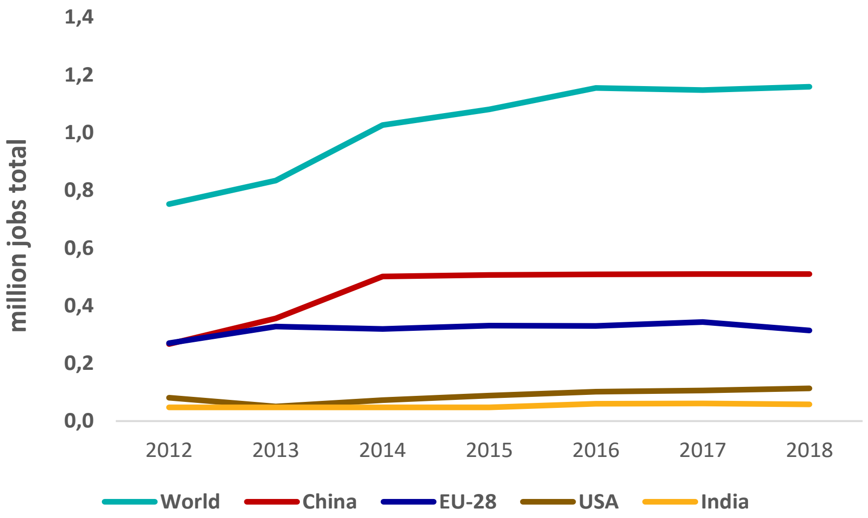


Source: (EurObserv'ER, 2019)

5.4 Wind

The wind sector is the fourth largest employer globally among renewable energy industries (behind solar PV, liquid biofuels and hydropower) (Figure 6). In 2018 it accounted for nearly 1.2 million jobs worldwide (Figure 21). Most wind jobs are in the onshore sub-sector. 44 % of all wind jobs are in China and 75 % of all global wind jobs are in the top five countries leading in wind employment (China, Germany, the USA, India and the United Kingdom) (IRENA, 2019b).

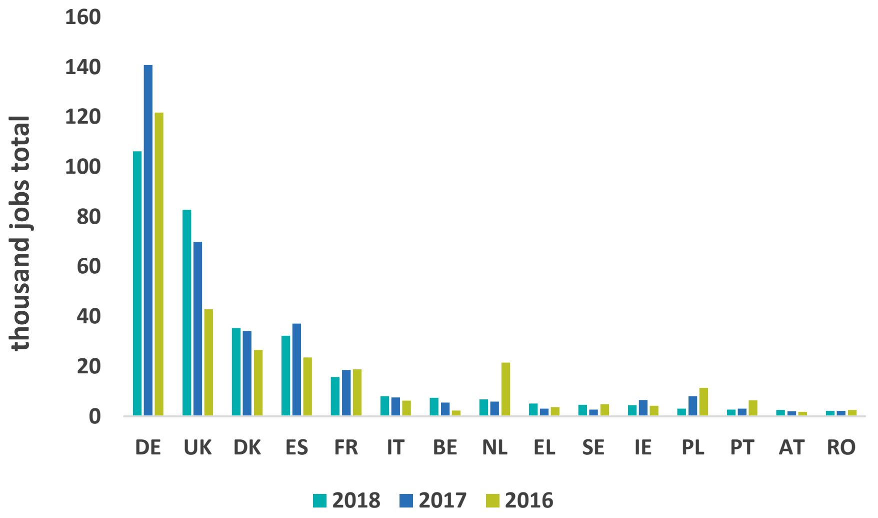
Figure 21. Wind employment, world and selected major players, 2012-2018



Source: (IRENA, 2013, 2014, 2015, 2016, 2017, 2018, 2019b)

Wind is among the leading renewable energy sectors in Europe. In 2018 it supported over 325 000 jobs in total, making it the second largest sector in terms of renewables employment in the EU-28 (Figure 12). Member States with the highest number of jobs in the wind sector include Germany, the UK, Denmark and Spain (Figure 22).

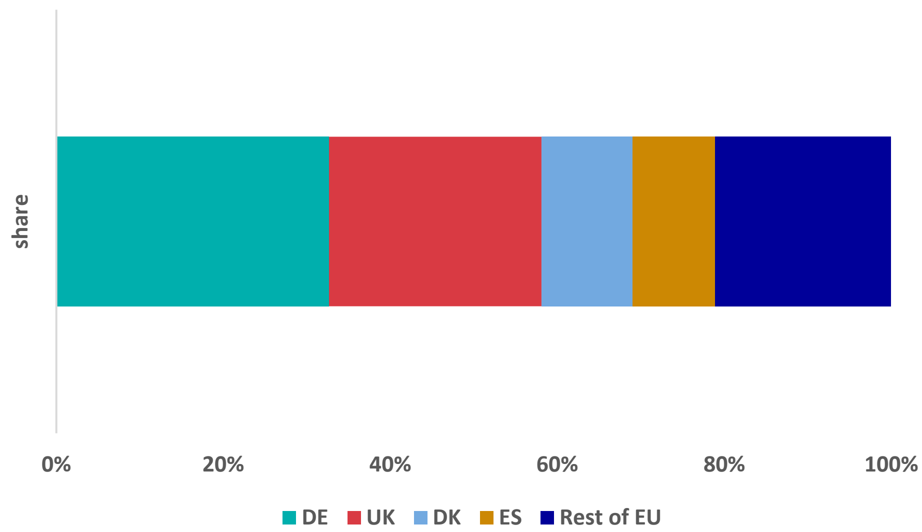
Figure 22. Wind employment in selected EU Member States, 2016-2018



Source: (EurObserv'ER, 2018)

The four leading Member States accounted for nearly 80 % of all EU wind jobs in 2018 (Figure 23). Germany, the leader in wind employment and the UK in second place were together home to nearly 60 % of total European wind jobs that year.

Figure 23. Member States' share in EU wind employment, 2018



Source: (EurObserv'ER, 2019)

European wind jobs are driven by domestic installations as well as manufacturing. Denmark, Germany and Spain are the major players in wind turbine production and exports (EurObserv'ER, 2018). The offshore sub-sector in the EU is led by the UK, Germany and Denmark (EurObserv'ER, 2018), creating jobs in coastal communities with often relatively less favourable economic conditions. Due to social acceptance and space constraint issues affecting more the onshore sub-sector, the offshore sub-sector is growing more rapidly. At the same time social innovations and participatory approaches (e.g. co-ownership in local on-shore wind farms) seem to have helped increase social acceptance of onshore wind. Total employment associated to offshore wind in the EU-28 was estimated to reach 210 000 in 2018, a 15 % increase compared to the previous year (European Commission, 2019c).

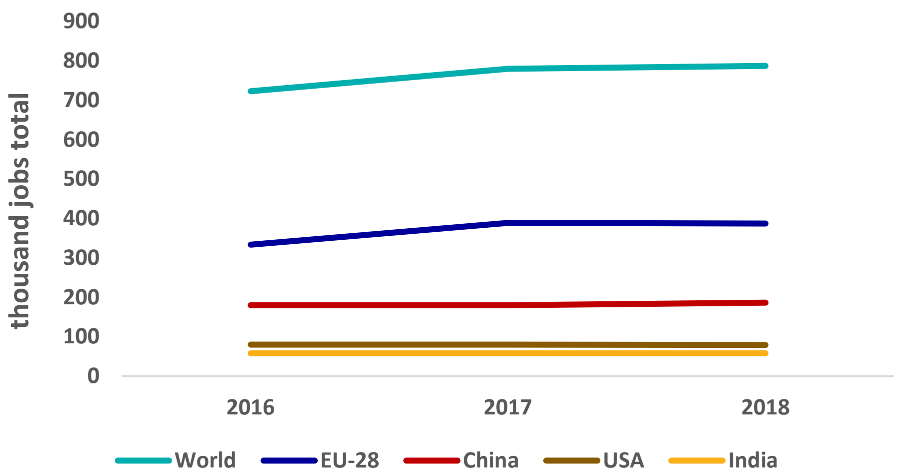
The European wind industry is experiencing significant challenges, also with implications for wind employment. Wind farm developers face a large degree of uncertainty stemming from government decarbonisation targets, permitting arrangements and investment in new grid capacity (Business Green, 2019). In the last four years 35 000 wind jobs have been lost in Germany alone[17], in connection to public policy issues (Business Green, 2019).

Europe is still the dominant global player in wind turbine manufacturing. However its dominance is eroding in connection to the gaining of ground by Chinese manufacturers and major innovations affecting the supply chain (EurActive, 2019). Parallels are apparent with the European solar PV industry that experienced a rapid drop in employment starting from 2011 onwards, due to lack of sufficient capacity additions and Asian countries gaining ground in module manufacturing.

5.5 Solid biomass

The EU-28 is the largest employer in the world in solid biomass for power and heat applications. China follows, while other major players include the USA and India. In recent years world employment in solid biomass for power and heat applications was slightly increasing, reaching 787 000 total jobs in 2018 (Figure 24).

Figure 24. Employment in solid biomass, world and selected major players, 2016-2018



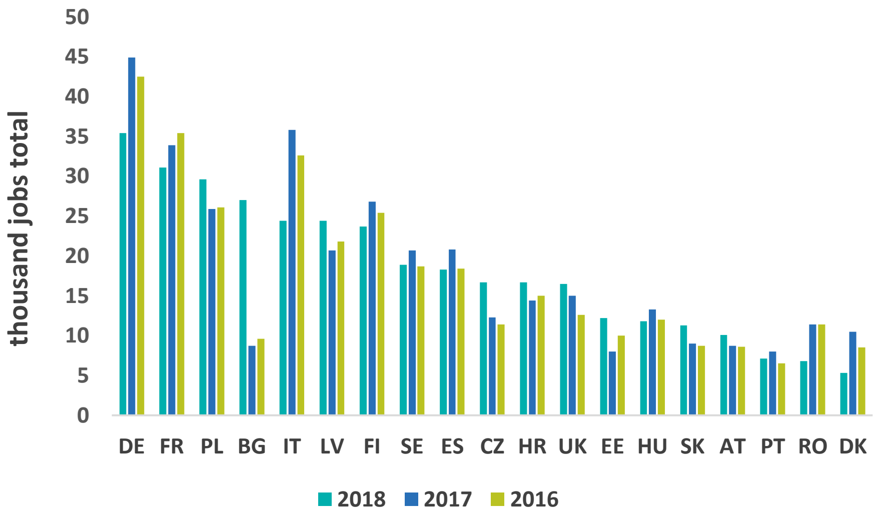
Source: (IRENA, 2017, 2018, 2019b)

[17] This effect becomes apparent between the 2017 and 2018 in EurObserv'ER figures for Germany due to model characteristics, which lead to picking up employment effects with some delay.

Solid biomass is the largest renewable energy sector in terms of employment in the EU-28, providing jobs across the continent (Figure 12 and Figure 25). Member States with the highest total employment in the solid biomass sector included Germany, France, Poland, Bulgaria, Italy, Latvia and Finland in 2018. Nearly half of total solid biomass jobs were located in these Member States in 2018 (Figure 26).

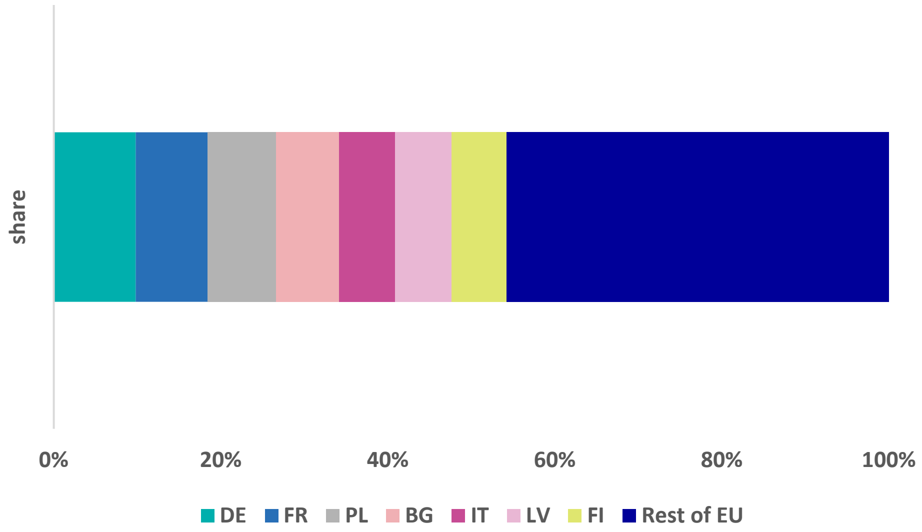
The conversion of coal fired power plants to the burning of biomass is a key driving force behind high employment levels in the sector. The notable spike in solid biomass employment in Bulgaria in 2018 constitutes an example (Figure 25).

Figure 25. Solid biomass employment in selected EU Member States, 2016-2018



Source: (EurObserv'ER, 2018) (EurObserv'ER, 2019)

Figure 26. Member States' share in EU solid biomass employment, 2018

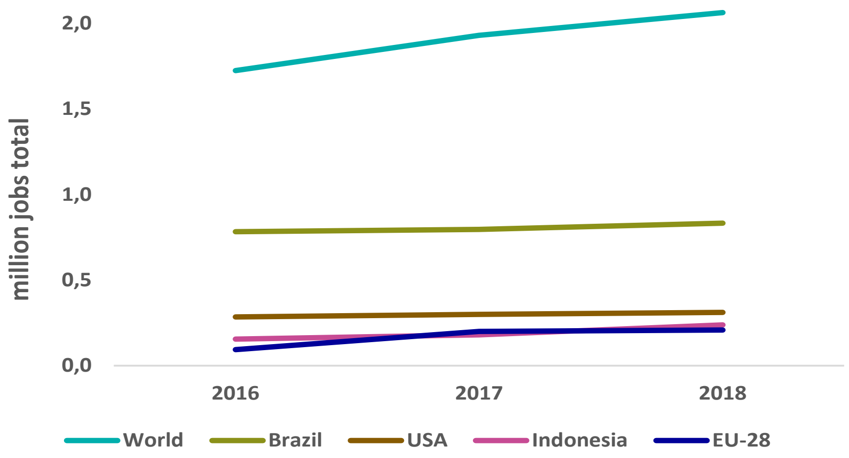


Source: (EurObserv'ER, 2019)

5.6 Liquid biofuels

Liquid biofuels is among the largest renewable energy employers in the world. Total global employment in the sector reached over 2 million in 2018 (Figure 27). Brazil is world leader in biofuels employment, with over 830 000 total jobs in the sector in 2018. It is followed by the USA, Indonesia and the EU-28. Colombia is also a major player, with employment numbers close to that of the EU-28.

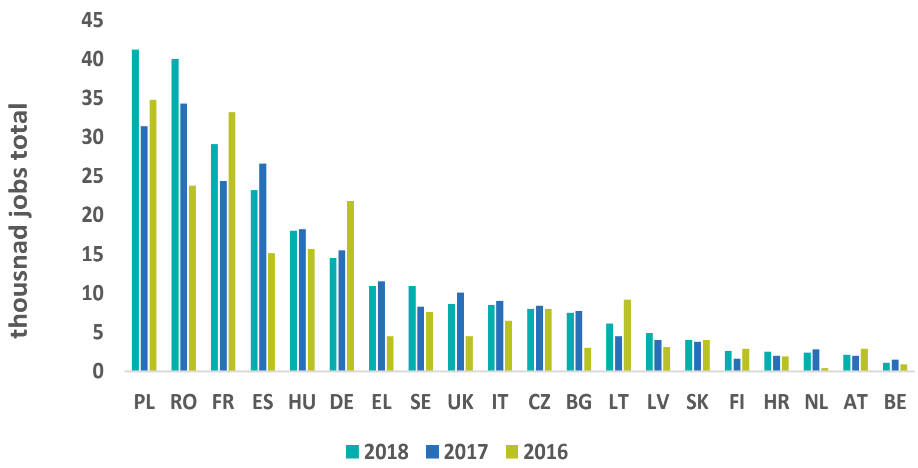
Figure 27. Employment in liquid biofuels, world and selected major players, 2016-2018



Source: (IRENA, 2017, 2018, 2019b)

Liquid biofuels is the third largest renewables employer in the EU-28. A precondition of liquid biofuels production is the availability of agricultural area. In 2018 the sector had over 248 000 jobs in total (Figure 12). Member States leading in biofuels employment include Poland, Romania, France, Spain, Hungary and Germany. The leading Poland had over 41 000 biofuels jobs in 2018 (Figure 28).

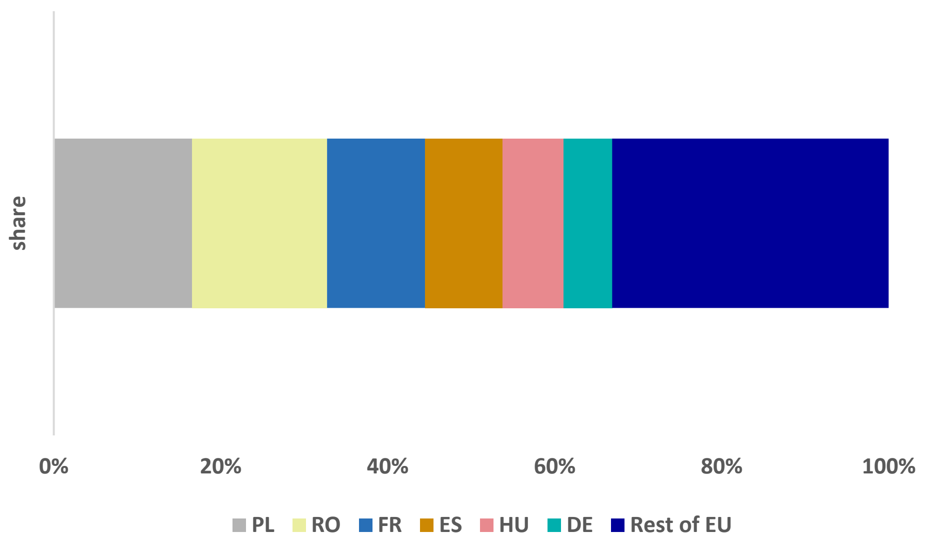
Figure 28. Liquid biofuels employment in selected EU Member States, 2016-2018



Source: (EurObserv'ER, 2018) (EurObserv'ER, 2019)

67 % of total jobs in the European liquid biofuels sector was located in the six Member States leading in biofuels employment in 2018 (Figure 29).

Figure 29. Member States' share in EU liquid biofuels employment, 2018



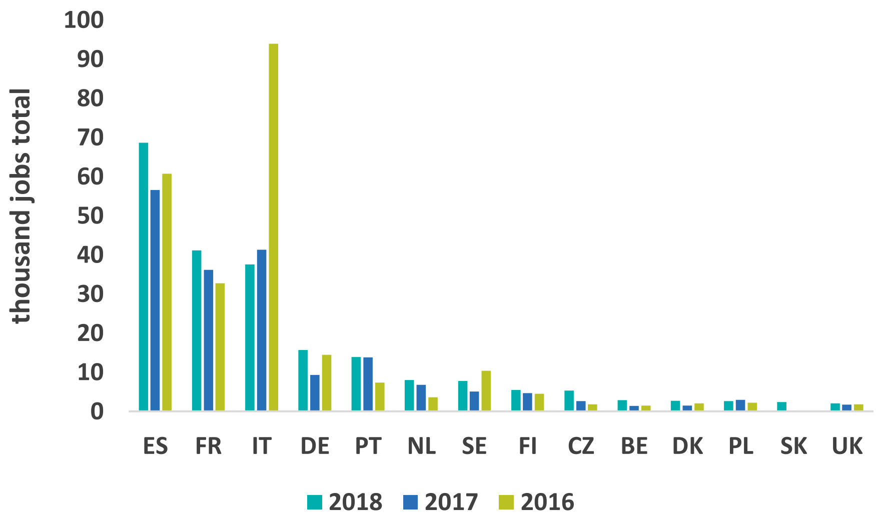
Source: (EurObserv'ER, 2019)

5.7 Heat pumps

The heat pump sector was the fourth largest employer among renewables sectors in the EU-28 in 2018, supporting 224 500 total jobs (Figure 12)[18]. Employment in the sector increased by 17 % between 2017 and 2018 (EurObserv'ER, 2019).

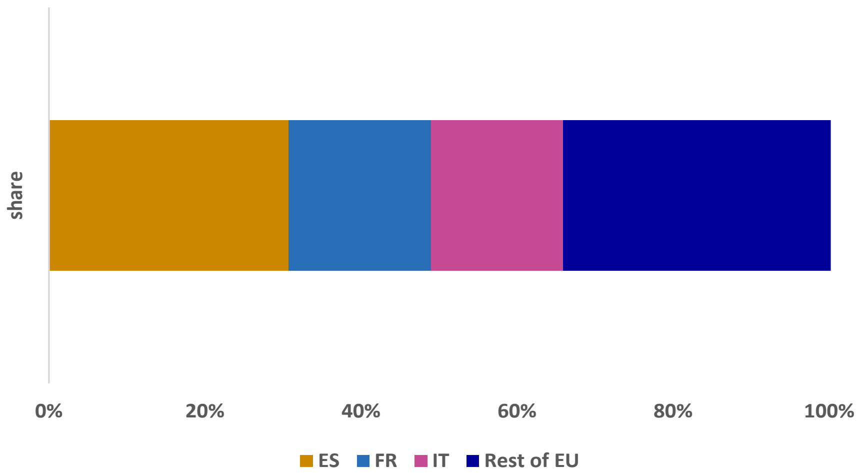
Member States leading in heat pumps employment include Spain, France and Italy (Figure 30). 66 % of jobs in the European heat pumps sector were located in these countries in 2018 (Figure 31). Summer cooling needs is a key driver behind employment in heat pumps sector.

Figure 30. Heat pumps employment in selected EU Member States, 2016-2018



Source: (EurObserv'ER, 2018) (EurObserv'ER, 2019).

Figure 31. Member States' share in EU heat pumps employment, 2018



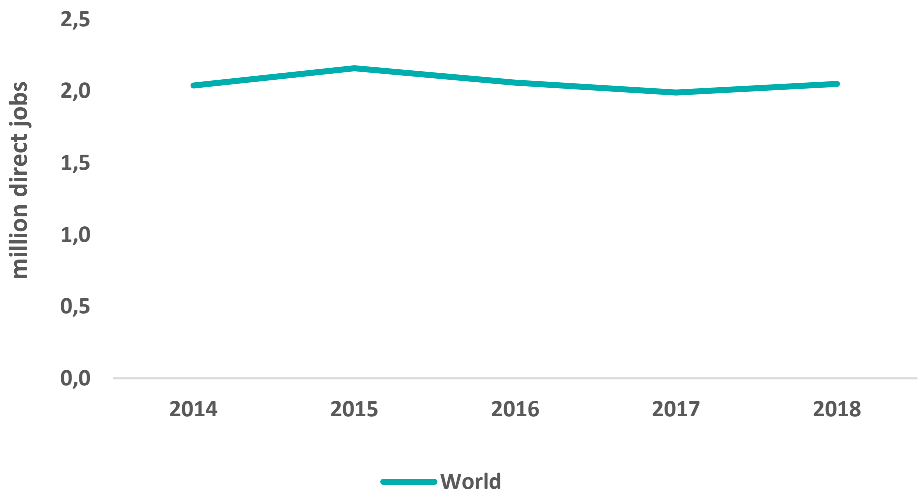
Source: (EurObserv'ER, 2019)

[18] For the heat pump sector no global level employment data was available. Ground-based heat pumps related jobs in the EU are included as part of geothermal energy in global RES employment estimates [see (IRENA, 2019b)].

5.8 Hydropower

Hydropower (including large and small hydro) is the third largest RES employer globally, supporting 2.1 million direct jobs in 2018 (Figure 32). Between 2014 and 2018 employment in hydropower fluctuated around 2 million direct jobs. The sector has the largest installed capacity among RES in the world, with the pace of construction slowing but remaining positive (IRENA, 2019b). In connection to this, more than 70 % of global direct hydropower jobs are in operation and maintenance (IRENA, 2019b).

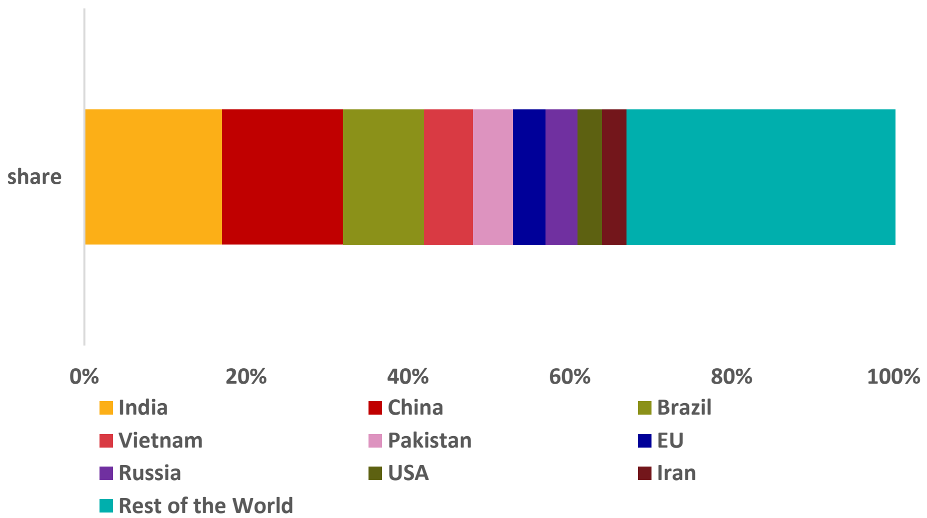
Figure 32 Global employment in hydropower, 2014-2018



Source: (IRENA, 2019b)

India, China and Brazil are in the lead in global hydropower employment. Together they accounted for 42 % of direct jobs in this sector in 2018 (Figure 33).

Figure 33 Hydropower employment by country, 2018

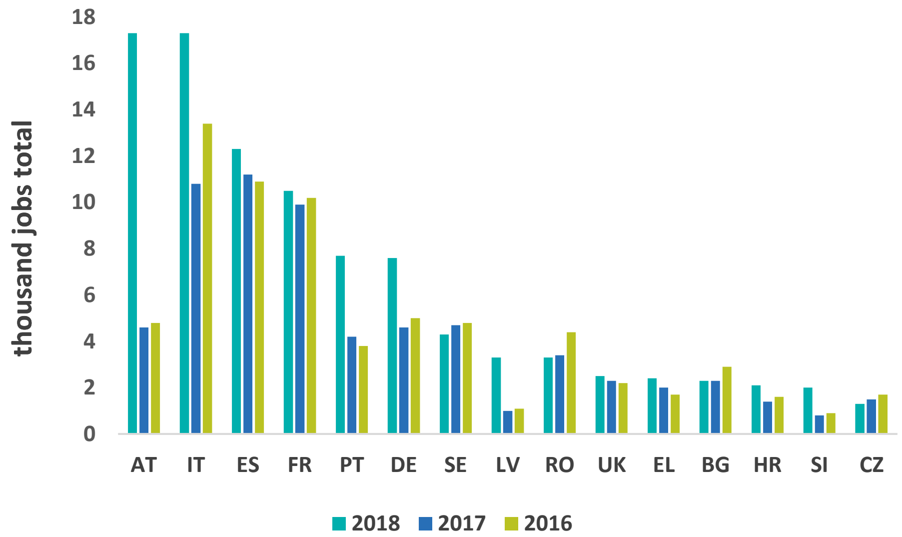


Source: (IRENA, 2019b)

With 102 100 total jobs in 2018, hydropower is the sixth largest employer among RES sectors in the EU-28, following solar PV (Figure 12). Leading countries in hydropower employment in Europe are Italy, Spain and France, joined by Austria in 2018 (Figure 34). Together they accounted for nearly 60 % of total jobs in the sector in the EU-28 that year (Figure 35).

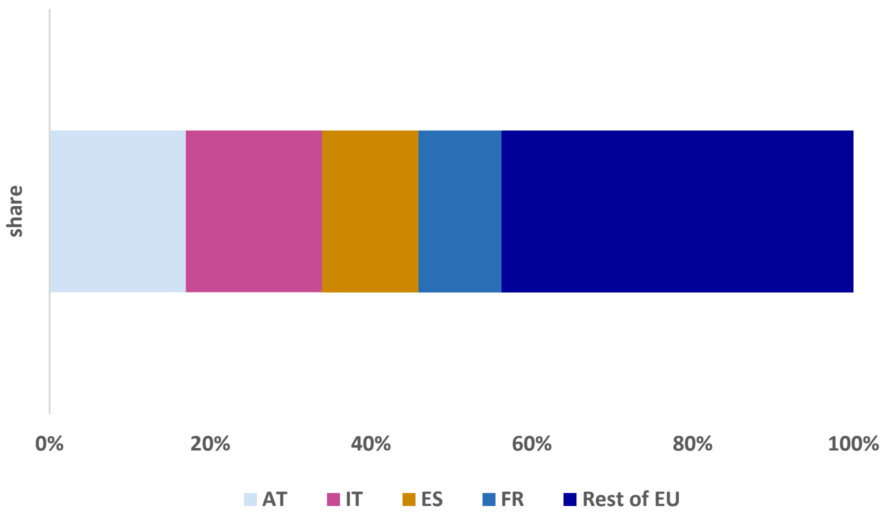
The market for large hydropower is saturated in the EU with limited prospect for new plants, capacity additions concerning mostly smaller installations (around 10 MW capacity). Having said that, in the case of Austria the notable peak in hydropower employment in 2018 was due to the commissioning of the large scale 360 MW Obervermuntwerk II pumped storage power plant.

Figure 34 Hydropower employment in selected EU Member States, 2016-2018



Source: (EurObserv'ER, 2018) (EurObserv'ER, 2019).

Figure 35 Member States' share in hydropower employment, 2018



Source: (EurObserv'ER, 2019)

5.9 Solar thermal and CSP

Solar heating and cooling is a mid-range employer globally among RES sub-sectors. It supported 801 000 total jobs in 2018 (IRENA, 2019b). 84 % of these jobs were in China.

Concentrated solar power (CSP) is the smallest employer globally among RES subs-sectors. It supported 34 000 total jobs in 2018 (IRENA, 2019b). A third of these jobs were in China, while the rest equally distributed between the USA and the EU-28.

Solar heating and cooling is among the smallest RES sub-sectors in terms of employment in Europe. It supported 25 300 total jobs in 2018 in the EU-28 (EurObserv'ER, 2019)[19]. A third of these jobs were in Spain, the European leader in the sector. Nearly 15 % of EU solar heating and cooling jobs were in the second placed Germany.

5.10 Biogas

The biogas sector supported 334 000 total jobs globally in 2018 (IRENA, 2019b). 43 % of these jobs were in China, 25 % in India and 20 % in the EU-28.

In Europe, the biogas sector in terms of employment is seventh in size, following hydropower. It supported 68 800 total jobs in 2018 in the EU-28 (EurObserv'ER, 2019). 45 % of these jobs were in Germany. The runners up Italy and United Kingdom sustained around 10 % of total jobs each in the European biogas industry.

5.11 Waste

At the global level total employment in the municipal and industrial waste sector is estimated to have reached 41 000 jobs in 2018 (IRENA, 2019b).

Renewable municipal waste is one of the smallest RES sub-sectors not only globally but also in Europe. It supported 31 000 total jobs in the EU-28 in 2018 (EurObserv'ER, 2019). 25 % of these jobs were in the leading waste sector employer Germany, while 14 % in the second placed United Kingdom.

5.12 Geothermal energy

Geothermal energy (including both power and heat applications, including heat pumps in the EU) supported 94 000 total jobs in 2018 worldwide (IRENA, 2019b). The United States, China and the EU-28 led in geothermal energy employment.

The geothermal energy sector is also among the smallest RES sub-sectors in the EU-28. It supported 9 500 total jobs in 2018 (EurObserv'ER, 2019). Leading European countries in geothermal energy employment that year were Italy, Romania, France and the Netherlands. Together they accounted for over half of total jobs in this sector in the EU-28 in 2018.

5.13 Ocean energy

Ocean energy (tidal and wave power) is an emerging renewables industry. Global ocean energy employment is estimated to have reached 1 100 total jobs in 2018, principally reflecting employment estimates in the European Union (IRENA, 2019b).

According to other expert estimates, the ocean energy supply chain generated 2 250 jobs in 2016 across Europe (European Commission, 2019c).

[19] EurObserv'ER does not provide separate estimates for employment in the Concentrated Solar Power (CSP) sector. Global estimates for solar heating and cooling may include CSP for some EU countries (IRENA, 2019b).

6 Education and skills

The clean energy and green economic transition are taking place parallel to and in the context of digitalisation. These simultaneously occurring global trends require education and skills responses from policy makers, companies and education institutions alike.

6.1 Skill levels

Climate action favours middle skilled and middle paying jobs overall, and mitigates job polarisation (European Commission, 2019b). Jobs created by the transition to a low-carbon economy in Europe by 2030 are expected to be filled by low to medium educated employees and involve the performance of less advanced tasks (Lewney et al., 2019).

Projected job opportunities reflect a similar pattern regarding jobs polarisation in the context of the oil and natural gas, and the petrochemicals industries in the US: until 2035 a higher demand is expected for skilled and semi-skilled blue collar roles, vis-à-vis both higher skilled white collar and unskilled blue collar roles (API, 2016).

Different skill levels will benefit from different stages of the greening process. Initially higher-skilled roles are favoured (e.g. in technology research). As the green economy develops, demand will increase also for lower-skilled labour. This can occur in waste management and circular economy related sectors (European Commission, 2019b).

At a later stage, parallel to technological improvement, waste management and circular economy related sectors will also be affected by automation, which in turn requires higher skill sets with more digital knowledge (European Commission, 2019b). Demand towards medium- and high-skill sets will increase in the renewable energy sector as well, in connection to automation and remote operation increasing demand for ICT skills. A simultaneous shift in demand towards more multidisciplinary knowledge is also likely in the context of new business models and societal initiatives, including social enterprises.

6.2 Skills mismatch

Currently the process of greening the economy is facing skills mismatches. In 21 of 27 countries surveyed worldwide by the ILO only a few integrate environmental sustainability and skills policies, leading to imbalances between skills offered and skills needed for the green transition (ILO, 2018).

Even if a coordinated skills response is initiated from the national level, regional characteristics might act as barriers. Most EU regions with a high proportion of employment in energy-intensive industries and automotive manufacturing have a tertiary education level below EU average and low participation rates in adult training (European Commission, 2019b). Potential related low participation in up- and reskilling activities will influence the ability and speed of transition of these regions towards greener industries.

6.3 Skills response

The clean energy and green economic transition are taking place parallel to and in the context of digitalisation. These simultaneously occurring global trends require education and skills responses from policy makers, social partners, companies and education institutions alike. This allows students and job seekers to obtain theoretical knowledge, on-the-job training opportunities, as well as information about recruitment needs of companies.

The experience of the BUILD UP Skills[20] initiative running in the European construction sector for nearly a decade confirms the importance of the capacity of mobilising key national stakeholders. This has been highlighted as the absolute prerequisite to establish the credibility of any new training scheme. Other success factors include innovation in the delivery of the training (e.g. e-learning platforms and apps as time-effective and user-friendly ways to convey technical knowledge), fostering better understanding between different crafts and professions,

[20] BUILD UP Skills is a an EU initiative running since 2011 aiming to meet stringent energy efficiency requirements by improving skills in the construction sector. At the first stage it helped to map the skills gaps and needs in each of the 30 participating countries. It focused on the increase of the number of qualified trade professionals by developing national qualification platforms and roadmaps, and by providing training in the field of energy efficiency and renewable energy in buildings. Later the initiative was expanded to develop pilot trainings aimed at other building professionals developing multi-country qualification and training schemes and also address "white collar" professions (engineers, architects, building managers) (European Commission, 2020).

the importance of the training of trainers for successful skills development process, as well as the recognition for the obtained skills (e.g. through public registers of qualified workers) (Berrutto & De Coster-Lacourt, 2018).

Examples of coordinated skills response also arise from Member State level in the EU in different clean energy industries. Publicly initiated vocational training programmes for clean energy technologies were implemented in cooperation with the private sector in Germany. Under the initiative, Enercon, a major player in the German wind power industry tutored apprentices in 20 professions, including commerce, product design, and diverse industrial trades ranging from metalwork to industrial engineering (Hockenos, 2017).

A combination of public and private resources covered the Upskilling and Training Subsidies and Apprenticeship Wages Subsidies programmes as part of the Greenport Hull partnership in the UK (University of Hull, 2017). The partnership was established to attract RES investment in the region, impacted by economic decline. In 2014 Siemens Gamesa confirmed its investment into an offshore wind turbine blade manufacturing facility in the Hull. Upskilling and apprenticeship programmes were launched to make both individuals and employing businesses more competitive in the context of the investment.

In the absence of timely reaction from education institutions and the public sector, companies in clean energy industries have initiated programmes to directly train or retrain workers. Through these initiatives they can quickly develop a local labour force with skill sets relevant for the respective sectors. Former coal workers in Wyoming in the US were retrained by a Chinese investor to obtain the relevant skills for installation, operation and maintenance of new wind farms on former coal mine sites (Cardwell, 2017). In the case of a planned community wind farm in Scotland in the UK, the company implementing the project foresees traineeships targeting young unemployed local people, giving a boost to the local economy (Banks Group, 2017).

Private companies have also taken more coordinated action in order to influence education and skills policy in the context of the clean energy transition. Eleven European associations in the electrical and construction sector formed the '#Skills4Climate Coalition' at the end of 2019, upon the taking of office of the new European Commission (EuropeON, 2019). The Coalition aims to induce policy action in order to overcome skills shortages in the buildings sector in the context of greening and digitalisation. Vocational education and training has been highlighted as often being suboptimal, with outdated curricula not aligned with the needs and technological developments of the industry (European Construction Sector Observatory, 2017). This has relevance both in terms of energy efficiency improvements as well as the integration of renewable energy sources in buildings. Training and qualification schemes have been found to be lacking in novel technologies (such as Building Information Modelling) that are becoming more widespread and expected to bring important benefits in the energy performance of buildings (Berrutto & De Coster-Lacourt, 2018).

The limited, aging and inadequately skilled workforce in the construction sector may create a bottleneck for the building renovation related flagship initiative as part of the new Green Deal for Europe. The call for action addressing policy makers includes points on integration of skills and climate strategies, strengthened public-private partnerships, and provision of incentives for technical education, apprenticeships, as well as up- and reskilling.

6.4 Profiles in demand

Science Technology Engineering and Mathematics (STEM) skills are generally in high demand in the energy sector, and in the clean energy transition.

Top employability skills in the energy industry include business and costumer awareness, problem solving, team working, self-management, application of IT and communication and literacy (LMI Humber, 2019). Digital knowledge and computer skills are not only a requirement in high- and medium-skilled roles. In a career guide for the US oil and gas industry, computer skills are listed among the top ten foundational skills demanded by employers (from high-skilled engineering roles through middle-skilled technicians to low-skilled machinist, as well as construction and transport workers) (ShaleNET, 2013).

In the oil and gas sector traditional disciplines, including subsurface and surface engineering will remain important. Parallel to this demand will increase for software engineers and data scientists in the context of the digital transition. Achieving the right balance of engineers versus technological staff will be a challenge for energy companies (PwC, 2018).

In solar PV, the largest global renewables employer the most sought after occupational profiles are in STEM fields. These include technology researchers at the manufacturing stage of the value chain, electrical, process and structural engineers in project planning, and field technicians in operation and maintenance (KnowRES, 2016).

Skills have proven to be transferable to the energy sector from other industries as well as from the military. Mechanical skills in manufacturing and supervisory skills in road construction can be utilised in the oil and gas sector. Deep-sea exploration and diving skills can be transferred from military applications to the offshore oil and wind sectors. Skills are also transferable between conventional energy and clean energy sectors. Skills transferability to solar PV from other sectors is high. Possible origins include the automotive, architecture, construction and recycling sectors (KnowRES, 2016).

Mechanical skills and sophisticated safety experience of some occupations in the coal sector, as well as the experience of coal workers in operating under difficult conditions were highlighted as making them attractive potential candidates for the wind and solar PV industries (Pearce, 2016). At the same time, advanced digital technology will improve the efficiency of predictive maintenance, including the use of drones to inspect offshore platforms. This will in turn reduce workers' exposure to hazardous tasks (PwC, 2018). Digital skills will be in demand in order to be able to operate these devices.

7 Workforce characteristics

The energy sector faces the challenge of being able to draw from a large enough talent pool with the right skill sets in a changing landscape of work. Within this context, renewable and conventional energy sectors have different public perceptions. Renewables industries have a more positive image, especially among women and young people (EY, 2017). Conventional energy industries are male dominated and characterized by an aging workforce. Bringing more people in the energy labour force by expanding towards different talent profiles, including women and younger age cohorts with increasingly digitally focused skill sets, will be essential in the energy sector in the green transition. The following sections aim to highlight key influences affecting energy sector employment from a gender and intergenerational perspective.

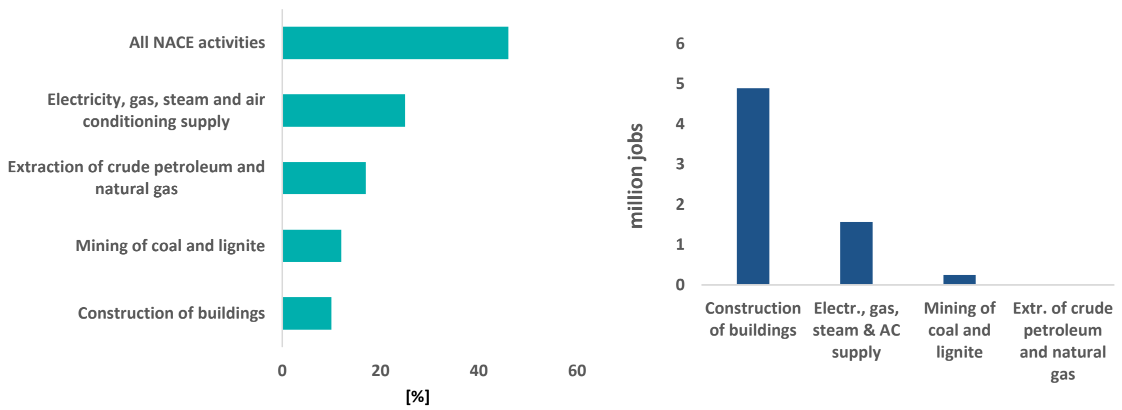
7.1 Gender aspects

Globally the labour force participation of women is much lower than that of men. In 2018, 60 % of the 3.5 billion people constituting the global labour force were men (ILO, 2019). The participation of women in the labour force is strongly influenced by cultural and social norms. Accordingly, the gender gap in labour force participation varies according to region and sector. The effect of gender diversity on company performance is influenced by normative acceptance: increase in productivity is more likely to occur in cultural contexts where there is widespread belief that gender diversity is important, creating a self-fulfilling cycle (Turban et al., 2019).

The energy industry, especially conventional energy sectors are male dominated. Renewables industries are more appealing to the female workforce due to their multidisciplinary dimension, as well as the holistic, democratised energy future that they represent (IRENA, 2019a). In the energy access context, in off-grid, local productive applications of electricity, in rural settings, women are better represented than in the "modern" renewable energy sector as a whole. Only 22 % of the workforce of conventional energy sectors are female globally, while in the renewables industry 32 % of the workforce are women (IRENA, 2019b).

Further differentiation is apparent by sub-sector and region. In the global oil and gas industry the vast majority, 92 % of workers are men (Airswift, 2019). Only 21 % of the global wind labour force is female, in the presence of regional differences: while in Europe and North America the share of women in the wind energy sector is 26 %, in Africa only 8 % (IRENA, 2020b).

Figure 36 Women's share in employment in selected economic activities and women's employment in the same sectors, EU-28, 2018



Source: Eurostat [lfsa_egan22d][21]

A quarter of the workforce in 'electricity, gas, steam and air conditioning supply[22]' was female in the EU-28 in 2018 (Figure 36). This is well below women's representation across all economic activities, at 46 % in the same

[21] In this section Labour Force Survey data was used as it is provides gender specific employment breakdown by economic activity. However, due to difference of methodology and sample size, the Labour Force Survey presents larger employment figures than Structural Business Statistics (European Commission, 2019a). The latter was used in previous sections of the report as it is considered a better approximation of direct jobs.

[22] Covering energy supply from both renewable and conventional sources.

year. In extractive fossil fuel industries the share of female employees is even lower (12 % in 'coal and lignite mining' and 17 % in 'crude petroleum and natural gas extraction'). The construction of buildings, a larger sector in terms of employment overall with large potential for employment creation in the green economic transition, women constitute only 10 % of the labour force in the EU-28.

Women face a range of barriers when trying to enter and advance in both the conventional and renewable energy sectors. The perception of gender roles and industry-wide workplace culture remain the most important barriers to entry for women in energy (BCG & WONY, 2018; Clancy & Feenstra, 2019; EBRD, 2019; IRENA, 2019a). Besides recruitment, other areas where women face challenges in the wider energy sector include retention, promotion, advancement, and leadership (BCG & WONY, 2018; IEA, 2017).

Networking initiatives are launched worldwide to assist women in overcoming entry and career advancement related barriers in the energy sector. They do so by offering platforms to exchange experience, structured mentoring activities and trainings, as well as study visits to energy infrastructure installations and energy companies. These networks contribute to widening the talent pool by retaining women who already entered in the energy workforce and attracting new entrants. Women in Renewable Industries and Sustainable Energy (WRISE) is a US-based initiative launched in 2005 that expanded its original focus from the wind sector. Regional and national examples include Women in Energy in Central Eastern Europe and the Ethiopian Women in Energy Network, among others.

An important aspect in women's participation in the energy workforce is the types of job roles they fill. Women dominate clerical, administrative, paralegal, human resource and public relations related roles in the energy sector. At the same time, they are underrepresented in highly specialised technical roles that tend to be more connected to better career advancement opportunities in the sector. In the global renewable energy industry only 28 % of STEM job roles, while 45 % of administrative roles are filled by women (IRENA, 2019b). In upstream oil and gas industry operations and investment in the US, 71 % of office and administrative support roles were estimated to be filled by female employees in 2015 (API, 2016).

The underrepresentation of women in technical roles in the energy sector is closely connected to the underrepresentation of female students in STEM education. In 'Information and Communication Technologies' only 20 % and in 'Engineering, manufacturing and construction' only 27 % of total graduates were female at Bachelors or equivalent level in 2017 in the EU-28[23]. 'Natural sciences, mathematics and statistics' fields have a more gender balanced distribution of graduates.

In male-dominated fields such as STEM the chances of women finding employment in same field in which they graduated is significantly lower than it is for men. At vocational education level it is even more so than at tertiary level (European Commission, 2018a). Therefore, women graduating in STEM fields need to be supported in entering the job market and staying in their field. The involvement of women in the renewable energy sector can be encouraged by visibility of women in STEM, mentoring and networking programmes, as well as corporate responsibility (Clancy & Feenstra, 2019).

The demand for STEM professionals and associate professionals is expected to grow by 8 %, while on average for all occupations by 3 %, between 2014 and 2025 (CEDEFOP, 2014). STEM fields will therefore need a steady supply of workforce. Attracting more women to study in STEM fields will on the one hand help increase the number of graduates in these fields. On the other hand, gender balance in terms of access to well-paid and rising in demand STEM jobs can improve.

Decision to study in STEM fields is formed early and becomes progressively more difficult to change as children get older (Clancy & Feenstra, 2019). Therefore, participation of female students in STEM education should be encouraged already from at least middle school, as surveys mapping the energy sector from a gender perspective reveal (Airswift, 2019; BCG & WONY, 2018; IRENA, 2019a).

Initiatives already exist that point in the direction of more inclusive STEM education. In the context of the offshore wind energy sector in the UK, mainly male workers took place in the upskilling and wage subsidies for apprenticeships programmes at Greenport Hull (University of Hull, 2017). To provide greater diversity additional programmes were launched targeting underrepresented groups, including Women in Manufacturing and Engineering (WiME).

[23] Eurostat [educ_uoe_grad02]

7.2 Generational aspects

The energy industry faces the double challenge of an aging workforce and the changing skills needs resulting from digitalisation. Around 40 % of oil and gas companies in North America and Europe say the talent crisis is already here (Airswift, 2019).

Younger age cohorts[24] are underrepresented in clean energy industries and even more so in conventional energy sectors. They approach work differently than previous generations in the sense that they are generally more educated, more concerned about equality, less motivated by money, less loyal to a single employer, more task orientated, and more tech-savvy (Oosterhuis & Adams, 2018).

According to a global survey, 4 % of workers in the oil and gas industry are aged between 18-24, while 20 % are over 55 (Airswift, 2019)[25]. An aging workforce is more of an issue in the upstream oil and gas sector (Sumbal et al., 2017). In the Netherlands, where renewables related age-disaggregated employment data is available, the average age of workers in the clean energy sector is between the relatively high average age of the conventional energy sector and the average age in total Dutch enterprises (Economisch Inistituut voor de Bouw, 2016).

A negative environmental and social image is impacting conventional energy sectors when recruiting new talent. According to an assessment conducted in the USA, the oil and gas industry is not attractive among younger generations, especially women, due to its impact on both the environment and society in general (EY, 2017). Layoffs in the oil and gas industry following the 2008 financial crises led to concerns about job security in the sector, reinforcing its negative image among potential recruits. At the same time there is not enough action in the oil and gas industry to prevent knowledge loss from former employees when layoffs take place (Sumbal et al., 2017).

The construction sector in the EU is also characterized by lack of attractiveness to younger workers, while the participation of women and gender inclusiveness have experienced and increase. Multiple initiatives are in place in the EU to improve the attractiveness of the construction sector to younger workers, as well as to incentivize apprenticeships and improve the quality of vocational training programmes (European Construction Sector Observatory, 2017).

Willingness to participate in reskilling, upskilling and adult education is an important factor in the successful transition of regions from fossil fuels and energy intensive industries towards a greener economy. There is indication that members of younger age cohorts are more open to upskilling and reskilling initiatives. As part of a training subsidies programme in the offshore wind sector in the UK, 80 % of people trained were under the age of 39 ('Millennials') and 45 % of people trained were under the age of 25 ('Generation Z') (University of Hull, 2017).

In high income European countries and likely also in other high-income countries, the COVID-19–induced labour market shock is disproportionately borne by young and poorly educated workers (Garrotte Sanchez et al., 2020). These workers are already employed in low-paying jobs, live in regions that are already lagging and are subject to a greater prevalence of temporary employment contracts.

[24] Younger generations comprise 'Millennials' also known as 'Generation Y', and 'Generation Z'. The former is the demographic cohort born between 1981 and 1996, the latter is demographic cohort born between 1996 and 2010.

[25] Based on the Global Energy Talent Index (GETI) Report, a global energy talent survey involving 21 000 professionals and hiring managers from 169 countries and 151 nationalities (GETI, 2020).

8 Conclusions

The green economic transition is underway within the context of policy efforts to act against climate change. As part of this process, the energy sector is also undergoing a significant transition. Renewable energy industries as key components of the green economic transition are expanding. Fossil fuel sectors have registered job losses in some parts of the world, including in Europe. On the demand side of the energy system the buildings sector has substantial energy saving potential and consequently the construction industry has energy efficient employment creation potential.

This report provided an overview of employment trends at the global and EU level related to the greening and decarbonisation of the economy, with a focus on the energy sector. A solid and coherent method to track employment impacts of the green economic transition is lacking. Therefore, figures presented from different sources in this report are not directly comparable due to the different methodologies and underlying assumptions.

18 million net jobs can be created by 2030 worldwide by limiting global warming to 2°C by the end of the century (ILO, 2018). A full implementation of the Paris agreement could create additional 1.2 million jobs in the EU as a whole by 2030 (European Commission, 2019b). Sectors benefiting in terms of employment from the green transition include construction, electrical machinery manufacturing, copper mining, renewable energy production, biomass crop cultivation, transport and services (European Commission, 2019b; ILO, 2018). The outbreak of the COVID-19 coronavirus crisis in early 2020 puts this in new light, creating opportunity for an accelerated green transition parallel to economic and social recovery.

Employment in the broad energy sector, comprising fossil fuels and renewables sectors, as well as energy flexibility and grid development, is expected to reach 87 to 100 million total jobs by 2050, depending on the ambition of decarbonisation policies (IRENA, 2020a). Renewable energy employment is increasing globally. It reached 11 million total jobs in 2018 (IRENA, 2019b).

A net positive employment effect of energy efficiency in the EU-28 until 2030 was estimated by different studies relying on different methodologies and assumptions to be in the range of 0.41 – 4.8 million.

Solar PV, bioenergy and hydropower are the largest employers in renewables globally. 80 % of global renewable energy jobs are in these sectors. A third of global RES jobs are in the solar PV sector. China is the largest RES employer, accounting for 37 % of total RES jobs in the world (IRENA, 2019b). More than half of Chinese RES jobs are in the solar PV sector. Parallel to increasing deployment, PV manufacturing has also shifted to China and other Asian countries, while decreasing in Europe. A similar shift may occur in the wind industry.

Employment in the EU energy supply sector as a whole has been decreasing over the past decade, supporting over 1.6 million direct jobs in 2017 (European Commission, 2019a). Direct employment in fossil fuel extraction and related activities has been decreasing in this period. Overall, direct employment in coal as well as oil and gas related extractive and processing activities stood at 367 000 jobs in 2017 in the EU-28 (European Commission, 2019a).

Direct employment in the production of energy from renewable sources reached nearly 660 000 jobs in 2016 in the EU-28[26]. The number of directly employed in the EU RES sector peaked at 900 000 in 2011 and returned to 2009 levels by 2016. The aftermath of the 2008 financial crisis, moving of some renewables manufacturing capacities outside of Europe, as well as the change in the subsidisation of renewables within the EU are underlying factors.

With reference to total employment (direct at the establishment and indirect within the value chain), the EU renewables sector accounted for over 1.5 million jobs in 2018 (EurObserv'ER, 2019). Over three-fourth of total European RES job were in the solid biomass, wind, liquid biofuels and heat pumps sectors. Solid biomass and wind together accounted for nearly half of total European RES jobs.

Over half of total RES jobs in the EU are located in Germany, Spain, France, the United Kingdom and Italy. Germany alone accounts for nearly a fifth of total EU RES jobs. At the same time, the leaders in renewables jobs per capita are less populous Member States, including Latvia, Estonia, Denmark and Finland.

The workforce in the energy industry, especially in conventional energy sectors is male dominated and is aging. While younger age cohorts are underrepresented in the energy sector, they are characterized by higher

[26] Eurostat [env_ac_egss1]

willingness to participate in upskilling and reskilling programmes. Lower willingness of members of older cohorts to participate in adult learning can exacerbate the situation in regions with declining industries, including the extraction of fossil fuels.

STEM profiles and digital skills are in high demand in the energy industry as a whole. An increase in demand for more multidisciplinary knowledge is also likely in the context of new business models and societal initiatives. By addressing gender imbalance already present in STEM education, the number of women working in the energy industry can be increased, as well as overall available workforce in the energy sector.

Policy recommendations

Policymakers in the context of a just green transition should

- *develop and implement strategies in an integrated manner* in order to appropriately address complex impacts (e.g. climate, employment, social, education and skills, regional, digital, industrial strategies).
- *ensure the provision of coordinated social and professional reskilling/upskilling support in declining sectors and regions.* This is relevant both in case employees have to leave the active labour force, as well as in the process of entering other, including greening economic sectors.

The public and private sectors should take coordinated action, where appropriate in the form of public-private partnerships to

- *facilitate sub-sector, gender and age disaggregated data collection in the energy industry* in a comparable manner across the EU and globally, in order to better understand labour force characteristics and needs.
- *improve and adapt STEM education profiles* to market demand in the context of the expanding green economy.
- *improve visibility and wider perception, incentivise STEM education* both for men and women already from a young age.
- *increase the availability of apprenticeships, as well as up- and reskilling programmes* to ensure that enough job seekers with the required skill sets are available for the energy industry.

The private sector should take action to

- *better attract underrepresented workforce categories in the energy industry*. These include female and millennial job seekers. This is expected to increase the number of suitable candidates, provide better access to energy jobs for a more diverse population, as well as to help overcome the challenges posed by an aging energy workforce.
- *improve policies to retain knowledge* from workforce leaving the energy industry.

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List of abbreviations and definitions

CGE	Computable General Equilibrium model
CSP	Concentrated Solar Power
EED	Energy Efficiency Directive
EGSS	Environmental Goods and Services Sector
EPBD	Energy Performance of Buildings Directive
FDI	Foreign Direct Investment
FTE	Full-time Equivalent
GETI	Global Energy Talent Index
ILO	International Labour Organization
I-O	Input-Output model
IRENA	International Renewable Energy Agency
LFS	Labour Force Survey
MS	Member State
PV	Photovoltaic
RES	Renewable Energy Source
SBS	Structural Business Statistics Survey
STEM	Science, Technology, Engineering and Mathematics

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Annexes

Annex 1. Key concepts and methodological approaches

Key concepts in employment assessment include the differentiation between direct, indirect and induced employment effects, as well as gross and net employment effects. These effects can be assessed with different methodological approaches, ranging from employment factor based calculations to complex models.

In the context of the green economic transition, employment can be created directly within a specific sector, indirectly in supplying industries along the technology value chain, or induced within the wider economy. Changes in direct and indirect employment affect household income and spending along a specific technology value chain. This in turn affects consumption and final demand for products in other industries, inducing wider employment effects in the economy as a whole. Gross employment effects do not take into account changes in the number of jobs in other sectors, while the concept of net employment covers economy wide changes in employment.

Direct and indirect employment effects in a given sector in the present and future can be assessed using analytical models based on employment factors and multipliers. This bottom-up approach is not suitable to estimate changes in net employment in the economy as a whole, which requires cross-sectoral analysis. Input-Output (I-O) models, full macro-econometric models and computable general equilibrium (CGE) models enable the top-down assessment of economy wide net employment effects. This allows analysing the change in economic activity in all sectors.

Analytical models are less resource intensive and provide clear information about direct employment effects in a specific sector, covering gross employment effects only. While I-O, macro and CGE models have an economy-wide scope and cover both gross and net effects, they heavily rely on assumptions and are more resource intensive. The underlying complex set of assumptions, different system model borders and modelling approaches, policy scenarios and feed-back mechanisms cause problems regarding the comparability of results.

It is difficult to calibrate assessment methodologies against time series data, or even against current data in some regions, as quantitative data on present employment based on actual surveys is often not available (Rutovitz et al., 2015). Bottom-up and top-down modelling approaches can be applied in parallel, drawing on their respective strengths to fine-tune employment impact estimations (although this also has resource implications).

Annex 2. Recurring data sources

In the context of the transition to a green economy, employment in renewable energy industries is the best documented compared to other sectors. At the global level the International Renewable Energy Agency (IRENA), and at the European level the EurObserv'ER project has been publishing RES employment estimates on an annual basis for nearly a decade. Eurostat and some national statistical offices also publish energy, renewables and energy efficiency related employment figures. Methodologies used by these sources differ.

IRENA

IRENA publishes renewable energy employment estimates on an annual basis since 2013 (first year for which data is available being 2012). Employment figures are a result of a comprehensive review of primary (national ministries and statistical agencies) and secondary (regional and global studies) data sources. Econometric models are also used in some cases (e.g. to estimate employment in the hydropower sector in 2018 an econometric model was used based on capacity data, employment factors, and various national estimates and statistics).

In addition to the annual renewable energy and jobs reports, time series employment data globally per technology starting with year 2012, and country specific information for the latest year is available online as part of the REsource IRENA Dashboards (IRENA, n.d.).

EurObserv'ER

The EU-funded EurObserv'ER project has been publishing RES employment estimates for the EU Member States since 2011 (first year for which data is available being 2010). Until 2016 estimates were mainly based on primary data from government entities, statistical offices and industry organisations. Starting with the 2017 edition of the EurObserv'ER annual report RES employment estimates are based on a new methodological approach that focuses on money flows from four distinct activities:

- Investments in new installations;
- Operation and maintenance activities for existing plants including the newly added plants;
- Production and trading of renewable energy equipment;
- Production and trading of biomass feedstock.

Further details about the new EurObserv'ER RES employment estimation methodology have been published in a separate report (Marsidi et al., 2017).

For the year 2016 EurObserv'ER RES employment estimates are available based on both the old and the new methodological approach. This report focuses mostly on years covered by the new EurObserv'ER methodology (2016-2018) when discussing employment in different RES sub-sectors in the EU.

Eurostat

Eurostat publishes figures on the number of persons employed in the broader energy sector in the EU based on information collected in the Structural Business Statistics Survey (SBS) and the Labour Force Survey (LFS). The unit of analysis of the SBS is the enterprise, which carries out one or more economic activities at one or more locations and may comprise one or more legal units. The unit of analysis of the LFS are persons aged 15 years and over and living in private households. In SBS and LFS based energy employment figures the production of electricity in not broken down according to energy sub-sector (according to conventional and renewable sources). Due to difference of methodology and sample size, the LFS presents larger employment figures than SBS (European Commission, 2019a).

Eurostat provides information on EU renewable energy employment as part of the environmental accounts, in the Environmental Goods and Services Sector (EGSS). In EGSS information is reported on the production of goods and services that have been specifically designed and produced for the purpose of environmental protection or resource management. The unit of analysis in EGSS is the establishment. The establishment is an enterprise or part of an enterprise that is situated in a single location and in which a single activity is carried out or in which the principal productive activity accounts for most of the value added. In this sense it is a narrower category than the concept of enterprise used in the SBS.

As comprehensive surveys would be too costly, EGSS data is estimated by combining data from different sources (SBS, PRODCOM[27] and National Accounts) (Eurostat, 2016). EGSS data is broken down by Member State, environmental domain and NACE[28] sector. Renewable energy sub-sector specific breakdown is not provided for employment. Data gaps remain in RES relevant EGSS categories for several MS.

Eurostat also publishes employment figures that are relevant with regards to energy efficiency. However, similarly to renewable energies, it is difficult to isolate the relevant activities within economic sectors according to currently used statistical classifications.

The construction sector as a whole comprises the categories ‘specialised construction activities’, ‘construction of buildings’ and ‘civil engineering’ (approximately 60 %, 26 % and 13 % of construction as a whole, respectively, ranked on value added) (Eurostat, 2015). Energy efficiency related employment may occur in the construction of new buildings and in some specialized construction activities (also known as ‘special trades’). ‘Specialized construction activities’ are usually specialised in one aspect common to different structures, requiring specialized skills. The category includes within a wider range of activities renovation work and energy retrofits including thermal insulation, and installation activities related to heating and air conditioning. However, the exact share of energy efficiency employment within the broader category is not defined. The EGSS category ‘heat/energy saving and management’ is also relevant for energy efficiency.

[27] Community Production

[28] NACE - Statistical Classification of Economic Activities in the European Community.

Annex 3. Overview table

Table 4 Overview table of data sources

Source	Type	Scope	Sectorial coverage	Method	Time fame
IRENA Renewable Energy and Jobs: Annual Review	Annual publication (first edition in 2013)	Global	RES sub-sectors	Comprehensive review of primary and secondary data sources	Historical data[29]
EurObserv'ER Annual overview barometer – The State of Renewable Energies in Europe	Annual publication (first edition in 2011)	EU-28	RES sub-sectors	Since 2017 modelling approach focusing on money flows (until 2016, review of primary data sources)	Historical data
Eurostat – EC EU Energy in Figures Statistical Pocketbook	Annual publication	EU-28	Energy sector RES (no sub-sectoral breakdown)	Surveys – SBS, LFS EGSS – estimation based on SBS, PRODCOM, National Accounts	Historical data
ILO (2018)	Report	Global	Green economy (energy, agriculture, circular economy)	Multi-regional I-O tables	Forecast until 2030
IRENA (2020a)	Report	Global	Energy system, power system, RES	Integrated global macro-econometric model linking energy, environment, economy	Forecast until 2050
Alves Dias et al. (2018)	Report	EU-28	Coal	Analytical	2017 estimate
European Commission (2019c)	Report (covering blue economy as a whole)	EU-28	Ocean energy (tidal and wave)	Analytical	2016 estimate

[29] In the 2019 edition a macroeconomic model was introduced to estimate direct jobs in the hydropower sector.

Deloitte (2019)	Report	EU-28	Nuclear	CGE model	2019 estimate
Cambridge Econometrics (2016)	Report	EU-28	Energy efficiency in buildings (EPBD review)	Macro-econometric model and CGE model	Forecast until 2030
European Commission (2016)	Impact Assessment	EU-28	Energy efficiency (EED review)	Macro-econometric model and CGE model	Forecast until 2030
Naess-Schmidt et al. (2018)	Report	EU-28	Energy efficiency	I-O model and CGE model	Forecast until 2030 and longer term
Lewney et al. (2019)	Report	EU-28	Transition to a low-carbon economy	Macro-econometric model	Forecast until 2030

KJ-NA-30186 EN-N

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of the European Union

doi:10.2760/95180

ISBN 978-92-76-18206-1