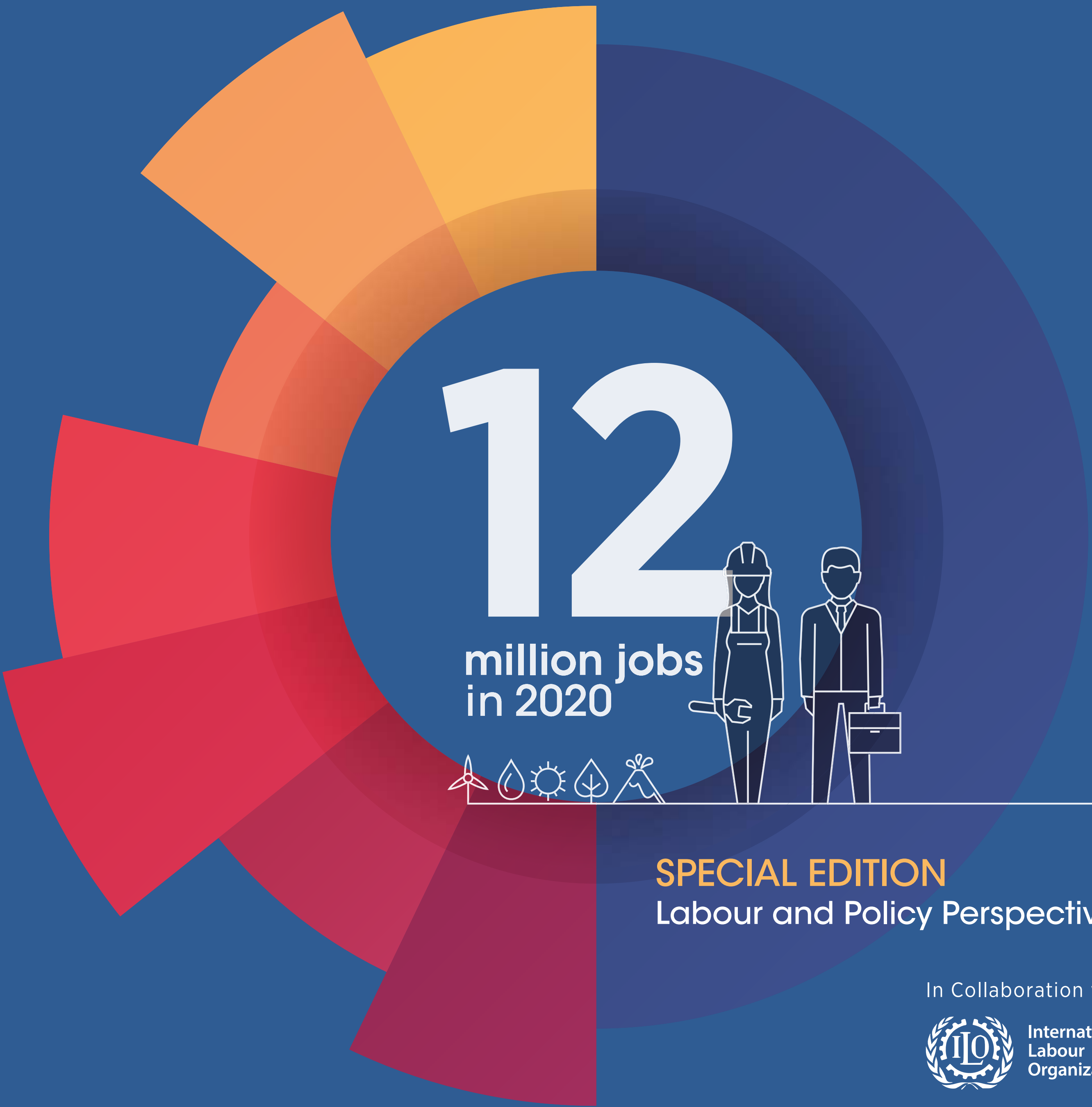
IRENA
International Renewable Energy Agency

Renewable Energy and Jobs
Annual Review 2021



SPECIAL EDITION
Labour and Policy Perspectives

In Collaboration with
International Labour Organization

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ABOUT IRENA

The International Renewable Energy Agency (IRENA) serves as the principal platform for international co-operation, a centre of excellence, a repository of policy, technology, resource and financial knowledge, and a driver of action on the ground to advance the transformation of the global energy system. A global intergovernmental organisation established in 2011, IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security, and low-carbon economic growth and prosperity.

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ABOUT ILO

The only tripartite U.N. agency, since 1919 the ILO brings together governments, employers and workers of 187 member States, to set labour standards, develop policies and devise programmes promoting decent work for all women and men.

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FOREWORD

The year 2020 demonstrated that not even a global pandemic can slow the advance of renewable energy. It also revealed the tight connections between environments, economies and human well-being. These, and the rapidly rising challenges of climate change, reinforce the need for a just and inclusive transition toward a clean, reliable energy supply and decent and climate-friendly jobs. That transition is well under way: Last year jobs in the renewable energy sector grew to 12 million.

The 1.5°C pathway put forward by the International Renewable Energy Agency (IRENA) in its *World Energy Transitions Outlook* will lead to 122 million energy sector jobs globally by 2050 (of which 43 million will be in renewables) and will set the conditions for long-term economic resilience, development and equality. Solar photovoltaics will provide the most jobs by 2050 (20 million), followed by bioenergy, wind and hydropower.

Renewable energy employment has been on an upward trajectory since IRENA's first jobs report in 2012. Then as now, solar photovoltaics has led the field, accounting for some 4 million jobs today. Large-scale solar facilities feed power to the grid, while small, off-grid solar applications offer much-needed access to electricity to remote and energy-poor communities. Although off-grid sales took a hit from COVID-19 in 2020, off-grid solutions will continue to power farming, food processing, education and health care.

Bioenergy employed some 3.5 million people and hydropower another 2.2 million. Wind energy follows with 1.25 million jobs, with a growing number in operations and maintenance and in offshore wind energy. The wind sector's workforce is still male dominated; only a fifth of workers are women, comparable to the traditional oil and gas industry. The renewable energy sector as a whole shows a better gender balance (32% women). Yet, much remains to be done to ensure that the industry benefits fully from women's skills, talents and ideas.

The energy transition has revealed the need to expand skills in all regions of the world to create a capable renewable energy workforce. Meeting that need will require more vocational training, stronger curricula and greater training of trainers. Making use of digital innovations in teaching is another task, especially in light of the pandemic.

Decent jobs will not be created automatically in the energy transition; ambitious policy support and investments in a future-oriented, climate-safe and just energy transition will need to be sustained and expanded. IRENA is working to operationalise policy commitments for job creation in the sector.

Comprehensive policy frameworks grounded in effective social dialogue must use labour market incentives to open new possibilities for workers who lose jobs in conventional energy, along with industrial and enterprise policies to leverage existing domestic industries. Social protection measures may be needed in the interim and subsequently. The ILO tripartite *Guidelines for a just transition towards environmentally sustainable economies and societies for all* offer an important framework to further promote decent work and social justice in the energy transition, addressing all aspects from the quantity to the quality of employment.

The ongoing energy transition is poised to be one of history's great success stories if the world is indeed able to accelerate increase its speed and scale through a holistic approach.

Francesco La Camera

Director-General

International Renewable Energy Agency

Guy Ryder

Director-General

International Labour Organization

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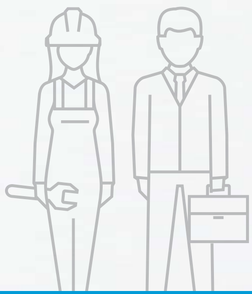

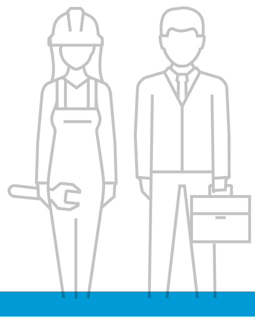

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KEY NUMBERS

12 million renewable energy jobs in 2020

39% in China

4 million jobs in the solar PV industry

32% of renewable energy jobs are held by women

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KEY FACTS

- Renewables fared better than conventional energy during the COVID-19 pandemic, but impacts were uneven among individual countries, technologies and segments of the value chain. Employment in 2020 was shaped first by delays and later by surges in activity.
- Worldwide employment in renewable energy was estimated at 12 million in 2020, up from 11.5 million in 2019.
- At 4 million workers, the solar PV industry employs a third of the total renewable energy workforce.
- Sales of off-grid solar PV equipment suffered because of COVID-19. Companies managed to avoid layoffs in many cases.
- Biofuels jobs worldwide fell slightly to 2.4 million (from 2.5 million), owing to COVID-19–driven reductions in demand, lower prices for conventional transport fuels and some adverse policy changes.
- Wind power supports 1.25 million jobs. The offshore segment is gaining prominence, as multiple countries build or expand their domestic industrial base.
- The integration of local content and local employment remains a challenge, particularly in wind energy, and requires further efforts in contracting arrangements, technical development and co-operation, and local capacity development.
- Decent jobs – good wages, safe workplaces and workers' rights – are a must for a just transition. Outcomes depend on enforcing internationally recognised labour standards, national legislation and collective bargaining arrangements in individual industries.
- Women account for one-third of the global renewables workforce, but their participation varies widely among countries and industries. The pandemic has had a negative impact on gender equity.
- Along with gender equity, adequate opportunities for youth and greater inclusion of minorities and marginalised groups are the keys to developing a workforce that reflects society at large.

KEY PROJECTIONS

Under IRENA's 1.5°C-compatible global pathway, the renewable energy sector could account for 38 million jobs by 2030 and 43 million by 2050, double the number under current policies and pledges.

Jobs in the energy sector as a whole will grow to 122 million in 2050 under the 1.5°C pathway, compared with 114 million under current policies and pledges.

As is the case today, solar will make up the largest share of renewable energy jobs in 2050, with 19.9 million jobs, followed by bioenergy (13.7 million), wind (5.5 million) and hydropower (3.7 million).

RENEWABLE ENERGY JOBS

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This eighth edition of IRENA's *Renewable Energy and Jobs – Annual Review* series provides the most recent estimates of renewable energy employment. It is part of IRENA's ongoing effort to refine and improve underlying data. In addition to IRENA's employment factor calculations, the reported job numbers are based on a wide range of studies and reports by government agencies, industry associations, non-governmental organisations and academic experts, with information of varying focus, detail and quality.

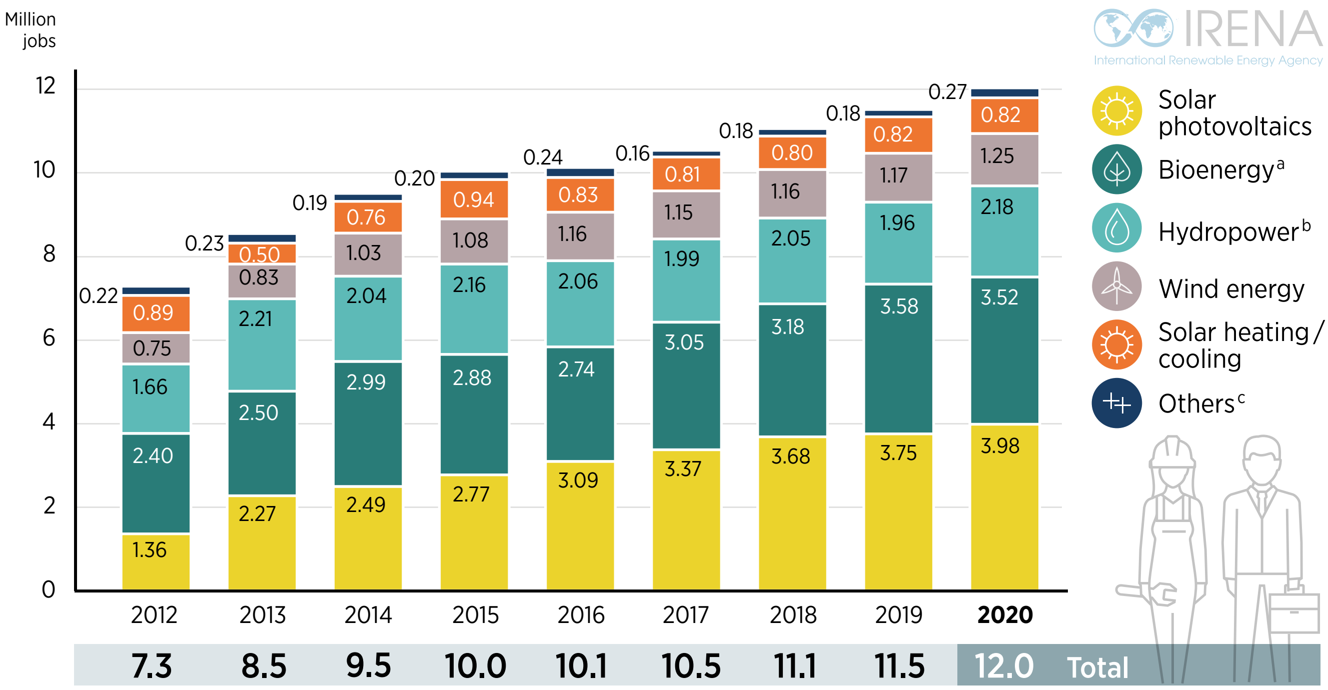
This special edition, co-published with the International Labour Organization, expands on the scope of earlier editions. Following a discussion of impacts of the COVID-19 pandemic, Chapter 1 surveys the renewable energy employment landscape as of 2020, with findings at the global level and for individual industry segments. It then discusses employment results for selected countries in relation to deployment trends, policy contexts and pandemic impacts, with an eye to job quality as well as job numbers.

The need to accelerate the energy transition through expanded use of renewables is evident in the face of a growing number of extreme weather events and other repercussions of climate change. Ambitious policy action in response to these realities will translate into more jobs in renewables, as indicated by IRENA's *World Energy Transitions Outlook*. Chapter 2 offers key employment findings from the *Outlook*'s scenarios for 2030 and 2050. Education and skills training, including efforts to retrain workers from fossil fuel industries, will be essential to building the workforce of the future. Chapter 3 presents key challenges and opportunities in this regard. Skills training is among the broad array of policies needed to create large numbers of good jobs, develop a diverse workforce and address other aspects of the unfolding energy transition. Finally, Chapter 4 examines priority actions within a holistic policy framework and considers the kinds of jobs that are likely to be created.

Chapter 1. RENEWABLE ENERGY JOBS: MAIN FINDINGS

The renewable energy sector employed 12 million people, directly and indirectly, in 2020.[1] The number has continued to grow worldwide over the past decade. The solar photovoltaic (PV), bioenergy, hydropower and wind power industries have been the largest employers. Figure 1 shows the evolution of IRENA's renewable energy employment estimates since 2012.[2]

Figure 1. Global renewable energy employment by technology, 2012-20



a Includes liquid biofuels, solid biomass and biogas.
b Direct jobs only.
c "Others" includes geothermal energy, concentrated solar power, heat pumps (ground based), municipal and industrial waste, and ocean energy.

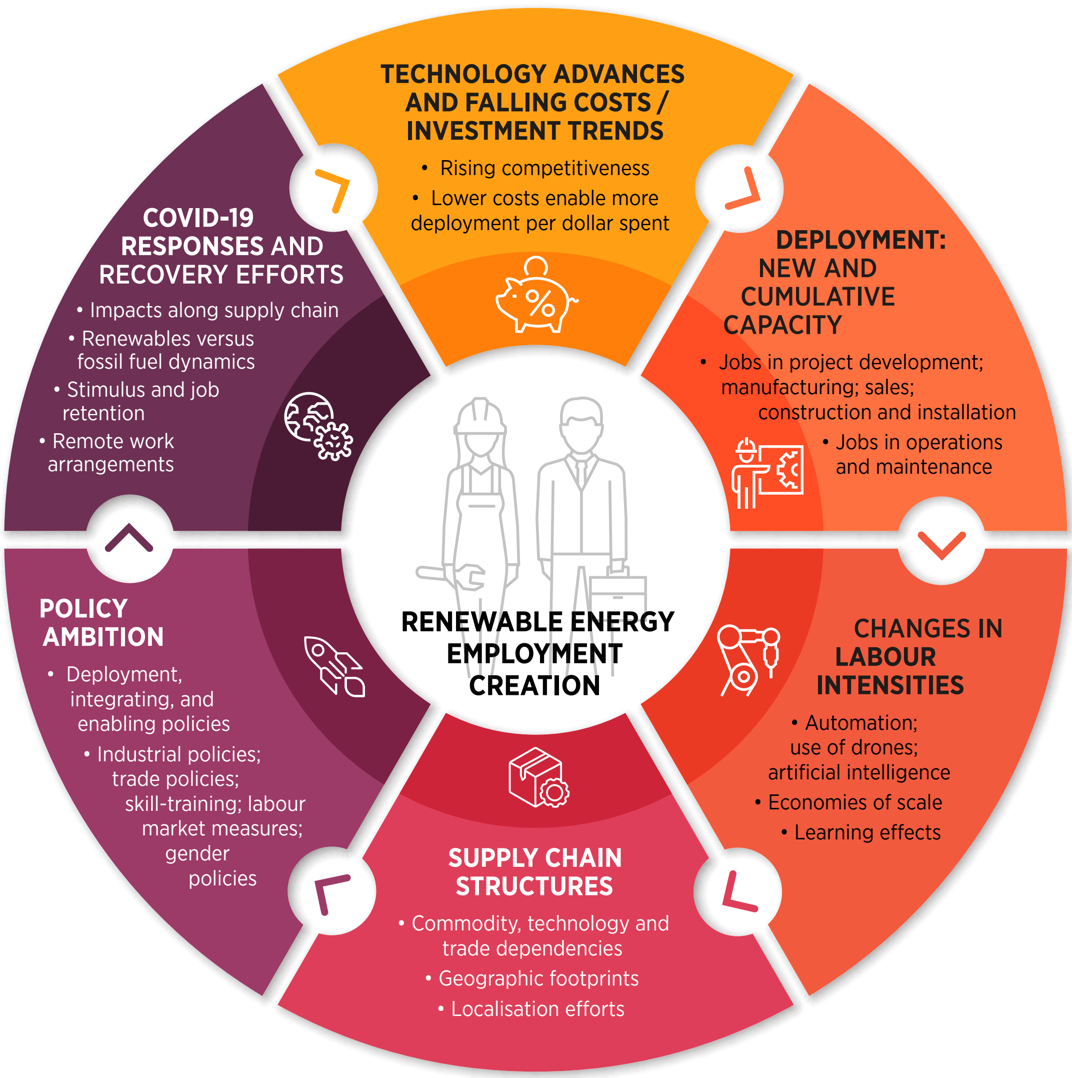
Source: IRENA jobs database.

1 *Data are principally for 2019–20, with dates varying by country and technology, including some instances where only earlier information is available. The data for hydropower include direct employment only; the data for other technologies include both direct and indirect employment wherever possible.*

2 *The jobs numbers shown in Figure 1 reflect what was reported in each earlier edition of this series. IRENA does not revise estimates from previous years in light of information that may become available after publication of a particular edition.*

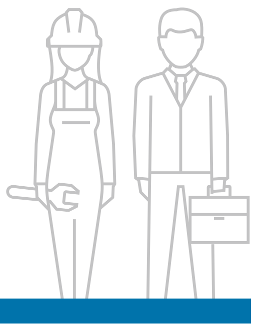
These employment trends are shaped by a multitude of factors (see Figure 2). Key among them is the rate at which renewable energy equipment is manufactured, installed and put to use (largely a function of costs and overall investments). Costs, especially of solar and wind technologies, continue to decline. With relatively steady annual investments, lower costs have translated into wider deployment. An increase in investments would boost future job creation, even allowing for growing labour productivity. Policy guidance and support remain indispensable for establishing overall renewable energy roadmaps, driving ambition, and encouraging the adoption of transparent and consistent rules for feed-in tariffs, auctions, tax incentives, subsidies, permitting procedures and other regulations.

Figure 2. Factors influencing renewable energy employment



The geographic footprint of renewable energy employment – the physical location of the jobs – depends on the dynamism of national and regional installation markets; on technological leadership, industrial policy and domestic content requirements; and on the resulting depth and strength of the supply chain in individual countries. As the industry changes and matures, policy instruments must be fine-tuned.

Creating a skilled workforce – project managers, scientists, engineers, technicians, electricians, welders, pipefitters, truck drivers, crane operators and many others – is also essential. Balancing skills demand and supply requires close co-ordination among industry, government and educational and training institutions to attract a broader and more diverse set of candidates for the future workforce (see In Focus Box 1). The need for labour inputs and skills changes over time as technologies mature, the scale and complexity of operations grows, learning takes effect and automation progresses, raising demand for people with backgrounds in fields such as artificial intelligence, computer science and engineering, and telecommunications radio telemetry, among others.



In Focus Box 1.
Building a diverse workforce

One of the key elements of a just energy transition is ensuring that the workforce includes people from underrepresented and marginalised groups. Population groups of particular concern in this context are women, minorities, people with disabilities, low-income people, youth and older workers. For many, the challenge is magnified where energy access is lacking.

Targeted education and training will play a key role in addressing disparities and promoting inclusion. Early exposure to renewable-energy-related topics and careers through school curricula is vital to inspire young people of all backgrounds to pursue education, training and a career in the sector. This requires adequately integrating renewable energy into national curriculum frameworks, as well as training for teachers and career advisors. Other important measures for diversifying the talent pipeline include scholarships and funded training opportunities, mentorship schemes and targeted apprenticeship programmes. As an example, the **United States (US)** Energy Department's programme for Minority University Research Associates encourages minority students to pursue careers in science and technology and supports research faculty (including principal investigators) from selected institutions in their research projects (US DOE, 2012). The department's Equity in Energy initiative expands the inclusion of minorities, women, veterans and formerly incarcerated persons (US DOE, 2021d).

Many companies have introduced measures to include people with disabilities. For example, in Hull (**United Kingdom, UK**), Siemens Gamesa partnered with Pathway Plus in 2017 to offer internships and subsequent employment to students with disabilities. In **Canada**, the same company announced a multiyear accessibility plan for 2017–21 to remove accessibility barriers for employees and customers and to align operations with the Accessibility for Ontarians with Disabilities Act. Another firm, Électricité de France, is a member of the International Labour Organization's Global Business and Disability Network; it has established multistakeholder networks to support employees with disabilities and monitor progress on disability-related action plans (ILO, 2019b).

Diversifying the energy workforce is not only a question of equity and progress toward a just transition; it also allows the renewable energy sector to draw from a wider and deeper pool of talent. The size of this talent pool will be increasingly important as the renewable energy sector expands and demands growing numbers of people with technical, business, administrative, economic, legal and other skills. Indications are that the sector may soon confront shortages of well-trained and experienced individuals, even as wages rise. Moving toward a more diverse, inclusive workforce therefore represents a tremendous opportunity for renewable energy.

The complex impact of COVID-19

The COVID-19 pandemic loomed over the global economy for most of 2020 and 2021, affecting both the volume and structure of energy demand. Employment, including in the energy sector, has been deeply affected by repeated lockdowns and other restrictions which put pressure on supply chains and constrained economic activity. Across the global economy, millions of jobs were lost and many others put at risk. According to the International Labour Organization (ILO, 2021), 8.8% of global working hours were lost in 2020, equivalent to 255 million full-time jobs. Available information indicates that women were more affected than men, given that they tend to work in sectors more vulnerable to economic shocks. This comes on top of a long-standing imbalance in the energy sector, including renewables, *i.e.* a marked gender inequality. A two-page feature on this topic begins on page 18.

In renewable energy as elsewhere in the economy, the ability of companies and industries to cope with the pandemic and comply with social-distancing requirements in the workplace varies enormously. Companies and government agencies face not only the direct health impacts of the virus, such as sick and quarantined workers or temporary factory shutdowns, but also the economic repercussions of border closures and interruptions in deliveries of raw materials and components.

Project delays and supply disruptions prompted some rethinking of complex international supply chains. The pandemic also caused organisations and institutions to consider remote working arrangements, although the ability to implement them differs enormously across industries and among occupational groups. Generally, however, the ability of employees to use videoconferencing and other software to work in far-flung locations rather than in specific buildings and hubs may well affect where jobs will be created in the future.

Available information suggests that, overall, renewable energy fared well compared with conventional energy[3] – indeed, far better than expected. Worldwide, the more than 260 gigawatts (GW) of renewables installed during 2020 expanded cumulative capacity by about 10%, a substantial uptick from the 180 GW added in 2019. Solar and wind power fared exceptionally well, accounting for a combined 238 GW of total additions in 2020. Solar PV added 127 GW, up from 98 GW in 2019; wind additions doubled from 58 GW to 111 GW. By contrast, bioenergy power capacity expanded by less than half the pace set in 2019 (2.5 GW compared to 6.4 GW) (IRENA, 2021a). And biofuels demand fell significantly in some countries, owing to lower costs of conventional fuels.

Notwithstanding the generally impressive performance, uncertainties and disruptions dotted the way. Impacts varied by renewable energy technology, by segment of the renewables value chain (see Table 1) and by end-use sector.

3 Hit hard by the reduction in oil use, many oil companies cut back on exploration, laid off workers and wrote off assets; others merged or folded. In the United States, for example, about 90 000 jobs out of the 640 000 in the mining, quarrying and oil and gas extraction sector were lost during 2020 (US BLS, 2021).

Table 1: COVID-19's impacts on employment in segments of the renewable energy value chain

Segment of value chain	Magnitude of impact	Comments
Project planning	Low	Many job roles lend themselves to remote working arrangements.
Manufacturing and procurement	High in short term	Factory workers, technicians and engineers have been heavily affected by temporary factory closures.
Transport and logistics	High in medium term	This segment was heavily affected by parts shortages, social distancing measures, quarantines and border controls.
Construction and installation	High	The segment was hit by lockdowns and delays; limits on numbers of workers allowed on-site; and social distancing requirements. The shock waned in the second half of 2020.
Operations and maintenance	Low to medium	Energy generation is an essential service, and the physical space available at wind and solar farms often allows for social distancing. But border closures and quarantine rules restricted travel to some project sites.
Technology	**Magnitude of impact**	**Comments**
Distributed renewables	Very high	Demand was affected by lower incomes and social-distancing requirements.
Biofuels	High	Demand was cut by a drop in transport volume, moderated by a rise in blending mandates in some countries.

Source: Adapted and updated from IRENA, 2020a.

In many countries a cycle was established in which delays were followed by surges of activity. This reflected the newfound reality in which countries' varying degrees of success in reducing COVID-19 infections alternated with a resurgence of cases. But some of the late surge was also driven by developers rushing projects to meet permitting deadlines (some of which were extended in response to pandemic delays) or reacting to impending changes in policies, such as expiring tax credits, phaseouts of subsidies or cuts in feed-in tariffs. In a sense, the pandemic further amplified the ups and downs seen in the sector in ordinary years.

Due to the mobility constraints inherent in the COVID-19 policy response, transport energy demand was far more affected than electricity use. This played to renewables' advantage, in that the bulk of renewable capacity has been installed in the power sector, whereas renewables' role in transport fuels remains quite small for the time being. An added wild card were the extreme swings in the price of oil during parts of the year, triggered by oversupply and a price war among some major producers. Cheaper petroleum fuels had the effect of diminishing demand for biofuels, as mentioned earlier.

Experiences diverged not only by end-use sectors, but also by country, with implications for local employment. The lion's share of new renewables capacity installed in 2020 was added in China, already the dominant country in the field. In the wind sector, China's share of new installations was 65%; in solar PV it was 39% (IRENA, 2021a). Collectively, the rest of the world still managed to add record amounts of capacity, but this was distributed unevenly. Some countries, like India, installed far less than in previous years, while others, like the United States, added unparalleled amounts despite the pandemic. For still others, particularly in Europe, the record was mixed.

Off-grid renewable power was among the categories that performed less well, with capacity additions during 2020 at a considerably lower level than in 2019, the last pre-COVID year. COVID-19's impacts came on the heels of other challenges to off-grid development, such as limited funding. Off-grid solar sales plummeted in many developing countries, as discussed in the next section.

Gender inequality in renewable energy workplaces

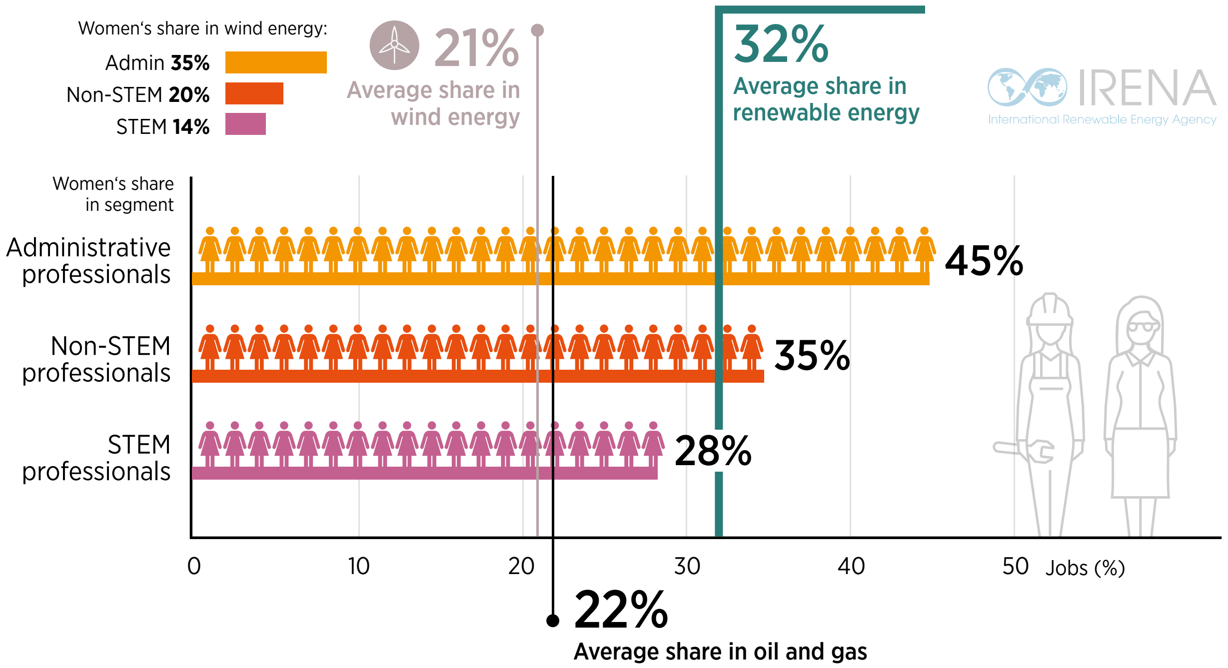
The COVID-19 pandemic has had a significant impact on women all over the world, amplifying or preserving the inequities they confront every day. At home, women have more domestic chores due to the impact of the pandemic. At work, they still represent a small share of the labour force.

The gender dimensions of renewable energy are seldom captured in national economic statistics, as gender-disaggregated data are especially hard to find. Seeking to address this situation, IRENA undertook an initial gender analysis in its report *Renewable Energy and Jobs* (IRENA, 2013), followed by similar surveys in 2016 (IRENA, 2016a), 2017 (BNEF, CEBC and IRENA, 2017) and 2018 (IRENA, 2019). In 2020, IRENA published a report on gender aspects in wind energy (IRENA, 2020b) and in 2022 will release a new report focused on the solar PV industry.

IRENA's surveys have found that women account for only 32% of the overall renewable energy workforce and 21% of the wind workforce. When it comes to roles in science, technology, engineering and mathematics (STEM), these figures are even lower: 28% and 14%, respectively (see Figure 3). While this demonstrates that women have a much stronger presence in renewable energy than in the energy sector as a whole and in oil and gas, it confirms that they remain underrepresented. Reports from countries such as **Canada, Germany, Italy, Spain** and the **United States** all indicate that fewer than 30% of jobs in the renewable energy sector are held by women

IRENA's analysis also finds that women are more likely to be employed in lower-paid, non-technical, administrative and public relations positions than in technical, managerial or policy-making positions

Figure 3: Women's share in the oil and gas, renewables, and wind power workforce, with breakdown by STEM, non-STEM and administrative positions in renewables



Note: STEM = science, technology, engineering and mathematics.

Based on: IRENA, 2019, 2020b.

(IRENA, 2013). This contrasts sharply with the fact that women represent more than half of university students and almost half of the labour force in the countries under study (Pearl-Martinez, 2015).

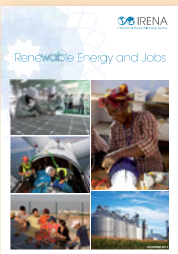
Both IRENA's analyses and the rest of the literature are quite clear about the fact that women face a series of barriers that make them less likely than men to take up a career in renewable energy. And when women do join, they confront attitudes, perceptions and structural obstacles that can make it difficult for them to stay in the workforce and to advance in their careers. These barriers are not exclusive or specific to the energy sector, of course; they are found in the economy and society at large. But because women make up such a large share of the talent pool for renewable energy, dedicated measures are needed to ensure equal access to job opportunities and capital for women-led enterprises.

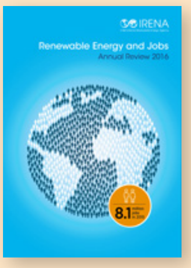
IRENA's work highlights policies in progress that can help increase the share of women in the workforce. These include equal-pay legislation; policies to accommodate caregiving responsibilities and provide better work-life balance for all employees, such as parental leave and part-time work; access to education and training programmes through post-secondary courses, internships, scholarships and apprenticeships; and gender targets and quotas to ensure a critical mass of female employees at all levels of management, as well as in technical and operational roles. In many cases policies on the books must be better enforced, and underlying social and cultural norms need to be addressed.

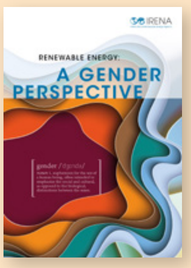
Workers employed by organisations that have fairness policies in place reported 10% lower levels of perceived barriers to female employment. Reported perceptions of barriers were also lower among people entitled to paid maternity leave (9%), those who benefit from gender targets (8%) and those with access to training opportunities (7%). The availability of paternity leave and childcare facilities also had a significant positive impact on the perception of barriers to female employment, although relatively few employers in the sample offered these benefits (IRENA, 2019).

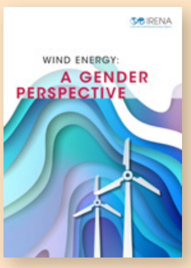
Efforts are needed not just in the modern energy sector but also where access to energy is limited. Respondents to IRENA's survey noted that cultural and social norms, lack of gender-sensitive programmes and policies, and lack of skills and training opportunities are key barriers that prevent women from participating in the decentralised renewable energy workforce.

Policies and programmes should mainstream gender equity at all levels to ensure women are eligible to participate in the workforce. For example, the multi-institutional Sustainable Energy for All initiative aims to build the capacity of female energy leaders through its Women at the Forefront Training Programme (SEforAll, 2021). The programme encompasses four strategic activities: an internship programme; a mentorship programme that matches female energy access professionals with mentors; technical training that aims to train 1750 young women in the skills needed for careers in the access workforce; and sponsored participation in industry events.





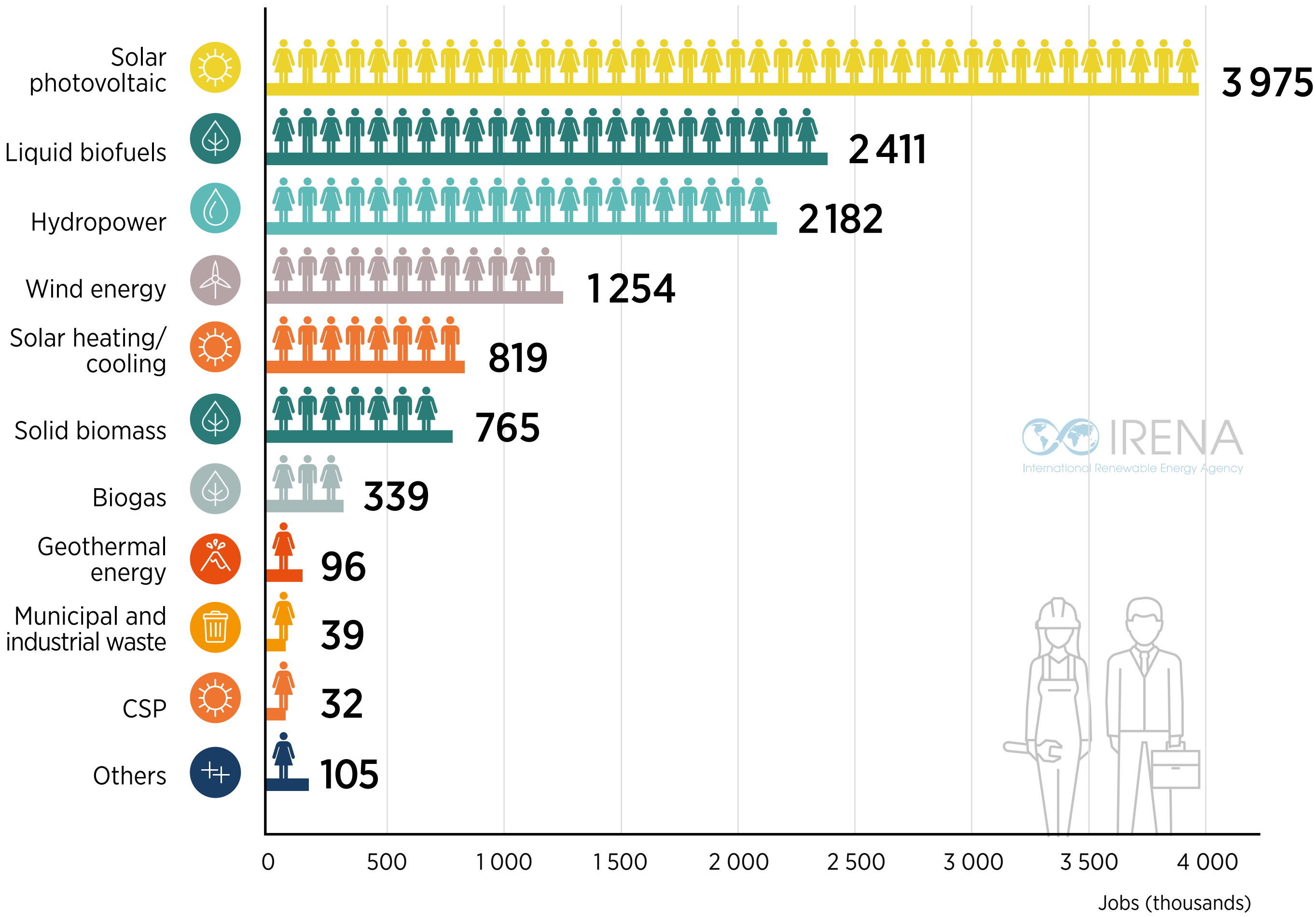




Renewable energy employment by technology

This section presents estimates for employment in solar PV, liquid biofuels, wind and hydropower. Less information is available for other technologies such as solid biomass and biogas, solar heating and cooling, concentrated solar power (CSP), geothermal energy and ground-based heat pumps, waste-to-energy, and ocean or wave energy. Most of these other technologies also employ fewer people (see Figure 4). Observations on off-grid and mini-grid developments are also offered here, as well as glimpses at other energy transition technologies (battery storage and green hydrogen).

Figure 4: Global renewable energy employment by technology



Note: CSP = Concentrated solar power. "Others" include tide, wave and ocean energy, and jobs not broken down by individual renewable energy technologies.

Source: IRENA Jobs database.

Solar photovoltaic

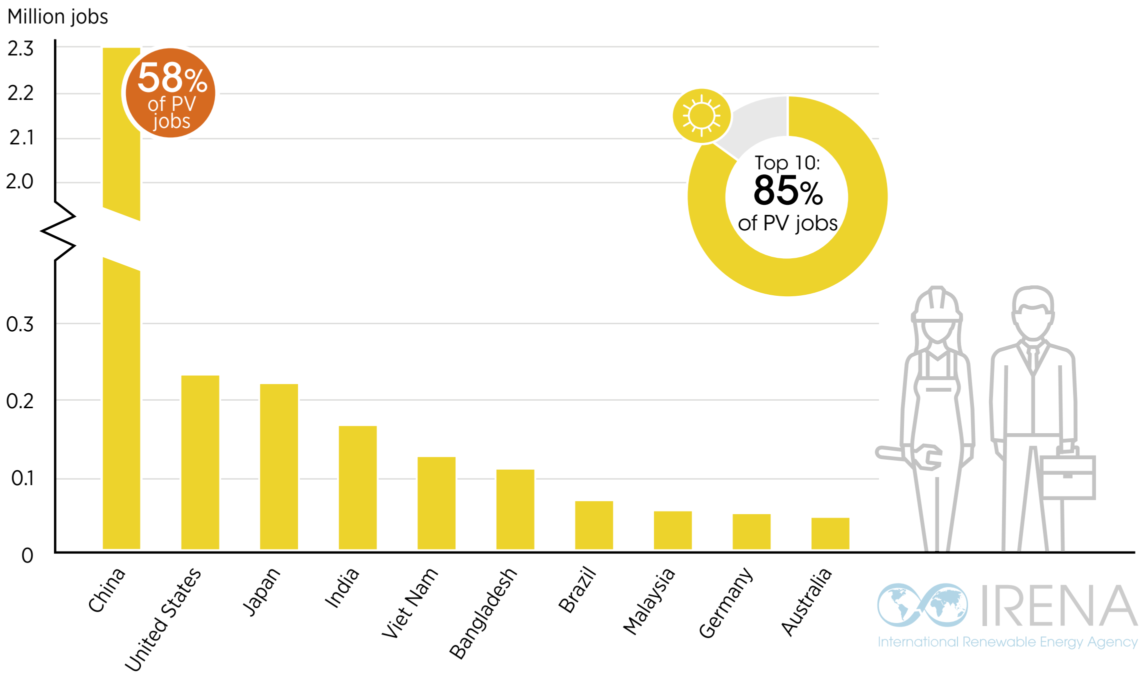
4.0
million jobs

Worldwide, solar PV added 127 GW of new capacity in 2020, up from 98 GW in 2019. More than 60%, almost 78 GW, was added in Asia, principally in five countries (**China, Viet Nam, India, the Republic of Korea and Japan**); **Europe** installed 20.8 GW, the **United States** another 15 GW, **Australia** 4.4 GW and **Brazil** 3.3 GW (IRENA, 2021a).

By the end of the year, strict pandemic lockdowns had ended in most countries, allowing construction to resume. In China and the United States, for example, more than 40% of the year's installations took place in the last quarter. In Europe, by contrast, activities were more evenly spread, with the last quarter being the weakest (Izquierdo *et al.*, 2021).

IRENA estimates global solar PV employment at close to 4 million in 2020, up from 3.8 million in 2019.[4] The global total includes an estimate of 342 000 off-grid jobs for **South Asia** and parts of **Africa**. Of the leading ten countries shown in Figure 5, seven are in **Asia**, two in the **Americas** and one in **Europe**. Together, the top ten accounted for almost 3.4 million jobs, or 85% of the global total. Among all countries, **Asian** nations held 79.4% of the world's PV jobs, reflecting the region's dominance in manufacturing and strong

Figure 5: Solar PV employment: Top 10 countries



Source: IRENA jobs database.

4 The countries for which IRENA's database contains solar PV employment estimates represent 701 GW of cumulative installations in 2020, or 99.1% of the global total. They represented 99.6% of new installations in 2020.

presence in installations. The **Americas** had 8.8% of all jobs; **Europe** held a 6% share (with members of the European Union accounting for 4.9%); and the rest of the world another 6%.

China, the leading producer of PV equipment and largest installation market, accounted for about 58% of PV employment worldwide, or some 2.3 million jobs (CNREC, 2021). **Japan** added less capacity in 2020 than the previous year; IRENA estimates that jobs there fell to 220 000 in 2020, from 241 000 in 2019. Employment in all solar technologies in the **United States** dropped 6.7% in 2020, from some 240 000 to about 231 000 workers. **India**'s on-grid solar employment is estimated at 93 900 jobs, with another 69 600 in off-grid settings, for a total of 163 500 jobs. PV employment in **Europe** is estimated at 239 000 in 2020, of which 194 000 are in EU members states.

The industry is increasingly consolidated. In 2019, the leading ten firms supplied 83% of global polysilicon and 95% of wafers. Given lower barriers to entry, cell and module production are less concentrated, with 59% and 60% shares, respectively, for the top ten (Ladislaw *et al.*, 2021; BNEF, 2021a).

Employment in the main components of the solar PV manufacturing value chain is highly concentrated in a few countries, with **China** in a dominant position. In 2019, two-thirds of the world's polysilicon output was produced by Chinese firms (some operating outside of China), with another 14% each by companies headquartered in **Germany** and the **Republic of Korea** (but the Korean plants closed in 2020), and 5% in the **United States**. Backed by strong domestic polysilicon supplies, more than 90% of the world's wafer manufacturing capacity is in **China**. Chinese companies (with factories in China and **Southeast Asia**) also contributed 78% of the world's cell production and 72% of module output. China is also home to the largest manufacturers of key module components like glass and aluminium frames (Ladislaw *et al.*, 2021; BNEF, 2021a). While Asia-based producers had a 95% share of c-Si (mono- and poly-crystalline silicon) PV module production in 2020, **Europe** had a 3% share and **North America** 2% (Fraunhofer ISE, 2021).

The Fraunhofer Institute for Solar Energy Systems (Fraunhofer ISE, 2020) proposes creation of a 10 GW PV production capacity in Europe, arguing that **Europe**'s technological leadership can once again make it competitive in PV manufacturing. Manufacturing now is highly automated, but up to 7 500 jobs could be created in the European value chain – from wafers to modules. In addition, installation of PV systems creates about 3 500 full-time jobs per gigawatt of capacity.

Liquid biofuels

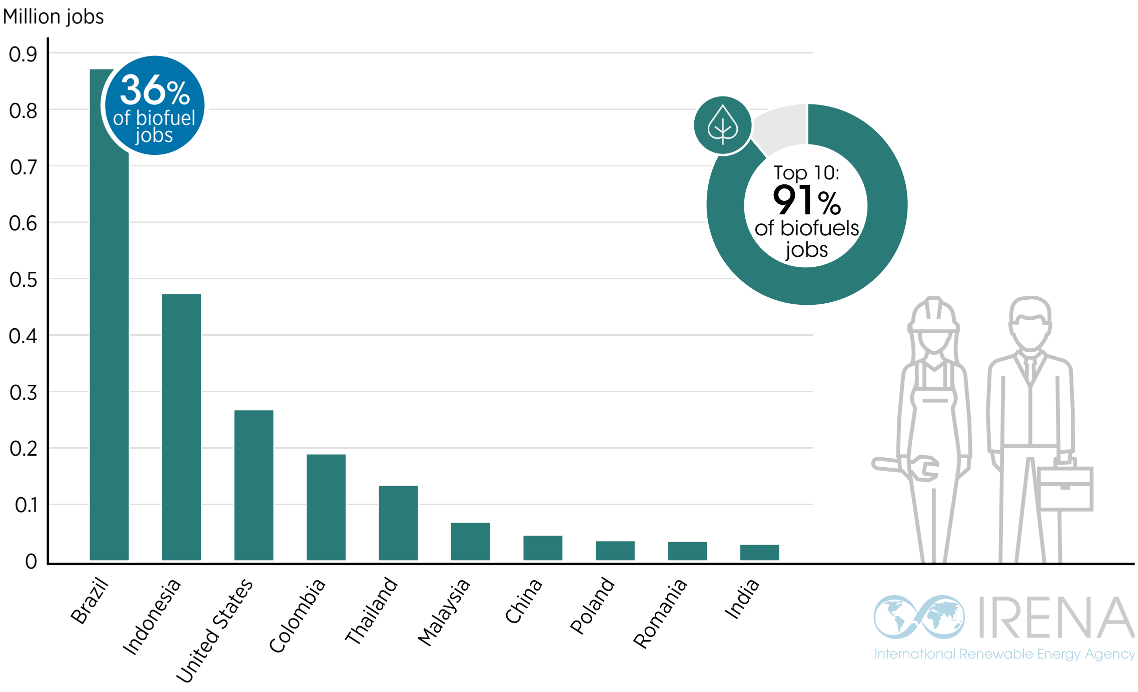
Global biofuels production fell from 161 billion litres in 2019 to 151 billion in 2020, a drop of 6%, reflecting the pandemic's effect on transport energy demand and the fact that lower crude oil prices made biofuels less competitive. Ethanol output fell 8%, while biodiesel production (much smaller in volume than ethanol) held almost steady. The **United States** and **Brazil** remained the world's dominant ethanol producers, with a combined 83% share, while biodiesel production was more spread out geographically, with **Indonesia**, the United States and Brazil producing 45% of the global total and the **European Union** another 31% (REN21, 2021).

2.4
million jobs

IRENA estimates worldwide biofuels employment in 2020 at 2.4 million, a slight decline from 2019. Fuel processing requires relatively few people, and the bulk of jobs are in the agriculture supply chain, planting and harvesting feedstock. But many of the latter are casual and seasonal in nature, rather than full-time, formal jobs. There are also distinctions between plantation workers and independent farmers, with varying levels of labour productivity.

Latin America accounts for 44.4% of all biofuel jobs worldwide and **Asia** (principally Southeast Asia) for 33.6%. The more mechanised agricultural sectors of **North America** and **Europe** translate into smaller employment shares – 11.8% and 10%, respectively. Figure 6 shows the top ten countries, which together account for about 91% of global estimated employment.

Figure 6: Liquid biofuels employment: Top 10 countries



Source: IRENA jobs database.

Highly mechanised operations in the **United States** required a direct and indirect labour force of about 271 000 people in 2020. Labour intensity is also relatively low in the **European Union**, where biofuels employment was estimated at about 239 000 jobs in 2018, the most recent year for which complete data are available (EurObserv'ER, 2020).

Other producing countries depend much more on human labour. With about 871 000 jobs, **Brazil** remains the world's biggest liquid biofuels employer. According to revised estimates, **Colombia**'s biofuels output declined for a second year in a row to 950 million litres in 2020 (USDA-FAS, 2020f). Employment factor calculations suggest that the number of people involved was down more than 10%.[5] As is true for biofuels producers in Southeast Asia, Colombia's 194 000 jobs in the supply chain are not all full-time equivalent (FTE) jobs.

Indonesia's biodiesel employment remained virtually unchanged from 2019 at about 475 000, but the sector was buffeted by highly contradictory forces. While COVID-19 restrictions reduced the overall consumption of diesel fuels, a rise in the nation's biodiesel blending mandate from 20% to 30% was estimated to have lifted 2020 biofuels consumption by 20%. At the same time, exports collapsed, owing not only to the pandemic but also to unfavourable price trends vis-à-vis conventional diesel and 8-18% countervailing duties imposed by the European Union in 2019.[6] Preliminary estimates put overall production at 7.8 billion litres, a slight increase over 2019[7] (USDA-FAS, 2020a).

Malaysia's 2020 biodiesel production was projected at 1.25 billion litres, a 16% drop reflecting lower domestic and export demand due to the COVID-19 pandemic and lower prices for fossil-based diesel. The government also decided to defer to mid-2021 its plan to increase the blending mandate from 10% biofuel to 20% (USDA-FAS, 2020b). IRENA estimates that the biodiesel sector accounted for about 73 700 jobs in 2020, down about 15 000 from the previous year.[8]

The chief objective of **Thailand**'s biofuels development plan is to increase farm incomes through higher feedstock demand for molasses, cassava and palm oil. However, ethanol and biodiesel price subsidies will be phased out gradually between 2020 and 2022 (USDA-FAS, 2020c). With production up less than 2%, IRENA estimates biofuel jobs in Thailand at 138 700 in 2020.

Because of COVID-19 measures, the **Philippines**' ethanol production is estimated to have declined by 20% and biodiesel by 30% (USDA-FAS, 2020d). Biofuels employment is estimated by IRENA at 28 900 jobs. Direct jobs in biofuels processing were reported at only 2 887. Processing plants suffered COVID-19–related shutdowns driven by mobility restrictions and the resulting reduced demand for fuel. Construction of new plants was also delayed by problems with procuring necessary equipment and manpower (REMB DOE, 2021).

5 The estimate breaks down into 91 164 jobs in ethanol and 82 250 jobs in biodiesel.

6 The European Union explained that it acted in response to growing concerns over the environmental impact of palm oil and Indonesia's biodiesel subsidies. In December 2019, the Indonesian government filed a complaint against the tariffs with the World Trade Organization (Jong, 2020).

7 The 2020 edition of the Annual Review reported 2019 production of 8 billion litres, but estimates were subsequently revised downward to 7.7 billion litres (USDA-FAS, 2020a).

8 Malaysia's biodiesel production figures for several years were revised by USDA-FAS (2020b), causing deviations from the job estimates reported in previous editions of the Annual Review.

Wind

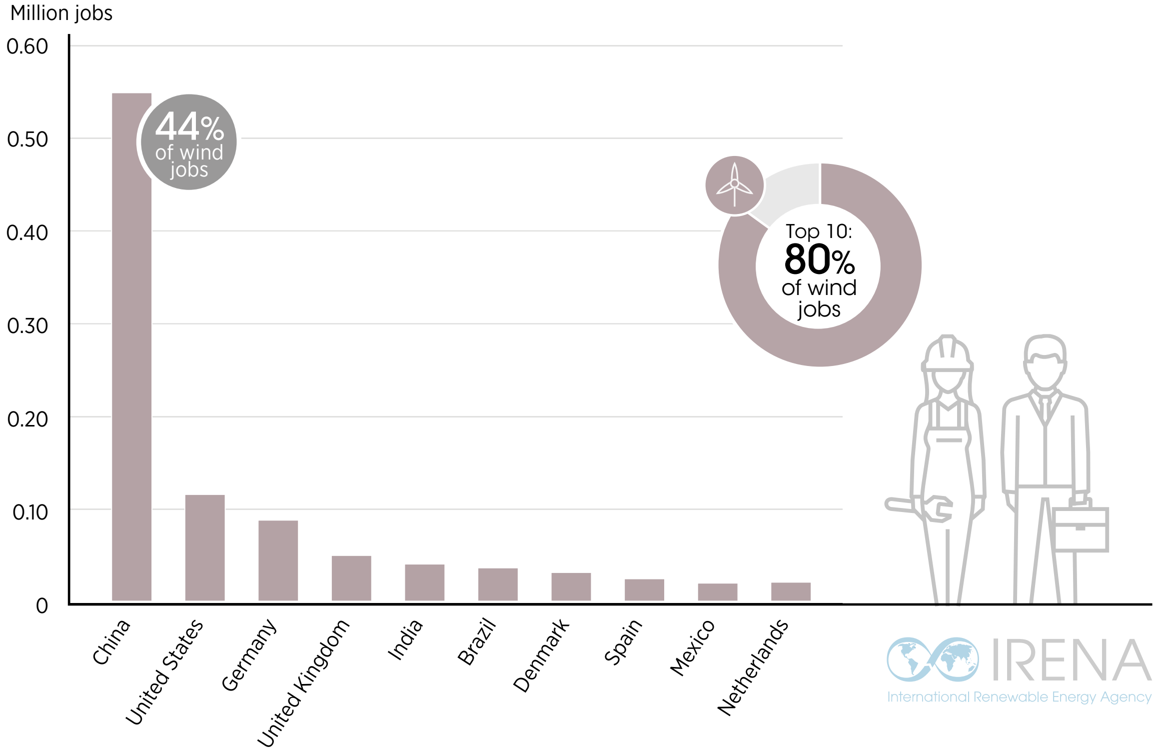
COVID-19 notwithstanding, by the end of 2020 the wind energy sector saw a strong expansion. Capacity additions almost doubled to 111 GW, from 58 GW added in 2019. **China** added by far the most (72 GW), followed by the **United States** (14 GW). Ten other countries installed more than 1 GW each (IRENA, 2021a).

1.3
million jobs

The COVID-19 pandemic caused numerous disruptions, including in the supply of raw materials and other inputs. For example, balsa – a material used in blades – was in short supply because of severe pandemic impacts in **Ecuador**. In response, some companies invested in balsa production in countries like **Papua New Guinea**, while others switched to PET plastics (Barla, 2020).

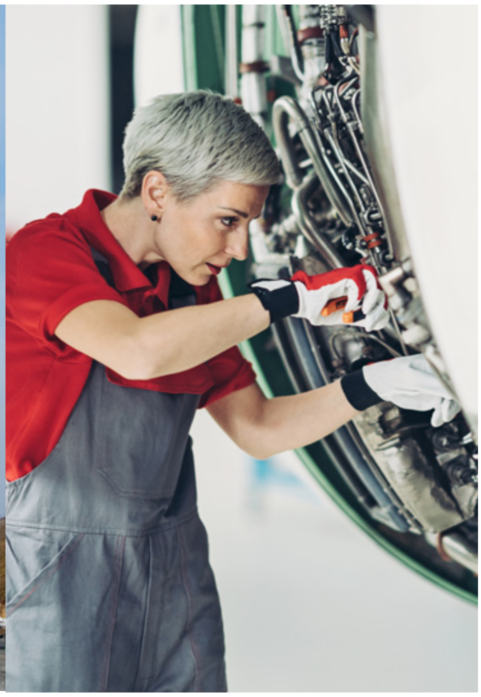
Overall employment in onshore and offshore wind grew slightly to 1.25 million jobs worldwide in 2020, from 1.17 million in 2019.[9] IRENA's gender survey indicated that women hold about a fifth of these jobs (IRENA, 2020b). Most wind employment is concentrated in a relatively small number of countries. **China** alone accounts for 44% of the global total. **Asia** represented 54% of global wind jobs in 2020, while **Europe** accounted for 27% (of which EU members 21%), **the Americas** for 17%, and **Africa** and **Oceania** for less than 3%. The top ten countries shown in Figure 7 together employ 1 million people. Five countries are European, three are in the Americas and two are Asian.

Figure 7: Wind employment: Top 10 countries



Source: IRENA jobs database.

9 The countries for which IRENA's database has estimates of wind power employment represent 95% of global capacity and cover 95% of new installations in 2020.



In addition to the geographical distribution of wind farms, the industry's equipment manufacturing footprint affects where jobs are created. Job creation depends to some extent on countries' ability to establish a strong local supply chain, including through investment in manufacturing, grids, and, for offshore projects, port infrastructure and specialised vessels. It also depends on countries' varying abilities, and political will, to apply performance requirements such as local content rules.

Of the almost 800 factories worldwide that produce wind-turbine components, 45% are in China and 31% in Europe, 7% in India, 5% in Brazil and 4.5% in the United States, Canada and Mexico (Wind Europe, 2020). Close to 40 countries manufacture components, but only a few (**China, Germany, India, Spain** and the **United States**) produce the full range (*i.e.* nacelles, blades, towers, generators, gearboxes and bearings) (BNEF, 2021b).

Europe's wind-power employment depends more on export markets than is true in other regions. In 2019, companies in **Denmark**, **Germany** and **Spain** accounted for three quarters by value of all wind-turbine exports. By contrast, employment at Chinese wind companies depends mainly on the strength of the domestic market, as is true for companies in the United States (BNEF, 2021b).

For nacelle production, firms in **China, Denmark, Germany, India** and the **United States** held a combined 98% of the world market in 2019. Blade and tower production is also highly concentrated. Close to 40% of the plants manufacturing generators are in **China**, with a similar share in Europe. Companies in **Europe, Japan** and the **United States** supply most high-quality bearings for onshore and offshore wind turbines (BNEF, 2021b). Manufacturing of gearboxes is more geographically dispersed owing to increasing outsourcing, including to lower-wage countries such as **India** (Barla, 2020; Wind Europe, 2020).

Upstream, among key materials used in wind turbines, steel production is dominated by **China**, while concrete production is largely locally sourced. Glass-fibre-reinforced plastic for blades is produced principally in **China, Japan**, the **United States** and **Europe**. Two-thirds of the production of rare earths (used in the direct-drive generators that account for 10% of the global onshore market but 70% of the offshore market) is in **China** (BNEF, 2021b); some **African** countries are also important sources of minerals and metals inputs.

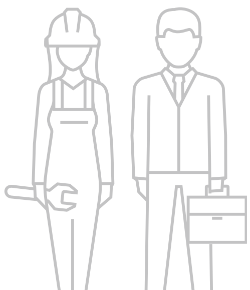
Boom-bust cycles and policy changes have encouraged consolidation among equipment-producing companies. In 2019, the top ten turbine manufacturers had an 84% global market share, up from 74% five years earlier. Just 15 manufacturers supply half of global demand for blades; the total number of blade producers has fallen by a third since 2016, as smaller suppliers have been squeezed on cost, research and development spending and lack of a global presence (GWEC, 2020b). The **US** wind-turbine market is highly concentrated, with just three companies accounting for 98% of the 2020 total.[10]

With falling costs and ambitious deployment plans, the offshore wind market is coming into its own. Offshore wind farms require more labour than onshore wind farms. Construction and installation are more complex, involving not just the usual towers, blades and turbines, but also complex foundations and installation vessels, as well as substations and undersea cables to bring electricity onshore. Many of these functions can leverage the capabilities found in the offshore oil and gas sector (GWEC, 2020a).

Europe is the leader in offshore installations and technology development, with a robust supply chain in countries bordering the North Sea and Baltic Sea (GWEC, 2020a). Developing an adequate logistics infrastructure is also critical. This includes improvements in port infrastructure to support warehousing, staging for assembly and transport, and installation and operations vessels.

For both offshore and onshore wind, the Global Wind Energy Council (GWEC, 2021a) projects that an additional 480 GW of capacity will be installed globally between 2021 and 2025. This will create some 3.3 million jobs along the entire value chain (including in operations and maintenance over the course of typical 25-year project lifetimes).

The Global Wind Organisation and the Global Wind Energy Council (GWO and GWEC, 2021) estimate that the wind capacity that is expected to be added in 2021–25 will require 480 000 trained workers in the construction, installation, and operations and maintenance segments (308 000 onshore and 172 000 offshore). Training capacity – 150 000 workers at the end of 2021 – thus needs to be expanded significantly to ensure safe and quality work.



10 GE Renewable Energy had a 53% share of 2020 installations, followed by Vestas (35%) and Siemens Gamesa Renewable Energy (10%) (American Clean Power, 2021).

2.2
million jobs

Hydropower

Overall, growth in hydro recovered in 2020 after a few consecutive years of decline. Several large projects delayed in 2019 were commissioned in 2020 (IRENA, 2021a). Still, COVID-19 affected the sector, hampering supply chains and causing several projects to be delayed or declared uncompetitive. Additionally, hydroelectric projects had trouble obtaining financing and up-front capital. Revenue difficulties arose because of changes in currency valuation, inflation and the pandemic's economic fallout.

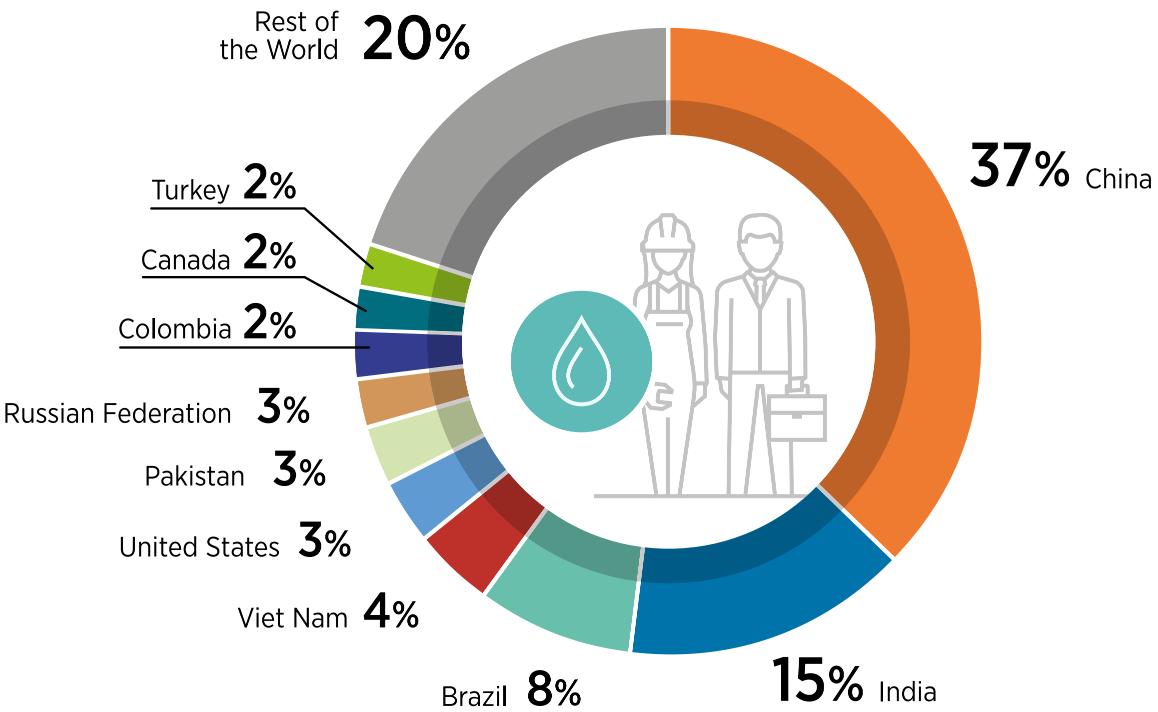
IRENA estimates jobs in the hydropower sector based on an employment-factor approach together with national-level data for some countries. Taking into account data revisions and an updated methodology from the previous edition of the Annual Review, this report estimates that approximately 2.2 million people worked directly in the sector in 2020.

With regard to both deployment and jobs, the situation in 2020 varied across countries. On the one hand, the Chinese government has reintroduced hydropower development, particularly pumped storage, into its five-year development plan. In 2020 alone, **China** added 12 GW of capacity (IRENA, 2021a). The 13th Five-Year Plan includes a target of 470 GW of hydropower capacity by 2025; the Chinese commitment to expanding the nation's hydropower capacity will create many jobs over the next few years (NEA, 2016).

On the other hand, countries such as **Argentina** and **Brazil** experienced a reduction in demand that resulted in the cancellation of a new round of energy auctions in Brazil that included hydropower projects. Still, Brazil's employment in the sector is substantial. Figure 8 shows the ten leading countries.

The potential for micro- and small-scale hydropower units is substantial, thanks to relatively low capital investment and the advantages offered by particular geographic features. Given that micro and small hydropower can satisfy low-to-medium voltage electric needs like lighting and telecommunication, and can even provide motive power for small industry, such schemes are a viable alternative source of energy and, for struggling rural areas, a source of income and jobs (IRENA, 2016b; IRENA, forthcoming 2022). While less job intense than large-scale projects, the unique nature of the technology involved makes small hydro ideally suited to community ownership, which can be the key to unlocking the economic potential of hard-to-reach rural areas.


Figure 8: Hydropower employment by country, 2020



Source: IRENA jobs database.

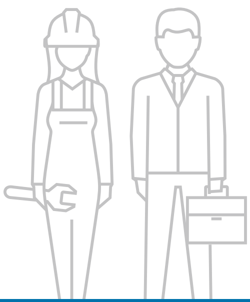
Off-grid and mini-grids

COVID-19 slowed the pace of activity in the off-grid sector. While off-grid capacity grew to a cumulative total of 10.6 GW in 2020, the 365 megawatts (MW) added represented modest growth of 3.5%, down from 5.6% in 2019. In the solar off-grid segment, just 250 MW were added during 2020 – less than half the average annual amount installed during 2015-19 (IRENA, 2021a).

Worldwide sales of off-grid solar lighting products fell sharply in the first half of 2020 compared with the same period in 2019, especially in **South Asia** (-57%) and in **East Asia and the Pacific** (-49%). Driven by the pandemic's disruptions, companies faced tight finances while households' reduced incomes suppressed cash purchases (although pay-as-you-go sales were less affected) (GOGLA, 2020). The second half of 2020 brought a partial recovery, but the 6.6 million off-grid solar lighting units sold during the year were still 26% below the 2019 volume. For the full year of 2020, GOGLA estimates that COVID-19 caused 10 to 15 million people and 300 000 to 450 000 enterprises to miss out on improved energy access (GOGLA, 2021).

It is unclear how these developments changed the employment picture, though women were probably more negatively affected than men. Applying regional sales trends on a pro-rated basis to available job figures from 2018 translates into a dramatic loss of jobs. However, there is evidence that some, and perhaps many, companies in the off-grid solar sector succeeded in retaining much of their workforce during the pandemic, with financial help from governments and donors (Ketelaars, 2021). Applying a combination of sales trends and assumed workforce retention rates, it is possible that some 342 000 off-grid solar jobs may have been retained in 2020: 191 400 in **South Asia** and 150 000 in **East, West and Central Africa**. More information is needed, however, to validate this rough estimate.

For mini-grids, too, insights into the pandemic's employment impacts are limited. Along the value chain, jobs are created by manufacturers of equipment such as solar panels, control systems, inverters, transformers and storage systems. **Chinese** and **European** firms are dominant. Local jobs are created principally in installation and in operations and maintenance, but there are also plenty of opportunities to create jobs and livelihoods in productive uses (see In Focus Box 2). Hiring details typically depend on whether a private developer, national utility or community co-operative – actors having different objectives – is in charge (Mini-Grids Partnership, 2020). Aside from COVID-19, limited commercial funding presented a challenge. Of the USD 2.07 billion pledged by development finance institutions between 2012 and March 2020 in support of mini-grids, only 13% had been disbursed, with the greatest shortfall in **Sub-Saharan Africa** (Mini-Grids Partnership, 2020).



In Focus Box 2.
Jobs and livelihoods in the access sector

Access to affordable, modern and reliable energy services is a prerequisite for sustainable livelihoods and socio-economic development. Today some 750 million people lack access to electricity; around 2.6 billion people lack access to clean cooking. Projections indicate that by 2030, 660 million people will still lack access to electricity and nearly 2.3 billion people to clean cooking, most of them in Sub-Saharan Africa (IEA, IRENA, UNSD, World Bank and WHO, 2021). Beyond households, enterprises and public facilities (*e.g.* clinics, schools, water supply infrastructure) in some countries lack access to reliable and affordable energy.

Linking renewable energy supply with income-generating activities across sectors can improve productivity, raise incomes, create local jobs and catalyse rural economies. In **Ethiopia**, for instance, deploying renewables-based solutions in the horticulture, wheat and dairy sectors could create about 190 000 jobs across value chains by expanding production capacity and reducing losses (Ethiopia Jobs Creation Commission, 2021). Evidence from **Kenya** and **Nigeria** suggests that, compared with the direct jobs created in delivering decentralised renewable energy solutions, up to five times more employment is created through gained productivity and productive uses in rural enterprises, ranging from retail and services to agricultural processing businesses (Shirley, 2020).

Targeted efforts to link renewables with livelihoods are well aligned with the objective of building back better from the COVID-19 pandemic – and with the Sustainable Development Goals (IRENA, 2020a). Achieving both these goals will require co-ordination within governments to assess existing and new livelihood opportunities across sectors that stand to gain from improved access to modern energy services. Beyond technology deployment, efforts are also needed to raise awareness of productive end-use applications, to improve access to markets for new products and services, and to build capacity and skills for enterprise development (IRENA and SELCO Foundation, 2021).

In many developing countries, the transition to improved energy access and modern renewables has large-scale implications for livelihoods. In **Nigeria**, where 75% of total primary energy supply comes from biomass (almost exclusively traditional uses), about 40 million people (a quarter of the total population) are directly engaged in collecting firewood and producing charcoal, representing some 400 000 full-time equivalent jobs. These jobs far outnumber the 65 000 direct jobs in oil and gas but are largely informal, and working conditions are poor (ILO and UNDP, 2021). Other Sub-Saharan African countries similarly have large numbers of livelihoods bound up in the fuelwood and charcoal economies (ILO, 2017).

Significant risks of livelihood loss during the energy transition must be addressed in tandem with the problems associated with traditional biomass (losses of livelihoods and sustainability through forest clearance). Solutions will hinge on sustainable forest management; forest rights for local communities and indigenous peoples; and skills training and social protection for those losing jobs. Women, who are most often responsible for energy in African communities, will be significantly affected by the transition away from traditional biomass and so will require particular attention (ILO and UNDP, 2021).

In Focus Box 3.
Jobs in battery storage and green hydrogen

The global capacity to manufacture lithium-ion battery cells for automotive and stationary storage purposes grew seven-fold in the decade to 2020. **China** holds 78% of that capacity, with much smaller shares in **Japan** and the **Republic of Korea** (both of which, like China, were able to draw on their existing consumer battery manufacturing base), and in **Europe** and the **United States**. Including new plants under construction or announced, worldwide capacity may quadruple by 2025, with 64% of the total in China, 23% in Europe and 6% in the United States (BNEF, 2021c).

Employment in manufacturing of cells and their key components is thus highly concentrated geographically. This is also true for the key metals used. A large share of lithium mining takes place in **Australia, Chile** and **China**; cobalt mining in the **Democratic Republic of Congo**; and nickel mining in **Russia, Canada, Australia** and a few other countries. Except for nickel, China leads in refining these metals (BNEF, 2021c).

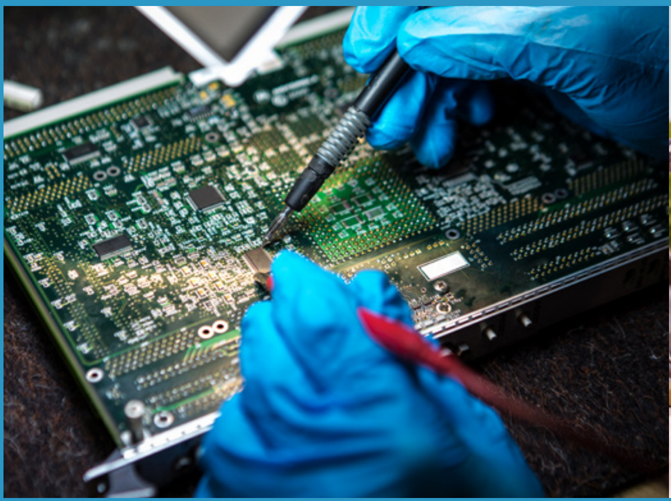
As a dominant producer of components for batteries and by far the largest market for electric cars and buses, **China** claims the bulk of related employment. In addition to demand-side policies (like subsidies for purchases of electric vehicles), industrial policy measures were key to China's success. Those policies included targets, incentives, government guarantees, public procurement programmes, research and development funding, and efforts to build up expertise in the electric vehicle and battery supply chain while shielding local manufacturers from competition (Ladislaw *et al.*, 2021).

Expanding the battery sector – and basing it in large part on recycling key metals like cobalt and nickel – could be a source of large-scale employment. According to the World Economic Forum and Global Battery Alliance (2019), "a circular battery value chain" could create 10 million jobs worldwide by 2030.[a]

Another field of growing interest is "green" hydrogen generated from renewable energy to transform hard-to-decarbonise industries such as iron and steel, cement and chemicals. For the time being, the hydrogen economy remains small and heavily based on natural gas, but this could change significantly in coming decades.

The scenarios in IRENA's *World Energy Transitions Outlook* indicate that investment in electrolysers and other green hydrogen infrastructure could create about 2 million jobs worldwide between 2030 and 2050 (IRENA, 2021c).

A study focused on the **United States** (FCHEA, 2020) projected that by 2030 the hydrogen economy could generate USD 140 billion in revenue per year, with 700 000 jobs along the value chain, expanding to USD 750 billion and 3.4 million jobs by 2050.



This includes hydrogen production, its distribution and infrastructure, and manufacturing of needed equipment, components and materials, as well as of end-use applications in the power sector, transport, buildings and industry. The study's assumption was that hydrogen would cover 14% of final US energy demand by 2050 but would also be exported extensively. Employment estimates were based on present-day jobs multipliers applicable to segments of the hydrogen value chain.[b]

However, the study assessed not only strictly green hydrogen but also what it terms non-renewable "low-carbon hydrogen" including expensive and energy-intensive carbon capture and storage technologies, gasification of municipal and agricultural waste, and hydrogen as a by-product recovered from industrial processes. A new study by researchers at Cornell University and Stanford University found that the carbon footprint for "blue" hydrogen (made from the methane in natural gas) is more than 20% larger than that created by using natural gas or coal directly for heat, or 60% greater than using diesel oil (Howarth and Jacobson, 2021).

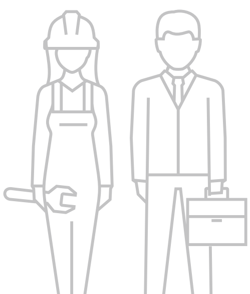
As the energy transition picks up speed and widens its scope, it will be increasingly important to clarify and define terms like decarbonisation, low-carbon energy and green economy to ensure that the technologies pursued are fully consistent with the needs of climate stability and environmental protection.

a. This estimate includes usage for electric mobility, stationary storage and consumer electronics, with overall demand projected to grow 19-fold over 2018 levels, or about 3 600 GWh, in 2030.

b. The multipliers estimate the jobs created for each USD 1 million in revenue: 6.7 for the hydrogen sector itself, 10.2 in the automotive industry, 12.2 for machinery and equipment and 14.5 in the aftermarket.

Other technologies implicated in the energy transition

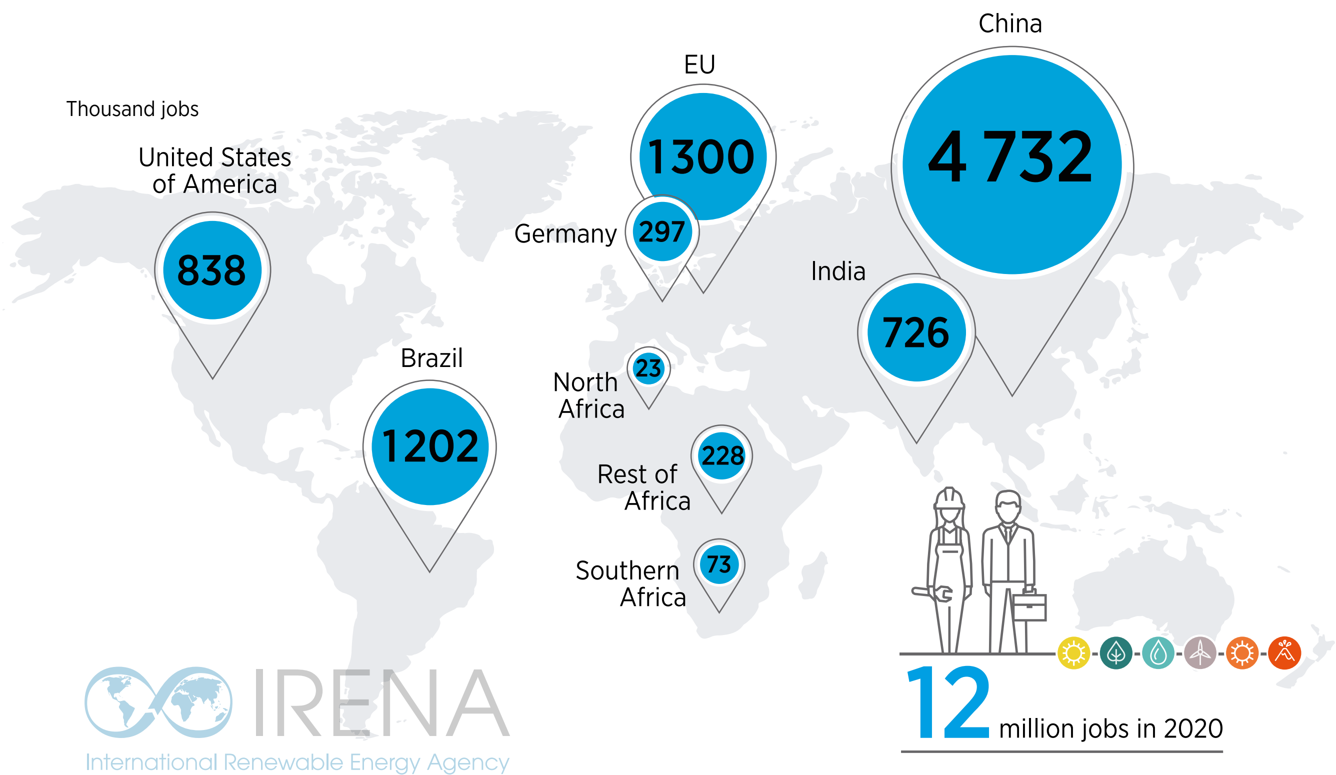
Renewable energy is at the core of the energy transition, but its expansion goes hand in hand with a range of additional technologies and related infrastructure. The *Annual Review* series focuses principally on the renewable energy sector itself, but there are a few closely related technologies of rising importance, notably batteries for energy storage and electric vehicles, and "green" hydrogen. These appear set to expand significantly in coming years as vehicle technology shifts from internal combustion engines to electric motors, and as industries look to decarbonise their energy supply (see In Focus Box 3). Grid transmission and distribution networks will play an important role in the expansion of these technologies, but at present not all of the associated jobs can be counted as transition related, given that the energy system is still centred strongly on fossil fuels, especially for transport. It should also be noted that a comprehensive accounting of employment impacts of the energy transition should include jobs in industries that cannot be considered "green" in their own right, including mined materials needed for renewable energy equipment (such as nickel and lithium for batteries) and inputs from energy-intensive industries such as aluminium, steel or concrete (for wind, solar and other renewable energy installations).



Renewable energy employment in selected countries

This section presents trends and observations for selected countries. The focus is on China, Brazil, the United States, India and members of the European Union (see Figure 9 and Table 2), countries that lead in equipment manufacturing, project engineering and installations. This is followed by information on several additional countries. Overall, the bulk of renewable energy employment is in Asian countries, which accounted for 62% of jobs in 2019.

Figure 9: Renewable energy employment in selected countries



Source: IRENA jobs database.

Table 2: Estimated direct and indirect jobs in renewable energy worldwide, by industry (thousand jobs), 2019-20

	World	China	Brazil	India	United States	European Union (EU27)[o]
Solar PV	3 975[e]	2 300	68	163.5[h]	231.5[i]	194
Liquid biofuels	2 411	51	871[g]	35	271[j]	229
Hydropower[a]	2 182	813.6	175.8	319.5	71[k]	80
Wind power	1 254	550	40	44	116.8	259
Solar heating and cooling	816	670	47.2	21	na	21
Solid biomass[b, c]	765	188		58	44.5[l]	368
Biogas	339	145		85	na	76
Geothermal energy[b, d]	96	3			8[m]	40[d]
CSP	32	11			na	6
Total	**12 018[f]**	**4 732**	**1 202**	**726**	**838.4[n]**	**1 300[f]**

Note: The figures presented here are the result of a comprehensive review of primary national entities, such as ministries and statistical agencies, and secondary data sources, such as regional and global studies. This is an ongoing effort to update and refine available knowledge. Columns may not add up to totals due to rounding.

a. Direct jobs only.

b. Power and heat applications.

c. Traditional biomass not included.

d. Includes 8 700 jobs for ground-based heat pumps in EU countries.

e. Includes an estimate of 342 000 jobs in off-grid solar PV in South Asia and in East, West and Central Africa. This is a very rough estimate based on sales trends and assumed worker retention rates.

f. Includes 39 000 jobs in waste-to-energy and 1 000 jobs in tide, wave and ocean energy.

g. About 180 600 jobs in sugarcane cultivation and 166 700 in alcohol/ethanol processing in 2019, the most recent year available. Figure also includes a rough estimate of 200 000 indirect jobs in equipment manufacturing, and 323 800 jobs in biodiesel in 2020.

h. 93 900 jobs in grid-connected and 96 700 in off-grid solar PV. Also see note e.

i. Jobs in all solar technologies, principally PV but also including solar heating and cooling and CSP.

j. Includes 200 250 jobs for ethanol and about 70 860 jobs for biodiesel in 2020.

k. US DOE (2021a) estimate, including 51 880 jobs in traditional hydro, 11 251 jobs in low-impact hydro and 7 822 jobs in pumped hydro.

l. Woody biomass fuels (32 442 jobs) and biomass power (12 039 jobs).

m. Direct geothermal power employment.

n. Includes 95 578 jobs in technologies not separately broken out in the table, such as solar heating and cooling, geothermal heat, heat pumps and others. Solar heating and cooling is also included (but not reported separately) in the Solar Foundation's estimate on all solar technologies, so there is effectively a small amount of double counting.

o. Solar PV and wind jobs are for 2020; hydropower for 2019 and 2020; other technologies for 2018.

Source: IRENA jobs database.

Leading markets

CHINA added 136 GW of renewable power capacity last year, the bulk from 72 GW of wind (China's largest addition in a single year[11]) and 49 GW of solar (its second largest ever) (IRENA, 2021a). The country thus further extended its global lead; with 4.7 million jobs, China commands 39% of total renewable energy employment worldwide (CNREC, 2021).

Solar PV installations in China surged by 67% during 2020, close to the 2017 peak of 53 GW (IRENA, 2021a), and the country continues to dominate export markets. China's solar PV workforce was estimated at 2.3 million, growing from 2.2 million in 2019 (CNREC, 2021). Chinese firms have benefitted from government support of large production capacities, yielding economies of scale. Such support includes low-cost credit, free land, tax exemptions, direct cash payments and export credits (JMK Research and IEEFA, 2021).

Wind capacity additions of 72.4 GW were almost triple the previous year's, with much of the added activity driven by impending cuts in feed-in tariffs. In offshore wind, China's 3.1 GW of new installations surpassed additions in the rest of the world combined (IRENA, 2021a). The record pace was partially driven by installers wanting to benefit from government subsidies before they came to an end in 2020 (Shepherd, 2021). Chinese wind employment is estimated by CNREC (2021) at 550 000 jobs in 2020, up from 518 000 in 2019.

Domestic companies have commanded a share of more than 90% of onshore installations in China over the past decade. Bearings are the only wind-turbine component for which foreign companies control the majority of manufacturing capacity; for everything else, their share is 25% or less (Barla, 2020). Wind employment is principally driven by domestic projects. Apart from Goldwind, Chinese firms have had limited presence in export markets, but Envision set up the first nacelle manufacturing plant outside China, in India (Barla, 2020).

The impending expiration of China's feed-in tariff for offshore wind at the end of 2021 prompted developers to rush their projects to completion. Ambitious targets set by coastal provinces (Guangdong, Jiangsu, Zhejiang and Fujian) are another key driver. The country's expertise in onshore wind has allowed it to develop local supply-chain clusters in a relatively short time, though some bottlenecks persist (World-Energy, 2020). A total of 18 industrial parks are being developed along the coast, half of them in just two provinces, Jiangsu and Guangdong. The dominant model of offshore wind-farm development is a joint approach between mostly state-owned Chinese companies and provincial governments. Foreign developers have a share of less than 1% (Li, 2020), so most jobs will be accrued domestically.

11 The wind installation figure may include capacity installed prior to 2020 but not previously connected to the grid, and possibly also some partially completed projects (Deign, 2021).

BRAZIL has an estimated 1.2 million renewable energy jobs, close to the previous year. The majority are in biofuels. Overall job numbers remain relatively unchanged, but the composition is shifting. Biodiesel production is rising to new peaks, reaching 6.4 billion litres in 2020 (ABIOVE, 2021a). This is driven by a higher biodiesel blending mandate, which rose to 12% (B12) in March 2020 (USDA-FAS, 2020e). Employment climbed to 323 800 jobs in 2020, according to IRENA estimates.[12] By contrast, preliminary estimates indicate that Brazil's ethanol output may have fallen by 16% in 2020, to 28.7 billion litres (USDA-FAS, 2020e). The most recent available employment estimate for bioethanol is for 2019, with 547 300 jobs. The number is expected to continue to decline as the sector becomes increasingly mechanised, translating into a reduced need for manual labour in feedstock operations.[13]

Additions to Brazil's wind power generating capacity ran close to 2.3 GW in 2020, a significant increase over the 2019 pace and more in line with what was added annually during 2014–17. Cumulative capacity was 17.7 GW (ABEEólica, 2021). IRENA estimates the country's wind workforce at about 40 200 people, primarily in construction, followed by operations and maintenance.[14]

The number of Brazil's solar PV installations has been rising rapidly in recent years. The country now ranks in the top 15 countries worldwide. Although panel shipments dropped significantly in the second and third quarters of 2020 due to the COVID-19 pandemic, Brazil nonetheless set a strong new record, with more than 3 GW added (80% in distributed solar PV), for a total of close to 7.7 GW (ABSOLAR, 2021). The bulk of solar PV panels are still imported. Domestically produced modules are eligible for low-interest-rate financing; these met 3.8% of demand in 2020, up from 3.2% in 2019 (Greener, 2021). Four of Brazil's states (Minas Gerais, São Paulo, Rio Grande do Sul and Mato Grosso) account for half of cumulative distributed PV capacity, and therefore for many installation jobs. For large-scale installations, Minas Gerais is the clear leader (ABSOLAR, 2021). IRENA estimates Brazil's solar PV employment at about 68 000 jobs in 2020, based on employment factors.[15] The bulk of jobs, close to 57 500, are in the labour-intensive distributed segment.

According to ABRASOL, sales of solar thermal collectors rose 7.3% in 2020, despite the COVID-19 pandemic (ABRASOL, 2021). The residential segment accounts for most sales (70%), followed by commercial installations (16%), with the remainder in industrial and other deployments. Employment is estimated by IRENA to have risen to 47 200 jobs, the second-highest number since 2014.[16]

12 The calculation is based on employment factors for different feedstocks (Da Cunha, Guilhoto and Da Silva Walter, 2014). The shares of feedstock raw materials, principally soybean oil and animal fat (beef tallow), are derived from ABIOVE (2021b).

13 In 2019, around 180 600 workers were engaged in sugarcane cultivation in Brazil (a decline of 36 000), and 166 700 in alcohol and ethanol processing (an increase of about 8 000 jobs [MTE/RAIS, 2021]). IRENA's employment estimate of 547 300 jobs includes 200 000 indirect jobs in equipment manufacturing, though this figure reflects a dated supply-chain estimate.

14 This calculation is based on employment factors published by Simas and Pacca (2014).

15 A jobs-per-megawatt employment calculation distinguishes between labour requirements for centralised and decentralised deployments.

16 This IRENA calculation of installation-related jobs is based on Brazilian market data and a solar heating and cooling employment factor. The estimate for manufacturing jobs is derived from an original 2013 estimate by Alencar (2013), pro-rated to yearly changes.

In **INDIA**, most power-generating capacity additions in 2020 were in solar. Still, the 4.1 GW of solar PV capacity installed was down significantly from the previous two years (IRENA, 2021a). The labour-intensive rooftop solar segment (mostly commercial and industrial applications) added 1.35 GW (Gupta, 2021a), but has been held back not only by COVID-19 impacts but also by cumbersome permitting rules (Gupta, 2021b).

Employment in solar-related manufacturing remains limited. India has virtually no presence in polysilicon, ingot or wafer production, and remains a net importer of modules. In the first half of 2020, **China** accounted for 80% of the country's module imports, with the remainder coming from **Thailand, Viet Nam** and **Malaysia** (Ladislaw *et al.*, 2021). While India's domestic module suppliers contribute about a third of utility-scale solar installations in 2020 (up from 15% in 2018), they hold a share of nearly 60% in the commercial and industrial markets and in the distributed segment (JMK Research and IEEFA, 2021).

The Indian government has long sought to support domestic manufacturing through measures such as domestic content requirements, incentives and manufacturing-linked auctions. But to date Indian module manufacturers have struggled to match Chinese competitors on cost, research and development, scale of production, or integration of module, cell and wafer production. A key policy question in India concerns the rate at which an existing "safeguard duty" (an import tariff) should be levied; the current rate was more than offset by the continued decline in foreign manufacturers' costs (Ladislaw *et al.*, 2021).

IRENA's estimates based on employment factors suggest that India had 93 000 jobs in grid-connected solar PV in 2020, a decline of 15% from 2019. Roughly 96 700 people work in off-grid solar. As mentioned earlier, South Asia as a whole saw sales plummet in 2020 due to COVID-19, but some companies may have been able to hold on to staff.

A range of recent studies indicates that India has substantial potential for additional solar jobs. Akanksha, Kuldeep and Joshi (2021) estimate the direct employment potential of deploying floating solar PV technology. By 2019, 1.5 GW of floating solar capacity was under development, and the government set a 10 GW target for 2022. A small-scale plant of less than 1 MW capacity directly requires 58 workers, while one of medium size (up to 10 MW) can employ 45 people directly. In a medium-sized plant, about half of the jobs (52%) prior to the operations stage would be in construction, 29% in business development, 15% in manufacturing of modules and system components, and 4% in design and preconstruction. Business development and design jobs are predominantly highly skilled and permanent. In construction and operations, by contrast, a quarter or fewer of jobs are permanent and most are semi-skilled.

Solar mini-grids improve the quality and reliability of power supply and generate jobs and income opportunities in rural areas. Mini-grid developer Mlinda deployed 45 mini-grids with 1125 kilowatts of capacity in 2016–20. Based on an estimated number of jobs per mini-grid (15–28), these projects created an estimated 311 jobs (including direct FTE jobs and temporary jobs in construction expressed in FTE) or 986 jobs if including jobs in productive uses made possible by access to power. This translates into 0.877 jobs per kilowatt peak deployed. Comparable projects elsewhere (in India, **Bangladesh** and

Myanmar) are estimated to have created 0.8 jobs per kilowatt peak on average. The Indian government has a goal of deploying 10 GW of small or micro renewable power, with an initial target of 1 GW.[17] If the initial target is met through mini-grids, some 800 000 to 877 000 jobs could be created (Joshi *et al.*, 2021).

In the wind industry, India has the world's fourth-largest cumulative generating capacity. But new additions have waned in recent years. The pandemic cut new installations in half, from 2.2 GW added in 2019 to just 1 GW in 2020 (IRENA, 2021a). Most of the country's projects and equipment manufacturing ground to a halt between March and May, and supply-chain delays made themselves felt later in the year (Tenddulkar, 2020). Accordingly, IRENA estimates that employment in India's wind sector may have declined from 62 800 jobs in 2019 to 44 000 in 2020.

Export markets could steady the situation. Given trade issues between **China** and the **United States**, India is positioning itself as an alternative blade and gearbox manufacturing hub, serving US and other markets. A number of turbine manufacturers and component suppliers have made investments in India for that purpose, including Siemens Gamesa, Vestas, TPI and LM Wind Power. Indeed, the share of foreign firms producing many components of wind turbines in India is high (as of 2019, nearly 100% for bearings, gearboxes and converters; 72% for blades; but 53% for nacelles and 29% for towers) (Barla, 2020).

17 The goal for small and micro renewable power is part of the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM KUSUM) programme, launched in 2019.

The **UNITED STATES** had 838 400 renewable energy jobs in 2020. This included more than 31 000 jobs in biofuels, biomass power and woody biomass fuels, about 231 500 in solar PV, almost 117 000 in wind, close to 71 000 in hydropower,[18] about 95 600 in renewable heating and cooling,[19] and 8 000 in geothermal power. In addition to the renewables sector, there were an estimated 126 580 jobs in storage and grids.[20] Further, US DOE (2021a) estimates that energy efficiency employed about 2 million people.[21]

Pandemic impacts were uneven. While total US electricity use fell 3.8% in 2020, electricity generation from wind and solar expanded 15%, and the renewable share of the power mix rose from 17% to 20% (BNEF and BCSE, 2021). Record amounts of new wind (14.2 GW, up from 9.2 GW in 2019) and solar PV capacity (14.9 GW, up from 7.5 GW) were installed during 2020 (IRENA, 2021a). COVID-19 outbreaks did force work to slow or stop during part of the year, but activity later in the year more than compensated for this (BNEF and BCSE, 2021).[22]

While some wind developers reported delays, many benefitted from having started construction early in the year, before major COVID-19 impacts were felt, because they sought to meet previously established deadlines for federal tax credits. The Energy Act of 2020, passed as part of COVID-19 stimulus efforts, steadied the situation for large numbers of projects in the pipeline by extending the wind production tax credit by one year and the solar investment tax credit by two years. Also, offshore wind projects became eligible for a new investment tax credit equal to 30% of project capital expenditures (BNEF and BCSE, 2021).

Utility-scale solar PV installations surged, and residential installations hit a new peak despite COVID-19–related permitting and construction delays. Only the commercial segment declined from the previous year's volume (BNEF and BCSE, 2021), benefitting neither from standardised financing nor from economies of scale (Davis, 2020). New solar loan products and pricing promotions helped, along with the fact that most homeowners who decided to install panels were economically relatively well off and not hit hard by the pandemic (Eavis and Penn, 2021). However, many small- and medium-sized installers struggled because the cash sales they rely on so heavily did decline during the COVID-19 recession (SEIA, 2021).

Notwithstanding record numbers of new installations, the Solar Foundation (2021) finds that employment in all solar technologies dropped 6.7% in 2020, to 231 474 workers,[23] and was down 11% from the 2016 peak of 260 077.[24] The report pins the blame on two factors. One is the impact of the pandemic, including a shift from in-person sales to online marketing in order to comply with social distancing needs. The other is continued growth in labour productivity (since 2010, productivity has increased by 19% in the residential sector and 32% in utility-scale deployment). During 2020, increasingly large utility-scale projects accounted for three-quarters of all new solar installations, benefitting from government decisions to classify them as "essential work" (Solar Foundation, 2021).

Installation and construction jobs accounted for close to 155 000, or 67% of all solar jobs. Solar manufacturing – with some 31 000 jobs (Solar Foundation, 2021) – is a relatively small component, given the limited domestic production of equipment (BNEF, 2021a). Imports of

18 This consists of 11 251 jobs in low-impact hydro, 51 880 in traditional hydro and 7 822 in pumped hydro.

19 This includes solar thermal, geothermal, biomass, heat pumps and other technologies (US DOE, 2021a).

20 The jobs in storage and grids include battery storage (66 749 jobs), smart grids (23 089), micro grids (18 555) and other grid modernisation (18 187) (US DOE, 2021a).

21 The energy efficiency category includes appliances; heating, ventilation and air conditioning; water heaters; electronic goods; windows, roofing,and insulation; commercial equipment; and lighting.

22 A report by BW Research Partnership (2021) points out that in addition to outright unemployment, many workers were furloughed temporarily or became beneficiaries of the Paycheck Protection Programme. Other workers had their hours slashed, resulting in underemployment.

23 The Solar Foundation figure includes only solar workers who spend at least 50% of their working hours on solar goods and services. By contrast, the US Energy and Employment Report (US DOE, 2021a), which pegs 2020 solar PV employment at 316 675 jobs, includes all employees engaged in solar technologies regardless of the share of time spent on solar-related work.

24 In the course of the year, employment fluctuated strongly. Workers were furloughed or laid off in response to lockdowns, and only later rehired. Year-on-year, the biggest decline happened in sales and distribution (-12.2%), followed by manufacturing (-9.3%) and installations (-4.2%).

PV modules (mostly from **Viet Nam, Malaysia** and **Thailand**[25]) were about 90% of total shipments in the United States during 2020 (EIA, 2021c). The United States had a domestic module capacity of 2 GW in 2020, compared with 19.2 GW of installations that year (Wagman, 2021a).[26]

The Solar Foundation noted improvements in workforce diversity, with gains by minority groups in 2020 and the share of women rising from 26% to 30% (compared with 47% across the whole economy). The number of female workers rose by about 4 800 to more than 69 000. The survey also estimates that 10.3% of US solar workers in 2020 were unionised,[27] roughly the same low level as in the economy at large. But in solar manufacturing the share was 8.6% and in sales only 4.5% (Solar Foundation, 2021). Solar's unionisation rate compares with rates as high as 20.7% in the nuclear power industry and as low as 5.2% in natural gas fuels. The fuel sector as a whole (*i.e.* encompassing all types of fuels) has fewer women workers than power generation (US DOE, 2021a).

Solar job numbers could grow strongly in coming years. The US government (US DOE, 2021b) has estimated that investments and installations to enable a largely decarbonised electricity sector by 2035 could create anywhere from 500 000 to 1.5 million solar jobs in the United States by 2035.

Of 116 817 US wind power jobs in 2020, more than a third were in construction, a quarter in professional services and a fifth in manufacturing (US DOE, 2021a).[28] Wind was the only US energy industry to expand its workforce in 2020, by 1.8%. This rate pales in comparison with the rapid pace of new installations but may simply mean that pandemic work delays lowered FTEs for the year. Also, some projects were already close to commissioning at the beginning of 2020 and thus did not require extensive additional labour inputs to reach completion.

25 Most of the plants in these countries are Chinese owned, and about 70% of total module value reflects inputs made in China, including polysilicon, ingots, wafers and cells. Only 27% of the value is added locally in Southeast Asia, reflecting assembly labour and some other inputs (Bloomberg NEF, 2021a).

26 A 3.3 GW module plant being built by FirstSolar in Ohio is scheduled to start operations in 2023. Construction requires some 500 workers, and the facility is expected to create more than 700 permanent jobs (Wagman, 2021b).

27 The Solar Foundation (2021) notes that its 2019 estimate of unionisation, at just 4%, was an underestimate. For 2020, it adopted an improved statistical methodology that sought to correct for a non-response bias in the previous survey. The percentages refer to the union coverage rate, which includes union members plus non-members covered by a union contract (USEER, 2021).

28 US wind job estimates in previous editions of the Annual Review were based on data from the American Wind Energy Association, but they cannot be directly compared because of different underlying methodologies.

US offshore wind deployment is still limited but poised for rapid growth. The American Wind Energy Association (AWEA, 2020) modelled the likely impacts of a base scenario of reaching 20 GW by 2030 (with local content limited to 21% in 2025 and 45% in 2030) and a more ambitious scenario of 30 GW (with increased local content of 32% and 60%, respectively[29]). Assuming annual installations of 2 GW and 3 GW under the two scenarios, the base scenario could create close to 30 000 direct and indirect FTE jobs in 2030, but 52 400 FTE jobs under the high scenario.[30]

About 70% of the total value of a typical US wind project is accrued within the country, and thus generates employment domestically. For manufactured inputs, the share was 57% in 2019. Many key components for offshore wind turbines are manufactured in **Europe** (Stromsta, 2020). But a significant share of imports in 2020 also came from countries with comparatively low wages. Most blades came from **Brazil, China** and **India**, and more than half of towers from **Indonesia, Viet Nam** and **India** (BNEF, 2021b). There is also a lack of wind-turbine installation vessels built domestically.[31] The number of US shipyards able to build such vessels is limited, as is the number of ports currently equipped to support them (GAO, 2020). Construction of the first US-flagged installation vessel began in Texas in 2020 (US DOE, 2021c).

Developing stronger local supply chains has become a priority in states on the US east coast with plans to build offshore wind plants (AWEA, 2020). In December 2020, the state of New Jersey announced a USD 250 million investment in a monopile manufacturing facility to supply steel components for the 1.1 GW "Ocean Wind" project. This follows on plans to develop a dedicated "wind port". Construction of the plant began in April 2021 and is scheduled for completion in 2023. The plant is expected to create 260 jobs initially and more than 500 jobs at peak, with a project labour agreement ensuring well-paid jobs (State of New Jersey, 2020; North American Windpower, 2021).

29 For comparison, the domestic content of land-based wind energy in the United States grew from 20% in 2005 to 67% by 2011 (AWEA, 2020).

30 Induced effects would add 16 000 and 30 000 FTE jobs, respectively.

31 While installation vessels will take years to construct, other, smaller types of necessary vessels, such as those for site surveying, cable-laying, and operations and maintenance, are either available or can be built relatively quickly and inexpensively (GAO, 2020).

In September 2020 New Jersey's Economic Development Authority decided to provide USD 4.5 million to support development of an offshore wind workforce through the state's Clean Energy Programme. In neighbouring New York, the State University of New York and the Energy Research and Development Authority (NYSERDA) launched a USD 20 million Offshore Wind Training Institute in January 2021. Maryland and Massachusetts are also supporting training programmes (GWEC, 2021b).

In tandem with these efforts, some states focus on hiring unionised labour. Massachusetts assigns a 70% weight to bid costs when evaluating offshore wind bids, with the remaining 30% assigned to the bidder's provision of in-state economic benefits such as the use of local ports. In New York, legislation requires companies to sign contracts with construction unions or to pay "prevailing wages" reflecting union benchmarks, and to permit unions to organise workers (Meyer, 2021). Smooth and productive labour relations will be key to success (see In Focus Box 4). At the federal level, the administration of US president Joe Biden is supporting the creation of "good-paying, middle class, union jobs" (White House, 2021).

US biofuels employment in 2020 ran to about 271 000 jobs, 9% below the 2019 figure. Given much-reduced motor fuel consumption owing to COVID-19 lockdowns, ethanol production fell by 11.6% in 2020 (EIA, 2021a), while capital investment and purchases of feedstock and other inputs dropped precipitously. An input-output model calculation estimates 2020 employment at 200 250 direct and indirect jobs, 12.8% fewer than in 2019 (Urbanchuk, 2021). Biodiesel output, by contrast, rose 5.3% to about 8.26 billion litres in 2020 (EIA, 2021b). IRENA estimates that the number of jobs climbed to about 70 860.

In Focus Box 4.
Management-labour co-operation in US offshore wind development

As offshore wind companies look to build the workforce they will need, Denmark's Ørsted (the world's largest offshore wind developer) reached a memorandum of understanding with North America's Building Trades Unions (NABTU) in November 2020 to train workers for the company's projects along the US east coast. NABTU represents 3 million workers. Ørsted operates the first US utility-scale offshore wind farm (the Block Island Wind Farm off Rhode Island), a project that was built with more than 300 union workers. Ørsted and NABTU agreed to collective bargaining arrangements and to work jointly to identify needed skills and co-operate in training and certification efforts (Volcovici, 2020). The deal could become a model for labour management co-operation and workforce development that other developers may want to emulate (NABTU, 2020a).

Countries in **EUROPE** hosted a combined total of 1.6 million renewable energy jobs, approximately 1.3 million of them in EU member countries (the EU-27, following Brexit). The bioenergy sector is the largest renewables employer on the continent. Solid biomass (for heat and electricity) leads with approximately 414 000 jobs (of which 368 000 in the European Union), followed by biofuels, with 242 000 jobs (229 000 in the European Union), and biogas with 79 000 jobs (76 000 jobs in the European Union).

IRENA estimates European wind power employment at 333 200, with 259 500 of those jobs in EU member states.[32] The continent's cumulative wind-generating capacity stands at 208 GW. Some 14.3 GW were added in 2019, while the 2020 addition (11.4 GW) was level with the pace in 2018. **Germany, Spain** and the **United Kingdom** are the leaders in overall installations in Europe, but in all three countries the pace slowed considerably in 2020 (IRENA, 2021a). The European offshore wind industry continues to expand, and GWEC (2021b) estimates that nearly 100 000 jobs have been created in this segment.

In addition to domestic markets, export sales have been an important source of wind jobs in **Germany, Spain** and **Denmark**. But Wind Europe (2020) points out that European wind equipment exports have stayed steady in the past decade at around EUR 8 billion annually, even as wind capacity has expanded around the world. This is partly due to rising local-content requirements, but the growth of steady markets outside Europe has also led firms to set up manufacturing facilities on their own in various other locations. Europe is still an important exporter of equipment such as nacelles, hubs and blades, commanding 30–40% of the global turbine installation market in the past decade. But components and certain materials are increasingly produced elsewhere (Wind Europe, 2020).

Both Europe as a whole and the EU member states added record amounts of solar PV in 2019 and 2020, more than double the volume in 2018 (IRENA, 2021a), defying worries that COVID-19 could shrink the market. EU members took the lion's share, with 90% of the continent's capacity additions, up from 79% in 2019. Solar PV employment in all of Europe is estimated by IRENA at 239 000 jobs in 2020; for the European Union, the estimate is 194 000.

32 This is similar to a 2019 figure of 300 000 direct and indirect jobs in the EU-28 (still including the United Kingdom prior to Brexit) as estimated by Wind Europe (2020) on the basis of data collection from companies and economic modelling. Of these, 224 000 jobs were in the onshore segment and 77 000 offshore. By value segment, close to 24 800 jobs were estimated among developers, about 83 000 among turbine and component manufacturers, about 44 800 among service providers and 7 900 for substructures.

In **GERMANY**, the most recent available government data indicate that renewable energy employment continued a decade-long decline from a 2011 peak of 416 800 jobs, to 299 700 in 2019 (BMWi, 2021). But the performance of individual industries diverged, with strong changes in the wind and solar industries. In contrast, hydropower and geothermal increased marginally, while bioenergy registered a small decline of 2 200 jobs.

According to BMWi (2021), wind industry jobs fell 12% in 2019 to 105 700, a loss of 15 000 jobs from 2018 and almost 58 000 from the 2016 peak. For 2020, IRENA estimates a further decline to 90 000 wind jobs. These changes are principally the result of the precipitous decline in new installations, from more than 6 GW in 2017 to only 2 GW in 2019 and 1.5 GW in 2020.

Onshore additions declined to just 865 MW in 2019 and about 1.2 GW in 2020 (IRENA, 2021a) – the lowest volumes in 20 years. Apart from COVID-19, several factors slowed the pace, including strict annual deployment caps, reduced feed-in tariffs, complex tender requirements and restrictive state-level policies for wind-farm siting. The average time required to bring wind projects to completion doubled from previous years (a change partially driven by more difficult permitting processes) (FA Wind, 2021).

Offshore, new wind installations fell to 1.1 GW in 2019 and to just 218 MW in 2020 (IRENA, 2021a). No new capacity was expected to be added in 2021, the first year of zero growth in a decade (BWE, 2021). A continued slump could endanger the industrial base of Germany's wind industry, but the coming years may bring better news. In June 2020 the German government amended the Offshore Wind Act (WindSeeG), raising the target for offshore wind by 2030 from 15 GW to 20 GW, and aiming for 40 GW by 2040. The government has also invested in training programmes and apprenticeships for offshore wind. The North Sea ports of Bremerhaven and Cuxhaven host manufacturing facilities for turbines, foundations and service vessels (GWEC, 2020a).

The solar PV industry, by contrast, gained about 5 800 jobs in 2019, rising to 43 900 (BMWi, 2021). For 2020, IRENA's employment-factor methodology generates a rough estimate of a further hike to 51 000 jobs. The pace of new PV installations rose to 3.9 GW and 4.7 GW in 2019 and 2020, respectively, reversing the decline in additions over much of the past decade (IRENA, 2021a). The government removed a 52 GW cap that had been put in place in 2011. That threshold was crossed in 2020 and would have limited feed-in tariff incentives for residential and commercial installations (Izquierdo *et al.*, 2021).

Renewable energy employment in **SPAIN** continued to rebound in 2019, expanding 17% to 95 100 jobs, up from 81 300 in 2018. The expansion was entirely driven by wind and solar PV. These two industries employed 28 600 and 21 400 people, respectively, or 53% of all Spanish renewables jobs. With 31 900 jobs, biomass power still is in the lead, but the number keeps falling year after year. According to the Spanish Association of Renewable Energy, the renewables sector's contribution to gross domestic product rose by 19%, to EUR 12.5 billion in 2019 (APPA, 2020).

In 2020, one of the world's strictest COVID-19 lockdowns slowed administrative functions in Spain, closed factories temporarily, and delayed projects under construction or at the point of commissioning. New installations fell: to 2.8 GW from 4.2 GW added in 2019 for solar PV; and to 1.5 GW, down from 2.2 GW in 2019, for wind (IRENA, 2021a). IRENA estimates that solar PV employed some 17 500 people in 2020 and wind another 27 800.

Allocations from the European Recovery Fund aimed to position renewables as one of the main catalysts for the recovery of the Spanish economy. Optimistic in their expectations, companies continued to train new staff. In 2021, the most in-demand professions in Spain in the renewable energy sector were project developers, design engineers with expertise in high-voltage lines and substations, and product sales representatives (Walters, 2021; Raso, 2021).

IRELAND's grid operator ESB is transforming its Moneypoint site, which had long burned coal to generate power, into a renewable energy hub. It will feature a 1.4 GW floating offshore wind farm, a facility to integrate renewable electricity into the grid, a wind-turbine construction hub around an existing deep-water port, and a green hydrogen production and storage facility. The expectation is that hundreds of jobs will be created (Windfair, 2021).

In the **UNITED KINGDOM**, renewables employed about 138 300 people in pre-pandemic 2019/2020, up 3% from 134 000 the previous year (REA, 2021). Offshore wind employed the most people within the renewables sector, at 28 300 in 2019/2020, followed by 23 100 in onshore wind, for a combined total of about 54 400 people. Bioenergy employed 45 600, of whom some 13 200 were in biofuels, an equal number in biomass production and close to 16 000 in biomass use for power and heat. The solar sector continued the employment slide of recent years, though at a lower rate: In 2019/2020, solar PV had about 7 500 jobs and solar thermal another 7 100 (REA, 2021).

A survey conducted by the Offshore Wind Industry Council (OWIC, 2021) offers a figure of 26 093 direct and indirect positions in 2020, a smaller drop than might have been predicted given the decline in new installations that year. Skilled, technical and professional job roles accounted for 62% of the slots. Women held an 18% share of the sector's workforce; the industry has committed to raising that share to 33% by 2030 and 40% after. By region, 30% of offshore wind jobs were in Scotland, 35% along England's east coast, 16% in London and the southeast, and 17% in the rest of the country. A number of regional offshore wind clusters – collaborations among developers, supply-chain companies, local governments and educational bodies – are emerging.

The UK government aims to have 40 GW of offshore wind capacity by 2030. It plans to invest GBP 160 million (USD 220 million) in ports and manufacturing infrastructure in coastal regions. According to the Ten Point Plan for a Green Industrial Revolution (UK Government, 2020), this could generate

60 000 domestic jobs, while OWIC expects close to 70 000 jobs by 2026, premised on private sector investments of GBP 60.8 billion (OWIC, 2021).

These job projections ride on an assumption of 60% domestic content, to be achieved through auction specifications. However, these auctions focus on cost rather than local content. At present only 29% of capital expenditures on offshore wind projects are spent within the UK economy, or 48% if development costs and operations and maintenance are included (Thomas and Tighe, 2021). Projects are mostly owned by foreign firms and a significant portion of the supply chain is located abroad (STUC, 2020; Ferns, 2020). The country's sole tower factory was mothballed (STUC, 2020), with towers imported instead from **Viet Nam** (Meeks, 2021). Two blade factories employ about 2 100 people directly (Bounds *et al.*, 2020). A third factory with 750 jobs is to be completed at a brownfield site in Teesside by 2023. But the investment decision behind the factory was driven by significant concessions, such as GB 20 million in public funding and making Teesside a low-tax freeport (Thomas, Pickard and Foster, 2021).

The bankruptcy of BiFab at the end of 2020 underscored the challenge of translating projects into domestic jobs. The company, a Scottish producer of foundations for offshore turbines, used to supply the oil and gas industry and once had as many as 2 000 employees. But it lost out on lucrative offshore wind contracts to companies in Europe and Asia (Thomas and Tighe, 2021). Construction of the 714 MW East Anglia One wind farm created almost 3 500 jobs, but the project's foundations were built in **Ireland, Spain** and the **United Arab Emirates**, and a marine substation was manufactured in **Spain** (Scottish Power Renewables, n.d.). Similarly, most of the foundations for EDF's Neart Na Gaoithe wind farm will be built in a low-wage, low-tax zone in **Indonesia** (STUC, 2020).

DENMARK's experience shows what an industrial policy strategy can accomplish. As a pioneer in wind development, the country built one of the most complete supply chains in the world, driven by public sector steering and investment. Denmark is not just a principal developer of wind farms, but is also home to major turbine manufacturers housed in industrial clusters with more than 500 suppliers across the value chain and supported by leading research and development facilities (GWEC, 2020a). Danish companies have an estimated 40% share of the European offshore wind market – a 25% share of installations, but 80% of operations and maintenance. For each megawatt installed in offshore wind farms in Denmark, Danish companies create an estimated 4.9 direct FTE jobs. Their large share of the regional wind market allows them to create another 3.1 FTE jobs for each megawatt installed elsewhere in European waters (QBIS, 2020).

Ports serving offshore wind farms are typically located in remote coastal communities. Although they tend to employ relatively few people directly, they generate additional economic opportunities for shipyards, steel manufacturers and other suppliers. The port of Esbjerg was once Denmark's leading service hub for the oil and gas industry but transformed itself over the past two decades into the world's largest centre for offshore wind. A quarter of Esbjerg's revenue is from offshore wind, compared with just 10% from oil and gas. It is involved in more than 50 wind projects representing just over half of Europe's cumulative capacity. As local firms applied their oil and gas expertise, Esbjerg became a base for some 250 offshore wind suppliers. Esbjerg's experience suggests that ports and other actors need to be proactive in innovating, securing a continuous portfolio of projects and attracting investments. Clear policy commitments from public authorities are crucial.

In **FRANCE**, direct and indirect wind employment ran to about 20 200 jobs at the end of 2019, a gain of 11%. With the capacity expansion planned under the government's Pluriannual Energy Programming for 2023–28, employment could rise to 50 000 jobs (FEE and Capgemini Invent, 2020). Wind power generation grew during the pandemic, and several offshore projects began construction. But temporary halts to construction and sluggish administrative procedures reduced new installations by 50% (IRENA, 2021a), clouding job prospects – at least temporarily.

Siemens Gamesa will supply five projects from a blade and nacelle plant under construction in Le Havre (Siemens Gamesa, n.d.). Of an expected total of 750 direct and indirect jobs there by 2023, 210 positions are to be filled in 2021 (Frebou, 2021). In Montoir de Bretagne, GE is assembling nacelles, with 450 direct and indirect jobs, in addition to 200 people at the Nantes headquarters (FEE and Capgemini Invent, 2020). In Cherbourg, the GE subsidiary LM Wind Power is recruiting an additional 250 people for its blade manufacturing facility. The plant currently has 300 employees and produces blades for projects in the **United States** and the **United Kingdom** (Lavalley, 2020). A factory located in Saint-Nazaire employs 200 people in the production of foundations and electrical substations (FEE and Capgemini Invent, 2020).

Other countries

Many other countries – in Asia-Pacific, Latin America and the Caribbean, the Middle East and North Africa, and Sub-Saharan Africa – continue to expand their presence in renewables. This section highlights some of them, beginning with the Asia-Pacific region.

In **JAPAN**, cumulative solar PV capacity reached 67 GW in 2020, the third largest after China and the United States. But the pace of annual additions continued to slow, to about 5.5 GW, less than half the volume of 2018 (IRENA, 2021a). Scarce suitable land puts a premium on distributed solar, reinforced by decreasing feed-in tariff rates for utility solar. The National Survey Report of PV Power Applications (IEA PVPS, 2021a) puts direct solar PV employment at 74 800 in 2020. IRENA estimates direct and indirect employment at some 220 000 jobs, down from 241 000 jobs in 2019.[33] The bulk of Japan's solar panels are imported. In the fourth quarter of 2020, foreign-produced modules accounted for 95% of total shipments (JPEA, 2021), implying a limited number of domestic manufacturing jobs.

In the **REPUBLIC OF KOREA**, direct solar PV employment was estimated at about 19 300 jobs in 2019, up from 13 800 in the previous year. Close to 7 600 jobs were in manufacturing, 3 400 in distribution, and 8 300 in installation (IEA PVPS, 2021b).

MALAYSIA is a major solar PV manufacturer, with a module-production capacity of about 8.9 GW as of 2019 and direct PV employment of 26 200 people (of whom 17 700 are in manufacturing) (IEA PVPS, 2020). If indirect employment were included, the number would at least double. The Sustainable Energy Development Authority (SEDA, 2020) estimates the number of people working in solar PV in 2019 at 54 900.

33 In the absence of direct employment data, this calculation is based on the assumption that employment closely tracks the drop in demand during 2019.

The number of solar PV jobs in the **PHILIPPINES** continued to rise, from 33 700 in 2019 to 41 035 in 2020. Large and small hydropower was estimated at close to 53 600 jobs.[34] Wind power jobs rose to 23 800, with solid biomass contributing another 11 200, geothermal power 8 300 and biofuels processing close to 2 900 (REMB DOE, 2021). IRENA estimates that another 36 100 jobs (not necessarily FTE) were in the agricultural supply chain for biofuels. Altogether, renewable energy may employ as many as 178 000 people. COVID-19 mobility restrictions slowed project development activities for wind and solar, and caused some construction delays, whereas operations were less affected. However, delays were addressed through special permits that declared workers in these sectors as essential personnel and through a general streamlining of the permitting process in the energy sector. By contrast, COVID-19 put on hold or postponed many activities in geothermal energy, reducing the number of jobs by 30% (REMB DOE, 2021).

VIET NAM is a notable manufacturer and exporter of PV modules and has also established itself as a major installer, adding 11.6 GW in 2020. That was the third-highest amount worldwide, up from 4.8 GW installed in 2019 (IRENA, 2021a). Viet Nam was able to control the COVID-19 virus much better than many other countries, and installations were driven up by a rush to complete projects before an expected (but now delayed) switch from feed-in tariffs to auctions (Ha, 2021). IRENA estimates the solar PV workforce at 126 300 jobs in 2020, with 99 700 jobs in rooftop solar and 26 600 jobs in utility-scale projects. Because grid congestion is likely to limit additional utility-scale installations, the overall pace is set to slow, while the focus is increasingly on rooftop installations for self-consumption (BNEF, 2021d).

Meanwhile wind power deployment is beginning to accelerate. For 2020, IRENA estimates Viet Nam may have 3 500 wind jobs. Some 4 GW of wind projects, approved and under construction, could create some 21 000 jobs. But the pandemic did cause supply-chain bottlenecks and limited the mobility of workers. This has led to significant construction delays, which could cause projects to miss the November feed-in tariff deadline (GWEC, 2021c).

In **Bangladesh**, the focus in the solar sector is shifting from decentralised solar home systems to grid-connected solar installations, with implications for the types of jobs that are generated, and where. The Sustainable and Renewable Energy Development Authority intends to train a skilled rooftop solar workforce. It has issued a call to people who wish to gain PV installation skills and who either hold a first degree in engineering or have five years' experience in the solar sector (Islam, 2020).

Kalyon Solar Technologies opened a factory in Ankara, **TURKEY**, with an initial 500 MW annual production capacity for ingots, wafers, cells and modules. The firm plans to expand to 1 GW. Based on German-made production equipment, the project created some 1 400 factory jobs and 100 jobs at an affiliated research centre (Enkhardt, 2020).

On the basis of installation trends and employment factors, IRENA estimates that the **RUSSIAN FEDERATION**'s wind industry employs some 12 000 people. The country had only about 100 MW of cumulative capacity installed at the end of 2019, but added 843 MW in 2020 alone (IRENA, 2021a). Hydropower remains dominant among renewables in Russia, with 51.8 GW capacity and some 57 600 direct jobs, according to IRENA calculations. But little new hydro capacity has been added in recent years.

34 This is a larger number than IRENA's employment factor estimate, likely due to varying methodologies and other assumptions.

Under the impact of COVID-19, **AUSTRALIA**'s solar PV capacity additions dropped precipitously in the first half of 2020 but surged in the second half, ending with an annual total of 4.4 GW, close to the volume added in 2019 (IRENA, 2021a). The decline principally affected the utility-scale segment, while rooftop installations rose from 2.2 GW to 2.6 GW year-on-year (AEC, 2021a, 2021b).

Energy transition scenarios indicate a large potential for job creation. Briggs *et al.* (2020) suggest that compared with about 26 000 renewables jobs in 2020 (roughly the level of the previous year), some 34 400 could be generated in the period to 2035 in solar, wind, hydro and batteries. (The estimate does not include jobs in bioenergy or hydrogen.) A more ambitious plan foresees some 124 000 jobs in renewable energy construction and 22 000 in operations through deployment of 90 GW of capacity, as part of a much larger economic transformation entailing 1.8 million jobs in green transport, building retrofits, clean manufacturing and other areas (BZE, 2020).

At the subnational level, Australia's New South Wales province has adopted a renewables-focused Electricity Infrastructure Roadmap. Expected private sector investment of AUD 32 billion (USD 23.6 billion) by 2030 in generation, storage and transmission is estimated to support some 6 300 construction jobs and 2 800 jobs in operations (NSW DPIE, 2020).

In the Western Hemisphere, hydropower continues to be the largest employer in **CANADA'S** renewable sector, with 33 260 direct and 15 530 indirect jobs in 2020.[35] Liquid biofuels and wind power are the next largest, at 13 000 and 12 000 jobs, respectively. Other forms of bioenergy and solar PV generate comparatively fewer jobs, at about 3 000 each. Including solar thermal, geothermal energy and energy storage, the renewables sector as a whole is estimated to employ a total of 97 250 people (Natural Resources Canada, 2021).

In **MEXICO**, the Mexican Wind Energy Association (AMDEE) reports that as of March 2021, the country had some 16 000 wind jobs, up from 13 000 a year earlier. About 56% were in manufacturing, 34.5% in construction and 9.5% in operations and maintenance (Zarco, 2020, 2021). Substantial job creation potential exists. An earlier study (AMDEE and PWC, n.d.) estimated that installing 12 GW of wind could generate more than 45 000 jobs and stimulate industrial development. In addition to 9 000 jobs in construction, the most jobs would be in metal products, plastics, machinery and equipment, electrical equipment, and information technology. A 2018 study of all renewables estimated that installing a capacity of 32.6 GW between 2018 and 2032 could support some 206 000 jobs, of which 36% would be in solar PV, 29% in wind, 14% in bioenergy, and 9% in hydropower. The rest would be in geothermal energy and co generation (CESPEDES, 2018).

35 *This figure is larger than IRENA's employment-factor-based estimate, likely due to varying methodologies and assumptions.*

Elsewhere in the region, IRENA estimates based on employment factors suggest some 9 400 wind jobs in **CHILE**.

In the **MIDDLE EAST**, a study combining an employment-factor analysis and input-output modelling concluded that **JORDAN** had some 5 000 people working directly and indirectly in the renewables field in 2020. From about 600 jobs in 2013, principally in solar water heaters, the numbers started to rise in 2014. In 2020, solar PV employed more than 2 000 people, wind power close to 2 000 and solar thermal more than 1 000. In addition to renewables, the study estimates more than 6 000 jobs in energy efficiency (lighting and buildings), for a combined 11 300 jobs. Women held only about 5% of the jobs (8% in solar but only 1% in wind) (RCREEE and GWS, 2020).

In **SUB-SAHARAN AFRICA**, in response to the COVID-19 pandemic, the government of **NIGERIA** launched the Solar Power Naija project in December 2020 as part of its Economic Sustainability Plan. The project aims to expand energy access to 25 million individuals via 5 million new household connections in rural areas through solar home systems and mini-grids. Long-term, low-interest credit is to be extended to prequalified solar home system distributors and mini-grid developers, as well as to manufacturers and assemblers of solar components. The intent is to raise local content in solar manufacturing and assembly, with import substitution possibly worth USD 10 million per year. The government hopes to incentivise the creation of 250 000 jobs (Bungane, 2020). The target for the first year is 750 000 connections and 37 500 new jobs (Sunday, 2020).

With few exceptions, Sub-Saharan African countries import renewable energy equipment rather than manufacture it domestically. Following the start of construction in 2017, a 30 MW factory in Ouagadougou, **BURKINA FASO**, is the first facility in West Africa to assemble solar PV modules, delivering 60-100 PV panels per day (Spaes, 2020). The country is also stepping up domestic solar PV deployment, more than doubling its 2019 installations (Deboutte, 2020).

Neighbouring **TOGO** completed one of the largest solar projects in West Africa, a 50 MW plant financed under the IRENA-ADFD Project Facility.[36] Able to provide electricity to some 160 000 homes and small businesses, the facility will allow Togo to reduce fossil fuel imports. More than 700 local jobs were created during construction, with an additional 120 direct and indirect jobs in operations (IRENA, 2021b).

Cumulative direct employment through **SOUTH AFRICA**'s Renewable Energy Independent Power Producer Procurement Programme has risen from 31 207 job-years in 2016–17 to 55 217 by September 2020. However, the bulk – 44 290 job years, or some 80% – occurred in construction, which typically provides employment for only a limited time. Indeed, construction employment over the past decade came in three waves, with peaks and troughs. The remainder of employment was in more permanent occupations in operations and maintenance, with the number slowly building to about 11 000 job years. Women have held 10% of the jobs created so far (IPPPP, 2021). For 2020, the government estimated solar PV jobs at 21 451, with another 10 442 jobs in concentrated solar power and 18 840 jobs in wind power (DMRE, 2021).

Transitioning from fossil fuel to renewable energy poses geographical challenges. South Africa's coal sector remains the dominant energy employer, with about 92 000 direct jobs and 170 000 indirect jobs. Some 80% of conventional power plants are in Mpumalanga (RES4Africa, 2020), a province that to date has only two small biomass projects with 30 MW but no wind or solar installations (IPPPP, 2021).

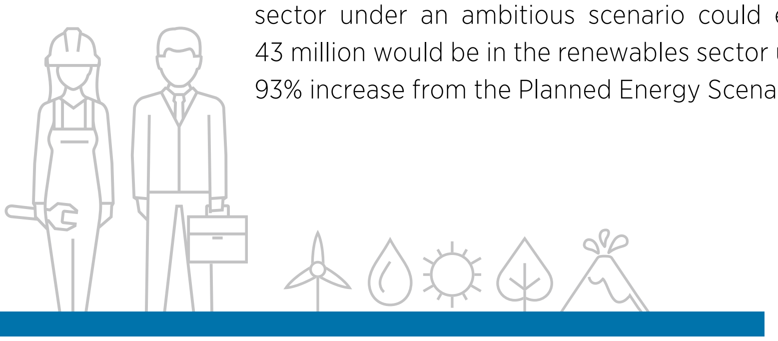
36 IRENA and the Abu Dhabi Fund for Development (ADFD) have collaborated in supporting replicable, scalable and potentially transformative renewable energy projects in developing countries. The IRENA/ADFD Project Facility has selected 32 renewable energy projects. See www.irena.org/adfd/ for details.

Chapter 2. EMPLOYMENT FOR A CLIMATE-SAFE FUTURE:

OUTLOOK FOR THE ENERGY TRANSITION

Accelerating the energy transition in line with global climate and development objectives will continue to have significant implications for employment in the energy sector as well as the wider economy. The energy transition can create many new job opportunities along the value chain. Reaping the benefits and overcoming challenges in this regard requires a deep understanding of the interplay of the energy transition with economies and societies. For this reason, IRENA has put forward a comprehensive approach that links the world's energy systems and economies within one consistent quantitative framework, which allows socio-economic indicators to be compared under different scenarios. All other things held equal, this leads to an analysis of the impacts of the energy transition expressed in the indicators of employment, gross domestic product and welfare.[38]

In IRENA's *World Energy Transitions Outlook* (IRENA, 2021c), the transition toward a 1.5°C compatible global pathway is compared to a Planned Energy Policies Scenario (PES) (see In Focus Box 5). While the former is aligned with the 1.5°C climate ambition, the latter refers to current energy plans, including each country's Nationally Determined Contributions. IRENA's analysis finds that the global net effect of the energy transition aligned with the Paris Agreement's goal to limit the global average temperature rise to 1.5°C on jobs is positive. A transformed energy sector under an ambitious scenario could entail 122 million jobs in 2050, of which 43 million would be in the renewables sector under the 1.5°C Scenario. This represents a 93% increase from the Planned Energy Scenario.



In Focus Box 5.
IRENA's *World Energy Transitions Outlook*

IRENA's *World Energy Transitions Outlook* is a unique 1.5°C-compatible pathway that is guided by the UN Agenda for Sustainable Development and the Paris Agreement on Climate Change. It also examines full socio-economic and policy implications and provides insights on structural changes and finance. IRENA's 1.5°C pathway assumes that the world pursues the development path that is most likely to drive down energy emissions in the coming decade and puts the world on a 1.5°C trajectory.

The 1.5°C Scenario involves assumptions including systematic support of emerging technologies most likely to become competitive in the short term and most effective in achieving emissions reductions in the long term; limited investments in oil and gas; the phasing out of coal and fossil fuel subsidies; adapted market structures and investment in policies that promote resilience, inclusion and equity and protect workers and communities affected by the energy transition.

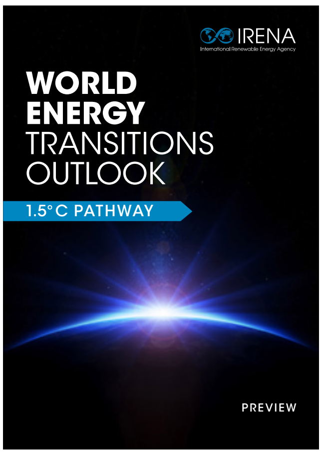
Among others, this implies that under the 1.5°C trajectory and by 2050 electricity will be the main energy carrier, with hydrogen and derivatives accounting for 12% of final energy, and bioenergy for 18%. Energy efficiency technologies and measures are "ready-to-go" solutions, available for significant scale-up now.

Close links and feedback loops exist between the energy sector and broader economic and social systems. Jobs are an integral part of this, but to manage distributional impacts and equity concerns related to the energy transition, it is essential that policy makers have a clear understanding of the wider context and are aware of the instruments available to address broad socio-economic goals.

Therefore, the *Outlook* includes a holistic climate policy basket. This basket encompasses a broad set of fiscal policy measures, such as adequate carbon pricing of emissions across sectors. Additionally, subsidies and public investment in infrastructure are needed, as well as expenditures to support a just energy transition and address social challenges. It also highlights the critical role of international co-operation to foster economic diversification; support a just transition specifically in fossil-fuel-dependent countries; and enable developing countries to leapfrog to modern and sustainable energy systems and to harness the benefits of the energy transition.

The macro econometric modelling framework underlying the *Outlook* then captures the effects and feedback loops of different climate and energy transition policies, including their effect on government revenue streams and government spending but also distributional and social impacts.

Figure 10: IRENA's PES and 1.5°C Scenarios



The **Planned Energy Scenario (PES)** is the primary reference case for this study, providing a perspective on energy system developments based on governments' current energy plans and other planned targets and policies, including Nationally Determined Contributions (NDCs) under the Paris Agreement.

PES

The **1.5°C Scenario (1.5-S)** describes an energy transition pathway aligned with the 1.5°C climate ambition – that is, to limit global average temperature increase by the end of the present century to 1.5°C, relative to pre-industrial levels. It prioritises readily available technology solutions, which can be scaled up at the necessary pace for the 1.5°C goal.

1.5-S

Source: IRENA, 2021c.

The energy transition leads to additional economic activity and shifts economic activity from fossil fuels toward energy transition sectors. Beyond renewables, additional jobs are related to the other pillars of the energy transition, such as efficiency, grid enhancement and flexibility, storage and hydrogen, to name a few. The net balance of the related employment differences is positive throughout the energy transition. Global, economy-wide employment is 0.9% higher on average under the 1.5°C Scenario than under the PES.

This chapter presents impacts of the energy transition on renewable energy jobs, followed by those in the energy sector as well as the wider economy. The results are shown in absolute numbers for the PES and the 1.5°C Scenario, or as the difference between both scenarios.

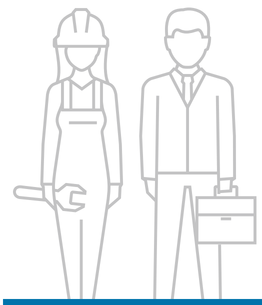
Future jobs in renewables

If the world follows IRENA's 1.5°C pathway, employment in the renewable energy sector can grow to about 43 million jobs over the next three decades. Under the PES, job numbers increase more slowly and to a lesser extent, with 18 million by 2030 and, after accelerating efforts in a delayed response to the climate challenge, 23 million by 2050. Because the 1.5°C Scenario prescribes immediate and more ambitious action, it makes rapid gains in renewable energy deployment and in employment possible. Comparing the two pathways, there are about 21 million additional jobs in renewables under the 1.5°C Scenario by 2050 (see Table 3).

Table 3: Renewable energy jobs worldwide in the 1.5°C Scenario and differences with the PES, 2030 and 2050

			2030	2050
Renewable energy	Absolute	million jobs	37.8	43.4
	DIfference with the PES	million jobs	19.8	20.8
		relative	110%	92.8%

Source: IRENA, 2021c.



Future renewable energy employment by technology

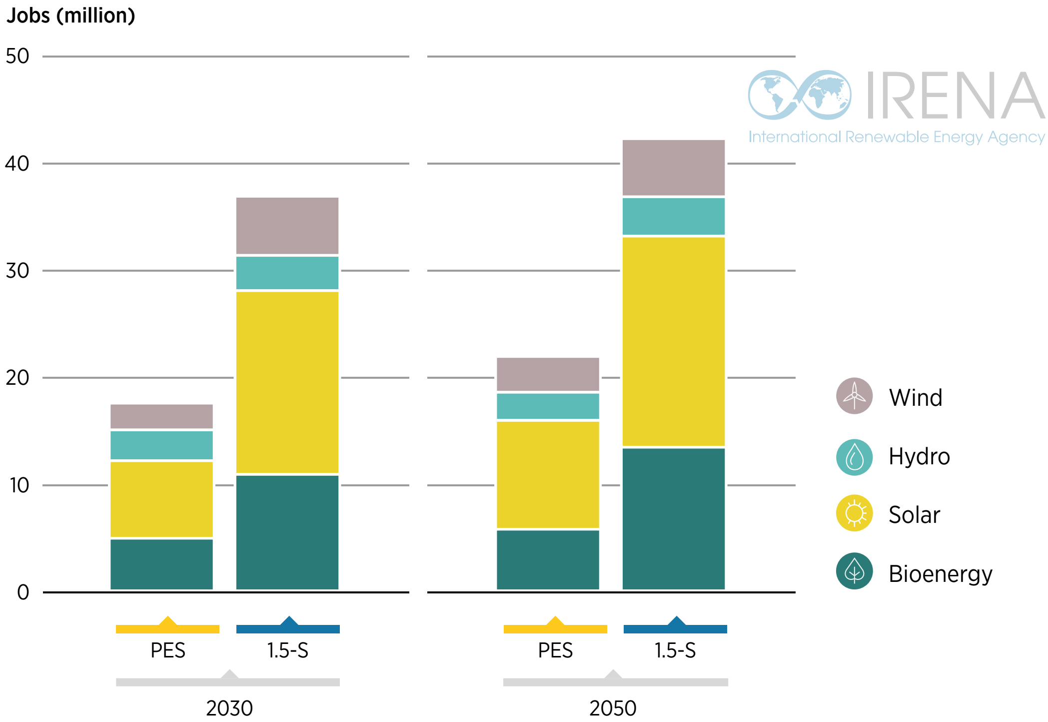
SOLAR PV: Under both scenarios, solar PV remains the largest driver of job growth in the renewable energy sector. In the 1.5°C Scenario, around 20 million jobs by 2050 are in solar energy, 77% of which are in PV, 15% in solar water heaters (SWHs) and 8% in concentrated solar power (Figure 11). This is, on the one hand, because more investment continues to go toward solar PV than to any other single source, and on the other, because PV, in particular distributed rooftop or off-grid, has greater labour intensity. Labour intensity varies depending on the region where capacity is installed and the scale of the installation.

Jobs relating to **SWHs** are more prominent in the first decade in the 1.5°C Scenario than in later decades, owing to the effect of increased electrification of end uses and decreasing labour intensity in the SWH industry over time. This implies that by 2030, there will be 4.2 million jobs in SWHs, which decline to 2.9 million by 2050, albeit far surpassing the number under the PES (around 0.9 million throughout the scenario). Many countries have actively pursued the deployment of SWHs. One prominent example is **Tunisia** (ILO, 2018), where solar energy has developed considerably in recent years. The PROSOL solar water heater support programme, launched in 2005, has created a local market, giving rise to increasing domestic production along the value chain. Under the Tunisian solar plan, which also covers PV, wind and concentrated solar power, up to 10 000 additional jobs can be expected; if the Tunisian economy achieves greater integration rates and manages to produce most system components within the country, employment may increase by almost 30 000 jobs.

BIOENERGY is the second-largest contributor to renewable energy jobs until the 2050s, followed by wind and hydro power, across both scenarios. Bioenergy is labour intensive, particularly in the case of biofuel production, but limits to its sustainability imply a boundary for growth that is reflected in little difference in job creation over time under the 1.5°C Scenario. By 2050 bioenergy employs 6 million people in the PES and 14 million people in the 1.5°C Scenario; and wind energy employs 3.4 million in the PES and 4.5 million in the 1.5°C Scenario.

HYDROPOWER: Jobs in hydropower are expected to amount to 3.7 million[37] in 2050 under the 1.5°C Scenario. For one, this is because significant hydro potential has already been exploited, implying smaller incremental capacity additions, and thus slower growth than newer technologies. In addition, new hydro installations increasingly have to be aligned with efforts to protect natural habitats and to minimise social impacts and conflicts surrounding the use of water resources among different communities and countries that share watersheds. Some regions may see more hydro development, and hence job creation, than others; for instance, hydro power is growing fast in **Africa** owing to some large-scale projects and, to date, limited environmental regulation and local community protection laws that make further development of large-scale hydro resources possible (IRENA, 2021e forthcoming).

Figure 11: Jobs in renewable energy, by technology, in the 1.5°C Scenario and PES, 2030 and 2050



Source: IRENA, 2021c.

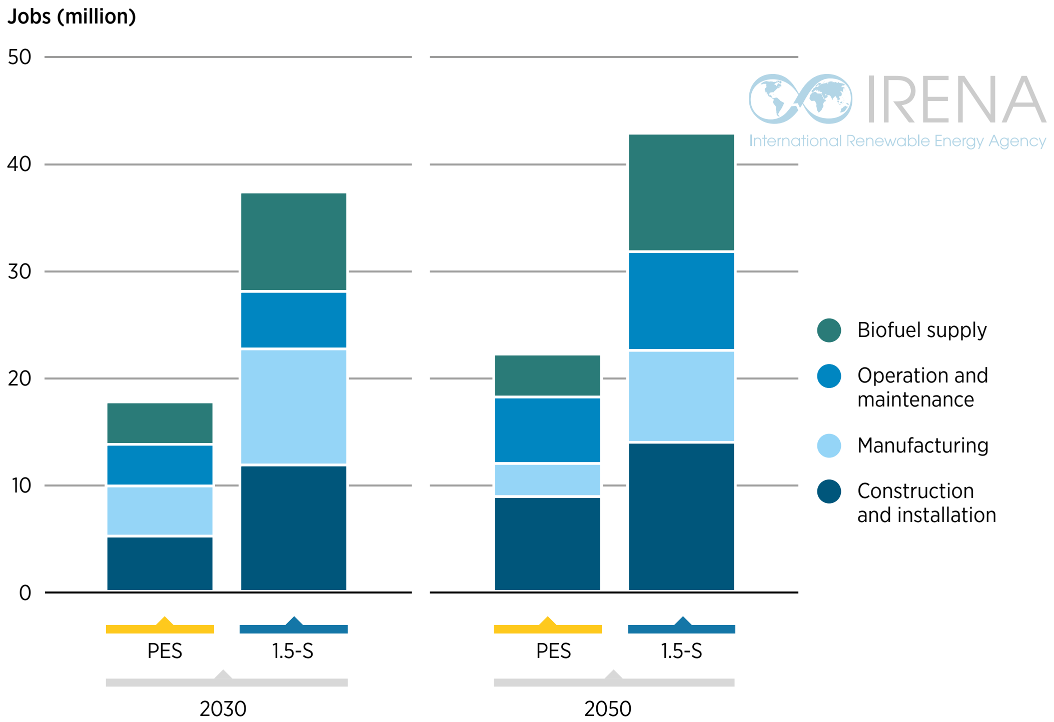
37 The 3.7 million jobs figure includes indirect jobs, whereas the 1.98 million jobs discussed in Chapter 1 relate to direct employment only, due to different methodologies.

Future renewable energy employment by value chain component

IRENA's analysis of the different segments of the value chain of renewable energy technologies provides further insights. Construction, installation and manufacturing boost renewables jobs during the next decade in the 1.5°C Scenario, with operation and maintenance gaining relative weight as cumulative capacities expand. Biofuel feedstock supply jobs also provide an important contribution to 1.5°C Scenario jobs. By 2050, the 43 million jobs in renewable energy under the 1.5°C Scenario are distributed across the value chain with 33% in construction and installation, 26% in biofuel supply, 21% in operation and maintenance and 20% in manufacturing (Figure 12).

Skills matching is an important objective in leveraging the employment benefits from the energy transition (see discussion in Chapter 3). IRENA's 1.5°C Scenario involves the following trends: a steady increase of jobs requiring primary education, an initial contraction and later recovery of the number of jobs requiring a secondary education and a sharp peak by 2030 in jobs requiring a tertiary education, which by 2050 decrease to lower numbers than today. Due to inertia in the dynamics of the education system, insights into the future evolution of the labour force's occupational patterns need to be carefully considered to ensure that the appropriate skills are developed. Further, the implied fluctuations in skills demand need to be managed carefully so as not to upend people's educational and career choices. This is one of several areas where public policy needs to be highly proactive and include a strong social protection component to ensure a just transition.

Figure 12: Renewable energy jobs, by segment of value chain, in the 1.5°C Scenario and PES, 2030 and 2050



Source: IRENA, 2021c.

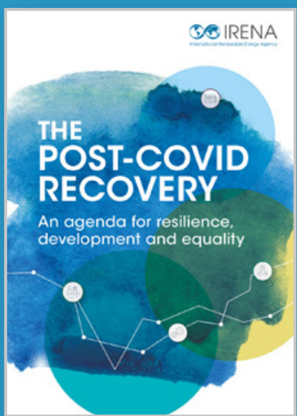
In Focus Box 6.
Post-COVID recovery and job creation

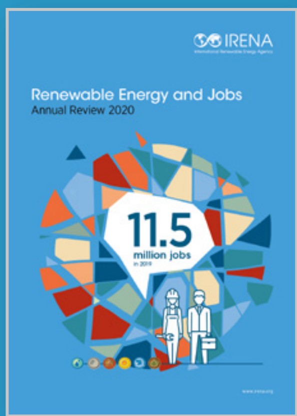
As discussed in Chapter 1, the COVID-19 pandemic has had a devastating impact not only on people, health and livelihoods but also on the world's economies. Renewable energy deployment had to contend with negative impacts along the value chain as well. But as various studies indicate, the unprecedented stimulus packages mobilised to overcome the COVID-19 pandemic and its socio-economic impacts provide an opportunity to accelerate the energy transition and the creation of much-needed jobs and economic benefits (IRENA, 2020a; Cambridge Econometrics and UN PAGE, 2021; IASS, 2020).

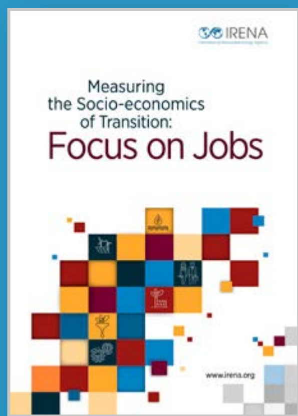
An analysis undertaken by IRENA for its post-COVID recovery agenda indicates a substantial potential for job gains in the energy sector, assuming that a large share of stimulus investments is indeed directed toward a green recovery in line with global climate objectives under the Paris Agreement (but see the brief discussion on page 83 of current priorities in stimulus spending).

Under this agenda, annual investments in technologies related to the energy transition would more than double, from the 2019 level of USD 824 billion to nearly USD 2 trillion in the 2021-23 recovery period, before reaching an annual average of USD 4.5 trillion in the decade leading up to 2030 (IRENA, 2020a). An additional investment stimulus could add 5.5 million more jobs in energy-transition-related technologies by 2023 than would be possible without such spending.

These scenarios point to the importance of linking energy policies to employment and labour market policies, and this requires a whole economy approach when designing a green energy transition.





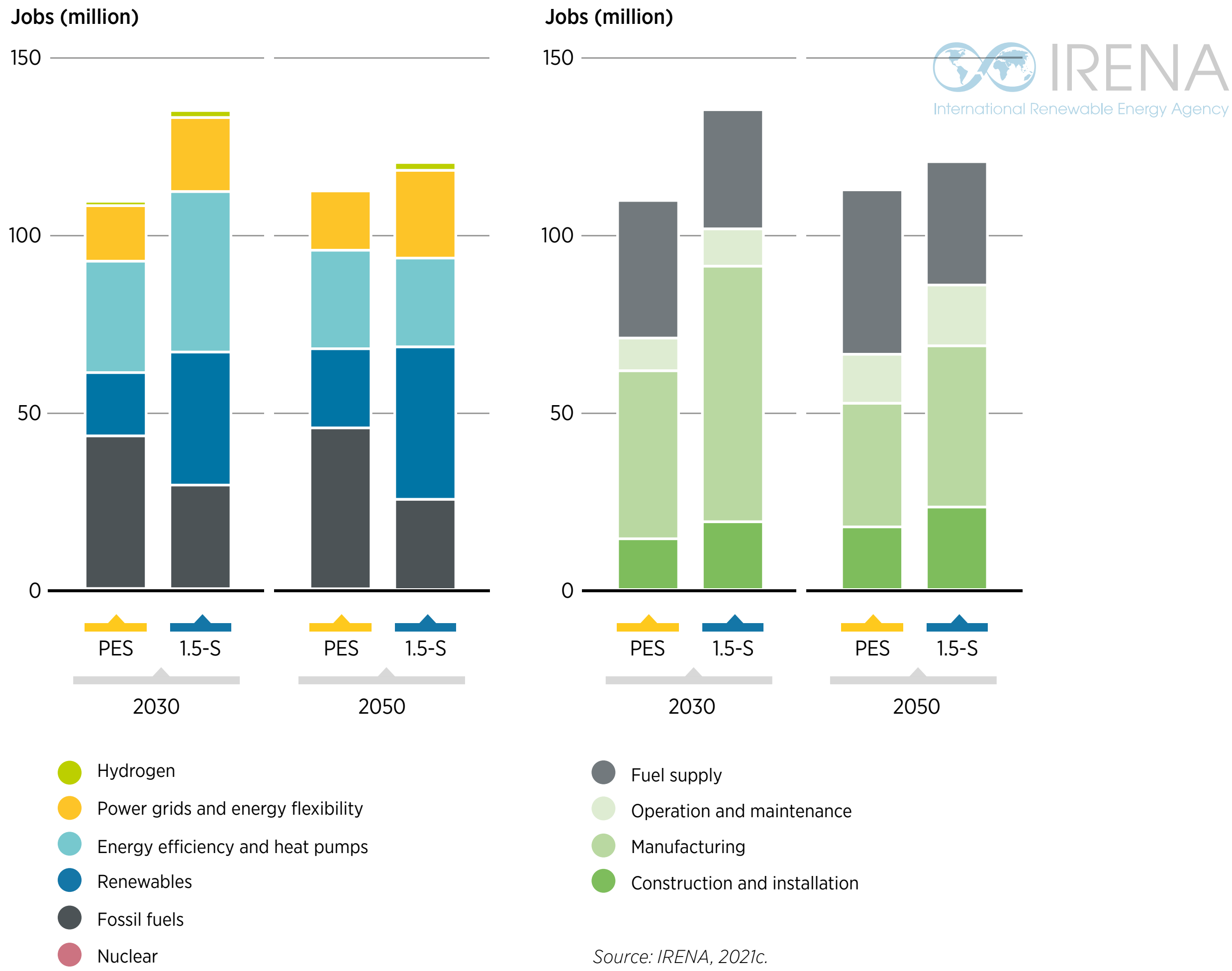


Future jobs in the overall energy sector

In addition to the impact of the energy transition on renewable energy jobs, IRENA has analysed its effects on employment in the entire energy sector, where the net impact is positive under both scenarios. The bulk of growth would take place in the period to 2030, with a smaller net increase in jobs in the later decades, reflecting the front-loading of investment and changes in labour intensity over time.

Figure 13 gives an overview of employment in the energy sector under the 1.5°C Scenario and PES in absolute values over time. Under the 1.5°C Scenario, the energy sector would employ 137 million people by 2030, compared with 111 million under the PES. Compared with today, the number of fossil fuel jobs under PES would actually grow by 7.1 million in 2030 and by 9.4 million by 2050. Under the 1.5°C Scenario, on the other hand, it would decline by 6.9 million and 10.5 million, respectively. But fewer jobs are lost in fossil fuels than are gained in transition-related fields.

Figure 13: Energy sector jobs by technology (left) and segments of value chain (right) under the PES and 1.5°C Scenario, 2030 and 2050



Source: IRENA, 2021c.

Energy efficiency is an important pillar of the energy transition and hence employment, particularly between 2020 and 2030, reaching above 45 million jobs by 2030. Renewables contribute about 39 million jobs. As the transition progresses beyond 2030, the further decrease of fossil fuel jobs in the 1.5°C Scenario is more than compensated by gains in renewables, power grids and flexibility, and hydrogen. Overall, of the 137 million energy sector jobs in the 1.5°C Scenario by 2030, 107 million jobs (about 78%) are transition related. This is also reflected in employment generation by value chain segment. Qualifications, skills and occupations under the ambitious 1.5°C Scenario are increasingly concentrated in manufacturing, followed by fuel supply.

POWER GRIDS AND ENERGY FLEXIBILITY will be the backbones of the energy transition. Almost three times as many people as today will work in this sector, bringing employment to 21 million by 2030 and nearly 25 million by 2050 under the 1.5°C Scenario. Grid enhancement, and flexibility options matter more under the 1.5°C Scenario as the complexity of the system grows. Compared with the PES, 1.5 times as many people would be employed by 2050.

HYDROGEN jobs, presented in Figure 13, include both electrolysers and hydrogen infrastructure. In the 1.5°C Scenario they remain stable at around 2 million jobs from 2030 to 2050, while in the PES they decline because of decreasing investment after 2030. In relative terms they represent a small share of all energy jobs, but the introduction of hydrogen in the energy system can have ripple effects throughout supply chains.

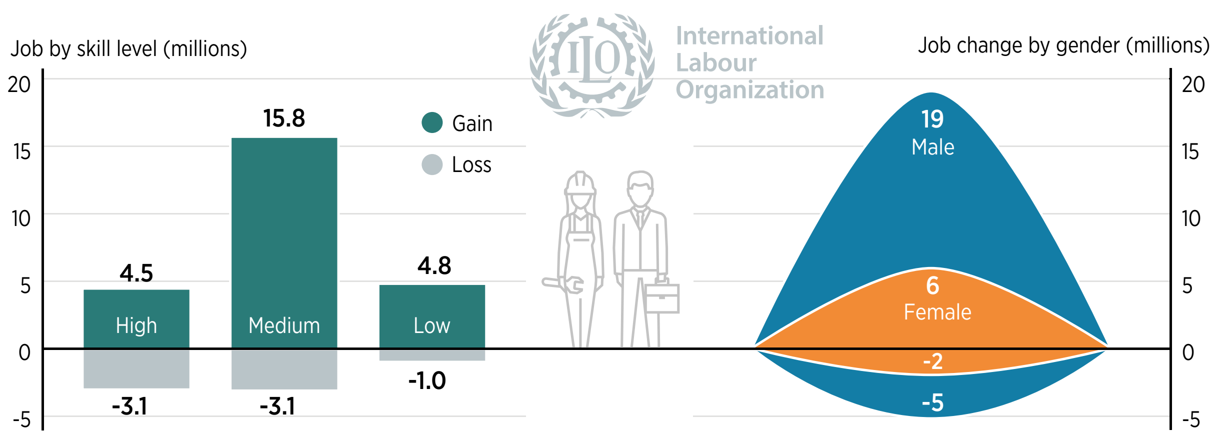
In Focus Box 7.
Jobs implications under the ILO's sustainability scenario to 2030

Similar to IRENA's modelling work, the ILO also assessed the jobs implications of a sustainability scenario to 2030, and the degree to which workers losing their jobs could expect to find jobs in the same occupation elsewhere.

In 2019, the ILO estimated that 25 million new jobs are globally possible under a sustainability scenario to 2030. The ILO scenario results imply that nearly 7 million jobs will be lost. Many of the jobs lost can be reallocated – that is, 5 million workers who lose their jobs due to contraction in specific industries will be able to find jobs in the same occupation in another industry within the same country. Yet, irrespective of efforts toward the reallocation, between 1 and 2 million jobs will be obsolete without vacancies opening for the same occupation in another industry.

It is also important to note that not everyone will be able to reap the decent work dividend equally from the transition. The ILO study suggests that the greatest impact of the transition will be on male-dominated, medium-skill occupations, and that current occupational gender gaps are likely to persist (see Figure 14). Women will get only a fraction of the jobs created, unless adequate measures are taken to train them in relevant skills, so that they can benefit from new jobs. Therefore, gender equality should be at the core of countries' efforts in developing forward-looking and inclusive skills strategies for the energy transition.

Figure 14: Jobs created and destroyed in an energy sustainability scenario to 2030:



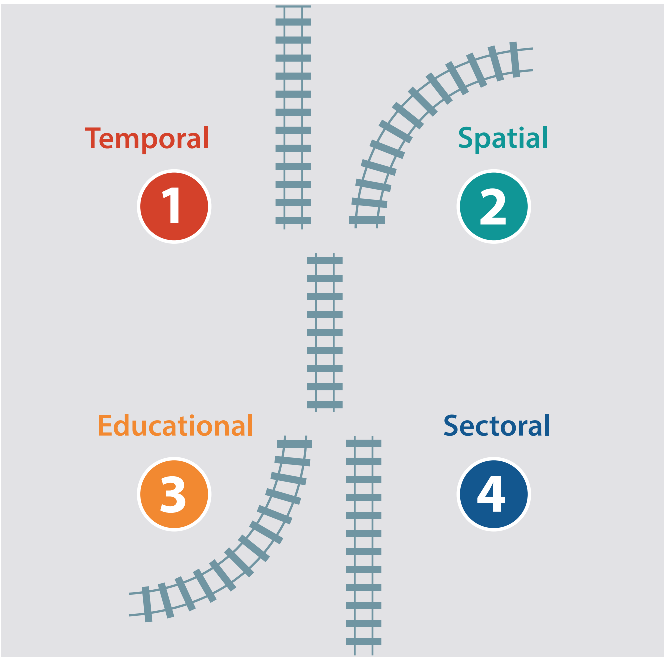
Source: ILO, 2019a.

Policy needs and opportunities

The scope for action is wide. Deployment policies, together with enabling and integrating policies, remain essential to provide an enabling environment in which the energy transition can unfold. Paired with such measures are a set of structural policies to address challenges like fossil fuel dependence and a variety of other commodity and technological dependencies (see Chapter 4).

Education and skill training, labour market measures, social protection and regional development efforts are essential tools to help local economies innovate and to overcome potential misalignments between job losses and gains. Labour market policies to accompany the transition are also essential to help generate decent jobs with workers' rights respected, fair and equal opportunities and adequate remuneration, and to ensure that the energy industry workforce of the future reflects the natural diversity in a society, offering opportunities for women, youth and minorities.

As is the case with any transition, the energy transition cannot be expected to proceed smoothly without appropriate policy intervention and guidance. Analysis by IRENA (2020c) and by ILO (2019a) has shown that the energy transition will encounter frictions and misalignments in several dimensions, such as time, space, education and economic structure, with skills gaps emerging.



1 **TEMPORAL MISALIGNMENTS** occur when job losses precede job gains on a large scale. Examples are the closure of mining activities that do not necessarily coincide with new activities in renewable energy or energy efficiency.

2 **SPATIAL MISALIGNMENTS** occur when new jobs are emerging in other communities or regions and are a challenge for people who lost jobs and might have the right qualifications and skills, but have financial, family or property ties to the region where they live.

3 **EDUCATIONAL MISALIGNMENTS** occur when the skills levels or the occupation required under the energy transition have not been developed or needed under the previous energy system. Addressing them requires careful planning and foresight of the skills requirements ahead.

4 **SECTORAL MISALIGNMENTS** occur because of changing value chains and supply chains under the energy transition. Shifting from fossil fuel power generation to, for instance, solar energy shifts inputs from fuel extraction to the semi-conductor industry. If both are located domestically, we see a shift from one industry to another, and the job headcount depends on labour productivity. If the new value chain heavily depends on imports, job impacts move outside the country.

Developing the renewable energy sector brings opportunities to create new employment opportunities and enhance human health and welfare. Bolstering efforts to strengthen local value chains will result in the creation of new renewable energy jobs, in addition to the generation of income by leveraging existing and new economic activities. Support for a green post–COVID-19 pandemic recovery in many countries offers a historic opportunity to pursue the ambitious measures required for this much-needed structural change. Stocktaking of regional and local strengths is a prerequisite to identify opportunities for localisation, and the potential of creating regional hubs for the manifold technologies necessary for the transition along a 1.5°C trajectory.

Enhancing and leveraging domestic capabilities require carefully crafted incentives and rules, business incubation initiatives, supplier-development programmes, support for small and medium enterprises and promotion of key industrial clusters. A thorough understanding of the jobs that will emerge domestically and the existing knowledge and skills that can be leveraged either from other industries or with skilling policies must go hand in hand with measures to increase renewable energy deployment.

ILO (2014) gives an example of how the value chain can also comprise informal labour in sectors that are rooted in traditional and rural activities. Analysing the value chain of the use of dung for biogas generation in **India** shows the non-monetary value of related activities as much higher than anticipated. Most of women's labour, such as producing fuel to cook from dung, is unaccounted for and the volume of the informal economy in this field is high. Turning to modern biomass, for instance, with biogas digesters, could help overcome informality, though it also would replace labour with capital. Hence, policies leveraging local value chains need to carefully address informality, in particular in developing countries.

The use of industrial policy can support the development of internationally competitive local or regional suppliers, particularly in developing economies. A key element to unlock opportunities along the value chain of renewable energy industries is addressing barriers to more localised market entry, such as the capital intensity of starting new production lines and of building new supply chains. Small and medium enterprises in this context play an important role in any attempt to maximise local benefits and diversify economies. It is thus important to incentivise small and medium enterprises, ease access to information, support the digitalisation of small firms and open up access to finance to support start-ups and, in the long run, innovation and economic opportunity. Start-ups benefit from the promotion of key industrial clusters, as do firms of any size along the value chain of a technology. The proximity of manufacturers, services and designers of a certain technology to a relevant market has additional benefits (IRENA, 2021c).

The availability of materials and equipment, as well as quality assurance, and the availability of skills along the renewable energy value chain are critical to the gradual establishment of a localised or regional renewables-based industry. Some key government policies to this end include:

- Designing renewable-energy-focused research and development strategies and ensuring uptake in the public and private sectors;
- Facilitating learning effects, spill-overs and technological transfers in renewables and energy efficiency through carefully designed incentives;
- Incentivising supply-chain participation in renewable energy sectors by local firms, and actively supporting the creation of partnerships; and
- Establishing direct links to labour policy to translate targets and support measures into employment creation (IRENA, 2021c).

Some countries have already been investing in facilitating the creation of local value chains, through dedicated government policy. In **India**, for instance, a key feature of the recovery plan has been to encourage manufacturing across sectors such as solar PV, automobiles, textile, medical devices and electronics. A production-linked incentive scheme has been launched to promote manufacturing of high-efficiency solar PV modules and reduce import dependency. The incentive offered is designed to increase as the value addition grows (MNRE, 2021).

The future energy transition poses cross-cutting challenges to all policy realms. It needs the international community to co-operate, join forces and support the energy transition where needed. IRENA describes the pathway toward 1.5°C not only in terms of technologies needed but also the relevant policy basket.

To prepare workers for this challenge, a comprehensive educational, skills-oriented policy framework is needed, as described in the following chapter. Chapter 4 then brings it all together and suggests the comprehensive policy framework for enhancing deployment of renewables, making the energy system fit for the future and ensuring that the energy transition is just and inclusive.

Chapter 3. SKILLS NEEDS FOR THE ENERGY TRANSITION

To bring about the expanded renewable energy workforce of the future (as discussed in Chapter 2), a range of policy measures need to be undertaken. A holistic policy framework encompasses industrial policies, labour market policies, social protection measures, diversity and inclusion programmes, and skills training and retraining strategies. This chapter focuses on skills, given that training the future workforce requires time and is therefore one of the most immediate steps in pursuing the energy transition.

The energy transition offers significant employment opportunities across different countries and market segments. Education, skills, training and retraining will support realignment. The trends in the educational requirements of the energy sector call for better co-ordination between the sector and educational institutions. An integrated approach to labour and educational policy and planning will be needed to address this challenge, and also to better integrate the educational requirements in the energy sector with those of other sectors. Part of the answer will lie with efforts to better anticipate emerging trends that influence education levels and specialisations. Another aspect concerns identifying transversal skills, *i.e.*, skills that are not exclusively related to a particular job or task but rather are applicable to a wide variety of work settings and roles.

Despite positive trends and recent developments, skills gaps and shortages are increasing and likely widespread across countries unless proactive measures are taken. In high-income countries, including those even with well-developed skills anticipation systems, a lack of both technical and transferable core skills remains a significant recruitment barrier for employers, while developing countries are especially challenged by deficiencies at higher skills levels. Many of the most significant changes in skills and occupations in the green economy are taking place at higher skill levels, requiring university education. This represents a critical barrier for many low-income countries, where university graduates and high-level skills in general tend to be in short supply. These may constitute a constraint on the net-zero transition.

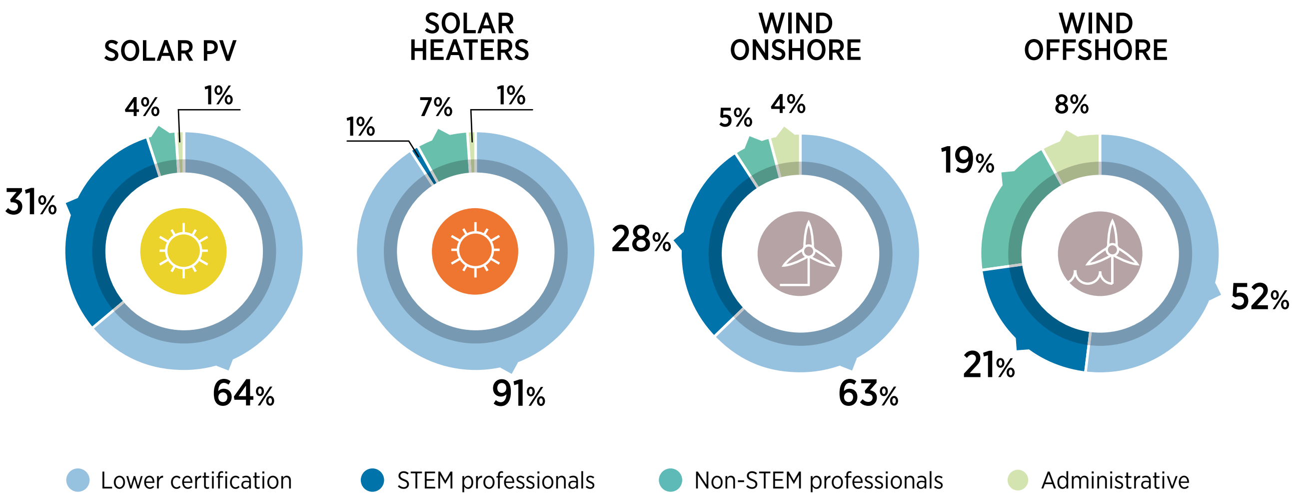
This chapter first gives an overview of the patterns of skills requirements under the energy transition, today and in the future, highlighting potential mismatches and synergies. It then turns to the policies to support the skill development for the energy transition, addressing new training, reskilling and wider educational policies.

Occupational patterns and skill levels

Renewable energy employs people across all trades and levels. IRENA's analysis of the human resource requirements for the solar PV (IRENA, 2017a) and onshore wind (IRENA, 2017b) industries shows that over 60% of the workforce requires minimal formal training. Individuals with degrees in fields such as science, technology, engineering and mathematics (STEM) are needed in smaller numbers (around 30%). Highly qualified non STEM professionals (such as lawyers, logistics experts, marketing professionals or experts in regulation and standardisation) account for roughly 5%, while administrative personnel make up the smallest share (1 4%). In offshore wind, the proportion is similar: those with lower skills and training again represent the largest share of employment (47%) (IRENA, 2018). When it comes to the value chain of SWHs, less than 10% of the human resources required are for STEM and non-STEM professionals. In comparison, the remaining 90% required are workers with minimal or no certification (IRENA, 2021d) (see Figure 15).

In addition to these four technologies, more analyses are in preparation. They offer insights into the types of jobs needed to support the transition by technology, segment of the value chain and educational and occupational requirements. These are crucial elements to inform the transition's policy framework.

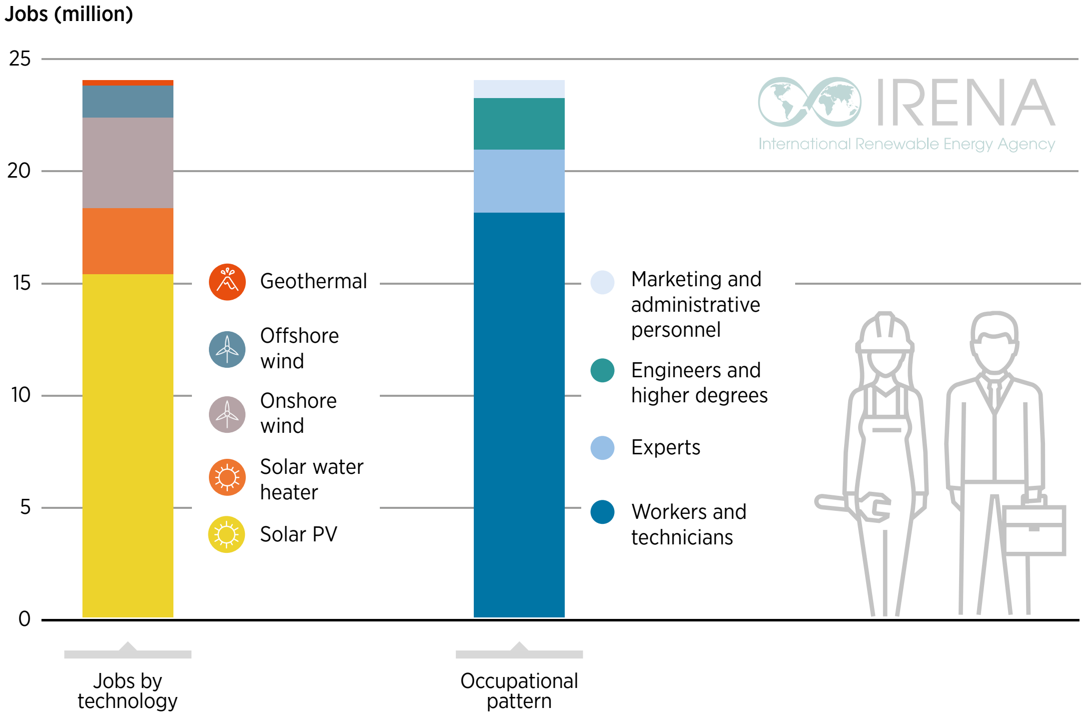
Figure 15: Human resource requirements for workers in solar PV, wind energy (onshore and offshore), and solar water heaters



Note: STEM = science, technology, engineering and mathematics
Source: IRENA, 2017a, 2017b, 2018, 2021d.

As outlined in the previous chapter, renewable energy will employ 43 million people by 2050 under a 1.5°C Scenario. For selected industries, namely geothermal energy, wind energy, PV and SWHs, IRENA offers a deep-dive analysis into the evolving skills patterns, which are distributed across marketing and administrative personnel, engineers and those with higher degrees, experts and workers and technicians. Figure 16 shows the close to 25 million jobs in this subset of technologies.

Figure 16: Renewable energy jobs, 2050, by selected technologies and occupational categories



Source: IRENA, 2021c.

ILO (2019a) shows the 20 occupations most in demand across industries in its own global energy sustainability scenario by 2030 and comes to structurally similar results. Figure 17 shows differences in employment – job gains and losses – between the sustainability scenario and a business-as-usual scenario.

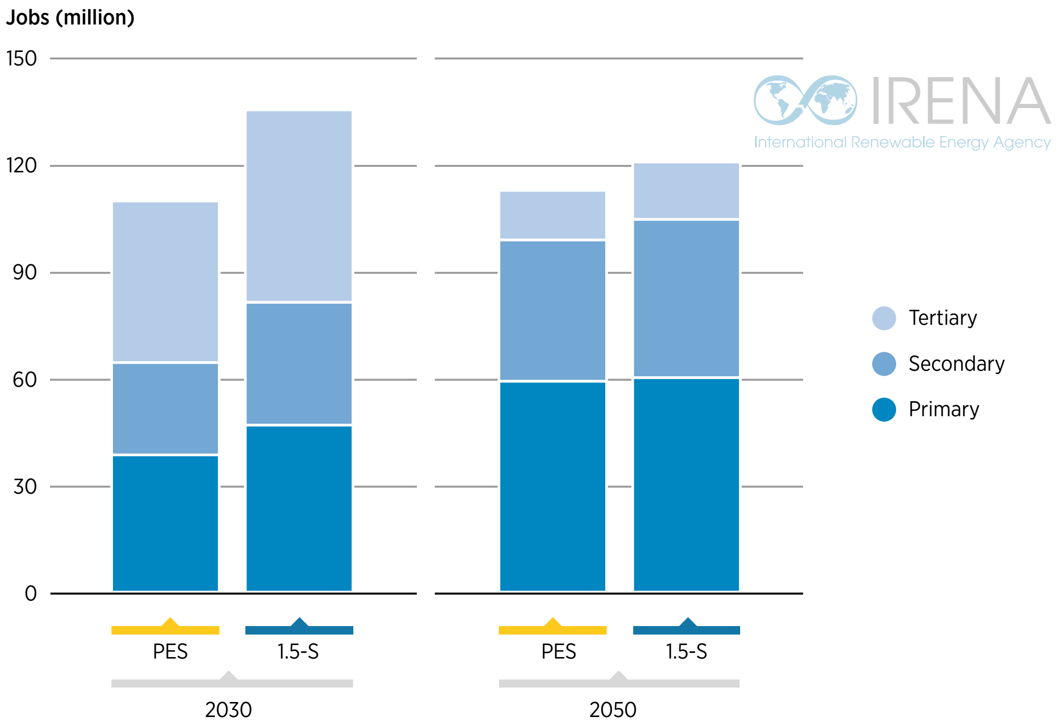
Figure 17: Occupations most in demand across industries in a global energy sustainability scenario, 2030

Source: ILO, 2019a.

Examining needed jobs by education level in the energy sector as a whole shows that under a Paris-compliant 1.5°C scenario half of the 122 million jobs created by 2050 will require only a primary or lower secondary education (IRENA, 2021c). An additional 37% of occupations will need secondary education. The remaining 13% of jobs will require a tertiary education at the bachelor's, master's or doctoral level (see Figure 18).

This disaggregation of jobs by the associated formal educational requirements underscores some important points. The first is that the energy transition can create opportunities for people with a range of skills and educational levels. The prevalence of jobs requiring a primary or secondary level of education rather than those requiring academic credentials also points to the central role of workplace learning. Many jobs in the renewable energy sector can be accessed with on-the-job training to ensure that workers have the necessary skills. It should be noted, however, that referring to "lower" skills in a formal sense does not mean that many jobs in factories or in construction do not entail valuable practical skills, including manual dexterity and practical problem-solving abilities that cannot be conferred through academic course work.

Figure 18: Distribution of energy sector jobs by educational level



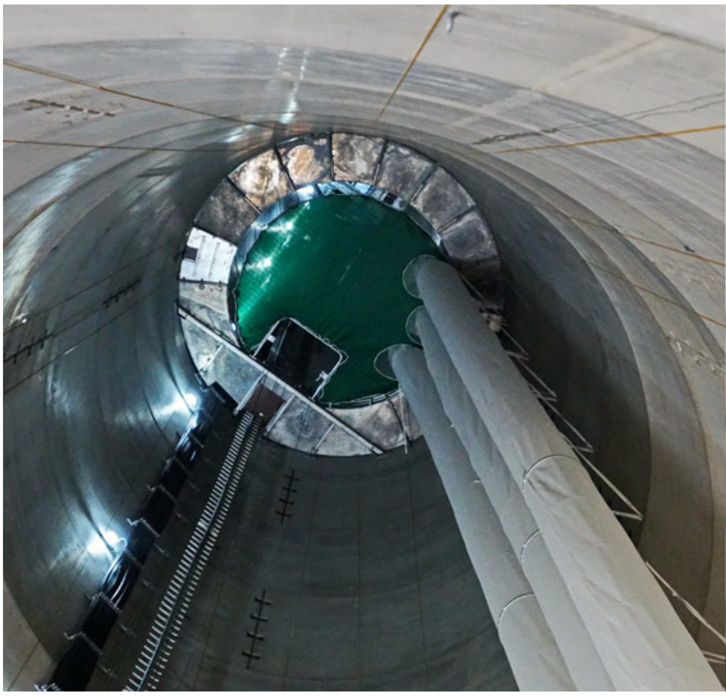
Source: IRENA, 2021c.

Skills synergies and misalignments in the energy transition

In parallel to preparing people for new careers in the renewable energy sector, reskilling and upskilling measures will be vital for extending the employment benefits of the transition along the value chain and in the wider economy to workers. IRENA's work demonstrates that the number of economy-wide jobs, as well as jobs within the energy sector created through the energy transition, outweigh jobs losses, and a percentage of these new jobs will be available for a reskilled workforce. The *World Energy Transitions Outlook* (IRENA, 2021c) finds that employment outcomes under both energy transition scenarios (PES and 1.5°C) are fundamentally positive (as discussed in Chapter 2, IRENA's and ILO's work).

These numbers paint an encouraging picture on a macroeconomic scale. However, on the microeconomic and even more so the individual worker level, there is undoubtedly a need for enabling people to move from jobs in a declining sector to new jobs in rising sectors. While there may well be substantial overlaps in needed skills, in many cases there is also a need for at least some reskilling, reorientation and also recertification of skills.

One challenge is to provide realistic transition perspectives for fossil fuel workers and to ensure that their existing skills and expertise do not simply fall by the wayside. Some of these workers may be able to move into the emerging clean energy economy. For example, offshore wind could offer an alternative to oil and gas workers, whose work prospects are clouded. Many workers in conventional energy industries are increasingly open to the idea of transitioning, assuming that the necessary reskilling and recertification support is available (Ferris, 2021). In Focus Box 8 examines the situation in the UK context.



In Focus Box 8.
Transitioning workers from offshore oil and gas to wind: UK findings

Worsened by the impact of the COVID-19 pandemic, energy demand and price volatility have weakened job security in the oil and gas industry. By some estimates, more than 1 million oilfield services workers worldwide may have lost their jobs by the end of 2020. In the United Kingdom, oil production has fallen from a peak of close to 3 million barrels per day in 1999 to about 1 million barrels at present (BP, 2020). In recent years, the direct UK offshore oil and gas workforce had already declined from 41 300 in 2014 to 30 400 in 2019, but due to COVID-19 and imploding oil prices, jobs in this male-dominated sector shrank further during 2020 to 25 700, with just 3.4% held by women (UKOGIA, 2019, 2021). Including the supply chain, all oil and gas jobs fell from 191 100 in 2016 to 117 400 in 2020 (UKOGIA, 2021).

As the numbers declined, a widening chasm opened between workers with full employment status and those on contracts with little job security and few rights at work. Growing numbers of workers in UK offshore oil and gas are weighing their prospects, with 81.7% of respondents in a 2020 survey saying they would consider moving to a job outside the sector. About half (53%) indicated a preference for offshore wind, particularly if they could receive retraining assistance (Platform, FOE Scotland and Greenpeace, 2020).

A recent assessment found that some 70% of the UK oil and gas workforce have medium skills transferability to other energy industries, principally offshore wind; another 20% have high transferability (RGUETI, 2021). But for now, the high cost of certifications for new jobs is shouldered by workers individually (an average of GBP 1 824 a year was spent by 600 offshore workers in a recent survey). The situation is complicated by the lack of alignment among accreditation entities across different parts of the energy sector (Thomas, 2021).

Transitioning workers into renewable energy requires identifying transferable skills; standardising skills certifications; establishing a well-funded retraining programme aligned with energy transition plans and ensuring a living wage for workers during the retraining period. This is best accomplished in direct consultation with worker representatives (Platform, FOE Scotland and Greenpeace, 2020).

There have been some discussions involving business and labour on transitioning from fossil fuels to renewables (O'Connor, 2021). In Scotland, the regional government set up a Just Transition Commission (with members drawn from climate science, academia, business and unions) in September 2018, which led to a decision to establish a GBP 2 billion Low Carbon Fund and a GBP 100 million Green Jobs Fund (Rushton, 2020).

Many of the skills required for work in the fossil fuel sector are relevant and in principle transferable to the renewable energy sector. For example, In Focus Box 9 discusses skills synergies between the offshore wind and oil and gas industries. They include expertise in surveying and offshore installation; design and manufacturing of support structures and large-scale installation and operation and maintenance of offshore assets (IRENA, 2018).

In Focus Box 9.
Skills synergies between offshore oil and gas and offshore wind

As the offshore wind energy sector continues to grow, it offers businesses and individuals from the offshore oil and gas sector new opportunities along the different segments of the value chain. A growing number of oil and gas companies and suppliers, such as 3sun, Ecosse Subsea and ROVOP, have in fact already won offshore wind installation work by leveraging existing skills. However, reskilling and recertification processes for workers need to be managed proactively.

PROJECT PLANNING. Surveying companies can offer services ranging from environmental, geophysical and geotechnical surveying to offshore wind development. Designing and handling complex offshore oil and gas projects offers invaluable expertise for working in similarly inhospitable environments typical of offshore wind projects and coping with associated health and safety concerns.

MANUFACTURING. Existing know-how in designing and producing support structures for offshore oil and gas is already being leveraged for offshore wind projects. Suppliers can have great competitive advantages thanks to their expertise, especially in deep water sites.

INSTALLATION AND GRID CONNECTION. There are similarities in constructing and decommissioning foundations of offshore projects in both industries. Notwithstanding some differences in array cables, many oil and gas suppliers would be able to provide offshore wind projects with the needed cables without significant additional investments.

With respect to substantiation structures, past experiences with energy transmission or offshore marine engineering are relevant.

For steelwork, while load strength requirements differ, the types of fabrication are comparable, and many common standards and certifications apply.

Further opportunities also include manufacturing and supplying ancillary equipment such as flanges and cable pull and protection equipment and access systems.

OPERATION AND MAINTENANCE. Expertise in managing offshore assets from planned maintenance to defect detection and repairs consists of additional transferable skills. Knowledge of existing offshore standards, such as safety practices, is likewise relevant.

COAL SECTOR workers can also find new opportunities in renewables; in recent years coal miners have been recruited for work in the solar, wind and energy storage sectors (Marston, 2018). A **US** study of synergies between coal and solar PV skills found that 43% of coal-fired power plant workers could be transitioned to the PV sector without additional training, while in the coal mining industry 30–35% of jobs are specific to the industry and would require reskilling (Louie and Pearce, 2016).

Similarly, those with training in many **science and engineering disciplines** can in principle readily work in both the fossil fuel and renewable energy industries. Mining engineers working in the coal sector can reorient for renewables by specialising in the minerals needed for batteries or solar panels, while reservoir engineers working in oil and gas can reskill for the geothermal sector.

The energy transition also presents opportunities for current workers in **non energy related industries** to apply their skills for new opportunities within the renewable energy sector. This is especially true of tradespeople such as electricians, roofers and construction workers. Table 4 shows the results of a 2020 survey of US tradespeople, carried out by North America's Building Trades Unions, which highlighted the skilled trades most relevant to the solar and wind sectors. In addition to solar PV installers the top five occupations included wiremen (electricians who specialise in connecting electrical systems to the outside power source), roofers, electricians and construction laborers (NABTU, 2020b). However, the survey results also highlighted the perception among tradespeople (backed by available statistics) that the oil and gas sector offers better pay, benefits and career opportunities in comparison to renewables, highlighting the need to address concerns related to job quality in the renewables sector and the importance of collective bargaining arrangements.

Table 4: Top trades in oil and gas, wind and solar projects, United States

Top 5 trades most likely to work on oil and gas projects

Trade	Wind	Solar	Oil	Natural Gas
Pipelayer, Plumber, Pipefitter, or Steamfitter (n=276)	14%	20%	74%	79%
Stationary Engineer (n=25)	28%	40%	64%	80%
Operating Engineer (n=156)	28%	46%	67%	72%
Construction Equipment Operator (n=246)	36%	47%	63%	73%
Boilermaker (n=33)	24%	36%	55%	76%

Top 5 trades most likely to work on wind and solar projects

Trade	Wind	Solar	Oil	Natural Gas
Solar Photovoltaic Installer (n=79)	34%	91%	29%	43%
Wireman (n=19)	47%	63%	32%	47%
Roofer (n=14)	43%	64%	36%	57%
Electrician (n=177)	33%	66%	47%	50%
Construction Laborer (n=218)	38%	56%	64%	66%

60% or more of tradespeople reported having worked in this oil and natural gas industry during their career

60% or more of tradespeople reported having worked in this renewables industry during their career

Source: NABTU, 2020b.

Policies to support the skill side of the energy transition

This section discusses a number of key policy areas to ensure adequate levels of skill training and education, including efforts to keep up with emerging skill requirements; implementation of national skill standards; the connection between skill building and a just transition; labour market interventions to facilitate skills transitioning and investing in transition training funds.

TARGETED EFFORTS TO ADDRESS EMERGING SKILL REQUIREMENTS

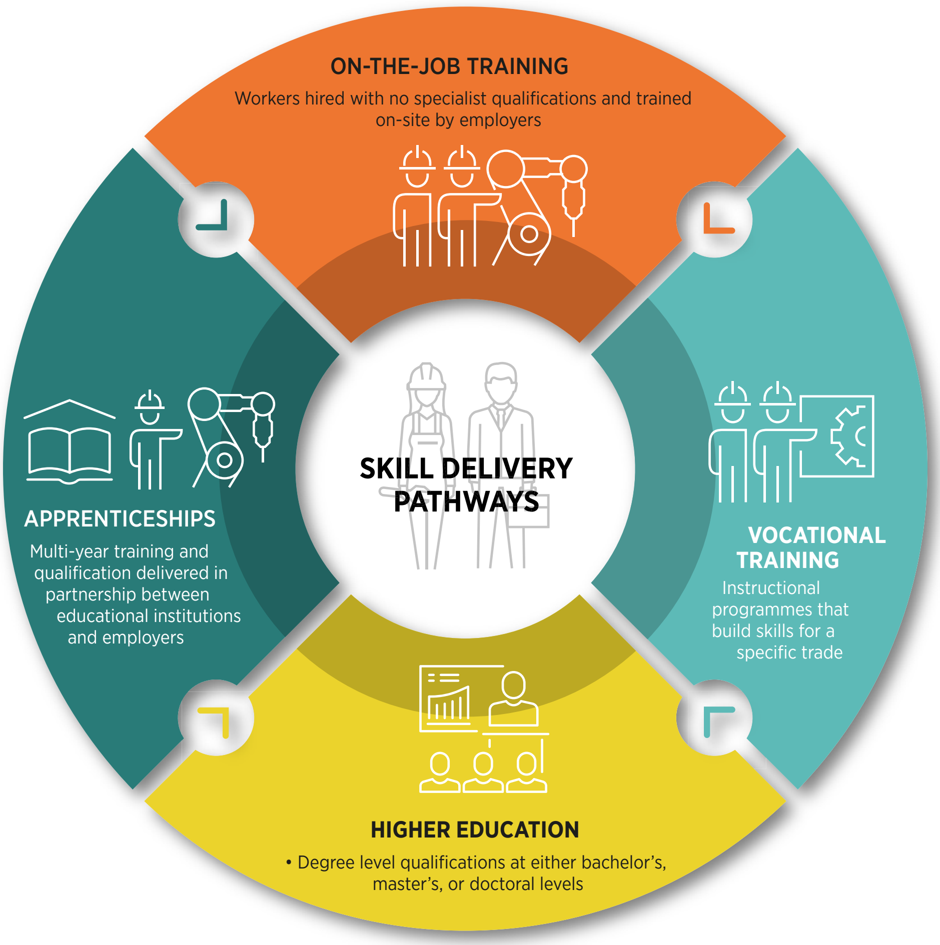
The rapid innovation taking place within the energy sector brings with it a constantly evolving set of skills needs. Targeted efforts to address emerging skill requirements in areas such as electric vehicles, energy storage, bioenergy, heating and cooling sectors, manufacturing, digitalisation and energy access (see also IRENA, 2021c; ILO, 2019a) will be vital for avoiding skills shortages and ensuring that the development of human resources is in line with anticipated skills demands. Innovation and entrepreneurship skills will be vital for the development of not only new technologies but also viable business models and service delivery. Curricula at vocational training and higher education institutions may need to be adapted or in some cases newly introduced in order to meet the emerging skills and competences necessary for the transition. As In Focus Box 10 details, there are different routes to deliver skills.

In Focus Box 10.
Skill delivery pathways

Skills delivery can take place in a variety of ways. Figure 19 highlights some of the key pathways for the delivery of transition skills including on-the-job training (workers can be hired with no specialist qualifications and trained on-site by employers); vocational training (this includes both vocational courses and specialised short courses); university degrees (e.g., bachelor's, master's and doctoral level degrees) and apprenticeships (qualifications delivered in partnership between education institutions and employers). Some roles also require a government-regulated professional licensure, for example, in the case of professional engineers and skilled trades persons.

Depending on the country context, multiple pathways may be available for skilling for the same role including either through an apprenticeship scheme, vocational training or on-the-job training. The analysis of the skill delivery pathways for 35 key occupations in the solar PV sector, for example, shows that only 16 of these jobs require a university degree with the remainder of skills built through either on-the-job training, vocational training and/or apprenticeships.

Figure 19: Skill-delivery pathways



Financial and technical support will need to be provided to **technical and vocational education and training (TVET) institutions** to enhance the quality of renewable energy training provisions and ensure that programmes can meet the workforce needs of a continuously evolving renewable energy sector. Regions with limited TVET capacity, particularly rural areas where renewable energy can have a transformative impact on communities, will require particular attention and support. Training may need to be provided to instructors to build their practical expertise. Lack of training equipment and materials is also a barrier to adequate practical instruction and here the private sector can play an important role in equipping institutions.

Workplace learning opportunities such as apprenticeships or short-term placements should also be integrated into TVET programmes to provide learners with real-world learning experiences. Many countries also need to build local professional capacity to develop, manage and execute renewable energy projects. The importance of this was underscored by travel bans in early 2020 hindering the progress of projects that are dependent on foreign expertise for professional services (see Chapter 1). The building of such capacity requires close partnerships between universities, governments and the private sector to ensure that curricula adequately prepare students for energy transition careers including in energy engineering, management and policy. Professional and workplace training will also play an important role in upskilling the current workforce by building specialist knowledge and ensuring that workers' skills evolve along with the demands of the sector.

Experiential learning methods whereby students are encouraged to develop problem solving strategies can also help to prepare learners for jobs in the rapidly changing renewable energy sector where independent knowledge seeking will often be necessary. The shift to online and digital learning, which has been accelerated by the COVID-19 pandemic, has drawn attention to the potential role of information and communications technology in enhancing the instructional methods used for skill building.

Figure 20 highlights key applications of information and communications technology for skill delivery including authentic learning that replicates the workplace environment using models and simulations; improved access through remote and flexible learning; personalised content delivery that takes into account the differing starting points of learners and the facilitation of collaborative learning and teaching.

Figure 20: Applications of information and communications technology for skill delivery

IMPLEMENTATION OF NATIONAL SKILL STANDARDS

Standardisation of curricula and accreditation of training programmes can further help to ensure that courses are able to meet the needs of industry. National skill standards can be an important mechanism for ensuring that workers are equipped with the necessary knowledge and competencies to perform their role to a high standard (see In Focus Box 11, for an example from India). While the implementation varies from country to country, typically these standards are developed in co-operation among industry, educational institutions, labour associations and governments. In addition to the definition of skill requirements a national system would also include standardised assessment and certification processes. Although such skill standards are common in various trades and sectors, many countries are yet to implement equivalent standards within the renewable energy sector. In addition, there is a need to revamp existing standards for related occupations. For example, as electricians increasingly work on connecting solar PV systems, standards may need to be revised to ensure that newly qualified electricians have the necessary skills rather than relying on additional training post-qualification.

In Focus Box 11.
National occupational standards in India

To scale up skilling efforts and achieve its goal of skilling 150 million people, India created the National Skill Development Corporation (NSDC), a public-private partnership between the Government of India, through the Ministry of Skill Development and Entrepreneurship, and the private sector (NSDC, 2020).

Sector Skills Councils, which bring together industry, labour and academia, are a key pillar of the NSDC and are responsible for identifying skill development needs, determining skills and competency standards, and standardising qualifications and certifications.

The Skill Council for Green Jobs (SCGJ) was formed in 2015 and covers sectors including renewable energy, green transportation and green construction (SCGJ, 2021).

The SCGJ has developed a number of National Occupational Standards within the renewable energy sector (see Figure 21), for instance for a solar photovoltaic maintenance technician or an improved cookstove installer. These standards include details of the requisite course level and length, key learning outcomes to be achieved, and theoretical and practical elements of the curriculum.

Figure 21: Sectoral focus of India's Skills Council for Green Jobs

Source: SCGJ, 2021.

Skills and a just transition

It is clear that countries have different challenges and priorities in their pursuit of the energy transition, and thus their approach to skills is best tailored to the national context. Yet, there are several key principles that may guide countries and the energy sector toward a clean energy economy. To name a few, enhanced policy coherence between skills, energy and environmental policies is needed, and institutional co-ordination among line ministries and agencies – with the active involvement of social partners and systemic mechanisms for skills anticipation and monitoring – can help accelerate the transition to energy sustainability (see In Focus Box 12).

In Focus Box 12. How can countries effectively build the skills and human capacities for a just transition to net-zero?

Enhanced policy coherence at the planning, design and implementation stages is required to enable the green transition. Skills gaps and shortages are almost inevitable whenever any new product or service appears, and the green transition is no exception. A policy coordination gap is a common feature at the national level. Where social partner engagement is weak, this can have negative consequences for the co-ordination and relevance of policies on skills for green jobs. Thus, a combination of top-down co-ordinated policy making and bottom-up initiatives could provide effective and more sustainable support to the green transition.

Well-developed and sound policies at subnational and sectoral levels can help fill the gap in national co-ordination. A combination of centralised and decentralised approaches to policy co-ordination can best promote the transition at sectoral, local and subnational levels. Sectoral plans for skills for green jobs, supported by government taxes and incentives, are most common in those sectors directly affected by climate change and environmental depletion, such as energy, transport, construction and waste management. The private sector and trade unions play essential roles in the transition to sustainable economies.

A wide range of both technical and core skills is needed to support an inclusive green transition. The International Labour Organization's estimates of the impact on occupational skill needs in two global scenarios (energy transition and circular economy) reveal the core and technical skills that are potentially transferable, within occupations, from declining to growing industries; but retraining will be needed to enable workers to acquire new skills for use in the latter. Of particular importance will be core (or soft) skills, which can confer a comparative advantage as they can be transferred across occupations. Some core skills are needed by all workers, regardless of the skill level of their occupation.

Effective mechanisms to anticipate and monitor skills needs for the energy transition should be put in place so that with better information and data on skills needs and gaps, policy makers, employers, workers and education and training institutions can make much more informed decisions and address skills challenges more effectively. Well-developed skills anticipation systems augment countries' ability to identify skills gaps, and to analyse future training needs and shortages systematically and comprehensively. This in turn contributes to develop specific skills policies, shape technical and vocational education and training (TVET) appropriately and adapt skills training and active labour market programmes to current and future demand.

Training that is targeted, inclusive and prioritises the skills needs of vulnerable groups, with well-equipped teachers, is essential to effective climate education. The availability of teachers and trainers with current knowledge on sustainable land and ecosystem management, energy efficiency and green technologies is crucial. Their role is critical in promoting environmental awareness among young people and in spreading environmental training beyond the formal education system into the adult population. The education and training of such teachers and trainers should therefore be a top priority in any skills response strategy at the national, sectoral and local levels.

Skills funds and public-private partnerships (PPPs) could drive the sustainable development agenda beyond 2030 skills development, and training needs can also be met through collaboration between private-sector and multinational companies and the public sector through promoting and empowering a PPP for green jobs. Private-sector engagement and involvement of workers' organisations is essential, both in establishing a sustainable and functional TVET system and in developing skills within sectors and enterprises. PPPs can catalyse and boost diversified, innovative and new approaches in financing lifelong learning and provide a platform for combined contributions to support the TVET system systematically and independently. Financial incentives are a key aspect of the operation of green markets and support other drivers of skills for green jobs. Some countries operate specific financial incentives to encourage training. Strong and inclusive PPPs could be instrumental in reducing the financial constraints on effective delivery of high-quality training, as well as in generating more opportunities to formulate new, innovative and data-driven skills development policies.

Source: ILO, 2019a.

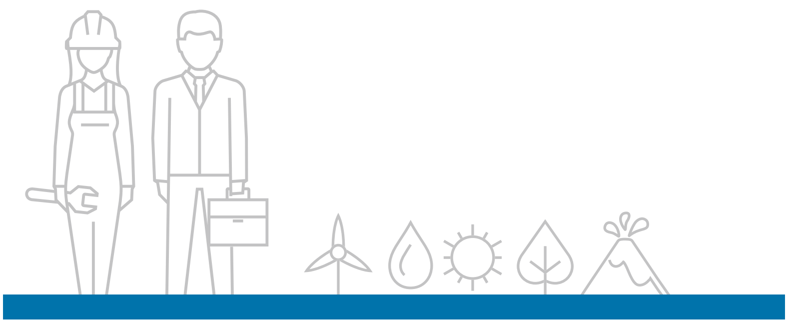
LABOUR MARKET INTERVENTIONS

Labour market interventions will be required to facilitate the transition of those working in conventional energy industries to the renewable energy sector. These include adequate employment services (matching jobs with qualified applicants; promoting employee well-being; facilitating on- and off-job training and implementing job safety nets), along with measures to facilitate labour mobility, such as relocation grants. Facilitating collaboration between industry and educational institutions will also contribute to more co-ordinated skill-matching efforts.

In addition to the identification of transferable skills, governments will also need to dedicate funds to the reorientation and reskilling of the workforce (see also discussion below). As discussed earlier in this report, the costs of securing formal recognition and credentialing of existing relevant skills can be steep and are often borne by workers who may not be able to afford them. For example, the Scottish regional government's Transition Training Fund offers grants for the retraining of oil and gas workers who have lost their jobs or are at risk of redundancy (Skills Development Scotland, 2019). Related efforts include measures to support income stability through unemployment insurance and other programmes, policy incentives for employers to retain (and retrain) workers where possible and flexible, longer-term employment contracts to promote job stability. Proactive strategies designed to minimise socio-economic disruption may also encompass public investments and economic diversification measures for affected regions and communities.

Skilling measures hence will play a critical role in empowering current and future workers to benefit from the job opportunities emerging from the energy transition. They will also be vital for building the sizeable human resource capacity necessary for achieving national plans. Matching the skill supply with the anticipated demand requires an identification of skills needs, education and training pathways and priority groups to be targeted.

Key education and training priorities will include: the skilling of an inclusive and representative workforce; investment in transition training funds; responding to emerging occupational patterns; implementation of national skill standards and enhanced curricula and programmes that address emerging skills needs. Education and training policies and measures will be needed for both reskilling and reorienting the current workforce as well as building the pipeline of new talent. Partnerships between industry and employers, educational institutions, governments and labour unions will be key for increasing access to high quality education and training provisions.



Investment in transition training funds

The global COVID-19 crisis has triggered a series of public investment programmes aimed at stimulating economic activity in the wake of the economic restrictions in 2020 and 2021. In the energy sector, a majority of early stimulus investments have favoured fossil fuels. According to the latest data from the Energy Policy Tracker (2021), as of late August 2021 USD 335.6 billion was committed in support of the fossil fuel sector and fossil fuel dependent industries by 31 major economies and by 8 multilateral development banks, mostly without conditions to improve environmental sustainability. This represents 42% of all funds. After lagging behind earlier, clean energy commitments have now risen to USD 274 billion (34%), though the majority of that sum has been given as conditional support. Another USD 193 billion (24%) has been pledged to "other energy"[38] priorities.

Refocusing investment and economic stimulus packages into dedicated "transition funds" that include training components for existing and future energy sector workers could play an important role in building more resilient economies able to benefit from the energy transition in the near term. Such packages could include funds and training programmes dedicated to the reskilling of workers in communities and regions affected by job losses for new transition-related careers. Training funds can be either stand-alone or created as a component of broader funds, such as Just Transition Funds or economic recovery packages and can be delivered through various mechanisms. For example, funding can be used to expand access to employer-provided training to increase opportunities for workers without higher qualifications or sector-specific backgrounds (Fife, Greenberg and Fitzpayne, 2020).

The large proportion of renewable energy occupations which can be accessed directly with only on-the-job training implies a potential role for public funding to help share the financial burden of employers in providing such training. Particularly small- and medium-sized businesses in developing economies could benefit from public support for on-the-job training in transition-related jobs, and thereby increased opportunities for workforce development. Distribution of funds can be achieved through avenues such as cost-sharing programmes, targeted grants and reimbursements (Fife, Greenberg and Fitzpayne, 2020). Funds can also be disbursed in partnership with education and training institutions in the form of scholarships and funded opportunities for students from target demographics taking specific courses. The financing of these transition training funds can be achieved through various mechanisms including payroll training levies and tax incentives.

Recent years have seen increasing examples of such funds. In the **United States**, for instance, Colorado enacted a bill that provided USD 15 million to assist coal-dependent workers and communities in the transition to clean energy, including USD 7 million specifically for apprenticeship and training programmes for workers and their families (Colorado General Assembly, 2021). Last year in the **United Kingdom**, the Scottish government launched a GBP 25 million National Transition Training Fund which will train people facing redundancy, including as a result of the COVID-19 pandemic, and boost the supply of key transition skills (Scottish Government, 2020). This is in addition to the GBP 12 million Transition Training Fund launched in 2016 in response to the downturn in the North Sea oil and gas sectors. However, such funds will need to be scaled up if they are to address the scope of the challenge.

38 This category includes nuclear energy and uranium mining, "first generation" biofuels, biomass and biogas with proven negative impact on the environment, incineration, hydrogen of unspecified origin and multiple energy types, e.g. intertwined fossil fuels and clean energy.

Chapter 4. THE JOBS AGENDA FOR A JUST TRANSITION

As the world navigates to a climate-safe energy system centred on renewables and energy efficiency, it seems clear that more energy jobs will be created than lost, especially if governments ensure strong policies in support of deployment and integration of renewables. Workforce development is essential, and job quality deserves increasing attention. While skills training is important, policy makers need to understand it within a broad, holistic policy framework. Among other measures, that framework embraces industrial policies, labour market policies, social protection measures, and diversity and inclusion strategies. This final chapter discusses this holistic approach for a smooth and successful energy transition.

What kinds of jobs are needed for a just transition?

Moving from fossil fuels to a sustainable energy system entails both benefits (such as creating new jobs and livelihoods, or dramatically improving access to energy for all) and challenges (such as the disruptions faced by fossil-fuel-dependent workers, communities and countries). The COVID-19 pandemic has further raised the stakes, and short-term recovery efforts must be aligned with the longer-term transition.

The need for a just transition was first articulated by labour unions many years ago, but as this concept has become more widely accepted, its precise contours are receiving growing attention. A just transition requires that benefits be shared widely and equitably (among countries, communities and population groups, especially those lacking energy access or who are otherwise marginalised), and that burdens of adjustment be minimised. This concerns not only the ultimate outcome of the energy transition, but also the process of what will be a decades-long transformation of all economies. It includes the effects that the energy transition will have on the quality of work, but also on income inequality and energy costs for low-income communities as a price is put on carbon, policies governing energy subsidies are altered, and consumer prices for electricity, heat and fuel undergo change.

Success hinges on high ambition, on a strong public policy to drive progress, and on strong governmental institutions and competent policy implementation. But it also rides on efforts to hear all stakeholders, particularly those most affected by the impending changes. An open, honest and meaningful social dialogue among governments, employers, unions, communities and others is essential.

In 2015, the International Labour Organization adopted guidelines for a just transition toward environmentally sustainable economies and societies for all (ILO, 2015). The guidelines were designed to enable governments, workers and employers around the globe to leverage the process of structural change to achieve a greener, carbon-neutral economy, create decent jobs on a large scale and promote social protection.[39] They present a clear roadmap and lay out concrete policy areas for action on growth, industrial and sectoral policies, enterprise, skills, occupational safety and health, social protection, labour market policies, rights, and social dialogue and tripartism.

Policy makers should strive to gain a sophisticated and holistic understanding of both the overall context that requires just transition policies in the first place (such as structural problems that may hinder a transition in national economies, or inequities such as gender imbalances that have been in place all along); and the specifics of a just transition process (such as misalignments between renewable job gains and fossil fuel job losses as discussed on page 62, and other challenges that may emerge along the way).

Beyond job numbers, the nature of job and workplace quality matters immensely for a just transition. It finds expression in wages (and health and retirement benefits), occupational health and safety, overall workplace practices, and job security. Today, only limited information is available on many of these aspects, in part because renewable energy stretches across many different sectors of the economy, complicating the picture. The sector provides employment to people with a wide variety of qualifications and backgrounds (IRENA, 2017a, 2017b, 2018, 2021d). Broad occupational categories include labourers, machine operators and drivers, administrative workers, trades specialists and technicians, professionals, and managers (Briggs *et al.*, 2020).

Whether jobs are in fact well-paying and decent depends on a host of factors, including occupational and skills patterns (and opportunities for upskilling), the geographic footprint of the clean energy system, the extent of unionisation and labour rights, and the presence of collective bargaining arrangements (see In Focus Box 13). Governmental enforcement of labour standards (or lack of it) is an additional factor, but such standards tend to be limited or even non-existent in economies with high levels of informality.

Renewable energy companies vary in their stances vis-à-vis unionisation of the workforce. In some cases, the desire to squeeze costs may lead management to regard labour more as a cost factor than a valuable resource. Still, capital costs and other factors typically weigh more heavily than labour (Kishan, 2021). In the solar PV industry, labour accounted for just 6-7% of total polysilicon costs in 2018-19, 10-11% of cell and module manufacturing, but 27-31% for wafer production (BNEF, 2021a). A US study (Mayfield and Jenkins, 2021) pegged labour costs as a share of installed capital costs at 17% for utility-scale solar, 22% for onshore wind and 10% for offshore wind. As a portion of operation and maintenance, labour costs are higher – 32%, 28% and 16%, respectively. Raising wages by 20%, for example, would increase installed capital costs by 2-4% and operations costs by 3-6% for overall wind and solar PV costs, but the increases could be offset by higher labour productivity.

Wage levels and pay structures do vary tremendously in countries around the world, as well as from one renewable energy industry to another. A large share of the supply chain for bioenergy employs low-paid agricultural labourers, and their working conditions can be hazardous. In a globalised world, there is a danger that demand for low-cost clean energy will be met in part through what is known as social dumping, whereby some companies seek to gain a competitive advantage

39 *The guidelines were drafted by a tripartite meeting of experts convened from 5-9 October 2015. Eight of the experts were nominated by the governments of Brazil, Indonesia, Germany, Kenya, Mauritius, Turkey, South Africa and the United States, while the ILO's employers and workers groups appointed another eight for each of the two groups. The meeting was chaired by an independent chairperson, Minister Esther Byer Suckoo (Barbados). The vice-chairs were Ms Vanessa Phala (employer expert from South Africa) and Mr Kjeld Jakobsen (worker expert from Brazil).*

In Focus Box 13.
Renewable energy wages: Findings from the United States

A recent report on wages and benefits in the US energy industry (BW Research, NASEO and EFI, 2021b) found that energy industries paid significantly higher wages overall, and in different industry segments, than the 2019 national median hourly wage of USD 19.14. Within the energy sector, however, median wages in wind and solar (USD 25.05 and USD 24.48, respectively) are lower than those in nuclear power (USD 39.19) and fossil fuel industries (from USD 26.59 to USD 30.33).

There are multiple reasons for these disparities. Besides varying levels of training, qualifications and experience that workers may bring to a job, the structure of an industry's value chain and its occupational requirements matter greatly. Relatively low-paid construction, wholesale trade and maintenance jobs account for larger shares of solar employment in the United States than is the case for natural gas and coal, which have larger shares of mining and utilities jobs.

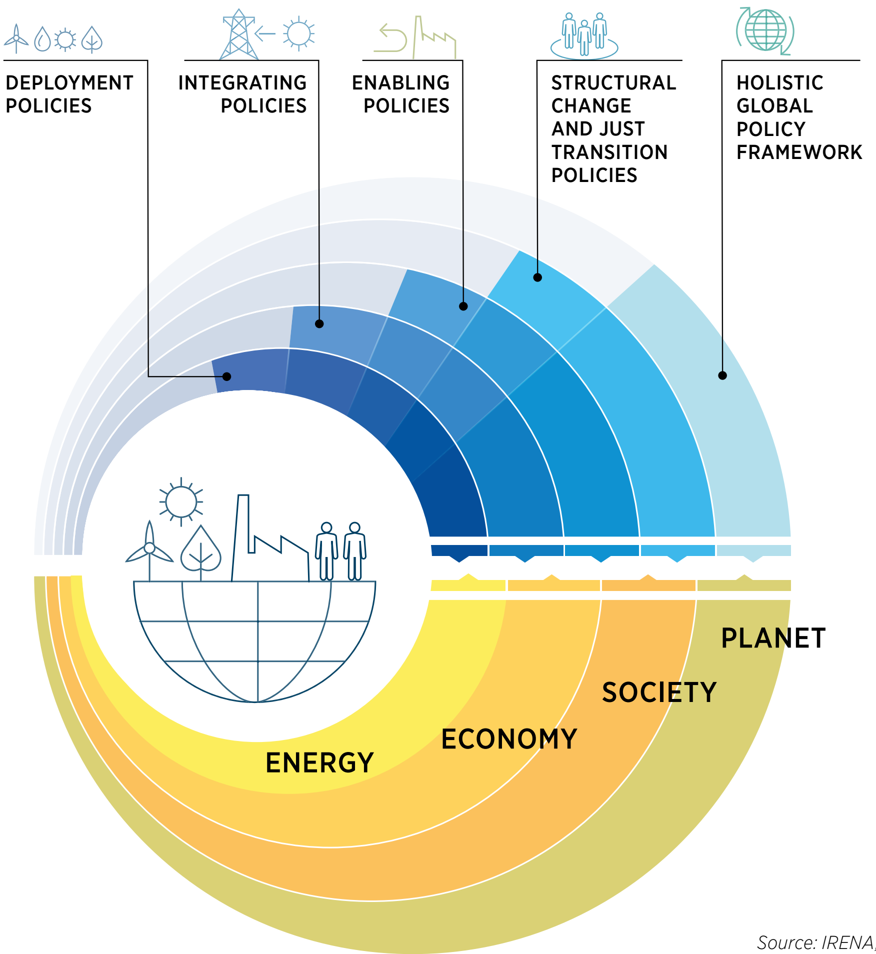
The degree of unionisation and the geographical footprint of industries (reflecting varying prevailing wage levels in different locations) can also make a big difference. Project developers often use recruitment agencies, categorising workers as contractors rather than employees, which makes them ineligible for union membership. Less than a quarter of wind and solar projects begun in 2020 used unionised workers. Non-union construction workers earn USD 16-19 an hour in the solar sector and USD 17-25 in wind. This compares with USD 28.41 (solar) and USD 27.65 (wind) for unionised workers (Kishan, 2021).

by keeping wages low, demanding long hours and skimping on safety standards and social protections (Meeks, 2021). Even in higher-wage countries, work is sometimes outsourced to low-wage workers. For example, Filipino, Indonesian and Russian migrant workers have been hired for construction work in the UK offshore wind sector at below minimum wages (STUC, 2017, 2020).

A comprehensive policy framework for jobs and a just energy transition

This report reveals the need for a holistic approach to policy making that focuses not only on policies and programmes in the energy sector itself, but builds on a sophisticated understanding of the close inter-connections between energy, the economy at large, and social and planetary sustainability. This implies a need for renewable energy policies that are linked to structural change and the assurance of a just transition – all within a holistic global policy framework (see Figure 22).

Figure 22: Jobs in the just energy transition: Challenges and policies



Source: IRENA, 2021c.

Air pollution
Climate change
Lack of energy access
Energy poverty
Unemployment

Fulfilling renewable energy's jobs potential will depend, first, on recovery from the COVID-19 crisis and, second, on comprehensive policy making to drive and support the energy transition in coming decades.

The **IMPACTS OF THE EXISTING ENERGY SYSTEM**, including environmental problems such as air pollution and climate change; social inequities such as the lack of adequate energy access in remote and poor communities; and economic challenges such as unemployment and insecure, precarious jobs, are key drivers of the desire for a far-reaching energy transition.

Technology policies
Deployment policies
Integration policies
Enabling policies

Countries have accumulated valuable lessons and experience in pursuing **RENEWABLE ENERGY POLICIES**. IRENA continues to analyse and document various elements of a successful policy mix in which measures pertaining to research and development and technology are synchronised with policies to create an enabling environment for the deployment of renewable energy and its integration into economic and social systems.

Policy design and implementation must be built on the strengths and capabilities of different countries, with the goal of enabling each to take advantage of emerging opportunities. Each country must determine a suitable balance between demand-side policies (focusing on lowering costs and spurring renewables deployment) and supply-side policies (focusing on localising equipment manufacturing and other segments of the value chain, and on creating domestic jobs).

As the energy transition unfolds, several types of challenges must be overcome to create jobs and ensure just outcomes:

Supply chain strengths and limits
Fossil fuel structures
Commodity, technology, trade dependence

Analyse **STRUCTURAL BARRIERS**. One such barrier is countries' continued dependence on the production and export of fossil fuels – and the associated sectoral structures, institutional fabrics, and prevailing skills profiles. Another is domestic supply-chain structures that may lack the strength and depth necessary to fully support the development of renewable energy. The third obstacle consists of patterns of commodity and technological trade dependence related to the first two barriers.

Spatial misalignment
Sectoral misalignment
Temporal misalignment
Occupational misalignment

Assess the **POTENTIAL JOB MISALIGNMENTS**. Although job gains in renewable energy (and other fields implicated in the energy transition) are likely to outweigh losses of fossil fuel jobs over the coming decades, several misalignments will need to be addressed, as discussed earlier. Some temporal challenges may arise, given that the creation of new jobs does not necessarily occur on the same time scale as the loss of employment. Spatially, new jobs are not necessarily in the same locations – communities, regions or countries – where losses occur. Job gains and losses may affect different sectors of the economy, given diverging sets of inputs needed in rising and declining industries. And educationally, the skills associated with vanishing jobs do not necessarily match those required by emerging jobs.

ENSURE DECENT JOBS. As parts of this edition of the *Annual Review* have pointed out, beyond the numbers of jobs, job quality matters enormously. The decent jobs agenda is concerned with issues such as wages, working conditions, and workplace rights. Legislation and enforcement of labour standards; collective bargaining; and social dialogue among governments, employers and unions will be critical.

Wages
Workplace conditions
Rights at work
Collective bargaining

SUPPORT WORKFORCE DIVERSITY. Diversity in the workforce concerns the need for gender equity (a topic to which IRENA has devoted an ongoing report series); greater inclusion of minorities and marginalised groups; and more training, hiring, and advancement opportunities for young people, for whom jobs are often scarce.

Gender
Minorities
Marginalised groups
Youth

A comprehensive set of structural and **JUST TRANSITION POLICIES** can help overcome these challenges:

- Industrial policies to form viable supply chains
- Education and training strategies to create a skilled, capable workforce, including 1) coordination between the renewable energy industry and the educational system, and 2) retraining (and re-certification) of fossil fuel workers (as discussed in detail in Chapter 3)
- Energetic labour market measures to provide adequate employment services and facilitate labour mobility where necessary
- Social protection programmes to help affected workers and communities cope with a potentially lengthy and difficult transition period
- Public investment strategies to finance training and social protection, and to support regional economic development and diversification.

Financial policies
Labour market and social protection
Education and skills
Industrial policies

Figure 22 laid out the broad mindset for thinking about transition approaches and policies. Figure 23 illustrates the barriers that countries are likely to encounter in creating jobs, along with the solutions that will make for a successful energy transition (distilling the above text). It is based on the understanding that sustainability, employment and social justice must be pursued in tandem, rather than seen as competing demands. Just and fair outcomes will raise the level of popular acceptance of the energy transition.

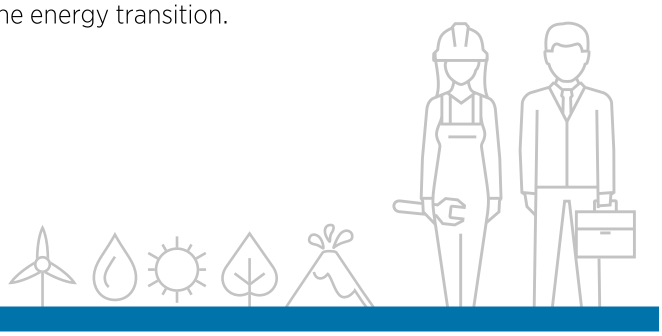
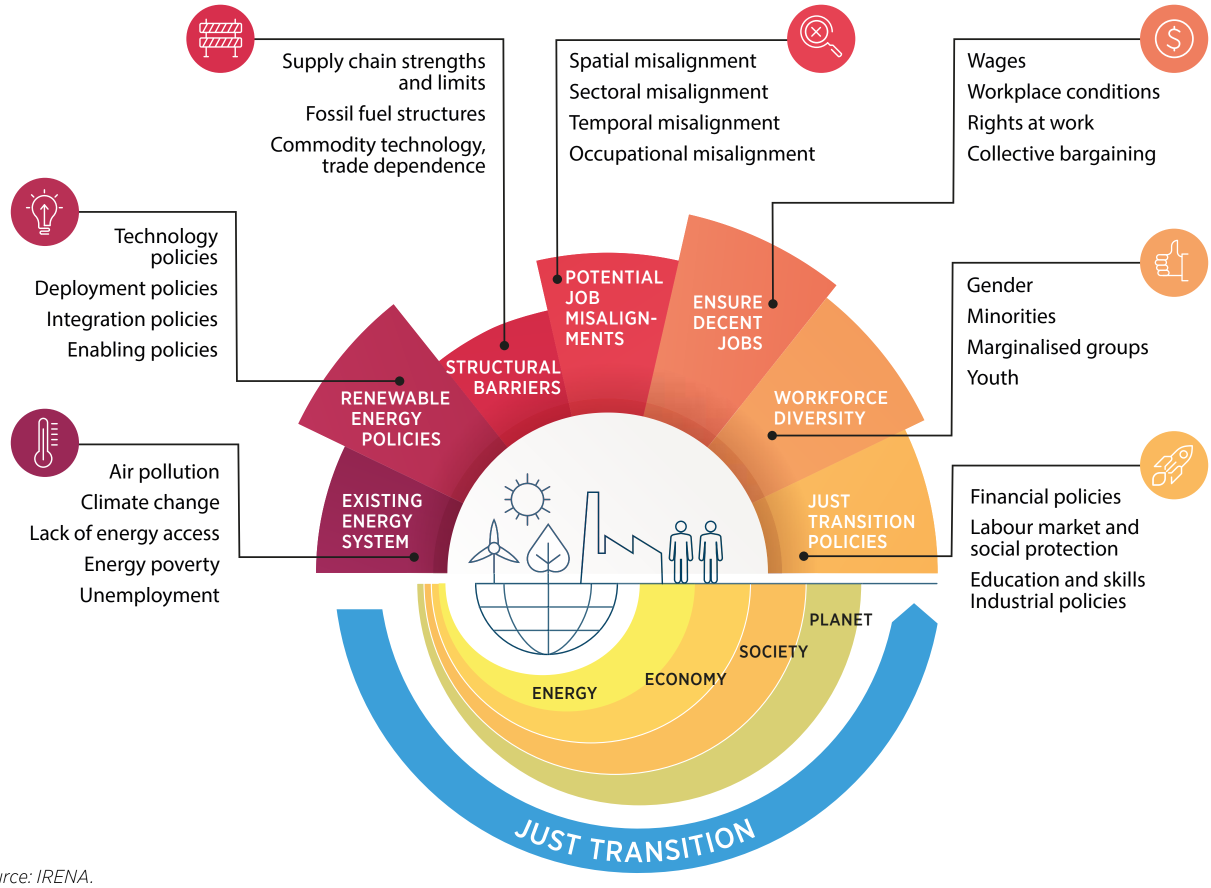


Figure 23: Jobs in the just energy transition: Challenges and policies



Source: IRENA.

A critical dimension in all of this is the proper balance between the public and private sectors – and their respective strengths and weaknesses. In past years, the policy landscape has been focused on enabling private sector actors and reducing risks, and it has yielded maturing technologies and lower costs. But this alone will no longer suffice. As the climate challenge mounts, strategic action is urgently needed to deliver a comprehensive, holistic and just transition. A speedy and co-ordinated approach requires governments to take on a much more proactive role, acting in the public interest and safeguarding broad social imperatives. This may occur through regulations and incentives, public investment strategies, and public ownership of transition-related assets and infrastructure (both at national and community levels). As the policy discussion continues to evolve, it is likely to yield varying answers in different national settings.

Transitioning toward an energy system dominated by renewable energy and energy efficiency will be imperative for achieving sustainable development and urgent climate objectives. Energy transition planning must exploit the close linkages between the energy system and the wider socio-economic structures in which it is embedded. IRENA continues to examine these linkages (see In Focus Box 14). As this report has indicated, effective planning depends not only on access to good current information on job numbers and job quality, but also on continued tracking of the transition's impact on employment so as to shape and seize opportunities to localise value chains, advance gender equity, expand energy access, and improve local livelihoods.

In Focus Box 14.
IRENA's work on the socio-economic benefits of the energy transition

The *Annual Review* series is part of IRENA's broadening assessment of the socio-economic impacts of the global energy transition. The agency publishes a variety of reports that analyse ways to maximise local value creation along the renewable energy supply chain, estimate the socio-economic footprint of the transition in the decades ahead, assess the gender dimension of renewable energy and examine strategies to boost energy access in communities currently lacking it (see Figure 24).

Figure 24: IRENA's knowledge base on renewable energy employment and the socio-economics of the energy transition

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