TABLE 1. **ESTIMATED DIRECT AND INDIRECT JOBS IN RENEWABLE ENERGY WORLDWIDE, BY INDUSTRY, 2018–19**

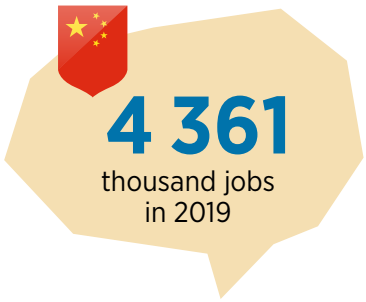
Thousand jobs	World	China	Brazil	India	United States	European Union[m]
Solar photovoltaic	**3 755**[e]	2 214	43	204[h]	240	127
Liquid biofuels	**2 475**	51	839[g]	35	297[i]	239
Hydropower[a]	**1 957**	561	213	367	22[j]	78
Wind energy	**1 165**	518	19	63	120	292
Solar heating/ cooling	**823**	670	44	23.8	5	36[n]
Solid biomass[b,c]	**764**	188		58	51[k]	392
Biogas	**342**	145		85	7	75
Geothermal energy[b,d]	**99.4**	3			9[l]	40.6[d]
CSP	**29.5**	11			5	
Total	**11 459**[f]	**4 361**	**1 158**	**824**	**756**	**1 317**[f]

Source: IRENA jobs database.

Note: Figures provided in the table 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 on-going effort to update and refine available knowledge. Totals may not add up due to rounding. Previous editions in this series distinguished small from large hydropower. Given changes in the available industry capacity data, this edition offers a single estimate for all hydropower facilities.

a. Direct jobs only.
b. Power and heat applications.
c. Traditional biomass is not included.
d. Includes 8 700 jobs related to ground-based heat pumps for EU countries.
e. Includes an estimate by GOGLA of 372 000 jobs in off-grid solar PV in South Asia and in East, West and Central Africa. South Asia accounts for 262 000 of these jobs. IRENA estimates Bangladesh's solar PV employment at 137 000 jobs (almost all off-grid), India's off-grid solar PV employment at 95 000, and the rest of South Asia at 30 000.
f. Includes 39 000 jobs in waste-to-energy and 1 100 jobs in ocean energy (reflecting available employment estimates in the European Union) as well as 9 000 jobs that are not broken down by individual renewable energy technologies.
g. About 216 100 jobs are in sugarcane cultivation and 158 600 in ethanol processing in 2018, the most recent year available. Figure also includes a rough estimate of 200 000 indirect jobs in equipment manufacturing, and 264 100 jobs in biodiesel in 2019.
h. 109 000 in grid-connected and 95 000 in off-grid solar PV. Also see note e.
i. Includes 229 600 jobs for ethanol and about 67 300 jobs for biodiesel in 2019.
j. IRENA employment-factor calculation. NASEO and EFI (2020) report a higher estimate of 67 700 jobs.
k. Biomass fuels and power, and biomass combined heat and power.
l. Direct geothermal power employment.
m. Almost all European Union data are for 2018. Hydropower data for several EU countries are from 2019.

LEADING MARKETS



China remains the clear leader in renewable energy employment worldwide, with a share of 38% of the world's total. The country's job number held steady at 4.4 million (CNREC, 2020).

China's solar PV workforce remained at 2.2 million, but the composition of jobs related to domestic and export markets changed dramatically. Employment in the construction and installation segment declined because of the slowdown in the domestic market, whereas jobs in the O&M and manufacturing segments increased (CNREC, 2020).

Solar PV installations in China declined for the second year in a row in 2019 and were estimated at 30 GW, down from 45 GW the previous year and 53 GW in 2017 (IRENA, 2020a). The drop can be attributed to the uncertainty surrounding the delayed release of auction rules, which left only limited time for project completion in 2019 (Wang and Tao, 2020; CNREC, 2019).

As the pace of installations slowed at home, manufacturers had considerable success in finding overseas markets for their modules. Exports of solar modules during the first three quarters of 2019 reached 58 GW, almost 40% higher than the export volume in all of 2018 (Xu and Stanway, 2019). In 2018, China accounted for 93% of global wafer production, and close to three-quarters of the world's cell and module production (Foehringer Merchant, 2020).

Employment in the Chinese solar water heating industry is thought to have held steady at 670 000 jobs. New installations declined by 8% in 2019, which contributed to a reduction in employment in the installation segment. However, as was the case with solar PV, exports of solar heating equipment rose, leading to an increase in the manufacturing workforce (Epp, 2020b).

While new domestic installations in solar PV and solar heating declined, wind had a good year. Capacity additions ran to almost 26 GW in 2019, driven by feed-in tariffs (IRENA, 2020a). Wind employment remained steady at around 518 000 jobs. China added about 24.5 GW of onshore wind capacity (up from 18.5 GW the previous year), and another 1.3 GW in the offshore segment (compared with 1.8 GW in 2018) (IRENA, 2020a).

Domestic companies have commanded a share of more than 90% of onshore installations over the past decade. This will likely also be the case as the offshore segment expands. Western firms provide advanced technology, but typically do not offer the type of lowwind-speed turbines well suited to China's offshore wind conditions. China's own firms, meanwhile, are not yet able to rely on a mature supply chain for the needed turbines (Li, 2019a).

Coastal provinces are now working to establish local chains, however, bringing together turbine manufacturers and key component suppliers. Manufacturers that build their facilities at local industrial parks are given preference in procurement. Localisation has progressed the most in Jiangsu Province, north of Shanghai. Other coastal provinces with ambitious installation plans, such as Guangdong and Fujian, have not yet been able to establish strong offshore turbine production capabilities (Li, 2019b).

1 158
thousand jobs
in 2019

Brazil has an estimated 1.2 million renewable energy jobs. As in previous years, the country remains the world's largest employer in biofuels. Output of fuel ethanol is driven by tax incentives and a mandate of 27% ethanol content in gasoline. Feedstock production set new records in 2018 and 2019, with 30.3 billion litres and 31.4 billion litres of sugarcane, respectively (USDA-FAS, 2019c). The most recent available employment estimate for bioethanol is for 2018, when employment held steady from the previous year at close to 575 000.[13] Biodiesel production reached a new peak of 5.9 billion litres in 2019 (ABIOVE, 2020a), and IRENA estimates employment rose to 264 100 jobs in 2019.[14]

Wind energy is today the second-largest power source in Brazil, following hydropower. But new additions to Brazil's wind power generating capacity ran to just 745 MW in 2019, a significantly lower amount than during the five previous years, bringing cumulative capacity to 15.4 GW. About 80% of this capacity is located in the country's northeast, which has the best wind conditions (ABEEólica, 2020).

IRENA estimates the country's wind workforce at about 18 750 people, down from close to 34 000 the previous year.[15] Prior to the onset of COVID-19, employment was expected to climb again during 2020, in view of planned installations. Local content requirements and subsidised loans for project developers have brought about a strong domestic supply chain for tower production, though less so in turbine manufacturing (Ferreira, 2017). Overall, domestic content in Brazil's wind sector is estimated at about 80% (Yamamoto, 2020).

New installations in Brazil's solar heating market increased by 6% in 2018 (ABRASOL, 2020), and employment is estimated to have increased to 43 900 jobs.[16] Brazil's solar PV installations have been rising rapidly since 2017. With new additions of about 2 GW in 2019, total capacity was close to 4.5 GW (ABSOLAR, 2020). IRENA estimates employment at about 43 200 jobs in 2019.[17] The distributed solar PV segment, which includes systems up to 5 MW under Brazil's net-metering scheme, is estimated to account for around two-thirds of capacity additions and 85% of solar PV jobs in 2019.

More than half of all PV installations, and therefore many PV jobs, are concentrated in four of Brazil's states (Minas Gerais, Rio Grande do Sul, São Paulo and Paraná) (ABSOLAR, 2020). Brazil is expanding its PV manufacturing capacity, with several Chinese companies setting up plants. Solar farms that use local components can access financing from BNDES, the national development bank, and from the regional Banco do Nordeste (Molina, 2020).

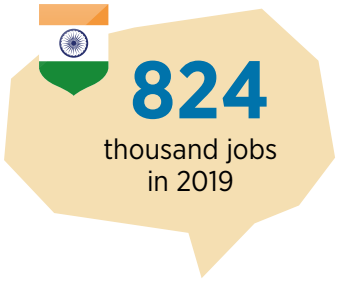
13 In 2018, around 216 100 workers were engaged in sugarcane cultivation in Brazil, and almost 159 000 in ethanol processing (MTE/RAIS, 2020). IRENA's employment estimate for the country includes 200 000 indirect jobs in equipment manufacturing, though this figure is rough and dated.

14 The calculation is based on employment factors for different feedstocks (Da Cunha, Guilhoto and DaSilva Walter, 2014). The shares of feedstock raw materials, principally soybean oil and animal fat (beef tallow), are derived from ABIOVE (2020b).

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

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).

17 IRENA calculation uses a jobs-per-megawatt employment calculation that distinguishes between labour requirements for centralised and decentralised deployments.



India added 7.7 GW of solar PV capacity in 2019, 16% less than in the previous year. After eight years of continued growth, the labour-intensive rooftop solar market also contracted by 7%, reaching 1.5 GW in 2019 (IRENA, 2020a). The drop in solar PV installation can be attributed to several factors, including policy uncertainties, reduced project developer participation in auctions (due to low tariff caps, land and transmission bottlenecks, payment delays by distribution companies, and steps by some state governments to renegotiate power purchase agreements), and an increase in module prices traceable to import duties and currency devaluation (IRENA, 2019b; Gupta, 2019; Mohanty, 2020).

IRENA's employment-factors-based estimates suggest that India's jobs in grid-connected solar PV declined by 14% to settle at 109 000 in 2019. Jobs in off-grid solar applications were believed to number some 95 000 (Power for All, 2019).

Today, Indian solar manufacturers continue to struggle with costs, though the gap between imported and local modules has narrowed gradually to less than USD 0.015 per watt. Exports of cells and modules increased by around 137% in 2019. The United States accounted for 76% of these shipments, followed by Viet Nam, Belgium and Turkey (Ranjan, 2020).

India's imports of solar cells and modules declined in 2019 owing to duties imposed and a decrease in installations. Despite falling volumes, Chinese suppliers still account for around 78% of total module imports, followed by Viet Nam, Singapore and Thailand. The proposed introduction of a 20% import duty on solar inverters in August 2020 could help local suppliers seize a larger share of the market (Chatterjee, 2020; Stoker, 2020).

Attempts to set up a domestic solar manufacturing industry better able to compete with cheap imports have run into problems in recent years. Yet, according to a KPMG study, by 2030 domestic manufacturing could save India USD 42 billion in equipment imports and create as many as 50 000 direct and 125 000 indirect jobs over a five-year period (Dewan, 2019).

Based on consultations with industry representatives, India's Energy and Resources Institute (TERI, 2019) proposed a three-stage industrial policy strategy for the expansion of solar manufacturing in India. A first step would create 15 GW of cell and module production capacity at manufacturing hubs over two to three years. State governments would assist with the acquisition of land and infrastructure. A second step would focus on the production of silicon ingots and wafers; the third on the production of associated machinery to complete the value chain.

Measured by total capacity, India is the world's fourth-largest wind market. But annual installations have waned; the 2.2 GW added in 2019 was only slightly more than half of the 4.1 GW installed in 2017 (IRENA, 2020a). IRENA estimates jobs in the country's wind sector at 62 800.

India's wind manufacturing industry produces close to 75% of the equipment used in domestic installations. The plans and policies in place have led to reduced installations, hurting the supply chain. Many component manufacturers that had been expecting increased deployment had aimed to scale up production. However, the slowing pace of new installations resulted in extensive competition and an over-supply of equipment. The number of wind turbine makers has dropped from fourteen to four or five, with attendant job losses (Arora, 2019).

756
thousand jobs in 2019

The **United States** has an estimated 755 600 renewable energy jobs. The expected reduction of federal tax credits at the end of 2019 prompted a rush to initiate wind and solar projects before the cut-off point, contributing to a combined 20 GW of capacity installed in the two sectors during the year. Ultimately, the US Congress decided to extend the production tax credit for wind by another year, but not the investment tax credit supporting solar (BNEF and BCSE, 2020).

Utility-scale solar PV additions in 2019 were estimated at 7.3 GW, the second highest after the 10.2 GW peak in 2016. Another 3.9 GW were added in residential and commercial installations (BNEF and BCSE, 2020). The expansion was aided by declining costs, reduced uncertainty over trade tariffs and the tax credit rush among project developers. Solar jobs grew 2.3% to just under 250 000 in 2019, about 10 000 below the 2016 peak.[18] Two-thirds were in installation and project development (Solar Foundation, 2020).

Three-quarters of the solar modules installed in the United States in 2019 were imported, as were half of all inverters, whereas 90% or more of batteries, electronics, wires, cables and mounting structures came from domestic sources (Solar Foundation, 2020). Tariffs enacted in February 2018 have had mixed effects. Under the assumption that tariffs lead to higher prices, the Solar Energy Industries Association (SEIA, 2019) argued that they could reduce installations by 10.5 GW and create 62 000 fewer jobs. However, Chinese module suppliers set up factories in Malaysia and Viet Nam to avoid the tariffs, and these two countries accounted for close to three-quarters of US PV imports in the first eight months of 2019 (Murray, 2020; BNEF and BCSE, 2020). Further, foreign manufacturers set up five new module plants in the United States with a combined 3 GW of capacity (Foehringer Merchant, 2020).

The pace of new US wind installations, 9 GW in 2019, was the quickest since 2012. Just two turbine manufacturers, GE and Denmark-headquartered Vestas, accounted for 82% of US domestic manufacturing capacity in 2018, and for 79% of installations (BNEF and BCSE, 2020). In 2019, US wind employment rose 5% to 120 000 jobs, of which equipment manufacturing accounted for 26 000 distributed across 530 factories.

Wind development mostly benefits rural areas, in states like Texas, Iowa, Illinois, Colorado and Indiana. Projects in 2019 added USD 912 million to state and local tax revenues, and USD 706 million went to landowners in lease payments (AWEA, 2020).

The US offshore wind segment is still in its infancy, but projected capital investments of USD 78 billion in the 2020s will rival planned spending in offshore oil and gas; this will be in sharp contrast to the past decade, when USD 154 billion was spent on offshore oil but zero on offshore wind (Meyer, 2020).

Many components are manufactured in Europe. But a planned 2.6 GW wind farm in the coastal waters off Virginia could spur the emergence of a domestic supply chain (Stromsta, 2020).

US biofuels employment runs to about 297 000 jobs. With biodiesel output dropping 7% to about 6.5 billion litres in 2019 (EIA, 2020), IRENA's estimate suggests that the number of jobs fell to about 67 300. Ethanol production also slipped, to 59.8 billion litres, with employment estimated at 229 600 jobs (Urbanchuk, 2020).

The US energy sector remains less gender-diverse than the overall national workforce, which is nearly half (47%) female. Women account for a minority of energy sector jobs, ranging from 23% to 33%, depending on the specific industry. Renewables fare comparatively well, with women accounting for about 32% of the workforce in hydropower, 31% in wind and 30% in solar PV (NASEO and EFI, 2020).

18 *This figure includes jobs in solar PV, solar heating and cooling, and CSP, but US solar capacity additions since 2016 have been exclusively in the PV sector (BNEF and BCSE, 2020). A solar job is defined as one held by a worker spending at least 50% of his or her time on solar-related work. About 90% of these workers spent all of their time on such work. An additional 94 549 employees spent less than half their time on solar-related work, for a total of 344 532 workers (Solar Foundation, 2020).*

1 317
thousand jobs in 2019

In 2018, the most recent year for which data are available, the number of renewable energy jobs in the 28-member **European Union** was estimated at 1.3 million (EurObserv'ER, 2020).[19] This was up from about 1.2 million the previous year. Germany, the United Kingdom, France, Italy, Spain, and Poland led the job rankings.

The bioenergy sector is the largest renewables employer in the European Union. Solid biomass (heat and electricity) leads with approximately 392 400 jobs, followed by biofuels (239 000), and biogas (74 900).

IRENA estimates EU wind power employment at about 292 300 jobs.[20] The continent's cumulative capacity stands at 205 GW, after 12.1 GW were added in 2018 and 15.4 GW in 2019 (Wind Europe, 2020). Germany, Spain and the United Kingdom are the leaders in new and overall installations. The pace of European installation markets slowed in the last two years, but a substantial portion of European jobs is created by companies that also serve export markets, notably Vestas, Siemens Gamesa, Enercon and Nordex (EurObserv'ER, 2020).

Employment in the solar PV industry grew to about 127 300 jobs, reflecting a significant upturn in several European markets. After adding about 6 GW of PV capacity in 2016 and a like amount in 2017, EU member countries installed about 8 GW in 2018 and close to 15 GW in 2019 (IRENA, 2020a).

Germany's renewable energy employment continued to decline from a peak of 416 700 jobs in 2011. In 2018 (the most recent year for which estimates are available), the number of jobs was 312 000 (BMWi, 2020; EurObserv'ER, 2020).[21] O&M jobs continued to expand, but manufacturing and installation employment suffered. After losing many jobs between 2011 and 2014, Germany's solar PV industry stabilised and registered a gain of 4 000 jobs in 2018. Most other renewables industries also showed small improvements.

But the wind sector, dominant among renewables, has been shedding jobs since 2016. Employment in the onshore wind segment went from 113 400 in 2017 to 96 600 in 2018, overshadowing smaller gains in the offshore segment (BMWi, 2020). This is due to a precipitous decline in new onshore installations, from 5.5 GW in 2017 to about 2.5 GW in 2018, and further to 958 MW in 2019, the lowest level since 1998 (FA Wind, 2020).

Policy changes, including restrictive rules for the siting of wind farms and a lengthening permitting process, lie behind this development (Diermann, 2019; IRENA, 2019b).[22] Although data for 2019 are not yet available, it is very likely that job losses in onshore wind continued. Manufacturer Senvion declared insolvency in April 2019. Enercon announced in late 2019 that it was laying off some 3 000 workers, affecting northern and eastern parts of the country that are not well diversified economically (Balser and Bauchmüller, 2019).

In **Spain** the enforcement of laws in the context of the EU's Renewable Energy Directive at national, regional and local levels, as well as growing interest from the public and private sectors, have injected a new dynamic into what had been a stagnant sector. According to APPA, the Spanish Association of Renewable Energy, the sector experienced 10.7% growth in real terms in 2018. The same year, a new export record of EUR 4.7 billion was set, and the sector contributed EUR 10.5 billion to GDP, close to 1% of Spain's total (APPA, 2019).

19 *Including the United Kingdom prior to Brexit. The EU total, along with the estimates for individual renewable energy technologies, is based on EurObserv'ER (2020) and adjusted with national data in the cases of Germany (BMWi, 2020), France (FEE and Capgemini Invent, 2019), Spain (APPA, 2019) and the United Kingdom (REA, 2020). Differences in methodologies used by the cited sources generate widely differing employment estimates.*

20 *The data are for the EU-28, including the United Kingdom. The country withdrew from the European Union effective 31 January 2020, after the period of time that serves as the basis for this report.*

21 *The data reported in the 2019 edition of the Annual Review are not directly comparable with the estimates reported here, since they were based on a different source and methodology. This year, an estimate of 7 600 jobs in energy from municipal waste reported by EurObserv'ER (2020) was added to the BMWi figure of 304 400 jobs.*

22 *Boosting wind generating capacity in line with projected demand would require expanding it from 54 GW at present to 97 GW by 2030. This would translate into annual additions similar to those made in 2014-18. The government's 2030 climate policy implies adding 17 GW, or less than 2 GW per year (Diermann, 2019).*

APPA highlights that the sector employed 81 294 people in 2018. The largest employer was biomass (with 32 300 jobs), followed by wind energy and solar PV (22 200 and 13 300, respectively). By technology, wind energy created most of the net new jobs (1 961), followed by solar PV (966) and biofuels (158). The total represents a 3.3% increase in employment, the highest figure since 2013, but still far from the record set in 2008, when the sector employed 144 000 people (APPA, 2019).

In the **United Kingdom**, renewables employment in 2018 is estimated at 114 500 jobs.[23] According to the UK National Grid Net Zero Energy Workforce Report, the country's energy sector workforce employs 144 000 people directly. As is true in other countries, women are under-represented across the energy sector; they account for only 12% of its engineers (National Grid, 2020).

Employing some 44 100 people, the wind industry accounted for 37% of the United Kingdom's renewable energy total. Wind jobs are concentrated in London and the southeast (one-third of employment), northern parts of England (another one-third) and Scotland (10%) (REA, 2020). In northeast England, an offshore wind industry cluster helped Hull (East Yorkshire) cut its unemployment in half (Reed, 2020).

The United Kingdom has Europe's third-largest installed wind capacity after Germany and Spain, with a significant portion of its industrial supply chain located abroad. The turbines for Dogger Bank, set to become the world's largest offshore wind site, are to be supplied by GE Renewable Energy from factories in France. Nacelles will come from Saint-Nazaire (400 employees) and blades from Cherbourg (more than 550 direct jobs and 2 000 indirect) (WEAMEC, n.d.). Locally, the Port of Tyne will serve as the O&M base for Dogger Bank, with more than 200 direct jobs expected (Dogger Bank, 2020).

In **France**, direct and indirect wind jobs were estimated at 18 400 in 2018, a gain of 1 400, or 8% over the previous year. Planning and design jobs have seen the most growth, employing 5 400 people in 2018. This compares with 4 900 in engineering and construction, 4 100 in component manufacturing and 3 700 in O&M. The two northeastern regions of Hauts-de-France and Grand Est are home to half of France's wind capacity and 20% of total wind employment. But it is the capital region, Île-de-France, that has the single-largest number of jobs, at 29%.

The French wind supply chain now comprises more than a thousand companies. In the traditional industrial region of Auvergne–Rhône-Alpes, a competitiveness cluster focused on energy transition innovation, Tenerrdis, brings together some 300 partners from industry, R&D centres and local authorities (FEE and Capgemini Invent, 2019). Another noteworthy cluster is the West Atlantic Marine Energy Community, which groups more than 100 regional companies, engineering schools and research laboratories, and offers training courses relevant to marine-based renewable energy (WEAMEC, 2020).

According to EurObserv'ER (2020), solid biomass was the largest employer in France in 2018 with 31 100 jobs, followed by liquid biofuels (29 100 jobs), wind (15 700 jobs) and solar PV (15 000 jobs).

23 This figure is principally based on reporting from the Renewable Energy Association (REA, 2020), with some adjustments. REA published a figure of 9 796 jobs in air- and ground-source heat pumps, but IRENA includes only ground-source heat pumps (2 100 jobs). IRENA's estimates indicate 1 900 jobs in hydropower in 2019. The REA estimates energy from waste employment at 8 084 jobs.

OTHER COUNTRIES

Several other countries – in Asia, Latin America and the Caribbean, the Middle East and North Africa, and Sub-Saharan Africa – are expanding their presence in renewables. In the process, they are creating jobs in various segments of the value chain. This is particularly true of the solar PV sector, where several **ASIA-PACIFIC** countries are major players.

In **Japan**, cumulative solar PV capacity reached 61.8 GW in 2019, the second-largest after China and just ahead of the United States (IRENA, 2020a). The growth came amid a shift from large-scale to rooftop assemblies, because suitable land is scarce in Japan. IRENA estimates 2019 employment at some 241 000 jobs, a reduction of 10 000 from 2018.[24] The bulk of Japan's solar panels are imported. In the first three quarters of 2019, domestic production accounted for just one-sixth of total shipments (JPEA, 2020), limiting the extent of domestic manufacturing jobs.

The **Republic of Korea** estimates all renewable energy employment at 25 730 in 2018 – the most recent year for which estimates are available (Korea Energy Agency, 2020). In solar PV, the country employs about 13 800 people directly in manufacturing and in construction and installation. Production is heavily export oriented, with about 90% of the modules shipped abroad (IEA PVPS, 2020c). The domestic market received a boost when the capital city, Seoul, announced plans to deploy rooftop PV on a million homes and all public buildings, with the intent to quintuple its total capacity to 1 GW by the end of 2022. The initiative is expected to create up to 4 500 new jobs (Bellini, 2019).

Malaysia is a major solar PV manufacturer for export markets; half a dozen leading companies have set up facilities with a module-production capacity of about 5.4 GW (IEA PVPS, 2020a). The Sustainable Energy Development Authority (SEDA, 2020) estimates the number of people working in solar PV in 2019 at 54 900. IRENA's calculation yields an estimate of 100 900 jobs in the agricultural supply chain for biodiesel in 2019. Altogether, IRENA estimates Malaysia's renewable energy workforce at 187 000 in 2019.[25]

In **Thailand**, a total of 15 companies produced PV modules in 2018, with an annual capacity of 4.3 GW. There are also 80 PV inverter suppliers, 20 companies in the storage battery field, and 70 engineering, procurement, and construction companies specialising in both utility-scale and rooftop systems. Direct PV jobs were estimated at 18 710 in 2018, of which 14 000 were in operations and 3 000 in manufacturing (IEA PVPS, 2020b).

Solar PV jobs in the **Philippines** increased from 20 800 in 2018 to 33 700 in 2019. Wind power contributes close to 18 780 jobs, solid biomass more than 11 000 and geothermal power another 11 980 (REMB DOE, 2019). IRENA estimates biofuels employment at 36 100 jobs, including informal jobs in the agricultural supply chain.

Viet Nam had already become a notable PV manufacturer in recent years. But in 2019 the country joined the ranks of large installation markets with additions of 5.6 GW (IRENA, 2020a). This was driven by deployment policies (feed-in tariffs and most recently, auctions). Developments have been so rapid that they completely overtook recent projections, such as a 2019 World Bank supply-chain assessment that foresaw 12 GW of solar PV installations and some 45 000 full-time equivalent (FTE) jobs by 2030 (World Bank, 2019). IRENA estimates that, due to the accelerated pace of deployments and large exports, Viet Nam's solar PV workforce already stood at 56 700 jobs in 2019. The manufacturing and construction and installation segments of the value chain each accounted for around 25 000 of these jobs, with the remainder in operations and maintenance.

As noted earlier, **Indonesia** is a large biofuels producer and employer. The government is now working on the Solar Archipelago (Surya Nusantara) plan to install 1 GW each year over the next four to five years, with a focus on serving the poorest households. The initiator of the plan, the Institute for Essential Services Reform, estimates that up to 22 000 jobs could be generated in installations. But because experienced installers are in short supply, stepped-up training is essential to make the plan a reality (Harsono, 2020).

24 In the absence of direct employment data, this calculation is based on the assumption that employment closely tracks the reduction in demand during 2018.

25 Hydropower employment is estimated by the government at 22 000 jobs. IRENA's employment-factor calculation is lower, at 7 000 jobs.

In **Bangladesh**, IRENA estimates 137 400 jobs are related to the country's 5.8 million decentralised solar home systems that represent about 80% of total installed solar capacity. However, in recent years, grid-connected solar generation installations surpassed those of off-grid solar home systems (SREDA, 2020), some 25 and 18.3 MW in 2019, respectively (Islam, 2020a). Although most Bangladeshi solar jobs are in sales, installation and maintenance, some 10 000 people are also employed in module assembly (Islam, 2020b).

In **Australia**, direct FTE renewable energy employment ran to about 26 850 jobs in 2018-19 (ABS, 2020), 27% more than the previous year. Rooftop solar PV leads with 13 070 jobs, ahead of utility-scale PV (4 740 jobs), wind (3 240) and hydro (3 060),[26] with biomass and geothermal weighing in less heavily. Australia's 2020 renewable energy target drove much investment. But now the renewable energy sector is contending with problems of grid connection and transmission infrastructure – and with a lack of continued federal government policy support (Maisch, 2019). Still, Australia's Clean Energy Council (CEC, 2020) projects that renewable jobs could rise to 44 000 by 2025 if ambitious policies and adequate skill training are put in place (CEC, 2020).[27]

In **EASTERN EUROPE**, **Ukraine** had a stellar year for solar PV deployment in 2019. Solar PV capacity tripled, as close to 3.9 GW were added to the grid, encouraged by a combination of feed-in tariffs and net metering. IRENA's estimates put solar PV jobs in the country at close to 24 800, one-third of which are in the labour-intensive rooftop solar segment. Reductions in feed-in tariffs could reduce jobs in the utility-scale segment in 2020, but will not affect rooftop deployment, which is driven by net-metered projects (UNIAN, 2020; Teush, 2020).

In **LATIN AMERICA**, Argentina, Brazil, Chile and Mexico are among the largest actors in the renewables sector, but with each passing year more countries are adopting new policies and increasing the share of renewables in their energy mix.

Mexico has the region's largest installed solar PV capacity, ahead of Chile and Brazil. Solar PV grew from 2.5 GW to 4.4 GW in 2019. Utility-scale plants account for more than 80% of this total, with employment estimated at more than 50 000 jobs. Solar rooftop installations are responsible for another 6 000 jobs, according to the Asociación Mexicana de Energía Solar (ASOLMEX) (Zarco, 2019). INEGI (2020) suggests a lower value of direct and indirect solar PV employment, estimated at 23 300 jobs.

In **Argentina**, the successful RenovAr auction programme remains strong; it is oriented toward innovation trends and now provides guarantees to back up contracts and mitigate risks. Domestic technology is being promoted; technology imports are not allowed when local alternatives are available. Projects that source at least 60% of their materials locally can apply for special tax regimes (IRENA, 2019b). This has helped mobilise private sector participation and increased local employment. As of March 2020, Argentina reported that 15 000 people were working directly in renewable energy. The liquid biofuels sector is the main employer with 5 530 jobs, followed by wind energy with around 3 750 jobs (lower than previous years as many projects under construction came to an end) and solar energy, with some 2 720 jobs (Ministerio de Energía, 2020).

Since 2008, **Ecuador's** constitution has included an explicit reference to the need to address climate change mitigation, implying a governmental responsibility for promoting the use of clean energy sources and energy efficiency measures to preserve the environment and maintain food and water security. Since then, Ecuador has increased its renewable energy generation, mostly from hydropower, followed by wind and solar PV, creating ample job opportunities.

As reported in the first quarter of 2020, around 44 000 people were directly employed in solar (PV and CSP), geothermal and wind. Additionally, 67 000 people are directly or indirectly employed in other renewables, notably biofuels, biogas, solid biomass and waste management. The country reports that women and men participate equally in the biogas industry, while women's participation is lower in other renewable energy technologies: accounting for 44% in solid biomass, 38% in wind energy, 33% in all solar technologies and only 22% in the geothermal workforce (IIGE 2020).

26 The ABS estimate contrasts with an estimate of 12 000 jobs based on IRENA's employment calculation.

27 For purposes of comparison, coal mining employs some 40 000 people in Australia.

Costa Rica is already a front-runner in the deployment of renewable energy. Yet the country still has great unexploited potential in various end uses (namely transport and heating and cooling) and in diversifying the power generation mix, which is highly focused on hydropower. Geothermal energy employed over 100 people in 2019 (SEPSE, 2020). The Solar Energy Association of Costa Rica, Acesolar, reports that up to 1 467 people were employed in 2018 (Acuña *et al.*, 2018), supporting the addition of 30 MW of solar capacity between 2014 and 2019 (IRENA, 2020a). As of early 2020, national statistics reported 46 employees in the design and operation of solar PV and CSP plants. With some wind farm construction coming to an end, jobs in that sector decreased to 53 in O&M and environmental management (SEPSE, 2020).

Colombia remains a top biofuels producer and employer, as noted previously. The country also reports over 4 900 jobs in solar and wind energy. It is important to mention that, inspired by the success of auctions in other Latin American countries and thanks to a conducive market structure, Colombia has recently awarded contracts for nine projects that will provide 1 374 MW from wind and solar sources. These should bring ample employment opportunities in the coming years. Most of the projects will be located in La Guajira, a region that has been historically marginalised and energy-poor. The inclusiveness and long-term sustainability of the employment opportunities in the region will depend on the presence of a labour force with the requisite education and skills, and social protection policies that will need to be coordinated with industrial and financial ones (IRENA and USAID, forthcoming; IRENA, 2019b).

A number of other countries in the region are creating jobs while ensuring better energy access. For example, benefiting from funding provided by the Abu Dhabi Fund for Development through the IRENA/ADFD Project Facility, **Cuba** finished construction of four solar PV parks with a cumulative 10 megawatt peak (MWp) of capacity, employing about 40 people. The project will be expanded by an additional 5 MWp, requiring 50 persons to complete.

In the **MIDDLE EAST AND NORTH AFRICA**, **Egypt** is nearing completion of its Benban solar complex. Employment estimates hovered around 3 000 for installing the site's PV panels, with more in construction and in other activities (Nordrum, 2019).

Algeria is slowly expanding its capacity to produce solar PV modules (Bellini, 2020a). SPS, a local firm, is to begin production of panel mounting structures in a joint venture with Dubai-based Qi-energy. Mounting systems could account for up to 12% of a project's balance-of-system costs, and this would help achieve the Algerian government's domestic content objectives. Algeria is also adding to its solar panel manufacturing capacity. By 2024, the government is planning to install 4 GW of PV through five annual tenders. The expectation is that construction of these facilities will create some 56 000 jobs, and operating them could create another 2 000 jobs (Bellini, 2020b, 2020c, and 2020d).

In **SUB-SAHARAN AFRICA**, direct employment in projects under **South Africa's** Renewable Energy Independent Power Producer Procurement Programme rose from 17 800 job-years in 2014 to 45 450 by mid-2019. The bulk – some 82% – came in construction, the remainder in operations (IPPPP, 2020). About 80% of renewable energy capacity procured as of September 2019 is being installed in just two provinces that account for 15% of the country's population and 10% of its GDP (see Figure 12). The Northern Cape, with a per capita GDP figure close to the country's average, has 56% of the capacity and 60% of the job-years (in construction, installation and O&M). The country's poorest province, the Eastern Cape, accounts for 24% and 16%, respectively. By contrast, the third-poorest province, KwaZulu-Natal, has garnered only 0.3% of installations and jobs (IPPPP, 2020).