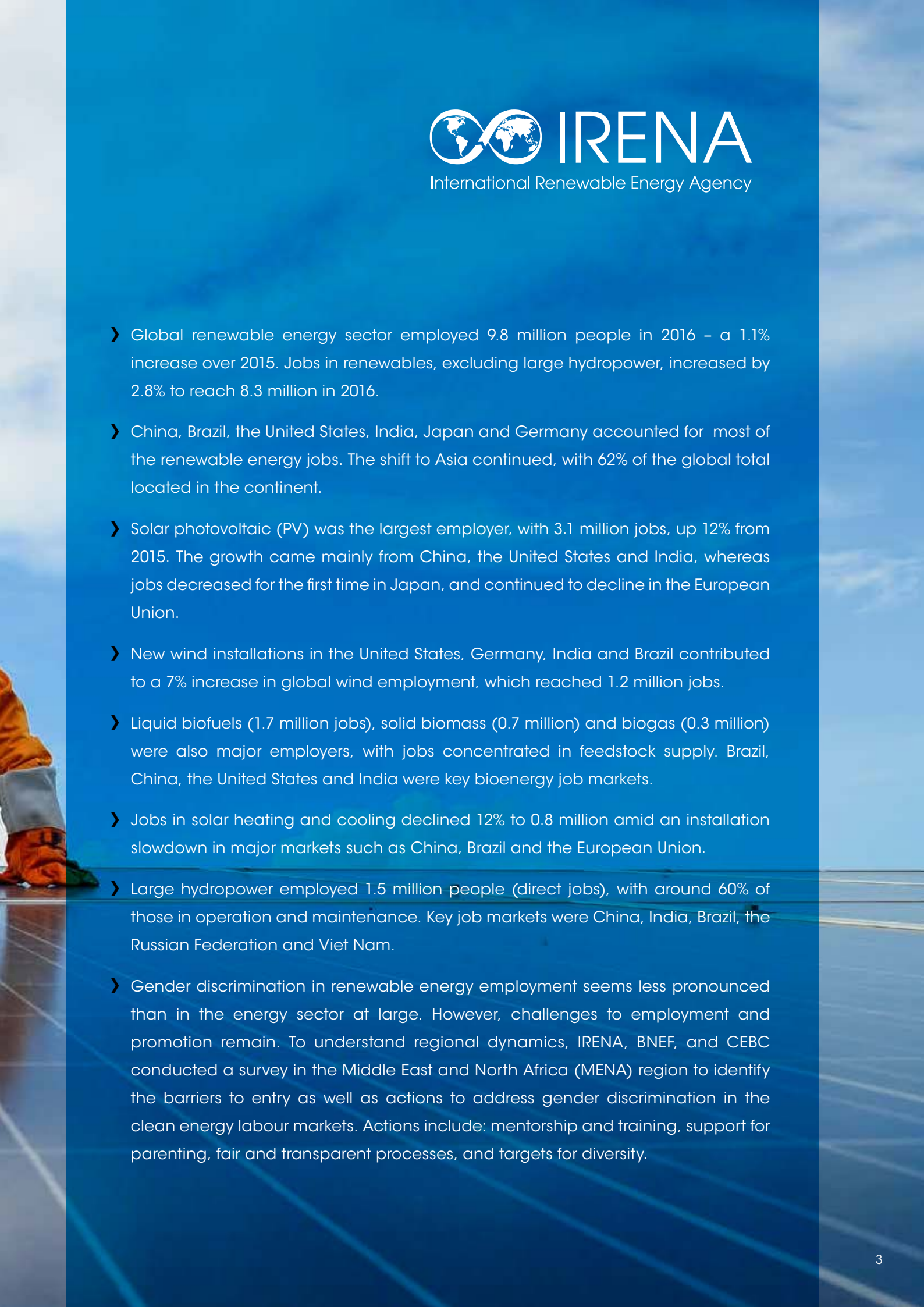
IRENA
International Renewable Energy Agency

Renewable Energy and Jobs

Annual Review **2017**

KEY FACTS

Annual Review 2017



IRENA
International Renewable Energy Agency

- Global renewable energy sector employed 9.8 million people in 2016 – a 1.1% increase over 2015. Jobs in renewables, excluding large hydropower, increased by 2.8% to reach 8.3 million in 2016.
- China, Brazil, the United States, India, Japan and Germany accounted for most of the renewable energy jobs. The shift to Asia continued, with 62% of the global total located in the continent.
- Solar photovoltaic (PV) was the largest employer, with 3.1 million jobs, up 12% from 2015. The growth came mainly from China, the United States and India, whereas jobs decreased for the first time in Japan, and continued to decline in the European Union.
- New wind installations in the United States, Germany, India and Brazil contributed to a 7% increase in global wind employment, which reached 1.2 million jobs.
- Liquid biofuels (1.7 million jobs), solid biomass (0.7 million) and biogas (0.3 million) were also major employers, with jobs concentrated in feedstock supply. Brazil, China, the United States and India were key bioenergy job markets.
- Jobs in solar heating and cooling declined 12% to 0.8 million amid an installation slowdown in major markets such as China, Brazil and the European Union.
- Large hydropower employed 1.5 million people (direct jobs), with around 60% of those in operation and maintenance. Key job markets were China, India, Brazil, the Russian Federation and Viet Nam.
- Gender discrimination in renewable energy employment seems less pronounced than in the energy sector at large. However, challenges to employment and promotion remain. To understand regional dynamics, IRENA, BNEF, and CEBC conducted a survey in the Middle East and North Africa (MENA) region to identify the barriers to entry as well as actions to address gender discrimination in the clean energy labour markets. Actions include: mentorship and training, support for parenting, fair and transparent processes, and targets for diversity.

RENEWABLE ENERGY AND JOBS

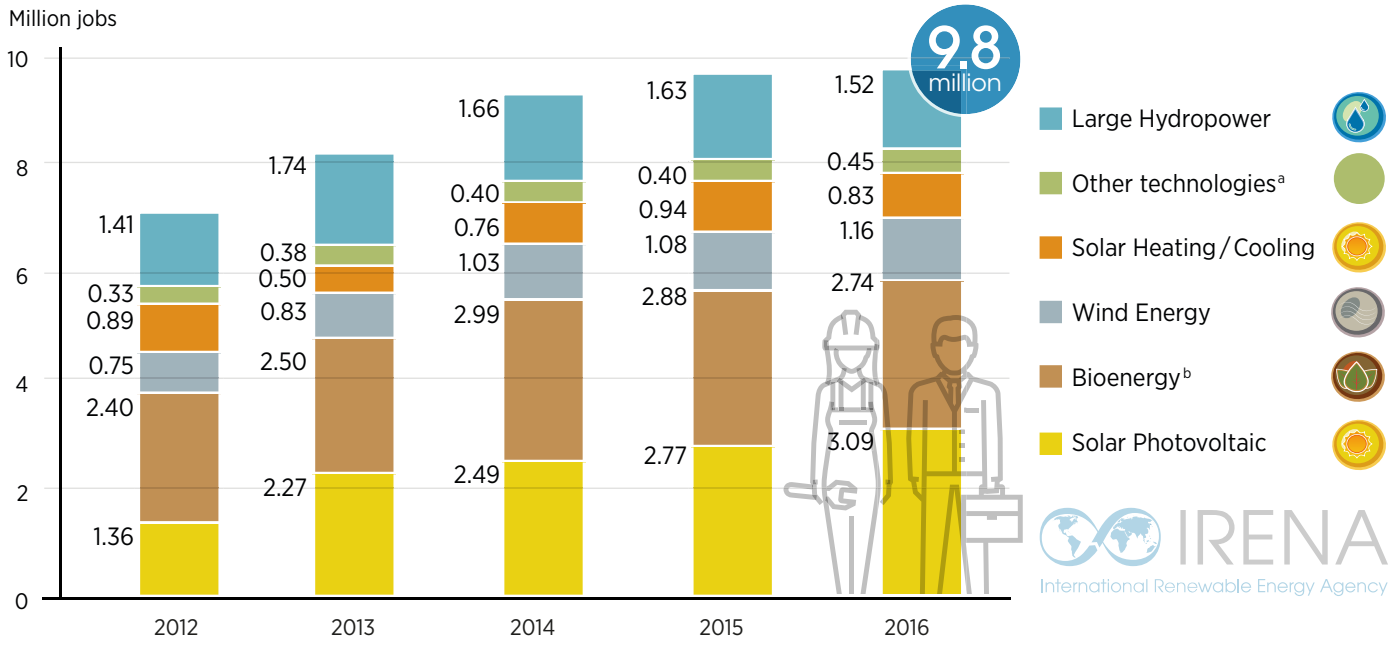
Annual Review 2017

The renewable energy sector employed 9.8 million people, directly and indirectly, in 2016[1] – a 1.1% increase over 2015. Jobs in renewables, excluding large hydropower, increased by 2.8% to reach 8.3 million in 2016.

Renewable energy employment worldwide has continued to grow since IRENA's first annual assessment in 2012, but the last two years have seen a more moderate rate of growth. The most consistent increase has come from jobs in the solar PV and wind categories, together more than doubling since 2012. In contrast, employment in solar heating and cooling and large hydropower has declined (Figure 1).

1 Data are principally for 2015–2016, with dates varying by country and technology, including some instances where only earlier information is available.

FIGURE 1: **GLOBAL RENEWABLE ENERGY EMPLOYMENT, 2012-2016**



Note: a) Includes geothermal energy, hydropower (small), concentrated solar power (CSP), municipal and industrial waste, ocean energy and miscellaneous
b) Includes liquid biofuels, solid biomass and biogas

These employment trends can be attributed to several underlying factors. Falling costs and supportive policies in several countries, for instance, have spurred deployment of renewables at a record pace, and has resulted in job creation. However, these positive developments were moderated by lower investments, rising automation and policy changes, resulting in job losses in some major markets, including Brazil, Japan, Germany and France.

The presence of a stable, favourable policy framework remains a key factor for renewable energy job creation. Auctions, for instance, were central to the growth of solar PV installation jobs in India. In some cases, expectations of adverse policy changes can induce an extensive pipeline of projects before the cut-off date, leading to a hike in jobs. In the United Kingdom, for instance, announced cuts to feed-in tariffs for solar, wind, hydropower, and biogas led to a rush to complete projects before changes took effect in April 2016.

Another factor shaping labour needs is increasing labour productivity, especially in bioenergy. The ongoing mechanisation of feedstock harvesting in countries such as Brazil and the United States keeps lowering the requirement for agricultural labourers. Production of equipment such as solar PV panels and wind turbines is also subject to increased automation and results in the reduction in labour requirement in manufacturing. Finally, the automation of operation and maintenance (O&M) of solar PV and wind plants may further reduce jobs.

While the rate of growth in renewable energy jobs has been moderate for the last two years, the trend remains positive in contrast to traditional energy industries, which have been facing employment cuts

in several markets (Box 1). Furthermore, project-level data indicates that, on average, renewable energy technologies create more jobs than fossil-fuel technologies. Solar PV, for instance, creates more than twice the number of jobs per unit of electricity generation compared with coal or natural gas (UKERC, 2014).

This fourth edition of *Renewable Energy and Jobs – Annual Review* provides the latest available estimates and calculations on renewable employment. The first section of the review highlights employment trends by technology (Figure 2), with the second section providing insights for selected countries (Figure 5). As last year, in-depth analysis on large hydropower employment (Box 2) and the gender dimension (Box 3) are also included.

BOX 1: EMPLOYMENT LOSSES IN THE FOSSIL FUEL SECTOR

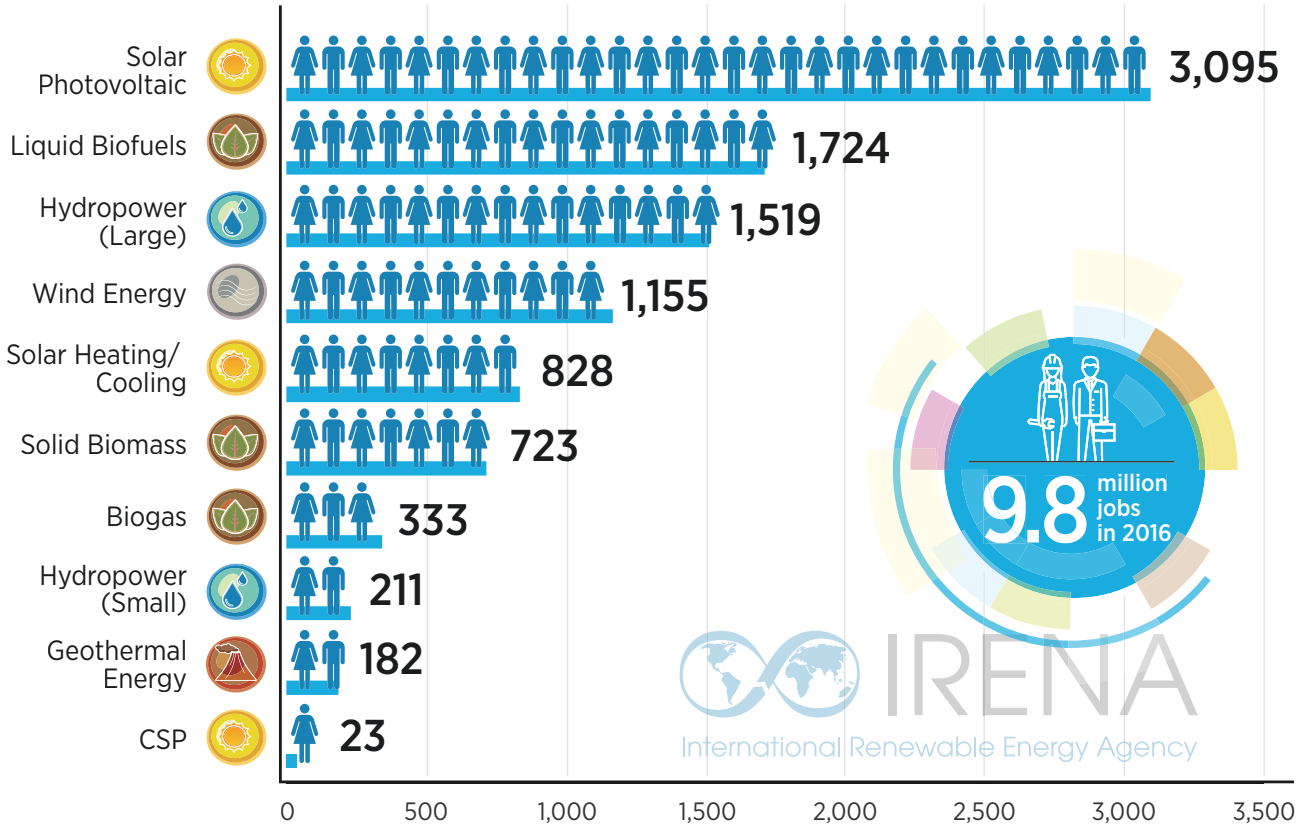
Rising automation in extraction, overcapacity, industry consolidation, regional shifts, and the substitution of coal by natural gas in the power sector are resulting in job losses in the fossil-fuel sector in some countries. Moreover, climate policies and the rise of renewable energy may add pressure on the sector. In some power markets, the increased integration of variable renewable energy in the grid is already creating financial issues for incumbent fossil fuel based generators (IRENA, 2017a).

Employment in the coal industry is decreasing due to several factors such as power plants closing, overcapacity and improved mining technologies. China produces nearly half the world's coal, but excess supply and a slowing economy have led the government to plan closing of 5,600 mines (Reuters, 2016). This may lead to the loss of 1.3 million coal mining jobs, or 20% of the total workforce in the Chinese coal sector (Yan, 2016). In India, employment at Coal India, the world's largest coal producer, has fallen 36%, from 511,000 workers in 2002/03 to 326,000 in 2015/16 (Statista, 2017). Coal production among EU countries has been on the decline for 30 years. German coal-mining employment, for example, is down to about 30,000 jobs, a tenth of the number three decades ago (Statistik der Kohlewirtschaft, 2016). In the United States, employment in coal has declined from 174,000 to 55,000 in the last 30 years (FRED, 2016).

The global oil and gas industry is also facing job losses due to low oil prices and oversupply. At least 440,000 people were laid off in 2015 and 2016. This included 196,000 jobs in support services, 91,000 in exploration and production, and 45,000 in drilling. The United States alone accounted for 40% of the job loss, the British North Sea offshore sector for 28%, and for Canada 10% (Jones, 2017).

Renewable energy is already contributing to job creation in many of these markets. In the specific case of the United States, solar generating capacity represents only slightly more than 1% of the total power capacity (coal at 26%). However, solar workers are already twice as numerous as those in the highly-automated coal industry (Solar Foundation, 2017; USDOE, 2017a).

FIGURE 2: **RENEWABLE ENERGY EMPLOYMENT BY TECHNOLOGY**



RENEWABLE ENERGY EMPLOYMENT BY TECHNOLOGY

SOLAR PHOTOVOLTAIC

Declining costs and supportive policy frameworks in several countries around the world led to a record year for solar in 2016, leading to significant job creation. New capacity additions surpassed those in 2015 by around 50% to reach 71 gigawatts (GW), with China, the United States, Japan and India as the key markets. Employment increased by 12% to approach 3.1 million jobs in 2016.

China accounted for more than half of these jobs, by consolidating its position as the largest installer and manufacturer of solar PV panels. Strong growth in installations boosted employment in India to 121,000 jobs, 17% higher than in 2015. US employment increased by 24% to reach 242,000 people. Similarly, the solar PV sector in Bangladesh continued to grow, supporting 140,000 jobs in 2016.

By contrast, Japan's slowing pace of installations in 2016 led to a 20% decrease in jobs. Similarly, the European Union's declining installations and module

manufacturing resulted in a 22% decrease in solar PV jobs in 2015[2], down to 111,000.

Continued declines in the cost of solar panels in 2016 were welcome news for employment in the construction and installation segment of the value chain in several markets. Jobs in this segment of the Chinese solar PV industry, for instance, jumped by 81% to reach 635,000, as installations rose. Accordingly, the share of construction and installation jobs rose from 20% in 2015 to 32% in 2016 (CNREC, 2017).

While falling costs spurred installation jobs, they also continued to threaten the financial health of manufacturers. In India, for instance, local manufacturers struggled in the face of cheap imports. Chinese firms supplied an estimated 80% of the total, with Indian firms accounting for no more than 13% (Bridge to India, 2016a&b). In the European Union, low demand and lack of competitiveness is forcing module manufacturers out of business. Module production fell by 16% to 2.7 GW in 2016. In contrast, domestic module production in the United States increased by 35% during the first three quarters of 2016 (compared to the same period last year). Consequently, jobs in US solar PV manufacturing increased by 26% to reach 38,000.

Trade policies also continued to affect employment. Prompted by duties imposed by the United States and the European Union on panel imports from China, Chinese manufacturers continued to expand their footprint to other manufacturing hubs in Asia. India, following a World Trade Organization (WTO) ruling against its domestic content rules, is searching for other measures to support its PV manufacturing industry that will not run afoul of global trade norms (Mercom Capital Group, 2017).

2 The jobs data for the European Union and its member states throughout this report is for 2015, the most recent year for which such information is available.

LIQUID BIOFUELS

With the notable exception of the European Union, bioethanol output increased among all leading producers. Biodiesel production also rose, although it remained below the records set previously in some countries, including Argentina, Brazil and Indonesia. It continued to decline in China. Worldwide employment in biofuels is estimated at over 1.7 million, an increase of 2%. Most of these jobs are generated in the agricultural value chain – in planting and harvesting various types of feedstock. Fewer jobs, though often better-paid ones, are found in the construction of fuel processing facilities and in O&M of existing plants.

Continued mechanisation reduced labour requirements in countries such as the United States and Brazil. With an estimated 783,000 jobs, Brazil continues to have the largest liquid biofuel labour force by far. Employment also declined in the United States despite record production of ethanol and biodiesel. Biofuel output remained around the same level in the European Union, while employment decreased by 8.6% in 2015[3].

Following a dramatic fall in 2015 due to collapsing exports, Indonesia's biodiesel production boomed again in 2016, buoyed by growing domestic demand and government subsidies (USDA-FAS, 2016a). Utilisation of refinery capacity doubled in 2016 from its 2015 low of 17%. IRENA estimates Indonesia's biofuel employment in 2016 at about 154,300 jobs, roughly double the level of the previous year[4]. Biofuel output is also growing in other South East Asian countries such as Thailand and Malaysia, with employment reaching an estimated 97,000 and 52,500 jobs, respectively[5]. Biofuel employment in the Philippines is estimated at about 42,400, split almost evenly between ethanol and biodiesel[6].

Colombia is another important and labour-intensive Latin American biofuel producer. IRENA's estimate based on inputs from country experts indicate 85,000 jobs in the country. However, a higher estimate from Federación Nacional de Biocombustibles de Colombia (FNBC) (n.d.), counted more than 191,200 biofuel jobs in 2015.

3 Revised employment estimates for 2014 (Eurobserver, 2017) indicate that EU biofuels jobs decreased by 2% from 97.400 in 2014 to 95,900 in 2015.

4 The calculation relies on an employment factor initially developed by APEC (2010). This factor is applied as a constant each year for smallholder production, which accounts for 45% of volume (WWF, 2012) and which is more labour-intensive than large-scale plantations. For plantations, IRENA applies an assumed "decline" factor of 3% per year as a proxy for rising labour productivity.

5 The calculation for Indonesia was applied to Thailand. Small holders have a 73% production share, and an average of values reported by Termmahawong (2014) and by RSPO (2015). In Malaysia, smallholders account for 35% of production (WWF, 2012).

6 The Philippines' National Bioethanol Board puts sugar cane jobs related to ethanol production at roughly 20,000 (Biofuels International, 2015).

WIND

The wind industry employs 1.2 million people worldwide, a 7% increase over 2015. China retained its lead in new installations during 2016, with 19.3 GW of new capacity, or 30% of the world's total additions. The country's wind employment edged up slightly in 2016 to 509,000, close to half the global total. The United States, Germany, India, and Brazil together accounted for 35% of new capacity additions (GWEC, 2017).

Wind employment in the United States rose by 28% to 102,500 jobs in 2016 (AWEA, 2017), as capacity expanded by 11% and more manufacturing took place domestically. With several companies expanding and opening new manufacturing facilities, manufacturing jobs in the United States grew by 15% to reach 25,000 jobs in 2016. Though cumulative installed wind capacity surpassed 10 GW, Brazil's pace of installations slowed from 2015. Employment is estimated at 32,400 jobs, 21% below the previous year.

In Europe, new wind installations reached 13.9 GW during 2016, slightly up from the year before (Wind Europe, 2017b). Germany's offshore wind jobs grew 10% to reach 20,500 in 2015, but total wind employment decreased by 4% due to reduced activity in the onshore sector. Germany remains the leader in Europe, employing 142,900 people – as many as the next five-largest European countries combined (the United Kingdom, Denmark, Italy, Spain, and France). France also experienced a 10% growth in their wind employment (EurObservER, 2016).

Jobs in wind manufacturing continue to depend on several factors, including corporate market strategies, public renewable energy policies, and national plans for development. China is a good example. Local projects have been a significant market for Chinese manufacturers, since they have supplied approximately 97% of wind turbines installed in the country (Broehl, 2016). Now, however, the wind-equipment and services industry is attempting to boost exports to compensate for fluctuations in domestic demand. Increasingly, manufacturers such as Goldwind are also competing in the international market, in line with the Government's "Go Out Strategy".

As costs decline and competition between companies intensifies, the consolidation of the global wind industry is underway, with the recent mergers between Siemens Wind and Gamesa, and Nordex and Acciona. While these mergers enable the companies to sell and produce in many countries, and achieve greater economies of scale, they may also imply fewer jobs per unit of production.

Wind energy employment is likely to increase with continued deployment. An accelerated ramp up in wind energy deployment in line with global climate imperatives can lead to around 3 million jobs in the sector by 2030, compared with the current level of 1.2 million, and 4 million by 2050 (IRENA, 2017b). The Global Wind Energy Council projects employment could double to 2.4 million under its most favourable policy scenario by 2030 (GWEC, 2017).

SOLAR HEATING AND COOLING

The rate of new installations in the 18 leading national solar-heating markets declined by 14% during 2015[7]. The available information for 2016 shows a decline in several major markets including China, Brazil and the European Union (Epp, 2016a). Global employment in the sector in 2016 stood at 828,000 jobs, a 12% decline from the 2015 level.

Jobs fell in China for the third year in a row as equipment manufacturing dropped by 10% in 2016 and factories were reported to have produced only 65% of capacity. Employment thus decreased to an estimated 690,000 jobs (CNREC, 2017).

The Brazilian installation market declined by 3% in 2015 (Epp, 2016a). IRENA employment factor-based estimates[8] suggest that the country's employment in solar heating in 2015 fell by a similar margin, to 43,400 jobs.

A 2011 estimate had put India's employment at 75,000 jobs. However, this figure is likely to be on the high side, given that domestic manufacturers now serve only 11% of the market (Epp, 2016b). IRENA's employment-factor calculation suggests a much smaller figure of 18,000 installation jobs.

Turkey has an estimated 16,600 people working in this sector (Erim, 2017). In the United States, employment reached 13,000 jobs in 2016, and 10,000 jobs in Germany in 2015.

7 The most recent year for which a consistent and comprehensive set of data is currently available.

8 IRENA uses an employment factor of one full-time job per 87 m^2 installed, as suggested by IEA SHCP, 2016.

HYDROPOWER

As noted in last year's edition, estimating small hydropower employment is challenging since certain activities in the supply chain are shared with large hydropower and a significant portion of the jobs are informal. At 211,000 jobs, this year's estimate was 4% higher over 2015. Large hydropower employed more than 1.5 million people, with the majority in the O&M segment of the value chain (Box 2).

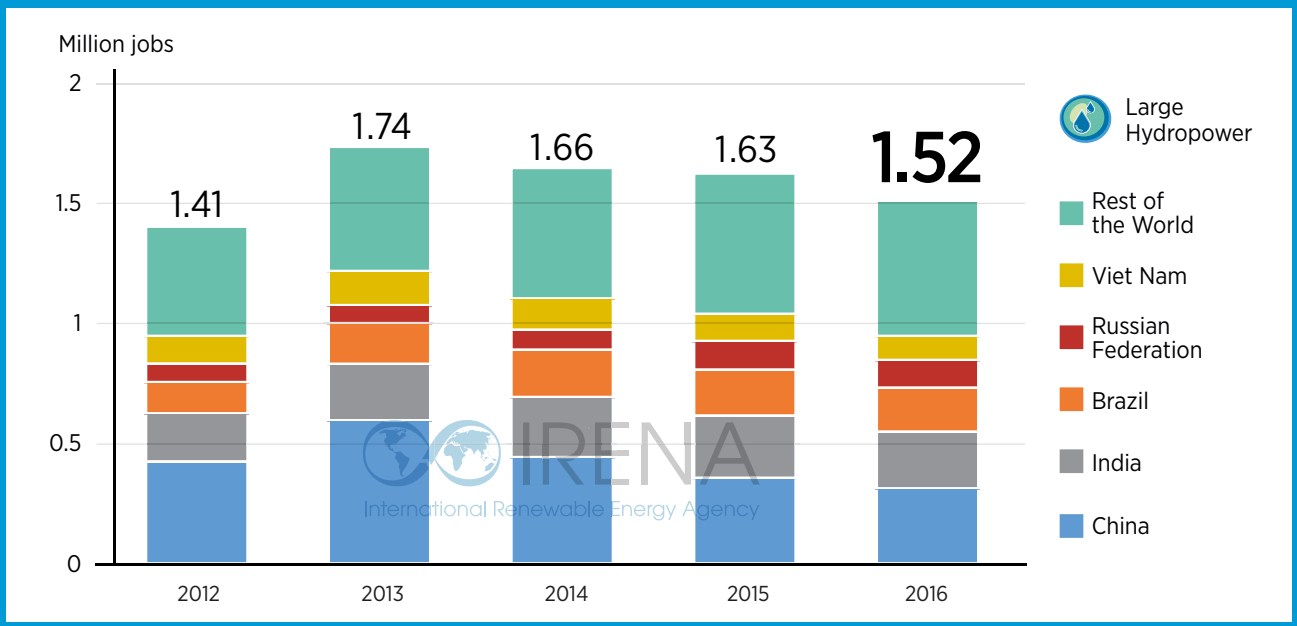
BOX 2: EMPLOYMENT IN LARGE HYDROPOWER

Large hydropower is the biggest renewable energy technology in terms of total installed capacity (47%). However, information on employment in the sector remains scarce. To fill the knowledge gap, IRENA has been conducting a global estimation of employment in the large hydropower sector for the past three years. This estimation is based on an employment-factor approach, which helps calculate jobs in each segment of the large hydropower value chain (including manufacturing; construction and installation; and O&M).

This year's results reveal approximately 1.52 million direct jobs in 2016, down 7% from last year's estimates[9]. Results show that direct jobs in the sector have been declining steadily since 2013. This decline is primarily driven by job losses in China, where new installations in 2016 have been cut by half compared to their peak of 27 GW in 2013 (Figure 3).

9 The global estimate for 2015 has been updated from 1.3 million to 1.63 following a major revision of employment factors, statistics and available data from countries. Temporal and geographic variations in labour productivities were also reviewed.

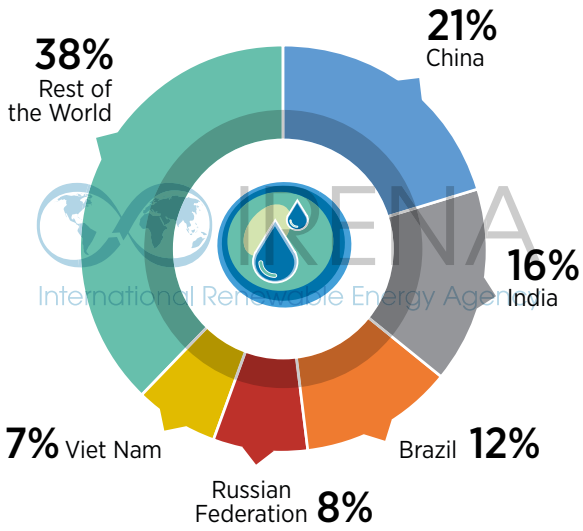
FIGURE 3: EVOLUTION OF LARGE HYDROPOWER EMPLOYMENT BY COUNTRY



The key job markets in the sector are China, India, Brazil, the Russian Federation and Viet Nam, which together account for 62% of the total (Figure 4). China's share of large hydropower employment continued to decline in 2016, from 37% in 2013 to 21%, because of rising labour productivity and a decline in new installations. India's labour-intensive hydropower sector accounted for 16% of the jobs, followed by Brazil, the Russian Federation and Viet Nam.

The results provide interesting insights about segments of the renewable energy value chain. Given the extensive installed base of large hydropower, O&M jobs account for close to 60% of global employment. The share of jobs in the construction and installation segment decreased from 41% of jobs in 2015 to 34% in 2016, due to a leaner project pipeline.

FIGURE 4: **COUNTRY LEVEL BREAKDOWN OF EMPLOYMENT IN 2016**



RENEWABLE ENERGY EMPLOYMENT IN SELECTED COUNTRIES

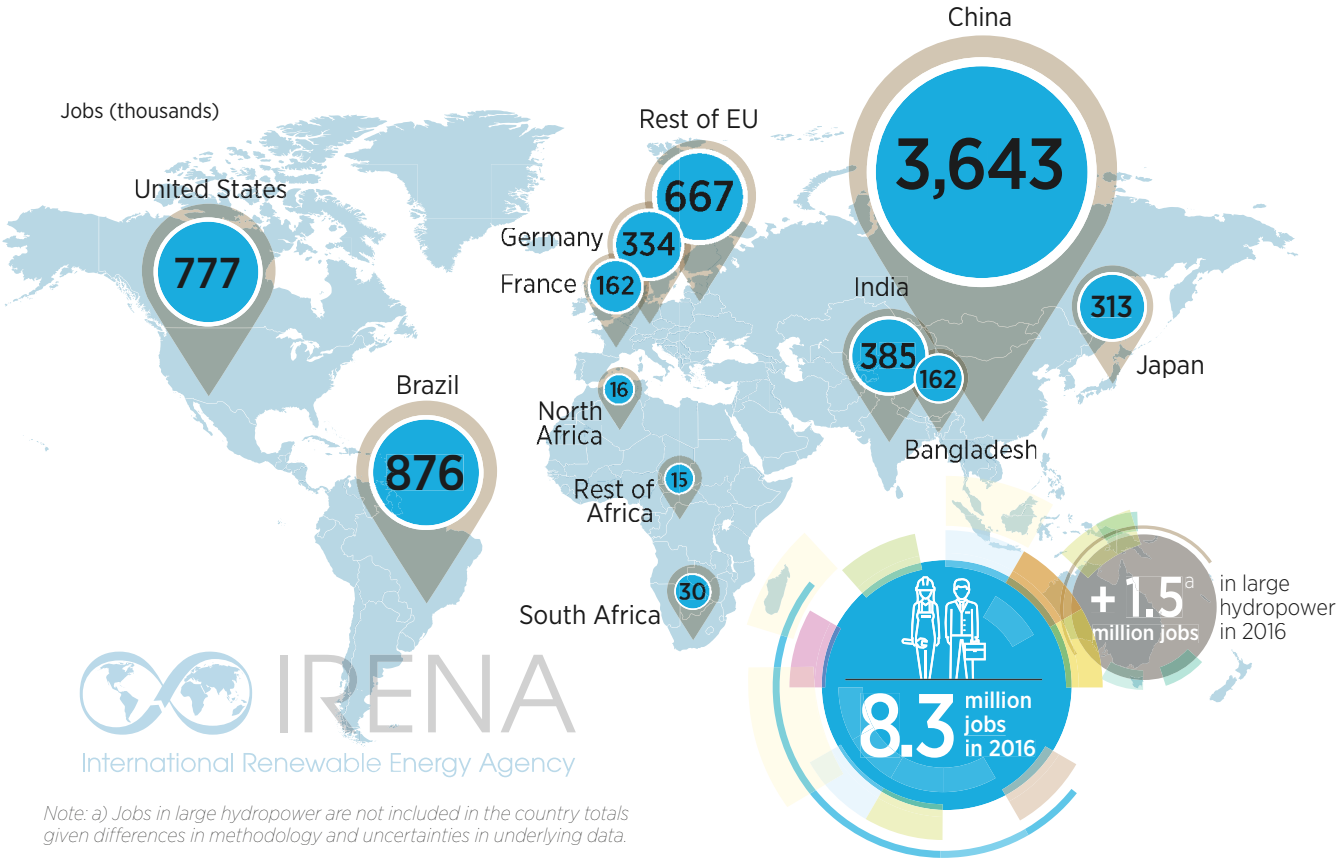
The renewable energy sector employed 9.8 million people, directly and indirectly, in 2016. Employment in large hydropower decreased by 7% to reach 1.5 million. Most of these jobs were in China, India and Brazil (Box 2). Employment in renewables, excluding large hydropower, increased by 2.8% to reach 8.3 million in 2016, with China, Brazil, the United States, India, Japan and Germany being the leading job markets (Figure 5).

The following section highlights key country-level trends in renewables, excluding large hydropower. Jobs in the sector have not been included in this analysis for two reasons. First, job estimates for large hydropower are based on an employment factor approach and include only direct jobs, whereas data for most other renewables are primarily based on data collection from primary and secondary sources[10] and include both direct and indirect jobs. Second, there are uncertainties in large hydropower estimates due to lack of reliable data on variables such as construction time and employment factors. In future editions of *Renewable Energy and Jobs - Annual Review,* IRENA will continue refining the data and the methodology to further improve the results.

Renewable energy employment continued to shift towards Asian countries, which together accounted for 62% of jobs in 2016, compared to 50% in 2013. China has benefitted from this transition, increasing its share of global jobs from 41% in 2013 to 44% in 2016. During the same period, the European Union's share declined from 19% to 14%.

While equipment manufacturing is a key strength of several Asian countries, they are also increasingly leading global deployment of renewable energy projects. Their share of new installed capacity (excluding large hydropower) has increased from 40% in 2013 to 46% in 2016, resulting in growing

FIGURE 5: **RENEWABLE ENERGY EMPLOYMENT IN SELECTED COUNTRIES**



Note: a) Jobs in large hydropower are not included in the country totals given differences in methodology and uncertainties in underlying data.

10 Primary data are collected through correspondence with government entities and industry representatives. Secondary data are referenced from a review of a wide range of national, regional and global studies.

job opportunities in the construction and installation segments. Other factors that continue to influence the geographic pattern of renewable energy employment include trade flows, changes in equipment costs, labour productivity, and policy instruments, which range from feed-in tariffs and auctions to subsidies and local content rules.

China continues to lead renewable energy employment, with 3.64 million jobs in 2016 (CNREC, 2017). The Chinese renewable energy job market grew by 3.4% in 2016, primarily due to strong gains in the solar PV sector. Employment declined in bioenergy, solar heating and cooling and small hydropower.

Solar PV accounted for close to 1.96 million jobs, of which 1.3 million were in manufacturing; 635,000 in construction and installation and 26,000 in O&M. Despite increased installation, employment in solar PV manufacturing remained essentially unchanged from 2015, due to rising labour productivity and economies of scale. Jobs in the construction and installation segment doubled as new installation increased by 125%. O&M jobs rose 18%.

Wind employment edged up slightly to reach 509,000 jobs in 2016, as new installations declined. The loss of jobs in construction and installation was more than offset by gains in O&M jobs. For a third straight year, employment in the Chinese solar water heating industry fell to 690,000 jobs, as sales declined 10%. At 95,000 jobs, employment in small hydropower dropped by 5%.

At the beginning of 2017, China's National Energy Administration (NEA) announced plans to invest CNY 2.5 trillion (USD 360 billion) into renewables-based power generation by 2020, including USD 144 billion for solar, USD 100 billion for wind, and USD 70 billion for hydropower. NEA projected that more than 13 million jobs would be created from 2016 to 2020 (Reuters, 2017). This would be a gain of 2.6 million jobs annually. Additional job gains may be secured as Chinese companies boost their overseas investments in hydropower, solar PV and wind power. In 2016, China's foreign investments in renewables increased 60% to USD 32 billion (Buckley, 2017).

In **Brazil**, most renewable energy employment is found in liquid biofuels. Total biofuel employment dropped by 5%, following a decline in ethanol-related employment and a smaller gain in biodiesel jobs. Even though ethanol production increased by close to 8% in 2015 (USDA-FAS, 2016b), employment declined by 10% to reach 613,000[11]. Some 30,000 jobs were lost in sugarcane harvesting and 15,000 jobs in ethanol processing due to mechanisation. Mechanisation of sugarcane harvesting proceeds apace especially in São Paulo state, the single largest ethanol producer in Brazil.

Meanwhile, Brazil's biodiesel production dropped slightly to 3.8 billion litres in 2016 (ABIOVE, 2017). There was a slight increase in overall estimated employment, however, to 169,700 jobs in 2015[12]. This was because of changes in feedstock mix to raw materials that require additional labour inputs.

The expansion of Brazil's wind industry slowed in 2016 compared with the preceding year, with 2 GW of new installations, down from 2.8 GW. Correspondingly, IRENA's employment factor-based calculation results in estimated wind employment of about 32,400 jobs, down from 41,000 in 2015. The total number of workers in construction and installation fell, as did manufacturing jobs. O&M employment edged up slightly.

New installations in Brazil's solar heating market declined by 7% in 2016 because of deteriorating economic conditions and delays in implementing the next phase of the social-housing programme Minha Casa Minha Vida. Total employment in 2016 was estimated at about 43,370 jobs, with about 30,500 in manufacturing and the rest in installation[13] (Alencar, 2013) (Epp, 2016a).

11 In 2015, Brazil had around 238,000 workers in sugar-cane cultivation and 175,000 workers in ethanol processing (MTE/RAIS, 2017). A rough and dated estimate suggests that there may be another 200,000 indirect jobs in equipment manufacturing.

12 Calculation based on employment factors (Da Cunha et al., 2014) and on the shares of different feedstock raw materials (USDA-FAS, 2016b). The share of beef tallow, for which production requires relatively limited labour inputs, declined from 19% of feedstock in 2015 to 17% in 2016. Soybean and other vegetable oils account for the bulk of feedstock.

13 IRENA calculation of installation 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).

The solar and wind industries were the primary engines of job creation in the **US** renewable energy sector, which employed around 777,000 people in 2016. Adding workers almost 17 times as fast as the overall economy, the US solar industry employed 260,077 people[14] as of November 2016, up 24.5% from the previous year (Solar Foundation, 2017). Most of these jobs (241,900) were in solar PV, with 13,000 in solar heating/cooling and 5,200 in CSP.

The tremendous growth of solar PV during 2016 – principally in the utility-scale segment was the result of falling costs and legislative conditions (Solar Foundation, 2017). During 2015, companies had initiated many projects that were to be completed before the end of 2016, when many anticipated that the federal Investment Tax Credit[15] would expire. But the US Congress ultimately agreed to a multi-year extension in December 2015.

More than half of all US solar jobs were in the installation segment; followed by manufacturing (15%), project development (13%), sales-and-distribution (12%) and other categories such as research-and-development (6%).

Overall, the US solar labour force is becoming more diverse. The share of women workers has risen from 19% in 2013 to 28% in 2016, and is as high as 33.8% in the sales-and-distribution segment. These shares are larger than female representation in the conventional energy industry, but still below their 47% share in the US economy. The share of women in the US solar labour force is higher than Germany and Spain, where the proportion is 24% and 26%, respectively (see Box 4).

Employment in the US wind industry rose to about 102,500 jobs in 2016, as generating capacity of 82 GW exceeded hydropower's 80 GW (Cardwell, 2017). Growth was driven by the multi-year extension of the Production Tax Credit (PTC). The PTC is projected to drive employment to 147,000 jobs by 2020 (Navigant Consulting, 2017). In 2016, construction, project development and transportation employed 35,500 people and O&M accounted for 42,000[16], and the manufacturing sector 25,000 (AWEA, 2017). Domestically-produced inputs account for more than 60% of the average wind farm's value in the US (Cusick, 2016). Following industry consolidation, just three companies – GE, Vestas, and Siemens – account for 86% of manufacturing capacity and 94% of all orders (BNEF and BCSE, 2017).

While the US ethanol production was up more than 3% in 2016, employment declined by 2% to about 222,500 jobs, reflecting rising labour productivity (Urbanchuk, 2017). The bulk of ethanol-related employment (161,700 jobs) was in the agriculture supply chain, followed by ethanol production with around 35,000 jobs.

Biodiesel production increased by 23% in 2016 (EIA, 2017), resulting in 61,100 jobs in the sector – a 23% increase over last year.

New US capacity installations in solid biomass and biogas approached 131 megawatts (MW) in 2016 (BNEF and BCSE, 2017). An employment-factor-based calculation suggests that direct and indirect employment in solid biomass might be close to 80,000[17]. The construction and operations of biogas plants in 2016 may have supported around 7,000 jobs[18].

14 The survey captures most of the direct jobs and many of the indirect jobs in the solar industry, except some indirect jobs in the supply chain for components and materials. Those jobs, combined with induced impacts of the industry, support an additional 764,792 jobs throughout the economy. A separate assessment by the US Department of Energy (USDOE, 2017) found that there were close to 374,000 people who spend at least some of their work time engaged in solar-related activities. The report did not attempt to generate a full-time equivalent estimate.

15 The 30% tax credit was extended to the end of 2019. It drops to 26% in 2020 and to 22% in 2021, then falls to 10% for commercial projects and to zero for residential projects.

16 The US Bureau of Labor Statistics (USBLS, 2015) projects that "wind-turbine service technician" will be the single fastest-growing occupation during the next decade, expected to increase by 108%, or twice as fast as the second fastest growing occupation.

17 This figure is based on an employment factor of 4 jobs per MW, applied to 16 GW of biomass power capacity, for some 64,400 jobs, and to 3.8 GW of biomass-fired CHP plants, for an additional 15,300 jobs.

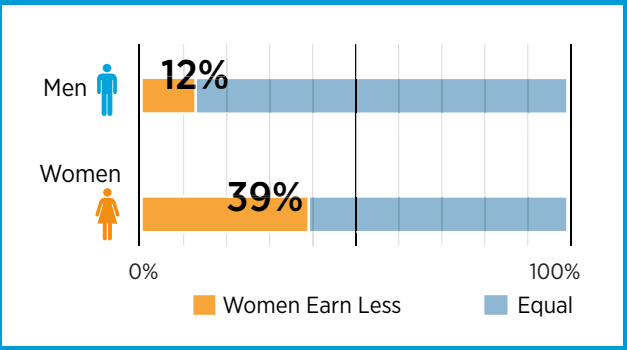
18 Estimate based on data from the American Biogas Council.

BOX 4: WOMEN IN CLEAN ENERGY, MIDDLE EAST AND NORTH AFRICA

Renewables jobs are set to rise with the transition to sustainable energy, with labour force projections reaching 26 million by 2050, a 144% increase (IRENA, 2017b). Women can expand the pool of skills and talents and boost the sector's prospects. Moreover, the clean energy sector could potentially be more attractive for women than the broader energy sector, because they are generally more receptive to issues related to local and global sustainability. A study investigating more than 1,500 companies found that increases in women on their board of directors led to more investment in renewable energy and greater consideration of environmental risks in their financial decision making (McElhaney, 2012).

IRENA's survey of 90 renewable energy companies worldwide found that women represent an average 35% of the workforce (IRENA, 2016). The finding was consistent with national level surveys from the United States, Germany and Spain (Solar Foundation, 2017; IRENA, 2013). They show that the share of women in renewables is greater than in the traditional energy sector, but lower than that of the broader economy.

FIGURE 6:
PAY GAP – PERSPECTIVE DIFFER BY GENDER



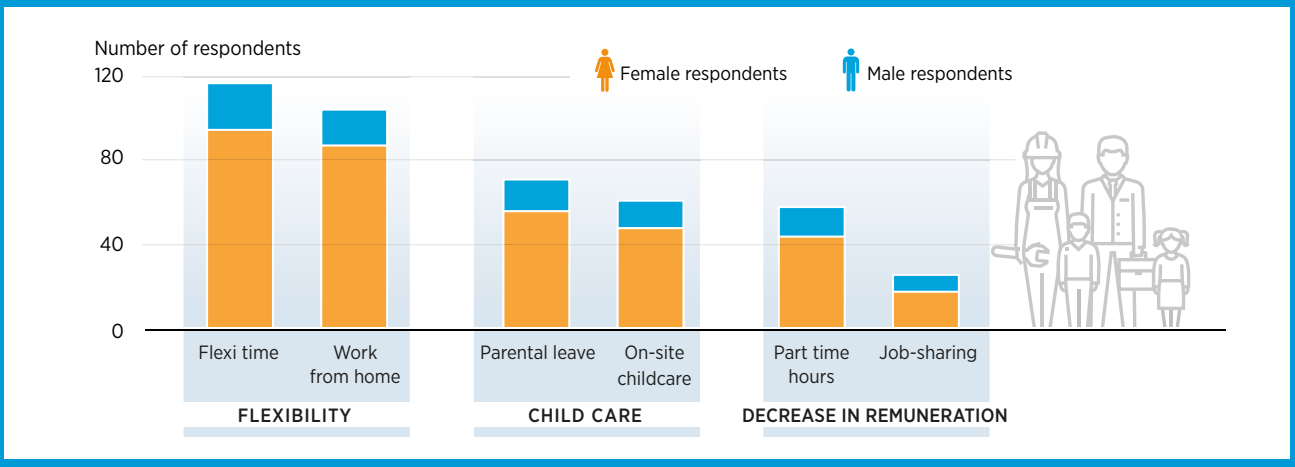
While there are some national level studies, gender-disaggregated data in the renewable energy sector remain rare in several regions, including the Middle East and North Africa (MENA). IRENA collaborated with the Clean Energy Business Council, and Bloomberg New Energy Finance to conduct a survey[19] to identify ideas on how the clean energy industry in the region can attract more women (BNEF, CEBC and IRENA, 2017).

Over 50% of the respondents stated that their companies employ more men than women, with only 29% reporting even shares. They also indicated that there were fewer women in management due to the presence of a glass ceiling. Moreover, women are less likely to take up technical positions due to a biased view of gender roles; and lower enrolment in science, technology, engineering and mathematics (STEM) education.

Women in MENA clean energy sector face discrimination in pay, like women in many countries. But perceptions of it differ. One third of respondents in MENA revealed that women earn less than men for the same position, while two thirds believe they earn the same. Men were more likely to believe that salaries were equal (Figure 6).

Respondents provided interesting insights into the kind of policies that can create more welcoming workplaces for women. They strongly favoured policies that allow for more flexibility such as work from home and flexi hours. Policies that facilitate child care, such as parental leave and onsite childcare were also popular. Policies that imply a decrease in remuneration, such as part time hours and job-sharing, were least favoured (Figure 7). Survey respondents also identified several other actions to address gender discrimination while supporting the growth of the sector. These included mentorship and training; fair and transparent processes; support for parenting and targets for diversity.

FIGURE 7: **FAMILY FRIENDLY POLICIES**



19 The survey benefited from 250 respondents from 38 countries, 12 of which are part of the MENA region. Close to 20% of the responses were from men. Most respondents (85%) identified as working in clean energy.

Source: BNEF, CEBC and IRENA (2017)

In **India** utility-scale and rooftop solar installations reached 4.9 GW in 2016, and domestic project developers won more than 90% of tendered PV capacity - benefiting domestic employment (Bridge to India, 2016b). While domestic installers fared well, manufacturers continued to struggle. At the end of 2016 at least a third of India's module capacity (8 GW) and half of cell capacity (2.8 GW) remained idle[20]. Indian-made modules are about 10% more expensive than Chinese imports, which account for the bulk of installed panels (Mercom Capital Group, 2017).

Following the WTO's ruling against India's local content requirements (LCR)[21], the government has sought to find other ways to support the industry. These include capital subsidies, interest-free loans and tax breaks, so-called Viability Gap Funding allocated through a bidding process, and a waiver of VAT and countervailing duties on domestically-produced components (Mercom Capital Group, 2017).

For 2017, PV installations employment should continue to expand dramatically, given that an expected 8.8 GW of capacity will be added, almost double the pace of 2016 (Bridge to India, 2017). The Council on Energy Environment and Water (CEEW) and the National Research Development Corporation (NRDC) project that utility- and park-scale PV projects through 2022 could create 58,000 direct jobs[22] (CEEW, 2017).

India had the world's fourth-largest additions to wind capacity in 2016 at 3.6 GW, up from 2.6 GW during the previous year (GWEC, 2017). IRENA estimates that employment has grown from last year's 48,000 jobs to 60,500.

In 2015, the most recent year for which complete data are available, jobs in the **European Union** decreased slightly by 5,500 jobs to reach 1.16 million in 2015[23]. While the solar industry continued to experience job losses, employment in geothermal and solid biomass increased.

The wind industry remains one of the mainstays of the renewable energy sector in Europe. Employment declined slightly to 329,700 in 2015 (EurObserv'ER, 2017). Germany was the leader in wind jobs with 43% of the total in the European Union, followed by the United Kingdom, Denmark, Italy and France. However, the Global Wind Energy Council has noted that ongoing economic crises and austerity measures as well as weakened legislative frameworks may have harmful effects in 2016 (GWEC, 2016). Offshore wind drove total wind investments, with the United Kingdom, Germany and Denmark as the leaders in employment (Pialot, 2017).

The European solar PV industry continued to see a fall in employment in 2015. At 114,450, it has lost two thirds of jobs since 2011. Germany, the United Kingdom, France, and Italy are the leaders, with 67% of the European PV jobs in 2015. In solid biomass (for heat and power applications), employment rose 7.4% to 333,300 jobs, close to the peak of 2013. The biofuels sector employed close to 93,000 people, a slight decline from 2014. Another sector that added jobs is the heat-pumps industry, providing livelihood for 110,000 people. Biogas, small hydropower and CSP all saw small reductions.

Renewable energy employment in **Germany** continues its recent downward trajectory. At 333,700 jobs in 2015, the labour force was 6% lower than the preceding year. In general, falling investments and installations in the domestic market were only partially offset by exports. The offshore wind and small-scale solid biomass industries added jobs, and CSP and geothermal energy were steady, but all other sectors lost jobs. The wind industry was Germany's largest employer among all renewables in 2015, but it shed about 6,300 positions, as offshore gains and rising export sales could not fully offset the

20 The nominally operational module capacity figure of 5.2 GW underlying this calculation may well understate the extent of the problem, with some sources putting the actual working capacity at no more than 3 GW (Mercom, 2017).

21 DCR was applicable to central government projects; 400MW of projects were completed under that category in 2015, with another 2GW in the pipeline for 2016-17 (Khurana, 2016). Some companies are planning to increase reliance on domestic inputs, such as NEXTracker, which decided to use up to 80% of Indian steel for its solar tracking systems (Clover, 2017).

22 These projections exclude rooftop installations and any equipment manufacturing jobs.

23 This total, along with the other EU figures, is based on EurObserv'ER (2017), but is adjusted with national data from APPA (2016) for Spain. This newest edition of EurObserv'ER offers employment data for 2015 and revises 2014 data.

slow-down in onshore projects (O'Sullivan *et al.*, 2016). The wind industry fared much better again in 2016 (Euractiv, 2017), but no job data are available yet.

In the German biogas sector, exports softened the impact of plummeting domestic investments; employment fell by 7% to reach 45,000 jobs. Some 3,100 jobs were lost in the solid biomass industry, which essentially stopped adding new capacity in the wake of subsidy cuts (Euractiv, 2017).

German solar PV employment was down to about 31,600 jobs in 2015, from a peak of 111,000 in 2011. The domestic PV market has declined from around 7.5 GW annual installations during 2010-12 to about 1.5 GW each in 2015 and 2016 (BSW-Solar 2016 and 2017). The PV industry's reliance on exports has risen from just 14% of production in 2004 to 70% in 2015 (BSW-Solar, 2017), due to strong competition from Chinese manufacturers in the global market.

France maintained its position as the second largest renewable energy employer in the European Union at 162,100 jobs in 2015, despite a loss of around 8,000 jobs. According to a joint report by several NGOs and trade unions, an ambitious policy to live up to the goals enshrined in the Paris Climate Agreement could mobilise public investment of EUR 100 billion and generate 1.4 million green jobs in France by 2030, including 330,000 jobs in the renewable energy sector (Robert, 2017; HBS France, 2016).

In the **United Kingdom**, close to 110,000 people were employed across the renewable energy value chain in 2014/15[25]. Announced cuts to feed-in tariffs for solar, wind, hydropower, and biogas, along with other adverse government policy changes, led to a rush to complete projects already under development before changes took effect in April 2016 (REA, 2016; Mourant, 2016). A survey of UK solar businesses in July 2016, however, found that perhaps a third of solar jobs (up to 12,500) had been lost from the previous year, with more cuts likely on the way. (PWC and STA, 2016).

Renewable energy employment in **Spain** stabilised in 2015, following six years of job cuts that resulted from adverse policy changes and economic crisis. Employment in 2015 totalled 76,150 jobs, or about half the 144,300 jobs in 2008. Biomass power is the largest sector with about 34,400 jobs (APPA, 2016).

Following a peak of 11.5 GW in 2015 installations, **Japan**'s solar boom weakened during 2016 because of tariff cuts, land shortages, and difficulties in securing grid connections (Bloomberg, 2016a). The shrinking domestic market forced manufacturers to lower costs to remain competitive with international players. Consequently, around 65 solar companies went into bankruptcy in 2016. Employment in operations is also affected by the fact that as of mid-2016, only about a third of the projects awarded feed-in tariff rates had begun to generate electricity (Watanabe and Stapczynski, 2016). IRENA's estimate indicates that solar PV employment in Japan stood at 302,000 in 2016, following a 20% decline from the 2014 peak of 377,000 jobs.

Turkey employed 53,000 people in wind power and 16,600 in solar heating and cooling, and 12,700 in PV. Altogether, the number of people working in renewable energy totals about 94,400 (Erim, 2017). With the help of its local content requirements, the country is hoping to become a solar and wind manufacturing hub. Winners of a December 2016 tender for utility-scale PV projects will be required to build panels in Turkey, and a 50% tariff on panel imports was introduced in July 2016. In the wind sector, generators are awarded preferential feed-in tariff rates that rise with the share of local content (Hirtenstein and Ant, 2016).

24 Under the proposal, the necessary funds would be raised through closing tax loopholes for the fossil fuel industry, a financial-transactions tax, and a variety of other measures.

25 Not including some 7,300 jobs in the waste-to-energy industry.

Solar PV jobs in **Bangladesh** increased by 10% reaching 140,000. Jobs in solar home systems are plateauing with the slowdown in installation. Jobs in mini-grids and solar pumping are picking up as the government shifts its focus towards these applications. Jobs in the biogas sector grew by more than 60% following numerous initiatives to provide rural household biogas digesters across the country.

Malaysia's solar PV industry jumped to 27,900 jobs in 2016 from 19,110 in 2015. While domestic use is small, at 296 MW, Malaysia has become a major solar-cell manufacturing hub for export markets. Foreign companies account for 95% of solar investments in manufacturing (Publicover, 2017). The country's Sustainable Energy Development Authority also estimates that solid biomass and biogas provided about 11,000 jobs, and small hydropower about 4,200 jobs. Further, an IRENA employment factor based calculation estimated almost 52,500 jobs in biodiesel development, for a total of about 95,600 renewable energy jobs.

Thailand now has the fourth-largest solar module production capacity in the world, following China, Japan and Malaysia (IEA-PVPS, 2016a). Counting direct employment only, the Department of Industrial Works reported 2,510 Thai solar jobs for 2015: 696 in manufacturing and assembly and the rest in PV generation plants (IEA-PVPS, 2016b).

The **Republic of Korea** is another important Asian solar PV player. In 2016, there were 8,700 jobs in manufacturing and distribution of solar PV, and another 6,630 for all other forms of renewable energy (Korea Energy Agency, 2017).

Jobs data on **Africa** is scarce. However, IRENA estimates the total for the continent at 62,000, almost half which are in South Africa and one-fourth in North Africa. Several African countries are making important strides in utility-scale renewables while important developments are taking place in the off-grid sector (see Box 4).

BOX 4: DEVELOPMENTS IN SELECTED AFRICAN COUNTRIES

Full-time work opportunities under projects in **South Africa**'s fourth bidding round for all renewables were estimated at 26,246 jobs (Deign, 2016). Developers have responded to local content rules with domestic purchases of non-module items such as inverters, grid connections and civil works (Deign, 2016). A challenge for domestic manufacturers is the lack of sustained demand for their products, as South Africa's bid windows create sporadic spikes in demand (Oirere, 2016).

Algeria installed 14 grid-connected solar PV projects with combined capacity of 286 MW in 2015. These projects resulted in around 3,500 jobs in construction and installation and could create 700 permanent jobs in O&M. The projects were part of the first phase of the country's goal of installing 4.5 GW of renewables by 2020.

Egypt's solar PV sector is also estimated to employ around 3,000 people, with an additional 1,200 jobs in other technologies including wind, small hydropower, CSP and solar heating and cooling.

Kenya's Lake Turkana wind farm, Africa's largest, is expected to be fully operational by July 2017, and has created more than 2,000 local jobs in construction since October 2014 (Cookson, Kuna, and Golla, 2017). Three quarters of the permanent operations staff, or about 150 employees, will come from local communities. Additional job opportunities are also found in Kenya's off grid sector. M-KOPA, a Kenyan solar home system company was employing some 2,500 people in East Africa, including full-time staff and sales agents working on commission (M-KOPA, undated). Kenya's Azuri Technologies, which provides pay-as-you-go solar solutions has created around 450 jobs across different African countries.

Off-grid solar start-ups are also creating jobs in Africa: D.light now employs more than 500 people (Fehrenbacher, 2016). Off Grid Electric is creating almost 600 jobs annually (Off Grid Electric, undated); and a venture with EDF in Cote d'Ivoire could create more than 1,000 jobs (mostly in sales and services) (Off Grid Electric, 2016).

Jobs in Africa are rising with increased efforts to boost electricity access. The Green Climate Fund agreed to serve as anchor investor in a USD 3.5 billion debt fund for decentralised renewables called "Universal Green Energy Access Program" (Brent, 2016). It is intended to enable lending by local banks in Benin, Kenya, Namibia, Nigeria, and the United Republic of Tanzania, to facilitate solar home systems, solar mini-grids, and solar systems for local businesses. As a result, as many as 15,600 permanent and 7,900 temporary jobs will be created in the next 15 years, about half for women (Deutsche Bank, 2016).

Rwanda wants to increase electricity access to more than 70% by 2018; with off-grid connections rising from 2% to 22%. A 3-year programme (Scaling up Off-Grid Energy in Rwanda, or SOGER) was launched in July 2016 with the aim to provide energy access to 77,000 people in rural communities through solar and hydropower mini-grids and solar-powered irrigation. Altogether, it is expected to create 7,000 jobs, especially for women and youth (Energy4Impact, 2016).

THE WAY FORWARD

As the global transition towards sustainable energy continues, renewable energy labour force requirements are set to increase. IRENA's analysis suggests that jobs in the sector could rise from 9.8 million in 2016 to 24 million in 2030, following an accelerated ramp up in deployment in line with global climate imperatives (IRENA, 2017b). Many job opportunities will be created along the different segments of the value chain, with increasing requirements for individuals with diverse skill-sets and talents. Significant efforts in training and education is needed to provide the labour market with the required skills. In this light, IRENA reports on *Leveraging Local Capacity for Onshore Wind* and on *Solar Photovoltaics* analyse the skill requirements along the segments of the value chain. The information on skills, training and education will help decision makers in designing policies to support renewable energy labour markets.

IRENA will continue to provide sound data and analysis on the topic through further editions of the Annual Review and by contributing to the growing knowledge base on the socioeconomic benefits of renewables (Figure 8).

FIGURE 8: **IRENA'S KNOWLEDGE BASE ON RENEWABLE ENERGY EMPLOYMENT**

TABLE 1: **ESTIMATED DIRECT AND INDIRECT JOBS IN RENEWABLE ENERGY WORLDWIDE, BY TECHNOLOGY AND COUNTRY**

	World	China	Brazil	United States	India	Japan	Bang-ladesh	European Union[i]		
								Germany	France	Rest of EU
Solar Photovoltaic	**3,095**	1,962	4	241.9	120.9	302	140	31.6	16	67
Liquid Biofuels	**1,724**	51	783[c]	283.7[f]	35	3		22.8	22	48
Wind Power	**1,155**	509	32.4	102.5	60.5	5	0.33	142.9	22	165
Solar Heating/ Cooling	**828**	690	43.4[d]	13	13.8	0.7		9.9	5.5	20
Solid Biomass[a,g]	**723**	180		79.7[e]	58			45.4	50	238
Biogas	**333**	145		7	85		15	45	4.4	15
Hydropower (Small)[b]	**211**	95	11.5	9.3[l]	12		5	6.7	4	35
Geothermal Energy[a]	**182**			35		2		17.3	37.5	62
CSP	**23**	11		5.2				0.7		3
Total (excluding Large Hydropower)	**8,305**[h]	**3,643**	**876**	**777**	**385**	**313**	**162**	**334**[j]	**162**	**667**[k]
Hydropower (Large)[b]	**1,519**	312	183	28	236	18		6	9	46
Total (including Large Hydropower)	**9,823**	**3,955**	**1,058**	**806**	**621**	**330**	**162**	**340**	**171**	**714**

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 ongoing effort to update and refine available knowledge. Totals may not add up due to rounding.*

a) Power and heat applications (in the case of geothermal energy in the European Union, 110,000 jobs in heat pumps are also included). b) Although 10 MW is often used as a threshold, definitions are inconsistent across countries. c) About 238,300 jobs in sugar-cane processing and 174,600 in ethanol processing in 2015; also includes rough estimate of 200,000 indirect jobs in equipment manufacturing in 2015, and 169,900 jobs in biodiesel in 2016. d) Equipment manufacturing and installation jobs. e) Based on employment factor calculations for biomass power and CHP. f) Includes 222,500 jobs for ethanol and about 61,100 jobs for biodiesel in 2016. g) Traditional biomass is not included. h) The total for 'World' is calculated by adding the individual totals of the technologies, with 4,870 jobs in ocean energy, 16,400 jobs in renewable municipal and industrial waste and 14,500 jobs in miscellaneous. These are not broken down by technology. i) All EU data are from 2015, except for wind energy jobs data for Finland and the Netherlands, which was available for 2016. The two major EU countries are represented individually. j) Includes 7,700 jobs in publicly funded R&D and administration; not broken down by technology. k) Includes 13,550 jobs in renewable municipal and industrial waste and 1,000 jobs in ocean energy. l) Direct jobs only.

REFERENCES

ABIOVE (Brazilian Association of Vegetable Oil Industries) (2017), "Biodiesel: Production and Delivery - December 2016," *www.abiove.com.br/site/index.php?page=statistics&area=MTAtMi0x.*

American Biogas Council. (2016), "Biogas Handout," 31 October, *https://www.americanbiogascouncil.org/pdf/ABC%20Biogas%20101%20Handout%20NEW.pdf.*

APEC (Asia-Pacific Economic Cooperation) (2010), "A Study of Employment Opportunities from Biofuel Production in APEC Economies".

APPA (Asociación de Productores de Energía Renovables) (2016), Estudio del Impacto Macroeconómico de las Energías Renovables en España 2015, Madrid.

AWEA (American Wind Energy Association) (2017), US Wind Industry Annual Market Report Year Ending 2016, Washington, DC.

Biofuels International (2015), "Bioethanol investments in Philippines may double next year," 12 August, *http://biofuels-news.com/display_news/9502/bioethanol_investments_in_philippines_may_double_next_year/.*

Bloomberg (2016a), "Japan's Solar Boom Showing Signs of Deflating as Subsidies Wane," 6 July, *www.bloomberg.com/news/articles/2016-07-06/japan-s-solar-boom-showing-signs-of-deflating-as-subsidies-wane.*

BNEF and BCSE (Business Council for Sustainable Energy) (2017), 2017 Sustainable Energy in America Factbook.

BNEF, CEBC and IRENA (2017), Women in Clean Energy, Middle East and North Africa Survey 2017, www.cleanenergybusinesscouncil.com/wp-content/uploads/2017-05-03-BNEF-CEBC-IRENA-MENA-Women-in-Clean-Energy-Final.pdf

BP (2016), Statistical Review of World Energy, June, London, bp.com/statisticalreview.

Brent, W. (2016), "Climate fund to push decentralised renewables into Africa's mainstream," Thomson Reuters Foundation News, 18 October, *http://news.trust.org/item/20161018065317-ct50s/.*

Bridge to India (2016a), "It's China vs China for Solar Modules Market Share in India," India Solar Weekly, 29 August.

Bridge to India (2016b), "2016 Was a Great Year for the Indian Solar Industry but the Best is Yet to Come," India Solar Weekly, 19 December.

Bridge to India (2017), "India's Solar Market Expected to Grow 90% in 2017," India Solar Weekly, 2 January.

Broehl, J. (2016), "The Global Wind Market: China Versus the World," Renewable Energy World, 6 July, *www.renewableenergyworld.com/articles/2016/07/the-global-wind-market-china-versus-the-world.html.*

BSW-Solar (Bundesverband Solarwirtschaft) (2016), "Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik)," March, *www.solarwirtschaft.de/fileadmin/media/pdf/2016_3_BSW_Solar_Faktenblatt_Photovoltaik.pdf.*

BSW-Solar (2017), "Statistische Zahlen der deutschen Solarstrombranche (Photovoltaik)," February, *www.solarwirtschaft.de/fileadmin/user_upload/bsw_faktenblatt_pv_2017_2.pdf.*

Buckley, T. (2017), China's Global Renewable Energy Expansion, Institute for Energy Economics and Financial Analysis, January.

Cardwell, D. (2017), "Wind Power Surpasses Hydroelectric in a Crucial Measure," New York Times, 9 February.

Cassady, A. (2014), "Complex Market Forces are Challenging Appalachian Coal Mining," Washington, DC, Center for American Progress, 6 October.

CEEW (Council on Energy, Environment and Water) (2017), Communication with experts, March 2017.

Clover, I. (2017), "NEXTracker Expanding Manufacturing Operations in India," PV Magazine, 16 March, *www.pv-magazine.com/2017/03/16/nextracker-expanding-manufacturing-operations-in-india/.*

CNREC (China National Renewable Energy Centre) (2017), Communication with experts, March 2017.

Coal India (2016), Annual Report & Accounts 2015-16, *www.coalindia.in/DesktopModules/DocumentList/documents/Annual_Report_2015-16_of_CIL_Shareholder_version_22082016.pdf.*

Cookson, P., Kuna, J., and Golla, E. (2017), "Benefits of low emission development strategies – The case of Kenya's Lake Turkana Wind Power Project," LEDS in Practice, Low Emission Development Strategies Global Partnership.

Cusick, D. (2016), "Trump Said the US Doesn't Make Windmills. It's Just Not True," ClimateWire, 30 November.

Da Cunha, M.P., Guilhoto, J. J.M., and Da Silva Walter, A.C. (2014), "Socioeconomic and environmental assessment of biodiesel production in Brazil," The 22nd International Input-Output Conference 14 - 18 July, Lisbon, Portugal, *www.iioa.org/conferences/22nd/papers/files/1771_20140512071_Paper_Cunha_Guilhoto_Walter.pdf.*

Deign, J. (2016), "South Africa's module industry grows on local content push," New Energy Update, 2 February 2016, *http://analysis.newenergyupdate.com/pv-insider/south-africas-module-industry-grows-local-content-push.*

Deutsche Bank (2016), "Deutsche Bank submits Sustainable Energy for Africa proposal to Green Climate Fund," 28 September, *www.db.com/newsroom_news/2016/medien/deutsche-bank-submits-sustainable-energy-for-africa-proposal-to-green-climate-fund-en-11700.htm.*

DGRV (Deutscher Genossenschafts- und Raiffeisenverband) (2016), "DGRV annual survey of energy cooperatives: renewed drop in number of new energy cooperatives," 6 July, *www.dgrv.de/en/services/energycooperatives/annualsurveyenergycooperatives.html.*

EIA (US Energy Information Administration) (2017), "US Biodiesel production capacity and production," *www.eia.gov/biofuels/biodiesel/production/table1.pdf.*

Energy4Impact (2016), "Energy 4 Impact unveils new programme to scale up off-grid energy in Rwanda," 23 August, *www.energy4impact.org/news/energy-4-impact-unveils-new-programme-scale-grid-energy-rwanda.*

Epp, B. (2016a), "Big Ups and Downs on Global Market," Solar Thermal World, 26 April, *www.solarthermalworld.org/content/big-ups-and-downs-global-market.*

Epp, B. (2016b), "India: Growing Demand for Vacuum Tube Technology," Solar Thermal World, 16 November, *www.solarthermalworld.org/content/india-growing-demand-vacuum-tube-technology.*

Erim, M.N. (2017), Communication with experts, March 2017.

Euractiv (2017), "Das stürmische Wachstum der Windkraft," 8 February, *www.euractiv.de/section/energie-und-umwelt/news/das-stuermische-wachstum-der-windkraft/.*

Fehrenbacher, K. (2016), "This Startup Has Brought Off-Grid Solar to 65 Million People," Fortune, 21 September, *http://fortune.com/2016/09/21/d-light-funding-solar/.*

FNBC (Federación Nacional de Biocombustibles de Colombia) (n.d.), "Estadisticas," *www.fedebiocombustibles.com, accessed 5 March 2017.*

FRED (Federal Reserve Bank of St. Louis) (2016), "All Employees: Mining and Logging: Coal Mining [CES1021210001]", 12 August, *https://fred.stlouisfed.org/series/CES1021210001.*

Grob, O. (2016), "Die Energiewende 'erfolgreich' versteigern," Klimaretter.info, 13 June, *www.klimaretter.info/energie/hintergrund/21242-die-energiewende-erfolgreich-versteigern.*

Greenpeace International, GWEC (Global Wind Energy Council) and SolarPowerEurope (2015), Energy [R]evolution: A Sustainable World Energy Outlook 2015, Amsterdam and Brussels.

GWEC (Global Wind Energy Council) (2016), Global Wind Energy Outlook 2016, Brussels.

GWEC (2017), Global Wind Statistics 2016, Brussels.

HBS France (Heinrich Böll Stiftung France) (2016), Un Million d'Emplois pour le Climat, Paris.

Hirtenstein, A. and Ant, O. (2016), "Turkey Seeking Renewables Industry With Make-It-Here Rules," Bloomberg News, 21 November, *www.bloomberg.com/news/articles/2016-11-22/turkey-seeking-renewable-energy-industry-with-make-it-here-rules.*

IEA-PVPS (International Energy Agency Photovoltaic Power Systems Programme) (2016a), Trends 2016 in Photovoltaic Applications. Survey Report of Selected IEA Countries between 1992 and 2015, *www.iea-pvps.org/index.php?id=92&eID=dam_frontend_push&docID=3390.*

IEA-PVPS (2016b), National Survey Report of PV Power Applications in Thailand 2015, *www.iea-pvps.org/index.php?id=93&eID=dam_frontend_push&docID=3375.*

IEA SHCP (Solar Heating & Cooling Programme) (2016), Solar Heat Worldwide. Markets and Contribution to the Energy Supply 2014, Gleisdorf, Austria.

IRENA (International Renewable Energy Agency) (2017a), REthinking Energy 2017: Accelerating the global energy transformation, Abu Dhabi.

IRENA (2017b). Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System. *www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf*

Jones, V. (2017), "More Than 440,000 Global Oil, Gas Jobs Lost During Downturn," RigZone, 17 February, *www.rigzone.com/news/oil_gas/a/148548/more_than_440000_global_oil_gas_jobs_lost_during_downturn.*

Khurana, J. (2016), "WTO ruling aside, India's DCR was a badly designed policy tool," PV Tech, 29 February, *www.pv-tech.org/guest-blog/wto-ruling-aside-dcr-was-a-badly-designed-policy-tool.*

Korea Energy Agency (2017), Communication with experts, March 2017.

Mercom Capital Group (2017), "Mercom Exclusive: Can Domestic Manufacturers Capture a Larger Piece of the Growing Indian Solar Market?," *http://mercomcapital.com/can-domestic-manufacturers-capture-a-larger-piece-of-the-growing-indian-solar-market.*

M-KOPA (undated), "Our Impact," *http://solar.m-kopa.com/about/our-impact/.*

Mourant, A. (2016), "Jobs Toll to Worsen Amid UK Renewable Energy Subsidy Cuts," Renewable Energy World, 17 June, *www.renewableenergyworld.com/articles/2016/06/jobs-toll-set-to-worsen-amid-uk-subsidy-cuts.html.*

MTE/RAIS (Ministério do Trabalho Emprego (Ministry of Labour and Employment) / Relação Anual de Informações Sociais (Annual Report of Social Information) [Brazil] (2017), Annual List of Social Information. Database including active and inactive employments for sugarcane cultivation and alcohol manufacture, accessed March 2017.

Myllyvirta, L. (2016), "Factcheck: China is Mining Less Coal, Not More," Greenpeace EnergyDesk, 30 November, energydesk.greenpeace.org/2016/11/30/factcheck-china-mining-less-coal-not/.

Myllyvirta, L. and Mills, J. (2016), "China starts cancelling under-construction coal plants," Greenpeace EnergyDesk, 21 October, *https://energydesk.greenpeace.org/2016/10/21/china-coal-crackdown-cancel-new-power-plants/.*

Navigant Consulting (2017), Economic Development Impacts of Wind Projects: Jobs and Economic Impacts Resulting from US Wind Projects 2017-2020, report prepared for AWEA, March, *https://www.navigant.com/-/media/www/site/insights/energy/2017/economic-development-impacts-of-wind-projects-2017.pdf.*

Off Grid Electric (2016), "Off Grid Electric and EDF team up in offering a new off-grid solar power solution for rural areas in West Africa," 9 November, *http://offgrid-electric.com/blog/2016/11/9/off-grid-electric-and-edf-team-up-in-offering-a-new-off-grid-solar-power-solution-for-rural-areas-in-west-africa.*

Off Grid Electric (undated), "Our Impact," *http://offgrid-electric.com/ourimpact/#impact.*

Oirere, S. (2016), "Challenge of Local Content in Renewable Energy Projects in Africa," Renewable Energy World, 30 August, *www.renewableenergyworld.com/articles/2016/08/challenge-of-local-content-in-renewable-energy-projects-in-africa.html.*

O'Sullivan, M., Edler, D., and Lehr, U. (2016), "Bruttobeschäftigung durch Erneuerbare Energien in Deutschland und verringerte fossile Brennstoffimporte durch Erneuerbare Energien und Energieeffizienz (Berlin: Bundesministerium für Wirtschaft und Energie, September.

Pialot, D. (2017), "Erneuerbare Energien: Offshore-Windkraft im Aufwind," EurActiv, 18 January, www.euractiv.de/section/energie-und-umwelt/news/erneuerbare-energien-offshore-windkraft-im-aufwind/.

Publicover, B. (2017), "Malaysian PV Investment Hits $544 Million in 2016," PV Magazine, 15 March, *www.pv-magazine.com/2017/03/15/malaysian-pv-investment-hits-544-million-in-2016/.*

PWC (PricewaterhouseCoopers) and STA (Solar Trade Association) (2016), Seeing trough the Gloom. UK Solar Seeks Stability after Subsidy Cuts, *www.pwc.co.uk/power-utilities/assets/solar-report-2016.pdf.*

REA (Renewable Energy Association) (2015), REview 2016, Renewable Energy View, 25 May, *www.r-e-a.net/resources/rea-publications.*

Reuters (2016), "China to Close More Than 1,000 Coal Mines in 2016: Energy Bureau," 22 February, *www.reuters.com/article/us-china-energy-coal-idUSKCN0VV0U5.*

Reuters (2017), "China to plow $361 billion into renewable fuel by 2020," 5 January, *www.reuters.com/article/us-china-energy-renewables-idUSKBN14P06P.*

Robert, A. (2017), "France's energy transition could create a million jobs," EurActiv, 13 January, *www.euractiv.com/section/climate-environment/news/frances-energy-transition-could-create-a-million-jobs/.*

RSPO (Roundtable on Sustainable Palm Oil) (2015), "Growth of Certified Palm Oil Smallholders in Thailand Showing No Signs of Slowing Down,"29 September, *www.rspo.org/news-and-events/news/growth-of-certified-palm-oil-smallholders-in-thailand-showing-no-signs-of-slowing-down.*

Saha, D., and Muro, M. (2016), "Rigged: Declining US oil and gas rigs forecast job pain", *www.brookings.edu/blogs/the-avenue/posts/2016/03/16-declining-us-oil-gas-rigs-saha-muro*

SEIA (Solar Energy Industries Association) (2015), "Impacts of Solar Investment Tax Credit Extension," 18 December.

Shearer, C. et al. (2017), Boom and Bust 2017: Tracking the Global Coal Plant Pipeline, CoalSwarm, Greenpeace USA, and Sierra Club, *http://endcoal.org/wp-content/uploads/2017/03/BoomBust2017-English-Final.pdf.*

Sierra Club (2017), "Attention Donald Trump: New Report Shows Clean Energy Employs Far More Workers than Coal, Oil & Gas," press release, 27 March, *http://content.sierraclub.org/press-releases/2017/03/attention-donald-trump-new-report-shows-clean-energy-employs-far-more-workers.*

Solar Foundation (2017), National Solar Jobs Census 2016. Washington, DC, January.

Solarserver (2017), "Another record year for utility-scale solar takes cumulative capacity close to 100 GW," 3 March, *www.solarserver.com/solar-magazine/solar-news/current/2017/kw09/another-record-year-for-utility-scale-solar-takes-cumulative-capacity-close-to-100-gw.html.*

Statista (2017), "Number of employees at Coal India Limited from 2002/2003 to 2016," *www.statista.com/statistics/244518/number-of-employees-at-coal-india-limited/, accessed 6 February.*

Statistik der Kohlenwirtschaft. 2016. Der Kohlenbergbau in der Energiewirtschaft der Bundesrepublik Deutschland im Jahre 2015, Herne and Köln.

Termmahawong, W. (2014), "Oil palm production in Thailand - with a special focus on small scale producers," Japan International Research Center for Agricultural Sciences, 28 June, *www.jircas.affrc.go.jp/program/proD/english/files/2014/07/fanglei/Thai-oil-palm-report-28-06-2014.pdf.*

UKERC (2014), Low carbon jobs: The evidence for net job creation from policy support for energy efficiency and renewable energy

Urbanchuk, J.M. (2017), Contribution of the Ethanol industry to the Economy of the United States in 2016, ABF Economics, Doylestown, PA, 30 January.

USBLS (US Bureau of Labor Statistics) (2017), "Current Employment Statistics - CES (National)," *www.bls.gov/ces/, accessed 6 April.*

USBLS (US Bureau of Labor Statistics) (2015), "Employment Projections — 2014-24," news release, 8 December, *www.bls.gov/news.release/pdf/ecopro.pdf.*

USDA-FAS (US Department of Agriculture, Foreign Agricultural Service) (2016a), "Indonesia Biofuels Annual Report 2016", 28 July 2016. Available at: *https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Jakarta_Indonesia_7-28-2016.pdf.*

USDA-FAS (2016b), "Brazil Biofuels Annual", 12 August 2016. Available at: *https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Sao%20Paulo%20ATO_Brazil_8-12-2016.pdf.*

USDA-FAS (2016c), "Colombia Biofuels Annual Report 2016," 12 August 2016. Available at: *https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Bogota_Colombia_8-12-2016.pdf.*

USDOE (US Department of Energy). (2017), US Energy and Employment Report, Washington, DC, January. *www.energy.gov/sites/prod/files/2016/03/f30/US%20Energy%20and%20Employment%20Report.pdf.*

USDOE. (2016), Hydropower Vision: A New Chapter for America's 1st Renewable Electricity Source, Executive Summary, Washington, DC, July, *https://energy.gov/sites/prod/files/2016/07/f33/Hydropower-Vision-Executive-Summary.pdf.*

Watanabe C. and Stapczynski, S. (2016), "Japan's Solar Boom Showing Signs of Deflating as Subsidies Wane," Bloomberg News, 6 July.

Wind Europe (2017a), Wind in Power: 2016 European Statistics, Brussels, *https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Statistics-2016.pdf.*

Wind Europe (2017b), The European Offshore Wind Industry: Key Trends and Statistics 2016, Brussels, *https://windeurope.org/wp-content/uploads/files/about-wind/statistics/WindEurope-Annual-Offshore-Statistics-2016.pdf.*

WWF (2012), Profitability and Sustainability in Palm Oil Production, *http://awsassets.panda.org/downloads/profitability_and_sustainability_in_palm_oil_production__update_.pdf.*

Yan, S. 2016. "China Plans to Cut 1.8 Million Coal and Steel Jobs," CNN Money, 29 February, Available at: *http://money.cnn.com/2016/02/29/news/economy/china-steel-coal-jobs/.*

Photo credits

page 02 Solar power station in Thailand

page 04 Wind farm, United Kingdom

page 08 Solar equipment production, Tangshan, China © Yuangeng Zhang

page 13 Ethanol manufacturing Plant, Minas Gerais, Brazil © T photography

page 16 © Suzlon, India

page 19 Lake Turkana Wind Power - Kenya G.Goodwin/M-KOPASolar

All other photos are from www.shutterstock.com or istock.com

IRENA
International Renewable Energy Agency

ISBN: 978-92-9260-027-3 (PDF)

Citation: IRENA (2017), Renewable Energy and Jobs - Annual Review 2017, International Renewable Energy Agency, Abu Dhabi.

ABOUT IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. 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.
www.irena.org

ACKNOWLEDGEMENTS

Authors: Rabia Ferroukhi, Arslan Khalid, Celia García-Baños (IRENA), and Michael Renner (Worldwatch Institute)

Contributors: Ulrike Lehr and Helena Walter (GWS)

Reviewers: Álvaro López-Peña, Bishal Parajuli, Divyam Nagpal, Verena Ommer, Neil MacDonald and Paul Komor (IRENA)

For further information: publications@irena.org

This report is available for download from www.irena.org/publications

DISCLAIMER

IRENA Headquarters

Masdar City
P.O. Box 236, Abu Dhabi
United Arab Emirates

www.irena.org