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Annual Review 2023

10th EDITION

In Collaboration with

International Labour Organization

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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.

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ABOUT ILO

The International Labour Organization is the United Nations agency for the world of work. We bring together governments, employers and workers to drive a human-centred approach to the future of work through employment creation, rights at work, social protection and social dialogue.

www.ilo.org

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DISCLAIMER

FOREWORD

We are pleased to present this edition of IRENA's *Renewable energy and jobs: Annual review*, the tenth in the series and the third produced in collaboration with the International Labour Organization (ILO). The report embodies the intersection of our agencies' respective mandates - namely the energy transition and decent work for social justice - and discusses key opportunities and challenges for workers, employers, communities and public policy makers.

This year's report finds that renewable energy employment worldwide has continued to expand - to an estimated 13.7 million direct and indirect jobs in 2022. We can expect the creation of many millions of additional jobs in the coming years and decades, provided that education and skills development programmes are appropriately expanded, workforce development programmes are put in place, and labour markets respond to evolving needs.

Nevertheless, challenges abound. Today's renewable energy jobs are concentrated in a relatively small number of countries, reflecting the uneven geographic footprint of equipment manufacturing and capacity installations. The detail and quality of available data varies among countries and between the different renewable energy technologies, and information on job quality and workforce diversity remains sparse. Yet, with each edition of this series, we shed more light on these aspects.

Renewable energy and other energy transition technologies are attracting growing investment; but even as spending rises and installations expand, new challenges emerge. Climate change, technological advances, shifts in demographics and the global economic outlook, as well as other key developments may bring about adverse effects for employment. While each country rightfully aspires to derive socio-economic benefits from the energy transition, global solidarity is vital, as humanity confronts not only rising dangers from climate change but also deep social and economic divides.

The energy transition requires urgent collective action to reduce reliance on fossil fuels and towards clean energy; but it also must ensure that all persons have access to basic human needs and security of modern energy. We call upon policy makers to ensure that the uncertainties and disruptions inherent in the transition are minimised, and that efforts are made to close social protection gaps in the transformation process.

This year, in June, the International Labour Conference reaffirmed the urgency of action to advance a just transition to achieve social justice, decent work and poverty eradication, and to tackle environmental and climate change. During discussions, representatives of governments, workers and employers endorsed the 2015 Guidelines for a Just Transition as the central reference for policy making and basis for action.

It is critical that new jobs provide adequate wages and high standards of occupational safety and health. Fundamental principles and rights at work must be upheld and workers' voices heard. It is essential that communities whose livelihoods now depend on fossil fuels be offered a stake in the new energy system through retraining and economic revitalisation strategies, wherever feasible. It is also vital that women have equal access to training and career paths in an industry that historically has been heavily male-dominated; that jobs be created for youth in the renewable energy sector; and that ethnic minorities and other vulnerable communities be welcomed into a workforce that reflects the diverse spectrum of modern societies.

This will not only enable the renewable energy industry to tap a much wider pool of human talent, thus minimising or avoiding future skill gaps; it will also advance the goal of creating a more fair, equitable and truly sustainable world. There is much to do, but we are enthusiastic and confident that we can achieve these aspirations.

Francesco La Camera

Director-General

International Renewable Energy Agency

Gilbert F. Houngbo

Director-General

International Labour Organization

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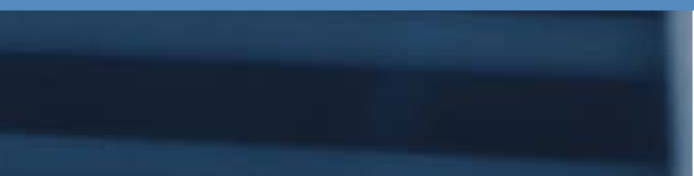
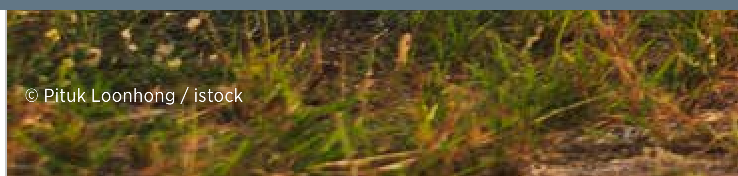
TABLE OF CONTENTS



Figures

Tables

Boxes



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Abbreviations

ALMM Approved List of Models and Manufacturers [India]

APPA Asociación de Productores de Energía Renovables [Spain]

BCD basic customs duty [India]

BUSA Business Unity South Africa

CCS carbon capture and storage

CDI Confederation of Danish Industry

CRES China Renewable Energy Society

DOE US Department of Energy

EU European Union

EU-27 27 Member States of the European Union

FTE full-time equivalent

GDP gross domestic product

GMG Green Mini-Grid Facility Programme [Kenya]

GW gigawatt

GW_{th} gigawatt thermal

GWEC Global Wind Energy Council

ILO International Labour Organization

IRA Inflation Reduction Act [United States]

IREC Interstate Renewable Energy Council [United States]

ITJ Instituto para la Transición Justa [Spain]

JET IP Just Energy Transition Investment Plan

kW kilowatt

MW megawatt

O&M operations and maintenance

PLI production-linked incentive [India]

PV photovoltaic

SAREM South African Renewable Energy Masterplan

SDG Sustainable Development Goal

STEM science, technology, engineering and mathematics

USDA-FAS US Department of Agriculture Foreign Agricultural Service

MESSAGE FROM THE DIRECTOR OF THE KNOWLEDGE, POLICY AND FINANCE CENTRE

This edition of *Renewable Energy and Jobs* marks the 10th anniversary of the series. It is also the final one produced under my guidance, with a dedicated and talented team. The idea for this series dates back to the early years of IRENA. From the very beginning, we insisted that the energy transition is a complex undertaking that needs to be approached not only from a technological angle, but from a holistic perspective that examines the socioeconomic dimension and analyses the array of policies needed for generating value along the supply chain and creating a skilled workforce.

When the agency was founded in 2009, information on the employment impacts of renewable energy was extremely scarce and mostly of an anecdotal nature. The jobs dimension was hardly in the public eye. Accordingly, the initial editions of our report were focused on identifying and marshaling existing data sources and supplementing them with our own calculations and estimates. Over time, we were able to close many gaps, and provide greater breadth and depth of coverage. We are proud that our work has brought greater visibility to this dimension of the energy transition – and stirred growing interest, which has led to more and better data becoming available.

Exciting work remains to be done. Over the years our focus has broadened to encompass qualitative employment aspects, workforce diversity, and the requirements of a just transition. The jobs review series is now part of a staple of IRENA reports on the socioeconomics of renewables and the energy transition. They include analyses of the gender perspective and assessments of opportunities for countries to leverage and enhance their local capacities. And in addition to our work on current renewable energy jobs, our socioeconomic modeling of energy transition pathways to 2030 and 2050 sketches how employment could expand in the future, with the right level of policy ambition in place.

I forge ahead in my career with the firm belief that IRENA has significantly broadened the horizon of many in the energy world. As I bid farewell to the Agency, I am confident that both my current team and those joining in the future will persistently prioritise placing people at the heart of the ongoing energy transition - and that the world will follow suit.

Rabia Ferroukhi

Director

Knowledge Policy and Finance Centre

10th EDITION

ABOUT THE IRENA RENEWABLE ENERGY AND JOBS SERIES

Renewable energy development not only changes the mix of energy sources powering the world's economies, but also creates jobs, builds economic value and enhances human wellbeing. The IRENA *Renewable energy and jobs* series quantifies current employment in the sector, examining different renewable energy technologies worldwide and in selected individual countries. The analysis considers a variety of public and private sector policy contexts, including those related to deployment, industrial policy, skill building, labour market measures and others. While available qualitative information about renewable energy jobs, such as education, skill requirements or workforce attributes, remains limited, the series asserts that decent jobs are a must for the energy transition.

This is the tenth edition of the series, and the third produced in collaboration with the International Labour Organization. Following an initial standalone report in 2013, IRENA launched this series to provide regular updates to its assessment of renewable energy employment worldwide. Each edition discusses the latest available data and highlights specific aspects, such as employment in the energy access context, the gender equity dimension or the requirements of a just transition.

The series is part of IRENA's extensive analytical work, ongoing since 2011, on the socioeconomic impacts of a renewables-based energy transition, including employment creation; leveraging of domestic capacities along the renewable energy value chain; women's participation in the renewable energy sector within the context of creating a diverse workforce; education and training opportunities; and the modelling of energy transition pathways to 2050 with regard to jobs, gross domestic product and a broad measure of welfare. This work is highlighted on the back cover of this report.

Annual reviews of employment in renewables

These publications and IRENA's comprehensive research on socio-economic impacts – all of which is showcased on the back cover – can be accessed by visiting www.irena.org/Publications.

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KEY NUMBERS

13.7 million

Global renewable energy jobs in 2022, up from 12.7 million in 2021. Close to two-thirds of all jobs are in Asia, where China alone accounts for 41% of the global total.

4.9 million

Solar photovoltaic (PV) jobs in 2022; among renewable energy technologies, solar PV is the fastest-growing sector, accounting for more than one-third of the total renewable energy workforce. Women hold 40% of these jobs.

2.5 million

Direct jobs in hydropower in 2022, 2.3% more than in 2021. Operation and maintenance represent almost two-thirds of the direct jobs, 30% of the jobs are related to construction and installation, and about 6% are in component manufacturing.

2.5 million

Jobs in biofuels in 2022, mostly in the agricultural supply chain.

1.4 million

Wind power jobs in 2022. China and Europe lead, although the geography of component production is becoming increasingly diverse.

International Renewable Energy Agency

KEY MESSAGES

› DECENTRALISED RENEWABLES: Decentralised solutions provide reliable power and employment in remote areas. Small-scale hydropower, for instance, requires anywhere from 17 000 person-days (for a pico plant, which averages 5 kilowatts [kW]), to about 64 000 person-days (for a 50 kW micro plant), to over 160 000 person-days (for a 500 kW mini plant) for initial planning and equipment procurement and manufacturing, installation, connection, ongoing operation and maintenance, all the way to eventual decommissioning.

› MILLIONS OF ADDITIONAL JOBS: Employment can be expanded substantially in coming years and decades with a comprehensive and ambitious policy mix.

› INDUSTRIAL POLICY: Vulnerability to global supply chain disruptions, along with geopolitical rivalries, is driving a new interest in industrial policy measures to build and strengthen local capacities and secure related job creation benefits.

› WORKFORCE DEVELOPMENT AND DIVERSITY: Education and training must be expanded to prevent the widening of skill gaps. They must be paired with efforts to tap talent among under-represented groups, including women, youth and minorities.

› A JUST TRANSITION: Labour rights and social dialogue are indispensable for an energy transition that produces just outcomes and secures workers' prospects.

› SYSTEMIC CHANGE: Achieving the energy transition in a manner consistent with climate stability requires much faster renewables deployment, in turn creating more jobs. It also demands broader, systemic change – moving beyond the pursuit of endless economic growth incompatible with planetary limits.

RENEWABLE ENERGY JOBS

Introduction

This tenth edition of *Renewable energy and jobs: Annual review* offers the latest set of global renewable energy employment estimates, which are based on IRENA's own methodologies and calculations, as well as a large array of reports published by government agencies, industry associations, non-governmental organisations and academic experts.

The report examines the renewable energy employment landscape as of 2022 globally as well as for selected countries. Against the backdrop of investment and deployment trends and a variety of policy contexts, it discusses job numbers as well as job quality and workforce diversity in the core segments of the renewable energy supply chain.

The key finding of this edition is that the global renewable energy sector employed 13.7 million people directly[1] as well as indirectly[2] in 2022.[3] The number has been growing over the past decade, from 7.3 million in 2012 (see Figure 1), thanks mainly to solar photovoltaic (PV), bioenergy, hydropower and wind power.[4] The socio-economic modelling undertaken for IRENA's *World Energy Transitions Outlook* series indicates that the large-scale investment required to put the world on a climate-safe pathway would create many millions of additional jobs in the next decades.

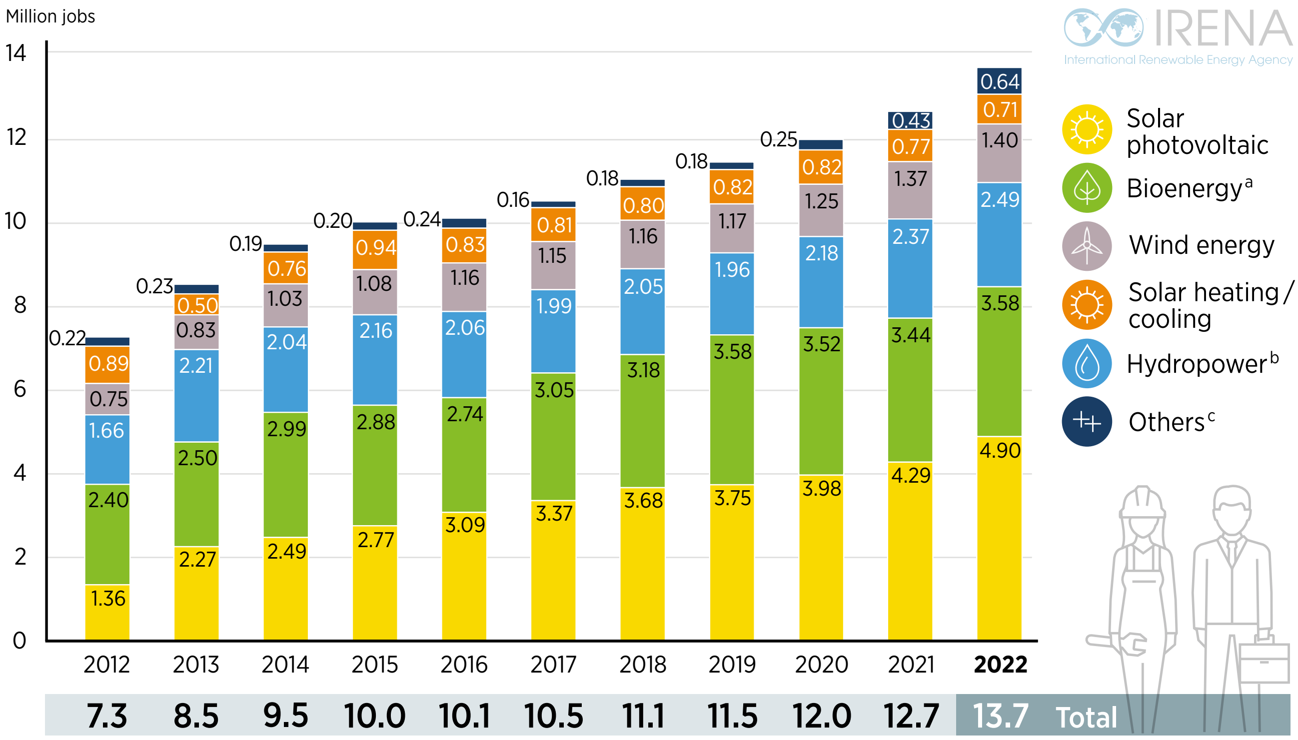
[1] *Direct employment refers to employment generated directly by core activities, without taking into account the intermediate inputs necessary to manufacture renewable energy equipment, or construct and operate facilities. These directly involved industries are also called renewable energy industries (sectors).*

[2] *Indirect employment includes employment in the upstream industries that supply and support the core activities of renewable energy deployment. Workers in such positions may produce steel, plastics or other materials, or provide financial and other services. These industries are not directly involved in renewable energy activities but produce intermediate inputs along the value chain of each renewable energy technology.*

[3] *Data are principally for 2022, with some data for 2021 and some instances where only information from earlier years is available. The data for hydropower include direct employment only, whereas data for other technologies include both direct and indirect employment wherever possible.*

[4] *The jobs numbers shown in Figure 1 for the period 2012-2021 reflect the figures reported in earlier editions of this series. IRENA does not revise previous years' estimates in light of information that may later become available.*

Figure 1 Evolution of global renewable energy employment by technology, 2012-2022



a Includes liquid biofuels, solid biomass and biogas.

b Direct jobs only.

c "Others" includes geothermal energy, concentrated solar power, heat pumps (ground based), municipal and industrial waste, and ocean energy.

The continued development of renewable energy – and thus employment in the sector – is influenced by a multitude of factors: notably, cost-competitiveness vis-à-vis other energy technologies; the ebb and flow of investments; the resulting size of national and regional markets; the availability of required inputs (components and raw materials) and the existence of a skilled workforce. These are shaped by corporate strategies and an array of public policy measures (incentives and regulations) intended to facilitate the scale-up of deployment, build viable supply chains and train workers. Policy changes could trigger a surge in activity or could lead to decisions to defer investments, in turn causing employment to fluctuate.

Following largely stagnant spending levels in the years between 2015 and 2020, annual renewable energy investments (including private capital and public spending) rose from USD 348 billion in 2020 to USD 499 billion in 2022 – a gain of 43%. The bulk of funds went to the solar and wind industries, whose combined share of overall renewable energy investments rose from 82% in 2013 to a stunning 97% in 2022. The majority of funds are directed to the power sector, with end-use sectors accounting for only 10% (IRENA, 2023a). It is little surprise, then, that solar PV and wind power have been the most dynamic renewable energy technologies, showing strong growth in both capacity and jobs.

Where jobs are created depends on the geographic footprint of equipment manufacturing and capacity installations, as well as the inputs of raw materials, semi-manufactured components and services along the value chain. Labour requirements depend on the scale of projects. Labour intensity tends to decline as technologies mature, learning curves are mastered, automation rises, and the use of new technologies like artificial intelligence (AI) advances.

Worldwide, some 295 gigawatts (GW) of renewable electricity were installed in 2022, with cumulative capacity reaching 3 372 GW. Renewable hydro remains the largest contributor with 1256 GW, although only 20 GW were added in 2022. Solar PV and wind added 191.5 GW and 74.7 GW, respectively, with cumulative total installed capacities of 1047 GW and 899 GW. Cumulative bioenergy power capacity is at 149 GW, with about 7.6 GW added in 2022 (IRENA, 2023b).

The cumulative solar thermal capacity at the end of 2022 was 542 gigawatts thermal (GW_{th}), corresponding to 774 million square metres of collector area. The net increase of 19 GW_{th} (27 million square metres) was a smaller addition than in the previous year; stronger contributions from European markets could not counteract a decline in the Chinese and Indian markets (Weiss and Spörk-Dür, 2023). Global liquid biofuel production appeared to be up slightly in 2022, at 6%, compared with 162 billion litres in 2021 (REN21, 2023).

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Half of the world's new wind power capacity and 45% of solar PV capacity were installed in China (IRENA, 2023b). China was followed by the United States, Brazil, the United Kingdom, Germany, Sweden and France in wind capacity installation, and the United States, India, Brazil, the Netherlands and Germany in solar PV capacity installation (IRENA, 2023b).

Annual capacity deployment does not necessarily correlate closely with equipment manufacturing or shipments. Employment dynamics in these different value chain segments can thus diverge substantially. For example, there were far more PV module shipments globally in 2022, 272 GW, than reported installations (Wood Mackenzie, 2023a). As of mid-2023, European PV panel inventories amounted to about 40 GW of capacity, roughly equal to the amount newly installed in Europe in 2022. This could rise to 100 GW by year end, given labour shortages and other installation bottlenecks (Rystad Energy, 2023).

This report is organised as follows: **Section 1** presents employment trends by major technology. **Section 2** discusses job findings in several leading countries and for several additional countries in different regions of the world. **Section 3** highlights the changing policy landscape regarding equipment manufacturing, which over time will affect the geography of job creation in renewable energy. **Section 4** revisits a topic that has been explored by previous editions of this report: the need for a just transition, with a focus on the perspectives and actions of governments, businesses and labour unions. **Section 5** emphasises that a faster energy transition will lead to greater job creation, but underscores the need for new thinking against the backdrop of multiplying global challenges.

CHAPTER 1

RENEWABLE ENERGY EMPLOYMENT **BY TECHNOLOGY**

This section presents employment estimates for solar photovoltaic (PV), wind, hydropower and liquid biofuels. Other renewable energy technologies, included in Figure 2 employ fewer people, and the information available on them is typically less detailed. For any given technology, equipment manufacturing, construction and installation, and operation and maintenance (O&M) are the main value chain segments, besides a range of support services.

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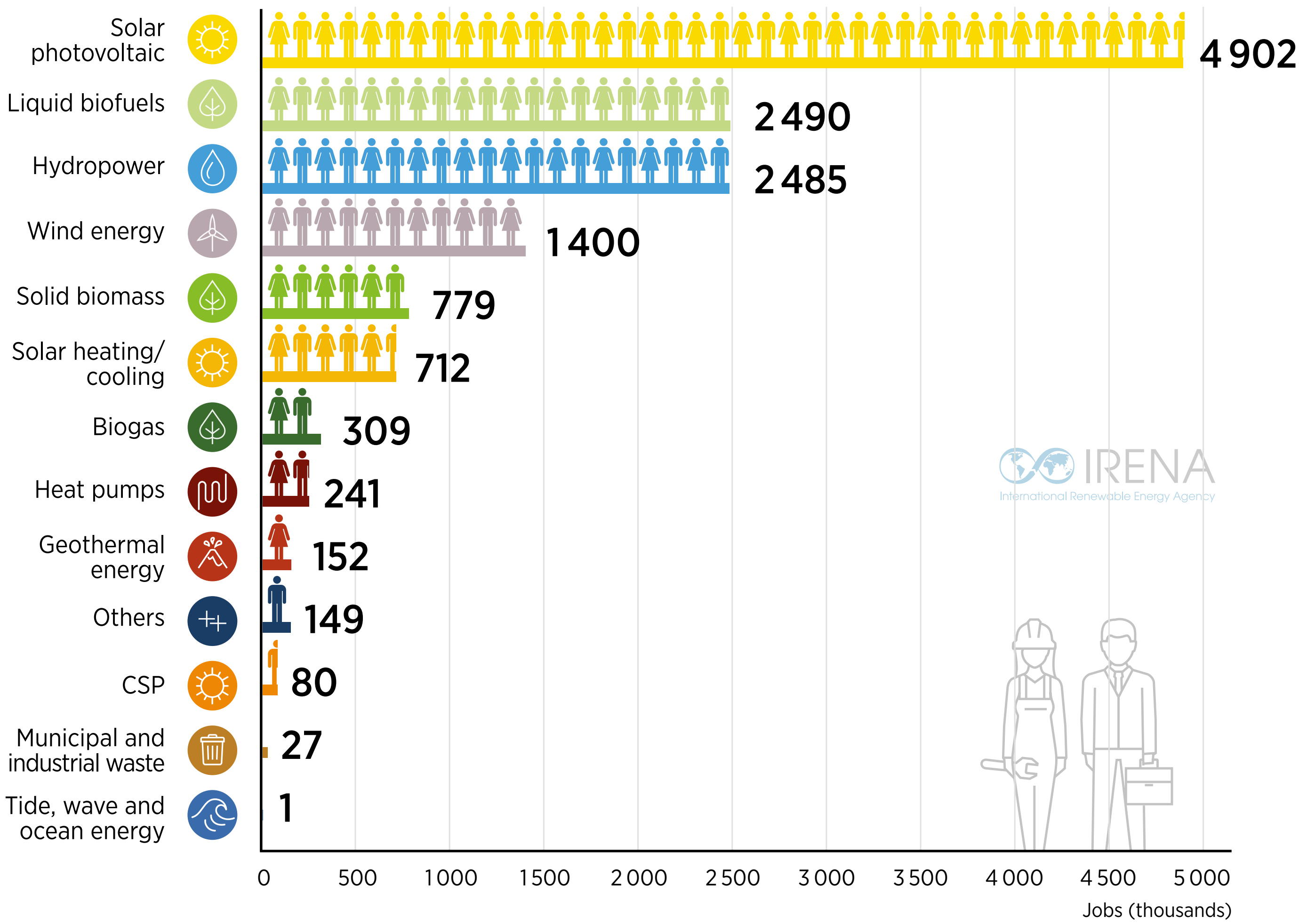
Figure 2 Global renewable energy employment, by technology, 2022



Note: CSP = concentrated solar power; "Others" include jobs not broken down by individual renewable energy technologies.

1.1 SOLAR PHOTOVOLTAIC

4.9
million jobs

Yet another record was set in 2022 – with the addition of 191.4 GW of solar PV capacity worldwide, up from 141.2 GW in 2021. **China** accounted for 45% of these installations, or 86 GW, and was followed by the United States, India and Brazil. The Netherlands, Germany, Japan, Spain, Australia and the Republic of Korea rounded out the top ten (IRENA, 2023b).

China is home to the vast majority of global solar PV manufacturing, supported by comprehensive industrial policies. The country retains a commanding position across the supply chain, from ingots and wafers to cells and modules. Southeast Asia has become an important, but much smaller, production and export hub, whereas the rest of the world has a marginal share in the supply chain.

Europe's PV imports surged during the first half of 2022 due to the Ukraine crisis and subsequent efforts to reduce reliance on oil and gas imports. However, installation rates trailed due to shortages of inverters and skilled labour, which subsequently slowed imports during the second half of the year. India's module imports declined significantly after the first quarter of 2022 once its basic customs duty took effect. In Brazil, a rush of installations was triggered by an impending law imposing a grid fee on small-scale distributed projects (Chen, 2023).

According to the United States (US) Department of Energy (US DOE, 2022), 1 GW of production capacity (for crystalline silicon [c-Si] modules, which account for about 90% of all manufactured modules) could generate anywhere from 1085 jobs to 2020 direct jobs across the full value chain.

IRENA estimates global solar PV employment at 4.9 million in 2022, up from about 4.3 million in 2021. Of the ten leading countries shown in Figure 3, four are in **Asia**, two are in **the Americas** and three are in **Europe**. Together, the top ten accounted for almost 4.1 million jobs, or 85% of the global total. **Asian** countries host 73% of the world's PV jobs, reflecting the region's continued dominance of manufacturing and strong presence in installations. The remaining jobs were in **the Americas** (11.5% of all jobs), **Europe** (11%; with European Union [EU] member states accounting for 10.6%) and the rest of the world (4.8%).

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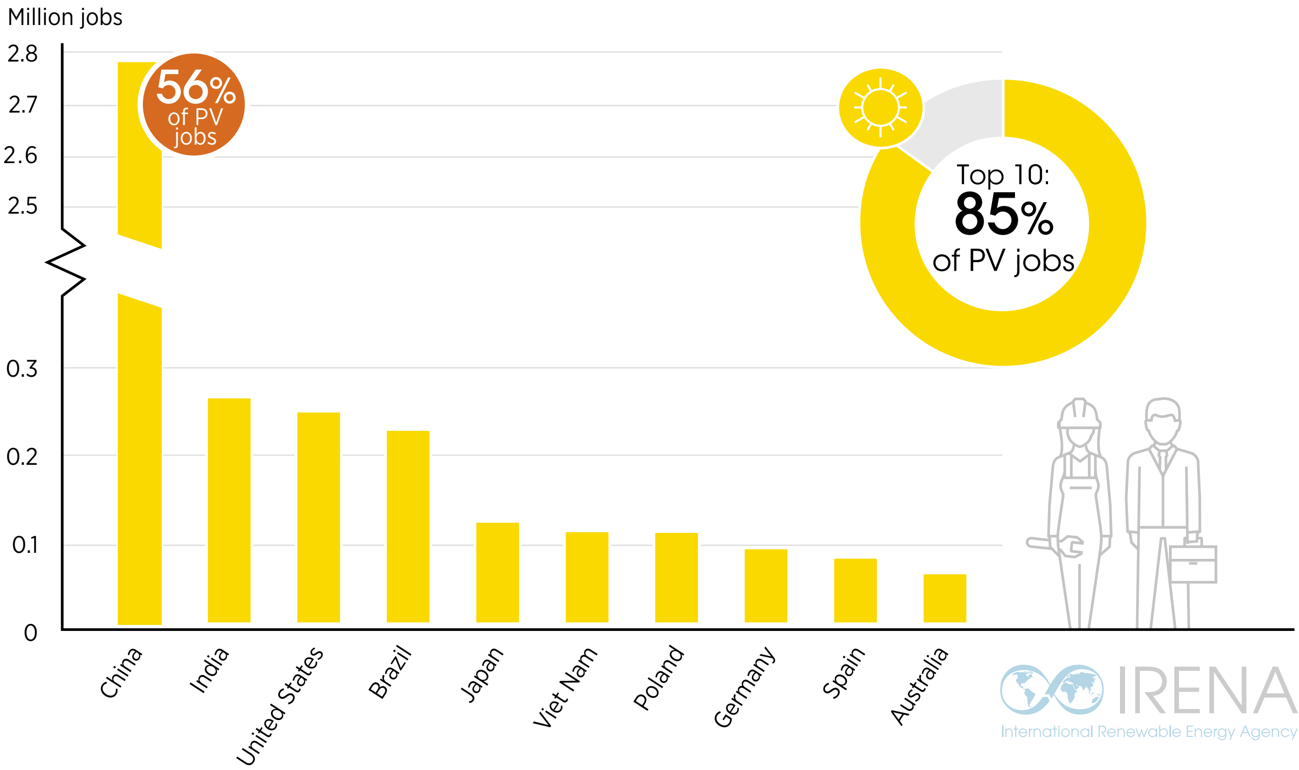
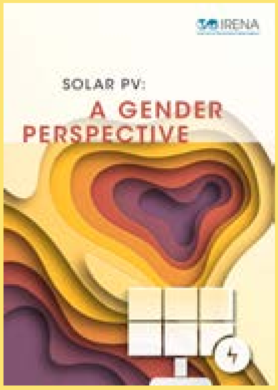
Figure 3 Solar photovoltaic employment in 2022: Top ten countries



China accounted for about 56% of PV employment worldwide, or some 2.76 million jobs. Employment in PV in the **United States** reached 264 000 jobs in 2022. PV employment in **Europe** was estimated at 540 000 in 2022 of which 517 000 jobs were in EU Member States. **India's** total solar jobs are estimated to be at 281 400. On-grid solar is estimated to have generated 201 400 jobs, with another 80 600 in off-grid settings. Increasing solar PV installations in **Brazil** boosted employment in this industry to 241 000 jobs. **Japan** added less capacity in 2021 than the previous year. IRENA estimates its workforce at 127 000.

Women's representation is higher in the workforce for solar PV than for other renewable energy technologies (see Box 1).

Box 1
Solar PV: A gender perspective



IRENA's socio-economic work seeks to close the information gap regarding gender in the renewable energy industry. In the most recent report in the series *A Gender Perspective*, IRENA assessed the challenges faced by women working in the solar photovoltaic (PV) sector. The assessment considered both modern markets and energy access scenarios. The study, the third in the series, obtained primary data from individuals and organisations in the solar PV sector by means of a global online survey (IRENA, 2022a).

The analysis showed that women represent 40% of the full-time positions in the solar PV sector, almost twice as much as in the wind or the oil and gas sectors (21% and 22%, respectively). The solar PV sector exceeds women's average 32% share across the broader renewable energy sector but falls somewhat short of the share of women employed in the overall economy (see Figure 4).

Women's representation across solar PV job roles is uneven. They are most frequently hired for administrative positions, where their share reaches 58%. Meanwhile, women represented comparatively small shares, 32% of STEM (science, technology, engineering and mathematics) positions and 35% of non-STEM technical positions (such as lawyers or procurement experts). Further, women hold 38% of other non-technical positions (*e.g.* marketing, sales, distribution, product assembly or installation). The better performance in this category is largely due to off-grid solar, which has multiple positions and initiatives targeting women. This may also influence leadership composition, with women accounting for 30% of managerial jobs. However, women represent 17% of the total senior management roles in the solar PV industry.

Effective actions are needed to ease women's entry into the industry and improve their career prospects and progression. Creating gender awareness is essential to fully understand the complexity of the barriers faced by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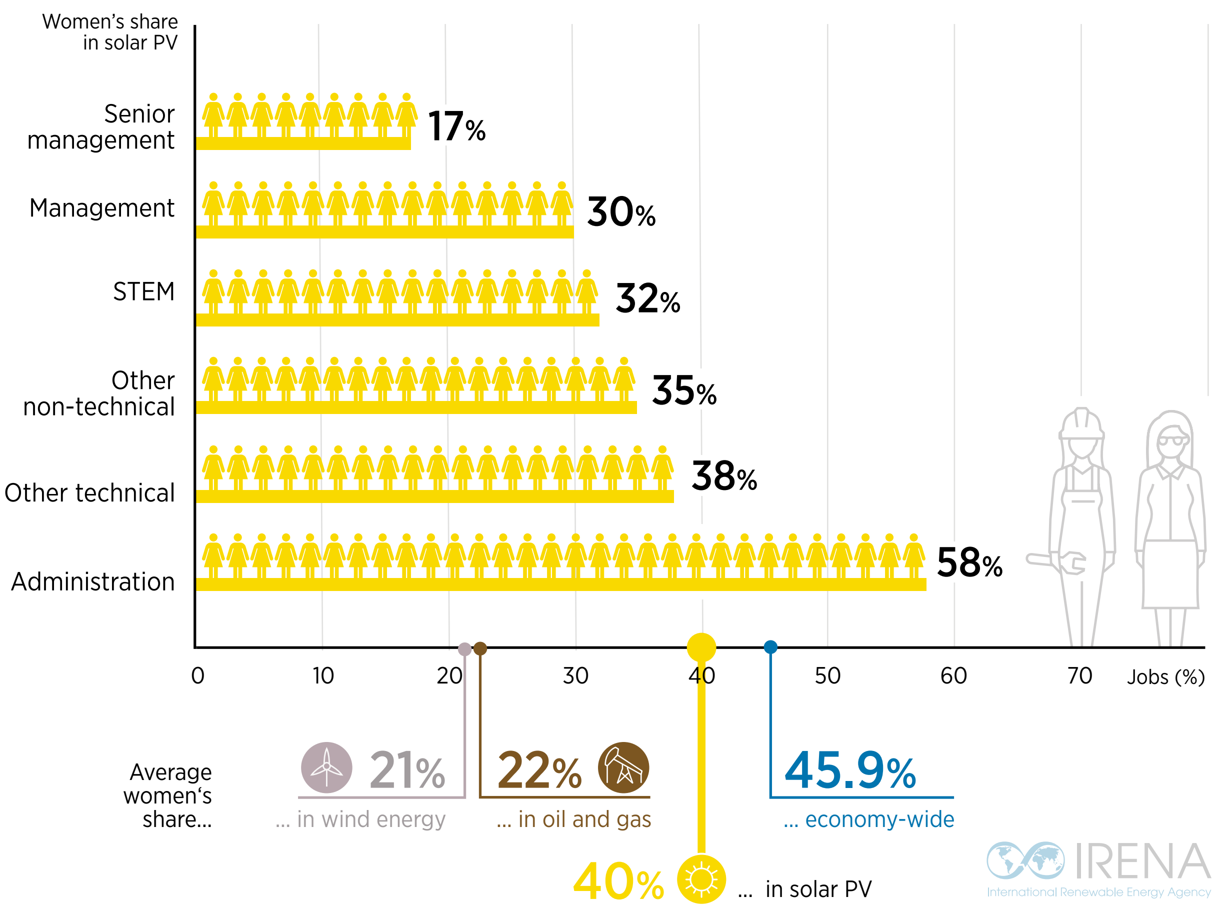
women. Further, national policies are needed to create safer spaces and better workplace practices, policies and regulations. Also, women need networks and systems to support training and mentorship to enable full utilisation of their talents.

IRENA will continue to work for reducing barriers, fostering inclusivity and empowering women to actively participate and excel in the sector. Furthermore, IRENA is fully committed to mainstreaming gender considerations, integrating gender equality and equity into its policies, programmes and initiatives. Prioritising gender equality and promoting diversity in the renewable energy sector fosters a more equitable and sustainable future for all.

Figure 4 Women in the solar photovoltaic sector compared with other sectors



Source: IRENA, 2022a.
Note: PV = photovoltaic; STEM = science, technology, engineering and mathematics.

1.2 WIND

1.4
million jobs

In 2022, the wind energy sector installed 74.6 GW of capacity, 19% below the previous year's and 33% slower than the record pace in 2020. Except for Sweden and France, new capacity additions in all leading countries were below that in the peak year. China retained the lead with close to half of global additions, far ahead of the United States, Brazil, the United Kingdom, Sweden, Türkiye, Germany, India, France and Spain (IRENA, 2023b).

Global employment in onshore and offshore wind remained steady at 1.4 million jobs in 2022. Wind employment was concentrated in a relatively small number of countries. **China** alone accounted for 48% of the global total, followed by **Asia** (representing 55%), **Europe** (representing 29%), **the Americas** (representing 16%) and **Africa** and **Oceania** (representing 0.7%). The top ten countries shown in Figure 5 together employed 1.23 million people. Four of these are in Europe, four in Asia and two in the Americas. The recent phenomenon of rising costs of inputs has led original equipment manufacturers to reinforce efforts to outsource some component production to low-wage countries. This will contribute to changing the industry's geographic make-up.

On average, installation of 1 GW of onshore wind capacity could create 130 000 jobs in development, construction and installation over a five-year period and 12 000 jobs annually during the 25-year O&M phase (GWEC, 2022). Meanwhile, the greater complexity of components like foundations, substations, cables and installation vessels creates higher labour requirements for offshore wind farms than onshore installations.


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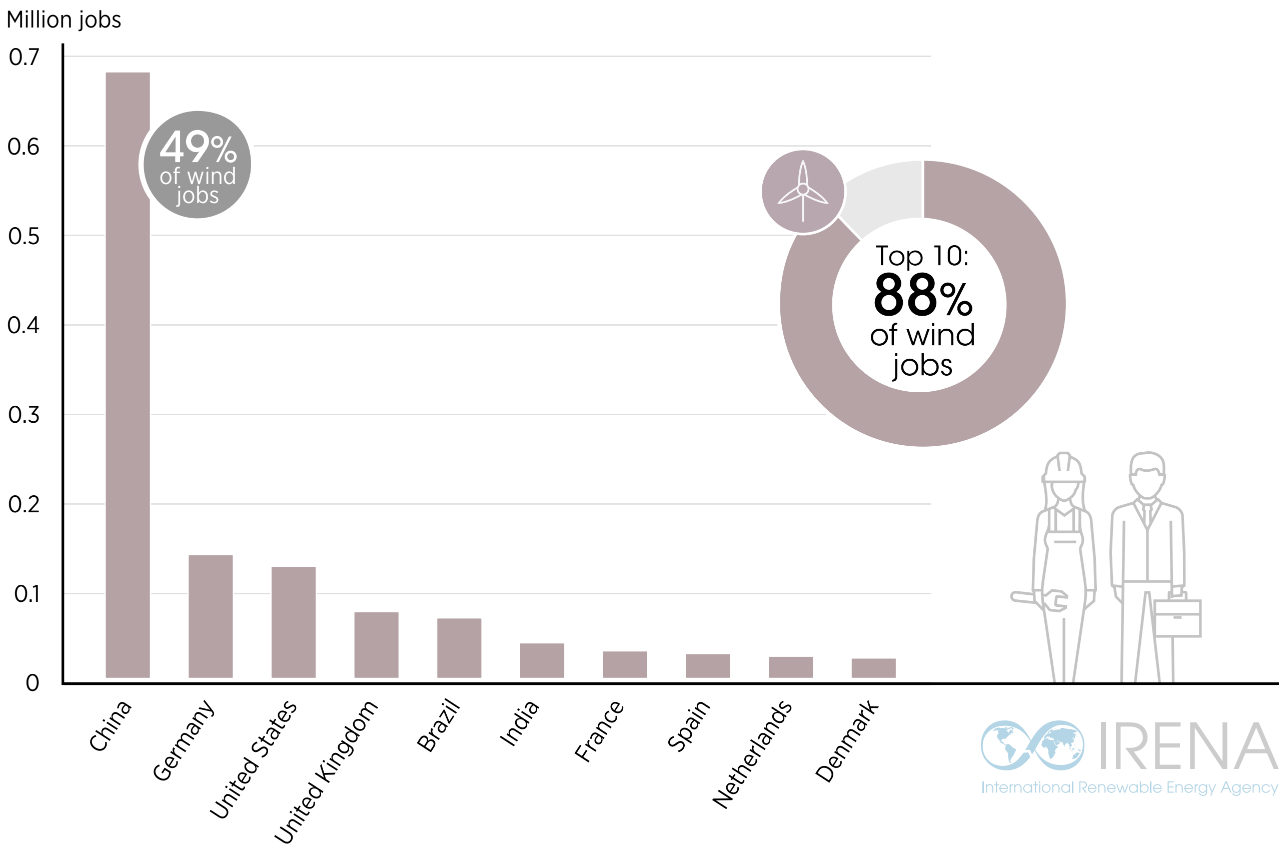
Figure 5 Wind employment in 2022: Top ten countries



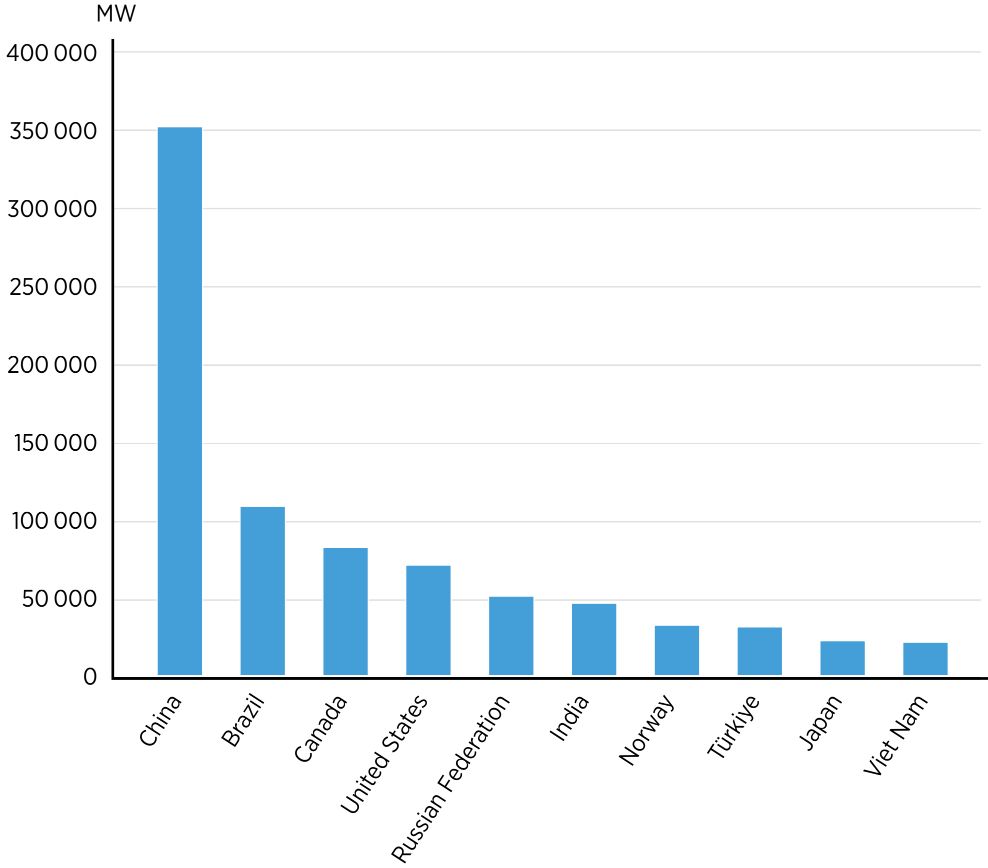
1.3 HYDROPOWER

2.5
million jobs

Hydropower remains at the forefront of the renewable energy landscape, boasting a global capacity surpassing 1255 GW as of 2022. This figure translates to an impressive 37% of the global total renewable energy capacity. Total installed hydropower capacity exceeds that of wind and solar PV, although annual additions are much smaller now – some 20.5 GW in 2022. As shown in Figure 6, China, Brazil, Canada and the United States are among the key actors in this sector (IRENA, 2023b).

To assess job numbers in hydropower, IRENA uses an employment-factor approach coupled with national-level data for select countries. Considering data revisions since the previous edition of the Annual Review, the latest report estimates that about 2.49 million individuals were directly employed in the sector in 2022, 2.3% more than in the previous year. Consistent with earlier findings, O&M represent two-thirds of the direct jobs, 30% of the jobs are related to construction and installation activities, and about 6% are in component manufacturing. The remaining fraction pertains to O&M services, which represent the smallest proportion of the workforce. China continues to dominate in hydropower employment with a 35% share of the global total. India (second to China with a 19% share), followed by Brazil, Viet Nam and Pakistan, are among the top five (see Figure 7).

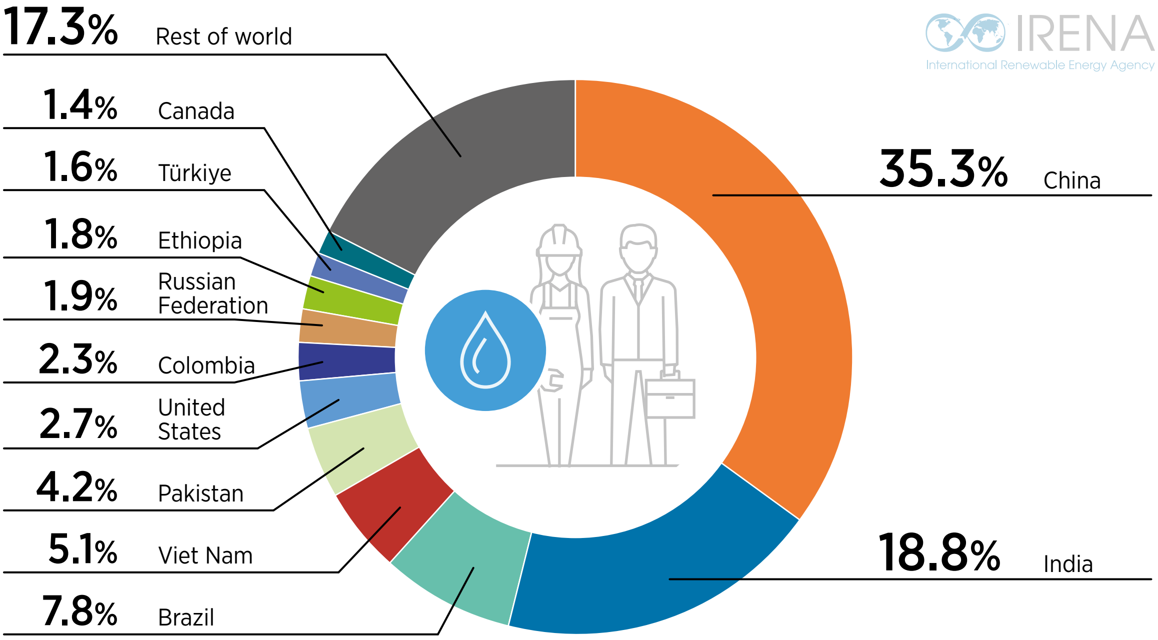
Figure 6 Hydropower capacity in the top ten countries, 2022



IRENA International Renewable Energy Agency

Source: IRENA, 2023b.

Figure 7 Hydropower employment (direct jobs), by country, 2022



1.4 LIQUID BIOFUELS

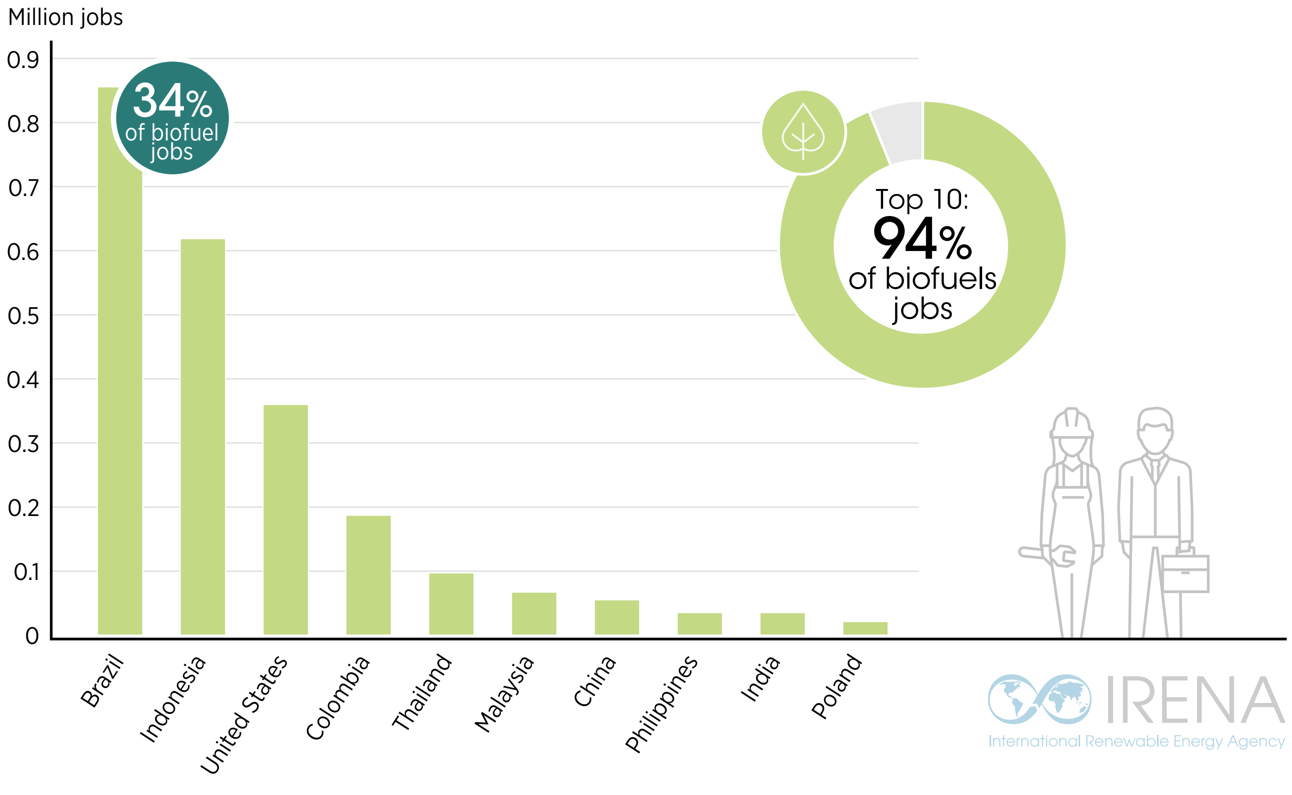
2.5
million jobs

A total of 162 billion litres of liquid biofuels were produced globally in 2021 (returning to 2019 levels after a decline in 2020, with bioethanol contributing 106 billion litres, biodiesel about 46 billion litres and hydrotreated vegetable oil [renewable diesel] adding close to 10 billion litres) (REN21, 2023).

According to preliminary estimates by the US Department of Agriculture's Foreign Agricultural Service (USDA-FAS), output among the world's leading biofuel producers was up slightly in 2022. As in earlier years, the United States, Brazil and the European Union were the dominant ethanol producers. EU members led in biodiesel production, followed by Indonesia, Brazil and the United States.

IRENA estimates worldwide biofuel employment in 2022 at 2.5 million, mostly in feedstock operations. **Latin America** accounts for 42% of all biofuel jobs worldwide, while **Asia** (principally Southeast Asia) accounts for 37%. The more mechanised agricultural sectors of **North America** and **Europe** represent smaller employment shares (15% and 6%, respectively). The top ten countries together account for about 94% of global estimated employment (Figure 8).

Figure 8 Liquid biofuels employment in 2022: Top ten countries



In the United States, 360 000 people were required for direct and indirect labour in biofuel feedstock and processing operations in 2022. In the 27 EU Member States, biofuel created an estimated 148 300 jobs in 2021 (up from 141 600 jobs in 2020) (EurObserv'ER, 2023). Total biofuels production in the European Union was relatively unchanged in 2022 (USDA-FAS, 2022e). Employment, therefore, may also be assumed to have remained at the 2021 level.

Many countries have labour-intensive feedstock operations, with informal and seasonal employment in the agricultural supply chain. Brazil remains the world's largest employer in liquid-biofuel-related operations (about 856 000 jobs), and is second only to the United States in biofuel production. Other countries estimated to have sizeable biofuel workforces include Indonesia (619 000), Colombia (186 700), Thailand (97 100), Malaysia (66 600) and the Philippines (44 900).

1.5 OTHER TECHNOLOGIES

As Figure 2 indicates, other renewable energy technologies employ far fewer people than solar PV, wind, hydropower and biofuels. The industries that manufacture and install these technologies are far less dynamic. For most of them the available information about their employment impacts is relatively scarce. Assessments for employment impacts of heat pumps, for example, are available only for some countries. Box 2 provides a summary of available information.

Box 2
Employment in heat pumps

China, Japan, the United States and Europe are the major markets for heat pumps. Global heat pump sales grew 11% in 2022, driven by developments in Europe, where rising energy prices and supportive installation policies are driving up sales (REN21, 2023). Three million units were sold in Europe in 2022. This is 38% more than in 2021, double the sales volume in 2019 and three times as many sales as in 2016 (Rosenow and Gibb, 2023).

Based on a survey of its members, the European Heat Pump Association estimates that in 2022, about 116 000 people were employed in this growing sector in European countries (see Figure 9). About 66 000 people were employed in manufacturing, 36 000 in installations and 15 000 in maintenance services (EurObserv'ER [2023] provides a much higher job number [some 377 300 in 2021], although this includes employment in air-source pumps and air-conditioning equipment).

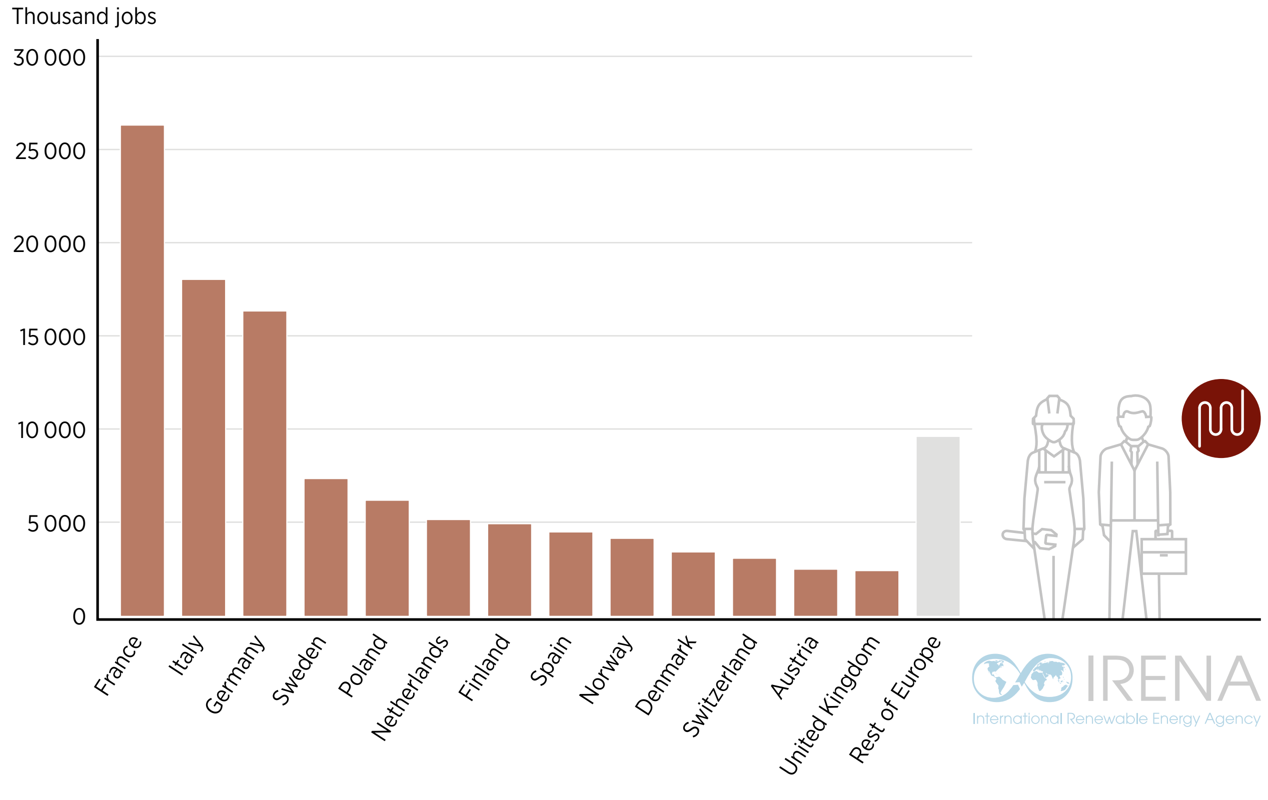
The largest number of European heat pump jobs are found in France, Italy and Germany, which together represent just over half of the European total (Nowak and Westring, 2023). A large portion of installations centres on European-made heat pumps. This creates local jobs, although recent demand growth has surpassed local manufacturing capacities and raised reliance on imports (EurObserv'ER, 2023). Companies announced plans for investments of more than EUR 5.5 billion in new European manufacturing factories (REN21, 2023).

In China, the heat pump industry provided employment opportunities for a similar number of people as in Europe, some 118 000 in 2022 (CHPA, 2023). Based on a survey,

this figure includes production, sales distribution, installation, and after-sales service. The numbers cover air-to-water heaters and water/ground-to-water heat pumps, but exclude air-to-air heat pumps, *i.e.* air conditioning. Some 28 000 people produced equipment and 20 000 people produced components. Sales and installation services, including sales, logistics, installation, and after-sales, provided employment opportunities for 71 000 people, about 60% of the total. The China Heat Pump Alliance forecasts that the heat pump industry could provide employment opportunities for 400 000 people by 2030 in China.

In the United States, the *Energy and Employment Report* estimates 6 465 jobs related to ground-source or geothermal heat pumps in 2022. The figure for air-source heat pumps is much higher, at 64 641 (US DOE, 2023).

Figure 9 Employment in the European heat pump sector, 2022



Source: Nowak and Westring, 2023.

1.6 DECENTRALISED RENEWABLES

Following the COVID-19–induced activity slump in 2020 (when just 340 megawatts [MW] were installed), the off-grid sector rebounded, adding 690 MW of new capacity in 2021 and 1400 MW in 2022 (IRENA, 2023b). Among various emerging technologies, decentralised renewable energy has emerged as a viable solution to provide reliable and clean power to communities, especially in remote areas. Beyond the environmental benefits, this decentralised approach creates local jobs and excellent opportunities for promoting diversity. This section discusses job and livelihood implications for mini-grids (often based on solar PV), small-scale hydropower and clean cooking solutions.

1.6.1 Mini-grids

Mini-grids will play an increasingly important role in closing existing gaps in energy access, especially in remote rural areas. In 2010, there were about 500 mini-grid installations in Sub-Saharan Africa. While the number has risen significantly, to over 3000 installations at present, further acceleration is needed. According to one estimate, more than 160000 mini-grids are required to address access needs (World Bank, 2023).

Kenya features prominently in the region, having deployed a significant share of Africa's mini-grids. The International Labour Organization has undertaken an assessment of the employment impacts of the EU-funded Green Mini-Grid (GMG) Facility Programme in Kenya, which consists of 33 sites, principally solar PV based. For a typical mini-grid, the study (Oyuma, Game and Lieuw-Kie-Song, 2023) assumes that the design and feasibility phase takes one month of work and the construction phase takes another month, engaging, respectively, 7 and 104 workers. This translates into 0.7 and 8.8 full-time equivalent (FTE) jobs, respectively, for a total of 9.5 FTE jobs, nearly all held by men. Most of the jobs are unskilled; almost half of the construction phase jobs pay an average daily wage of KES 500 (USD 4.69),[5] compared with KES 1600 (USD 15.025) for wiring work, and KES 2700 (USD 25.355) for field engineers and household mappers, for example. For O&M, the study estimates an additional 2.8 FTE jobs. For the 33 sites under GMG, the study also estimated indirect and induced employment at 652 jobs (these are not necessarily FTE jobs) in agriculture, manufacturing and services. Women account for about 20% of the total.

Based on average investment costs of EUR 195 275 per site and costs per connection of EUR 688, the study estimated that for every EUR 1 million invested, 58 FTE jobs could be created annually. Table 1 summarises key findings pertaining to direct jobs at present and direct jobs if future mini-grid targets are realised.

[5] *Average exchange rate of USD 1 = KES 106.488 in 2020, when the study was conducted. It should be noted that the exchange value of the Kenyan shilling has declined significantly since then. By September 2023, 1 USD equalled 146 KES.*

Table 1 Direct jobs in Kenyan mini-grid development

	Parameters	FTE Jobs
Average mini-grid site	Jobs in design and feasibility phase (temporary)	**0.7**
	Jobs in construction and commissioning phase (temporary)	**8.8**
	Jobs in operations and maintenance phase (permanent)	**2.8**
	Total direct jobs (temporary plus permanent)	**12.3**
For 33 GMG sites [a]	Permanent jobs	**92**
	Temporary Jobs	**314**
	Total jobs (temporary plus permanent)	**406**
Future connection targets	Estimated jobs created if 35 000 households served [b]	**1 439**
	Estimated jobs created if 1.1 million households served	**45 100**

Source: Oyuma, Game and Lieuw-Kie-Song, 2023.

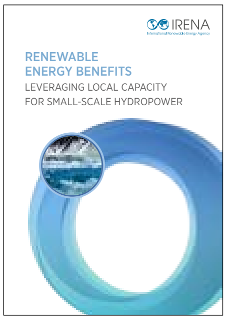
Notes: [a] *The number of sites that were developed under Phase 2 of the GMG programme.*
[b] *It is estimated that 117 mini-grid sites are needed to meet this goal.*
FTE = full-time equivalent; GMG = Green Mini-Grid.

1.6.2 Small-scale hydropower

Small-scale hydropower systems offer numerous benefits for local communities and the environment. They not only provide electricity but could also support irrigation services and connect communities to the central grid. They also make it possible to sell excess power, creating opportunities for additional income generation. In this way, they help transform local economies and generate inclusive growth by empowering rural women to participate in these activities. Further, community-based hydro mini-grids incentivise local communities to restore and maintain surrounding watersheds, contributing to environmental sustainability.

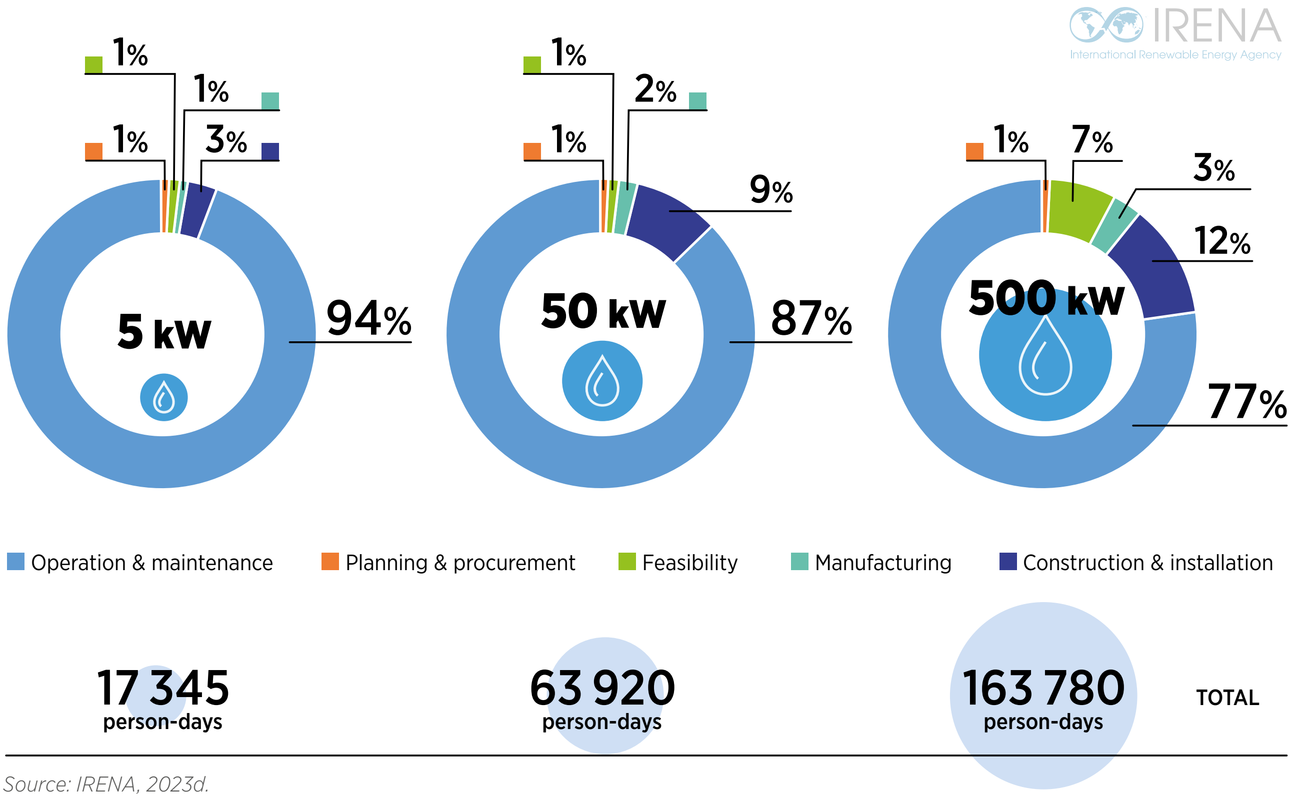
The implementation value chain of small-scale hydropower offers plenty of local job opportunities. Jobs can be created due to feasibility studies, planning and procurement, and equipment manufacturing, to installation and connection, O&M, and eventually, decommissioning.

According to IRENA's latest *Leveraging local capacity* analysis (IRENA, 2023c), a small-scale hydropower plant requires substantial labour to implement. For instance, a pico hydro plant (averaging 5 kW) requires over 17 000 person-days, a micro hydro facility (50 kW) requires approximately 64 000 person-days and a mini hydro system (500 kW) requires more than 160 000 person-days.[6] Among all value chain segments for a system, the majority of labour is needed for O&M work over the system's lifetime. This O&M work accounts for 94%, 87% and 78% of total person-days for pico, micro and mini hydro, respectively (see Figure 10).



[6] *Person-days reflect the amount of work done by one person working full-time for one day.*

Figure 10 Distribution of labour required along the value chain for pico, micro and mini hydro plants



Source: IRENA, 2023d.
Note: kW = kilowatt.

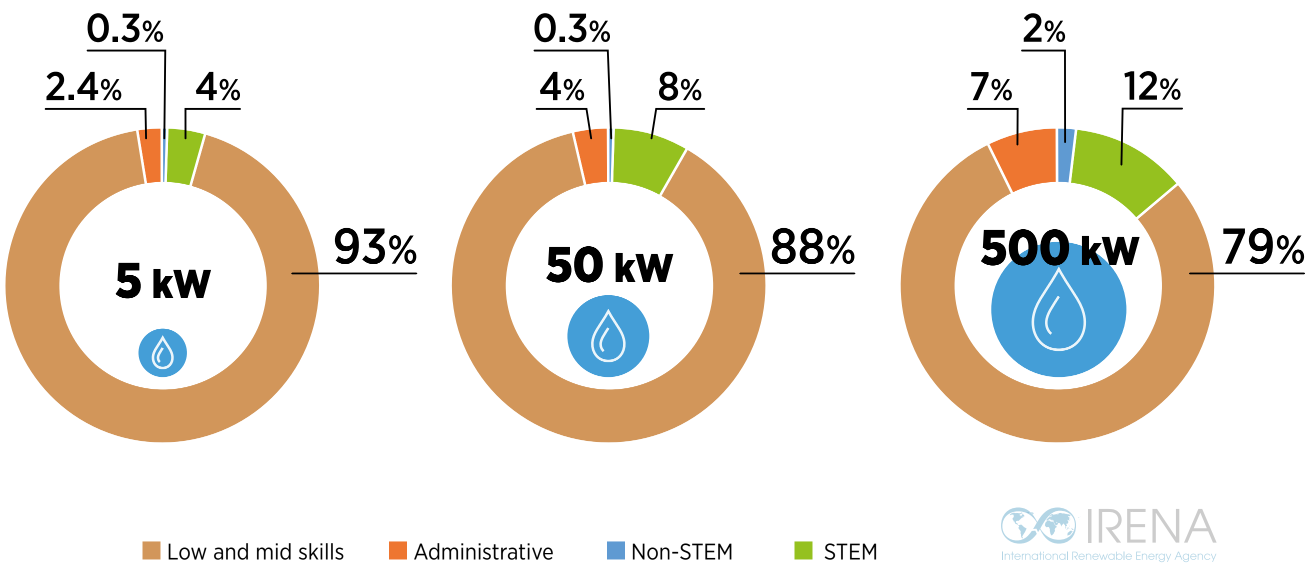
The above work mostly requires low to moderate technical skills (see Figure 11), which are typically readily available in a country's workforce or can be developed through certification programmes or vocational training centres. By employing local talent, small-scale hydropower projects contribute to local capacity development and skill enhancement.

Connecting renewable energy supply with income-generating activities, known as productive end uses, has the potential to boost productivity, increase incomes, create local employment and catalyse rural economies. However, translating energy access into livelihood improvements requires investing in a social ecosystem that fosters technology solutions tailored to the specific needs of local communities. This investment should include financing, capacity and skill training, market access and cross-sector policy support to fully realise the benefits of decentralised renewable energy solutions.

The hardware required for small-scale hydropower can be manufactured locally. This creates opportunities for local skill building and fostering enterprise development. However, costly international standards often hinder local developers from competing for projects. Donor-funded international programmes must encourage the involvement of local experts instead of relying solely on foreign service providers. Full realisation of small-scale hydropower's benefits and maximum domestic value creation require policies and measures to prioritise community capacity enhancement along the value chain and the promotion of social acceptance.

As the sector continues to grow, the demand for skilled workers in installation, maintenance, entrepreneurship and community engagement will increase. The expansion of the decentralised renewable energy job market has a positive multiplier effect, benefiting local economies, reducing poverty and fostering social development.

Figure 11 Distribution of skills required for pico, micro and mini hydro plants



Source: IRENA, 2023c.

Note: kW = kilowatt; STEM = science, technology, engineering and mathematics.

1.6.3 Renewables-based cooking solutions

Achieving universal access to clean cooking solutions is a pressing global challenge. Traditional cooking methods, such as open fires and inefficient stoves, not only contribute to indoor air pollution but also have severe health, environmental and socio-economic implications. Renewables-based clean cooking solutions, including bioethanol-based, biogas-based, electricity-driven and modern biomass-based solutions, present a significant opportunity to accelerate progress towards Sustainable Development Goal 7 and offer substantial job opportunities.

Studies show that countries such as Kenya had about 700 FTE jobs in the bioethanol sector in 2019, while the biogas sector employed 800 people and the electric cooking sector employed 200 (Lee *et al.*, 2021). The potential for an increase in jobs numbers in the clean cooking sector is substantial if renewable-based solutions were to replace liquid petroleum gas. Currently, the sector, including liquid petroleum gas, is estimated to provide approximately 19 000 direct, formal jobs. There is also potential for 15 000–35 000 direct but informal jobs. Viet Nam's biogas programme deployed over 180 000 biodigesters between 2003 and 2020, creating 2 500 jobs in the construction and services sectors (SNV and EnDev, 2021). Training and skill development is a critical element of local job creation in the clean cooking sector, which involves manufacturers, installers and O&M providers, as well as smallholder farmers where feedstock is needed (*e.g.* bioethanol supply chains) (IRENA, 2023d).

Lee *et al.* (2021) also showed that women's involvement in the sector is limited, representing only about 20% of the non-managerial workforce, due to the physically demanding nature of these jobs. However, there are more women managers in the clean cooking sector. For biogas-based solutions, about one-third of managers are women, a share that rises to one-half for bioethanol-based and electricity-powered cooking solutions. According to the study, companies typically express a strong desire to involve women in managerial roles and in the research and development of products. The clean cooking sector thus presents a unique opportunity to bridge both the skill and gender gap (Lee *et al.*, 2021).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1.7 THE FUTURE OF ENERGY TRANSITION JOBS

While this annual review primarily focuses on the renewable energy sector itself, several closely intertwined solutions of escalating significance significantly contribute to the emergence of job opportunities or the dynamics of the employment market and its requirements. Among them, energy efficiency measures represent a pivotal facet. Further, the development of grid transmission and distribution networks will be crucial in unfolding the energy transition, as is true for flexibility innovations, energy storage and hydrogen technologies, among others.

The shift towards sustainable energy sources fosters increased economic engagement and redirects financial endeavours from fossil fuels towards sectors involved in the energy transition. IRENA's *World Energy Transitions Outlook* presents a 1.5°C-compatible trajectory that is consistent with the Paris Agreement on Climate Change. The macroeconometric modelling framework underlying IRENA's 1.5°C pathway captures the effects of and feedback loops for different climate and energy transition policies, including their impacts on government revenue streams, spending, and distributional and social impacts. The 2022 edition of the *Outlook* indicated that if the world follows IRENA's 1.5°C pathway, employment in the energy sector could grow to 139 million jobs by 2030, with renewables accounting for 38.2 million and other energy transition technologies for 74.2 million (IRENA, 2022b).

These numbers are derived from socio-economic modelling of IRENA's 1.5°C scenario, which represents a complex set of investments and policies that can drive the needed change in the energy sector. However, IRENA's work has consistently emphasised that the transition has socio-economic effects (GDP, employment, and social welfare) far beyond the energy sector, across the economy at large. These impacts are shaped by an array of policies, and it is critical that outcomes maximise benefits for people while minimising uncertainties and adjustment burdens. Some of the key policies include carbon pricing, fossil fuel subsidy reduction, higher government spending on social infrastructures, and international collaboration. The forthcoming volume 2 of *World Energy Transitions Outlook 2023*, also explores the impacts of channeling revenues from wealth taxes towards social investments, and presents the impact of fair wages to workers in mineral mining industries in developing or emerging economies (IRENA 2023a, forthcoming).

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As the global transition gains momentum, it becomes increasingly evident that governments need to proactively establish robust policies to foster the widespread implementation and seamless integration of renewable technologies. Prioritising the cultivation of a skilled workforce remains imperative, alongside a growing emphasis on the calibre of these employment positions. Further, it is critical that policy makers conceive an overarching framework that encompasses a spectrum of measures, including industrial strategies, labour market policies, social safety nets and initiates for promoting diversity and inclusivity (see Section 4).

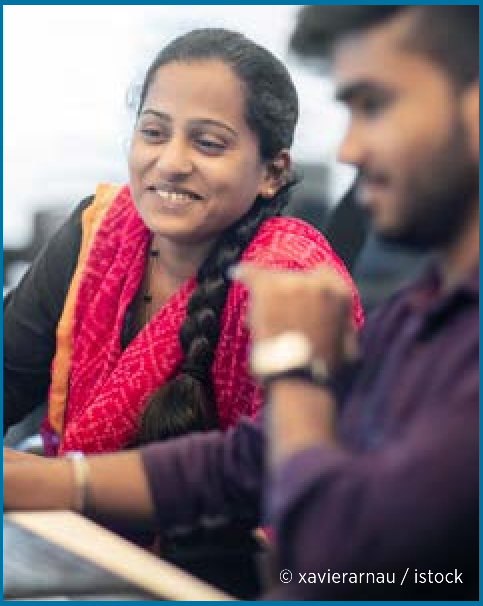
Moreover, the landscape of labour is undergoing a paradigm shift as automation increases in the manufacturing sector. This transformation is recalibrating employment dynamics, reducing traditional workforce dependencies while simultaneously generating demand for the skill sets required to program and operate automated systems. While this transition might entail job displacements, the positions that emerge from it are anticipated to be of higher quality, demanding advanced skills. Ensuring low-income individuals' access to these roles should be a top priority.

Meeting the human resource capacity challenge to fill these energy-transition-related roles requires a robust scaling up of education and training programmes. It also calls for strategic measures to cultivate an inclusive and gender-balanced transition workforce. By embracing these multi-faceted approaches, the energy transition can accelerate the move to a more equitable and empowered workforce.

CHAPTER 2

RENEWABLE ENERGY EMPLOYMENT **IN SELECTED COUNTRIES**

This section discusses employment estimates across several countries. As in previous editions, the principal focus is on countries leading in equipment manufacturing and installation – China, Brazil, India, the United States and the EU members. These countries are highlighted in Figure 12, with more detailed data in Table 2. Later, the section discusses a few other countries. Overall, the bulk of renewable energy employment is in Asian countries, which accounted for 62% of all jobs in 2022. While geopolitics and restrictive trade policies are increasingly influencing policy making on the production and deployment of renewable energy equipment, the jobs landscape is also affected by corporate decision making on production hubs and outsourcing.



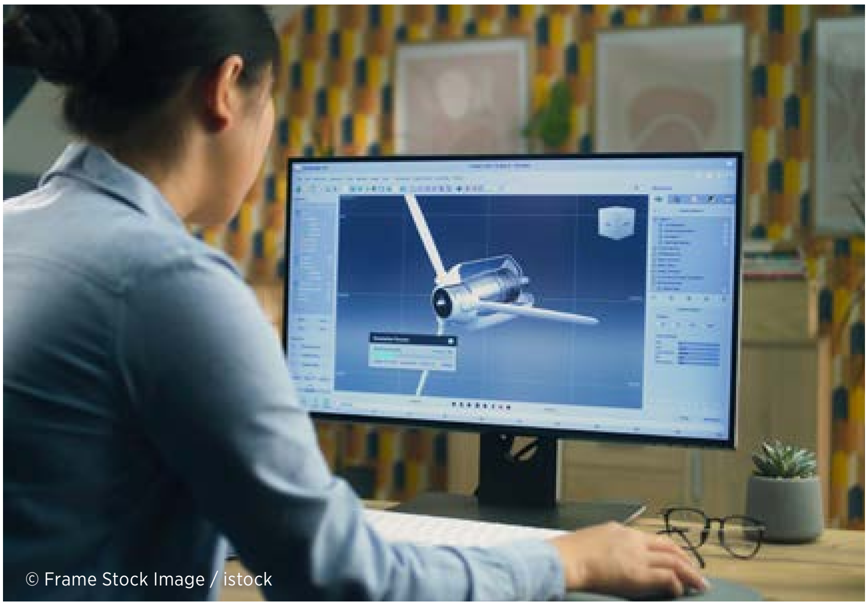
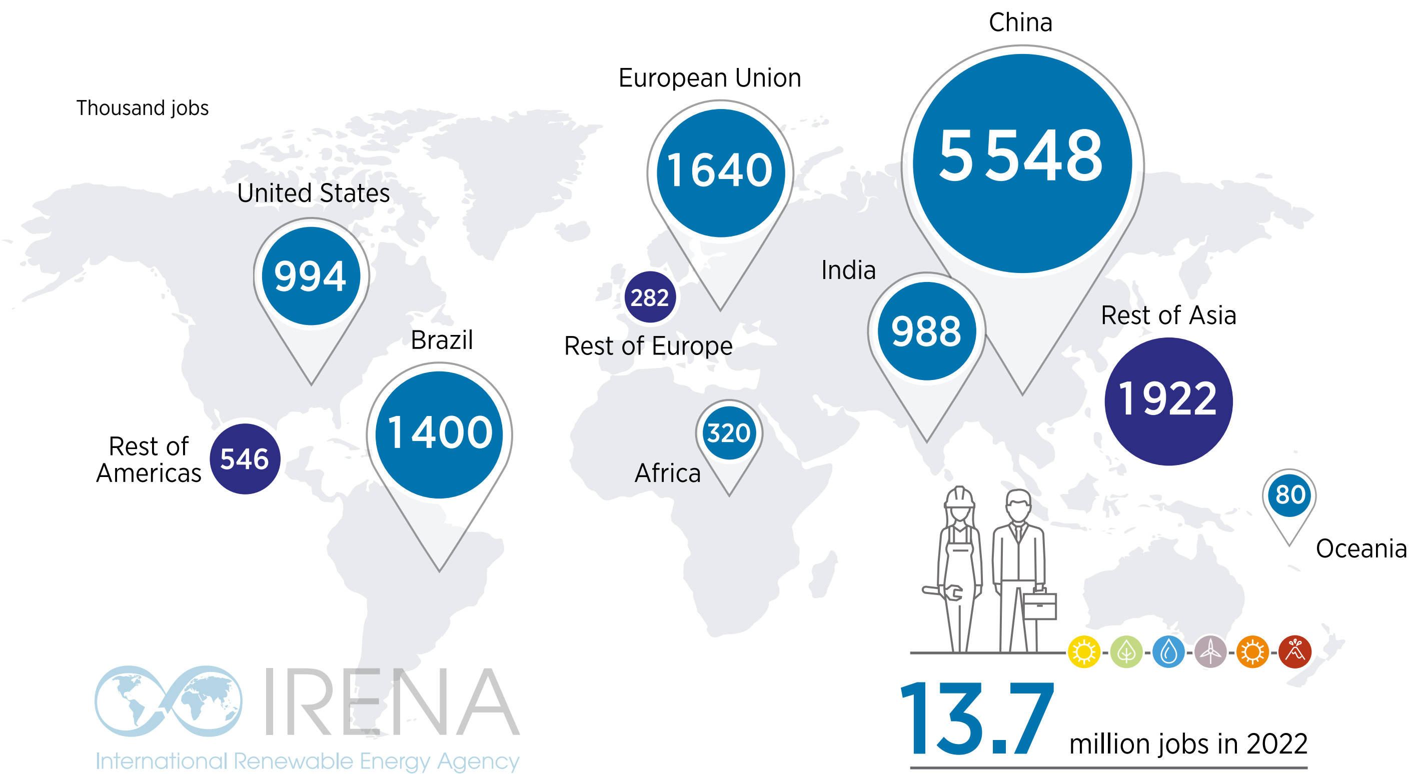


Figure 12 Renewable energy employment in selected countries and regions



Disclaimer: This map is provided for illustration purposes only. Any boundaries and names shown do not imply any endorsement or acceptance by IRENA.

Table 2 Estimated direct and indirect jobs in renewable energy worldwide, by industry, 2021-2022 (in thousands)

	World	China	Brazil	United States	India	European Union (EU27)[n]
Solar PV	4 902	2 760	241	264[f]	282[l]	517
Liquid biofuels	2 490	55	856[e]	360[g]	35	148
Hydropower[a]	2 485	876	194	66[h]	466	83
Wind power	1 400	681	68	126	40	319
Solid biomass[b, c]	779	195		47[i]	58	354
Solar heating and cooling	712	557	41	n.a.	19	38
Biogas	309	160		n.a.	85	47
Geothermal energy[b]	152	87		8.6[j]		7
Concentrated solar power	80	59.4		n.a.		5
Total	**13 720[d]**	**5 548**	**1 400**	**994[k]**	**988**	**1 534[e]**

Note: The figures presented 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. Empty cells indicate that no estimate is available. "n.a." indicates not applicable. The column values may not add up precisely to totals due to rounding off.

a. *Direct jobs only.*

b. *Power and heating applications.*

c. *Traditional biomass not included.*

d. *Includes 27 000 jobs in waste to energy and about 240 500 jobs in heat pumps (118 000 jobs in China, 116 000 in EU-27 countries, and about 6 500 in the United States).*

e. *Includes a rough estimate of 200 000 indirect jobs in equipment manufacturing.*

f. *Includes jobs in all solar technologies, but principally PV.*

g. *Includes 296 529 jobs in ethanol and 63 180 jobs in biodiesel.*

h. *US DOE (2023) estimate, including 54 595 jobs in traditional hydro and 11 677 jobs in low-impact hydro. The United States total does not include an estimated 8 333 jobs in pumped hydro (energy storage).*

i. *Includes woody biomass fuels (34 164 jobs) and biomass power (12 850 jobs).*

j. *Figure is for direct employment in geothermal power.*

k. *Includes 122 481 jobs in technologies not individually separated in the table, such as solar heating and cooling, geothermal heat, heat pumps and others. Solar heating and cooling are also included (but not reported separately) in the Solar Foundation's estimate for all solar technologies; there is thus slight double counting.*

l. *Includes 201 400 jobs in grid-connected solar photovoltaic (PV) and 80 600 in off-grid solar PV.*

m. *Solar PV, wind and hydropower jobs are for 2022. Jobs for other technologies are for 2021.*

2.1 LEADING COUNTRIES

China

5.55
million jobs

CHINA's renewable energy employment grew from 5.37 million in 2021 to 5.55 million in 2022.

The country's pre-eminence in **solar photovoltaic (PV)** employment reflects its strong position as the dominant equipment manufacturer as well as its commanding position in capacity installation. Although low labour costs are a factor in China's success, it is largely due to infrastructure provision and industrial policies, which supported the development of an integrated supply chain of unrivalled proportions.

According to the China Photovoltaic Industry Association, the country produced 827 000 tonnes of polysilicon, 357 GW of silicon wafers, 318 GW of cells and 289 GW of solar modules in 2022. Its exports rose by 80% to USD 51 billion when compared year over year, reflecting strong global demand (Joshi, 2023). Europe received the bulk of module exports (86.6 GW), with smaller volumes going to Asia Pacific (28.5 GW), the Americas (24.8 GW), the Middle East (11.4 GW) and Africa (3.4 GW) (Chen, 2023).

Regarding deployment, China added 86 GW of solar PV capacity in 2022, another record and equivalent to 45% of worldwide additions. Meanwhile, in wind, additions of 37 GW fell significantly short of the record capacity addition in 2020 and even of the smaller additions in 2021. These installations nonetheless represented half of the global total (IRENA, 2023b).

According to estimates by the China Renewable Energy Society (CRES, 2023), the country employed 2.76 million people in solar PV in 2022, about 80 000 more jobs than in 2021. The employment impacts of growing manufacturing and deployment are somewhat counterbalanced by rising automation, which diminishes the industry's labour needs. Manufacturing activities accounted for an estimated 1.8 million jobs, and construction and installation together with operation and maintenance (O&M) accounted for 918 000 jobs.

In the **wind** sector, China added 32.9 GW of onshore capacity in 2022 – slightly more than in the year before (when the expiration of a subsidy slowed construction activity), but still less than half of the record capacity added in 2020. Offshore capacity addition progressed significantly slower in 2022 than the year before, with new installations of 4.1 GW compared with 17.4 GW (IRENA, 2023b). Although grid limits will continue to constrain developments, China's 2060 carbon neutrality target will push further wind growth (Li, 2022).

Since 2008–2010, Chinese wind companies have established a large supply chain primarily for serving the domestic market. Due to substantial investments and strategic industrial policy making, China can benefit from unmatched economies of scale and has become the world's largest hub for the production of key components and raw material processing. This translates into substantial cost advantages. For example, reports indicate that Chinese wind firms could manufacture turbines at approximately 60% of the cost of their competitors (Barnard, 2023).

"Completed and firm" wind turbine orders filled by Chinese manufacturers doubled between 2020 and 2021 to 50.7 GW, and further grew by 18%, to 59.8 GW, in 2022 (Wood Mackenzie, 2023b). The bulk of production is for the large domestic market. Meanwhile, the market dynamics are changing, and favourable cost and profit margins over Western competitors are leading Chinese manufacturers to look more towards export markets. Both competition and co-operation with European manufacturers are expected to grow. Besides export sales, Chinese companies are building or planning to build manufacturing plants in India, Brazil, Spain and the United Kingdom (Ren and Diao, 2022; Diao, Li and Wang, 2022).

According to Wood Mackenzie's estimates, China is planning to add 17 GW of new blade capacity in 2023–2024 to serve both domestic and foreign demand. This is in sharp contrast to Western markets, where manufacturers struggling with low demand, rising costs and low profitability are outsourcing component production (Lico, 2022b).

According to CRES (2023), the Chinese wind industry employed an estimated 681 000 people in 2022, up from 654 000 in 2021. Manufacturing accounted for 234 000 of these jobs, construction and installation represented 276 000 and O&M accounted for 171 000.

In **hydropower**, global capacity additions in 2022 were predominantly in China, whose hydropower sector employed about 927 200 people directly, as per IRENA's estimates. **Solar heating and cooling** were estimated to have had 557 000 direct jobs, down from 636 000 jobs in 2021. **Concentrated solar power** represented another 59 400 jobs, roughly the same as in 2021. **Geothermal** heat and power had 87 000 jobs, also up slightly from 2021. **Bioenergy** technologies accounted for 410 000 jobs, up from 386 000 in 2021. Of this total, 240 000 jobs were in equipment manufacturing and 170 000 in O&M (CRES, 2023). China's fuel ethanol production remained below the 2019 peak value, but biodiesel output reached another record (USDA-FAS, 2022f). China's biofuels sector is estimated to have employed 55 000 people in 2022, up marginally (CRES, 2023).

Brazil

1.40
million jobs

BRAZIL had an estimated 1.4 million renewable energy jobs in 2022. **Biofuels**, with an estimated 856 200 jobs in 2022, remained the single-largest employer in renewable energy, although job numbers declined slightly from the previous year.

Biodiesel production was estimated at 6.37 billion litres in 2022, down about 6% from 2021. In November 2021, the mandatory biodiesel blend in vehicle fuels had been reduced from 13% to 10% given the increased cost of soybeans (the primary feedstock) (USDA-FAS, 2022a). IRENA estimates 282 400 biodiesel-related jobs in Brazil in 2022, down from 343 500 the year before.[7] The most recent available employment estimate for bioethanol is for 2021, at 344 500 jobs (MTE/RAIS, 2023),[8] along with an approximate 200 000 indirect jobs in equipment manufacturing. Brazil's estimated sugarcane-based ethanol output rose by about 8.5% in 2022. Applying this percentage change to employment would suggest some 573 800 ethanol-related jobs in 2022. Most ethanol is produced from sugarcane, but corn ethanol production is expanding, rising 37% in 2022 (USDA-FAS, 2022a).

Brazil ranked fourth in new **solar PV** capacity installation in 2022, after China, the United States and India. It added 9.9 GW, to bring the cumulative installed capacity to 24 GW (IRENA, 2023b). ABSOLAR (2023) reported even higher figures and found that 29% of cumulative PV capacity as of 2022 was in centralised generation facilities, down from 76% in 2018. The bulk of PV expansion over the past few years has been in distributed generation.

The Brazilian development banks BNB and BNDES are the principal sources of finance for large-scale PV. Altogether, some 42.4 GW of new solar PV projects were authorised between March 2022 and February 2023, of which 4.9 GW were under construction by mid-2023 and 7.5 GW were already in operation (Greener, 2023a).

Brazil remains heavily dependent on imports of (predominantly Chinese-made) PV modules. Imports for both large-scale and distributed projects rose from 4.8 GW in 2020 to 10.4 GW in 2021 and soared to 17.8 GW in 2022 (Greener, 2023b). Employment is thus created principally in sales, installations and O&M, which are typically handled by small enterprises. IRENA estimates about 241 100 jobs in Brazil's solar PV sector in 2022. This is a dramatic increase from 131 000 jobs in 2021, reflecting the fact that cumulative deployment in the labour-intensive distributed segment almost doubled.

Brazil added 1.78 million square metres of **solar water heating** capacity in 2022, just 2% below the impressive record set in 2021 (ABRASOL, 2023). IRENA estimates 41 100 jobs in solar water heating.[9]

In the **wind** industry, 4 GW of capacity were added in 2023, up somewhat from 3.8 GW in 2021 (ABEEÓLICA, 2023). Brazil ranked third in wind capacity addition in the world, after China and the United States (IRENA, 2023b). IRENA estimates the country's wind workforce at about 67 700 people, primarily in construction, followed by O&M.[10]

[7] The calculation is based on employment factors for different feedstocks (Da Cunha, Guilhoto and Da Silva Walter, 2014). The 2022 shares of feedstock raw materials, principally soybean oil and animal fat (beef tallow), are derived from USDA-FAS (2022a).

[8] In 2021, about 167 900 workers were engaged in sugarcane cultivation in Brazil, and 176 700 worked in alcohol and ethanol processing.

[9] This estimate is based on the assumption that employment changes mirrored the change in installations, thus applying a 2% decline to ABRASOL's 2021 estimate of 42 000 jobs (Johann, 2022). Mercantil Environmental (2023) mentions a figure of 50 000 jobs but does not explain how it was calculated.

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

The **UNITED STATES** had close to 1 million renewable energy jobs in 2022, including about 406 700 jobs in biofuels, biomass power and woody biomass fuels; about 263 900 in solar PV; almost 122 500 in various renewable heating and cooling technologies;[11] about 66 300 in hydropower[12] and 8 600 in geothermal power. In addition, but not included in this report, about 251 500 jobs were created for various energy-transition-related technologies.[13] US DOE (2023) further estimates that energy efficiency employed about 2.2 million people in 2022, up by 50 500 over the previous year.[14]

United States

0.99

million jobs

The passage of the Inflation Reduction Act (IRA) in August 2022 triggered announcements of new clean energy investments. Between August 2022 and the end of July 2023, over USD 270 billion in utility-scale investments and investments in 83 new or expanded utility-scale manufacturing facilities were announced, with a potential of 29 780 new jobs. They include 52 solar PV factories; 17 wind facilities; and 14 utility-scale battery storage sites (American Clean Power, 2023).

In 2022, the United States installed an estimated 17.6 GW of **solar PV** capacity, its second-highest capacity addition after the 19.2 GW installed in 2021 (IRENA, 2023b). The industry faced supply chain disruptions due to an anti-circumvention probe announced in March 2022 (affecting PV cells and modules imported from Cambodia, Malaysia, Thailand and Viet Nam) and the enforcement of the "Uyghur Forced Labor Prevention Act", which led to the months-long detention of many module shipments from the Xinjiang Uyghur Autonomous Region (Groom, 2022).

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[11] *This figure includes solar thermal, geothermal, biomass, heat pumps and other technologies.*

[12] *This figure includes 11 677 jobs in low-impact hydro and 54 595 jobs in traditional hydro. There are also 8 333 jobs in pumped hydro, which are, however, not included here (US DOE, 2023).*

[13] *This figure includes jobs in battery storage (72 923 jobs, of which 13 600 in battery manufacturing), smart grids (24 916 jobs), micro grids (19 845 jobs), other grid modernisation (20 794 jobs) and electrical vehicle charging (113 001 jobs) (US DOE, 2023).*

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

According to the *National Solar Jobs Census 2022*, US solar employment rose to almost 264 000 jobs in 2022, 3.6% more than in 2021.[15] Developments were mixed in different market segments. For utility-scale projects, the pace of installations slowed, with the loss of an estimated 6 000 jobs. However, employment in residential solar, which relies more on domestic modules, soared by 40%, with 9 500 jobs added. In 2022, two out of three solar jobs (or about 171 600 jobs) were in the installation and project development segments, with another 33 400 jobs in manufacturing, 30 600 jobs in sales and distribution, and 28 200 jobs in O&M and "other" activities (IREC, 2023).

Job creation has not kept pace with installations in recent years. This reflects growing labour productivity and installations with a focus on the utility-scale segment. The more labour-intensive residential solar segment accounts for 55% of jobs but just 28% of total capacity (IREC, 2023).

In 2022, only about 10% of US solar workers belonged to a union – no improvement over earlier years. Women accounted for 31% of all US solar jobs in 2022 (up from 29% the previous year and 27% in 2017). With a share of 9% of solar jobs, African Americans are less represented in the workforce than their share of jobs across the entire US economy would suggest. By contrast, Latinos and Latinas, at 22% of jobs, and Asians, at 9%, are above their respective national shares. A little over a quarter (27%) of the surveyed solar firms had strategies for hiring more women (compared with 31% in the previous year), and just 12% (up from 8%) took steps to increase LGBTIQ+[16] hires (IREC, 2023).

In the **wind** industry, US blade manufacturing capacity dropped by 63% between 2021 and 2022, from 8.3 GW to just 3.1 GW. Over 2 000 workers were laid off as a result (Lico, 2022b). In October 2022, General Electric Co. announced that it would lay off 20% of its onshore wind workforce in the United States, along with other workers in Latin America, the Middle East and Africa (Singh and Hampton, 2022). US domestic production was replaced with growing imports from Mexico and India, with smaller volumes coming from Spain and Brazil, and much reduced volumes from China. Corporate outsourcing strategies seek to leverage the lower wage levels in many of these countries in an environment where labour and material costs have increased. Manufacturing and assembly labour accounts for 35% of the cost of fibreglass blades,[17] a typical blade requires more than 2 000 hours of labour inputs (Lico, 2022b).

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[15] The Interstate Renewable Energy Council (IREC) includes only solar workers who spend at least half of their working hours on solar goods and services. By contrast, the United States Energy & Employment Report (US DOE, 2023) pegs solar PV employment at 346 143 in 2022, up from 333 887 in 2021. This includes all employees engaged with solar technologies, regardless of the share of time they spent on solarrelated work.

[16] LGBTIQ+ stands for lesbian, gay, bisexual, transgender, intersex, queer/questioning, asexual and many other terms (such as non-binary and pansexual) (ILO, 2022).

[17] However, fibreglass is expected to be increasingly replaced by carbon fibre, given the latter's advantages in weight, strength and flexibility. Labour represents merely 11% of carbon fibre costs, compared with 52% for material and energy, and 37% for capital costs (Lico, 2022b).

But the local content bonus included as part of the IRA may encourage a reopening of some factories. Also, subject to order confirmations and public funding, Vestas, Siemens and General Electric Co. intend to build new turbine component factories in Colorado, New York and New Jersey (Kessler, 2023; Woods, 2023).

In 2022, only 7.8 GW of wind capacity was installed in the United States, a little more than half of the over 14 GW added each in 2020 and 2021 (IRENA, 2023b). Still, the number of wind power jobs in 2022 was estimated at 125 580, up from 120 164 in 2021, given growing O&M needs. For onshore wind employment, the largest segment was construction, with a 36% share, followed by professional and business services, with a 26% share. For offshore wind, such services accounted for 48%, followed by construction, with a 32% employment share (US DOE, 2023).

Biofuels is estimated to have 359 700 jobs in the United States. Total biofuel production in 2022 remained below the 2018 peak level of 68 billion litres. Ethanol output rose slightly from 2021, but biodiesel volumes continued to decline. Input-output modelling suggests that bioethanol may have employed 296 500 persons in 2022 in the United States, including 78 800 directly and 217 700 indirectly in the agricultural supply chain (ethanol represents almost 40% of the entire country's corn crop; a large share of the industrial agriculture system is thus involved in producing this output). The total number of jobs includes close to 30 000 export-related positions (Urbanchuk, 2023). Biodiesel output fell to 6.14 billion litres in 2022, down 5% from 6.5 billion litres in 2021 (US EIA, 2023). IRENA estimates the number of biodiesel-related jobs at about 63 200 in 2022, down from 66 650 in 2021.

Across the US energy sector, 11% of workers were either represented by a union or covered under a project labour agreement or collective bargaining arrangement. While quite low, it was higher than the 7% across the private sector economywide (US DOE, 2023).

Unionisation offers a range of benefits, including higher wages and benefits. Some 46% of unionised employers offered or required workplace diversity and/or inclusion training, more than double the 22% share among non-unionised employers. They were also more likely to have specific strategies, policies or programmes for increasing the number of female, minority and LGBTIQ+ hires. Far fewer (29%) of the unionised employers found it "very difficult" to attract workers than non-union companies (48%) (US DOE, 2023).

Rewiring America (Griffith, Calisch and Laskey, 2020), a non-profit organisation, estimated that the United States will need an additional 1 million electricians to help install solar panels, heat pumps, electric vehicle charging stations and other technologies to meet the climate goals established under the IRA. Reaching that goal requires tapping into a broader pool of people, and, in particular, overcoming the barriers faced by women in the industry (see Box 3).

Box 3
Women – key to skilling the energy transition

As the world embraces renewable technologies and more sustainable practices, job opportunities in the electrical industry will multiply, especially for skilled electricians. Data from the US Bureau of Labor Statistics (BLS, 2023a) show that about 21% of currently active electricians will reach retirement age in the next ten years, whereas the demand for electricians could grow by 7%, resulting in nearly 80 000 job openings per year. That estimate does not even yet account for all the new incentives included as part of the Inflation Reduction Act – rebates for solar panels, electrical panels, heat pumps, stoves, cars, etc. – nor does it consider the possibility that demand might soar if local governments keep pushing to electrify buildings (Pontecorvo, 2023).

The evolving landscape in the electrical industry calls for urgent measures to attract fresh talent and invest in comprehensive training programmes to meet future demand. Women, largely underrepresented, at only 2% (see Table 3), can play a pivotal role in this transformation, bringing much-needed diversity and innovation to a male-dominated field.

However, achieving gender equality and empowering women in the electrical sector require addressing critical issues like harassment and abuse, which are rife in the field (Preston, 2021). Cultivating a safe and respectful workplace is essential to attract and retain women in the industry. Further, increasing visibility of women's contributions and combating exclusionary practices in unions will help remove barriers and provide more opportunities for women to advance in their careers.

Actively promoting an inclusive and supportive working environment – that fights against harassment, advocates for visibility, dismantles exclusionary practices and supports caregivers – can help the women in the electrical sector unlock their full potential, enabling the sector to secure a prosperous future (Renwick, 2023).

Table 3 Employed persons by selected occupations in the United States economy, 2022

Occupations		Total jobs (thousands)	Share of women (%)
All employment		**158 291**	**46.8**
Professional and related		38 749	56.5
	Electrical and electronics engineers	296	8.1
Natural resources, construction, and maintenance		14 260	5.7
of which:	Construction and extraction	8 427	4.2
	Roofers	208	5.0
	Carpenters	1 282	3.5
	Electricians	918	2.2
	Plumbers, pipefitters, steamfitters	610	1.1
of which:	Installation, maintenance, and repair	4 853	4.2
	Electrical power-line installers and repairers	119	1.5

Source: BLS, 2023b.

India

0.99
million jobs

INDIA had an estimated 988 000 renewable energy jobs in 2022. Hydropower, with some 466 000 jobs, was the largest renewables employer, followed by solar PV, which had 282 000 people involved with on-grid and off-grid systems. Other renewables represented far smaller numbers.

India added 13.5 GW of **solar PV** capacity in 2022, up from 10.3 GW in 2021. Both values were new records set by the country (IRENA, 2023b). India's domestic module production capacity grew from 10.4 GW in 2021 to 24.7 GW in 2022, although actual production did not keep pace and capacity utilisation declined from 36% to 28% (Wood Mackenzie, 2023a). While India remains heavily reliant on imports, its own solar module exports in 2022 more than quintupled, benefitting from US import restrictions imposed on Chinese products (Gulia *et al.*, 2023).

Based on an employment factor analysis, IRENA estimates that India had 201 400 jobs in grid-connected solar PV in 2022, up 47% from 2021. Roughly 80 000 people work in off-grid solar.

In fiscal year[18] 2022, India's solar industry added 52 100 jobs in project development (predominantly in construction and installation). Utility-scale solar accounted for 83% of added solar PV capacity, with a total of 72 700 jobs (up from 42 900 in 2021). Rooftop solar employment increased to 65 400 jobs from 43 000 jobs, while wind employment grew, at a slow pace, to 26 100 jobs (from 25 500) (CEEW, NRDC India and SCGJ, 2023; Tyagi *et al.*, 2022). These figures are lower than IRENA's estimates since they exclude indirect jobs, jobs in off-grid solar applications and jobs in equipment manufacturing.

India ranks fourth in the world in cumulative **wind** power generating capacity, although 2022 was another slow year, with just 1.9 GW added, compared with the peak installation of 4.1 GW in 2017 (IRENA, 2023b). The wind energy sector added only 600 new jobs in construction and installation. India has 10–12 GW of domestic annual wind turbine generator manufacturing capacity (GWEC, 2023), indicating the potential for a growth in domestic installations and exports. IRENA estimates that the Indian wind sector had 40 000 jobs in 2022, of which O&M represented almost half.


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[18] *India's fiscal year runs from 1 April to 31 March.*

EU-27

1.60

million jobs

Countries in **EUROPE** had a total of 1.8 million renewable energy jobs, of which about 1.6 million were in the 27 EU Member States (EU-27).

IRENA estimates European **wind** power to have had 402 000 jobs in 2022, of which 319 000 were in EU-27. The continent's total wind-generating capacity reached 240 GW in 2022, with a record 18.6 GW newly added. The EU-27 installed the bulk of this new capacity, (15.7 GW) for a total of 204.1 GW (IRENA, 2023b).

Meanwhile, the picture was less encouraging for manufacturing. According to the Global Wind Energy Council (GWEC, 2023), new wind turbine orders declined by 47%, reflecting growing competition from non-European suppliers and high levels of uncertainty. Although European manufacturers remain industry technology leaders, operating losses led to job cuts. For example, in the fall of 2022, Siemens Gamesa announced that it would cut 2 900 jobs, including 800 in Denmark, 475 in Spain and 300 in Germany. The company employs about 27 000 people worldwide (Lee, 2022).

Losses resulted from the combined effects of supply chain delays, rising costs for key materials and other inputs, and lengthy wind farm permitting processes (Hodgson, 2023, 2022). Turbine prices are typically set long before their actual delivery. In 2020 and 2021, costs were declining, but subsequently rose sharply; manufacturers have been unable to pass the rising costs on to project developers (Woods, 2023). Further, there is growing competition from Chinese manufacturers, which have benefited from a stable policy framework at home and are now increasingly turning their focus to exports. Chinese companies already have a strong presence in supplying turbine components used by Western firms (Reed, 2022).

In the **solar PV** sector, Europe as a whole added about 37.7 GW in 2022, a significant gain over the 27.3 GW added in 2021 – which in itself was a new record (IRENA, 2023b). The EU-27 members represented 36 GW and 25.7 GW, respectively, of the total.

The 2022 *EU Solar Jobs Report* (SolarPower Europe, 2022) estimates 465 600 full-time employees in 2021, up from about 357 000 in 2020. This includes about 205 000 direct jobs and 261 000 indirect jobs, in material processing and logistics. Close to 80% of the total, or 367 000 jobs, were in the deployment segment. By contrast, manufacturing employed only about 44 200 people, with another 40 000 employed in O&M, and 14 000 were employed in decommissioning and recycling. Within manufacturing, the bulk of employment relates to inverter production (about 31 000 jobs), whereas employment for modules and polysilicon is much smaller, and employment for the production of cells and ingots/wafers is marginal (SolarPower Europe, 2022).

Given Poland's strong focus on labour-intensive residential rooftop systems – which require three times as much labour as utility-scale deployments – SolarPower Europe believes that the country's solar PV sector had 113 000 jobs in 2021, up from 90 000 in 2020. Other leading countries include Germany (about 86 900 jobs), Spain (65 600), the Netherlands (36 400), Greece (33 700), France (33 200) and Italy (24 300). All of them have gained significantly in employment over the previous year, reflecting the growth of new deployments (SolarPower Europe, 2022).

Under changed economic and political conditions, companies and governments are rediscovering industrial policy as a prime area for action to advance critical societal objectives. In late 2022, the European Commission – in a bid for greater EU self-reliance and in support of accelerated solar deployment – launched a Solar Photovoltaic Industry Alliance to achieve 30 GW of annual solar manufacturing capacity across the value chain by 2025. The alliance is intended to develop an action plan on issues including, among others, innovation, industrial supply chain, raw materials, finance access, circularity and sustainability, and skills, and will see participation from industry, research centres, consumer associations and non-government organisations. The approach is patterned on initiatives such as the Battery Alliance and the European Clean Hydrogen Alliance (European Commission, 2022a, 2022b), and comes in the context of growing efforts in the United States and India to attract corporate investment in local manufacturing (Taiyang News, 2022).

As is the case in other parts of the world, building or reconstituting a domestic solar PV manufacturing industry, including in particular ingot and wafer capacities, is a steep challenge for Europe. As global leaders, Chinese companies derive strong competitive advantage from their much greater scales of production (Fuhs and Enkhardt, 2023).

SolarPower Europe projects that under a "medium scenario", EU solar PV jobs could grow to about 530 000 by 2026,[19] and double that figure under a more ambitious pathway to 2030. But as the organisation points out, this will depend not only on a concerted industrial strategy but also on boosting skilling and workforce development efforts, including efforts to better connect job seekers with companies' requirements.

According to EurObserv'ER (2023), the European **bioenergy** sector has the largest employment share, with a total of 549 200 people. Solid biomass (for heating and electricity) had a workforce of approximately 353 800 in 2021. Another 148 300 were employed for biofuels and 47 100 for biogas.

The use of **solid biomass** in the EU-27 rose substantially, reaching peak levels in 2021. Over 95% of EU's solid biomass supply need is met domestically, translating into significant local employment in feedstock operations. The largest employers in this regard were Poland and Germany, with over 40 000 jobs each, followed by France, the Netherlands, Sweden and Italy (each with over 20 000 jobs) (EurObserv'ER, 2023).

Ethanol fuel production in EU-27 rose to new peaks of 5.2 billion litres and 5.35 billion litres in 2021 and 2022, respectively. Meanwhile, **biodiesel** output in both years remained slightly below that in the 2020 peak year, at about 19 billion litres (USDA-FAS, 2022e). However, substantial biofuel production capacities still remain idle. EurObserv'ER (2023) estimated about 148 300 biofuel-related jobs in EU-27 in 2021, up from 141 600 jobs in 2020. Given that overall biofuel production was slightly higher in 2022, it stands to reason that employment that year aligned closely with the 2021 value.

EU biofuel-related jobs in 2021 were predominantly in countries with vast agricultural areas (Poland with 21 400 jobs, Romania with 17 800 jobs, Hungary with 17 000 jobs and Spain with 13 500 jobs) and among the biggest consumers – France (18 800 jobs) and Germany (12 400 jobs).

[19] *This scenario expects 34 GW in annual capacity additions. For a comparison, the European Union installed 36 GW in 2022.*

Among the EU-27 members, new solar PV installations in **GERMANY** rose to 7.3 GW in 2022, continuing a steady upward trend after multiple years of much slower capacity growth. The picture is quite different for wind. Following record installations in 2017, of 6.1 GW, the pace has slowed, with 2.5 GW added in 2022, even though it represented an uptick from just 1.6 GW in 2021 (IRENA, 2023b). Wind additions are affected by a time-consuming permitting process and restrictive siting rules in some of Germany's federal states.

The 2022 *EU Solar Jobs Report* (SolarPower Europe, 2022) estimated Germany's direct and indirect **solar PV** employment in 2021 at about 86 900 FTEs. Bundesverband Solarwirtschaft (BSW, 2023) provides a figure of 55 000 direct jobs in 2023, reflecting growing installation activity. IRENA's estimates suggest that the industry supported close to 94 000 jobs in 2022. German **wind** energy employment declined from 167 600 jobs in 2016 to 122 100 jobs in 2019, followed by a modest recovery to approximately 139 000 jobs in 2022. The slow pace of new capacity installations also makes it harder to sustain a sizable domestic manufacturing industry. **Bioenergy** – biofuels, biomass power and biogas – remains a key employer in Germany, with 78 000 jobs in 2022. The jobs number has, nevertheless, declined over the past couple of years. Geothermal energy (13 200 jobs) and hydropower (4 700 jobs) are much smaller employers.

The required solar and wind energy expansion in Germany in the coming years will need some 216 000 additional skilled workers in renewables supplies and support functions. Skill shortages specifically encompass electricians, heating and air-conditioning technicians, and information technology specialists. Greater recruitment of women and retraining workers from other fields could help address the challenge (Institut der deutschen Wirtschaft, 2022). Germany's metalworkers' union, IG Metall, in concert with heating, electrical, carpentry and other trade associations, points to a lack of 190 000 skilled workers in energy transition fields and an energy renovation backlog for over 19 million residential buildings. Policy makers will have to boost the capacities of vocational schools and other educational institutions and ensure that vocational and academic education paths hold equal value. In October 2022, the German government approved a new skilled labour strategy, which includes measures to help companies and businesses attract and retain skilled workers (Meza, 2022).

In 2021, renewable energy made remarkable strides in **SPAIN**, significantly contributing to the national economy and job market. According to a study by the Asociación de Productores de Energía Renovables (APPA, 2022), the renewable energy sector contributed 1.6% of gross domestic product (GDP). The sector provided employment to an estimated 111 409 workers. Solar PV installations witnessed a 59% increase in employment opportunities, especially those focused on self-consumption. Further, other renewable technologies such as wind, solar thermal and marine, also made positive contributions to job creation. All of this resulted in an overall impressive net gain in employment opportunities of almost 20% compared with the previous year (APPA, 2022).

Meanwhile, in a new study conducted in collaboration with the Naturgy Foundation, the Spanish Just Transition Institute (ITJ) estimates that the energy transition has created over 152 000 jobs over the past seven years (2015–2022). But importantly, the study points out that women represented just 18.2% of the sector's workforce in 2021, a marginal increase of 1.2% over 2012, almost a decade earlier. Also, the sector share remains significantly below women's representation across the entire economy in 2012, when women constituted 47% of the overall workforce (Martínez *et al.*, 2023). The study also identifies gender gaps in technical occupations (see Box 4).

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Box 4
Gender gaps in Spain's energy transition industries

According to a first full assessment of the Spanish labour market, women had four out of 10 of the new jobs linked to the energy transition in the period 2015-2021. From a low starting point, female employment grew much faster than male employment in the various subsectors of the energy transition. While positive, the evolution over the last decade is still very slow.

Women continue to be under-represented in essential technical fields related to the energy transition, both in terms of university programmes and vocational training. Of all university graduates in 2020, only 11% were women majoring in science, technology, engineering and mathematics (STEM) fields, compared with 36% of men graduating in these fields.

The gap is more pronounced in vocational training, where 7.9% of women are engaged. Women working in clean energy primarily hold administrative positions, whereas technical positions remain male dominated. Gender parity in energy transition employment, whose current lack indicates a deep and persistent gap, would require 265 years to achieve at the current pace of progress.

Additional analysis shows that the gender wage gap in the energy transition sector is comparatively less pronounced than in the overall economy, with women earning 6% less than men, as opposed to a 14% national wage gap. According to the study, women in the Spanish energy transition sector are often found to be overqualified for their positions.

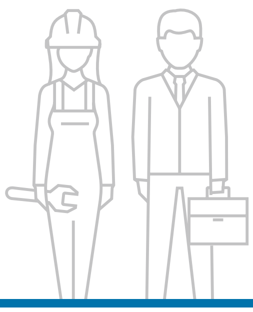
Further, the study shows that women occupied less than 20% of the jobs created in the renewable market across the European Union in 2020. Sadly, no country in the region managed to surpass the 30% threshold. Overall, these findings highlight the pressing need to address gender disparities in the energy transition industry by promoting women's participation in technical fields, fostering gender balance in various roles and ensuring equal pay for equal work. Only through concerted efforts can these gaps be bridged to create a more equitable and inclusive energy transition workforce.

Source: Martínez et al., 2023.

According to modelling estimates by EurObserv'ER (2023), in 2021, **FRANCE** had about 24 900 people engaged in solid-biomass-related jobs, 18 800 in biofuel-related jobs and 14 500 in wind-power-related jobs. This was a change by small margins over 2020. But the number of jobs rose dramatically in solar PV, from 3 600 to 23 300, reflecting a faster pace of installations, which also continued into 2022. The pace of wind capacity additions has been relatively slow, due in part to slow permitting processes. France added just 1.3 GW of capacity in 2021 but gathered speed thereafter, installing a record 2.4 GW in 2022, for a cumulative total of 21.1 GW (IRENA, 2023b).

A detailed assessment by France Énergie Éolienne and Capgemini (2022) suggests that the EurObserv'ER wind jobs estimate is rather conservative. According to this study, there were 25 460 direct and indirect wind-related jobs at the end of 2021, up 12.8% over the 22 600 jobs in 2020. Of the total jobs, 33% were in planning and development, followed by 28% in engineering and construction, 22% in component manufacturing and the remaining 17% in O&M. Close to 30% of all wind jobs are in the capital region around Paris, the Île-de-France, where much of the design and planning work takes place. Five other regions have an at least 10% jobs share each (together accounting for 56% of all jobs). Offshore wind accounts for 6 200 jobs, a quarter of all wind jobs, and these are primarily in Normandy and Pays de la Loire. In March 2022, the government and industry made an offshore wind pact (Pacte éolien en mer) to create 20 000 offshore jobs by 2035, with a view to achieving at least 50% local content.

Regarding regions outside the European Union, the Offshore Wind Industry Council (OWIC, 2023) reports that the **UNITED KINGDOM's** wind power workforce grew to 32 257 in 2022, up 4% from the previous year. This number includes about 17 400 direct jobs and 14 900 indirect jobs. OWIC forecasts that jobs could grow to 88 500 in 2026, as several projects are installed. By 2030, the workforce could grow to 104 400 if the current deployment target of 50 GW (almost double the 2022 capacity) is fulfilled. Some 56 300 jobs would be direct and 48 100 indirect. However, this projected growth needs to be supported by a skill strategy to bridge shortages of planners, technicians for high-voltage electrical works, engineers, turbine technicians and other skilled personnel. Women represent 20.6% of the current workforce, inching up from 16% in 2019, 18% in 2020 and 19.3% in 2021. Regionally, 29% of the UK's offshore wind workforce is in Scotland, followed by Yorkshire and Humber (16.4%), London (15.2%) and the North East and North West regions of England (about 11% each). The remaining parts of the country have much smaller shares.



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A study by Robert Gordon University (2022) argues that significant investments are needed to secure and expand renewable energy jobs. The most ambitious of four scenarios to 2030 entails GBP 17 billion in investments in manufacturing and deployment of wind, hydrogen, and carbon capture and storage. With skill transferability relatively high, close to 14 000 oil and gas workers may need assistance with reskilling and skill certification in transitioning to renewables.

Another study (Platform, 2022) examines the clean job creation potential (in offshore wind, hydrogen electrolysers and energy efficiency retrofitting) in four areas in eastern Scotland and England that now have significant oil-and-gas-related employment: Aberdeen and Aberdeenshire, Fife and Tayside, Tyneside and Teesside. It finds that by 2032, these areas could have between 97 800 and 138 900 jobs, of which 30 500–38 300 would be in offshore wind.

The report notes that the United Kingdom has so far created fewer offshore wind jobs than expected, mostly because components like foundations,[20] towers, nacelles and others are largely imported. Newly opening factories signal the beginnings of a bigger domestic supply chain, and public investment could reinforce this as the pipeline of projects exceeds operational capacities eightfold.

2.2 OTHER COUNTRIES

In West Asia, **TÜRKIYE's** new solar PV capacity installations reached a new record of 1.6 GW in 2022, but wind additions were at less than half the pace in 2021 (IRENA, 2023b). A key objective has been to boost the share of renewable energy equipment produced domestically. Türkiye has adopted tariffs and anti-dumping rules to limit imports, and it offers tax incentives for domestic module production. The country now has more than 60 module companies. Further, a number of large companies in industries such as textiles are setting up module production lines to supply their own needs (Gifford, 2023). IRENA estimates 26 000 solar PV jobs and 13 000 wind energy jobs in Türkiye.

In East Asia, **JAPAN's** cumulative solar PV capacity reached 78.8 GW in 2022. This is the third-largest capacity of any country worldwide, but new additions (4.6 GW) continue to be substantially below the record of 7 GW achieved in 2019 (IRENA, 2023b). IRENA estimates some 127 000 solar PV jobs in 2022,[21] when foreign-produced modules accounted for 90% of total shipments (JPEA, 2023).

Japan has about 4.4 GW of wind capacity. Almost all of it is onshore and is growing slowly. The country recently established its offshore wind presence in December 2022 (IRENA, 2023b). Japan adopted a goal of 10 GW of wind capacity by 2030 and 30–45 GW by 2040, with a 60% local content share by 2040. Input-output analysis suggests that reaching 7 GW by 2030 could create 54 000 jobs (of which 20 000 are direct and 34 000 indirect) in the construction of wind farms, and reaching 36 GW by 2040 could create 69 000 jobs. O&M could have about 4 560 jobs by 2030 and close to 18 000 jobs by 2040. However, appropriate measures will be required to train an adequate number of people in the required skills (Renewable Energy Institute, 2022).

Among **Southeast Asian** countries, Viet Nam, Malaysia and Thailand are leading solar PV cell and module manufacturers and exporters. They have also installed the largest PV generating capacities in the region, together with the Philippines. The PV footprint remains much smaller in the rest of the region (see Table 4). Malaysia, as a key module manufacturing hub, is home to nearly 45 000 solar PV jobs, whereas domestic installations have remained limited. For Thailand's solar PV manufacturing sector, IRENA estimates employment opportunities at over 29 000 people.

Table 4 Solar photovoltaic generating and manufacturing capacities in Southeast Asia, 2022

	PV generation capacity (MW)	PV manufacturing capacity (GW)			
		Polysilicon	Wafer	Cell	Module
Viet Nam	18 474	–	12.5	14	29.65
Thailand	3 060	–	–	9.35	6.2
Malaysia	1 933	11	1.2	23.6	13.9
Philippines	1 625	–	–	0.4	0.8
Singapore	572	–	1.8	2.9	3.7
Cambodia	456	–	–	1	2.2
Indonesia	291	12	–	1	2.05
Myanmar	103	–	–	–	–
Lao PDR	34	–	–	–	–

Sources: IRENA, 2023b (generating capacities); Yu and Dong, 2023 (polysilicon); Wood Mackenzie, 2023a (other manufacturing capacities).
Note: GW = gigawatt; Lao PDR = Lao People's Democratic Republic; MW = megawatt; PV = photovoltaic.

VIET NAM is a major manufacturer and exporter of PV cells and modules. Its cell production capacity rose from just 50 MW in 2013 to 12.5 GW in 2021, while module production capacity increased from 110 MW to 29.65 GW over the same period. Module output, meanwhile, soared from 22 MW to 11.4 GW (Wood Mackenzie, 2023a). However, domestic deployments have fluctuated dramatically. Following a massive surge in PV installations, new additions in 2021 came to a standstill due to power transmission bottlenecks, and in 2022, at 1.8 GW, were still much smaller than in 2019 and 2020 (IRENA, 2023b). The government now eyes adding only 4 GW by 2030, although distributed solar PV could grow significantly since it is not subject to grid connection limitations (Wood Mackenzie, 2023c). With a decrease in installations, Viet Nam's solar PV workforce declined to about 115 000 jobs in 2022, according to IRENA estimates. The jobs were predominantly (69%) in module, cell, inverter and wafer manufacturing. Viet Nam's wind additions were still strong in 2021, at 3.6 GW, but slowed considerably in 2022, to 0.5 GW (IRENA, 2023b). IRENA estimates that Viet Nam may have 9 000 wind jobs.

Indonesia, Malaysia, Thailand and the Philippines are large biofuel producers. Despite rising palm oil prices in 2022, **INDONESIA** maintained its 30% biodiesel blending mandate. Continued subsidies and tax incentives for flexible-fuel vehicles were expected to boost domestic consumption by 10% over that in 2021. Exports remain limited due to export levies and EU import policies imposing sustainability criteria. Production was estimated to rise to a record 10.3 billion litres in 2022, up 8% over 2021 (USDA-FAS, 2022c). Based on an employment factor calculation, IRENA estimates biodiesel employment to have risen to 619 000 jobs in 2022, up from 574 000 in 2021. This figure may not necessarily represent full-time and formal employment, however.

MALAYSIA's biodiesel production in 2022 was projected at 1.15 billion litres, the third straight year of decline and 35% below the 2019 peak. Less than half of the country's production capacity is utilised. The government had intended to introduce a biodiesel blending mandate (B20) in 2020 to counter high gasoline and diesel prices, but implementation had to be postponed repeatedly due to COVID-19 impacts, volatility in crude palm oil prices, political uncertainty and fiscal constraints affecting the government's ability to provide biodiesel subsidies. Exports rose, but prospects in the primary market in Europe are dim, given the EU's decision to limit the use of palm biodiesel (USDA-FAS, 2022d). IRENA estimates that the biodiesel sector accounted for about 66 600 jobs in 2022, down from 106 200 in 2019.

In the **PHILIPPINES**, ethanol and biodiesel production both grew somewhat in 2022. However, there has been no move to require higher blend rates (USDA-FAS, 2023a). An estimate by IRENA suggests biofuels may employ close to 45 000 people.

THAILAND's ethanol production remains below the 2019 peak, and biodiesel output has declined for the past three years. Total biofuel consumption fell by 7.8% primarily due to reductions in biodiesel use, which more than offset the growing ethanol demand. The government reduced the mandatory biodiesel blend rate from 10% to 7% at the beginning of 2022 (USDA-FAS, 2023b). IRENA estimates 97 100 biofuel jobs in Thailand in 2022, down from a revised figure of 115 400 in 2021.

In the Pacific, **AUSTRALIA's** government launched the Australian Energy Employment Report in January 2023, the country's first national energy workforce survey to improve understanding of the needed policies for job and skill development, provide support for energy transition pathways, generate a snapshot of workforce diversity, and improve workforce planning and industry investment (Department of Climate Change, Energy, the Environment and Water, 2023).

Researchers at the Institute for Sustainable Future estimate Australia's transition to 82% renewable energy in power generation – the government's aim – will require up to 30 000 workers to build solar and wind farms, rooftop solar and associated infrastructure like transmission lines. These jobs will predominantly be in project development and construction and, increasingly, in O&M. A dedicated skill strategy is required to build this workforce, although there already are shortages of engineers, electricians and transmission line workers today (Briggs and Langdon, 2022).

Another study, commissioned by the Future Battery Industries Cooperative Research Centre (FBICRC, 2021), finds that the battery industry currently employs about 6 000 people, although mostly in the mining of the needed raw materials. A continued focus on the mining segment of the value chain could expand the number of jobs to 18 700 by 2030. However, a greater focus on material processing, battery manufacturing and assembly, associated services, and end-of-life reuse and recycling could support 34 700 jobs in Australia.

The Australian government is actively building a renewable energy workforce. This includes the convening of a Jobs and Skills Summit, and commissioning Jobs and Skills Australia to conduct a capacity study for the workforce needed for a clean energy transition. The Clean Energy Council, meanwhile, released a report titled Skilling the Energy Transition with key recommendations such as anticipating workforce needs, better calibration between the higher education and vocational training sectors and the industry, increasing the visibility of clean energy jobs and establishing a Transition Authority (Clean Energy Council, 2023).

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In the Western Hemisphere, hydropower asserts its dominance as the foremost employer within **CANADA's** renewable sector, sustaining a substantial workforce of 28 800 in direct roles and bolstering an additional 15 500 jobs indirectly in 2020. IRENA's hydropower estimates (see Section 1.3) suggests over 35 000 direct jobs in 2022. Solar PV ranked next with 13 000 individuals in direct positions throughout 2022. The bioenergy sector was pivotal in employment, encompassing approximately 4 700 direct jobs, of which 1 300 were specifically attributed to liquid biofuels. Trailing behind, the wind sector contributed 3 600 direct jobs (Energy and Natural Resources Canada, 2023).

MEXICO added close to 1.2 GW of solar PV capacity in 2022, resulting in approximately 19 000 jobs in the sector. The wind market was relatively stagnant, with only about 160 MW added (IRENA, 2023b). The country, however, has become the primary wind blade supplier in the Western Hemisphere, with manufacturing capacity growing from 2.1 GW to 2.6 GW over 2021–2022. The United States' manufacturing capacity, by contrast, declined from 8.3 GW to 3.1 GW, while capacities in Brazil and Canada stagnated at a combined 3.9 GW over the same period (Lico, 2022b). The Mexican Wind Energy Association estimated 6 933 wind jobs in 2021 (the most recent year for which data were available), of which manufacturing accounted for almost two-thirds (AMDEE, 2022). A more vibrant domestic market could create some 29 000 jobs between 2022 and 2026, according to the Global Wind Energy Council (GWEC, 2022).

NICARAGUA's power generation sector has grown remarkably in recent years due to substantial public and private investments at the national level. The country has been able to meet its power demand through a substantial improvement in electricity coverage due to expanded installed capacity. There has been a significant push for renewable sources in the national energy mix. In the past decade, the country's installed renewable capacity increased from 550 MW to 743 MW (IRENA, 2023b). Nicaragua's progress can be attributed to its abundant natural resources and strategic geographical location, but also to the established legal framework to further encourage investments. This resulted in 8 400 direct jobs in 2022 across biomass, geothermal, solar PV, wind and hydropower.

In **COLOMBIA**, ethanol and biodiesel production in 2022 were estimated to have decreased to 360 million litres and 700 million litres, respectively, despite rising transportation fuel demand. This was due to adverse weather conditions and a decision to reduce blend mandates. Ethanol production fell for a fourth consecutive year and was estimated at 24% below the 2018 peak. Meanwhile, biodiesel production had risen year after year, but fell slightly in 2022 (USDA-FAS, 2022b). A rough employment factor calculation suggests that among those deriving a livelihood from biofuels (not necessarily full-time equivalents), about 82 000 are in ethanol-related jobs and 104 700 in biodiesel-related jobs. The combined total of 186 700 jobs is about 6% less than a revised estimate of 198 150 for the year 2021.

In **SOUTH AFRICA**, cumulative direct employment through the Renewable Energy Independent Power Producer Procurement Programme is estimated at 69 554 job-years. Of that, some 49 422 job-years, close to three-quarters, are in construction, a sector that offers employment only for a limited period, often low-skilled jobs, with limited cross-links to other sectors of the economy. The remainder, some 20 132 job-years, were in O&M roles. Women have a mere 16% share in all jobs, though up from a 10% share a year earlier. More than 60% of employment is in the Northern Cape region. The Eastern Cape and Western Cape together have close to a quarter share, whereas numbers are much smaller elsewhere (IPPPP, 2023). Aside from deployment-related jobs, South Africa has some solar and wind manufacturing capacity (which is although hampered by weak competitiveness with foreign producers and insufficient and variable local demand) (USAID and Power Africa, 2022).

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INDUSTRIAL POLICY INITIATIVES

CHAPTER 3

Equipment manufacturing for the solar photovoltaic (PV) and wind energy industries is highly concentrated in a few countries, as is much of the associated employment. However, these structures are in a state of flux due to corporate policies seeking locations with low labour costs for factories and government policies trying to localise or re-localise manufacturing operations. This section discusses the current geography of solar PV and wind equipment manufacturing and sketches recent industrial policy initiatives in several countries, which may change the geography of renewable energy employment.

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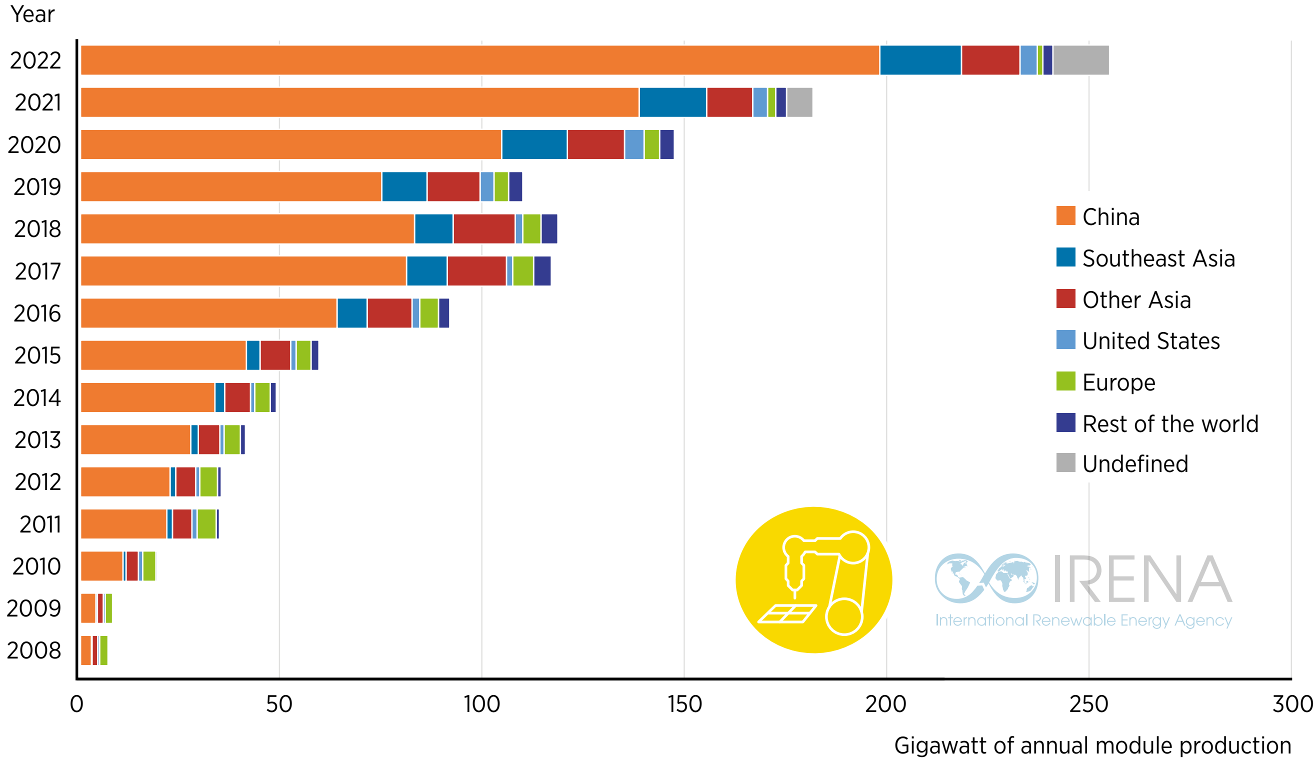
3.1 THE GEOGRAPHY OF SOLAR PV AND WIND EQUIPMENT MANUFACTURING

Global annual **solar PV module production** has multiplied 38-fold over the past 15 years, growing from 7.2 GW in 2008 to 271 GW in 2022. Production jumped from 193 GW to 271 GW in 2022 alone. Meanwhile, it is worth noting that a large portion of capacity sits idle; less than half has been utilised in recent years, down from as much as 83% in 2017 (Wood Mackenzie, 2023a).

Even more than is the case for installations, the centre of gravity in manufacturing shifted from Europe to China, with obvious implications for where jobs are created. In solar PV manufacturing, China's share of global module production doubled from 39% in 2008 to 78% in 2022. While China continues to expand its own manufacturing capacity, trade restrictions adopted in past years have led Chinese manufacturers to invest in module factories in Southeast Asia that essentially assemble Chinese-made PV cells for export (Yu and Dong, 2023). Southeast Asia's share of global module production rose from 2% to 11% in 2020 (but fell to 8% in 2022).

Only minimal manufacturing is taking place in other regions of the world. Europe's share plunged from 30% to 0.5% over 2008-2022, Japan's dropped from 11% to 0.2% and that of the United States dropped from 6.8% to 1.7% (see Figure 13) (Wood Mackenzie, 2023a). China holds an even more dominant position in wafer, cell and polysilicon production, with 97%, 84% and 83%, respectively, of the global production in 2022 (Yu and Dong, 2023).

Figure 13 Solar photovoltaic module production by country/region, 2008-2022



Source: Wood Mackenzie, 2023a.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Notwithstanding rising trade tensions, the value of China's solar PV exports (mostly modules, with Europe as the principal buyer) grew 64% in 2022, from USD 32 billion to USD 52 billion. This reflects the country's dominant position and the fact that its modules are up to 57% more affordable than those produced in the United States or Europe. China's principal cost advantage lies in its lower material costs; while labour costs are also lower in China, they contribute only about 10% or so to overall costs (Yu and Dong, 2023).

Regarding **wind equipment manufacturing**, Chinese firms have primarily produced for their own sizable domestic market, whereas European companies have dominated markets outside of China. Global competition is, however, set to grow, and this will strongly affect the geography of job creation in the industry. Cost pressures will likely lead to increased automation in blade manufacturing, affecting labour requirements (Lico, 2022b).

Global orders for "completed and firm" wind turbines grew from about 64.4 GW in 2020 to 104.8 GW in 2021, declining slightly to 100.9 GW in 2022. Chinese manufacturers managed to increase their share of global orders from 39% in 2020 to 59% in 2022. All other companies saw a reduction in 2022, from 54.1 GW to 41.1 GW (Wood Mackenzie, 2023b). Chinese firms benefit from stable long-term policies and demand certainty at home, and they have significant economies of scale along the supply chain segments (Lico, 2022a).

Meanwhile, European firms, which have long been the technology front runners, are facing several pressures, including, among others, rising raw material costs, skyrocketing logistics costs and port congestion, higher-than-expected costs of developing new turbines and lingering COVID-19 impacts (Lico, 2022a). In recent years, European equipment manufacturers have closed less profitable plants and outsourced production, especially of blades,[22] to low-wage countries (such as Brazil, India, Mexico and Türkiye) (Lico, 2022a, 2022b).

[22] *Only a third of onshore blades and half of offshore blades worldwide were produced in-house by original equipment manufacturers in 2021, down from 50% and 80%, respectively, a decade earlier (see Lico, 2022b).*

At the same time, an increasing number of countries have adopted domestic content requirements to incentivise or mandate the establishment of factories on their own territories, serving domestic, regional or global markets (David, 2021). For gearboxes and generators, India and Eastern Europe are positioning themselves as alternatives to dominant Chinese suppliers. All European suppliers of drivetrains have set up factories in low-wage Asian countries and invested in automation to reduce labour costs (Lico, 2022d).

China leads the world in terms of overall wind manufacturing capacity. According to the Global Wind Energy Council (GWEC, 2023), China had 60% of total 163 GW nacelle capacity in 2022, followed by Europe (19%), the United States (9%), India (7%) and Latin America (4%). China is adding over 60 nacelle assemblies to about a 100 already in operation (White, 2023).

China commands a 60% share also in blade manufacturing, followed by Europe (14%), India (11%), and the United States and Latin America (7% each). The distribution of other component manufacturing follows a similar pattern, except generators, where Europe still retains a 22% share. Three-quarters of gearbox manufacturing takes place in China, with the rest divided between Europe and India (GWEC, 2023).

Meanwhile, supply chains for towers are fragmented, with over 240 factories in 30 countries owned by 100 different suppliers (Lico, 2022c). However, growing regionalisation reflects high logistics costs for ever taller towers and is reinforced by tariffs and local content rules. Corporate outsourcing strategies are driven by cost control objectives amid rising competition and ongoing global oversupply. Chinese manufacturers (which supplied 87% of offshore towers in 2021) benefit from lower steel costs besides significant scale advantages to gain an edge over US and European suppliers. Between 2017 and 2020, EU tower production dropped 10%, while imports from China increased by 54% (Lico, 2022c). This prompted governments to impose tariffs[23] and domestic content requirements. For onshore towers, tariffs led to a shift in supply chains towards Indonesia, the Philippines, the Republic of Korea and Viet Nam.

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[23] The United States imposed high tariffs on towers imported from Spain and Viet Nam but much lower tariffs on towers imported from Canada, Indonesia, Malaysia, the Republic of Korea and India (see Lico, 2022c).


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3.2 INDUSTRIAL POLICY INITIATIVES AMID A NEW GEOPOLITICS

Policy making regarding the global renewable energy supply chain landscape is shifting due to a growing concern that reliance on distant supply chains – which involve a handful of dominant players – entails vulnerability to disruptions such as pandemics and other disasters. Diverging national strategies and corporate objectives, trade disputes and geopolitical rivalries have added to a sense of upheaval.

Indeed, the narrative has changed dramatically. Just a few short years ago, the dominant view was that solar PV panel and component manufacturing was essentially a commodity business that was best offshored to countries with low wages and other cost advantages.

While outsourcing to low-wage locations continues, the rising geopolitics of the energy transition has generated a new determination to "re-shore", "near-shore" or "friend-shore" a greater share of manufacturing capacities, as well as critical material supplies (IRENA, 2023e).

In a bid to build and strengthen local capacities, governments are re-embracing previously disavowed industrial policy measures (besides tariffs and non-tariff import restrictions, which have already increasingly been adopted in recent years). Such policies, which entail both incentives and mandates, may include, among other measures, local content requirements; manufacturing clusters; tax credits, subsidies, grants and loan guarantees for manufacturing; public research and development funds, and technology transfer policies; inexpensive electricity and land; and the creation of market demand.

Writing in a broad, economy-wide context, Mazzucato (2022) has argued that governments should "raise the bar" on expectations from the private sector in return for public funding. She suggests four types of conditions for public procurement, grants, loans and tax incentives: broad affordability and equitable access; social and environmental standards; adequate sharing of royalties, equity or intellectual property with the government; and a prohibition of the use of public funds for share buybacks.

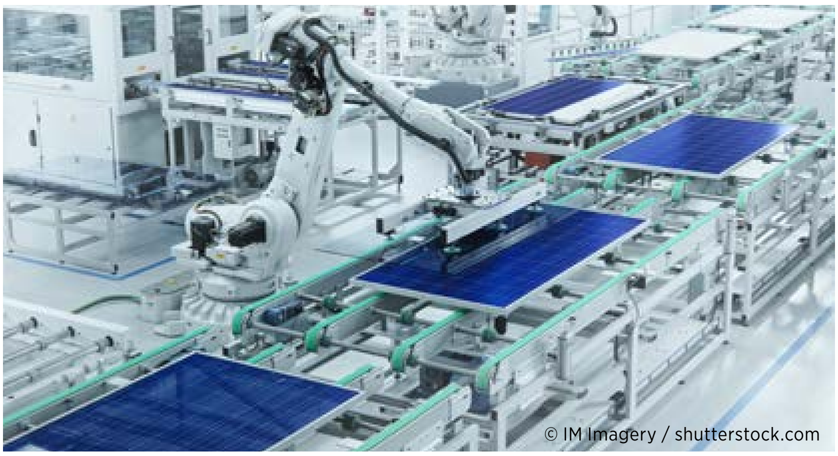
China has successfully pursued a broad array of industrial policies for several years, building a fully integrated wind and solar manufacturing industry. More recently, other countries are also prioritising efforts to localise or regionalise portions of the supply chain to reduce energy security vulnerabilities and also capture a greater portion of the socio-economic benefits of the energy transition. Japan, the United States, the European Union, India and South Africa, among others, have announced industrial policy initiatives to stimulate domestic manufacturing and become more competitive vis-à-vis Chinese suppliers.

Meanwhile, it is worth noting that current industrial policy initiatives will not fundamentally change the renewable energy manufacturing landscape for some years, since that requires substantial time and resources to establish the needed capabilities at the necessary scale. China will thus continue to host most renewable energy jobs for the foreseeable future. Further, in solar PV, China hinted in January 2023 at its possibility of imposing export restrictions on wafer, silicon and ingot casting technologies, complicating other countries' plans to expand their solar manufacturing capabilities (Martinez and Pierce, 2023).

Among the countries that have announced industrial policy initiatives, **Japan** seeks to establish its own manufacturing base for offshore wind through its "Programme for Promoting Investment in Japan to Strengthen Supply Chains" (GWEC, 2023), which will mandate developers to work with local companies and demonstrate local and national economic benefits. These two dimensions will account for one-fifth of the combined bid scores under the country's first offshore tender (Diao, Li and Wang, 2022).

India's industrial policy efforts have focused on solar PV. As shown by Garg and Jain (2022), Indian solar PV developers have preferred low-cost imports to domestic products, and solar manufacturers pay higher interest rates than project developers. India's solar manufacturing thus lags global technology development by three to five years. The cost of capital and electricity renders domestic production uncompetitive with China. The country continues to rely heavily on not only cell and module imports, but also imports of materials like glass, encapsulant film, backsheets and aluminium framing, as well as the machinery needed for cell and module production. This renders the country vulnerable to supply chain disruptions and price fluctuations, as experienced in 2020–2021 (Gulia *et al.*, 2023).

The Indian government has taken several actions to address this situation. Besides tariffs (a basic customs duty, BCD), non-tariff import restrictions (the Approved List of Models and



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Manufacturers, ALMM) and domestic content requirements, it implemented a production-linked incentive (PLI) scheme for solar PV manufacturing in April 2021 (Gulia *et al.*, 2023).

The BCD is imposed on module imports (40%) and cell imports (25%). Meanwhile, Indian module manufacturers rely heavily on imported cells, eventually paying hefty BCD fees. The ALMM lists over 70 approved domestic manufacturers. However, in March 2023, the government decided to defer its implementation until 2024 when the limited availability of high-quality, high-wattage modules from domestic firms added substantial delays in the completion of solar projects. The PLI provides some USD 2.26 billion in funds to stimulate domestic manufacturing. It triggered a doubling in nameplate capacity for PV modules in 2022–2023, to 38 GW. While only 50–60% of this is presently operational, capacity is expected to expand further to 110 GW by 2026. Cell, ingot/wafer and polysilicon production capacity, however, remains marginal or non-existent (Gulia *et al.*, 2023), with module and cell production being the focus of PLI funding (Yu and Dong, 2023).

An estimated 41 200 jobs in plant operation – on average, some 1 050 jobs per gigawatt – could be created if the government's plan to expand solar PV manufacturing capacity succeeds.[24] However, there has to be a skill-building strategy to address the lack of people with know-how of installing, commissioning and operating such plants (Gulia *et al.*, 2023).

In June 2023, news media reported on a draft proposal for a new PLI incentive, which will offer INR 216 billion (USD 2.63 billion)[25] in subsidies over 2023–2030. The scheme will target companies establishing manufacturing capacity of 50 gigawatt hours of battery energy storage systems for the power grid, and it is hoped that the subsidies will reduce import dependence. The proposed plan mandates the domestic generation of at least 90% of the value (Parkin, 2023).

In the **United States**, the August 2022 Inflation Reduction Act (IRA) provides significant incentives for renewables, including domestic manufacturing. Existing tax credits for solar and wind were extended to 2024 (GWEC, 2023), after which they will be replaced with a Clean Electricity Investment Credit (funded to the tune of USD 50.9 billion until 2031) and a Clean Electricity Production Credit (USD 11.2 billion) for specified renewable energy and storage technologies. The objective will be to reduce annual greenhouse gas emissions from power generation to 75% of 2022 levels. An Advanced Manufacturing Production Credit (USD 30.6 billion) is available for the domestic production of solar and wind energy components, inverters, battery components and critical minerals (Bhutada, 2023).

To qualify for a "domestic content bonus" payment, at least 40% of the overall mining, production or manufacturing cost of all products in land-based clean energy projects or facilities as well as their components must originate in the United States (a lower threshold of 20% applies to offshore wind projects). This threshold would increase to 55% after 2025. Iron and steel used in projects must be manufactured entirely in the United States. Importantly, the IRA also imposes wage and apprenticeship requirements as conditions

[24] *This entails 3 200 polysilicon-related jobs (16 GW), 10 875 ingot/wafer-related jobs (29 GW), 6 825 jobs in cell production (55 GW) and 20 300 jobs in module assembly (58 GW) (Garg and Jain, 2022).*

[25] *Average exchange rate of USD 1 = INR 82.18 in June 2023.*


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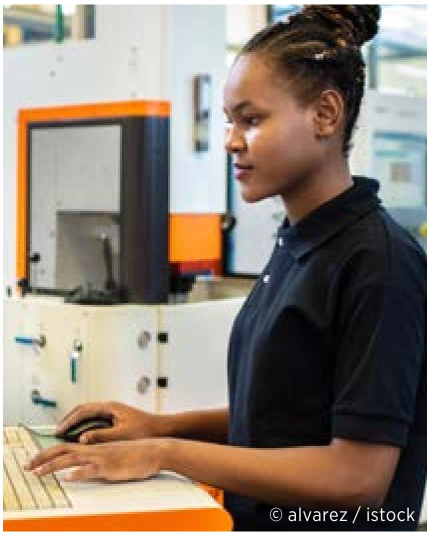
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for some of the incentives (White House, 2023). For a company undertaking a project larger than 1 MW to receive the full 30% investment or production tax credit, it must pay construction labourers either at or above the local prevailing wage. And with a view to promote workforce development, it mandates qualified apprentices to account for 12.5% of work hours in 2023 (increasing to 15% from 2024) (IREC, 2023).

The IRA triggered announcements of 16 new or expanded wind power manufacturing facilities, 18 new solar manufacturing facilities and 8 new grid-scale battery storage manufacturing facilities, with a potential of nearly 14 000 manufacturing jobs (GWEC, 2023). In solar PV, 52 GW of new module manufacturing capacity (9 GW currently in place) and 20 GW of cell capacity (none existing at present) have been announced since the passage of the IRA but will not be fully operational until 2025 or 2026 (Martinez and Chopra, 2023).

While **Europe** has a strong industrial base for wind, the continent has very limited PV manufacturing capacity, which is falling far short of the annual demand. The European Union had 19 GW of polysilicon manufacturing capacity, 5 GW of module manufacturing capacity and 1–2 GW of wafer and cell manufacturing capacity in 2022 (Yu and Dong, 2023).

In March 2023, the European Commission proposed a Green Deal Industrial Plan. This was motivated by China's dominant position in solar PV manufacturing and in minerals critical to the energy transition, as well as by initial concerns that subsidies offered by the US IRA may discriminate against foreign companies and would draw renewable energy and electric vehicle manufacturers across the Atlantic (Chazan, 2023). The Commission's objective is to scale up clean technology manufacturing in the European Union, so that the related[26] manufacturing capacity approaches or is able to fulfil 40% of the deployment needs by 2030. One key measure is a streamlining of regulations to speed up project permitting. Another measure is a relaxation of strict rules governing state aid for capital investments in low-carbon projects (Carbon Brief, 2023).

[26] *The Commission's list of eight "strategic net-zero technologies" includes solar power and solar thermal, onshore and offshore wind power, batteries and energy storage, heat pumps and geothermal energy, electrolysers and fuel cells, sustainable biogas/biomethane, carbon capture and storage, and grid technologies.*

A proposed Net-Zero Industry Act sets non-binding manufacturing capacity targets and requires member states to apply non-price criteria (environmental sustainability, energy system integration and supply chain resilience) to auction procurement mechanisms.[27] The Net-Zero Industry Act also includes measures to build a skilled workforce (European Commission, 2023a). A Critical Raw Materials Act aims to increase the EU's capacity for domestic sourcing and refinement of such materials, diversify imports and increase the "circularity and sustainability" of raw material use. It aims to speed up permitting processes and meet a quarter of the European demand for strategic raw materials through domestic mining (10%, up from 3% at present) and recycling (15%) (Bourgery-Gonse, 2023). Meeting these targets will not be easy and may clash with environmental protection objectives (Noyan, 2023). A European Critical Raw Materials Board would be established as a new central purchasing agency (European Commission, 2023b).

In September 2022, Germany's Ministry for Economic Affairs and Climate Action (BMWK, 2022) proposed creating a European Platform for Transformational Technologies "to develop and promote the EU's industrial production capacities in five strategically important technologies – wind energy, solar PV, electrolysers, electricity grids and cables, and heat pumps – large and small" (Taiyang News, 2022). Further, the ministry decided to fund a study on the feasibility of restoring a complete solar PV supply chain in Europe, including materials, manufacturing, research and development, and a workforce with the requisite skill sets (Hutchins, 2023).

In **South Africa**, the government responded to the high import reliance by releasing a draft South African Renewable Energy Masterplan (SAREM) for public comment in mid-2023. The Masterplan, which is based on a collaboration among government, industry and labour, seeks to foster industrial development and job creation through value chain localisation for solar, wind and battery storage technologies. SAREM acknowledges that prior efforts to build industrial capabilities for renewable energy have so far yielded mixed results due to stop-start procurement cycles, local content rules that were not well aligned with realities, and inconsistent policies.

Industrial policy measures proposed under SAREM include financial and non-financial interventions to support the growth of black-owned and black-managed businesses (Black Industrialist Programme); preferential-rate loans to support domestic manufacturers (Manufacturing Competitiveness Enhancement Programme); and local development finance institutions' support in enhancing industrial capabilities and stimulation of investment through efforts to reduce infrastructure costs (Critical Infrastructure Programme) (DTIC, 2023).

[27] *In January 2022, new "State Aid Guidelines for Climate, Energy and Environment" had already allowed governments to include up to 30% non-price criteria in selecting winning auction bids. The proposed act now defines these criteria (GWEC, 2023).*

3.3 CRITICAL MATERIALS, ECONOMIC DEVELOPMENT AND COMMUNITY RIGHTS

Besides building or strengthening industrial capacity, policies also highlight the "critical materials" needed to produce solar panels, wind turbines and other energy transition technologies. Countries strive to secure access to supplies as they increasingly compete to gain an advantage in the race towards building cleaner energy economies (IRENA, 2023e). As highlighted by a recent *Financial Times* report, this represents a sharp turnaround: "For decades, developed economies shunned these sorts of industrial activities, content to offshore the environmental damage to the developing world where costs would also be lower" (White, 2023).

However, this new race for resources may not offer much in the way of lasting socioeconomic benefits for resource-rich countries in Africa, Asia and Latin America. At present, many do not possess the capacity to refine raw materials into processed inputs. The risk is that they will once more be relegated to the role of commodity suppliers, dependent on unpredictable commodity markets for price setting and unable to create jobs and value further downstream. There also need to be safeguards to ensure that the race for materials does not translate into a race to the bottom, in terms of environmental degradation and burdens imposed on workers and local communities.

In January 2023, several organisations jointly launched an Africa Renewable Energy Manufacturing Initiative to scale up manufacturing capabilities on the continent and create substantial employment. Doing so would require sustained efforts in skill training and career development for engineers, technicians and others, besides measures to attract manufacturers and incubate African manufacturing projects (Bloomberg Philanthropies, 2023).

A related report by Sustainable Energy for All (SEforALL, 2023) identifies countries with the highest feasibility for such an approach. The report suggests that among the key success factors are sufficient demand, manufacturing scale, political stability, appropriate policies and regulations, trade relations with China (as the leading force in the sector and with strong foreign direct investment in the region), supporting infrastructure and the ability to export. The African Development Bank has launched an "Industrialise Africa" initiative to support such efforts, providing USD 300 million in financing (SEforALL, 2023).

A number of resource-rich countries are seeking to exert greater control over minerals critical to the energy transition. The objective is to retain a higher share of the socioeconomic benefits and avoid becoming locked into the role of raw material suppliers. According to an analysis of the Organisation for Economic Co-operation and Development (OECD, 2023), the number of export restrictions on critical raw materials worldwide grew fivefold since 2009.

The Plurinational State of Bolivia and **Mexico** have nationalised their lithium industries, while **Zimbabwe** introduced a ban on raw lithium exports (Stott and Bryan, 2023). **Indonesia** has since 2014 banned exports of unprocessed nickel ore and succeeded in attracting foreign direct investment for building a domestic smelting industry. The country also restricted exports of bauxite, an aluminium precursor, and a ban on copper concentrate exports is to take effect in 2024 (Hook, Dempsey and Nugent, 2023). Indonesia and the **Democratic Republic of Congo** have also adopted export restrictions on materials used in lithium-ion batteries (Crooks, 2023). In the Democratic Republic of Congo, a second copper smelter is under construction (Hook, Dempsey and Nugent, 2023).

In early 2023, **Chile's** government announced plans – subject to Congressional approval – to negotiate a majority stake in the country's two existing lithium projects. The negotiation is to be through the state-owned companies Codelco and Enami initially and later through a proposed national lithium company. Policy objectives include developing local value chains, increasing wealth retained within the country and establishing stricter environmental rules concerning the water-intensive process needed to extract lithium from salt flats. The environmental rules are to be established in consultation with local communities (Government of Chile, 2023). Chile is offering preferential prices for lithium carbonate to firms investing in domestic value-added projects. Examples of such firms include China's BYD, which plans to build a lithium cathode factory that could employ 500 people (Hook, Dempsey and Nugent, 2023).

In June 2023, **Namibia** decided to ban the export of unprocessed materials including lithium, cobalt, manganese, graphite and rare earths such as dysprosium and terbium in order to retain a greater share of the wealth generated from their use (Reuters, 2023).

While stepping out of a raw material supplier role can support a country's national economic development, it requires more than industrial policy to ensure equitable outcomes from this role transition. For example, as noted by the Business & Human Rights Resource Centre (Pouhe and Gwanyanya, 2023), violations of communities' land rights and livelihoods (including lack of consultation, evictions, unjust resettlements and inadequate compensation), as well as abuses of labour rights and human rights violations, have been recorded around several transition mineral mining projects as well as some renewable energy installations. Further, local protests and lawsuits have led to some planned projects being suspended. Meanwhile, better approaches and business models are beginning to emerge. Pouhe and Gwanyanya (2023) argue in favour of three core principles: co-ownership models that generate buy-in from workers and communities; human rights due diligence and social protection, with an emphasis on worker (re-)training and decent work; and free, prior and informed consent in negotiations with local populations, especially indigenous communities.

CHAPTER 4

PERSPECTIVES AND ACTIONS FOR A JUST TRANSITION

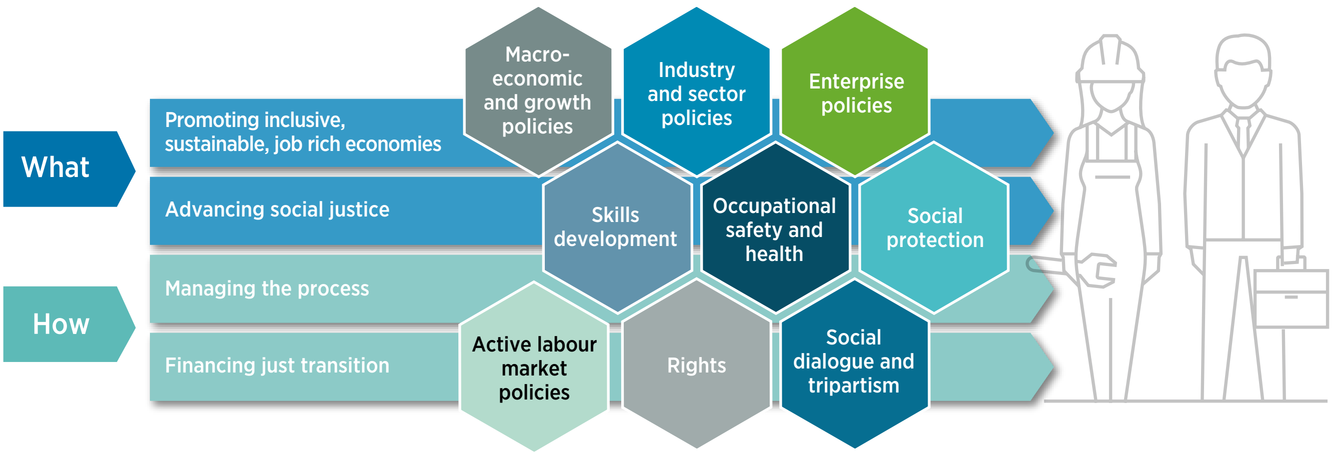
Previous editions of this report have emphasised that job quality matters just as much as job quantity, and that the transition from a fossil-fuel-dominated energy sector to a cleaner energy future needs to be just and inclusive in relation to workers and communities. This outcome requires not only foresight and comprehensive policies, but also meaningful social dialogue involving governments, private companies and business associations, labour unions and other stakeholders.

Based on its tripartite structure involving governments, businesses and organised labour, in 2015 the International Labour Organization developed guidelines for a just transition (ILO, 2015). At the June 2023 International Labour Conference, tripartite representatives reaffirmed the urgency of action to advance a just transition to achieve social justice, decent work and poverty eradication, and tackle environmental and climate change. The conference declared that "A just transition promotes environmentally sustainable economies in a way that is inclusive, by creating decent work opportunities, reducing inequality and by leaving no one behind" (ILO, 2023).

To accelerate and scale up the implementation of the 2015 guidelines, the International Labour Conference elaborated a coherent and practical framework for action based on four building blocks: (1) promoting inclusive, sustainable and job-rich economies; (2) advancing social justice; (3) managing the just transition process and (4) financing a just transition (see Figure 14).

This section discusses perspectives and actions by the tripartite stakeholders.

Figure 14 ILO guidelines for a just transition: A framework for action



Source: ILO, 2023.

4.1 GOVERNMENTS' PERSPECTIVES AND ACTIONS

Several countries have recognised the need for a just energy transition and are leveraging this unique opportunity to rebuild economic structures by generating jobs and income, promoting social justice, restoring natural capital and reducing environmental impacts. Renewable energy investments create jobs in equipment manufacturing, installations, and operation and maintenance, while energy efficiency programmes for buildings, transportation and industries create jobs in areas such as energy auditing, retrofitting and the manufacturing of energy-efficient technologies. A number of actions can ensure that the transition to a clean energy future is jobs rich and just (see Box 5).

Box 5
Policy elements to ensure plentiful, decent jobs

1 Workforce training and education initiatives to equip workers with the skills needed for renewable energy jobs.

2 Just transition policies to support workers and communities affected by the clean energy transition through retraining assistance, income support and job placement assistance, as well as assistance with infrastructure development, community projects and economic diversification efforts.

3 Engagement with labour unions, industry stakeholders and community organisations to develop collaborative strategies to ensure that workers' concerns and interests are accounted for while planning and implementing clean energy initiatives.

4 Green job creation targets for a clear focus on employment generation and drive policy efforts to achieve those targets.

5 Local and regional economic development initiatives to promote the establishment of renewable energy industries, attract clean energy investment and foster innovation in clean technologies.

6 Inclusive decision-making processes with inputs from diverse stakeholders to address the needs and perspectives of different communities and promote social equity.

7 Support for small and medium enterprises as job creators through financial incentives, capacity-building programmes and procurement policies.

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For example, the governments of South Africa and Spain have adopted several policies in this vein. The **South African** government, after submitting its Nationally Determined Contribution towards achieving the Paris Agreement's goals in 2021, launched the Just Energy Transition Investment Plan (JET IP), which is to be implemented between 2023 and 2027. This plan outlines a USD 98 billion investment in renewable energy, electric vehicles and green hydrogen, and includes provisions for social and economic development such as job creation, skill development and community empowerment. While the government's policy on just energy transition is still evolving, it nevertheless reflects the government's determination to diversify its energy mix and ensure that the transition to a low-carbon economy contributes to its efforts to tackle inequality, poverty and unemployment (ITJ, 2022).

It is crucial to recognise, however, that relying exclusively on funding from the JET IP will fall short of fulfilling the investment needs for a fair transition towards sustainable energy for each recipient. South Africa's JET IP agreement will contribute less than 10%, totalling USD 8.5 billion, in funding. Further, a mere 0.4% of the overall planned amount under South Africa's JET IP will be allocated to boost economic diversification, innovation and skill development. Grants constitute just 4% of the total JET IP funding package, exposing South Africa to risks related to privatisation, which could also be applicable to other beneficiary nations (Gunfaus *et al.*, 2022; IRENA and CPI, 2023).

The **Spanish government** has introduced a set of policies to optimise economic activity and employment prospects in the transition to a green, low-carbon economy, while minimising potential negative social and economic impacts. Known as the Spanish Just Transition Strategy, these policies encompass core objectives, which include boosting competitiveness and addressing social cohesion challenges arising from the economic transition towards ecological sustainability. Opportunities are intended to be accessible and equitable for women, vulnerable populations and rural residents, and labour market status and trends with respect to the green transition are closely monitored. Further, the strategy promotes the establishment of sectoral forums to facilitate collaboration and knowledge sharing. Specific plans for key economic sectors entail thorough analyses of challenges, opportunities and threats, and the formulation of necessary measures for a successful transformation.

The strategy also entails an evaluation and enhancement of the current tools and instruments provided by the General State Administration to support businesses. This support includes, among other factors, provisions for research and development, financing, loans, guarantees and training. Further, the Spanish Just Transition Strategy proposes suitable policies to support co-ordinated efforts among various entities, including the General State Administration, autonomous communities, local authorities and social stakeholders. These policies encompass industrial support, research and development, promotion of economic activity, employment and vocational training. Lastly, the strategy focuses on minimising adverse impacts in vulnerable regions through the implementation of Just Transition Agreements. It provides technical and financial support for the execution of these agreements, as demonstrated by the Urgent Action Plan, which targets regions that confront closure of coal mining and coal-fired power plants (ITJ, 2022).

To be effectively implemented, policies will have to be well co-ordinated, include all relevant stakeholders and be adequately financed. Managing the transition process will require coherence across policy areas and effective institutional co-ordination to plan and implement changes in accordance with evidence-based monitoring and evaluation frameworks.

Achieving a just transition requires determined policy action that puts a human face on policies and integrates climate and employment targets into a coherent policy framework. A well-designed and progressive climate environmental policy could be beneficial for employment and equity targets. A transition towards climate neutrality can generate net employment, although this varies significantly across sectors.

4.2 EMPLOYER PERSPECTIVES AND ACTIONS

Employer and business membership organisations play a crucial role in driving the renewable energy transition by advocating for supportive policies, promoting investment in clean technologies, and facilitating partnerships between businesses and governments. These organisations understand that a renewable energy transition can create new business opportunities, drive innovation and support economic growth.

For example, the United States Council for International Business participates in international forums such as the United Nations Framework Convention on Climate Change and represents business interests in global climate discussions. The Council launched the initiative Business for 2030 (n.d.) in 2015 to support the 2030 Development Agenda and the Sustainable Development Goals (SDGs). Business for 2030 is a platform to showcase private sector efforts aligned with the SDGs, and features over 200 projects of over 50 companies in more than 150 countries. These projects contribute to 89 of the 169 SDG targets.

In the United Kingdom, the Confederation of British Industry has published reports and policy recommendations highlighting renewable energy's economic benefits. The Confederation also engages with the government and stakeholders to advocate for supportive policies and regulatory frameworks. It has created several toolkits including best practices and practical information for its member companies. The toolkits cover topics like "how to create a culture of sustainability in your business" (CBI, 2023) and "how your business can take action and seize net zero opportunities" (CBI, 2022).

The National Business Association of Colombia (Asociación Nacional de Empresarios de Colombia, ANDI) collaborates with government agencies, industry stakeholders and civil society to develop strategies that support renewable energy adoption and provides businesses with guidance and resources related to sustainable practices and clean energy adoption. In 2014, it launched the Biodiversity and Development Initiative, which aims for greater comprehensive biodiversity management in the country through fostering collaboration among businesses, institutions and local groups as well as investment (ANDI, 2023).

In South Africa, the Business Unity South Africa (BUSA) advocates for policies and regulations supporting the growth of renewable energy sectors. BUSA also collaborates with industry stakeholders to develop skill training programmes and promote job creation in renewable energy. In the domain of sustainable energy and infrastructure, BUSA's specific objectives include, among others, public consultations for a co-ordinated highlevel road map of all pending energy legislation and policies; finalisation of the Integrated Energy Plan and the Integrated Resource Plan with planning transparency; and continuing the Renewable Energy Independent Power Producer Procurement Programme (BUSA, 2023).

The Confederation of Danish Industry (CDI 2016) supports knowledge-sharing platforms and provides resources to help businesses make a renewable energy transition that is fair and inclusive for workers. The CDI actively participated in the negotiations and discussions that led to the 2018 Danish Energy Agreement, which outlines the country's energy and climate goals, including a commitment to transitioning to renewable energy sources and mitigating greenhouse gas emissions. The CDI was crucial in advocating for policies and incentives that support and encourage clean energy investments and facilitate the transition for businesses and workers.

4.3 LABOUR UNION PERSPECTIVES AND ACTIONS

Labour unions contend that investing in clean energy transition technologies will not inherently guarantee the creation and sustainability of good jobs. Unions have concerns about the progress on a just transition in different countries and the lack of union involvement in the process (IndustriALL Global Union, 2021). While social dialogue experiences vary from country to country, fundamentally, a just transition is possible only with social dialogue and a well-organised workforce. Transitions will be challenging but not impossible, and workers must be assured of a just transition for them, their families and communities.

To gain insights on the future prospects of energy sector workers and address unions' concerns, the IndustriALL Global Union, the International Trade Union Confederation and LO Norway launched the Initiative for a Just Transition in the energy sector in 2022. The Initiative had 121 participants from unions in 32 countries and involved information exchange regarding the future of work in the energy sector and on ways in which workers could transfer jobs in the oil and gas supply chain to the renewables sector.

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Unions and experts shared information on jobs, skills, markets, investments and emissions for technologies such as hydrogen, carbon capture and storage, offshore wind and other renewables, alternative fuels and energy services. A subsequent report (IndustriALL Global Union, International Trade Union Confederation and LO Norway, 2022) offered conclusions and recommendations. A series of ten workshops[28] with experts from the International Renewable Energy Agency and the International Energy Agency, energy sector unions and national labour confederations was held between April and October 2022. The workshops focused on the implications of net zero for energy sector jobs. Participants exchanged information on emerging technologies, what the transition looks like in different parts of the world, as well as union strategies for ensuring good jobs and a just transition.

The US Project Labor Agreement – signed between North America's Building Trades Unions and the Danish offshore wind company Ørsted – is a good example of possibilities for renewables sector workers. The Project Labor Agreement was for Ørsted to construct its US offshore wind farms using a unionised workforce. The National Offshore Wind Agreement covers all Ørsted contractors and subcontractors that will construct offshore windfarms along the Atlantic coast.

The agreement is a commitment to build infrastructure that will reduce carbon emissions and create high-wage union jobs. It can be a model for the entire renewable industry as well as for other emerging technologies, where labour standards and environmental performance go hand in hand and where the goal of green jobs being union jobs becomes real.

According to Ørsted, US offshore wind projects could create some 80 000 direct jobs plus many thousands of indirect jobs in manufacturing, maritime work, logistics and clean energy technology (Ørsted, 2022). The training and other provisions of the Project Labor Agreement will help generate a workforce capable of building complex offshore wind energy infrastructure. Ørsted itself has committed USD 23 million to bolster existing efforts or establish new programmes for preparing US workers for offshore wind.


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[28] *The workshops covered the following topics and geographies: hydrogen, onshore and offshore wind, battery and solar photovoltaic, carbon capture and storage; Europe and the Americas; and Australia, Indonesia, Iraq, Japan, New Zealand, Nigeria, South Africa and Spain.*

CHAPTER 5

THE WAY FORWARD: MULTIPLYING CHALLENGES DEMAND NEW THINKING

This tenth edition of *Renewable energy and jobs* documents the continued growth of renewable energy employment, with job numbers estimated to have grown from 7.3 million in 2012 to 13.7 million in 2022 worldwide. The jobs are predominantly in a few countries – China in particular, but also Brazil, India and the members of the European Union – which represent the majority of capacity installations and play key roles in equipment manufacturing, as well as engineering and various services. At present, jobs are unevenly distributed between men and women, and, as pointed out in previous editions, the qualitative aspects of renewable energy jobs, including wages, occupational safety and health, job security and rights at work, demand greater attention.

Renewable energy investments have noticeably increased in volume in recent years. Further accelerating the pace implies that in the coming years and decades, millions of additional jobs will be created. However, this requires a range of accompanying measures, for example, increased efforts to expand education and skill-building programmes; retraining of workers from fossil fuel industries; and greater opportunities for women, youth and minorities to join the renewable energy workforce.

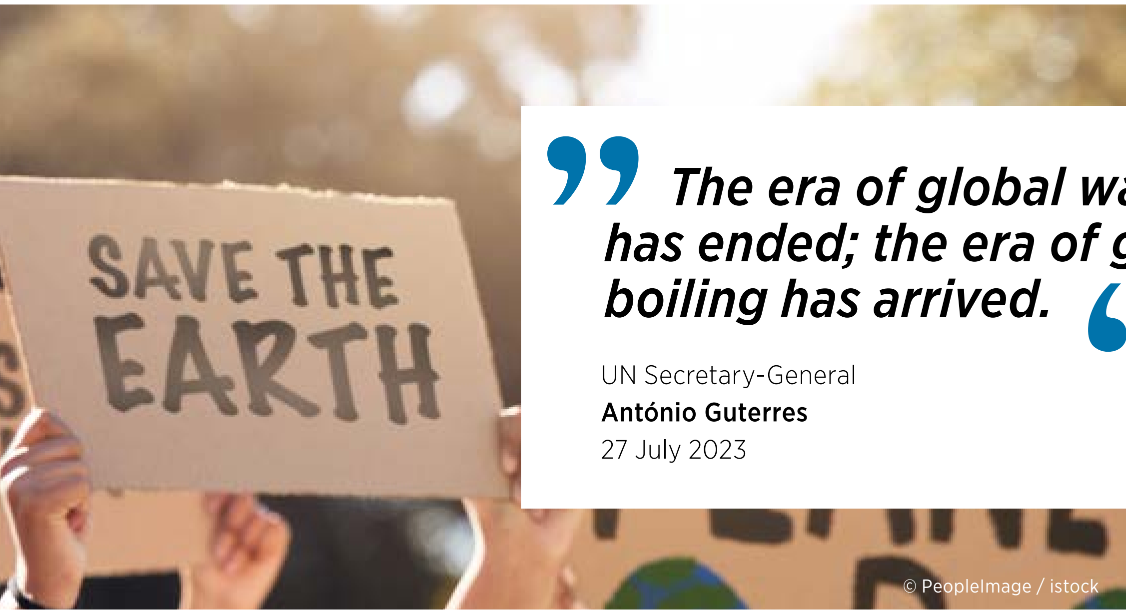
> ***We are on a highway to climate hell with our foot on the accelerator.***
>
> UN Secretary-General
> **António Guterres**
> COP 27, 7 November 2022

Achieving the energy transition in a manner that allows humanity to meet urgent climate and environmental priorities will require significantly accelerated investments and installations. Progress remains highly inadequate. In fact, it is not an exaggeration to say that, for now, the world is experiencing an energy *addition* – with renewables forming another layer on top of the existing, fossil-fuel-dominated system – rather than the needed energy *transition* (Hickel, 2022).

A steady stream of fresh scientific assessments and more frequent extreme weather events lend ever-greater urgency to a fundamental transformation. Yet, geopolitical tensions, trade rows and supply chain disruptions have led governments to become increasingly preoccupied with shoring up energy supplies, including the very fossil fuel sources that humanity has pledged to wean itself off.

Corporations and governments continue to look to economic growth as the remedy to many challenges. Yet an ever-expanding economy requires ever greater energy supply, making the transition even more challenging. And there can no longer be any doubt that endless growth is not possible on a planet with finite resources and capacity to absorb carbon and pollutants. The Earth is already sending unmistakable signals of increasing distress. The latest scientific assessment of nine planetary boundaries (Richardson *et al.*, 2023) finds that six of them have already been crossed.[29] Persisting with the current approach will worsen the situation, threatening a cascade of rising calamities. A destabilised climate system, widespread biodiversity loss and overburdened terrestrial and marine ecosystems form the greatest threats to humanity's well-being and indeed its long-term survival (Hickel, 2022).

[29] *In addition to climate change, they concern biosphere integrity, land systems, freshwater, biogeochemical flows, and novel entities. The remaining three boundaries our ocean acidification, atmospheric aerosol loading, and stratospheric ozone depletion. Richardson et al. (2023).*



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> ***"The era of global warming has ended; the era of global boiling has arrived."***
>
> UN Secretary-General
> **António Guterres**
> 27 July 2023

Also, given the wide – and growing – disparities in wealth and human development between and within countries, it is clear that the current economic approach has failed to bring about universal well-being. Studies show that even for those who are materially well off, growth in material consumption past a certain point does not lead to greater happiness and offers diminishing returns. But maintaining the current economic model under conditions of growing climate and environmental constraints exposes the poorer portions of humanity – principally people in the Global South – to the effects of accelerating resource depletion and renders them increasingly vulnerable to climate shocks.

IRENA's work has long emphasised the importance of ensuring the energy transition delivers broad socio-economic benefits, so that people can have a tangible stake in it, in turn securing popular and political acceptance. The energy transition needs to be embedded within broader systemic changes that aim to ensure a level of human well-being at lower levels of energy and material throughput, advance equity among countries and communities (overcoming historical disparities), and align economies with climate and resource constraints.

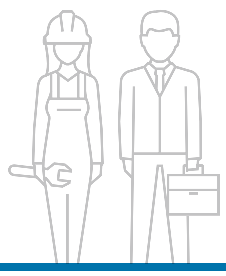
Socially, economically and politically, this transformation is an unavoidable yet most complex task. The increasingly evident limits and contradictions of conventional economics and growth-based paradigms have given rise to an increasingly vibrant discussion of workable concepts and approaches for a more just and inclusive transition and to allow humanity to live within planetary boundaries. For close to a century, GDP has been the accepted yardstick to measure progress, but it suffers from well-documented shortcomings and pitfalls – for example, the inclusion of activities that do not contribute to well-being while excluding others (such as unpaid work, most often carried out by women) that do. Modifications of the GDP, or full-blown alternatives such as Bhutan's gross national happiness index, may measure the economy and human well-being more accurately and could facilitate a different set of socio-economic policies (Hickel, 2022).

> ***We need a renewables revolution, not a self-destructive fossil fuel resurgence.***
>
> UN Secretary-General
> **António Guterres**
> 06 February 2023

Wealthy countries that have consumed the bulk of the world's energy and materials will have to reduce their claim. Greater efficiency can help, but experience shows that the "rebound effect" – cost reductions from improvements in efficiency allow consumers to buy more of the improved product or increase demand for other products – prevents any lasting reduction of overall consumption volumes.

There is thus a need to scrutinise fundamental production and consumption patterns and make an even stronger distinction between human needs and wants. Doing so could create the space needed by people who currently consume less than what is needed for sustaining a decent life. A less consumption-intensive economy would imply a shift in employment away from the extractive sector and manufacturing of disposable goods towards recycling, refurbishing and remanufacturing activities. Energy sector employment would be less extensive than under a conventional trajectory. Societies may thus need to explore new approaches – such as the concept of a universal basic income – to make people's incomes less dependent on unsustainable practices.

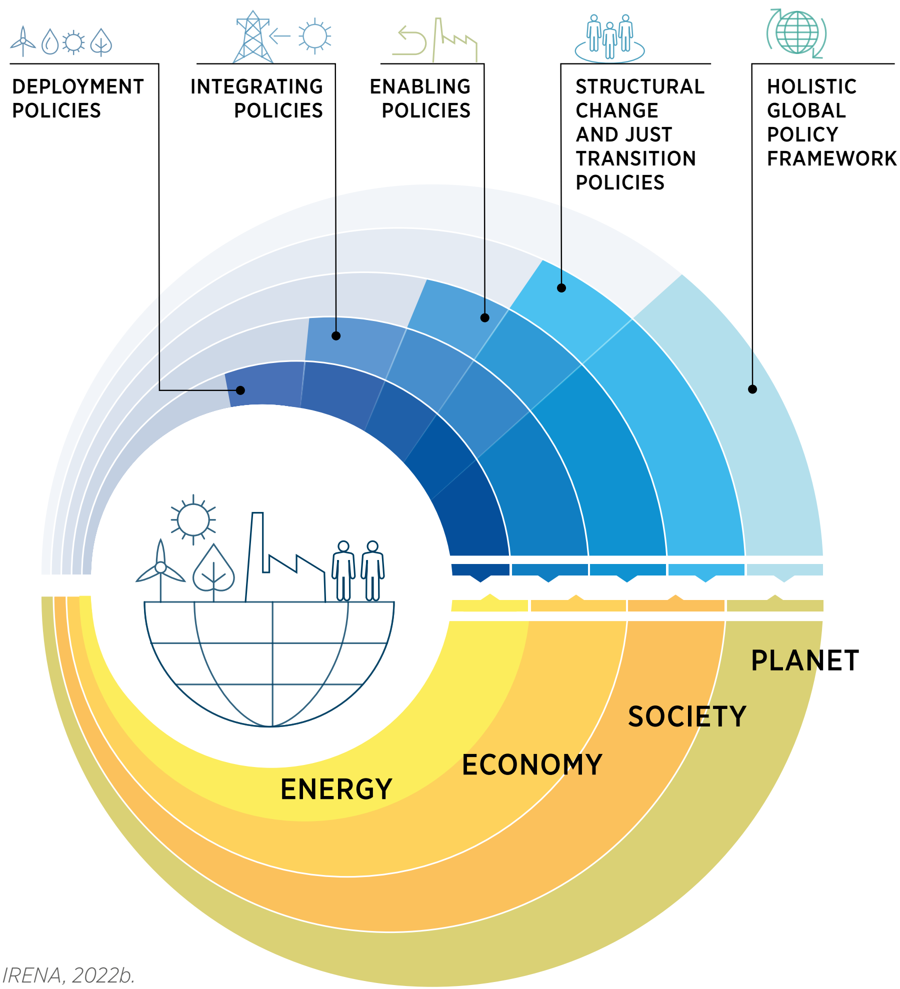
Humanity faces a broad, and potentially conflicting, set of objectives. For one, there is a clear need for a significantly rapid transition away from fossil fuels, in light of the growing climate crisis. However, renewed concern about energy supply security runs high and, to some extent, may reinforce fossil fuel reliance. Further, hundreds of millions of people need to be provided improved energy access, to fulfil the promise of Sustainable Development Goal 7. This concerns not just a need for more ample supplies but also for cleaner energy. Narrowing the vast chasm in energy consumption levels between rich and poor countries also requires re-thinking the excessive energy use in consumer societies. Yet socio-economic inequalities and pockets of energy poverty are growing even within richer societies.



Uncertain socio-economic prospects may strengthen the appeal of political forces that favour parochial approaches, in turn weakening global solidarity and diminishing prospects for cooperation in pursuit of shared goals. It is critical to ensure not only that fossil fuel-reliant workers and communities have a viable perspective in a new energy system, but also that women, youth, minorities and marginalised groups are given equal opportunities. Last but not least, the energy transition itself must proceed in a manner that safeguards ecosystems, a concern that ranges from the mining and processing of critical raw materials all the way to how renewable energy equipment is handled at the end of its useful life. Yet, the growing urgency of the energy transition could translate into tremendous pressure to extract energy transition minerals as quickly as possible while sidelining environmental concerns and local community interests.

This panoply of goals and interests may be difficult to reconcile, especially in a context of growing geopolitical rivalry that renders global co-operation more difficult. It is a task that cannot be left to markets if just, inclusive and sustainable outcomes are to be more than a slogan. Priorities must be determined in open debate and policy decisions must be guided by social dialogue. Governments and other stakeholders will have to play a proactive role in transforming economic systems, reinforcing an argument that has underpinned IRENA's staple of socio-economic reports: policy making must be inspired by a holistic framework that considers technological aspects in conjunction with social, economic and environmental priorities (see Figure 15).

Figure 15 Holistic policy framework for a just and inclusive energy transition



Source: IRENA, 2022b.

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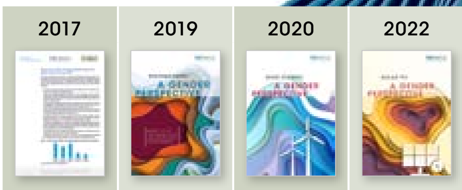

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