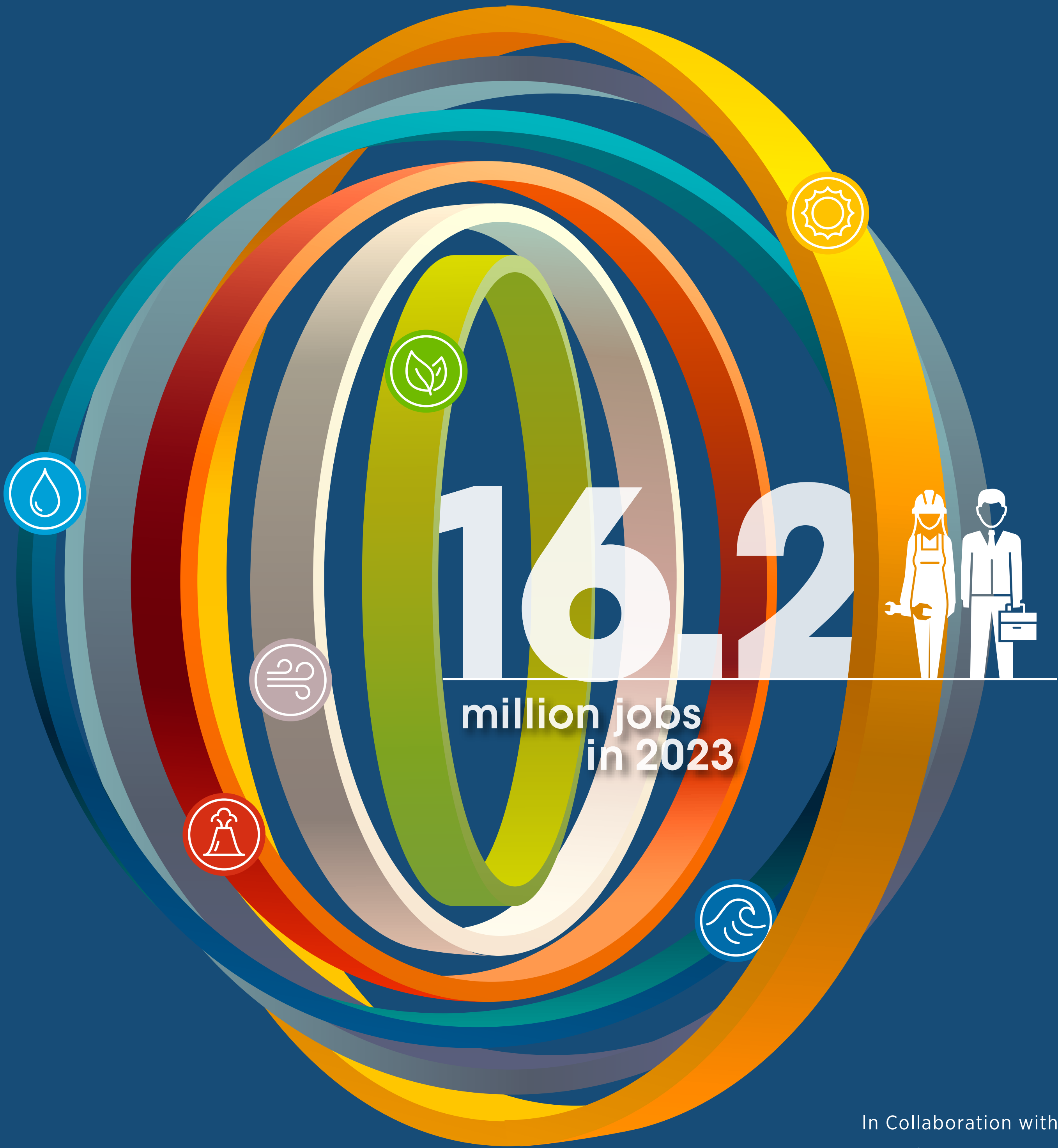
IRENA
International Renewable Energy Agency

Renewable Energy and Jobs
Annual Review 2024



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ABOUT IRENA

The International Renewable Energy Agency (IRENA), a global intergovernmental organisation established in 2011, is the world's principal platform for co-operation to advance the transformation of the global energy system in pursuit of sustainable development, energy access, energy security, and low-carbon economic growth and prosperity. Serving as a centre of excellence and repository of knowledge, IRENA promotes the adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy.

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ABOUT ILO

The only tripartite UN agency, the International Labour Organization (ILO) has, since 1919, brought together governments, employers and workers in 187 Member States to set labour standards, develop policies and devise programmes promoting decent work for all women and men.

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ACKNOWLEDGEMENTS

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FOREWORD

The existential threat to human wellbeing posed by climate change becomes clearer each year. Yet the collective action needed to confront this challenge remains inadequate, hindered by politics and disagreements, growing inequality and socio-economic uncertainty. Together, these are creating a fear of change.

The energy transition must be based on the understanding that human and environmental well-being are intrinsically linked. Environmental, social and economic considerations must go hand-in-hand. Governments, employers, workers and civil society must work together, proactively, using social dialogue to ensure that all voices are heard.

A just transition means not only marshalling the necessary financial resources and developing new technologies, it must also ensure the transition yields tangible benefits for all. Inclusion and equality are essential components.

Since its inception, this report series has illustrated the importance of ensuring the energy transition delivers socio-economic benefits and decent work in ways that are both inclusive and just. This latest edition adds to our knowledge of employment in the growing renewable energy sector, by providing the latest global data and estimates from around the world, and by highlighting the comprehensive policy choices that shape job creation both today and in the future. It finds that there are currently at least 16.2 million renewable energy jobs worldwide.

IRENA is monitoring progress toward the global goal of tripling renewable power capacity by 2030, adopted at COP28. Fulfilling this objective will create many more jobs in the years to come. Yet it is not enough to focus on the numbers alone. The backbone of the energy transition has to be a well-skilled workforce.

The 111th Session of the International Labour Conference in 2023 emphasised that skills development is a key enabler of a just transition. It follows that, collectively, we must enhance education and training for new labour market entrants and ensure that existing workers have opportunities for reskilling and upskilling. This report includes a chapter dedicated to this important issue.

The energy transition must be delivered by a workforce that is diverse, with ample opportunities for women, youth, and members of minority and disadvantaged groups. Attractive, productive and decent jobs must be created, offering good pay, safe working conditions and respect for workers' rights. Furthermore, the transition should champion equity and social justice and ensure that communities across the world gain a fair share of the jobs and incomes generated.

The mandates of IRENA and ILO place them at the intersection of these crucial economic and energy issues. We are proud to work together to bring our joint expertise and resources to bear on these pressing, multi-faceted priorities, and remain committed to supporting a just, inclusive and sustainable energy transition.

Francesco La Camera

Director-General

International Renewable Energy Agency

Gilbert F. Houngbo

Director-General

International Labour Organization

TABLE OF CONTENTS

Foreword 03

Abbreviations 07

About the IRENA Renewable energy and jobs series. 08

KEY NUMBERS AND MESSAGES 10

Introduction: Dynamics of the renewable energy industry 12

CHAPTER 1

RENEWABLE ENERGY EMPLOYMENT WORLDWIDE AND BY TECHNOLOGY 18

1.1 Solar photovoltaic 21

1.2 Wind 24

1.3 Hydropower 26

1.4 Liquid biofuels 28

1.5 Concentrated solar power 30

1.6 Decentralised renewables 32

1.7 Heat pumps 35

CHAPTER 2

RENEWABLE ENERGY JOBS IN SELECTED COUNTRIES 36

2.1 China 39

2.2 Brazil 43

2.3 United States 45

2.4 India 50

2.5 Europe 52

2.6 Other countries. 60

CHAPTER 3

SKILLS FOR A JUST ENERGY TRANSITION . . . 66

3.1 The energy transition and its implications for skills development 68

3.2 Key skills challenges for the renewable energy industry 71

3.3 Policy recommendations 72

CHAPTER 4

THE IMPORTANCE OF A PEOPLE- AND PLANET-CENTRED ENERGY TRANSITION . . . 76

References 84

Figures

Figure 1 Global renewable electricity capacity, 2010-2023 13

Figure 2 Solar PV (2a) and wind (2b) capacities, China and other top 10 countries, plus rest of the world: New additions and cumulative capacities as of 2023 14

Figure 3 Evolution of global renewable energy employment by technology, 2012-2023. 19

Figure 4 Global renewable energy employment, by technology, 2023 20

Figure 5 Solar photovoltaic employment in 2023: Top ten countries 22

Figure 6 Wind employment in 2023: Top ten countries .25

Figure 7 World renewable hydropower capacity additions (GW), 2013-2023. . . .26

Figure 8 Hydropower employment (direct jobs), by country, 2023. 27

Figure 9 Liquid biofuels employment in 2023: Top ten countries .28

Figure 10 Distribution of labour (a) and skills (b) required along the value chain for the development of a 100 MW + 10-hour TES CSP plant. 30

Figure 11 Renewable energy employment in selected countries and regions 37

Figure 12 China’s solar PV module exports (GW) by main destinations, 2017-2023. 41

Figure 13 Framework conditions for a successful energy transition 77

Figure 14 Diverging objectives of the energy transition: Implications for jobs and job quality 79

Tables

Table 1 Estimated direct and indirect jobs in renewable energy worldwide, by industry, 2023 (in thousands). 38

Table 2 EU clean energy equipment manufacturing capacity and EU production as a percentage of EU market demand 52

Boxes

Box 1 United States: Ensuring benefits for disadvantaged communities 49

Abbreviations

CRES	China Renewable Energy Society
CSP	concentrated solar power
DOE	Department of Energy [United States]
DRE	decentralised renewable energy
EU	European Union
EU 27	27 Member States of the European Union
FTE	full-time equivalent
GW	gigawatt
ILO	International Labour Organization
MW	megawatt
O&M	operation and maintenance
PV	photovoltaic
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme (South Africa)
SMEs	small and medium-sized enterprises
STEM	science, technology, engineering and mathematics
TVET	technical and vocational education and training
USEER	US Energy and Employment Report


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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 well-being. 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 and labour market measures. While available qualitative information about renewable energy jobs, such as education, skill requirements and workforce attributes, remains limited, the series asserts that decent jobs are a must for a just and inclusive energy transition.

IRENA's 2011 policy brief, *Renewable energy jobs: Status, prospects & policies*, laid the groundwork for the agency's work on employment. Building on additional standalone explorations of the topic (*Renewable energy jobs and access*, published in 2012, and *Renewable energy and jobs*, in 2013), IRENA launched this annual series to provide regular and detailed assessments 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 and the requirements of a just and inclusive transition.

The series is part of IRENA's extensive analytical work, ongoing since 2011, on the socio-economic 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; education and training needs and opportunities; and the modelling of the impact on jobs, gross domestic product and human welfare of energy transition pathways to 2050.

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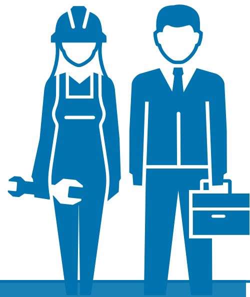

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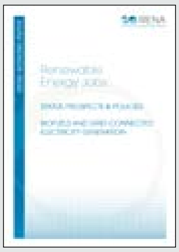

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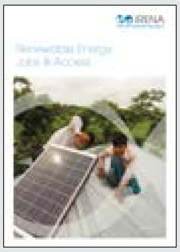

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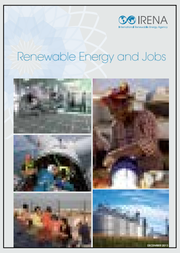

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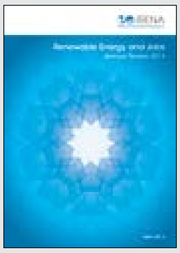

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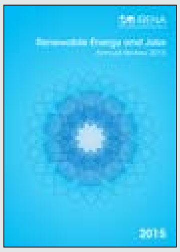

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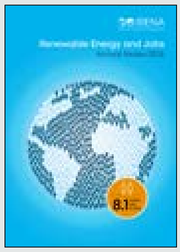

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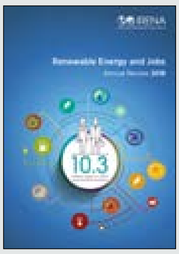
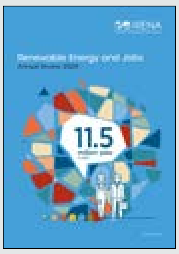


2018

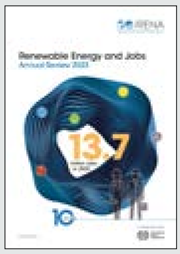
2019



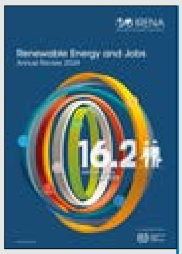
2020

2021

2022

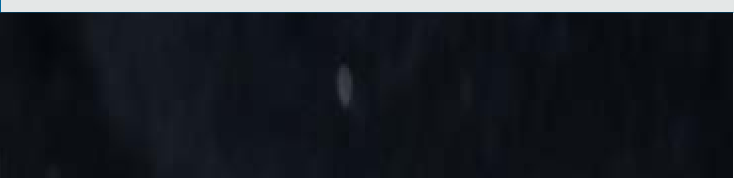


2023



2024

The agency's publications on renewable energy employment and its comprehensive research on socio-economic impacts can be accessed by visiting www.irena.org/Publications.



KEY NUMBERS

16.2 million

global renewable energy jobs in 2023, up from 13.7 million in 2022. China alone has 7.4 million jobs, or 46% of the global total. The European Union (EU) has 1.8 million jobs, Brazil 1.6 million, and the United States and India each slightly more than 1 million.

7.1 million **solar photovoltaic (PV) jobs** in 2023, representing 44% of the world's total renewable energy workforce. China dominates with 4.6 million jobs, while the EU is a distant second with 720 000 jobs.

2.3 million **direct jobs in hydropower** in 2023, down 4% from 2022, reflecting a slower pace in new additions.

2.8 million **biofuels jobs** in 2023. The bulk is in the agricultural supply chain, including seasonal and part-time work. Brazil has the largest number of jobs, at 994 000, followed by Indonesia, at 798 600.

1.5 million **wind power jobs** in 2023. China leads with 745 000 jobs, while second-ranked Europe – still a technology leader – has some 316 300 jobs.

KEY MESSAGES

› THE DOMINANT ROLE OF LEADING COUNTRIES.

China holds a widening lead in the deployment of renewables and dominates equipment manufacturing. Other countries, such as the United States, India, Brazil and members of the EU, are important installers, and they seek to build or rebuild domestic supply chains to support greater domestic value creation.

› SKILLS. A skilled workforce is essential for a successful energy transition and of particular significance for young people. Education and training do more than make individuals more employable. Skills development and lifelong learning are strategic imperatives for meeting climate objectives and ensuring a just transition.

› DIVERSITY. Women could play a pivotal role in the scaling up of renewables, especially off-grid technologies. The expansion of these technologies – for example, solar PV systems, which support entrepreneurship, especially in underserved and remote areas – can help women find employment and earn an income. Beyond gender, very little information is available for most countries on indicators of workforce diversity.

› A PEOPLE- AND PLANET-CENTRIC ENERGY TRANSITION. The global transition to clean energy is shaped by a multitude of public policies and private sector activities that, together with civil society actions, must seek to balance environmental, economic and social sustainability. While markets can be helpful in driving technological change, the global common good is not their primary motivation; indeed, there are trade-offs between the pursuit of profits and the objective of a just and inclusive energy transition that provides widely shared benefits.

Introduction

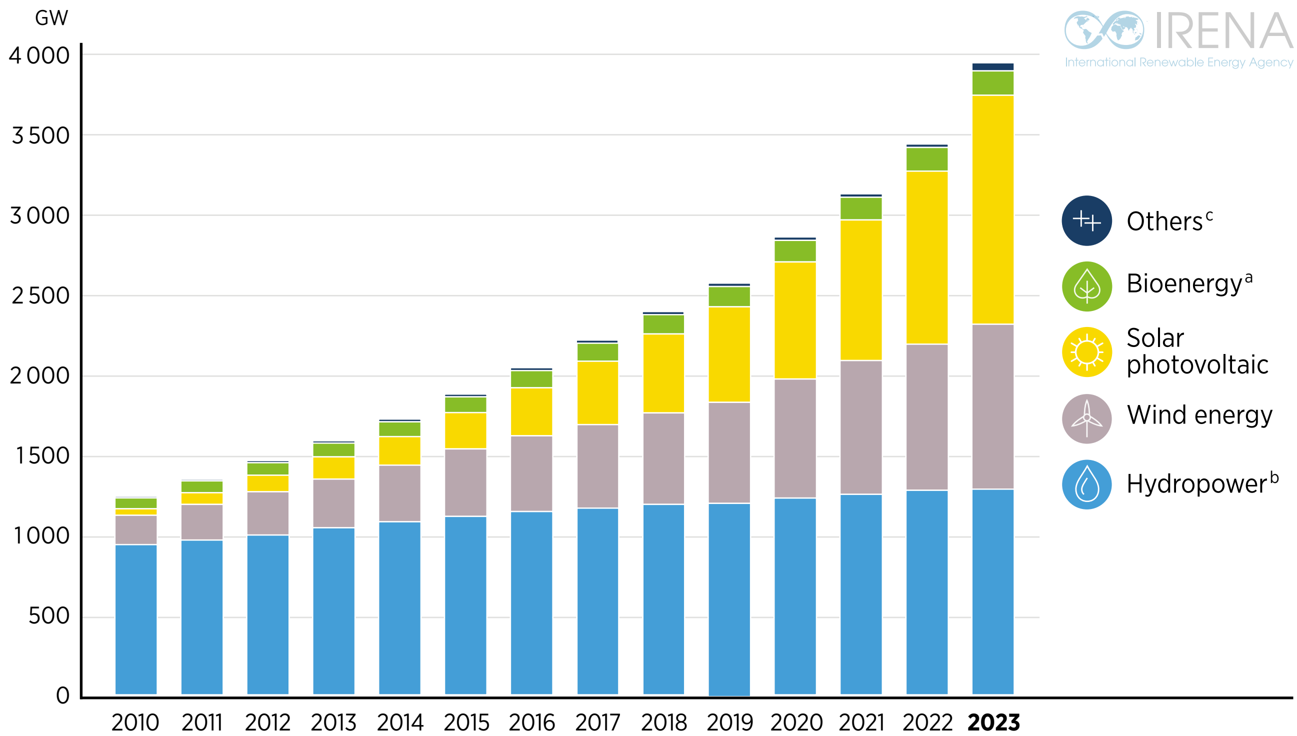
DYNAMICS OF THE RENEWABLE ENERGY INDUSTRY

Renewables-related employment is shaped by two major factors: (1) the annual rhythm of global deployments of generating capacity and (2) the dynamics of the industries that manufacture equipment (from solar panels and wind turbines to hydroelectric turbines and biodigesters) and provide a host of related services (such as project planning, permitting and financing).

Worldwide, some 473 gigawatts (GW) of new renewable electricity generation capacity were installed in 2023. Cumulative capacity reached 3 865 GW, a 14% expansion over 2022 and the largest annual addition recorded to date (see Figure 1). A record 347 GW of solar photovoltaic (PV) capacity were added. With a cumulative 1 411 GW of capacity, solar PV now exceeds the more slowly expanding hydropower sector (1 265 GW). Wind power ranks third with 1 017 GW, of which 115 GW were added in 2023. The installed generating capacity of all other renewable energy technologies accounts for a much smaller share, with bioenergy contributing 149 GW (IRENA, 2024a).

Outside the electricity generation sector, cumulative solar thermal capacity had risen to 560 gigawatts thermal by the end of 2023, corresponding to 800 million square metres of collector area. Between 2000 and 2023, this capacity expanded about nine-fold, although annual additions in the last ten years of the period were less than half the peak rate recorded in 2013 (Weiss and Spörk-Dür, 2024). Liquid biofuel production reached 170 billion litres in 2022, up from 162 billion litres in 2021. Ethanol accounted for close to two-thirds of the total (REN21, 2024).

Figure 1 Global renewable electricity capacity, 2010-2023



Source: IRENA, 2024a.

Notes: PV = photovoltaic.

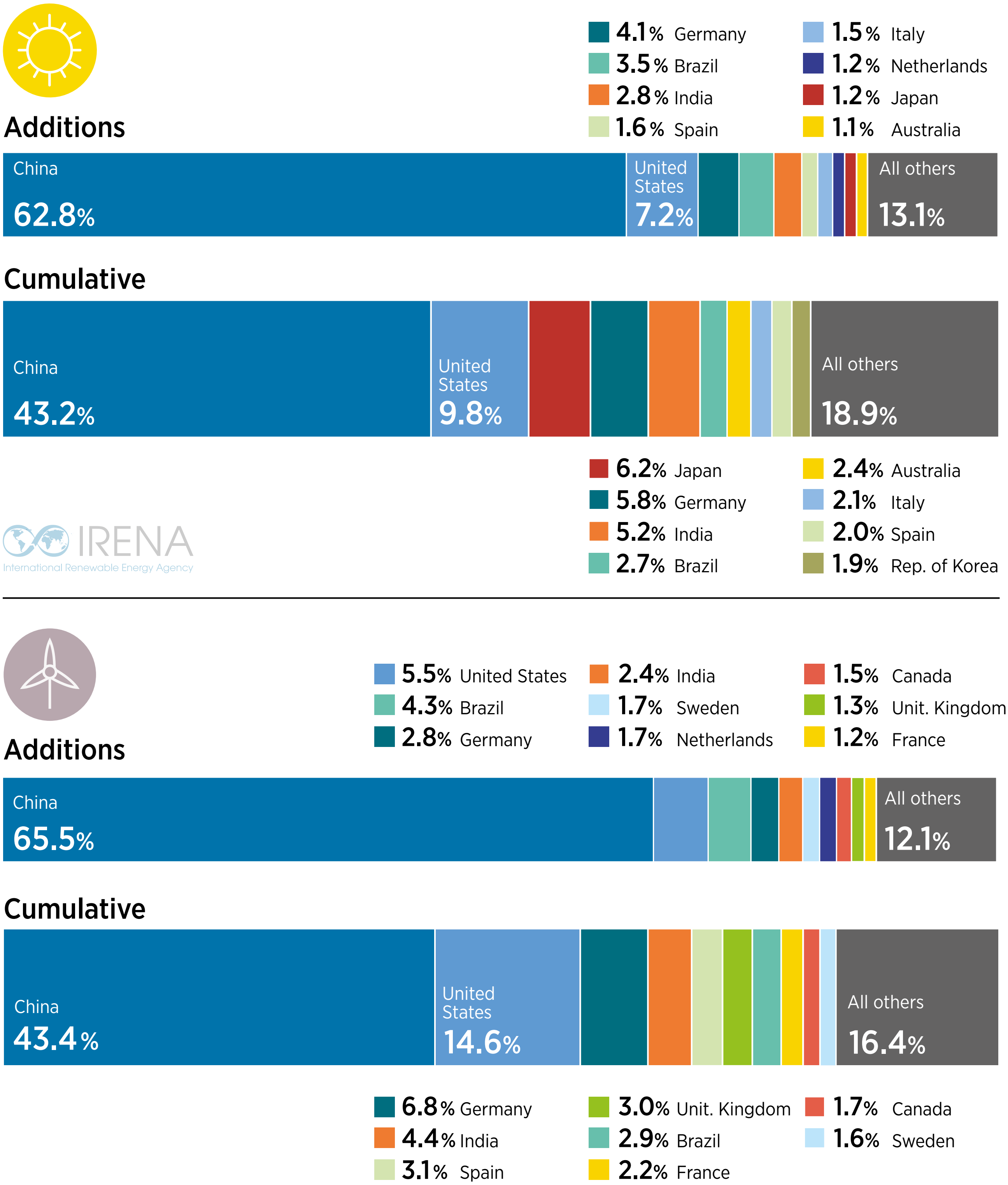
a Includes liquid biofuels, solid biomass and biogas.

b Direct jobs only.

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

347 GW of solar photovoltaic capacity were added in 2023.

Figure 2 Solar PV (2a) and wind (2b) capacities, China and other top 10 countries, plus rest of the world: New additions and cumulative capacities as of 2023



Source: IRENA, 2024a.

Note: PV = photovoltaic; Rep. of Korea = Republic of Korea; Unit. Kingdom = United Kingdom.

Renewable energy is expanding unevenly around the world.

Renewable energy is expanding unevenly around the world. China invests far more in renewables than any other country or region. Over 2014-2023, China invested USD 1572 billion in renewable energy, or almost three times as much as the United States (USD 550 billion) and twice as much as Europe (USD 785 billion), while surpassing other parts of the world by even greater margins (REN21, 2024).

China not only leads as an installer of generating capacity but is also the dominant equipment manufacturer in the two most dynamic renewable energy sectors, wind and solar PV. Most other countries are on a much slower, and often less steady, deployment trajectory. In 2023, close to two-thirds of the world's new wind and solar PV capacity (65.5% and 62.8%, respectively) were installed in China (IRENA, 2024a). As shown in Figure 2, China now accounts for about 43% of the global cumulative capacity of both wind and solar PV – a huge rise from 2010, when it held a 16% share of wind and just 2.6% of solar PV. Putting these percentages in context, they far exceed China's share of the world population (just under 20%), although they still fall below the country's 53% share of global coal-fired generating capacity (Russell, 2024).

China's cumulative solar PV capacity is more than four times that of the United States and 1.5 times as much as the rest of the top ten countries. Similarly, China has three times the wind generating capacity of the United States and holds a commanding lead over the rest of the top ten (IRENA, 2024a).

If the envisaged tripling of renewable power generating capacity by 2030, as endorsed at the 2023 United Nations Climate Change Conference (COP28) (COP28, IRENA and GRA, 2023), is to occur in a geographically balanced manner, countries other than China will have to significantly step up their efforts. The needed acceleration of the energy transition rides on much greater volumes of public and private investment, and requires governments to provide strong policy guidance.

As argued in previous editions of this report series, the human side of the energy transition is as essential as its technological side. A truly successful transition will require programmes and structures to facilitate the skilling of new workers and the upskilling and reskilling of existing workers for a wide variety of occupations. To ensure broad public acceptance and support, women, youth, community groups, organised labour and other stakeholders – such as minorities and other marginalised groups – must have an adequate voice in shaping the transition. At the same time, there is a need to ensure that industrialisation in support of the transition is managed sustainably. This means not only that policies on recycling and reuse will be needed to avoid large-scale waste flows, but also that workers will have to be protected from exposure to toxic materials. The energy transition must be centred on people and the planet.

Greater international collaboration is essential for ensuring that socio-economic benefits such as job creation are widely shared, especially in marginalised regions. For example, over 2000-2020, Africa received a minuscule 2% of the globe's total renewable energy investments of USD 2.8 trillion (IRENA and CPI, 2023), and the continent accounts for less than 1% of the world's solar PV and wind generating capacities (IRENA, 2024a). The reality is that despite high resource potential, energy access in Africa is low and the need for decent jobs is palpable.

The tripling of renewable power needs to happen in a geographically balanced and planet- and people-centric manner.

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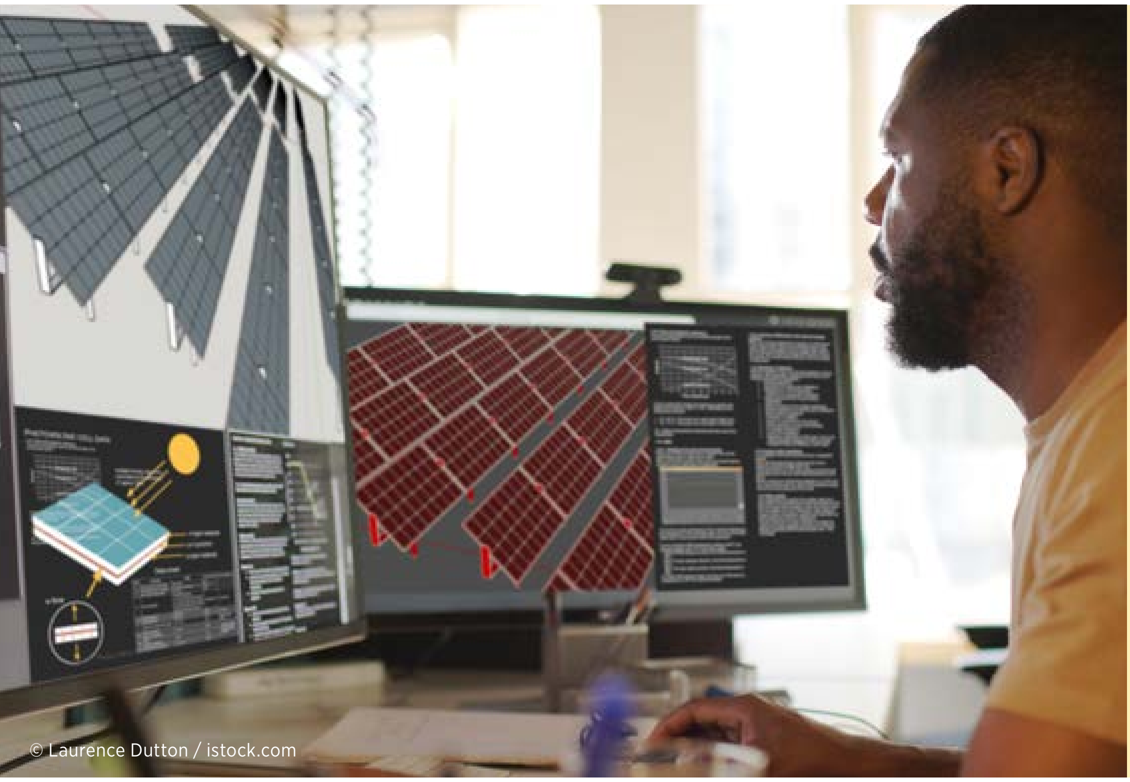

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The remainder of this report is organised as follows: **Chapter 1** presents employment trends worldwide and discusses them by major technology. In addition to the highly dynamic solar PV and wind sectors, it looks at hydropower and liquid biofuels, and offers insights on concentrated solar power and decentralised applications of renewables and heat pumps. **Chapter 2** provides the latest findings on renewable energy jobs in the leading countries – China, Brazil, the United States, India and EU members – and offers snapshots of several additional countries across the world. **Chapter 3** discusses the importance of skills for a successful energy transition. **Chapter 4** concludes with observations on two sets of transition objectives: those that seek to reduce costs and maximise profits and those inspired by a people- and planet-centred vision. The observations focus on the job-related impacts of both sets of policies.

CHAPTER 1

RENEWABLE ENERGY EMPLOYMENT WORLDWIDE **BY TECHNOLOGY**

This edition of the International Renewable Energy Agency's *Renewable Energy and Jobs – Annual Review* is the eleventh in the series, and the fourth produced in collaboration with the International Labour Organization. It provides current global renewable energy employment estimates, derived by applying IRENA's methodologies and calculations to the most recent data, and from a broad assortment of reports and analyses published by government agencies, industry associations, non-governmental organisations and academic researchers.

The report surveys global renewable energy employment as of 2023.[1] Against the backdrop of equipment manufacturing and deployment trends, industry dynamics and national policy making, it explores job numbers and qualitative aspects of the renewable energy supply chain.

The headline finding of this edition is that renewable energy employed 16.2 million people directly and indirectly in 2023.[2] This number represents a dramatic rise from 7.3 million in 2012 (see Figure 3), with the biggest contributions from solar photovoltaic (PV) installations, wind power, hydropower and bioenergy.[3]

[1] *In some cases, 2022 is the most recent year for which data are available.*

[2] *Direct employment refers to jobs generated by core activities, without accounting for intermediate inputs necessary to manufacture renewable energy equipment, or construct and operate facilities. Indirect employment includes employment in the upstream industries that supply and support the core activities of renewable energy deployment. Workers in such positions may be engaged in the production of 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. Data are principally for 2023, with some 2022 data 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.*

[3] *The job numbers shown in the figure for the period 2012-2023 reflect the figures reported in earlier editions of this series.*

Figure 3 Evolution of global renewable energy employment by technology, 2012-2023

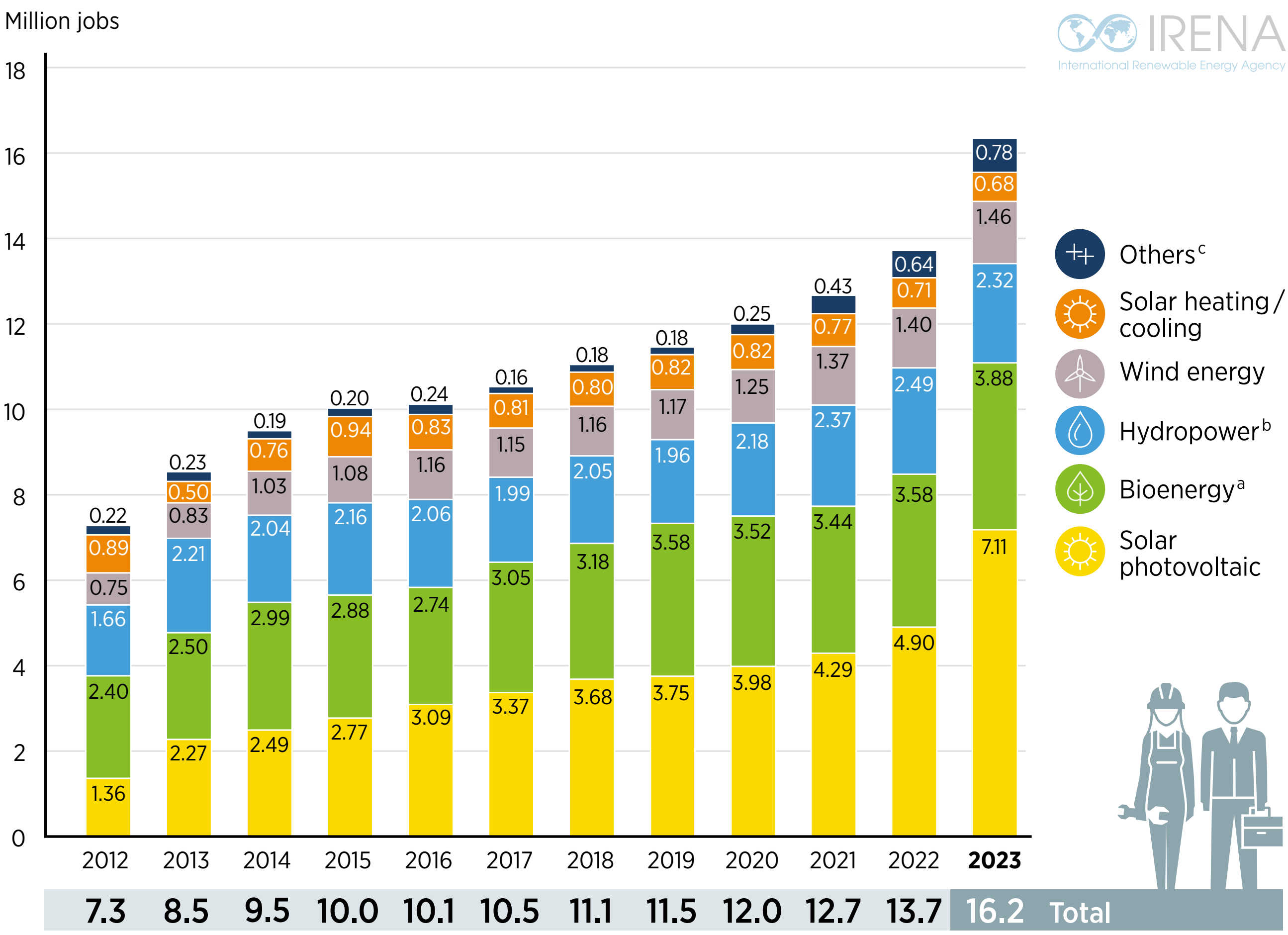
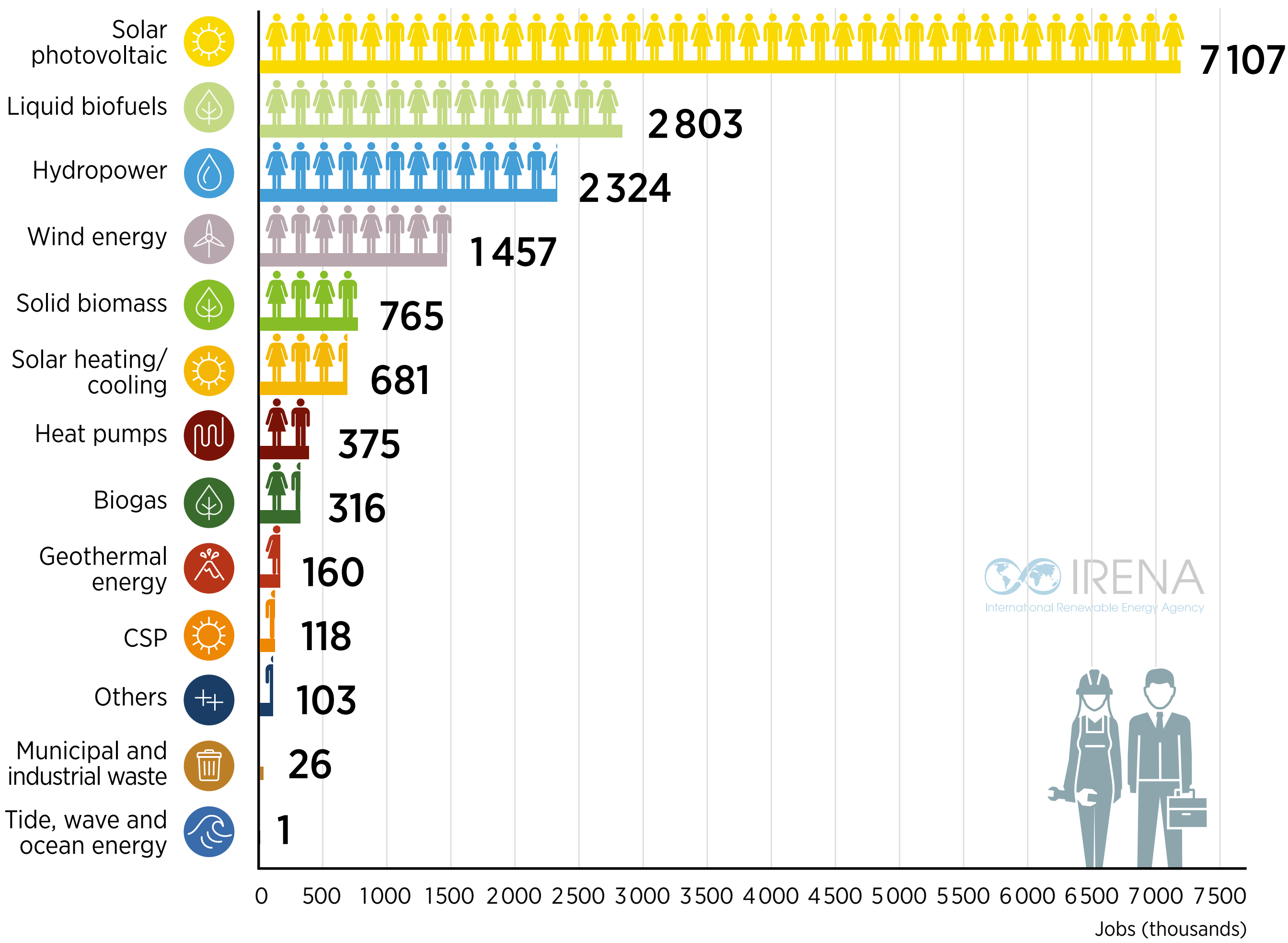


Figure 4 offers more details on employment by renewable energy technology. Solar PV, liquid biofuels, hydropower and wind led in 2023. Less detailed information is available for other technologies, but it is clear that they are smaller in scale, less dynamic and employ fewer people.

Figure 4 Global renewable energy employment, by technology, 2023



Note: CSP = concentrated solar power.

1.1 SOLAR PHOTOVOLTAIC

7.1
million jobs

In 2023, global solar PV capacity registered record expansion: additions reached 347 gigawatts (GW), 74% more than the previous record in 2022, thanks to a sharp drop in panel costs and to supportive policies. China accounted for 63% of the new capacity, or 216.9 GW. The rest of the top ten installers (the United States, Germany, Brazil, India, Spain, Italy, the Netherlands, Japan and Australia) added a combined 83.4 GW. So dominant is China's position that its 2023 additions alone far exceed the cumulative capacity of any other country to date (IRENA, 2024a). Some 120.6 GW, 55% of China's 2023 installations, were in utility-scale assemblies, while the remaining 96.3 GW were in rooftop solar and other distributed deployments (Bloomberg, 2024). Europe added over 54 GW in 2023, a 25% increase from the previous year, while the United States added about 25 GW, 30% more than the previous year (IRENA, 2024a).

Regarding manufacturing, China accounted for 96% of the global wafer capacity and 88% of the global cell capacity in 2023 (Pierce and Sun, 2023). China's manufacturers have scale advantages and enjoy lower material, capital and labour costs than their competitors. As of December 2023, China was able to produce modules for USD 0.15/watt, compared with about USD 0.22 in India, 0.30 in Europe and 0.40 in the United States (Financial Times, 2024). Persistent and growing overcapacities in manufacturing will continue to put pressure on manufacturers and drive prices down (which also implies pressure on wages). From 2020 to 2023, global excess capacity rose from 12% to 62% for polysilicon, from -2% to 45% for wafers, from -2% to 136% for cells and from 37% to 123% for modules (Wood Mackenzie, 2024c).

China's dominance is also noticeable in the inverter segment of the PV supply chain. According to data from Wood Mackenzie (2024e), global PV inverter shipments grew 56% to 536 GW in 2023, with the top ten producers (of which nine are based in China) commanding an 81% market share. China's Huawei and Sungrow alone accounted for more than half of global shipments.

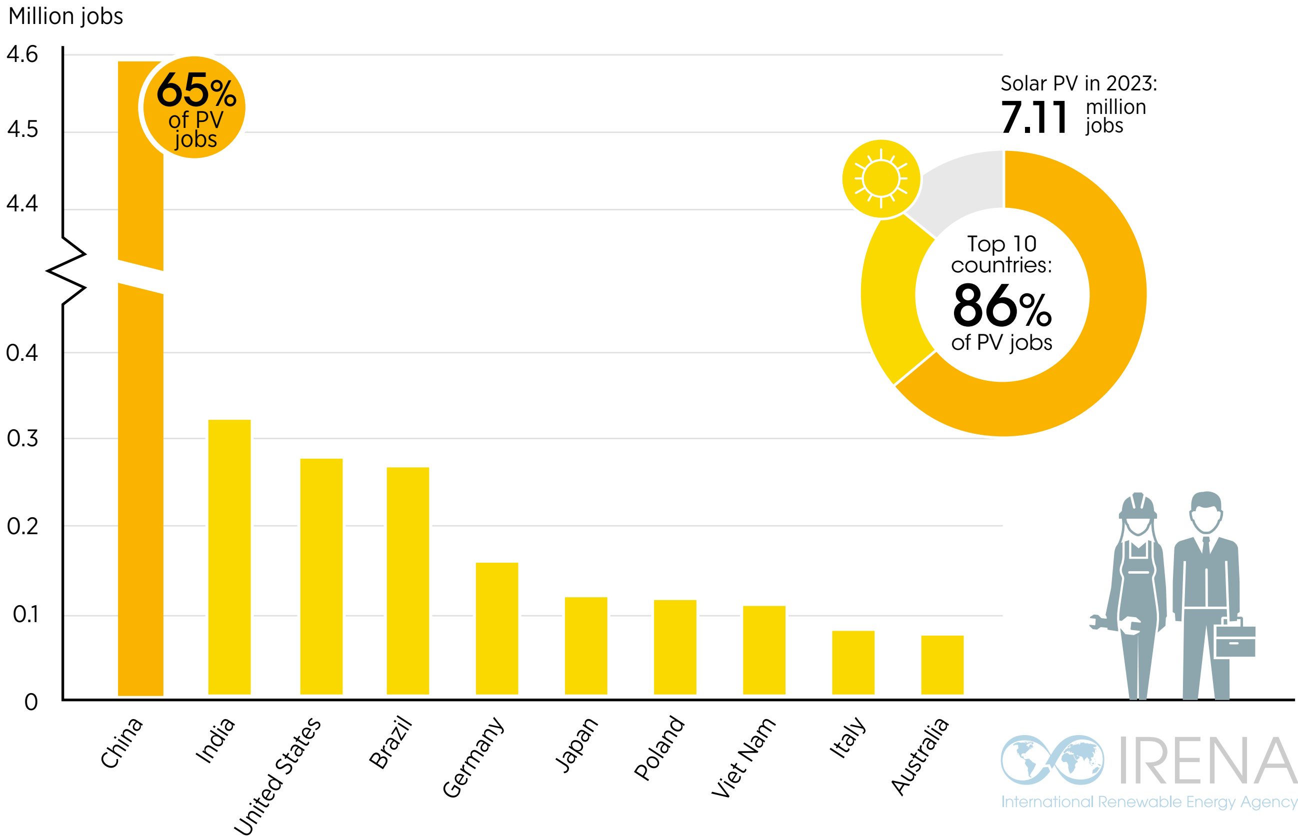
96%
of the global wafer capacity is located in China.

Southeast Asian solar PV factories have emerged as an important export hub. Many of these factories resulted from Chinese investments intended to circumvent US tariffs levied on Chinese imports. With the imposition of US tariffs on modules produced in Southeast Asia, companies in the region have begun to reorient towards the Indian market (Raghavan, 2023).

In the face of China's PV might, the United States, EU members, India and other countries are not only implementing tariff and non-tariff barriers but also adopting industrial policies in a bid to revive their own manufacturing base (see IRENA [2023] and the country-level discussion in the next chapter of this report). India is now the third-largest manufacturer following China and Southeast Asia, while the United States and Europe have a more marginal presence (Pierce and Sun, 2023).

Trade policy is a highly charged issue. Experience in countries as diverse as India, South Africa and the United States suggests that import restrictions alone do not work well because they fail to build up domestic capabilities. Instead, a combination of carefully designed constraints with industrial policy measures (*e.g.* government incentives for local manufacturing) better supports domestic solar supply chains (Hryshko, 2024).

Figure 5 Solar photovoltaic employment in 2023: Top ten countries



Well-crafted trade and industrial policy measures are essential for building **diversified supply chains.**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As a rule of thumb, 1 GW of module production capacity can generate anywhere from 1085 to 2020 direct jobs across the full value chain, although labour requirements vary worldwide (USDOE, 2022).

IRENA estimated global solar PV employment at 7.1 million in 2023, up sharply from 4.9 million in 2022. Of the top ten countries (see Figure 5), four are in **Asia**, another three in **Europe**, two in **the Americas** and one in **Oceania**. Employment in the top ten added up to 6.2 million jobs, representing some 86% of the global total. With China in the lead, **Asian** countries hosted 77% of the world's PV jobs. **Europe** had a 10.7% share (with the EU accounting for 10.1% of that), **the Americas** another 8.6% and all others the remaining 3.3%.

As will be discussed in Chapter 2, developments in **China** further boosted the country's dominance in this industry. In 2023, China commanded approximately 65% of global PV employment, or some 4.6 million jobs. Of **Europe's** estimated 757 500 PV jobs in 2023, 719 900 were in the EU Member States. **India** had an estimated 318 600 solar jobs (on-grid solar is estimated to have generated 238 000 jobs). The **United States** had close to 280 000 PV jobs in 2023. A rise in solar PV installations in **Brazil** boosted related jobs to 264 000. **Japan's** new capacity additions fell for a third consecutive year in 2023; IRENA estimates its workforce at 115 000.

1.2 WIND

1.5
million jobs

In 2023, the wind energy sector installed 115 GW of capacity, considerably more than the previous year and surpassing the record set in 2020. As is the case for solar power, China holds a wide lead in new and cumulative wind capacity installations. In 2023, it added 75.9 GW (65.5% of the global total), compared with 24 GW in the rest of the top ten countries (the United States, Brazil, Germany, India, the Netherlands, Sweden, Canada, the United Kingdom and France) combined. China's installations in 2023 surpassed the cumulative capacity of Germany, the third-largest deployer of wind power (IRENA, 2024a).

China also remains at the helm in the manufacture of wind power components. Although Chinese firms still principally supply the domestic market and have only a limited presence elsewhere in the world, the sheer size of China's market means that Chinese manufacturers hold a considerable share of global component production. The share is about 60% in blade manufacturing (compared with a 14% share for European companies, 11% for Indian firms, 7% for US suppliers and the remaining 8% distributed among firms in other countries). For generators, China commands a 65% share, ahead of Europe's 22% and much smaller shares elsewhere. For gearboxes, China's position is even stronger, at 75%, whereas Europe and India each have a 12% share (GWEC and MEC+, 2023).

The market shares of original equipment manufacturers in the global wind power industry have changed significantly in recent years. From a peak of 49% in 2017, the share of European companies (Vestas, Siemens Gamesa, Enercon, Nordex Acciona and Senvion) fell to 30% in 2022. By contrast, Chinese firms (Goldwind, Envision, Minyang, Sinovel and others) saw their share rise from a low of 17% in 2012 to 50% in 2022. The share of

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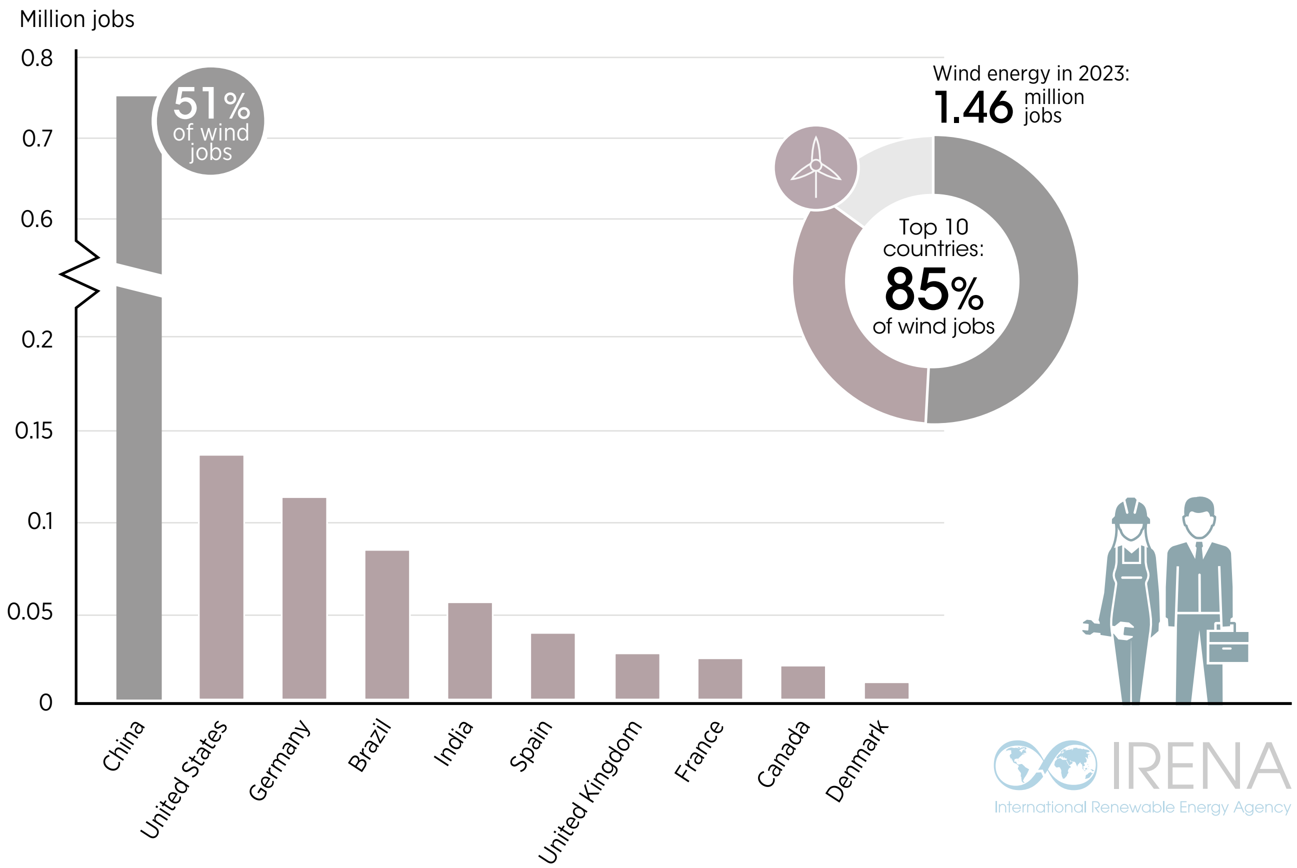
In 2023, the wind energy sector installed 115 GW of capacity, setting a new record.

the US-headquartered GE Vernova remained relatively steady, in the range of 8-12%. Producers from other parts of the world saw their share shrink from a high of 31% in 2015 to just 8% in 2022 (Tapoglou *et al.*, 2023). In the offshore wind segment, the share of the global market commanded by European original equipment manufacturers has declined precipitously, from around 90% a decade ago to 24% in 2021. Chinese firms captured 54% (EC, 2023).

Globally, onshore and offshore wind employed about 1.5 million people in 2023. Employment was highest in **Asia** (with a 59% share), followed by **Europe** (22%), the **Americas** (17.6%), and **Africa** and **Oceania** (1.4%). The top ten countries (see Figure 6) together employed 1.2 million people, or 85% of the global total. Five of these countries are in Europe, three in the Americas and two in Asia. But China had the clear lead with 745 000 jobs, or 51% of the global total.

Figure 6 Wind employment in 2023: Top ten countries



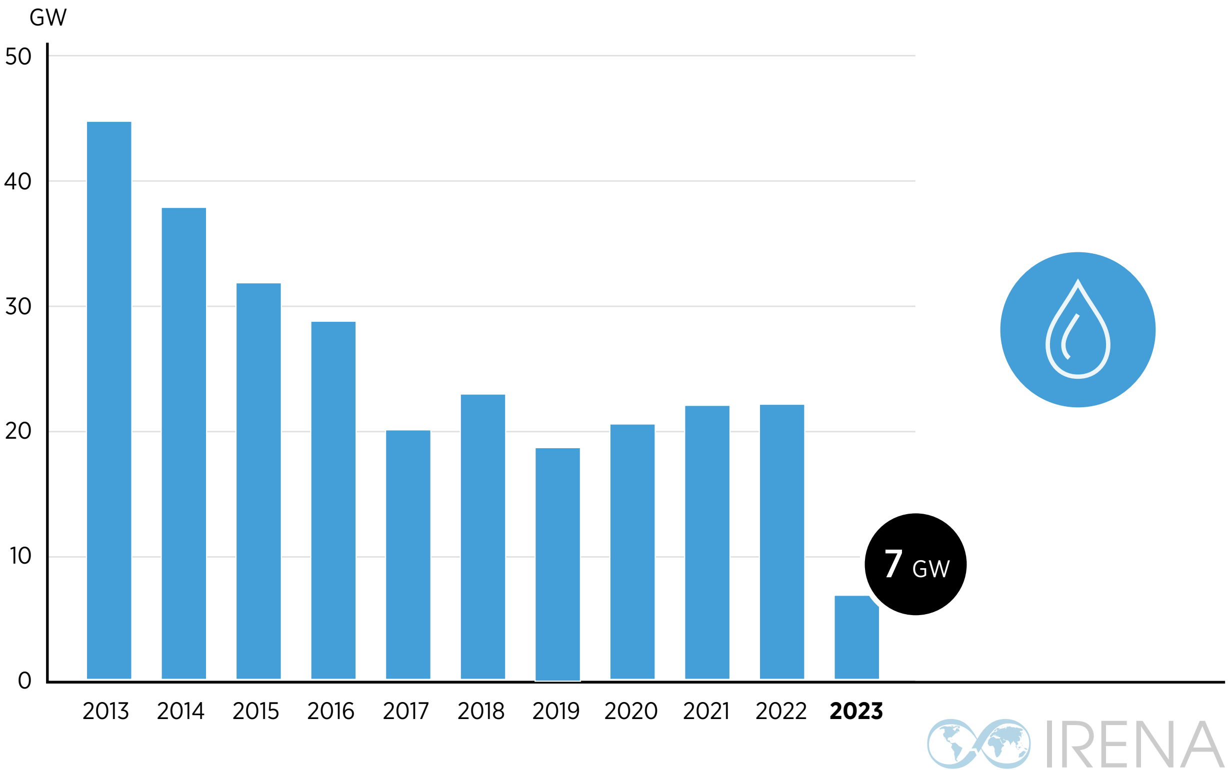
1.3 HYDROPOWER

2.3 million jobs

Renewable hydropower continues to be the largest source of renewable energy globally, representing 51.2% of total renewable electricity generation (IRENA, 2024a). Global renewable hydropower capacity stands at 1 265 GW, but annual additions are increasingly modest – only 7 GW in 2023, a sharp decline from the 23 GW added in the previous year and even larger additions in earlier years (see Figure 7). This partly reflects the fact that hydropower is a mature technology; also, concerns about projects' environmental impacts and displacement of adjacent communities have hindered further development. Hydro has therefore been bypassed by the rapidly expanding solar PV sector and could be overtaken by wind power in the next 2-3 years.

Hydropower development is slowing in the leading countries as well. China installed 2.9 GW of hydropower capacity in 2023 versus 13.2 GW in 2022. Similarly, India's 2023 additions of some 112 megawatts (MW) were down from almost 450 MW the year before. Brazil's net additions also slowed from 343 MW to roughly 100 MW (IRENA, 2024a). This slowdown has affected employment across major markets, leading to a 16% reduction in direct jobs across the sector. China remains the leading provider of hydropower jobs, accounting for 34% of the global total, followed by India, Brazil, Viet Nam and Pakistan (see Figure 8).

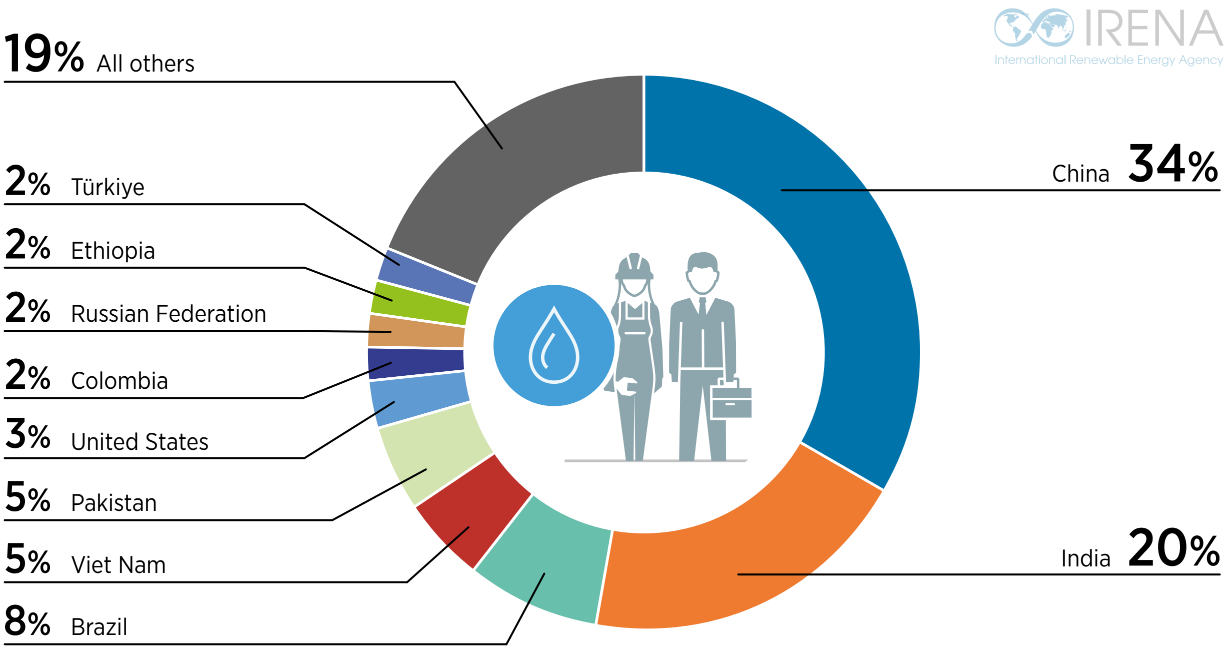
Figure 7 World renewable hydropower capacity additions (GW), 2013-2023



Source: IRENA, 2024a.
Note: GW = gigawatt.

Renewable hydropower development is **slowing** across all countries.

Figure 8 Hydropower employment (direct jobs), by country, 2023



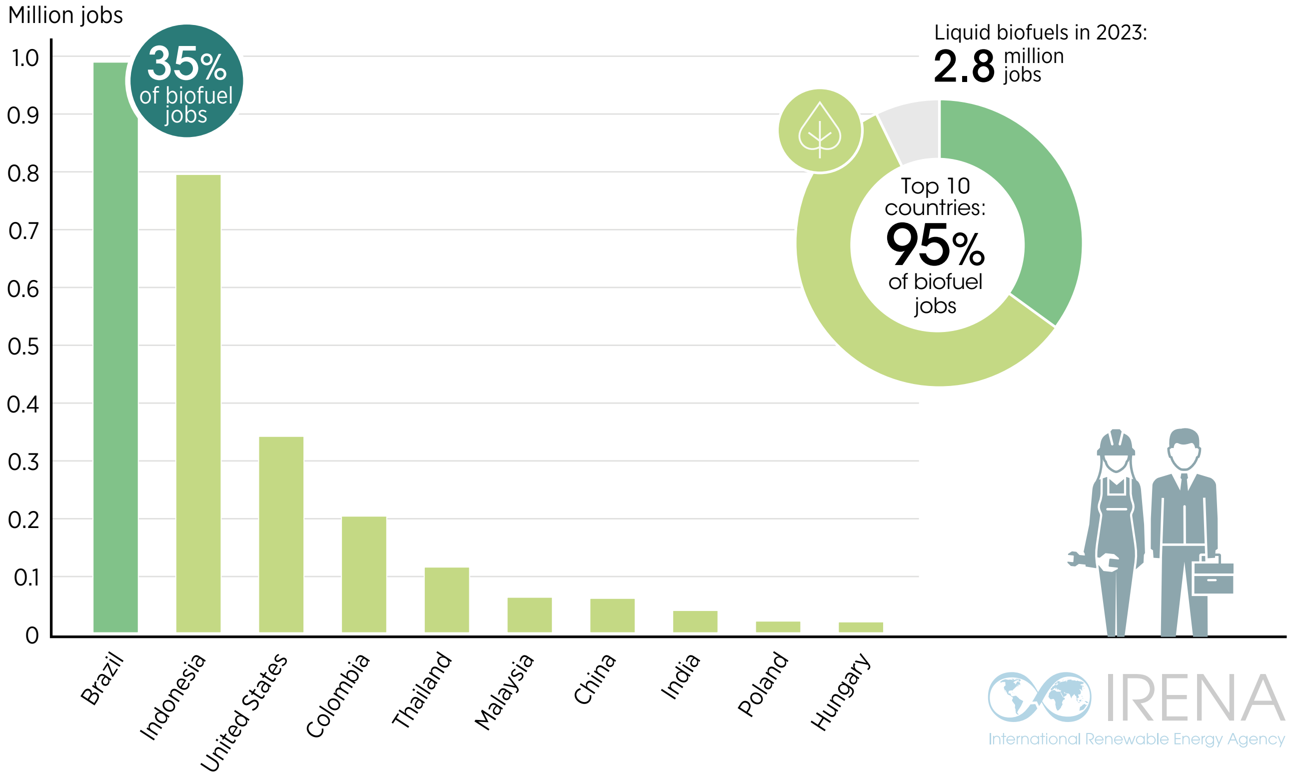
1.4 LIQUID BIOFUELS

2.8
million jobs

A total of 170 billion litres of liquid biofuels were produced globally in 2022, up from 162 billion litres in 2021, the most ever (REN21, 2024). Production is highly concentrated in just a handful of countries. The top ten producers (counting EU members as one unit) commanded more than 90% of global output. Direct employment at biorefineries constitutes a small portion of overall biofuel-related employment. The bulk of the jobs are in the agricultural supply chain. But the volume of feedstock production does not necessarily translate into employment at the same rate in each country, since industrialised countries have more mechanised agricultural sectors than do developing or emerging economies. Developing or emerging economies have labour-intensive feedstock operations, which often rely on informal and seasonal employment.

IRENA estimated worldwide biofuel employment at 2.8 million in 2023. **Latin America** accounts for 43% of all biofuel jobs worldwide, while **Asia** holds another 39%. **North America** and **Europe** have smaller shares (12% and 6%, respectively). Among the top ten countries, five are in Asia, three in the Americas and two in Europe. Together, the top ten account for 95% of the global total (Figure 9).

Figure 9 Liquid biofuels employment in 2023: Top ten countries



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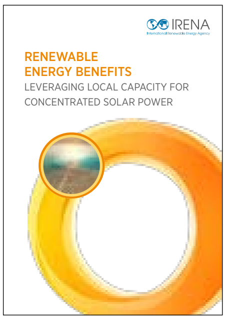
Labour-intensive feedstock operations in developing or emerging economies often rely on informal and seasonal employment.

Brazil is the second-largest biofuels producer worldwide and employs the largest workforce in the sector – an estimated 994 350 people in 2023. The United States has a more industrialised supply chain that relies on the labour of an estimated 342 260 individuals. In the EU 27,[4] biofuels supported an estimated 149 700 jobs in 2022. Given steady production levels, it is reasonable to assume that employment in 2023 was close to that in 2022. Other countries with sizeable biofuels sectors and workforces include Indonesia (where employment is estimated to have soared to 798 600 jobs), Colombia (203 250), Thailand (114 500) and Malaysia (61 900).

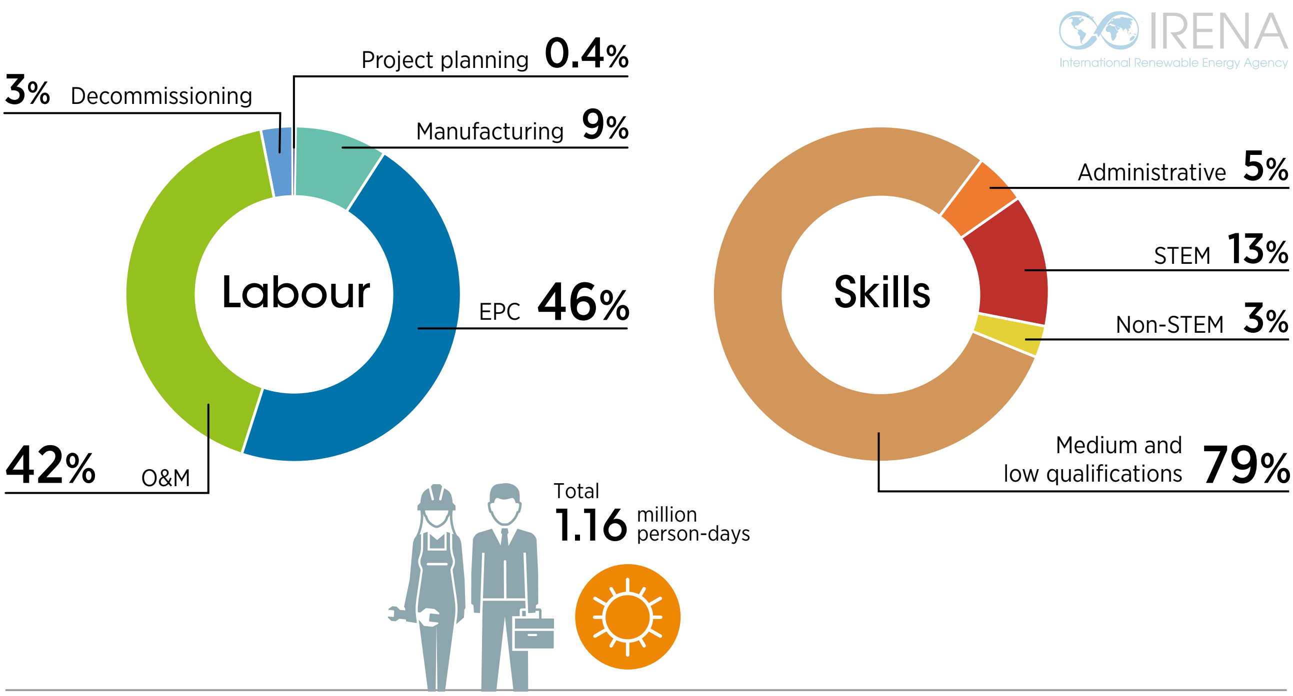
[4] *The 27 Member States of the European Union.*



1.5 CONCENTRATED SOLAR POWER

The other renewable energy technologies are smaller in scale and less dynamic, and only limited information is available on the employment they generate. Concentrated solar power (CSP) is one such technology. From 1990, the CSP sector advanced steadily; initial deployments were in the United States and Spain using parabolic trough and power tower technologies. After 2010, global CSP capacity grew significantly, surpassing 4 GW by 2014. This period was marked by improved designs and larger scales of parabolic troughs, along with broader implementation of power towers. The United Arab Emirates' Noor Energy 1 and multiple projects in China exemplify this expansion. Countries such as China, Morocco and the United Arab Emirates have been pivotal in CSP's global rise. CSP's growth has been supported by auctions and feed-in tariffs; notably, Spain's model influenced policies in India and China. However, since 2019, growth has levelled off; as of 2023, global capacity stood at 7 GW (IRENA, 2024a).

Figure 10 Distribution of labour (a) and skills (b) required along the value chain for the development of a 100 MW + 10-hour TES CSP plant



Source: IRENA, 2024d forthcoming.

Notes: STEM = science, technology, engineering and mathematics; CSP = concentrated solar power; O&M = operation and maintenance; MW = megawatt; TES = thermal energy storage; EPC = engineering, procurement and construction.

CSP offers job creation potential along its value chain, especially in engineering, procurement and construction; operation and maintenance (O&M); and decommissioning. The IRENA report *Leveraging Local Capacity for Concentrated Solar Power* (IRENA, 2024d forthcoming) estimates that a CSP plant integrating 100 MW of capacity with 10-hour thermal energy storage entails approximately 1.16 million person-days across the value chain and requires mostly low- to moderate-level technical skills accessible through local labour pools or vocational training (see Figure 10).

CSP can also boost broader economic growth. By offering grid operators an alternative, CSP can support grid flexibility and reliability as energy demand evolves. CSP's integrated storage capabilities make it a valuable asset for an ambitious energy transition while maintaining the stability of renewables-based grids. In fact, to meet the Paris Agreement's targets, CSP capacity needs to reach at least 196.7 GW by 2030 and 872.6 GW by 2050, requiring investments of USD 657 billion by 2030 and an additional USD 1.83 trillion by 2050. This expansion promises energy security, job creation and grid stability through storage solutions (IRENA, 2024d forthcoming).

A CSP plant integrating 100 MW of capacity with 10-hour thermal energy storage entails **1.16** million person-days across the value chain.

1.6 DECENTRALISED RENEWABLES

For the first time in over a decade, the number of people without electricity increased in 2022, as population growth, particularly in Sub-Saharan Africa, outpaced new electricity connections. In 2022, 685 million people lacked electricity access – 10 million more than in 2021. Given the constraints on grid expansion in underserved areas, decentralised renewable energy (DRE) is crucial for providing clean, reliable and affordable energy to remote and hard-to-electrify communities, where 80% of people without access live today (IEA, IRENA, UNSD, World Bank and WHO, 2024).

DRE technologies are more relevant than ever, especially in peri-urban and rural areas. Some studies project that DRE will help bring electricity to 55% of the world's unelectrified population, supporting not only sustainable livelihoods but also overall employment. Although data on DRE jobs remain limited, certain technologies, such as off-grid solar PV, show particular promise. In 2023, an estimated 307 000 people were directly employed in DRE across India, Kenya, Nigeria, Uganda and Ethiopia (Power for All 2022) (IRENA, 2024e forthcoming).

Accelerating the adoption of decentralised solar PV and other off-grid solutions requires substantial investment and the development of a well-trained, inclusive and diverse workforce. However, limited local supply of the skills necessary to develop, install, operate and maintain these technologies could impede future deployment, especially in developing countries. This skills gap is exacerbated by the risk of skilled personnel migrating to urban areas in search of better job opportunities (IRENA, 2022a).

In this context, women could play a pivotal role in the scale-up of off-grid technologies. The expansion of these technologies presents a significant opportunity to generate jobs that help women earn much-needed income to support their families, as well as contributing to wider development goals such as poverty reduction, improved access to education and improved health services. Further, involving women in the local workforce for solar and other DRE projects has additional safety benefits for rural communities, compared with large-scale projects that often bring in male migrant or temporary workers, potentially posing challenges for remote areas (UN Women and UNIDO, 2023).

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Off-grid technologies create opportunities for women in various roles, from technical positions to customer service and community engagement. Training programmes have shown women's ability to excel in technical roles, thus contributing to innovation and community acceptance. Policy makers should prioritise initiatives to boost women's employment in these technologies and prepare them for a shift towards more technical roles in mini-grids and other off-grid solutions as the sector matures. The sector's inclusivity will drive equitable, sustainable economic growth.

Women continue to hold an unequal yet steadily growing share of jobs in renewable energy. The global association for the off-grid solar energy industry (GOGLA) reports that women hold 27% of all full-time equivalent (FTE) jobs in the off-grid solar sector, and that female representation is expected to grow as the sector expands (GOGLA, 2023). IRENA's solar PV gender survey reveals that women constitute 38% of the workforce across all roles in Africa's solar PV industry[5] (IRENA, 2022b). This regional average is consistent with national data from select countries: decentralised solar PV employs 41% women in Kenya, 37% in Ethiopia, 35% in Nigeria and 28% in Uganda (Power for All, 2022). IRENA's survey estimates women's participation across the entire solar PV sector (decentralised and utility scale) at 40% (IRENA, 2019). This compares with women's 32% share of the overall renewable energy workforce – a relatively modest figure, although 10 percentage points higher than in the wider energy industry (IRENA, 2019).

However, IRENA's survey highlights significant disparities within the sector: women's representation in science, technology, engineering and mathematics (STEM) roles is particularly low; they hold only 24% of these positions. Similar gaps exist in other technical roles, where women represent just 22% of the workforce. Women have a stronger presence in administrative and non-technical positions, at 27% each. Gender disparities are even more pronounced in leadership roles. Women hold only 18% of management positions and just 15% of senior management roles, underscoring the persistent challenges in achieving gender equality at higher levels of responsibility (IRENA, 2022b).

Barriers to women's employment in off-grid solar PV, as in other sectors, include local socio-economic factors and the general workforce challenges faced by women globally.

Societal constraints play a major role. Cultural biases, stereotyped gender roles and practical challenges such as safety concerns and lack of family support shape women's options in the sector. Social norms often discourage women from entering technical fields. Women also bear the majority of household responsibilities, limiting their capacity to pursue careers.

Educational barriers begin early. Girls' limited access to STEM education and training translates into women's under-representation in technical roles. In many developing countries, additional hurdles include limited mobility and poor access to communication technologies.

Workplace barriers include gender bias in recruitment, unequal pay, lack of family-friendly policies and limited workplace flexibility. Women working in off-grid solar PV often face

[5] *No significant differences were found between on- and off-grid responses.*

Women entrepreneurs in off-grid solar PV face limited access to finance, land rights and modern energy, in addition to having to balance childcare and family obligations.

discrimination and biases from employers and customers (IRENA, 2019). Safety concerns further limit their mobility and job opportunities.

IRENA's analysis also highlights how women **entrepreneurs** in off-grid solar PV suffer limited access to finance, land rights and modern energy, in addition to having to balance childcare and family obligations. Cultural barriers and social norms further constrain their entrepreneurial opportunities and growth potential. Addressing these barriers requires comprehensive strategies and policies to support women's participation.

Off-grid solar PV is not the only technology with significant potential to boost women's livelihoods and overall quality of life. Solutions such as biogas and clean cooking technologies contribute to socio-economic development by promoting productive uses of energy. These technologies support income-generating activities, boost productivity, raise incomes and stimulate rural economies. They create employment opportunities for both men and women while lifting up communities. More attention should be given to how they can support a just energy transition that leaves no one behind.

Creating more and better jobs for women in decentralised renewables requires more and better data to understand and address the unique barriers to women's job access. Gendered data at the country level can help inform policies and interventions. Good data can support efforts to raise women's awareness of opportunities.

Employers, policy makers and communities can support women (as well as men) by offering flexibility, creating gender-sensitive policies, designing mentorship programmes and investing in public safety and information. Changing old views of gender roles that limit women's opportunities will require proactive efforts from policy makers, businesses, civil society and the media.

Mitigating barriers to female entrepreneurship is equally necessary, especially in small and medium-sized enterprises (SMEs). Women-led businesses, such as those focusing on e-cooking solutions, address social needs while creating economic opportunities. Supporting female entrepreneurs requires mentorship, training, financial literacy programs and access to non-traditional financing options.

1.7 HEAT PUMPS

The sales of heat pumps, whose market is mainly concentrated in China, the United States, Europe and Japan, grew from 84 GW to 111 GW from 2020 to 2022. In 2023, sales in China grew to 35 GW. By contrast, sales in Europe, the United States, Canada and Japan fell from a combined 66 GW to 60 GW in 2023 – a decline related to policy changes and other factors (IEA, 2024b). In Europe, sales decreased the most in Poland, Finland and Italy but grew significantly in Germany (Maisch, 2024). The slowdown is prompting job cuts and the introduction of shorter work schedules. As of February 2024, company announcements were expected to affect nearly 3 000 employees in Belgium, France and Germany (EHPA, 2024a).

Investments in heat pump manufacturing continued to surge in 2023 (REN21, 2024). Global manufacturing capacity, excluding air conditioners, was 139 GW in 2022, up from 120 GW in 2021 (EC, 2023). China led with 50 GW, followed by the United States (34 GW), Europe (25 GW), Japan and the Republic of Korea (16 GW in total), and the rest of the world (14 GW) (IEA, 2024a). European imports, especially from China, are growing, and the EU's net trade balance turned negative in 2020. At the same time, Asian and North American firms are increasingly setting up European subsidiaries (Lyons *et al.*, 2023).

As demand rises, more training will be required in manufacturing and installation, along with upskilling for plumbers, electricians, heating technicians and other trades (EC, 2023). Heat pumps take longer to assemble, install and maintain than conventional heating technologies (such as boilers). But labour productivity in assembly has risen in recent years (Lyons *et al.*, 2023), and new designs and digitalisation by manufacturers are expected to reduce the labour requirements for installation and maintenance (Missing and Lobo, 2023). As reported by Lyons *et al.* (2023), in Europe, an average worker assembles some 300 heat pumps every year, an installer deploys 61 heat pumps and a technician maintains approximately 1100 units.

The European Heat Pump Association estimates that in 2023, about 169 000 people were employed in this sector in **European countries**. About 99 000 people were employed in the manufacturing, 48 000 in installation and 22 000 in maintenance services (EHPA, 2024b). According to the preliminary statistics of the Heat Pump Committee of the China Energy Conservation Association, **China's** heat pump industry employed 133 000 people in 2023, up from 118 000 in 2022. Among these, 31 000 jobs were in central unit manufacturing and 22 000 in component and parts production; together, they accounted for about 40% of all related jobs. A total of 80 000 people were employed in sales and services such as logistics, installation, after-sales and other functions. Expected robust growth in coming years may increase jobs to 400 000 by 2030 (CHPA, 2023). In the **United States**, as estimated by the *Energy and Employment Report*, there were 6 631 jobs related to ground-source or geothermal heat pumps in 2023 and 66 343 related to air-source heat pumps, for a total of close to 73 000 jobs (USDOE, 2024b).

CHAPTER 2

RENEWABLE ENERGY JOBS IN SELECTED COUNTRIES

National policy making shapes the geography of employment generation. The policies at work are not only those that facilitate or hinder renewable energy capacities and supply chains, but also those that shape geopolitical decisions, trade restrictions and corporate investment decisions. The size and stability of markets, along with the availability of a skilled workforce, are key considerations for corporations deciding where to locate their production hubs. Comparative costs influence where investments are made and may drive relocation and outsourcing strategies. Ongoing technology development and changing economies of scale also affect labour needs. While direct jobs in construction and installation, as well as in operation and maintenance (O&M), are by definition local, the geography of employment related to inputs – from minerals and other raw materials to manufactured components and fully assembled production equipment – varies.

China, Brazil, India, the United States and members of the European Union are dominate equipment manufacturing, engineering, installation and other services. They continue to be major employers in renewable energy, as highlighted in Figure 11, with more detailed data in Table 1. A few additional countries are also discussed later in this section.

Figure 11 Renewable energy employment in selected countries and regions

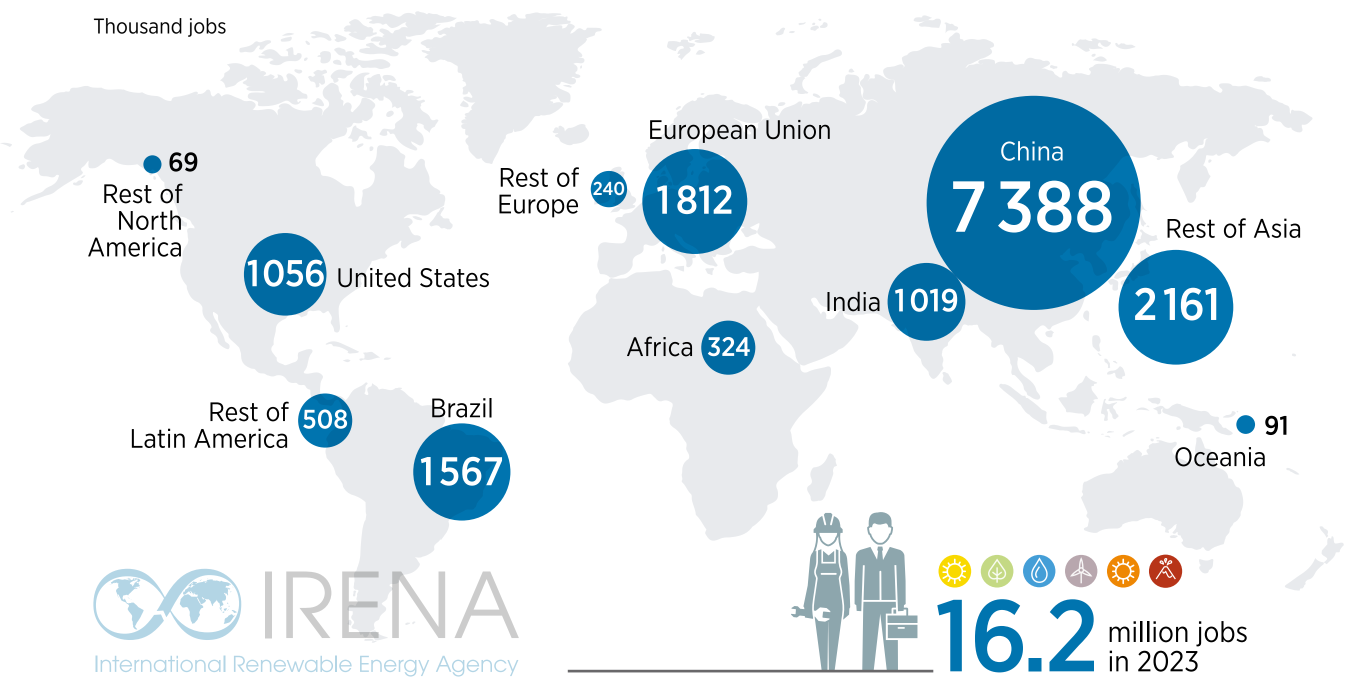

Table 1 Estimated direct and indirect jobs in renewable energy worldwide, by industry, 2023 (in thousands)

	World	China	Brazil	United States	India	European Union (EU 27)
Solar photovoltaic	7107	4590	264	279	319[l]	720
Liquid biofuels	2803	60	994[e]	342[g]	35	150
Hydropower[a]	2324	788	177	68[h]	453	71
Wind power	1457	745	80	131	52	282
Solid biomass[b, c]	765	200		47.4[i]	58	333
Solar heating and cooling	681	514	51[f]	30	17	22
Biogas	316	165			85	49
Geothermal energy[b]	160	94		9[j]		7
Concentrated solar power	118	98				5
Total	**16235[d]**	**7388**	**1567**	**1056[k]**	**1019**	**1812**

Source: IRENA jobs database.

Notes: The figures 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. The values in the columns may not add up precisely to the totals due to rounding off.

a. Direct jobs only.

b. Power and heating applications.

c. Traditional biomass not included.

d. Includes 26 000 jobs in waste to energy, about 375 000 jobs in heat pumps (133 000 jobs in China, 169 000 in European countries and 73 000 in the United States) and around 103,000 renewable energy jobs that are not disaggregated by technology.

e. Includes 390 560 jobs in bioethanol and 403 700 jobs in biodiesel, along with a rough estimate of 200 000 indirect jobs in equipment manufacturing.

f. Direct jobs only.

g. Includes 276 060 jobs in ethanol and 66 261 jobs in biodiesel.

h. Includes 56 641 jobs in traditional hydro and 11 730 jobs in low-impact hydro. Does not include 9 104 jobs in pumped hydro (energy storage).

i. Includes woody biomass fuels (34 542 jobs) and biomass-based power (12 857 jobs).

j. The figure is for direct employment in geothermal power.

k. Includes 76 175 jobs in technologies not individually identified in the table (geothermal heat, heat pumps and others).

l. Includes grid-connected and off-grid solar PV.

EU 27 = 27 Member States of the European Union.

2.1 CHINA

China was able to extend its already considerable lead in large parts of the renewable energy landscape. The country invested an estimated CNY 6.3 trillion (USD 890 billion[6]) in clean energy[7] in 2023, up 40% from 2022, according to an analysis published in *Carbon Brief* (Myllyvirta, 2024). USD 352 billion went to solar manufacturing and power generating capacity; USD 108 billion to wind manufacturing and power generating capacity; USD 83 billion to hydropower generation; USD 115 billion to energy storage (including batteries, pumped hydro and electrolysers); and USD 76 billion to transmission grids. GlobalData (n.d.) finds that China outspent all other countries combined in transmission grid investments in 2022.

China

7.39

million jobs

China's political leadership regards clean energy – and particularly solar photovoltaic (PV), electric vehicles and batteries – as a major engine of the Chinese economy (Bradsher, 2024). Indeed, clean energy contributed about 40% of gross domestic product growth in China in 2023 (Myllyvirta, 2024). In terms of manufacturing capacity, Chinese manufacturers account for 68% of the global total for wind turbines, 83% for solar modules and 81% for energy storage (lithium-ion batteries) (Li, 2024).

Low prices and integrated supply chains allow Chinese manufacturers to meet more than 65% of global demand for renewables-related equipment (Li, 2024). Between 2019 and 2023, Chinese renewable energy product exports grew from about CNY 220 billion (USD 30 billion) to CNY 739 billion (USD 102 billion).[8] Over this period, 53% of export sales were of batteries and 45% of solar modules; wind turbines contributed marginally given that the domestic market remains the predominant destination for Chinese firms' sales. Chinese manufacturers are also increasingly investing abroad, mostly in solar PV (Li, 2024).

Based on surveys, supply chain analyses and employment factor calculations, the China Renewable Energy Society (CRES, 2024) estimates that China's total renewable energy employment grew to 7.39 million in 2023. This growth, driven primarily by the expansion of solar PV, marked a 33% increase from the previous year.

A far-reaching industrial policy strategy has made

China

the undisputed leader in renewable energy manufacturing and deployment.

[6] *Exchange rate of CNY 1 = USD 0.14 as of 9 September 2024.*

[7] *Defined in the analysis to include renewables, nuclear power, electricity grids, energy storage, electric vehicles and railways.*

[8] *According to 2022 data provided by EurObserv'ER (2024), China commanded a 54% share of global renewable energy exports, and 69% of solar PV exports.*

CRES estimates that employment in **solar PV** grew dramatically from 2.76 million people in 2022 to 4.59 million a year later, a stunning 66% gain. This reflects an impressive ongoing expansion of manufacturing capacities and domestic installations, as well as rising exports. Jobs in PV manufacturing grew to 2.37 million, while those in construction and installation, plus O&M, are believed to have reached 2.22 million.

China deployed 216.9 GW of solar PV generating capacity in 2023 – 2.5 times the 2022 record of 86.1 GW and equivalent to 63% of worldwide additions (IRENA, 2024a).

Over the past two decades, China has built a dominant position in solar PV manufacturing, as a visionary industrial policy strategy and steady government support fostered a large-scale, integrated supply chain. Further large-scale expansions are planned for the coming years. In 2023 alone, polysilicon production capacity doubled from close to 500 GW to about 1000 GW. The bulk of new facilities in the coming years will be located in Inner Mongolia in the north, and Ningxia, Qinghai and Sichuan in Western China. Wafer capacity grew from 668 GW to 748 GW, while cell capacity expanded from 592 GW to 777 GW in 2023. For modules, the corresponding figures are 637 GW and 837 GW (Pierce and Sun, 2023).

China's solar PV exports are steadily expanding. Data from the General Administration of Customs of the People's Republic of China indicate that module shipments grew more than six-fold, from 33.2 GW in 2017 to 219.1 GW in 2023 (see Figure 12). In 2022 and 2023, half of all shipments went to the EU (EMBER, 2024).

Chinese solar PV manufacturers are planning to build factories abroad in response to tariffs and other restrictions in overseas markets. In Southeast Asia, factories were set up for export to the US market (but sales have now shifted to India, as noted in Chapter 1). Chinese-owned firms account for close to two-thirds of the region's existing module capacity, and additional investments of USD 3.1 billion have been committed or announced. Chinese manufacturers are also building facilities in the United States (with USD 1.2 billion in investments for 19 GW of module capacity). They also have plans for India, Germany and Turkey, which are, however, more limited in scale (Pierce and Sun, 2023).


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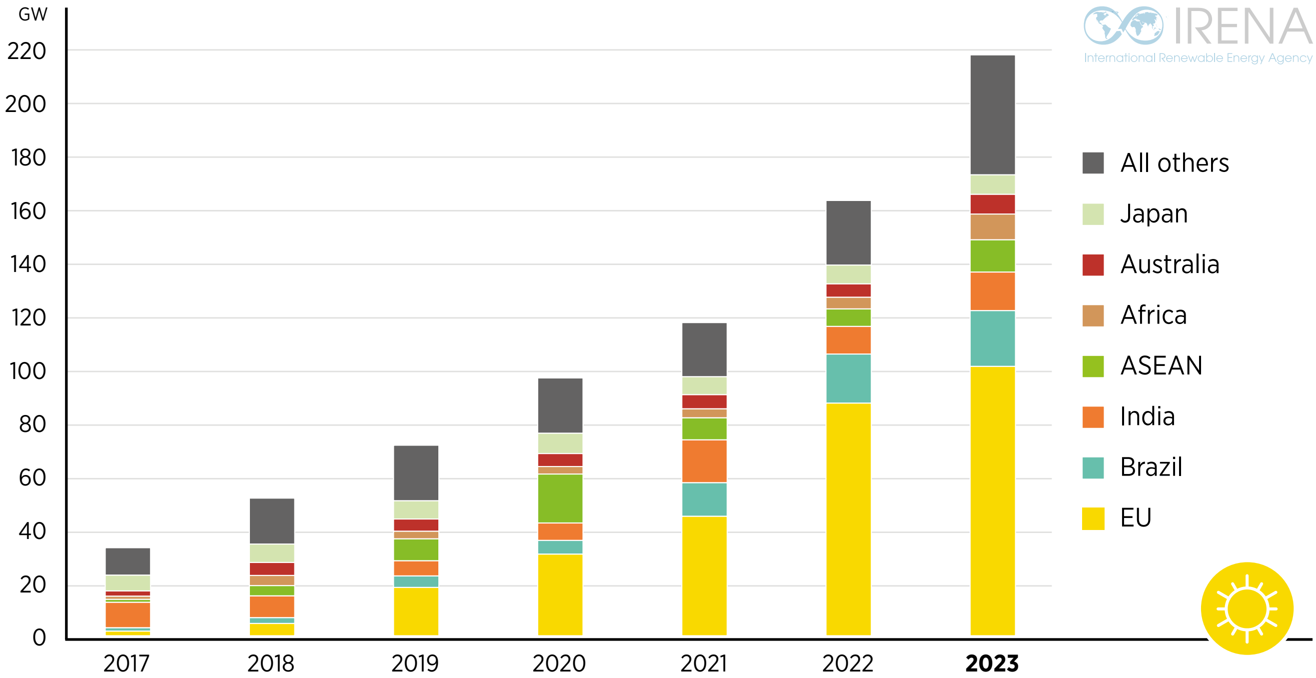
Figure 12 China's solar PV module exports (GW) by main destination, 2017-2023



Source: EMBER, 2024.

Notes: Includes assembled modules only; cells account for 9% of total solar PV exports by value.
ASEAN = Association of Southeast Asian Nations; EU = European Union; GW = gigawatt

Wind capacity installations reached a new peak of 75.9 GW in 2023, equivalent to 66% of the global total (IRENA, 2024a), despite challenges such as the cessation of central government subsidies for new wind projects in 2021 and increased competition among manufacturers, which drove down turbine prices in 2023. As turbines and blades become larger, rising costs are cutting into profit margins (Ren and Li, 2024). Onshore wind accounts for the bulk of new capacity, while the much slower pace of offshore projects reflects the challenges inherent in moving into deeper waters, developing larger projects and navigating more complex regulatory approval processes (Myllyvirta, 2024).

Chinese manufacturers' share of global wind turbine orders rose from less than 5% in 2019 to 82% in 2023 (124.9 GW of 153 GW in orders). Most of this is due to the exponential growth of their domestic market. Chinese original equipment manufacturers saw less than 9% of their orders coming from the rest of the world (principally India) (Wood Mackenzie, 2024b). In Europe, they currently have a 1% market share (Millard, Tani and Hancock, 2024).

According to CRES (2024), the Chinese wind industry employed an estimated 745 000 people in 2023, up 9% from 681 000 in 2022. Manufacturing jobs increased to 374 000 from 234 000 in 2022. Construction and installation jobs are estimated at 234 700, and O&M accounted for 136 300 jobs. The expansion of the industry was tempered by the growing application of automation and artificial intelligence technologies and rising labour productivity in wind power equipment manufacturing.

For **hydropower**, new capacity additions in China were limited to 2.9 GW in 2023, a much slower pace than the 13.2 GW added in 2022 (IRENA, 2024a). Employment may not necessarily have declined in line with this reduction, as companies and state agencies may have opted to retain experienced personnel in anticipation of increased activity the following year. IRENA estimates direct employment at some 788 000 jobs in 2023.[9]

Even though China's **solar heating and cooling** industry has been largely stagnant in recent years, it still dominates, representing a 73% share of global installed capacity (Weiss and Spörk-Dür, 2024). The industry directly employed about 514 000 people in 2023. This figure continues a downward trend from 557 000 jobs the previous year and 636 000 in 2021. Mirroring the downturn in the real estate market, the drop reflects a reduction in new installations. Still, installation and maintenance jobs together (398 000) significantly outnumbered those in manufacturing (116 000) (CRES, 2024).

Among the remaining renewable energy technologies, **bioenergy** accounted for 425 000 jobs in 2023, up from 410 000 the year before. Manufacturing accounted for 240 000 of these jobs. Broken down by technology, 200 000 people worked in solid biomass, 165 000 in biogas, and 60 000 in liquid biofuels (CRES, 2024). In biofuels, biodiesel production reached a new peak of 3.3 billion litres in 2023, but the bioethanol output of 3.9 billion litres remained below the 2019 record (USDA-FAS, 2023f). The **heat pump** industry was estimated to have employed 133 000 people in 2023 – 40% in manufacturing and 60% in sales, installations and services (CHPAlliance, 2023). **Concentrated solar power** was estimated to have employed 98 300 people in 2023, up substantially from 59 400 the previous year. The growth was driven by new construction, which accounts for more than half of the total. **Geothermal** heat and power offered 93 900 direct jobs, up from 87 000 in 2022. Most of these were in O&M for heating technologies (CRES, 2024).

[9] *The inclusion of indirect employment yields significantly larger numbers, given that China boasts an extensive domestic supply chain for this sector. The China Society for Hydropower Engineering (CSHE) estimates that as many as 2.4 million people may have been employed in the sector and its supply chain in 2023. This encompasses a segment – design and consultancy (with 422 300 jobs) – that is often not included in such estimates for lack of adequate information. Other segments include construction and installation (1.086 million jobs, although some may be of limited duration), O&M (603 300) and component manufacturing (301 600) (CRES, 2024). It should be noted that the CSHE figure is not directly comparable to IRENA's estimate, which is not only limited to direct jobs but also based on a fundamentally different methodology.*

2.2 BRAZIL

Brazil

1.57
million jobs

Brazil had an estimated 1.57 million renewable energy jobs in 2023. The country hosts a strong domestic industrial base for hydropower and biofuels and a more limited industrial base for wind development. However, according to EurObserv'ER (2024), overall, Brazil is a net importer of renewable energy products and services; imports in 2022 were more than double exports. Solar panels dominated imports, while biofuels contributed the most to exports.

In terms of installed capacity, **hydropower** remains Brazil's largest renewable energy industry, but it is far less dynamic than the solar and wind industries and not nearly as labour intensive as the bioenergy sector. IRENA modelling yields an estimate of 177 300 jobs in hydropower.

As in previous years, the **biofuels** sector was the largest employer in renewable energy, having grown strongly in 2023 to represent an estimated 994 260 jobs. Brazil is the world's third-largest biodiesel producer after Indonesia and the United States. Biodiesel production was estimated at 7.54 billion litres in 2023, up substantially from about 6.42 billion litres in 2022. Nameplate biorefinery capacity has steadily expanded in the past decade and is now almost double that in 2014. But the industry relies heavily on the government's mandatory blend rates, which have fluctuated in response to fears about price and inflation impacts (USDA-FAS, 2023a). IRENA estimates 403 700 biodiesel-related jobs in Brazil in 2023, up strongly from a revised figure of 284 700 the year before.[10]

Brazil ranks second in the world for bioethanol production. Government data indicate there were 359 700 jobs in bioethanol production as of 2022, up from 344 500 jobs in 2021 (MTE/RAIS, 2024).[11] A figure for 2023 is not yet available, but assuming that employment mirrored the estimated 8.6% growth of Brazil's fuel ethanol output (USDA-FAS, 2023a), it may have expanded further to some 390 560 jobs in 2023. IRENA includes, as a rough estimate, another 200 000 indirect jobs in equipment manufacturing.

[10] *The calculation is based on employment factors for different feedstocks (Da Cunha, Guilhoto and Da Silva Walter, 2014). The 2023 shares of feedstock raw materials, principally soybean oil and various vegetable oils, are derived from ABIOVE (2024).*

[11] *In 2022, about 176 300 workers cultivated sugarcane in Brazil, and 177 800 processed alcohol and ethanol.*

Brazil installed 11.9 GW of new **solar PV** capacity in 2023, the fourth-largest amount added worldwide after China, the United States and Germany. A cumulative 37.4 GW placed the country sixth worldwide. PV installations have soared 30-fold since 2017 (IRENA, 2024a).

About 70% of the cumulative PV capacity was in decentralised generation facilities. Residential installations, which are especially labour intensive, account for almost half of the decentralised capacity (ABSOLAR, 2024). However, there were 20% fewer new residential installations in 2023 than the year before (reflecting high interest rates and a credit crunch), whereas commercial, industrial and rural installations kept growing (Greener, 2024). In geographic terms, more than half of all decentralised capacity has been installed in just five states, most in the south: São Paulo, Minas Gerais, Rio Grande do Sul, Paraná and Mato Grosso (ABSOLAR, 2024).

Brazil imports the bulk of its PV modules (17.5 GW in 2023, slightly less than the 17.8 GW peak value in 2022) (Greener, 2024). Of the 147 domestic manufacturers of solar PV system kits, only 8 manufacture modules, another 8 inverters and 12 trackers (ABSOLAR, 2024). Among domestic manufacturers, Valmont Solar plays a prominent role in mounting systems. A new mounting systems factory serving the domestic as well as the regional Latin American markets is expected to create more than 300 direct jobs in 2024 (Jowett, 2024). IRENA estimates Brazil's solar PV jobs at about 264 000 in 2023, up from 247 100 in 2022.

The gender balance in Brazil's solar industry remains uneven. Among the companies active in solar PV equipment distribution, 41% of the workforce in 2023 were women (rising to 45% among firms with fewer than 100 employees). However, women represented only 20% of the jobs among PV system integrators (most of them SMEs) in 2023, down from 24% in 2022. The share of women was largest in administrative, finance and human resource roles, at 53%, compared with 24% in commercial activities. Women held a paltry 7% share in marketing, management and project engineering in 2023 and just 2% in assembly and installation. A third of PV integrators reported no female employees at all; by contrast, women outnumbered men in 3% of firms (Greener, 2024).

In 2023, Brazil added 1.83 million square metres of **solar water heating** capacity, slightly more than in the previous peak years of 2021 and 2022 (ABRASOL, 2024). IRENA estimates 50 700 jobs in the solar water heating industry (including manufacturing and installation) in 2023.

Brazil added close to 5 GW of **wind** generating capacity in 2023. This was the largest amount installed by the country to date. Brazil ranked third worldwide in capacity additions in 2023 (and seventh in terms of cumulative installations) (IRENA, 2024a). Two-thirds of the total capacity is located in two northeastern states: Rio Grande do Norte and Bahia (ABEEÓLICA, 2024). Based on an employment factor analysis, IRENA estimates Brazil's wind industry jobs to have grown to 80 300, up from 67 700 in 2022. Close to half of the jobs (44%) were in construction, followed by manufacturing (34%) and O&M (22%). While perceived wage inequalities are lower in wind energy than in the economy at large, the industry remains male dominated (as is the case worldwide); great effort is required to improve women's ability to join the workforce and to rise to leadership positions (ABEEÓLICA, 2024).

2.3 UNITED STATES

United States

1.06 million jobs

The United States is a large net importer of renewable energy products and services, with imports three times greater than exports in 2022. The bulk of imports were in solar PV panels, whereas the country is the world's largest biofuels exporter (EurObserv'ER, 2024).

Meanwhile, the Inflation Reduction Act of 2022, along with the Bipartisan Infrastructure Law of 2021, has triggered a large number of investment announcements for equipment manufacturing and related areas such as battery storage, grid upgrades and electric vehicles, as well as in the mining and processing of the minerals needed for the energy transition.

In 2023, the United States installed an estimated 24.8 GW of new **solar PV** capacity, the most ever (IRENA, 2024a). Domestic manufacturing of panels covers only a small share of annual installations. But corporate announcements of planned investments could theoretically increase US module manufacturing capacities almost ten-fold by 2026 (Pierce and Sun, 2023).

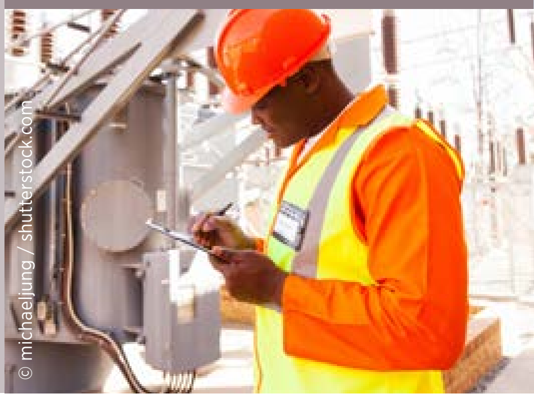
However, given the challenges of supply chain reliability, labour availability, access to capital and permitting delays, analysts expect that only half of the anticipated expansion may materialise. Meanwhile, there was no wafer or cell manufacturing in the United States in 2023 (Pierce and Sun, 2023; Wood Mackenzie, 2024d). In cell manufacturing, Ebon Solar intends to open a facility in Albuquerque, New Mexico, that could employ 900 people full time (Kennedy, 2024).

Unlike other domestic firms, First Solar, a producer of thin-film modules, has built a vertically integrated manufacturing profile and has more than 6 GW of capacity operational. An input-output study commissioned by the company estimated that its operations supported 8700 jobs in 2023 (of which 2700 were direct), with another 2730 temporary jobs in construction. This number could rise to about 16800 in 2026 (of which 4100 jobs would be direct) under a planned expansion to 14 GW (First Solar, 2024). Another vertically integrated facility, which had 3.3 GW of capacity (producing silicon ingots, wafers, cells and modules), was constructed by Hanwha Qcells in the state of Georgia. The US Department of Energy is providing a USD 1.45 billion loan guarantee. Together with an existing factory, planned output will rise to 8.4 GW. Some 3800 direct jobs were created in the state. Qcells plans to offer job training and apprenticeships to local residents (Misbrener, 2024; QCells, 2024).

According to the National Solar Jobs Census (IREC, 2024), solar PV employed 279 447 people in the United States in 2023, an increase of 15 564 jobs or about 6%.[12] Installations and project development accounted for 64%, trade and distribution for 12%, manufacturing another 12%, O&M for 8%, and other categories for 4.5%. By far the biggest chunk of employment in installations relates to residential solar, followed by the commercial segment, utility-scale deployments, and finally community solar.

The US **wind** sector installed 6.3 GW of capacity in 2023, down from 8.7 GW in 2022 and 14.9 GW added in 2020 (IRENA, 2024a). Almost all of this is onshore capacity. Backed by tax credits provided for component manufacturing, vessel construction and related infrastructure under the Inflation Reduction Act, the United States has ambitious plans to deploy 30 GW of offshore wind by 2030, up from the marginal 41 MW currently in place (GWEC, 2023). The American Clean Power Association (ACP, 2024) projects future offshore leases to yield more than 56 GW of capacity. They could generate 56 000 jobs in project development, construction and operations if investments of USD 65 billion materialise by 2030.

The state of New Jersey has sought to position itself as an emerging hub for offshore wind. A modelling assessment (NJEDA, 2022) found that about 20 000 jobs could be created by 2030 if the state meets the target of 7.5 GW capacity, in addition to providing supply chain support for another 26 GW of offshore windfarms elsewhere on the US east coast. Half of these jobs would be in manufacturing, about 1800 in construction and about 2 000 in professional services.



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[12] *The Interstate Renewable Energy Council includes only solar workers who spend at least half of their working hours on solar goods and services. By contrast, the US Energy and Employment Report (USEER) pegs solar PV employment at about 364 500 jobs in 2023. This includes all employees engaged with solar technologies, regardless of the share of time they spent on solar-related work.*

But US offshore plans face unexpected headwinds due to supply chain delays and rising project costs. These factors have led to a number of project cancellations. Three projects were cancelled in Massachusetts and Connecticut. Two projects off the coast of New Jersey were cancelled in October 2023 by Ørsted (Ørsted, 2023). And the Empire 2 Wind project off New York was stopped by BP and Equinor (Bindman, 2024). Cancellations reduce the anticipated US capacity for 2030 from 30 GW to 22 GW (Bindman, 2024), and possibly to as little as 15 GW (Penn, Reed and Plumer, 2023). Building a domestic supply chain for offshore wind projects would help reduce some uncertainties, but manufacturers require steady demand at a sufficiently large volume to justify building factories in the country. Deployment policies will have to be closely linked with industrial policy making if US offshore plans are to be realised.

There were an estimated 131 327 wind power jobs in 2023, up from 125 580 in 2022. The onshore segment accounted for almost all of these. Construction represented a third, professional services a quarter and manufacturing almost one-fifth of the jobs (USDOE, 2024b).

US **ethanol** output expanded in 2023, reaching levels close to the 2017 and 2018 peak years (USEIA, 2024). However, ethanol output absorbs a significant share of corn production, prompting questions about energy versus agricultural priorities. Ethanol's share in the US corn crop rose from under 7% in 2000 to 40% in 2011 and has remained above 35% since (USDA, 2024a). Input-output modelling suggests bioethanol to have employed some 276 100 people in 2023, including 72 500 directly and 203 600 indirectly in the agricultural-industrial supply chain. About 12 800 people were employed at 198 biorefineries in 24 US states. Exports grew 6% in 2023 and supported 28 500 jobs (Urbanchuk, 2024).

The United States produces much less **biodiesel** than ethanol. In 2023, output rose slightly to 6.4 billion litres, still well below the 2018 peak (USEIA, 2024). Biodiesel absorbs a growing share of soybean production, with demand rising from virtually zero in 2000 to just under 14% in 2011, and soaring to 46.3% in 2022 (USDA, 2024b). Based on employment factors, IRENA estimates about 66 260 biodiesel-related jobs in 2023, up from 63 260 in 2022.

According to the US Department of Energy (2024b), **hydropower** employs 68 372 people,[13] **solar heating and cooling** 29 652 and **geothermal power** 8 870. Various other **renewable heating and cooling** technologies account for 105 827 jobs.[14] In addition, but not included in this report, there were 147 322 jobs in various energy transition–related areas in 2023,[15] and energy efficiency employed about 2.2 million people. Altogether, IRENA estimates 1.06 million US residents were employed in renewable energy in 2023.

[13] *This figure includes 11 730 jobs in low-impact hydro and 56 641 jobs in traditional hydro. An estimated 9 104 jobs in pumped hydro are not included here (USDOE, 2024b).*

[14] *This figure includes jobs in geothermal heat, biomass heat, heat pumps and other technologies.*

[15] *This figure includes jobs in battery storage (75 702 jobs), smart grids (26 351), micro grids (20 632) and other grid-modernisation work (21848) (USDOE, 2024b).*

Very few US energy workers are represented by a labour union, collective bargaining agreement or project labour agreement. The 11% recorded in 2023 is higher, however, than the 7% average for the national workforce as a whole. The average share for companies working in fuel preparation is also just 7%, surpassed by coal (11%) and nuclear power (17%). Solar (14%), and wind power and hydro facilities with low environmental impact (both 12%) score higher, although not as high as utilities powered by coal, gas or nuclear energy (16%, 17% and 19%, respectively). Interestingly, unionised employers[16] have less trouble finding workers than non-unionised firms (USDOE, 2024b).

USEER data indicate that 36% of unionised firms, but just 24% of non-unionised ones, offered or required training aimed at increasing workplace diversity and inclusion in 2023. Unionised firms were more likely to embrace specific strategies, policies or programmes to increase the number of women, ethnic and racial minorities, and LGBTIQ+[17] hires (USDOE, 2024b).

Such measures are urgently needed. Women still hold only a small number of jobs in the US energy sector (26%), compared with their 47% share in the overall national workforce. Moreover, women held only 19% of the energy jobs newly created in 2023. Women's share was 30% in the wind and solar power sectors – less than the 34% in nuclear, coal- or gas-fired power plants, but more than the roughly 25% share in oil, natural gas and coal mining, or in transmission, distribution and storage (USDOE, 2024b). African Americans also remain under-represented in the energy sector. They hold 9% of the jobs in this sector, compared with their 13% share in the US workforce (USDOE, 2024b).

Alongside efforts favouring greater workforce diversity and gender equity, inclusion measures are critical to ensure that benefits reach disadvantaged communities. This is the goal of a presidential executive order issued in January 2021, Justice40, which aims to secure widely shared benefits of recent government investment programmes (see Box 1).


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19%
of the newly created jobs in the energy industry are held by women.

[16] *The USEER defines a unionised employer as one where at least 20% of the workforce is a member of a labour union or covered by either a project labour agreement or a collective bargaining agreement.*

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

Box 1
United States: Ensuring benefits for disadvantaged communities

The Justice40 initiative applies to more than 400 federal government programmes related to climate, clean energy and infrastructure. Many of these were created by the Bipartisan Infrastructure Law (BIL) of 2021[18] and the Inflation Reduction Act (IRA) of 2022. The agencies administering these programmes are required to ensure that 40% of the overall benefits created flow to disadvantaged communities – that is, communities with disproportionate socio-economic vulnerabilities due to pollution, underinvestment in critical infrastructure, and environmental and health risks. Among the eight priorities established by Justice40 are advancing the creation of clean energy enterprises and boosting clean energy jobs and job training for individuals from the target communities. Federal programmes that fall under the initiative's scope are required to engage in consultations with stakeholders and ensure that communities have meaningful involvement in determining outcomes (White House, 2023).

The US Department of Energy (USDOE) administers 167 programmes that are covered by Justice40. These include several programmes focused on renewable energy and energy efficiency, grid deployment, energy storage, manufacturing and energy supply chains, and energy justice and equity. The USDOE requires that all funding opportunity announcements under the BIL and IRA include Community Benefits Plans, which are scored at 20% of the technical merit when funding proposals are reviewed (USDOE, n.d.a).

A major effort under the Justice40 initiative, the USDOE's Electric Heat Pump Acceleration Initiative, addresses the high upfront costs that often prevent low-income households from accessing this technology by offering subsidies for installation. The initiative also seeks to accelerate domestic manufacturing of components and supports workforce development in manufacturing, installation and maintenance, helping to create good jobs in communities that need them most (USDOE, 2024a, n.d.b).

The Environmental Protection Agency (USEPA) manages a Solar for All programme that invests USD 7 billion to enable close to one million households in low-income and disadvantaged communities to deploy rooftop and community-owned solar energy, creating quality jobs and providing local training and workforce development programmes (USEPA, 2024a, 2024b).

USEPA's Clean School Bus Program aims to replace polluting diesel school buses in disadvantaged communities with electric models. The programme is to receive USD 5 billion in funds over 2022-2026. The programme strengthens the domestic manufacturing of zero-emission buses (USEPA, 2024c).

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[18] *Formally known as the Infrastructure Investment and Jobs Act.*

India

1.02
million jobs

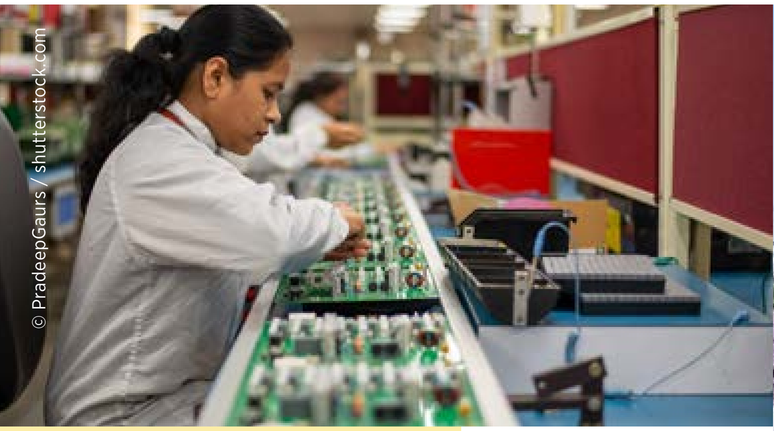
2.4 INDIA

India is a net importer of renewable energy equipment and related services. However, the country was able to reduce its imports and increase its exports in 2022, narrowing the imbalance somewhat. For wind and hydropower equipment, India enjoys an export surplus (EurObserv'ER, 2024).

In 2023, India had an estimated 1.02 million renewable energy jobs. Hydropower, with some 453 000 jobs, was the largest renewables employer, followed by solar PV, which had 318 600 people involved with on-grid and off-grid systems. Other renewables contributed much smaller numbers.

India added 9.7 GW of **solar PV** capacity in 2023. While this was less than the record 13.4 GW added in 2022, or the 10.4 GW in 2021, the country nevertheless ranked fifth in the world for capacity installation. It also ranked fifth for cumulative capacity (72.7 GW) at the end of 2023 (IRENA, 2024a).

To shield its domestic PV manufacturing, India adopted tariffs in April 2022 and December 2023 and imposed non-tariff import restrictions (the so-called Approved List of Models and Manufacturers, or ALMM). The ALMM, however, had to be temporarily relaxed in light of limitations in the local PV manufacturing industry. India also introduced a number of support measures, including a production-linked incentive scheme for solar PV manufacturing companies to build large-scale solar capacities. Two funding tranches in April 2021 and September 2022 together made available USD 2.25 billion (Wood Mackenzie, 2024a).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Operational module manufacturing capacity was estimated at 46 GW in 2023, growing to 58 GW in 2024. Operational cell capacity was 26 GW in 2023, growing to 32 GW by 2024. With this capacity expansion, India has become the world's second-largest PV manufacturer after China. Still, much of the current capacity consists of facilities producing small, low-efficiency modules. Wafer production capacity is expected in coming years (Wood Mackenzie, 2024a).

India's solar PV exports, the overwhelming majority of which are destined for the United States, have expanded markedly. Drawn by incentives from the US Inflation Reduction Act, Indian manufacturers are also planning to build module, cell and wafer factories in the United States. But India's PV exports are still dwarfed by imports. The largest share of imports continues to come from China, although this portion plummeted from 83% in January-August 2022 to just 49% in the same period in 2023. Meanwhile, Southeast Asia's market share tripled from 14.4% to 44.5%. Viet Nam, Malaysia, Thailand and Cambodia – listed in order of their respective export volumes – are increasingly selling to India after the United States imposed import tariffs on them (Raghavan, 2023). Effectively, as Wood Mackenzie (2024a) points out, Indian companies import cells from Southeast Asia, assemble them into modules, and then export them to the United States.

Based on employment factors, IRENA estimates that India had 238 000 jobs in grid-connected solar PV in 2023, up 18% from 2022. Roughly 80 000 people work in off-grid solar.

A cumulative installed **wind power** capacity of 44.7 GW puts India in fourth place globally. India added 2.8 GW in 2023, up substantially from the additions in each of the past five years but well below the 2017 peak of 4.1 GW (IRENA, 2024a).

Beyond serving the domestic market, India could assume a growing role in the export of various components and thus create more jobs. In addition to surplus nacelle manufacturing capacity (where capacity of 11.5 GW is more than double the current and expected domestic demand), India accounts for 11%, 7% and 12%, respectively, of global blade, generator and gearbox manufacturing capacity. US tariffs imposed on Chinese-made gearboxes led leading manufacturers to expand their production facilities in India, and the country subsequently replaced Europe as the world's second-largest gearbox production hub (GWEC and MEC+, 2023).

However, expanding wind component exports further depends on ensuring that the wind equipment produced in India is well matched with demand in overseas markets in terms of parameters such as nameplate capacity, hub height and rotor diameter. Also, the Global Wind Energy Council (GWEC) and MEC+ note that Indian-made turbines are currently 60% more expensive than comparable Chinese models; turbines assembled in India that have a majority of imported components still cost 30% more than Chinese-manufactured turbines. Manufacturers therefore must become more cost-competitive as local industries develop, and are nurtured and nudged by industrial policies.

IRENA estimates that the Indian wind sector had 52 200 jobs in 2023, with nearly 40% in O&M and approximately 35% in construction and installation.

EU 27

1.81
million jobs

2.5 EUROPE

Collectively, the countries of Europe are among the leading installers of clean energy capacity. The capacity to manufacture equipment for domestic markets, however, varies widely across the region. Table 2 provides data for EU members. The EU 27 are net importers of renewable energy equipment and services. An export surplus in wind and hydro is dwarfed by large and fast-rising solar imports as well as smaller biofuel import volumes (EurObserv'ER, 2024).

Europe had 2.05 million renewable energy jobs in 2023; about 1.81 million were in the EU 27.

IRENA estimates the European **wind power** sector to have employed 316 300 people in 2023, down from 402 000 in 2022. The EU 27 accounted for 282 000 of these jobs. The employment figures for Europe reflect the region's position as the world's second-largest installer and second-largest manufacturer of wind equipment. Germany was the leading employer, with about 108 640 jobs, followed by the United Kingdom, France and Spain.

At the end of 2023, the continent's cumulative wind power capacity reached 257 GW. New additions of 16.8 GW were somewhat lower than the record 18.6 GW installed in the previous year. EU 27 members accounted for 90% of the continent's new installations (IRENA, 2024a).

Particularly in the offshore segment, wind farm developers are grappling with rising costs, which far exceed the assumptions underlying the deals that developers had made with off-takers of the electricity they produce (Millard, 2023a). Denmark's Ørsted, the world's largest offshore wind developer, scaled back its 2030 target of developing 50 GW of renewable energy capacity to 35-38 GW and is halting project development in Spain, Portugal and Norway. It decided to lay off 800 of its 9 000 employees. Sweden's Vattenfall decided to stop work on its Norfolk Boreas windfarm in the UK North Sea in 2023, arguing that the fixed price previously agreed with the government left the project unviable (Millard, 2023b, 2024).

Table 2 EU clean energy equipment manufacturing capacity and EU production as a percentage of EU market demand

	EU manufacturing capacity (GW; GWh for batteries)	EU production as share of EU demand (%)
Wind	13	85
Heat pumps	14	60
Battery cells	75	54
Electrolysers	2.3	10
Solar PV	1	3

Source: EC, 2023.

Notes: EU = European Union; GW = gigawatt; GWh = gigawatt hour; PV = photovoltaic.

EU manufacturers produce an estimated 85% of the Union's annual wind deployment needs. They also have a strong presence in markets beyond the continent; about two-thirds of their total output (either exported or produced in facilities outside of Europe[19]) is installed in other regions of the world (EC, 2023). However, they now face significant volatility in the cost of materials and other inputs, as well as higher transportation and financing costs (Tapoglou *et al.*, 2023). Siemens Energy (the parent company of Siemens Gamesa) required financial guarantees worth USD 16.2 billion from the German government and banks when orders received were lower than expected and after engineering defects were detected in two of its turbine models (Jones, 2024).

In **solar PV**, European countries installed about 54.3 GW of new capacity in 2023 – a new record and almost double the 2021 pace. The EU 27 accounted for 51 GW of this total (IRENA, 2024a). Given the steep rise in deployments, solar employment in Europe is increasing. For 2022, SolarPower Europe (2023) put employment at 648 257 FTE positions – up from about 465 600 in 2021 and 357 000 in 2020 (SolarPower Europe, 2022). Deployment accounted for 84% of jobs; 8.1% were in O&M, 7.4% in manufacturing and 0.8% in decommissioning and recycling. Close to three-quarters of the manufacturing jobs were in the production of inverters.

Residential rooftop solar is labour-intensive, requiring as much as three times the labour needed for utility-scale deployments per kilowatt installed. Poland, Italy and the Netherlands have the highest shares of installations in this segment. In Poland, installations translated into an estimated 146 851 jobs in 2022 (though salaries are low compared with those of installers elsewhere in Europe). Poland was followed by Spain (103 337 jobs), Germany (95 643), the Netherlands (42 553) and Italy (41 911) (SolarPower Europe, 2023).


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[19] *The network of factories varies over the years but has typically included facilities in countries such as Brazil, India, the United States and China.*

For 2023, IRENA estimates solar PV employment in Europe at 757 500 based on a combination of national reports and employment factor calculations. Germany's 154 700 jobs mark a 54% increase from the previous year, the growth driven by a robust increase in new installations. Employment surged remarkably in Italy, doubling to 76 400 jobs. At the same time, substantial growth in construction and installation activity in Austria and Bulgaria led to large employment gains. By contrast, declines in new installations in Poland and Spain may have shrunk the countries' workforces to 112 000 and 51 228 jobs, respectively.

The factor that has driven the robust growth in installations in most European nations – rapidly falling panel costs – is also a major reason the continent is struggling in manufacturing. Unable to compete on price with Chinese suppliers, the continent's module production plunged from 9 GW in 2022 to just 1 GW in 2023. European manufacturers accumulated a stock of over 500 MW of modules, which they were unable to sell at a price that covers costs (Yuen, 2023). The bulk of Europe's solar panels are imported, and China commanded a 96% share of the flows into the EU in 2022 (Eurostat, 2023). By panel capacity, Chinese imports into EU skyrocketed from 1.7 GW in 2017 to 101.6 GW in 2023 (EMBER, 2024).

Between August 2023 and early 2024, eight European companies in the solar PV supply chain filed for bankruptcy, halted production or closed factories. Systovi (France), Meyer Burger (Switzerland) and REC Group (Norway) have closed plants (Hancock and White, 2024). Meyer Burger closed a module factory in Germany and laid off 400 workers (Shabani, 2024). Ingot manufacturer Norwegian Crystals entered insolvency in August 2023 (Enkhardt, 2023).

The European Commission has made several efforts to rebuild a local solar PV manufacturing industry. It aspires for a capacity of 30 GW by 2025 (ESIA, 2022) and 45% self-sufficiency, which, if successful, would bring robust job growth. Whether this is feasible within the intended time frame is open to question (Hryshko, 2024). Inverter manufacturing is Europe's strong suit, with a capacity of 70.7 GW in 2022. Polysilicon capacity stood at 21.2 GW in 2022, while capacity was more limited for modules (7.5 GW) and minute for cells (0.5 GW) and ingots/wafers (0.2 GW) (SolarPower Europe, 2023).

The solar industry has requested a range of support measures from the European Commission, including an emergency purchase of unsold module inventories; the establishment of an EU-level bank for manufacturers to overcome shortcomings in state aid; strict sustainability and resilience criteria in auctions (to reward panels produced with a low carbon footprint); and stringent measures against products tied to forced labour (Enkhardt, 2023). The Commission has given a green light to Member States on state aid. For example, in February 2024, Italy announced an investment of close to EUR 90 million in Enel's 3Sun Gigafactory in Catania. This expansion of an existing facility is expected to create an additional 1000 direct and indirect jobs (Enel Green Power, 2024).

Bioenergy is far less dynamic than the solar industry, but according to EurObserv'ER (2024), it has the largest employment share among renewables, employing 530 700 people. **Solid biomass** (for heating and electricity) had a workforce of approximately 331 700 in 2022 (down from 353 800 in 2021). Another 149 700 people were employed in **biofuels** (up from 148 300) and 49 300 in **biogas** (up from 47 100). Given that the bulk of solid biomass supply in the EU 27 comes from within the region, feedstock operations entail substantial local employment. The largest employers in 2022 were Germany (40 300 jobs), Poland (33 400), France (30 500), Sweden (20 600) and Italy (23 600 jobs) (EurObserv'ER, 2024).

Ethanol fuel production in the EU 27 was at peak levels of about 5.6 billion litres in 2022 and 2023. Meanwhile, **biodiesel** output has been fairly stable at about 16 billion litres (USDA-FAS, 2023d). EurObserv'ER (2024) reported 149 700 biofuel-related jobs in the EU 27 in 2022, up slightly from 148 300 jobs in 2021. Given steady production levels, it stands to reason that employment in 2023 was close to that in 2022. Poland (21 500 jobs), Hungary (20 400), France (19 000) and Romania (16 600 jobs) had the largest number of biofuel-related jobs in the EU 27 in 2022.

Among EU 27 countries, **GERMANY** has the largest cumulative solar PV capacity (81.7 GW). Annual installations have grown steadily over the past several years, and the 14.3 GW added in 2023 were almost double the previous record of 7.4 GW in 2022 (IRENA, 2024a). Reflecting the surge in **solar** installations, Bundesverband Solarwirtschaft (BSW, 2024) estimates 103 000 jobs in 2023, up from 55 000 jobs earlier. Still, BSW's figure appears conservative, given that SolarPower Europe (2023) estimated 95 643 direct and indirect jobs in 2022, when additions were much smaller. IRENA's estimates suggest that the industry supported 154 600 jobs in 2023.

Wind additions were much smaller, owing to slow permitting processes and state-level restrictions on project siting. The 3.3 GW built in 2023 were only about half of the peak of 6.1 GW reached in 2017 (IRENA, 2024a). German wind energy employment fell from a high of 167 600 jobs in 2016 to 108 600 in 2023. The slow pace of new capacity installations also makes it harder to sustain a sizable domestic manufacturing industry.

According to EurObserv'ER (2024), **bioenergy** employed 76 300 people in Germany in 2022, down slightly from 77 900 in 2021. Employment numbers are much smaller for solar thermal energy (6 500 jobs) and hydropower (7 300 jobs).

In **SPAIN**, renewable energy employed 127 576 workers in 2023, a slight drop (-2.5%) from the previous year. Of the total, 81 897 jobs were directly created by companies in the sector and 45 679 were created as a spillover effect in other sectors. The drop in employment was due to a decline in wind power installations (924 MW installed, compared with 1 658 MW in 2022) and in self-consumption (1 943 MW, compared with 2 649 MW the year before). Although PV energy for market sale registered an increase in 2023, with a total of 5 990 MW installed, the rise was not sufficient to offset the loss of activity in other areas (APPA Renovables, 2024).

Modelling by EurObserv'ER (2024) puts renewable energy jobs in **FRANCE** at 197 900 in 2022 (the most recent year available), up from 167 800 in 2021.[20] For wind jobs, EurObserv'ER sharply increased its estimate from 14 500 in 2021 to 36 500 in 2022 (but as discussed below, this appears too large a figure). By contrast, EurObserv'ER's assumption of a decline in solar PV employment from 23 300 to 20 500 does not seem to consider the pace of installations in 2022, which was on par with that in the previous year. About 2.7 GW were added each year; in 2023, a new peak of 3.2 GW was recorded (IRENA, 2024a). The estimate of 32 184 solar PV jobs by SolarPower Europe (2023) appears more aligned with deployment trends. According to EurObserv'ER, France had about 53 000 jobs in the bioenergy sector, up from 46 300 in the previous year. This included 30 500 people in solid biomass, 19 000 in biofuels and 3 500 in biogas. Employment is more limited in hydropower (3 800), solar thermal (1 400) and geothermal (1 200).

Despite fluctuating annual construction activity, France now ranks eighth in the world in wind capacity (some 22.2 GW). In 2022, the country installed 2.3 GW of new wind capacity, a record, and the first French offshore wind farm was commissioned in Saint-Nazaire. But in 2023, new additions fell to 1.4 GW (IRENA, 2024a). While France still lags on installations, it has started to build a domestic wind supply chain. Two blade factories and two nacelle plants produce for domestic and export markets; investments are flowing into port infrastructure; and many firms, primarily SMEs, produce a range of components and services.

A detailed study in 2023 by France Énergie Éolienne (FEE) and Capgemini finds 28 266 direct and indirect wind power jobs at the end of 2022, up 11% from 25 500 jobs in 2021 and 40% from 20 200 jobs in 2019. One-third of the jobs in 2022 were held by women. Along the value chain, 34% of wind employment was in planning and development, 26% in engineering and construction, 22% in component manufacturing and 18% in O&M. A quarter of all French wind jobs are in Île-de-France, the capital region around Paris, home to much of the project design and planning work, as well as many engineering firms. Almost one-third of employment in component manufacturing is in Normandy, followed by Auvergne-Rhône-Alpes and Pays de la Loire. Pays de la Loire, Île-de-France and Hauts-de-France lead in O&M jobs (FEE and Capgemini, 2023).

The March 2022 offshore wind pact between the French government and industry aspires to a minimum of 2 GW installed annually from 2025 onwards, with the hope of creating 20 000 direct and indirect jobs by 2035 (up from close to 7 000 now) and to having local content represent half of all project costs (FEE and Capgemini, 2023).

To drive the country's green industrialisation effort, France's parliament passed a Green Industry Bill in October 2023. The purpose of the legislation is to focus support on green sectors and technologies such as wind turbines, solar panels, heat pumps, green hydrogen and electric batteries. The bill entails plans to train more engineers and technical professionals and to enhance vocational training in co-operation with businesses. A "green industry" tax credit, which may cost about EUR 500 million, was designed to trigger EUR 20 billion in investments and create 40 000 new jobs by 2030 (Basso Hartmann, 2023).

[20] However, this figure includes an estimate of 80 300 jobs for heat pumps – a figure that does not separate out segments of the industry that are oriented to air-conditioning, thus overstating what can be justifiably counted as renewables-related jobs.

In the **UNITED KINGDOM**, wind power remains the leading source of renewable energy; about 30 GW of capacity has been installed. Solar PV capacity is half that of wind, but annual deployment has been rising, from 0.2 GW in 2021 to 1 GW in 2023, placing the country among the world's top 20 installers (IRENA, 2024a).

The UK Office for National Statistics (ONS, 2024) estimates direct employment in renewable energy to have been about 57 000 FTE positions in 2022. The wind industry employed about 17 900 people in 2022 (of which 11 300 in the offshore segment), up from 16 500 in 2021; solar employed about 9 000 people (up from 6 700); hydropower, 1 100; renewable heat and combined heat and power, 19 300 (up from 16 400); and bioenergy and alternative fuels, 9 100 (up from 7 900). These compare with 23 100 jobs in nuclear power. Energy efficiency employed 116 100 people. Low-emission vehicles and infrastructure weighed in with 34 800 jobs, and fuel cells and energy storage systems with 5 600.

The United Kingdom continues to be one of the leading deployers of wind power (principally offshore, for which it ranks second after China), but the pace of annual additions is uneven. In 2023, the country installed just 1.45 GW, less than half the amount of the year before (IRENA, 2024a). Uncertainty concerning auctions and bottlenecks in port infrastructure, grid capacity and skills development all played a role.

The United Kingdom's strength lies in areas such as blade and cable manufacture, and in the services to develop, build, commission and operate wind farms. It lags in the production of generators and foundations, and in the areas of engineering, procurement and construction contracting (OWIC and OWGP, 2023). The United Kingdom has two blade-manufacturing factories: a Siemens Gamesa plant in Hull (currently being expanded) and a Vestas facility on the Isle of Wight (Reed, 2024). In addition to 1 650 individuals directly employed in blade manufacturing, another 1 405 are involved in cable production, 1 220 in foundation manufacturing and 300 in tower manufacturing (Gasperin and Emden, 2024).

Between 2008 and 2022, the United Kingdom accounted for just 1.4% of Europe's wind turbine manufacturing, by value, in sharp contrast to its 15.2% share of European wind installations in the same period.[21] For many components, the country relies heavily on imports. It is thus unable to capture many of the economic spillovers that would otherwise derive from complementary activities along the supply chain. At present, the bulk of the country's domestic content in the wind sector relates to O&M and services (33%). For wind turbines, the UK content is about 5%; for the balance of plant, it is 2% (Gasperin and Emden, 2024).

Reflecting the lack of a stronger domestic wind manufacturing base, far fewer people are employed per megawatt of installed wind capacity in the United Kingdom than in leading European countries. If the country were to reach a jobs-to-megawatt ratio similar to that of Germany, it could create another 21000 jobs; a ratio equal to Denmark's could yield as many as 98000 jobs (Emden *et al.*, 2023).

An additional 20 factories (with a possible FTE workforce of 7500-30000 workers in direct and indirect jobs) would be needed to manufacture the components needed to meet the government's 50 GW offshore wind installation target (Gasperin and Emden, 2024), assuming domestic production of half of all inputs.

RenewableUK, the Offshore Wind Industry Council, the Crown Estate and Crown Estate Scotland (2024) jointly published a detailed industrial growth plan for tripling the United Kingdom's offshore wind manufacturing capacity over the next decade, potentially supporting an additional 10000 jobs per year. The plan proposes prioritising investment in the design and manufacture of advanced blades and towers, foundations, cables and other components, and includes plans for a national offshore wind innovation hub and an institute for advanced turbine technology. The report also highlights the need to build the required workforce, support SME development and foster co-operation through regional clusters.

Tripling the United Kingdom's off-shore wind manufacturing capacity over the next decade could support an additional

10000 jobs

per year.

[21] *The average annual value of UK wind turbine production amounted to just EUR 119.5 million, compared with Denmark's EUR 4.1 billion, Germany's EUR 2.3 billion and Spain's EUR 1 billion (Gasperin and Emden, 2024).*

2.6 OTHER COUNTRIES

This section offers snapshots of selected additional countries, presented by region.

In **North and Central America**, hydropower is the largest employer among **CANADA's** renewable energy industries. It accounts for 33 260 direct and 15 530 indirect jobs (Natural Resources Canada, 2024). Although these data are from 2020, Canada's hydro capacity has not grown appreciably in the intervening years; therefore, employment may have not changed much. IRENA estimates the direct hydropower workforce to have been 31 260 jobs in 2023. Canada installed a record 1.7 GW of wind power capacity in 2023 (IRENA, 2024a), and the sector was estimated to have provided 18 190 direct and indirect jobs. That was ahead of solar PV, which added 440 MW of new capacity and employed an estimated 12 520 people directly. Altogether, renewable energy provides at least 86 430 jobs (indirect employment figures are not available for all technologies) (Natural Resources Canada, 2024).

In 2023, **EL SALVADOR** had an installed renewable energy capacity of 1745 GW, which drove steady job growth across various sectors (IRENA, 2024a). Nearly 3 200 people were employed in renewables, principally in hydropower and solid biomass. Hydropower, encompassing both small- and large-scale projects, accounted for 1996 jobs. Women represented 18% and 45% of the workforce in small hydropower and large hydropower projects, respectively. Solid biomass, used for both electricity and heat energy, provided 507 jobs, of which just 4% were held by women. Further, geothermal power supported 381 jobs, with women constituting 26% of the workforce. Solar PV created 223 jobs, both directly and indirectly, with 27% female participation, while wind energy employed 20 people, 5% of whom were women. Finally, biogas production generated 50 jobs, with women representing 22% of the workforce (DGHEM, 2024).

In **South America**, ethanol production in **COLOMBIA** rose almost 9% to 380 million litres in 2023, according to preliminary estimates, but remains substantially below the historic peak of 2018 and 2019. Biodiesel output is believed to have remained at the level of the year before – some 780 million litres (USDA-FAS, 2023e). Based on an employment factor calculation, there may have been some 86 600 jobs in bioethanol (up from about 79 800) and 116 650 jobs in biodiesel (almost unchanged from the previous year). Combined, this would mean 203 250 jobs, although these are not necessarily FTEs.

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Africa continues to receive only a small share of global renewable energy investments. The result is comparatively small employment numbers. Africa's renewable energy potential – like its need – is immense. Translating potential into reality would require not only increased investments and greater international co-operation, but also efforts to support education, skill building and workforce development, as well as the formation of regional supply chains.

Based on an employment multiplier analysis, a new study of potential future value chains of 12 economic sectors (FSD Africa, Shortlist and Boston Consulting Group, 2024) asserts that there could be 1.5 million to 3.3 million new direct green jobs across Africa by 2030. Among these, the energy and power sector could generate up to 2 million jobs, primarily in solar PV (up to 1.7 million), but also in hydropower (165 000), power transmission and distribution (197 000), wind (79 000), battery storage (51 000) and geothermal energy (33 000). As would be the case in other regions of the world, low-skilled jobs would represent a large share of employment. For solar PV, low-skilled jobs would make up a 40% share, general and administrative jobs another 20%, specialised roles (installers and electricians) a 30% share and jobs requiring advanced skills (engineers and others) a 10% share.

Information on current employment remains relatively limited for most countries on the continent. In **SOUTH AFRICA**, the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) has drawn private investment of about ZAR 234.1 billion (USD 13 billion[22]). As of March 2024, 7.5 GW had been procured from 102 independent power producers, of which 6.2 GW was operational. For projects under the initial four REIPPPP bid windows, evaluations were based on a mix of criteria (70% price and 30% economic development). Relaxed requirements under bid windows 5 and 6 resulted in much lower economic development commitments from investors (IPPPP, 2024).

To date, 78 075 job years[23] in cumulative direct employment have been created through the REIPPPP, up from 69 554 a year earlier. Of the current cumulative total, 53 737 job years (close to 70%) relate to construction work (jobs of limited duration) and 24 338 to operations. Employment opportunities for women remain limited, at 13 315, or 17% of the total. Regional imbalances reflect the uneven deployment of renewables across the country. The Northern Cape saw 3.9 GW of projects procured, more than half of the total, whereas Limpopo, KwaZulu Natal, Mpumalanga, Free State and North West together had only 700 MW. Altogether, 63% of employment opportunities, some 48 890 job years, have materialised in the Northern Cape alone. A quarter of jobs are found in the Eastern Cape and Western Cape. Northern Cape's position is even more prominent when it comes to locally procured inputs for renewable energy projects that have begun construction; the Northern Cape secured a 68% share for itself (IPPPP, 2024).

[22] *Exchange rate of ZAR 1 = USD 0.06 as of 9 September 2024.*

[23] *A job year is the equivalent of a full-time employment opportunity for one person for one year.*

South Africa has some existing solar and wind component manufacturing capacity, but much of it is idle because domestic demand is inadequate or insufficiently stable. The bulk of the equipment is imported; domestic employment in manufacturing is thus limited. Imports of solar panels, inverters and lithium-ion batteries surged to ZAR 70 billion (USD 3.9 billion) in 2023, more than double 2022 imports of USD 1.7 billion and up almost five-fold from 2021 imports of USD 0.8 billion. According to Montmasson-Clair (2024), unlike earlier REIPPPP bid windows, round 6 does not include strong localisation objectives, nor are renewable energy tax incentives for households and businesses conditioned on local procurement. In addition to demand-side policies, industrial policies such as support for industrial parks, supplier development measures, quality standards and workforce skilling programmes could strengthen the competitiveness of locally manufactured products (Montmasson-Clair, 2024).

In **West Asia**, **TÜRKIYE** is among the world's top 20 solar PV countries, with 11.3 GW of generating capacity. Türkiye added a record 1.9 GW in 2023 (IRENA, 2024a). For the past decade, the country has offered a local content premium in its feed-in tariff structure for modules assembled domestically from imported cells (ETIP Photovoltaics, 2024). This incentive has been complemented by favourable value added tax rules and import duties on modules imported from several countries (Lynas, 2024). Indeed, module production capacity tripled from 5.2 GW in 2020 to 15.2 GW in 2023, but cell production remained at a more modest 1.5 GW in 2023, and wafer capacity at 1.2 GW (Wood Mackenzie, 2024c). Wind expansion, by contrast, slowed – from 1.8 GW added in 2021 to 0.8 GW in 2022 and 0.3 GW in 2023 (IRENA, 2024a). IRENA estimates 41 000 solar PV jobs and 5 100 wind energy jobs in Türkiye.

In **JORDAN**, employment related to commercial-scale solar PV projects (with 919 MW of capacity) was estimated at 28 100 direct jobs in 2023 based on employment factors. Most were temporary jobs in construction and installation, while some 551 permanent jobs were in O&M. The estimate does not include employment related to the roughly 1 GW of distributed solar PV capacity. Jordan's 614 MW of wind capacity was estimated to have supported some 1 842 direct jobs, of which 307 were permanent jobs in O&M. In addition, solar thermal energy created about 4 530 direct and indirect jobs (MEMR, 2024).

The **ISLAMIC REPUBLIC OF IRAN** (REEEO, 2024) estimates 45 195 renewable energy jobs (direct and indirect) in the country in 2023, up from an earlier estimate of 37 360. The estimate is based principally on industry surveys. The bulk of these jobs were in the solar PV sector, at 40 000. About 3 500 jobs were in wind power, and 630 jobs in solid biomass.

In **East Asia**, **JAPAN's** cumulative solar PV capacity reached 87.1 GW in 2023, but the pace of additions (4 GW in 2023) continues to be slow (IRENA, 2024a). The bulk of employment is in installations and O&M, given that modules are almost all imported (JPEA, 2024). IRENA estimates some 115 000 solar PV jobs in 2023.[24] Japan has about 5.2 GW of wind capacity. After years of very slow expansion, the country added some 850 MW in 2023 (IRENA, 2024a), with an estimated 8 500 jobs in the sector.

The New and Renewable Energy Center of the **REPUBLIC OF KOREA** offers statistics on employment in the renewable energy sector without providing a breakdown by technology. Altogether, the Center puts employment at 174 773 jobs in 2022, the most recent year for which data are available (up from 145 750 in 2021). The bulk of jobs are in electricity generation and heat supply (145 832), with more limited contributions from construction (13 011), manufacturing (11 381) and services and repairs (5 690) (KNREC 2023). IRENA's employment factor–based estimates, however, suggest a total of 31 000 jobs in the solar PV value chain.

Among **Southeast Asian** countries, Viet Nam, Malaysia and Thailand are important **solar PV** cell and module manufacturers. Most of the output is exported. The region's module capacity expanded from about 38 GW in 2020 to 102 GW in 2023, while the actual module production was 62.6 GW. Cell capacity has quadrupled to 100 GW in the past four years. Wafer capacity remains more limited, having grown from 2.7 GW to 19 GW (Wood Mackenzie (2024c).

[24] *Based on employment factors for direct employment and multipliers for indirect employment.*

VIET NAM is a major manufacturer of solar PV cells and modules. In 2023, Viet Nam's cell production capacity rose to 22.9 GW, from just 16.4 GW in 2020, while module production capacity increased to 35.5 GW, from 29.6 GW in 2020 (Wood Mackenzie, 2024c). However, on the deployment side, a massive surge in PV installations in 2019-2020 came to a sudden halt because of unresolved grid bottlenecks. In 2020 alone, the country had added 11.7 GW in generating capacity, but in the three years that followed, the combined total was a mere 416 MW (IRENA, 2024a).

IRENA estimates Viet Nam's **solar PV** workforce to have declined to 105 000 jobs in 2023, with approximately three-quarters of these positions in the manufacturing segment of the value chain. Viet Nam's National Power Development Plan VIII (PDP8), introduced in 2023, encourages rooftop solar PV development but also caps capacity at 2 600 MW to prevent grid overload. The aim is to equip half of the country's buildings – residences and offices – with rooftop solar by 2030 (REN21, 2024). In the **wind** sector, Viet Nam had installed 3.6 GW in 2021, but new additions declined to 947 MW in 2022 and 823 MW in 2023 (IRENA, 2024a). IRENA estimates that Viet Nam may have 13 000 wind jobs.

MALAYSIA, as a key solar PV module manufacturing hub, hosts nearly 43 000 solar PV jobs. Since domestic solar PV installations have remained limited, almost all of these jobs are in manufacturing. IRENA estimates **THAILAND's** solar PV manufacturing jobs at more than 30 000. The **PHILIPPINES** has only limited PV manufacturing, but a recent study finds that if the country were to reach 3-5 GW of module assembly capacity by 2030, half the output could supply domestic demand and half serve export markets. Investments of USD 150-250 million and adequate workforce training could help create 7 000-10 000 direct and indirect jobs (Asian Development Bank, Bloomberg Philanthropies, ClimateWorks Foundation and Sustainable Energy for All, 2023).

Southeast Asia – particularly Indonesia, Malaysia, Thailand and the Philippines – is also prominent in **biofuels**. **INDONESIA** raised its biodiesel blending mandate to 35% in August 2023. Production was estimated at a record 13.65 billion litres in 2023, up 25% from 10.9 billion litres in 2022. Exports (630 million litres) remained far below past records but are on the rise. China is the main destination, followed by the Netherlands, Peru and the Philippines (USDA-FAS, 2023b). Using an employment factor calculation, IRENA puts biodiesel employment at 798 600 jobs in 2023, up from 646 700 in 2022.

MALAYSIA's biodiesel production in 2023 was estimated at less than 1.1 billion litres; production continued to decline from the peak of 1.8 billion litres in 2019. Only 42% of production capacity is utilised. Domestically, the government was not able to implement its planned biodiesel B20 blending mandate; instead, a B10 mandate remains in place. Exports have declined to a third of the 2019 peak (USDA-FAS, 2023c). IRENA estimates the biodiesel sector to have had about 61 900 jobs in 2023, down from 66 700 in 2022 and 106 200 in 2019.

THAILAND's ethanol production has declined, but its biodiesel output has risen (reversing the trend in previous years). While the combined production volume in 2023 increased, it remained considerably below the peak values for 2019. Biodiesel use was driven up by the increase of the mandatory blend rate from 5% to 6.6% in 2023, even as demand for diesel fuel fell. Contrarily, bioethanol use fell despite an increase in overall gasoline demand, as reduced subsidies made ethanol more expensive (USDA-FAS, 2024a). IRENA estimates some 114 500 biofuel jobs in Thailand in 2023, up from 97 100 in 2022.

In the **PHILIPPINES**, both ethanol and biodiesel production increased in 2023. Ethanol output reached a new peak, whereas biodiesel production remained below the 2019 high (USDA-FAS, 2024b). A rough estimate by IRENA suggests biofuels may employ 11 600 people.

In the **Pacific**, **AUSTRALIA** added 3.7 GW of solar PV capacity in 2023; this was less than the capacity added in each of the previous six years (IRENA, 2024a). According to the Clean Energy Council (CEC, 2024), more than three-quarters of the new additions, or 2.9 GW, were in the labour-intensive rooftop segment. Most solar jobs by far are in O&M, given that Australia imports the bulk of the PV panels. A report outlining a roadmap to 2030 for increased solar PV manufacturing (Australian PV Institute, 2024) examines requirements and opportunities. At present, module capacity is only 160 MW, with no upstream facilities. The report estimates that a domestic capacity of 1 GW for polysilicon, wafers, cells and modules would require AUD 3.2 billion (USD 2.2 billion[25]) in subsidies over a decade, while a capacity of 5 GW would cost AUD 7.8 billion (USD 5.3 billion). A domestic industry could support up to 4 000 jobs directly. But the report notes that Australia will require an expatriate force of workers skilled and experienced in solar manufacturing, at least until skilling programmes can close labour gaps.

[25] Exchange rate of AUD 1 = USD 0.68 as of 9 September 2024.

CHAPTER 3 SKILLS FOR A JUST ENERGY TRANSITION

As noted at the start of this report, achieving a just energy transition and unlocking the job-creation potential of renewable energy relies on several factors. A crucial requirement is to address skill shortages, ensuring that both current workers and future entrants to the labour market possess the necessary skills. Investing in skills is essential for translating into reality the commitments made by countries, through their Nationally Determined Contributions, to achieve the core objective of the Paris Agreement on climate change.

As the world transitions towards renewable energy and gradually phases out fossil fuels while investing in energy efficiency, the current and future workforce will need education and training to acquire the necessary technical and core skills for emerging job opportunities. Ensuring a just transition also involves reskilling workers from declining sectors, such as fossil fuels, enabling them to shift to growing sectors such as renewable energy. As renewable technologies advance, upskilling existing workers will prepare them for future roles and help them remain competitive in the dynamic renewable energy landscape.

However, not everyone will be able to access renewable energy jobs, owing to geographic, temporal and other constraints. Therefore, it is essential to create diverse job opportunities that align with local contexts and to develop a comprehensive skills strategy to enhance and diversify the local economy.

The International Labour Organization's "Guidelines for a Just Transition towards Environmentally Sustainable Economies and Societies for All" (ILO, 2015), adopted through tripartite consensus, identifies skills development as a key policy area for addressing environmental, economic and social sustainability. In 2023, the resolution and conclusions adopted at the 111th Session of the International Labour Conference endorsed these guidelines as the primary reference for policy making and a basis for action. Notably, the guidelines emphasised the importance of promoting skills and lifelong learning, including quality apprenticeships, to enable a just transition, and serve as a buffer against the adverse impacts of structural changes in the economy.

The significance of skills development is further emphasised by the International Labour Standards. Since 1919, the International Labour Organization (ILO) has established and refined a system of International Labour Standards designed to promote opportunities for both women and men to secure decent and productive work in an environment of freedom, equity, security and dignity (ILO, 2014). In today's globalised economy, these standards are a crucial element of the international framework that ensures global economic growth benefits everyone.

International Labour Standards consist of legal instruments created by the ILO's constituents, representatives of governments, workers and employers. They outline fundamental principles and rights at work, and primarily focus on the development of individuals as human beings. These standards can take the form of conventions or protocols, which are legally binding international treaties that may be ratified by Member States. Alternatively, they may be presented as recommendations, which serve as non-binding guidelines that often complement the provisions of conventions.

The standards include the Paid Educational Leave Convention, 1974; Human Resources Development Convention, 1975; Human Resources Development Recommendation, 2004 and Quality Apprenticeships Recommendation, 2023 – as well as by the ILO's strategy to promote skills and lifelong learning by 2030. The Human Resources Development Recommendation, 2004, highlights that "education, training and lifelong learning contribute significantly to promoting the interests of individuals, enterprises, the economy and society as a whole, especially considering the critical challenge of attaining full-employment, poverty eradication, social inclusion and sustained economic growth in the global economy" (ILO, 2014).

For the energy transition to succeed, it is essential to have a skilled workforce capable of manufacturing and deploying renewable energy technologies as well as maintaining and repairing generating systems. Therefore, skills development is not just about improving individuals' employability; it is also a strategic necessity. By equipping workers with the relevant expertise, it is possible to fill critical job roles, foster industry innovation and evolution, and ensure a just transition.

3.1 THE ENERGY TRANSITION AND ITS IMPLICATIONS FOR SKILLS DEVELOPMENT

The impact of the energy transition on employment varies by skill level and gender. Evidence from ILO's global research indicates that the transition towards energy sustainability is likely to result in changes in occupations across all skill levels, with the most significant adjustments occurring in mid-skill occupations, followed by those at high skill levels (ILO, 2019). The growing demand for medium-skilled workers in renewable energy spans a range of roles, some more specialised than others, such as solar panel installers, wind turbine technicians, electricians, plumbers, welders and hydropower operators.

Technical and vocational education and training (TVET) facilitates the energy transition by equipping a skilled workforce with technical training relevant to future job opportunities and by supporting the reskilling and upskilling of current technicians and skilled workers. Both workers' and employers' organisations have a vital role to play in addressing skills gaps in renewable energy, as demonstrated by examples from Brazil and India.

The Brazilian labour union, **Central Única dos Trabalhadores** (CUT), has taken steps to address the skills gap in solar energy (CUT, n.d.). CUT has collaborated with local universities and technical schools to develop training modules that encompass a spectrum of skills, from basic installation to advanced system design and maintenance. These programmes also highlight the significance of occupational health and safety, taking into account the demanding conditions associated with solar panel installation and maintenance. Through these initiatives, CUT not only enhances the employability of workers but also ensures that the rapidly growing solar energy sector has access to a skilled and competent workforce.

In India, the **Confederation of Indian Industry** (CII) has established a Renewable Energy Council that includes developers; solar, wind and small hydro generators; component manufacturers; and other stakeholders (CII, n.d.). CII also operates a network of centres of excellence, such as the Green Business Centre, which focuses on renewable energy and energy efficiency, and the Centre of Excellence for Sustainable Development, which provides training and consultancy services while developing knowledge products for businesses.

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The energy transition will require a highly skilled workforce with advanced expertise in research, innovation and the development of pioneering renewable energy technologies. This calls for renewed investments in science, technology, engineering and mathematics (STEM) education and training for both men and women.

Research indicates that job creation during the energy transition is likely to outpace job loss. However, this net job growth will not guarantee a balanced distribution of opportunities between men and women in the workforce. While women's participation in renewable energy is generally better than in the fossil fuel industry, the energy sector as a whole remains male dominated (IEA, 2022; IRENA and ILO, 2023). Women are significantly under-represented in energy production, despite the urgent need for a more skilled workforce to advance the energy transition. They frequently encounter barriers to entry and career progression in renewable energy, largely due to prevailing gender stereotypes, unequal access to education and training, the burden of balancing work with family responsibilities (which disproportionately affects women in many cultures) and the lack of a supportive working environment (IRENA, 2019). It is critical to address gender bias in both education and training as well as in the labour market through targeted measures, informed by an understanding of the factors contributing to gender-based occupational segregation. An illuminating example from Zambia follows.

The **Skills Development for the Renewable Energy Sector (SkiDRES) pilot project in Zambia**, supported by the International Labour Organization and Swedish International Development Agency, aimed to develop partnerships with the private sector, assess market needs and provide demand-driven training (ILO, 2020). Because gender equity in energy efficiency and renewable energy jobs was low in Zambia, the project took a strategic approach to increase women's participation by incorporating gender-sensitive assessments of skill needs, conducting surveys to reflect industry requirements and providing targeted training measures. The project successfully increased the participation of women engineers in training courses and also offered scholarships to final-year female engineering students.

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Education and training programmes should prioritise a balanced mix of diverse skill sets to enhance individuals' flexibility and adaptability, rather than focusing solely on highly specialised training. While the specific skills required may vary by role within the industry, they generally include occupational and technical transferable skills such as engineering, design, quality assurance, product development, and maintenance and repair, as well as semi-technical transferable skills such sales and marketing, customer handling and project management. Technical skills are required for certain technologies, such as wind turbines, solar panels, hydroelectric turbines, geothermal equipment and various bioenergy technologies (ILO, 2019). Training programmes would do well to emphasise core (soft) skills such as collaboration, communication and problem solving, along with foundational skills that underpin all learning and work, such as numeracy and literacy (including digital and climate literacy).

3.2 KEY SKILLS CHALLENGES FOR THE RENEWABLE ENERGY INDUSTRY

Despite some progress over the past decade, several skills challenges threaten to hinder the global transition to renewable energy. The rapid growth of renewable energy is outpacing the development of a suitably skilled workforce (WEF, 2024; McKinsey, 2022), widening the skills gap and presenting a significant barrier to the energy transition. For instance, Europe faces a marked shortage of professionals such as electricians, electrical mechanics and fitters (ELA, 2021). Developing countries, in particular, grapple with a lack of professionals and a general scarcity of university graduates, especially those trained in STEM disciplines (UN OSAA, 2022; ILO, 2019). A lack of skill anticipation and monitoring systems further hinders countries' ability to identify skills gaps, analyse future training needs and adapt education and training programmes in line with market demands.

Meanwhile, national commitments to the energy transition aimed at fulfilling the Paris Agreement often lack the necessary skills development for successful implementation. And large-scale renewable energy projects frequently overlook the critical need for comprehensive local skills development plans. Yet the effective execution of these projects depends on the availability of relevant skills within the labour market. The lack of strong policy coherence and co-ordination among skills and energy and employment policies, as well as between line ministries and agencies, slows progress. In addition, there is little active involvement of employers' and workers' organisations, other industry stakeholders, education and training providers, and civil society to provide solutions.

Widespread funding obstacles and the neglect of the needs of vulnerable and disadvantaged groups within skills systems also impede progress towards a just energy transition. Traditionally, financial resources for education and training have been allocated to primary and tertiary education. Technical and vocational training at the secondary level, as well as informal education aimed at adult learners – including older workers, the unemployed and the inactive workforce – have received much less attention (ILO, 2021). Current education and training systems and policies fail to adequately address the needs of these groups, and work-based learning, essential for developing practical skills within enterprises, often lacks financial support (World Bank/UNESCO/ILO, 2023).

Lower-paying jobs in renewable energy also present a challenge to a just transition. Even with reskilling and re-employment, workers may not receive wages comparable to their previous positions. This disparity can diminish the overall attractiveness of renewable energy jobs and leave transitioning workers to face economic instability. It is therefore important to ensure that skill acquisition results in tangible benefits, allowing individuals who have gained relevant skills to access better employment opportunities, fair wages and career growth.

3.3 POLICY RECOMMENDATIONS

Policy coherence, social dialogue and strong public-private partnerships

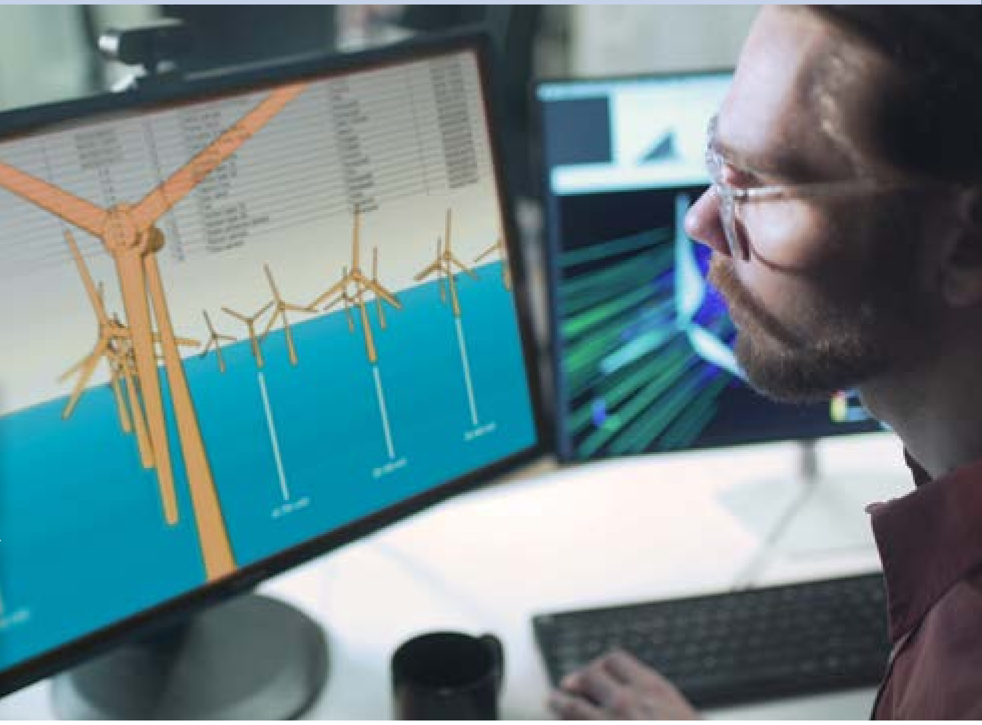
Strong policy coherence and co-ordination among skills, energy and employment policies reinforces their impact, minimises duplication and maximises effectiveness. The transition will require the joint and active engagement of governments, employers, workers, civil society actors, and education and training providers at all levels. In essence, effective energy response strategies must be grounded in social dialogue to ensure successful planning and implementation.

A sample application of this recommendation is the **Sectoral Human Resource Development (HRD) Plan on Renewable Energy in the Philippines** (ILS, 2023). As part of an update to the National Green Jobs Human Resource Development Plan 2023-2028 mandated by the Philippine Green Jobs Act of 2016, the country's Department of Labor and Employment is developing the Sectoral HRD Plan on Renewable Energy. Taking a whole-of-government approach, the department is collaborating closely with the Department of Energy, other government agencies, social partners, development partners and the private sector to prepare this plan. The DOE is spearheading a comprehensive programme to reskill and upskill Filipino workers specifically for renewable energy sectors, such as offshore wind development and solar PV. Significant efforts have been made to improve co-ordination among line ministries and to conduct tripartite consultations, thereby enhancing the country's ability to achieve its renewable energy goals.

More and better data

Good data are needed to make informed policy and investment decisions that align with the sector's evolving needs. The timely and effective delivery of training in renewable energy relies on institutional mechanisms that identify and anticipate this demand, ensuring that training programmes align with needs. Various national and sectoral stakeholders will need to collaborate more effectively to better understand the sector's current and future skill requirements, facilitating the effective preparation of the workforce. Anticipating demand and collaborating effectively will depend on good data.

An example is the **EU skills partnership for the renewable energy industrial ecosystem** (EC, n.d.). The European Commission has launched the Pact for Skills, a comprehensive partnership aimed at enhancing skills within the renewable energy ecosystem. This initiative unites over 40 employers' organisations and 35 chambers of commerce across the continent to establish robust skills partnerships. Its objectives include monitoring skill supply and demand and anticipating future needs, fostering a culture of lifelong learning and promoting gender equality and equal opportunities while combating discrimination. The pact also serves as a knowledge platform for governments, workers, employers and other relevant stakeholders to share best practices in upskilling and reskilling, and to transform the workforce for sustainable economies and societies.



Skills interventions

Skills development is a crucial pillar for achieving a just and inclusive energy transition. However, a just transition requires more than a single policy intervention; it demands an integrated and holistic approach to lifelong learning. This includes career guidance, job matching, social protection and active labour market policies to enhance skill relevance and matching in the context of the energy transition.

Measures to develop skills should be integrated into the planning stages of national transition frameworks and new renewable energy projects, while encouraging enterprises and industry to invest in upskilling and reskilling their workforce. Plans for installing new renewable energy capacity must include explicit strategies for sourcing the necessary skills, which requires effective co-ordination among education and training providers, employment services and other relevant entities. Mandating project developers to incorporate local content into their bid proposals could also help stimulate job creation and integrate skills into project planning, as illustrated by South Africa's Renewable Energy Independent Power Producer Procurement Programme (IPPPP, 2024).

In 2011, the **South African** government launched the **Renewable Energy Independent Power Producer Procurement Programme** to stimulate private investment in renewable energy via competitive bidding. Since its launch, the programme has generated over 6 GW of renewable energy capacity, mainly from wind and solar, while also fostering job creation. This policy-driven green procurement initiative incorporates local content and ownership requirements, encouraging the domestic production of renewable energy components, as well as the creation of jobs and development of skills. Companies involved in the programme are contractually obligated to support local socio-economic development, including education and training, across the project's lifespan.

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Enhanced TVET programmes

Enhancing TVET programmes by aligning curricula with specific industry needs and incorporating work-based learning will equip students with the hands-on experience and practical skills necessary for careers in renewable energy. Making such initiatives gender responsive and inclusive will prevent stereotyping and encourage female students to pursue non-traditional occupations. At the same time, prioritising the professional development of teachers and trainers is crucial for effective and inclusive skill delivery, as their expertise directly influences the quality of education and training provided.

A holistic approach to greening TVET is **Zimbabwe's Green enterPRIZE programme** (ILO, 2022b). In 2020, Zimbabwe's programme launched new TVET curricula for solar PV installation and maintenance mechanics, solar sales and marketing agents, and biogas system installers. With support from the ILO, the country adopted a holistic approach that involved key stakeholders from the government, industry, small and medium-sized enterprises, technical firms, TVET providers and social partners.

An integral component of the initiative were workshops for training of trainers; these aimed at developing a cadre of staff capable of teaching new courses. The curriculum incorporated gender-sensitive content, developed using a gender sensitivity checklist. However, to ensure delivery of the curriculum in a gender-equitable manner, instructors were provided with guidelines to be implemented at their training institutions. The project also facilitated the establishment of partnerships between training providers and SMEs to pilot and expand work-based learning programmes.

CHAPTER 4

THE IMPORTANCE OF A **PEOPLE- AND PLANET-CENTRIC** ENERGY TRANSITION

Employment in renewable energy is shaped by a host of factors, including technological developments and cost trends; the pace and level of investments and the resulting market dynamics; the development of viable supply chains; and (as discussed in chapter 3) the formation of a skilled workforce. Overall labour requirements – along with specific occupational patterns and skill needs – vary not only with project scale, but also with evolving technologies, increasing automation and other factors.

Where jobs are created depends on the geographic distribution of equipment manufacturing and its related inputs, and on the global spread of capacity installations. Countries vary significantly in their ability to provide needed inputs – such as raw materials, manufactured components or expert services – from domestic sources. In recent years, China has successfully developed integrated supply chains on a large scale, while many other countries have faced limitations owing to fragmented or non-existent manufacturing capacities. Numerous developing nations have relied not only on imports of solar panels and wind turbines, but also on engineering and other services provided by multinational corporations, which has constrained the potential for domestic job creation and benefits until local capacities can be strengthened.

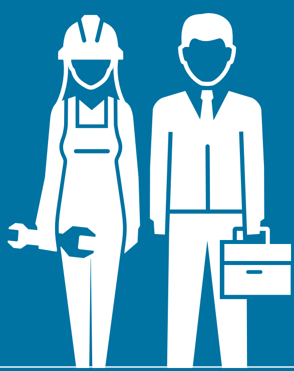
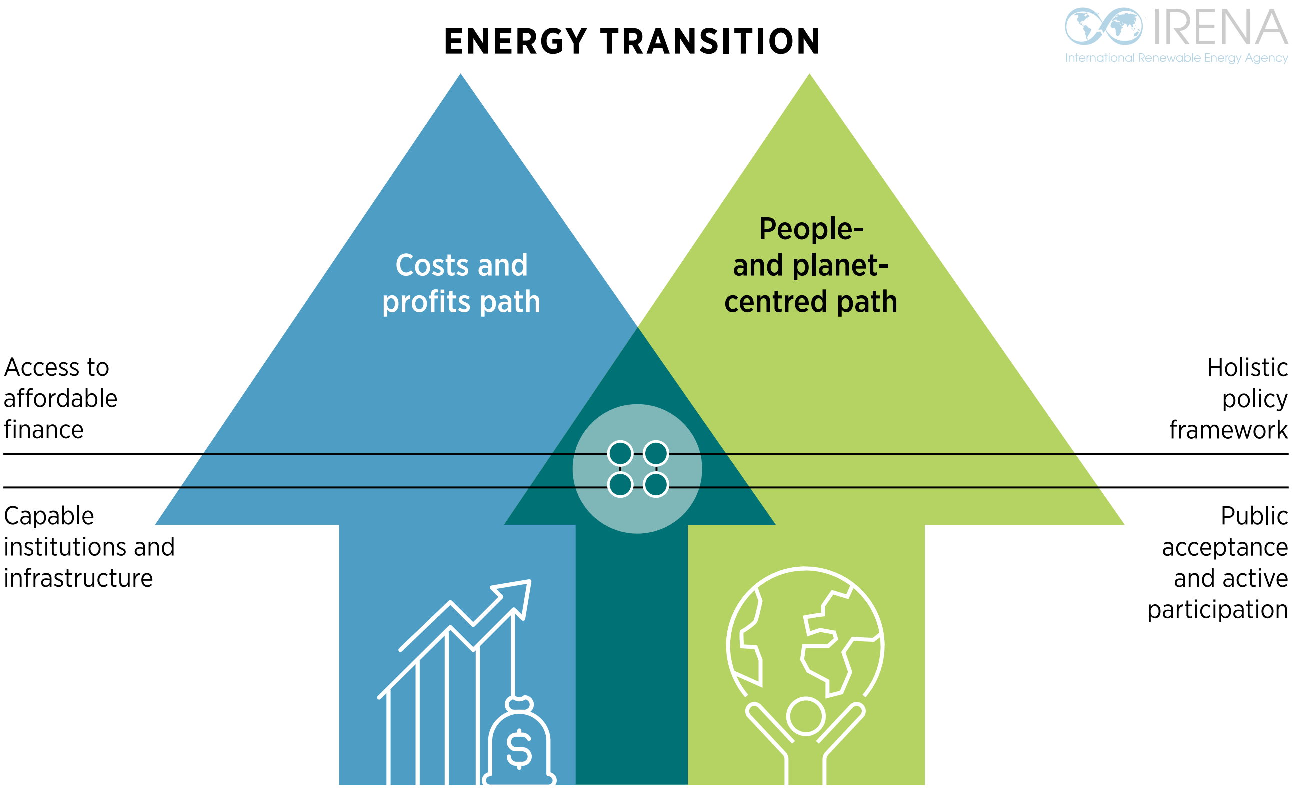


Figure 13 Framework conditions for a successful energy transition



Renewable energy jobs emerge from a complex mix of policy decisions made by governments and private companies, each pursuing a range of interconnected, yet sometimes conflicting, objectives. Policies suitable for one goal may not be entirely appropriate for another. Key objectives are many. They include accelerating the deployment of renewable energy; enhancing the security of energy supplies; improving access to energy services; fostering domestic value creation through viable local supply chains; developing a skilled workforce and avoiding significant skills gaps; ensuring decent wages and workplace conditions; achieving a better gender balance in a still male-dominated industry; delivering benefits to local communities; supporting fossil-fuel-dependent workers and regions; and ensuring environmental sustainability across the renewable energy value chain.

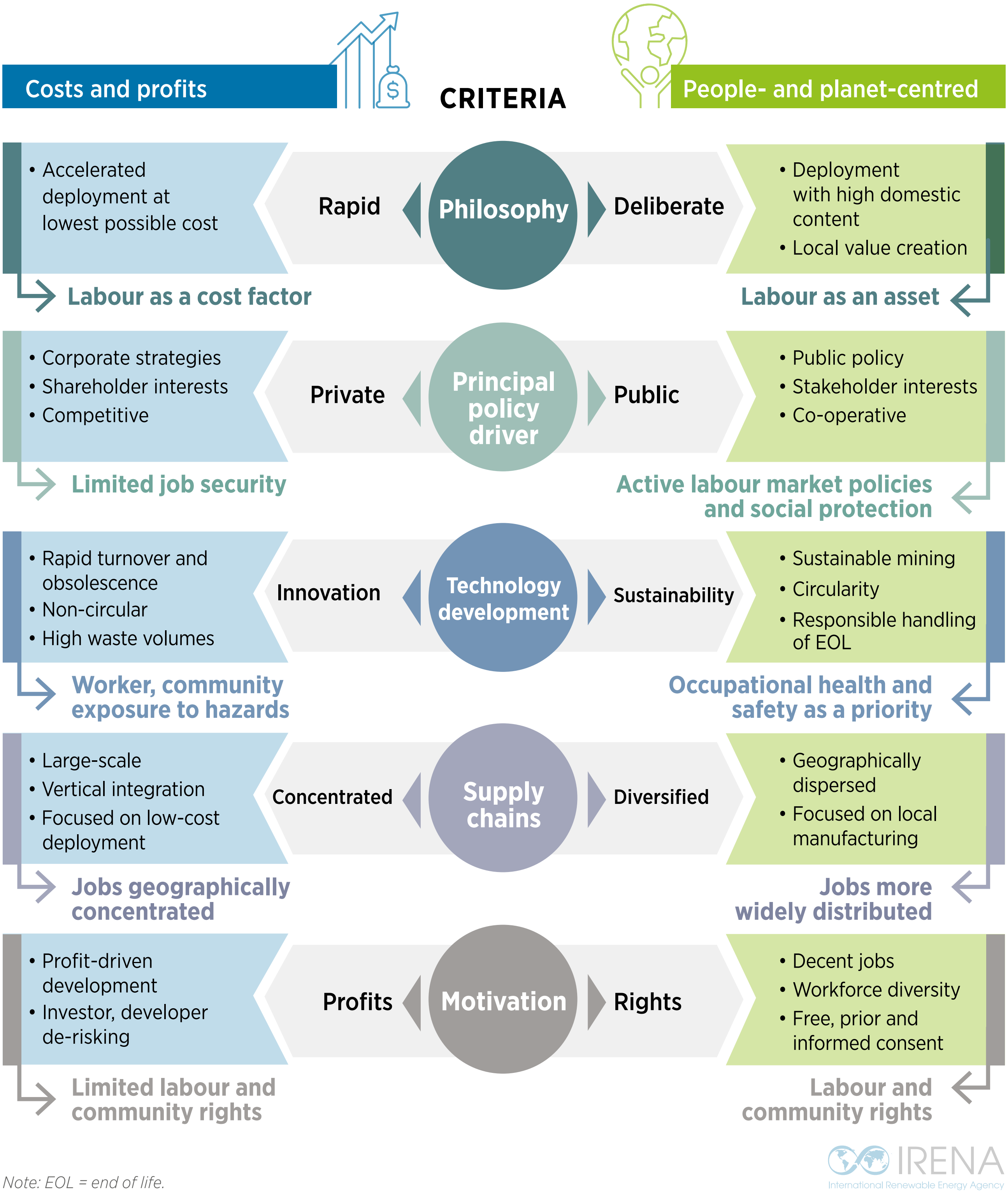
There is of course no single blueprint for the energy transition that will fit all circumstances. Generally speaking, the conditions for a successful transition, as illustrated in Figure 13, include access to affordable finance, a holistic policy framework, committed institutions, capable infrastructure, and active public acceptance and participation. These macro-level conditions, alongside various specific micro-level policies and actions, can nudge the transition towards either a hard-edged "costs-and-profits" model or a "people- and planet-centred" one.

In practice, the policy environment in most countries is likely to reflect a blend of strategies rather than a strict dichotomy. However, it is helpful to clarify the contrasts between opposing pathways and their implications for job creation and job quality.

Figure 14 outlines key criteria (shown in the centre of the graphic) and highlights the opposing policy directions (listed on the left and right sides, respectively) that may arise from the two approaches. The costs-and-profits path emphasises rapid deployment at the lowest possible monetary cost, features quick technological turnover and is driven by shareholder interests. It may assign comparatively low priority to social, equity and environmental concerns. In contrast, the people- and planet-centred path focuses on local value creation through appropriate "green" industrial development and is rooted in a rights-based approach that reflects diverse stakeholder interests.

The manner in which renewable energy expands has implications not only for the number of jobs and their geographic distribution, but also for the quality of these jobs and the extent to which local communities gain tangible and lasting benefits. Economic policy discussions have long been dominated by neoliberal principles, which tend to prioritise enabling the private sector over a more proactive role for public policy.

Figure 14 Diverging objectives of the energy transition: Implications for jobs and job quality



Note: EOL = end of life.

In their pursuit of profits, private industry often advocates for streamlined permitting processes, regulatory flexibility and "liberalisation" of energy markets, favouring voluntary measures over mandatory ones. Most auctions have prioritised cost when determining winning bids.[26] Just a few years ago, many analysts and policy makers viewed solar panels as commodity products best outsourced to low-cost, low-wage producers. A similar approach emerged to the production of wind power components.

Scaling up deployments at an increasingly lower cost per unit of capacity is indisputably critical for the energy transition. Lower costs allow more installations for the same amount of investment. Indeed, large-scale deployment of generating capacities and the establishment of integrated supply chains have led to substantial cost reductions… but also to persistent overcapacities that have triggered fierce cost competition among manufacturers. Thus, while lower costs have benefitted countries around the world, most have been unable to compete with China and as a result have relied heavily on imports of equipment, severely limiting their domestic manufacturing employment.

Cost pressures are now driving industry consolidation, factory closures and relocations, and increasing reliance on automation and other cost-saving strategies. In liberalised markets, the creation of economic value does not necessarily translate into benefits for local communities, as the pursuit of maximising shareholder value remains the primary objective. Consequently, even as the overall renewable energy market continues to grow, disruptive dynamics may lead to job losses and economic uncertainty. Such repercussions could jeopardise public support for the energy transition during a time of increasing economic instability.

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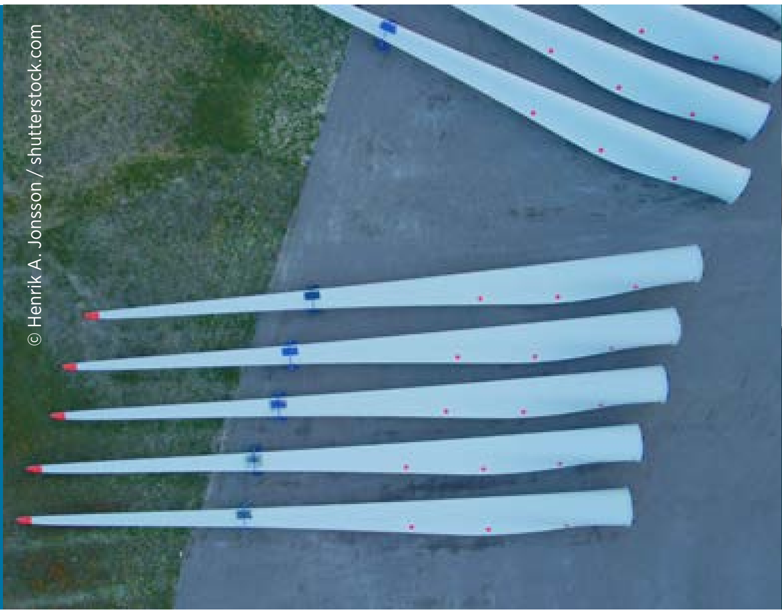
[26] *However, depending on the auction design, there is recognition of the significance of non-price criteria, including localisation of jobs and benefits to local communities, as well as sustainability criteria (IRENA, n.d.).*



As the challenges of rising import dependence became apparent, interest in re-shoring and "near-shoring" of supply chains surged. This localisation drive, motivated by the desire to capture more value and create domestic jobs, is to some extent infused with protectionist sentiments and has become entangled in the growing geopolitical and geoeconomic rivalries among major players such as China, the United States, Europe and India. For instance, the United States has implemented tariffs and, in the words of the *New York Times*, "embarked on the biggest industrial policy push in generations", aiming to attract investment in new factories through tax credits, grants, subsidies and other incentives (Swanson, Smialek, Rappeport and Nelson, 2023). The 2022 US Inflation Reduction Act has compelled other governments (notably in Europe) to determine how to prevent companies from relocating to the United States – although many had already moved. A potential danger in this context is that companies may be tempted to leverage competition between governments for the most generous support measures, resulting in zero-sum games.

A more proactive role for public policy would ideally include the implementation of policy mandates, investment strategies and public sector ownership of energy-generating assets in the interest of the public.

On the project deployment side, development can occur in different ways. It can be structured to favour private interests ranging from financiers to engineering, procurement and construction companies, or it can be designed to ensure that local communities share in the revenues and have access to job opportunities in project planning, construction, installation, and operation and maintenance. The manner in which financing is arranged can make a huge difference in the outcomes.

Deployment policies aimed at facilitating renewable energy installations and industrial policy making for building supply chains can be shaped around vastly different objectives. As noted above, a costs-and-profits approach that positions the private sector as the main driving force tends to focus on maximising shareholder value, often paying little attention to the perspectives of workers and communities. "Bankability" considerations (*i.e.* an assessment of whether projects are attractive enough to secure financing from private investors) explain the present highly uneven distribution of renewable energy investment worldwide. As of 2023, about 120 developing countries accounted for only 15% of global investments, which exceeded USD 2 trillion (IRENA, 2024b).

The bankability approach considers workers more as cost items than as valuable assets with much-needed expertise. Consequently, equipment manufacturers may be tempted to pursue locations with low prevailing wages, weak enforcement of occupational health and safety standards, and limited labour rights.

Even though project developers increasingly acknowledge the need to obtain a social license to operate within a country, many still tend overlook the wishes of nearby communities. Indigenous peoples and impoverished rural communities in the Global South often have little leverage or political power (see IRENA, 2024c). In some cases, hydropower, biofuel, solar or wind projects have caused unintentional harm, while in others they have involved deliberate land-grabbing tactics, displacement of people and the loss of cultural and sacred sites. There have also been reports of intimidation and violence against community activists, as well as violations of labour rights (CCSI, 2023).[27]

Similar concerns arise regarding the mining of materials considered critical to the energy transition.

Holding on to entrenched paradigms of endless growth and profit seeking – which have resulted in massive global inequalities and the climate crisis – contradicts the goal of carrying out the energy transition in a responsible and equitable manner. Fortunately, an alternative approach exists. Rather than simply accommodating private sector demands (such as expedited project permitting), government policy must actively shape the energy transition in the public interest. For instance, public support measures for the private sector should be contingent upon delivering tangible benefits to communities, such as high-quality jobs.

Other factors are in play. The energy transition will require the phasing out of fossil fuels to meet the goals of the Paris Climate Agreement. This will result in the loss of millions of jobs in fossil fuel industries, implying the need for an "employment transition" to assist affected individuals and communities in securing new employment and revitalising economies formerly dependent upon fossil fuels.

[27] *The Business and Human Rights Resource Centre (BHRRC, 2023) investigates allegations of human rights abuses linked to renewable energy projects and evaluates the policies of project developers to ensure the rights of communities and environmental defenders are upheld.*

If timely solutions are not developed, the consequences could be dire, as illustrated by the experience of UK coal miners in the 1980s. Within a decade, most UK coal mines were closed, leading to 90% of the workforce – more than 200 000 people – losing their jobs. A recent analysis of this experience (Rud *et al.*, 2024) reveals that hourly wages fell by 40% and earnings dropped by 80-90% one year after the job losses, and that these losses persisted for many years. These displacements had profound impacts on health, education and demographic trends. Similar social stress could arise in fossil-fuel-dependent regions, including oil-producing countries such as Iraq, Nigeria, the Russian Federation and the United States, if the energy transition fails to adopt a broad people-centred approach.

In terms of environmental and sustainability concerns, an energy transition driven primarily by the desire to minimise costs and maximise profits is likely to prioritise rapid technological innovation (such as the continuous scaling up of wind turbines or frequent changes in materials for solar panels and energy storage batteries). This approach may defer or limit attention to the increasing volumes of waste generated or the associated consequences for occupational safety and health. While innovation aimed at developing advanced and efficient technologies is undoubtedly desirable, a more sustainable approach will manage these dynamics responsibly, and ensuring that people's jobs, rights and health remain central to decision making.

Renewable energy projects can be implemented responsibly if communities are consulted from the outset in the design and execution of policies, and if their right to free, prior and informed consent is protected. A people- and planet-centric approach must empower civil society stakeholders, incorporate labour rights and ensure that jobs are attractive and decent. Such an approach also requires respecting gender and youth perspectives to promote diversity, equity and inclusion. These elements are essential for an energy democracy that can deliver lasting and widely shared benefits while securing public acceptance and support for the energy transition.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