World Energy Employment 2024

INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 31 member countries, 13 association countries and beyond.

Source: IEA.
International Energy Agency
Website: www.iea.org

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Lithuania
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Republic of Türkiye
United Kingdom
United States

The European Commission also participates in the work of the IEA

IEA association countries:

Argentina
Brazil
China
Egypt
India
Indonesia
Kenya
Morocco
Senegal
Singapore
South Africa
Thailand
Ukraine

Abstract

The third edition of the *World Energy Employment* (WEE) report examines the global energy employment environment as the transition progresses into a period of uncertainty. The report offers a detailed overview of energy employment, including estimates of the workforce's size and distribution across different regions, sectors, and technologies. The dataset provides in-depth information on workers across the entire energy value chain, encompassing fossil fuel supply, bioenergy, nuclear energy, low-emissions hydrogen, power generation, transmission, distribution and storage. It also covers key energy-related end uses, such as vehicle manufacturing and energy efficiency in buildings and industry. The report also assesses how energy labour requirements evolve to 2030 across various IEA scenarios.

This year's report also explores in detail whether emerging markets and developing economies are benefitting from energy job growth as a result of the transition. It also includes a special feature chapter on the fast-growing energy workforce of India.

The 2024 *World Energy Employment* report revisits many of the critical themes explored in WEE 2023, providing updated insights into the risks of skilled labour shortages and their potential impact on the energy sector and the transition. It continues to examine the key factors driving employment trends such as skills availability, certifications, wages and job vacancy rates, with new analysis on conversion to clean energy occupations. It also marks the second year the IEA carried out a cross-region and sectoral survey of energy companies to understand the challenges they face. The updated findings underscore that labour demand from the energy sector will continue to grow, presenting both opportunities and challenges. With the right policies and collaborative efforts from governments, energy firms, labour representatives, educational institutions, and other stakeholders, there remains a strong potential to manage labour transition risks and ensure a people-centred transition to cleaner energy sources.

Table of contents

Executive summary

Global energy employment outperformed broader labour market trends in 2023. The global energy sector added nearly 2.5 million jobs in 2023 on the back of rising investment, bringing total employment to over 67 million workers. Employment in energy – which in this report includes energy supply, the power sector, end-use efficiency and vehicle manufacturing – rose by 3.8%, outpacing the economy-wide average of 2.2%. Energy job growth was fuelled by record levels of investment across a wide range of energy sources in the wake of the global energy crisis. As a result, jobs grew rapidly in both clean energy sectors (1.5 million) and fossil fuels (940 000) in 2023, a trend that held for all regions, albeit at varied paces. In China, clean energy made up over 90% of energy job growth, while in the Middle East fossil fuels accounted for 80% of the gains.

Clean energy remains the primary engine of job growth. All clean energy segments expanded in 2023, with overall year-on-year growth of 4.6%. Solar PV continued to lead clean energy employment growth in 2023, adding over half a million jobs as the sector once again surpassed expectations for new installations. While persistent, growth in other sectors was tempered by various complications. Employment in electric vehicle (EV) manufacturing and batteries grew by 410 000 as firms positioned themselves to capture more of the growing market, even as the vehicle manufacturing industry grappled with rising costs and increased global competition. While a number of wind manufacturers implemented layoffs as rising costs contributed to a slower-than-anticipated offshore project pipeline, total wind employment still climbed as a record number of new projects entered construction. Many sectors are also straining against shortages of skilled workers, especially those requiring high degrees of specialisation, such as grids and nuclear power.

Intense competition for talent in clean energy sectors is prompting firms to hire aggressively in anticipation of future growth – a tactic that could prove effective but may also leave some companies exposed to uncertainties related to project flows and changing policies. Countries that are forging ahead into clean energy are seeing significant employment growth from these sectors, with clean energy job growth representing over 10% of economy-wide job growth in China and 4-6% in advanced economies such as the United States, the European Union and Japan in 2023. However, in many emerging and developing economies other than China, clean energy's share of new jobs is below 2%.

Employment in oil and gas increased in 2023, but coal jobs are in structural decline. Overall fossil fuel employment grew by 3% in 2023, but firms took varied approaches in balancing near-term labour demand against the longer-term outlook. The oil and gas supply sector added nearly 600 000 jobs after a period of cautious post-pandemic rehiring, with new liquefied natural gas (LNG) infrastructure and upstream developments in the Americas and the Middle East contributing to growth. Global coal employment fell in both supply and power, largely due to continued mining productivity gains and a slowdown in the pipeline of new coal-fired power plants

compared with the highs of the last decade. Employment in manufacturing vehicles with internal combustion engines rose by 440 000 jobs, just outstripping job additions in EVs.

Energy employment growth is set to slow in 2024 amid tight labour markets, high interest rates and an uncertain energy outlook. Based on early data for 2024, energy jobs are expected to grow by about 3% in 2024, down from 3.8% last year. The IEA's latest *World Energy Outlook* signalled a new context for energy markets, characterised on one hand by continued geopolitical tensions and on the other by ample supplies of oil, a surfeit of manufacturing capacity for key clean energy technologies such as solar PV and batteries, and an imminent overhang in LNG supply once a wave of new export projects begin operation. This could put downward pressure on prices and increase competition among suppliers which, combined with tight labour markets and elevated interest rates, may create a more fraught hiring environment for energy firms. While clean energy firms seem set to take more bullish positions on hiring in anticipation of growth, less diversified fossil fuel firms have been remaining cautious for now. As a result, fossil fuel job growth is expected to stall in 2024.

Manufacturing leads job growth as competition over clean energy supply chains ramps up. Manufacturing was responsible for the most job additions in clean energy sectors and the overall energy industry in 2023, contributing over 40% to overall growth. This contrasts with the 2019-2022 period, when construction and installation was responsible for over half of net job growth. The success of manufacturing reflects the 50% increase in clean energy manufacturing investment in 2023 as firms responded positively to a bevy of new policies aimed at attracting new clean energy technology manufacturing. China continued to lead gains in clean energy manufacturing with 300 000 new jobs, up 9% over the previous year. Growth in this sector in advanced economies was slightly faster at 10%, though these regions contributed fewer jobs overall.

Most emerging and developing economies face structural barriers to attracting new clean energy manufacturing jobs. Just one-quarter of clean energy job growth since 2019 has occurred in emerging and developing economies other than China, despite these regions representing two-thirds of the global workforce. Many of these countries have had limited success in attracting the clean energy investment that fuels job creation, with the competitive advantage of lower labour costs insufficient to fully overcome structural barriers such as the lack of a strong existing manufacturing base, limited skills availability and inadequate infrastructure. Clean energy manufacturing has been the most elusive portion of the supply chain in these regions, with jobs in this sector growing 3% year-on-year compared with 10% in the rest of the world. Africa and Central and South America are the most extreme examples of this phenomenon, each accounting for just 3% of global clean energy manufacturing employment today.

Even so, some of these countries have success stories, and all have opportunities to stimulate future growth. India and Southeast Asia have fared relatively well, with clean energy manufacturing jobs in

these regions representing nearly 15% of the global total. Other economies have found success in the upstream supply of raw materials for clean energy sectors, such as modern bioenergy and critical minerals, with emerging and developing economies other than China responsible for 80% of the job growth in this segment since 2019. Several countries, such as Viet Nam, Morocco and Malaysia, have also built sizeable automotive and appliance manufacturing bases. These factories mostly operate conventional production lines today but are well-positioned to pivot to clean technologies such as EVs and heat pumps as global demand continues to grow.

Skill shortages persist, but companies are finding temporary workarounds. The *2023 World Energy Employment* report signalled the growing risk that skills shortages and the inadequate pipeline of new workforce entrants pose to the clean energy transition. For the second year in a row, most respondents to the IEA's survey of over 190 energy employers across 27 countries reported plans to hire but had difficulties finding qualified applicants for nearly all occupation categories. Though labour shortages in construction have fallen from recent highs in many advanced economies, supply remains tight, with 75% of respondents struggling to hire for these roles. Governments are employing a variety of strategies to address these shortages, including a renewed focus on vocational training, where the number of certifications conferred annually has generally been in decline. Many firms facing shortages of qualified applicants are also increasing on-the-job training to deliver these skills themselves.

When markets encounter a dearth of clean energy-specific skills, upskilling workers from related occupations can be a time- and cost-effective way to address shortages in the short term. New IEA analysis indicates that trade workers such as plumbers and roofers can quickly upskill to in-demand clean energy occupations such as heat pump technicians or solar PV system designers – transitions which generally offer sufficient wage premiums to quickly pay back training costs. Government incentives for retraining can help, as many trade workers are self-employed or in micro-enterprises, meaning training must be self-financed. However, this pathway is only viable if there is a sufficient supply of workers to qualify for upskilling, which is not the case in many regions. Continuing to expand the general pool of trade workers is essential to avoid simply shifting shortages from one part of the economy to another.

Energy wages are rising, reflecting increasing competition for skilled workers. After real wages fell in many regions in 2022, growth resumed in much of the world in 2023, though absolute wages generally remain below pre-pandemic levels. Wages for energy-specific roles have broadly fared better than those for more generic occupations relevant to the energy sector, notably for technicians. In major markets, occupations with an energy specialisation saw wages rise by up to 9%, outpacing non-energy jobs at 6%. The rising wages in the energy sector are partially a response to skills gaps, as firms aim to attract new workers from both within and outside the industry. As a result, clean energy wage increases were on average greater than those in fossil fuels, even in major oil, gas and coal producing countries. However, this growth has been insufficient to close the

prevailing wage premium enjoyed by oil and gas workers, who earn around 15% on average more than workers in clean energy sectors.

Policy attention is needed to ensure a just and orderly transition for workers. Though net energy employment growth will be positive on a global level through 2030, the impacts of the energy transition on jobs and livelihoods will vary widely across localities. Just transitions policies, as well as broader labour market policies, can make a difference in determining the socio-economic impacts of transitions on communities and individuals. Coal is on the front line, with jobs in most regions facing a structural decline and workers generally possessing fewer transferrable skills than in other fossil fuel sectors. As of 2023, fewer than 15% of coal workers were covered by coal-specific just transition policies. Thoughtfully designed skilling programmes can help fossil fuel workers find new work in other parts of the economy, including in nearby clean energy sectors such as geothermal, modern bioenergy, critical minerals and hydrogen. Many energy companies prefer to hire from other parts of the energy sector before turning to other industries for talent.

With the right policies, the transition can address other objectives such as job quality and gender equity. Job creation does not automatically contribute to the goal of decent work for all. Informal employment makes up a significant part of the energy labour force, especially in emerging and developing economies, with informal workers often receiving much lower pay and facing inferior working conditions. Government-led initiatives to reduce the size of the informal workforce in countries such as India and Indonesia are increasingly including energy-specific provisions. With the right guardrails, these efforts can create local value and help attract investment while improving the lives of workers and their families.

The energy transition and the jobs that come with it also offer opportunities to improve the gender balance of the energy workforce, with some clean energy sectors already having higher shares of women than fossil fuel sectors. For example, women make up about 40% of the solar PV workforce today, nearly double the share of the oil and gas industry. Narrowing the gender imbalance in the energy workforce will ultimately depend on increasing the number of women entering vocational occupations, which make up half of energy jobs. For some occupations relevant to the energy industry, like roofers or electricians, women represent less than 3% of the workforce today.

Rising demand for skilled energy workers is a given, but uncertainties may dissuade hiring. Today, uncertainties are higher than ever, with geopolitical tensions and fragmentation threatening the pace of a secure and orderly energy transition. Firms operating in regions and sectors with greater policy clarity may have more competitive footing as they plan for expansion. The IEA estimates that about 50% of the energy jobs created through 2030 under today's policy settings will not be bound to where projects are being developed, such as roles in manufacturing, professional services, engineering and project finance. With the right policy choices, education and skilling programmes governments can work with companies and labour representation to enhance competitiveness while improving the lives and livelihoods of workers, creating lasting benefits for people and the planet.

Understanding the World Energy Employment report

Introduction

The *World Energy Employment 2024* (WEE 2024) report provides a comprehensive overview of the current state of the global energy workforce, a forward view of employment demand to 2030, alongside an analysis of the opportunities and challenges that these trends pose for policy makers and other stakeholders in the energy sector.

The report is organised principally around the results of a core quantitative model, which provides estimates of demand for labour by energy industry based on a number of key drivers. This modelling adds value by providing comprehensive, detailed labour statistics with global coverage. By contrast, most official labour statistics do not cover the energy sector in detail, and while they often provide specific estimates for some traditional parts of the sector, they do not do so for many other emerging subsectors. The level of detail available is also not consistent across countries, and categories are not harmonised. In addition, energy jobs exist across economic activities, such as construction and manufacturing, which make the entire value chain difficult to capture without secondary surveys.

Our modelled estimates are based on demand drivers such as energy investment, capacity and production. As such, our model results represent the demand for labour implied by future energy system pathways. Labour supply considerations, as well as other related topics, are addressed through qualitative and ad hoc quantitative analyses, based on a wide variety of sources and inputs.

For this year's report, the IEA conducted an expansive, in-depth survey of over 190 firms in the energy industry to gain better insight on the issues and problems they are facing in hiring skilled workers, trends in wages, labour needs by occupation and long-term plans. The anonymised findings are presented throughout the report.

A brief description of the definitions and scope of our core quantitative analysis follows, with more detail on our approach available in the Methodology section of the Annex.

Definitions and scope

Quantitative estimates of employment demand are expressed in full-time equivalent (FTE) units unless otherwise stated. The terms employment and jobs are used interchangeably for this purpose.

The scope of energy employment sectors discussed in this report includes:

- The **supply** of energy and related minerals includes oil, gas, coal, bioenergy, critical minerals extraction (lithium, copper, cobalt and nickel), nuclear fuels and low-emissions hydrogen.
- The **power sector** includes generation by source (solar, wind, hydropower, fossil fuels and nuclear), power transmission facilities and grids, distribution and storage.
- Key energy **end uses** include vehicle manufacturing (plus electric vehicle batteries) and energy efficiency (in buildings and industry).

Within each sectoral category, our employment estimates are also broken down by economic activity. This refers to the categorisation of workers and activities as defined by the International Standard Industrial Classification (ISIC). For instance, employment in solar PV not only includes the installation of this technology, but also the manufacturing and assembly of the panels, and their operation and maintenance. Throughout the report, economic activities are aggregated to five groupings for simplicity:

- Raw materials
- Manufacturing
- Construction
- Professionals and utilities
- Wholesale and transport

As such, the estimates include the direct employment effects of investment and activity in the energy sector, broadly defined to include both energy supplying sectors (e.g. oil and gas, power) and energy-using technologies (e.g. heat pumps, vehicles). They also include indirect jobs generated through the manufacture, construction and installation of core energy-supplying and energy-using facilities and devices.

On the other hand, the estimates exclude other indirect jobs generated by activities in the energy sector, such as workers who produce the steel required to construct a power plant. They also exclude induced jobs, defined as jobs supported by wages earned in the energy sector but spent elsewhere in the economy. For example, employment in shops and restaurants that open in a new mining town are not included.

The report's focus is predominantly on today's energy employment trends, but also includes projections to 2030 for two scenarios used in the *World Energy Outlook* series:

- The *Stated Policies Scenario* (STEPS), which is based on today's policy settings and is designed to provide a sense of the prevailing direction of energy system progression. The STEPS considers aspirational targets and pledges only insofar as they are backed by detailed policies.
- The *Net Zero Emissions by 2050 Scenario* (NZE Scenario), a normative scenario which sets out a narrow but achievable pathway for the global energy sector to reach net zero CO_2 emissions by 2050, while meeting key energy-related Sustainable Development Goals.

Overview

Energy employment resilient, despite labour market headwinds

While far from a normal year, 2023 saw some relief from the economic impacts of the Covid-19 pandemic, the global energy crisis and surges in inflation across the world. The shadow of these events lingered on in many regions, with elevated interest rates and persistently high inflation indicators. Despite these considerable economic headwinds, global employment growth remained resilient across most regions while labour markets remained tight throughout much of 2023. Notable exceptions to the broader trends included India, where employment growth accelerated at a much faster pace than other countries, and the People's Republic of China (hereafter, "China"), which saw a contraction in total energy employment in both 2022 and 2023.

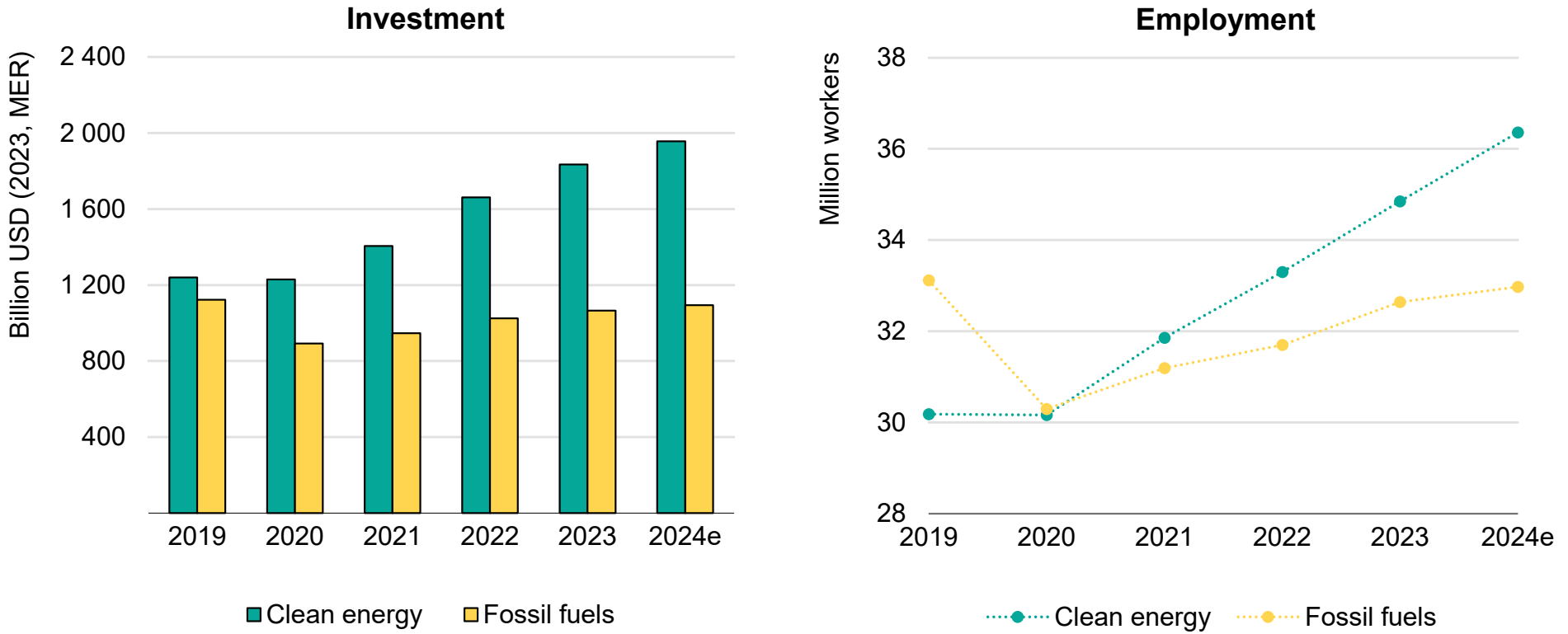
Job growth in energy sectors outpaced the wider economy in 2023, owing to rising investment, government support, and a flurry of new projects developed in response to the energy crisis. Economy-wide employment rose by 2.2% in 2023, whereas energy employment – defined as direct employment in energy supply sectors, energy-related infrastructure or equipment, or key energy-using technologies – grew by 2.5 million workers, or 3.8%.

Investment in clean energy and fossil fuels were both up in 2023. Clean energy investment rose 10%, extending a run of double-digit growth since 2020, aided by government financial support. This investment has reached macroeconomically significant levels: including sales of EVs and heat pumps, it accounted for 10% of global GDP growth in 2023. The world now spends almost USD 2.00 on clean energy for every USD 1.00 invested in fossil fuels. Investment in oil, gas and coal production also grew by 9%, boosted by a series of projects initiated in response to the energy crisis. As a result, jobs increased in both fossil fuel sectors (940 000 or 3%) and clean energy (1.5 million or 5%), bringing total energy employment to 67.5 million jobs in 2023. With these increases, clean energy employment extended its lead over fossil fuel employment, reaching 34.8 million jobs compared to 32.6 million jobs, respectively.

With growth in spending forecast to continue in 2024, the IEA estimates that energy employment will increase by another 1.8 million to reach a total of 69.3 million jobs. Based on the pipeline of planned investments, global energy spending is set to exceed USD 3 trillion for the first time in 2024, with USD 2 trillion going to clean energy technologies and related infrastructure. However, a number of uncertainties are clouding the outlook, including recent heightened geopolitical tensions and still-elevated lending costs. Firms are making personnel decisions cautiously, which is setting up 2024 to have slower growth than in 2023. Clean energy employment is expected to grow by 4.3% in 2024, only a slight decrease from the 2023 rate. Fossil fuel employment is likely to taper off at the global level, largely in anticipation of demand for coal, oil and natural gas peaking this decade, with growth easing to just 1%.

Strong investment has driven clean energy employment to new heights, a trend set to continue

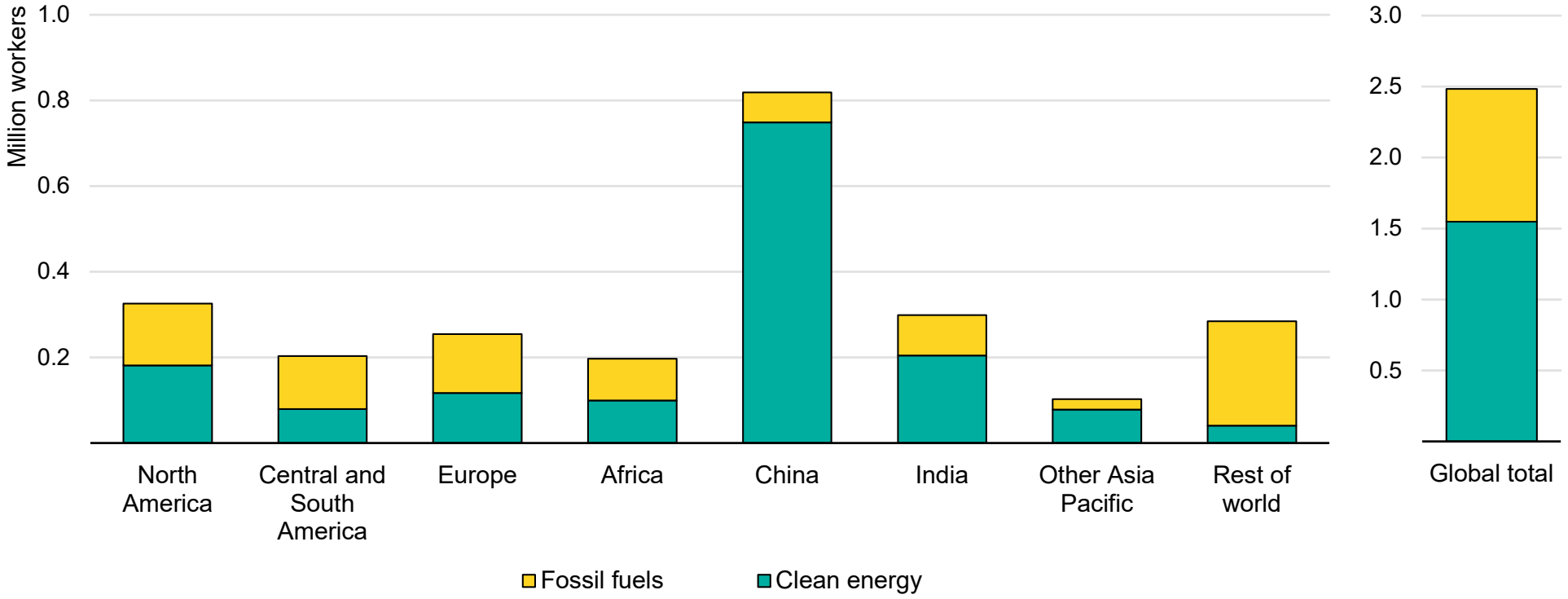
Global investment and employment, clean energy vs fossil fuels, 2019-2024e



Notes: For 2024 data “e” indicates estimated total. MER = market exchange rate. Clean energy includes low-emissions fuel sources, low-emissions power generation, power grids and battery storage, end-use efficiency, critical minerals extraction, and manufacturing of electric vehicles and their batteries. Fossil fuels include supply of oil, gas and coal, as well as unabated fossil fuel-fired power generation and internal combustion engine vehicle manufacturing. Please see the Annex for comprehensive definitions. Employment estimates for 2022 differ from WEE 2023 in some instances. These adjustments are largely due to revisions to input data, such as national statistics. Overall, there has been a downward revision of our 2022 energy jobs estimate by approximately 1.5 million worldwide. Please see the Annex for further information on historic revisions.

Clean energy captured the largest share of growth in energy jobs in 2023, while fossil fuel employment also increased in all regions

Changes in energy employment by sector and region, 2022-2023



Notes: Clean energy sectors include low-emissions fuel sources, low-emissions power generation, power grids and battery storage, end-use efficiency, critical minerals extraction, and manufacturing of electric vehicles and their batteries. Fossil fuel includes supply of oil, gas and coal, as well as unabated fossil fuel-fired power generation and internal combustion engine vehicle manufacturing. Please see the Annex for comprehensive definitions.

Clean power accounted for 40% of energy job growth in 2023, while oil and gas led gains in fossil fuels across all regions

Clean power represented the largest single source of growth in energy employment in 2023 – accounting for 40% of the increase in clean energy jobs last year. Roughly 21 million people worked in the power sector. Solar PV job growth had yet another banner year, adding over 500 000 workers to reach 4.5 million in 2023. Other clean power generation technologies contributed an additional 270 000 jobs, while employment in power grids and storage increased by 230 000 to 8 million in 2023.

Together, these clean power job additions overwhelmingly outweighed the 18 000 jobs lost in unabated fossil fuel power generation in 2023. To a large extent, this difference is explained by the jobs required to expand power capacity, including construction, installation and manufacturing, which grew by a combined 340 000 in 2023. Another 190 000 jobs were added for the expansion of new electrical lines, equipment and the digitalisation of power grids. Meanwhile, jobs related to the addition of new fossil fuel power facilities fell by 73 000, reflecting the slowing pace of further installations in this sector.

Oil and gas supply saw the largest growth among fossil fuel sectors, adding 590 000 jobs in 2023 to reach 12.4 million employees. This brought total oil and gas employment firmly above pre-pandemic levels, with much of the hiring in the Middle East and North America. Almost all of this growth was fuelled by the development of new projects. By contrast, the coal supply sector saw employment fall slightly in 2023, by 73 000, to 6.3 million jobs, despite elevated coal use amid the energy crisis. Much of this decline was seen in China, where despite ongoing growth in production and investment, consolidation of smaller mines and continued improvements in automation and mechanisation generated a net loss in employment.

Vehicle manufacturing employment continued its recovery from the pandemic, as consumer demand rose and bottlenecks in global supply chains began to subside. As car sales approached the highs last seen in 2019, vehicle manufacturing jobs grew by 6% in 2023, reaching 12.1 million. The strong growth in the global electric vehicle market continued, with EV manufacturing employment nearly tripling from 2019 to 2023. Two-thirds of global EV jobs were located in China, with the remainder mostly concentrated in the European Union (EU), the United States, and the rest of the Asia Pacific region.

This robust growth was mirrored by a rapid rise in the manufacturing and installation of heat pumps and batteries, creating 53 000 (+7%) and 150 000 (+11%) new jobs, respectively, in 2023. Nearly 80% of global employment in batteries was located in China. Heat pump jobs were more evenly distributed across North America, Europe and Asia Pacific, with China again capturing the largest share.

Employment in energy efficiency categories outside of heat pumps, including building retrofits and industrial efficiency measures, fell slightly by 0.3% year-on-year (y-o-y) in 2023. Meanwhile, jobs in

sectors supplying clean energy commodities (bioenergy, nuclear fuels, low-emissions hydrogen and critical minerals) collectively rose by 2.3%, to 4.3 million in 2023.

The employment associated with energy technologies cuts across industrial sectoral classifications. Throughout this report, categorisation of workers and activities are aggregated into five groupings for simplicity: raw materials, construction, manufacturing, professionals and utilities, and wholesale and transport. A large share of the global energy workforce is increasingly dedicated to the construction and manufacturing of energy technologies. In 2023, over half of global energy jobs fell into one of these two broad activities, at 14.3 million and 21.2 million, respectively, of which about 50% were in clean energy technologies. Employment mostly associated with the operation of existing projects, including utilities and professionals, and wholesale trade and transport jobs, amounted to 22.7 million. These jobs are expected to take up a larger proportion of the total once the global energy transition has been completed. Meanwhile, raw materials – which includes the extraction of minerals, oil, gas, coal and bioenergy feedstock cultivation – accounted for 9.3 million jobs.

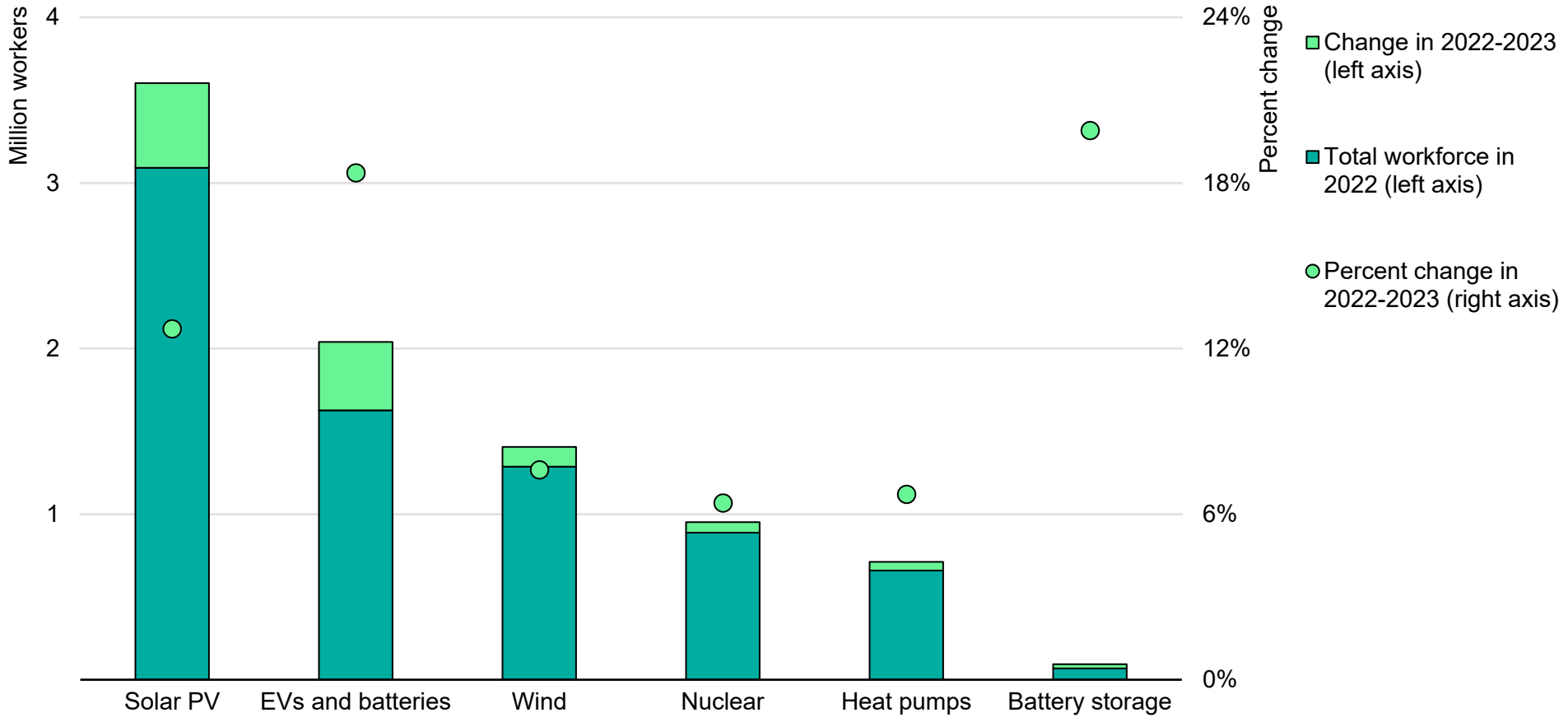
China dominated energy employment growth in 2023, with an increase of over 800 000 jobs to 20.6 million – more than twice as many as in any other country or geographic region. This growth on a percent basis is roughly comparable to other regions given the magnitude of China's energy workforce. However, China's clean energy employment growth surpassed other regions substantially, posting 6.4% growth, reflecting the country's leading role in global clean energy supply chains. North America followed at 5.6% growth, and then India at 4.9%.

China accounted for the largest share of global manufacturing employment in a number of key clean energy technologies, including EVs (68%), batteries (93%), heat pumps (48%), solar PV (84%) and wind turbines (54%). These clean technology manufacturing sectors are of particular interest since they are projected to be a major source of growth in energy employment in the coming decades, but also because the location of their employment is not linked to project sites, as is the case for jobs in construction or utilities. Despite recent efforts to onshore manufacturing jobs in these key clean energy sectors, advanced economies had a much smaller share of this workforce, at 21% of the global total.

Meanwhile, emerging markets and developing economies (EMDEs) other than China account for only 7% of global manufacturing jobs in EVs, batteries, heat pumps, solar PV and wind. For these countries, around half of all energy jobs in 2023 were in fuel supply at 14.3 million, of which 11.1 million were in fossil fuel supply. This represents an additional downside vulnerability for EMDEs, where some of this employment will be exposed to the risks of falling demand for fossil fuels, as clean energy transitions continue to accelerate. The uptake of clean energy jobs in these economies is a key area of focus for this report and is discussed in more detail in Chapter 2.

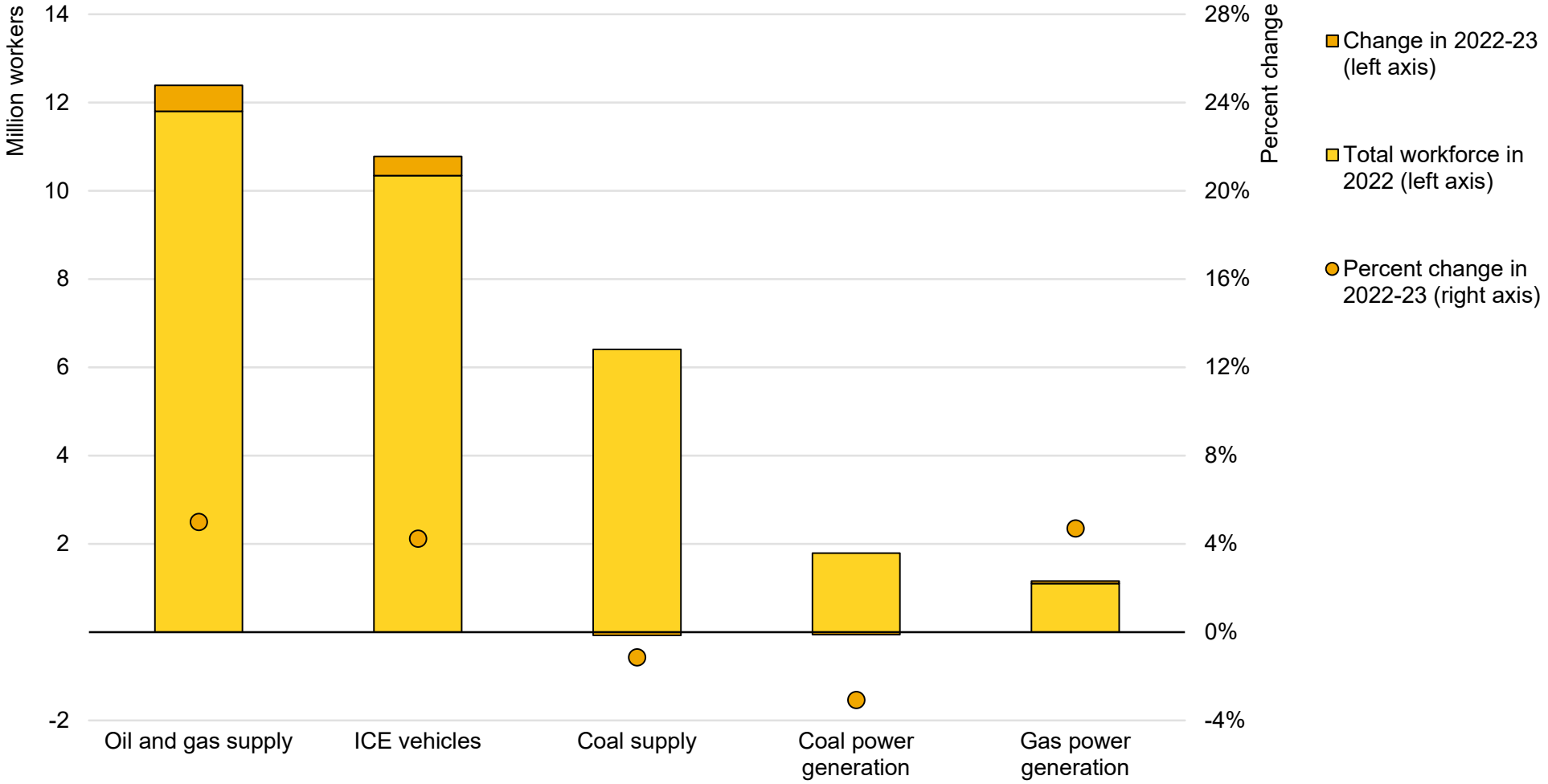
EVs and solar PV were the major contributors to new clean energy jobs in 2023, while battery storage grew fastest, albeit starting from a small base

Total workforce and changes in employment in clean energy technologies, 2022-2023



Upticks in oil and gas supply investment and ICE vehicle sales drove higher fossil fuel employment in all regions in 2023, while coal jobs declined

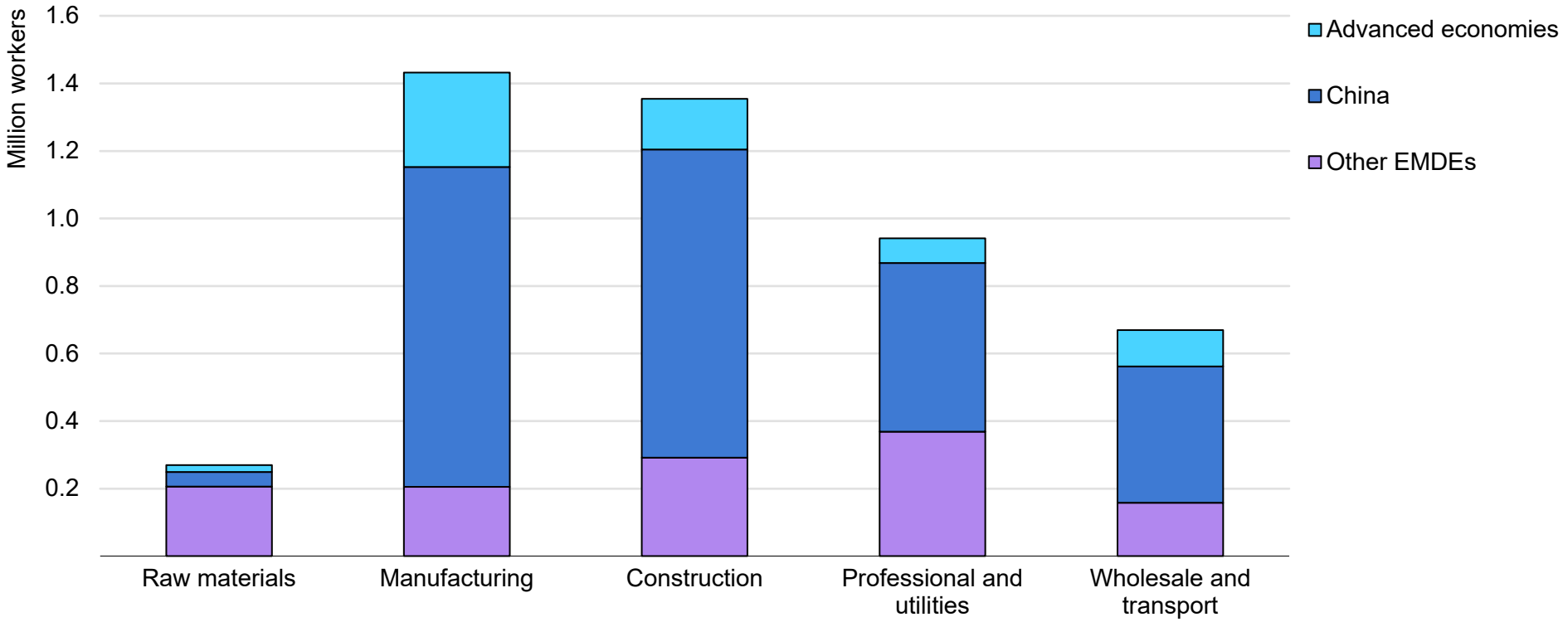
Total workforce and change in employment in fossil fuel sectors, 2022-2023



Note: ICE vehicles = internal combustion engine vehicles.

The construction and manufacture of clean energy infrastructure and technologies accounted for 60% of all new clean energy jobs added in 2019-2023

Clean energy employment growth by economic activity and region, 2019-2023



Note: CAGR = compound annual growth rate; EMDEs = emerging markets and developing economies.

Fuel supply, power and end-use sectors are key sources of employment in every region

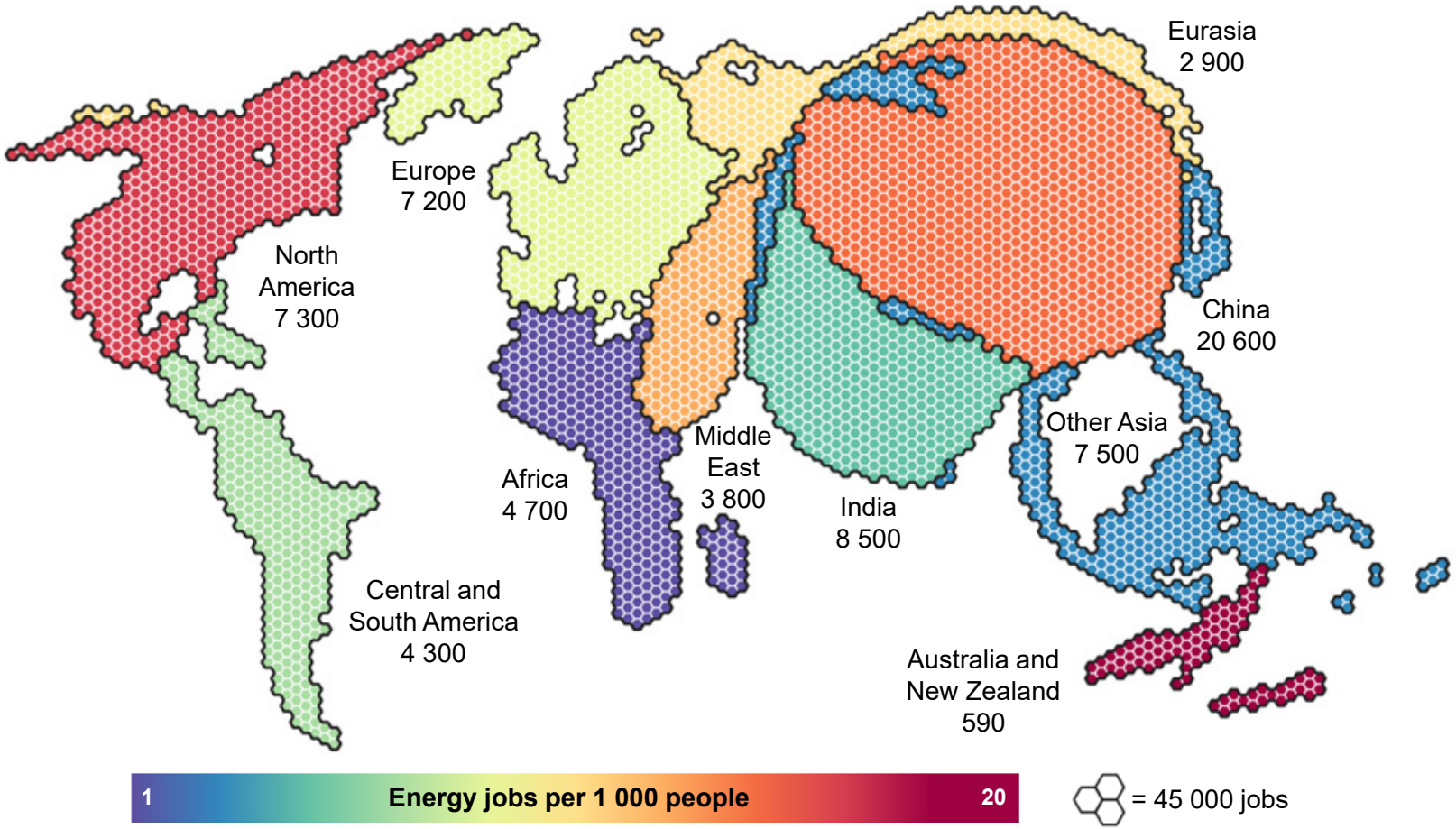
Energy employment by region and sector, 2023 (thousand workers)

	North America	Central and South America	Europe	Africa	China	India	Other Asia Pacific	Middle East	Eurasia	Global
Supply: coal	100	<50	100	200	3 300	1 600	800	<50	300	**6 300**
Supply: oil and gas	1 900	1 100	600	1 600	1 200	800	1 000	2 800	1 400	**12 400**
Supply: low-emissions fuels	200	800	300	700	300	700	500	<50	<50	**3 500**
Power: generation	1 000	900	1 500	500	5 200	1 400	1 700	400	400	**13 100**
Power: grids	900	500	1 000	400	2 400	1 600	800	200	200	**8 000**
End uses: vehicles	1 800	500	2 400	400	4 500	1 300	1 900	200	300	**13 400**
End uses: efficiency	1 400	400	1 200	500	3 500	1 200	1 300	200	200	**9 800**
Critical minerals	<50	100	<50	400	<50	<50	100	<50	<50	**800**
All energy	**7 300**	**4 300**	**7 200**	**4 700**	**20 600**	**8 500**	**8 100**	**3 800**	**2 900**	**67 500**

Notes: Power grids include transmission, distribution and storage. Low-emissions fuels include bioenergy supply, hydrogen supply and nuclear supply. Vehicles include the manufacturing of all road vehicles (two- and three-wheelers, passenger cars, light-duty commercial vehicles, buses and trucks) and batteries for EVs. Efficiency refers to energy efficiency in buildings (covering retrofits, heating, ventilation and air conditioning equipment, as well as appliances) and in industry (efficiency of electric motors). Values may not sum due to rounding. Employment estimates for 2022 differ from WEE 2023 in some instances. These adjustments are largely due to revisions to input data, such as national statistics. Overall, there has been a downward revision of our 2022 energy jobs estimate by approximately 1.5 million worldwide. Please see the Annex for further information on historic revisions.

China and India have the biggest energy workforces, but energy jobs per capita are highest in Australia and New Zealand

Magnitude of energy employment by region, 2023 (thousand workers)



Notes: This map is without prejudice to the status of sovereignty over any territory, or to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. Please see the Annex for definitions of regional groupings. The size of each region is scaled relative to the size of the total energy workforce in that region; the colour of each region corresponds to the rate of energy employment per capita in that region. Standard deviation per tile is approximately 4 000 jobs.

Clean energy will drive an increase in energy employment by 2030 in almost all regions, but also demand significant shifts within existing sectors to keep pace

This report provides projections for employment needs in 2030 based on two energy scenarios from the *World Energy Outlook 2024*: the Stated Policies Scenario (STEPS), which reflects today's policy settings; and the Net Zero Emissions by 2050 Scenario (NZE Scenario), which sets out a trajectory consistent with reaching net zero emissions globally by 2050. Annual energy investment continues to climb in both scenarios, reaching USD 3.5 trillion by 2030 in the STEPS, and USD 5 trillion in the NZE Scenario – around double the average annual investment over the past five years. This implies a continued increase in labour needs across many parts of the energy supply chain, and a shift in the occupational composition and skills required.

In both scenarios, energy employment is much higher than today, with job growth outpacing job losses to 2030. Energy employment in 2030 is substantially higher in the NZE Scenario (83 million) than in the STEPS (74 million). This difference is largely explained by the additional investment required under a faster transition scenario, which creates an increase in labour demand, particularly in the construction and manufacturing of new energy projects.

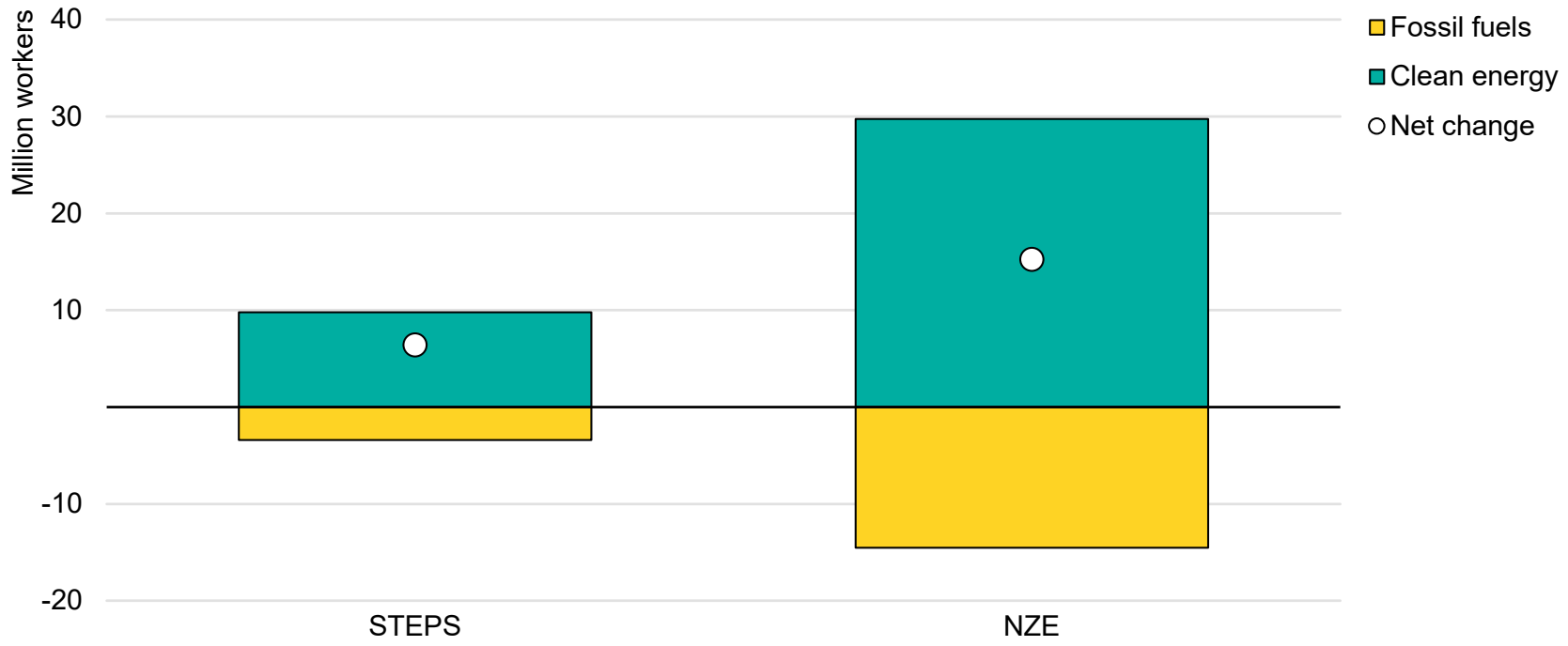
Companies, educators, and governments should be preparing for a much larger energy sector in both scenarios. In the STEPS, meeting clean energy employment demand implies maintaining a 4% annualised growth rate, roughly the same achieved over the last four years. However, in the NZE Scenario the required growth rate must be substantially accelerated, to 9%. In both scenarios, energy education and upskilling must be massively upscaled to overcome existing labour shortages and keep pace with the rapidly growing demand for more skilled workers. Governments should also remain watchful for how incentives that draw investment into clean sectors impact other industries competing for similar workers. For instance, construction workers shifting to support new energy projects may create labour supply bottlenecks in other energy sectors.

The sectors in which new jobs arise are not the same as where jobs are lost. In the NZE Scenario, nearly half of the 30 million new clean energy jobs emerging between 2023 and 2030 are in the power sector (14 million), whereas nearly half of job losses in fossil fuel sectors come from coal, oil and gas supply, with 7 million fewer jobs available in 2030 relative to 2023. Achieving just and orderly transitions for workers is a key focus of the Global Commission on People-Centred Clean Energy Transitions.

Beyond employment changes across industries and occupations, the transition also implies a shift in employment requirements across geographies. Many countries and regions could see a decline in energy employment if they do not diversify within and outside of the energy sector. Policy makers can play a meaningful role in facilitating a successful transition and proactively taking advantage of the opportunities for economic growth and equity associated with the transition.

Gains in clean energy jobs would outweigh losses in fossil fuel jobs by 2030 under both the Stated Policies Scenario and the Net Zero Emissions by 2050 Scenario

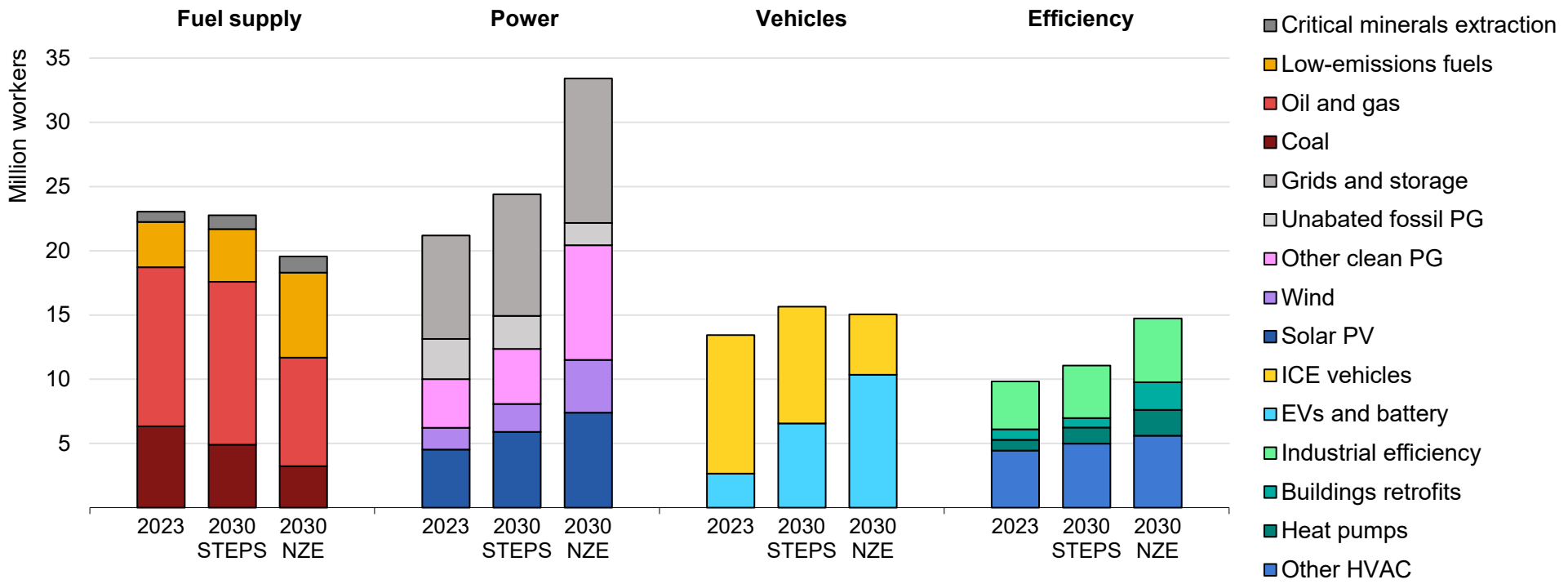
Change in energy employment by sector and scenario, 2023-2030



Note: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Some sectors see job losses by the end of the decade, but growth elsewhere ensures that energy transitions are a net creator of employment opportunities

Energy employment by technology and scenario, 2023 and 2030

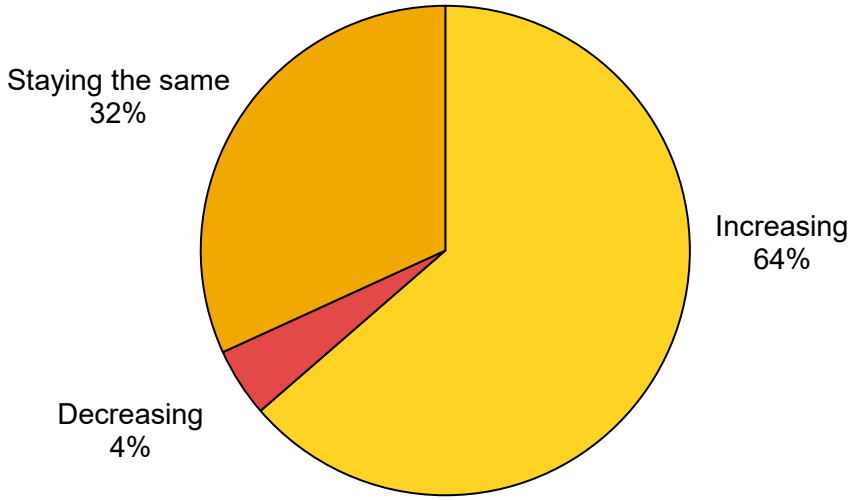


Notes: PG = power generation; ICE vehicles = internal combustion engine vehicles; EVs = electric vehicles; HVAC = heating, ventilation and air conditioning. STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario. Power grids include transmission, distribution and storage. Low-emissions fuels include the supply of bioenergy, nuclear fuels, hydrogen and critical minerals. Other efficiency includes building retrofits, heat pumps and other equipment, and appliances.

Labour and skills shortages persist unevenly across the energy industry

World Energy Employment 2023 included a special chapter on labour and skills shortages, which are threatening to slow the ramp up of clean energy technologies. Over the year since its publication, the struggle to hire skilled workers for the energy transition has become an increasingly prominent topic of discussion. For the second year in a row, the IEA carried out a survey of over 190 energy employers across 27 countries in Europe, the Americas, Africa and Asia Pacific. Most respondents reported plans to hire new workers but faced difficulties finding qualified applicants for almost all occupation categories.

Responses to IEA survey question, "How do you project change in headcount over the next year?"



Labour shortages imply that a specific market lacks enough candidates for a given job at prevailing wages, while skills shortages refer to an insufficient quantity of workers with the specific skills required by an occupation or employer. Some countries are facing broader structural labour shortages that inexorably affect the energy industry, such as the United States and Japan, where the number of job openings has for years been greater than the number of unemployed workers. But more widespread is a dearth of the skills demanded by the energy sector, even if the actual number of workers available is otherwise sufficient to fill positions. For example, a certain market might have enough workers to fill all open positions in heat pump installation, but there could still be an insufficient number of workers with the knowledge and skills needed to install heat pumps.

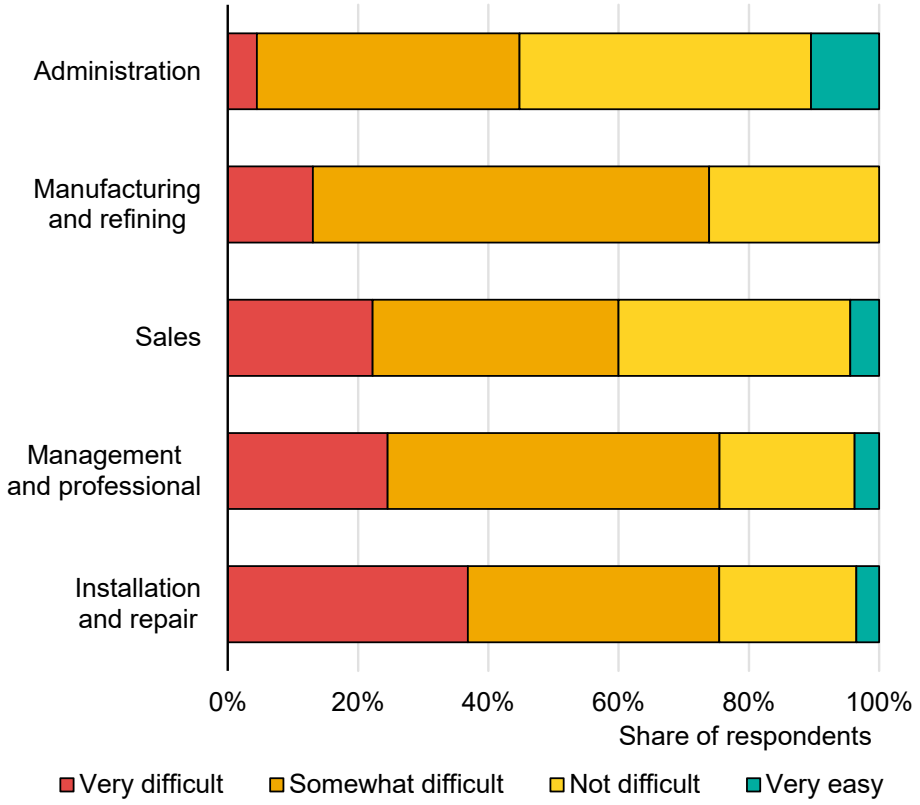
Installation and repair positions remain some of the hardest hit by skilled labour shortages, with over three-quarters of survey respondents finding it "very" or "somewhat" difficult to hire qualified technicians, trade workers and project supervisors. At 37%, the share of respondents that consider hiring "very" difficult was much higher for installation and repair than for other categories, with a lead of 12 percentage points over any other segment. This is further supported by public data on skilled labour shortages in major economies, with welders, plumbers, mechanics and electricians once again topping the list of widespread shortage occupations in the European Union and tradespeople remaining in high demand in the United States, Canada, the United Kingdom, Australia, and other

advanced economies. An ageing population is contributing to these shortages, with one in three electro-engineering workers in the European Union aged 50 or over and the average age of trade workers reaching 55 in the United States. The EU job vacancy rate for the utilities sector in the first quarter of 2024 was almost double its 2019 level.

Similar issues continue to plague the manufacturing sector in China, home to the largest energy manufacturing workforce. Chinese ministries have for years warned of a mismatch between the quantity of workers demanded by the manufacturing sector and the number of entrants as an ageing population puts pressure on hiring.

Installation and manufacturing are two of the most important sectors for clean energy employment, accounting for over half of all clean energy jobs worldwide in 2023, and approximately 70% of job additions through 2030 in the NZE Scenario. In many OECD countries, there is a widespread shortage of jobs in these sectors already. This is proving a pain point in the United States and Germany, where skilled labour availability has become more pressing amidst high-profile policies to boost domestic manufacturing of clean energy technologies. Although job vacancy rates in manufacturing have somewhat abated since soaring in 2021 and 2022, they remain roughly 20% higher than 2019 levels in both the United States and the European Union.

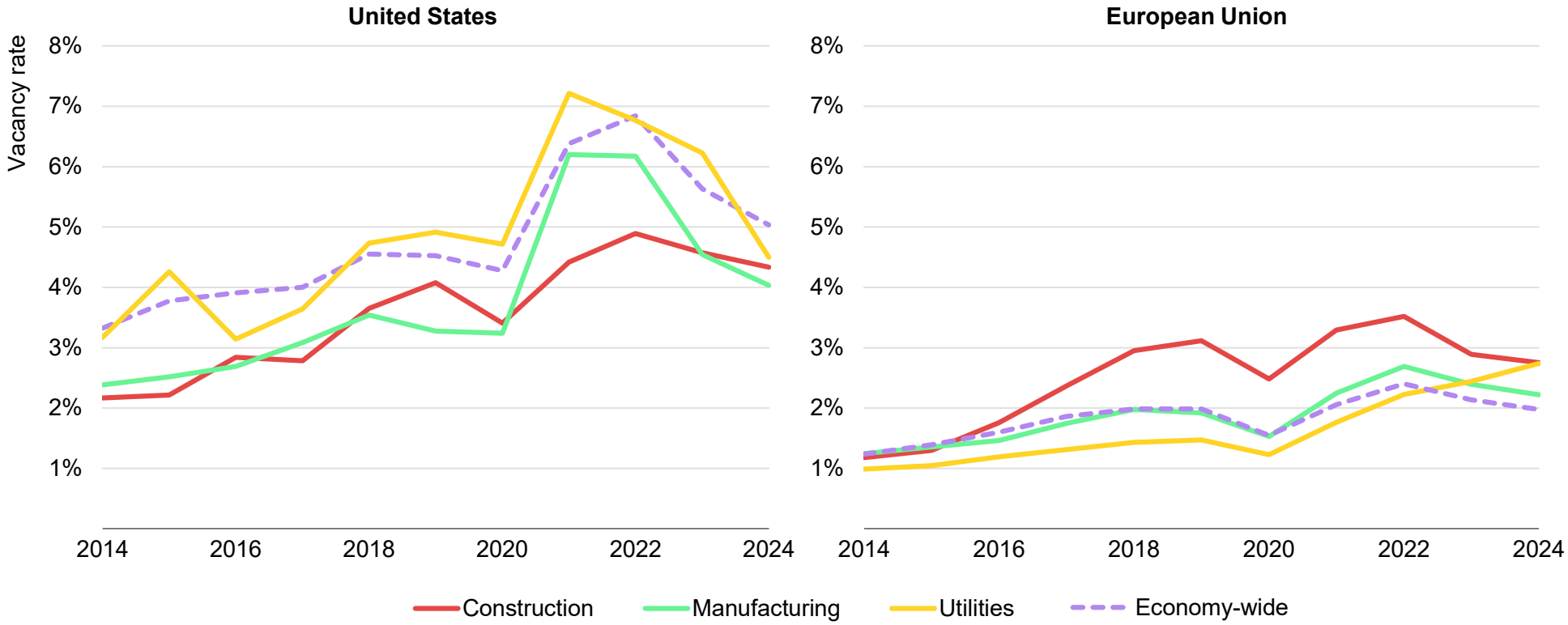
Share of energy employers reporting hiring challenges by degree of difficulty and occupation, 2024



Notes: Results of the IEA's survey for the *World Energy Employment 2024* report. Survey respondents were asked to indicate the level of difficulty they faced in finding qualified applicants compared to the average hiring process for each occupation type.

Job vacancy rates in energy-related sectors have fallen from recent peaks in the United States and the European Union, but remain elevated compared to pre-pandemic levels

Job vacancy rates in energy-related industries in the United States and the European Union



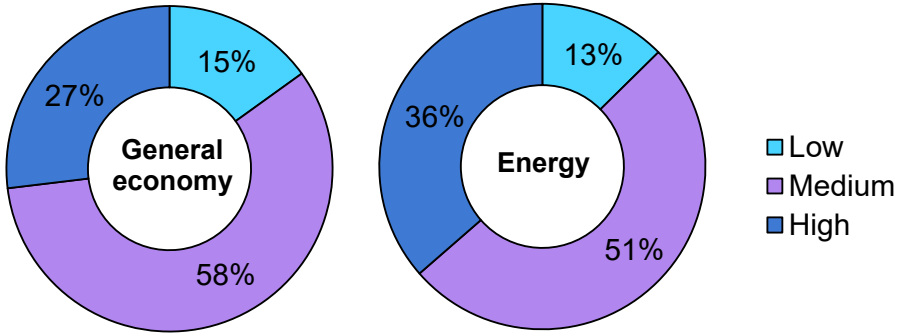
Notes: Vacancy rates, often used as a proxy for labour shortages, represent the number of job vacancies in an industry as a share of all jobs in that industry, filled or unfilled. Utilities differs in scope between regions; US utilities include transport, warehousing and utilities, while EU utilities include electricity, gas, steam and air conditioning supply. Data represent yearly averages of seasonally adjusted data. 2024 figures represent Q1 and Q2 for the United States and Q1 for the European Union.

Sources: IEA analysis based on the U.S. Bureau of Labor Statistics, Job Openings and Labor Turnover Survey (dataset), accessed 02 September 2024, and Eurostat, Job Vacancy Statistics (dataset), accessed 02 September 2024.

Declining vocational education and shifting skills requirements contribute to shortages

Exacerbating the demands on the limited supply of skilled energy labour is the fact that the energy sector already requires more highly skilled workers than the broader economy. Approximately 36% of energy jobs are high-skilled occupations, which generally require higher education such as a bachelor's degree or above. Another 51% are in medium-skilled occupations, usually requiring some vocational or technical education – many of the pressing skills shortages facing the industry today fall under this category, such as electricians and welders. That means just 13% of the energy workforce can be considered low-skilled, and performing primarily repetitive manual tasks. These jobs are heavily concentrated in emerging and developing economies, with advanced economies having eliminated many of these positions with automation and mechanisation.

Global employment by skill level, 2023



For most energy jobs, education institutions such as vocational schools and universities are the first stop in the skills development pipeline. Many high-skilled energy occupations, such as engineers and technicians, hire largely from graduates of science, technology, engineering and math (STEM) programmes, which have generally been rising in popularity around the world. The success of STEM programmes can be largely attributed to increasing government initiatives, especially in Asia, and shifting student preferences and perceptions regarding job security and earning potential. But many advanced economies, including Germany, Japan and the United Kingdom, are seeing STEM graduation rates not keeping pace with industry demand.

For the half of energy workers considered medium-skilled, vocational or technical education is the most likely path to develop the skills needed in energy occupations. In most major regions, the share and even the absolute number of students choosing to pursue vocational qualifications has fallen below historical highs. In China, the number of graduates in upper secondary vocational education dropped 30% between 2014 and 2022, with the number of graduates on the energy and power track plummeting by nearly 60% over the same period. Even countries with strongly embedded vocational education systems are experiencing downturns. Over one-third of secondary school graduates in Germany enter vocational training, but in 2022 the number of unfilled training positions was greater than the number of unplaced applicants for the first time ever. The decline of vocational education is attributable to a wide variety of factors that vary by region and field, including perceived social stigma, scepticism

about education quality, concerns over earnings potential, cultural and gender bias, programme management problems or insufficient investment, and a view that vocational occupations are outmoded.

The level of skills demanded by energy firms is also shifting and may not be sufficiently covered in current curricula. Respondents to the IEA survey ranked digital skills such as data analysis, programming and digital literacy as the most important when hiring, ahead of both soft and technical skills. Online job postings in many regions support this finding. The share of positions requiring at least one specialised digital skill has more than doubled in some countries and sectors. In Canada, for example, this share surpassed 50% in 2023 for solar PV and efficiency jobs, compared with less than 20% a decade ago.

A prolonged lack of sufficiently skilled workers threatens the pace and quality of the energy transition. The inability to source enough labour can impede energy companies from taking on new work, delivering clean energy projects on time or on budget, and has reputational implications for clean energy technologies, as has been observed in nuclear energy in several Western countries. Similar consequences can follow if clean energy installations suffer in safety or effectiveness due to errors made by inadequately skilled or a short-staffed workforce. Yet, despite these risks, over a quarter of respondents to the IEA's energy employment survey indicated that they had been forced to decrease the desired level of skilling in new hires to be able to fill vacant positions.

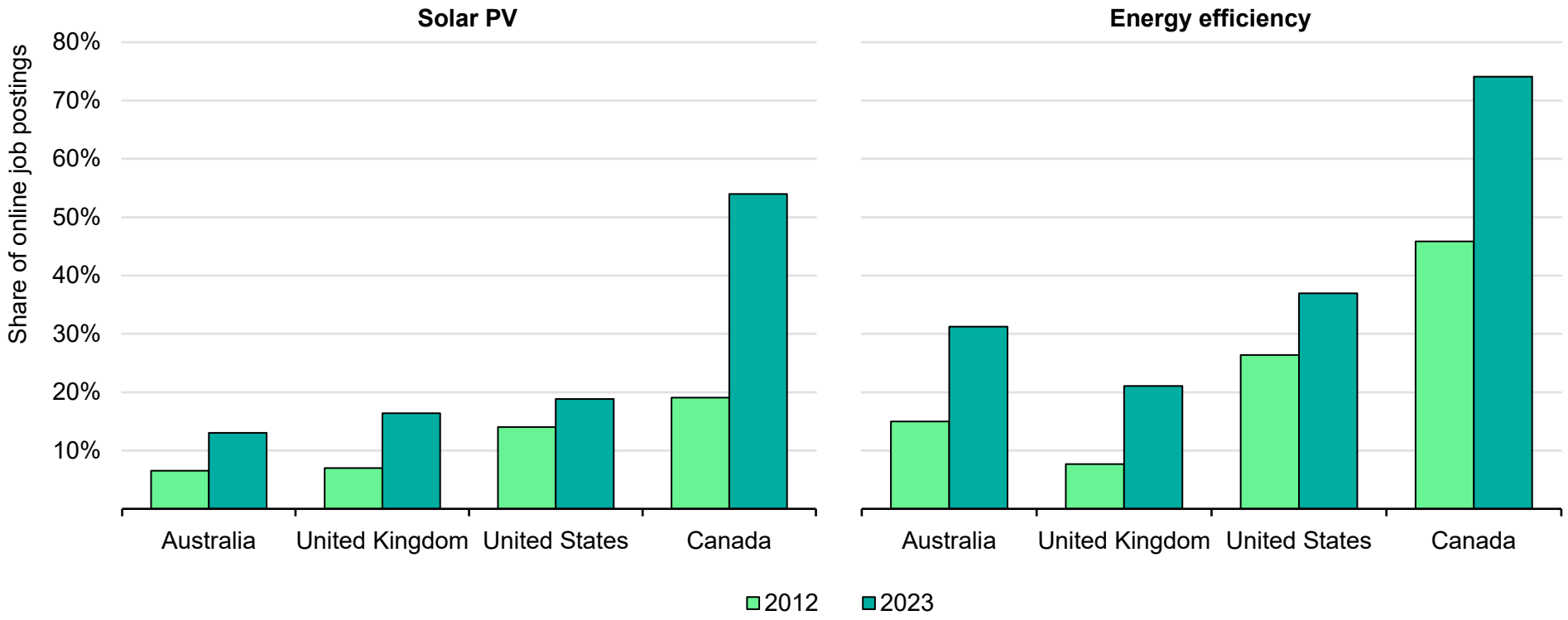
Energy firms are adopting a variety of strategies to cope with skills shortages. Many employers are increasing on-the-job training (OJT) for new employees. OJT is an effective approach that addresses the issue of knowledge transfer between old and young workers, but it can also contribute to a less liquid market for skilled workers. Over two-thirds of survey respondents indicated that new hires in manufacturing, refining, installation and construction positions required about one week of OJT before they could perform their tasks on their own, while approximately 40% reported that new workers require training of a month or more.

Apprenticeships or dual-track vocational programmes are another avenue to ensure training is market-relevant and ameliorate short-term bottlenecks. In the United States, this path has seen growing government support, with nearly USD 200 million in grants to expand apprenticeships in high-demand sectors such as energy as well as built-in apprentice labour requirements in the Inflation Reduction Act (IRA). There is evidence that these initiatives are beginning to pay off: In 2023, there were about 24 000 registered apprentices in the US energy industry, a 44% improvement over the previous five years.

The most effective blend of OJT and formal education will differ in each region and sector. Some companies with specific skilled labour needs are partnering with educational institutions to collaboratively design curricula. For example, the Urenco Group, a major British-German-Dutch nuclear fuel consortium, formed a partnership with Cambridge University to help shape the research strategy and master's curriculum at their Nuclear Energy Centre.

Digital skills are increasingly in demand in the energy sector

Share of online job postings requiring at least one specialised digital skill by sector and country, 2012 and 2023



Source: IEA analysis based on data from Lightcast.

Drawing upon skilled workers in other parts of the energy sector can help address skills gaps in clean energy, but is not enough to deliver a just transition for fossil fuel workers

Many companies prefer hiring workers already in the energy sector, with over 40% of respondents to the IEA survey reporting that they often hire employees from other segments within the energy industry. Transferable skills and knowledge of the energy sector were the most important motivating factor cited by two-thirds of respondents, followed by the desire for candidates with diverse experiences and perspectives.

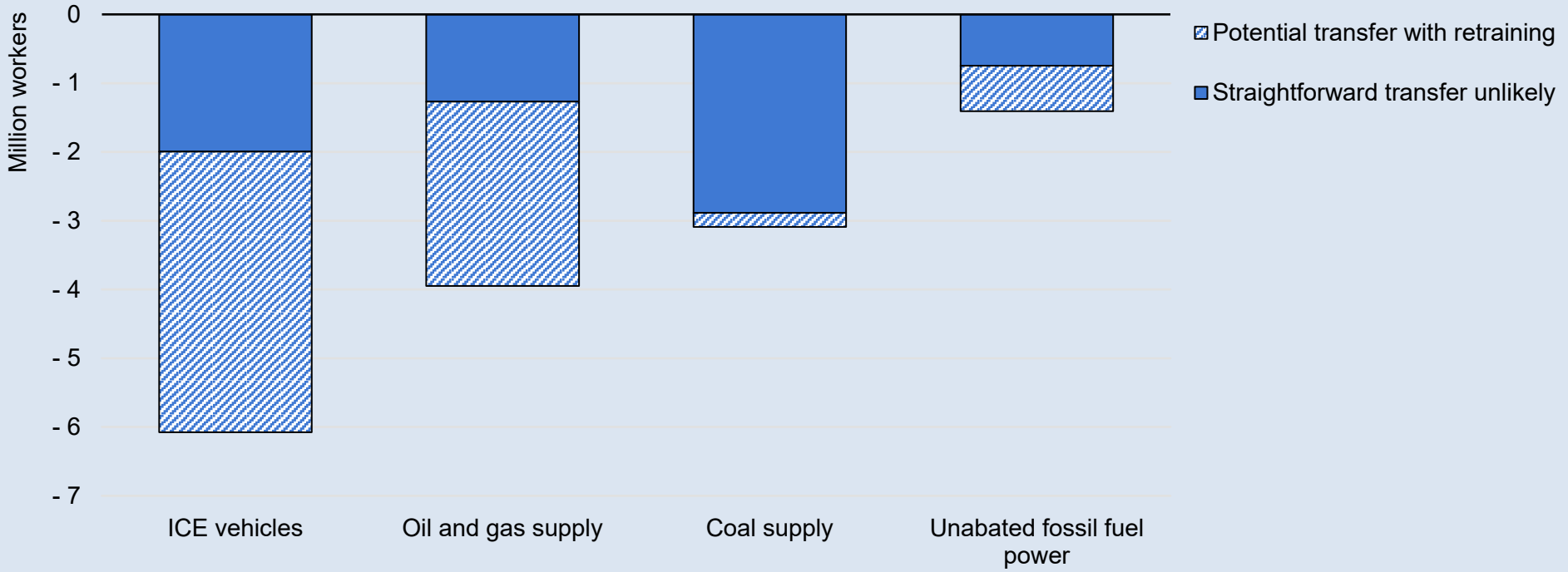
Growing clean energy sectors are already drawing upon workers from fossil fuel sectors, which will help manage the challenges for both sides of the energy transition. For example, oil and gas workers often have competencies proven to be both applicable and valuable to sectors including carbon capture, utilisation and storage (CCUS), low-emissions fuels, geothermal and wind. There are also more straightforward shifts, such as ICE vehicle manufacturing workers who may switch to work on an EV assembly line, or coal power plant operators who can upskill to work with CCUS retrofits.

Not all fossil fuel workers whose jobs are eliminated, however, will necessarily be able to make an easy transition to a new clean energy sector, highlighting the need for proactive government support and planning. Although clean energy job growth through 2030 outpaces fossil fuel job losses 2 to 1 in the NZE Scenario – and by even more in less ambitious scenarios – many of the new roles will require skills dissimilar from those jobs eliminated as the shift away from oil, gas and coal supply gathers pace in the energy transition.

Even under the generous assumption that all new clean energy jobs with similar skill needs are first offered, with training, to redundant fossil fuel workers with transferable skills in the same region, the number of clean energy jobs with similar skill needs that are created through 2030 in the NZE Scenario is equivalent to just over half of the job losses in fossil fuel sectors.

This means that, on average, there is no obvious clean energy job "transfer" with overlapping skill needs for almost half of the fossil fuel workers who may see their position eliminated. This does not account for subnational variation, job creation in non-energy sectors, or workers who may receive more extensive retraining to move to clean energy sectors with divergent skill requirements. Coal supply workers are especially unlikely to see an easy transition to clean energy sectors, with growth in critical minerals supply jobs equivalent to less than 10% of coal supply job losses through 2030.

Fossil fuel-related job losses and potential for inter-industry worker transfer in the NZE Scenario, 2023-2030



Notes: Job transfer is considered only across energy sectors with clear overlapping skill requirements. These are: EV manufacturing (excluding batteries) for ICE vehicles; bioenergy supply (excluding agriculture), low-emissions hydrogen supply, geothermal, and offshore wind for oil and gas supply; critical minerals extraction for coal supply; and fossil fuel power with CCUS for unabated fossil fuel power. Potential transfer is also limited to jobs created within the same region as the jobs lost. These are calculated at a national level for the United States, Canada, Mexico, Brazil, China, India, Indonesia, Japan, Korea, South Africa, and Russian Federation (Russia). For all other countries, multinational regional groupings such as the Middle East are used. ICE vehicles = internal combustion engine vehicles.

Attracting new talent to the energy workforce is contributing to rising wages

Rising wages in the energy sector are, in part, a symptom of the skilled labour gap. Wages are rising economy-wide but have not kept pace with inflation in all regions. However, energy wages are faring better. Real wages in key occupation groups that are relevant to the energy industry were largely outperformed in 2023 by occupations with an energy-specialisation, which saw their wages rise up to 9%, compared to 6% for non-energy jobs. This trend was strongest for higher-skilled technician roles: energy-related wages outgrew non-energy wages in these roles in over 90% of countries assessed in this report. This reflects the energy industry's willingness and ability to outcompete related industries for top talent and comes on top of the fact that energy occupations tend to be better paid than those in the broader economy. Energy companies confirm that raising wages has been a key part of their hiring strategy. For the second year in a row, most survey respondents indicated that they had to increase wages to attract talent, with nearly half of these employers raising salaries by 10% or more in target occupations.

Higher wages are an important incentive for workers to pursue specialised training on their own. Based on new IEA analysis, many energy-specific certifications require only short additional training over a base degree, and the wage premiums quickly pay back the cost of the training. However, building the base skills takes far longer. For example, IEA analysis of plumber and heat pump technician career paths reveals that training as a heat pump technician from scratch can take up to five years, depending on the country. But someone already trained as a plumber can gain the additional skills needed in just a few weeks to months, and the wage premium associated with this position in most areas allows the worker to break-even on the cost of training in 2-4 months on average. Government support to lower the cost and time burden on workers to retrain has also played an important role in these programmes, especially for contractors and self-employed workers who bear a high opportunity cost for retraining.

While wage premiums are sufficient to attract skilled workers from outside the energy sector, they may not always be competitive within the energy sector. The average worker in the oil and gas sector, for example, earns around 15% more than a worker in clean energy sectors such as wind. Nuclear wages also are significantly higher than most new clean energy technologies in major markets. These differences in average wages partly reflect the composition of occupations required in each sector, with highly skilled (and therefore better paid) occupations making up a larger share of the oil and gas supply and nuclear workforces.

In 2023, real wage growth in clean energy sectors such as solar PV and wind on average outperformed growth in fossil fuel sectors in most major economies. This trend reflects a number of factors, including rising levels of labour union representation and greater competition for skilled workers in this growing sector. Higher wages should help ease some of the skills shortages cited by firms, albeit at the price of rising project costs.

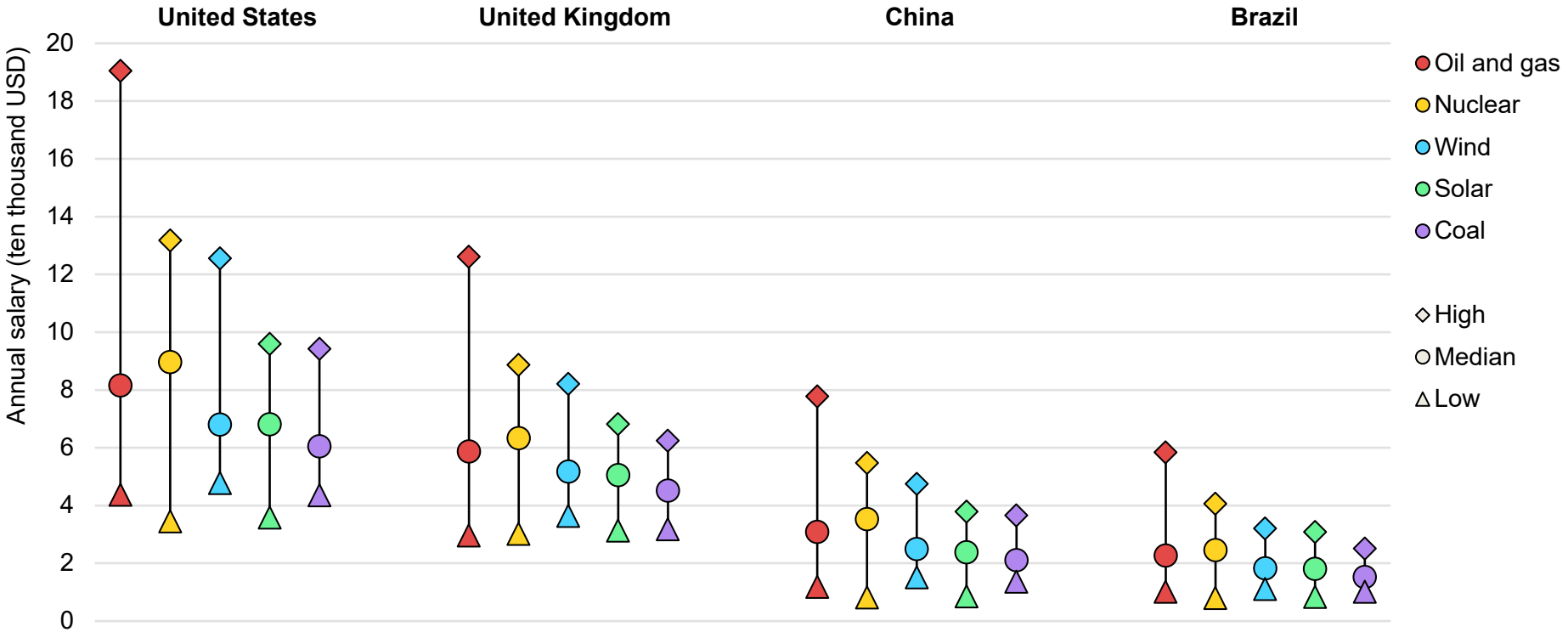
Wage increases in renewables have outpaced those of fossil fuel sectors in most regions, even in major fossil fuel producing countries

Notes: Wages by sector are averaged using the median wage value of several occupations. These are weighted based on the workforce composition by skill level. National statistics and data coming from the International Labour Organisation (ILO) were also used to complement this analysis.

Source: IEA analysis based on data from the Economic Research Institute (ERI).

Despite wage growth in renewable sectors, earning potential remains highest in oil and gas, presenting a barrier to inter-industry transitions

Median energy salary ranges by sector and country, 2023

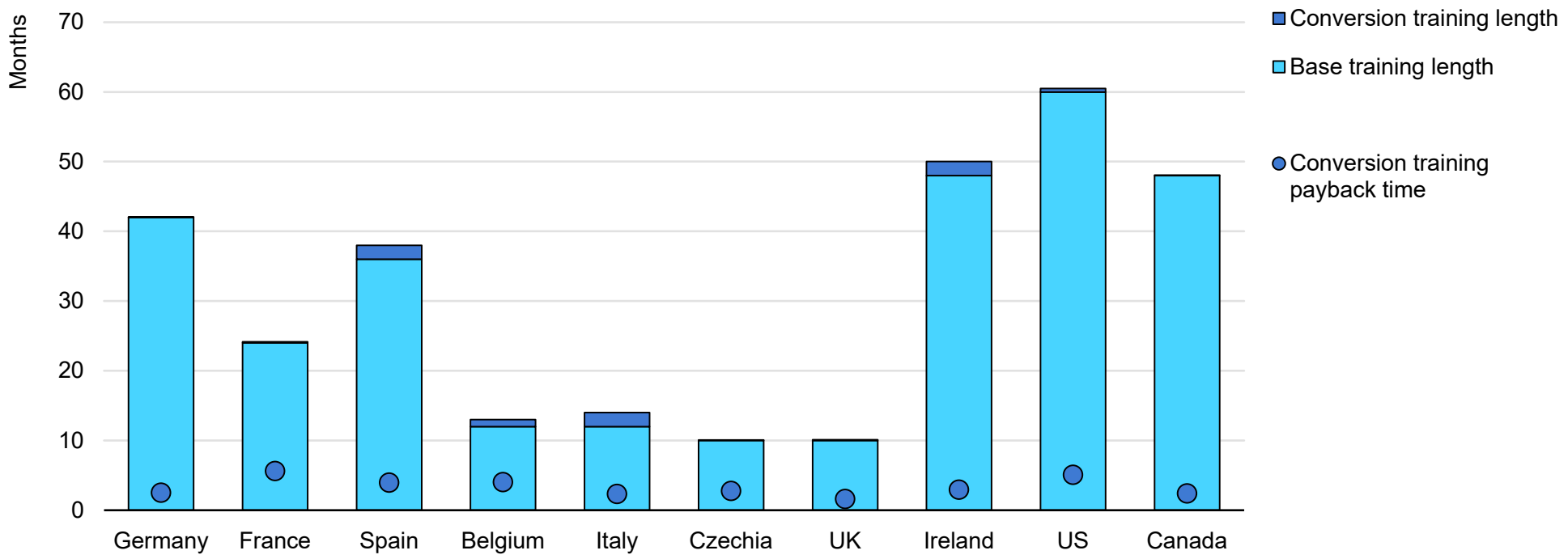


Notes: All data presented are median salaries. High refers to the highest median salary of any non-executive occupation; low refers to the lowest median salary; and median is the median of all occupations. For example, in the United States oil and gas industry, the high point represents the median salary of a well servicing foreman, and the low point represents the median salary of an oil field labourer.

Source: IEA analysis based on data from the Economic Research Institute (ERI).

Switching from plumbing to heat pump jobs confers a wage premium to workers, and incurs relatively minor additional costs in time and money in most regions

Training times and costs for plumbers and heat pump technicians by country, 2023

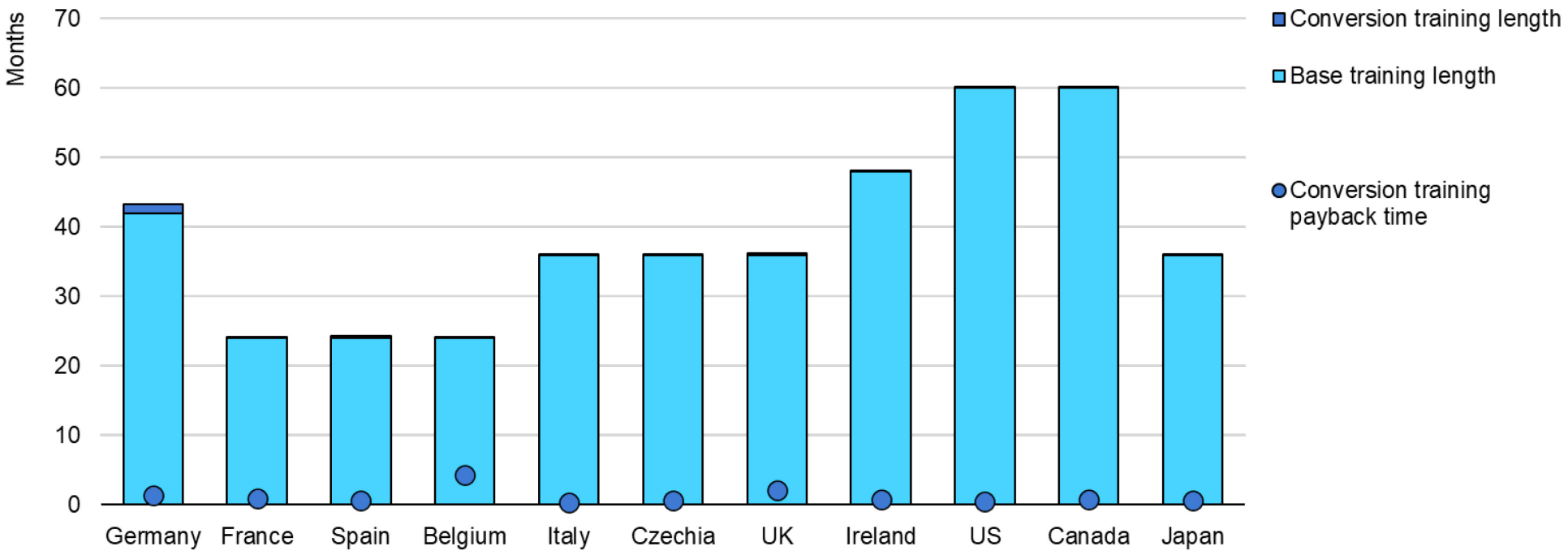


Notes: Payback time is defined as the number of months required to pay the costs of the training course, using only the wage premium gained from switching professions. In all countries assessed, HVAC technicians earned more than gas appliance servicers, indicating that investment in a skills conversion course will at some point pay for itself.

Source: IEA analysis based on salary data from the Economic Research Institute (ERI), and course times and costs from individual courses offered in each of the assessed countries.

Electricians can often upskill to become solar PV system designers in just a few weeks, and the wage premium is sufficient to pay back the cost of training shortly thereafter

Training times and costs for electricians and solar PV system designers by country, 2023

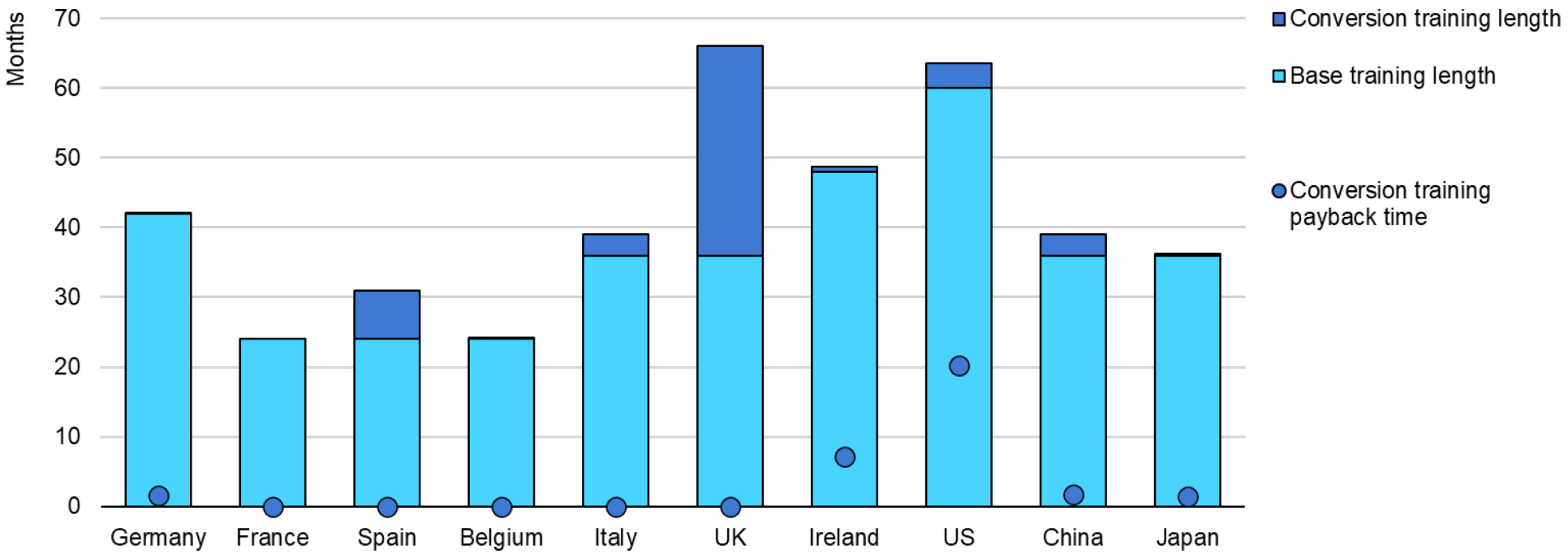


Notes: Payback time is defined as the number of months required to pay the costs of the training course, using only the wage premium gained from switching professions. In all countries assessed, solar system designers earned more than electricians, indicating that investment in a skills conversion course will at some point pay for itself.

Source: IEA analysis based on salary data from the Economic Research Institute (ERI), and course times and costs from individual courses offered in each of the assessed countries.

Conversion training times for high voltage line workers are more varied, which makes upskilling a slightly slower route to address skills gaps in transmission and distribution

Training times and costs for electricians and high-voltage lineworkers by country, 2023



Notes: Payback time is defined as the number of months required to pay the costs of the training course, using only the wage premium gained from switching professions. In all countries assessed, solar system designers earned more than electricians, indicating that investment in a skills conversion course will at some point pay for itself.

Source: IEA analysis based on salary data from the Economic Research Institute (ERI), and course times and costs from individual courses offered in each of the assessed countries.

Clean energy sectors tend to employ more women than fossil fuel sectors, but the share of women in senior leadership remains low across most of the energy industry

The energy industry is historically male dominated. Despite accounting for 39% of the global labour force, women made up less than 20% of the energy industry workforce in 2023. However, the transition to clean energy offers opportunities to improve this gender imbalance, with some segments already having higher shares of women than traditional fossil fuel sectors. In the solar industry, women make up about 40% of workers, nearly double the share in the oil and gas industry. Clean energy sectors also tend to have, on average, a greater share of women in senior leadership positions, with the solar and hydropower industries leading the way.

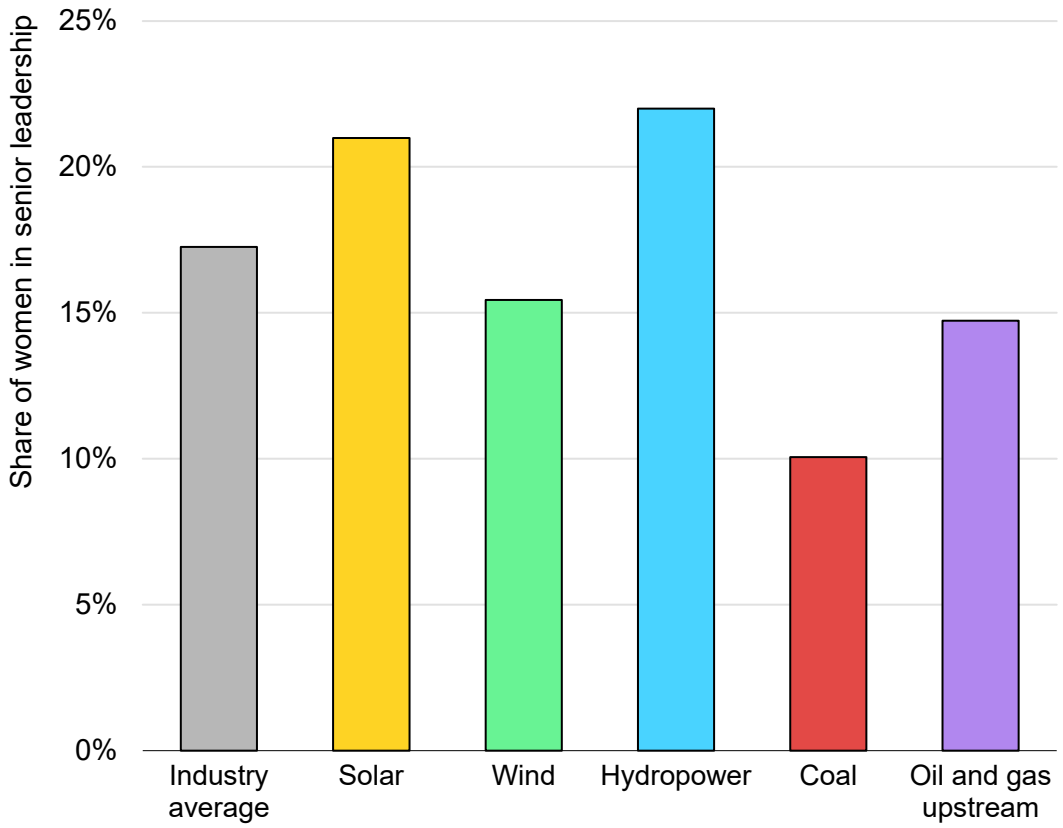
However, not all clean energy sectors attract more women into their workforce and the share of women in senior leadership remains only marginally higher than that of fossil fuel sectors in some key industries like wind (around 15%). In addition, although the absolute number of women by sector is a key indicator, the share by occupation or function reveals other imbalances. In the solar industry, for example, women represent more than 50% of administrative roles, with the shares comparatively smaller in STEM positions, construction, and manufacturing. Many trade occupations tend to have very low shares of women economy-wide, so energy industries that require high shares of such workers tend to have larger imbalances. For example, in some occupations, like roofers or electricians, women represent less than 3% of the workers in their ranks. In the European Union, less than 5% of electro-engineering workers are women. Addressing these barriers and narrowing the gender employment gap in these key occupations offers significant opportunities for all stakeholders involved to boost labour availability and tackle critical skills shortages still plaguing key sectors in the energy industry.

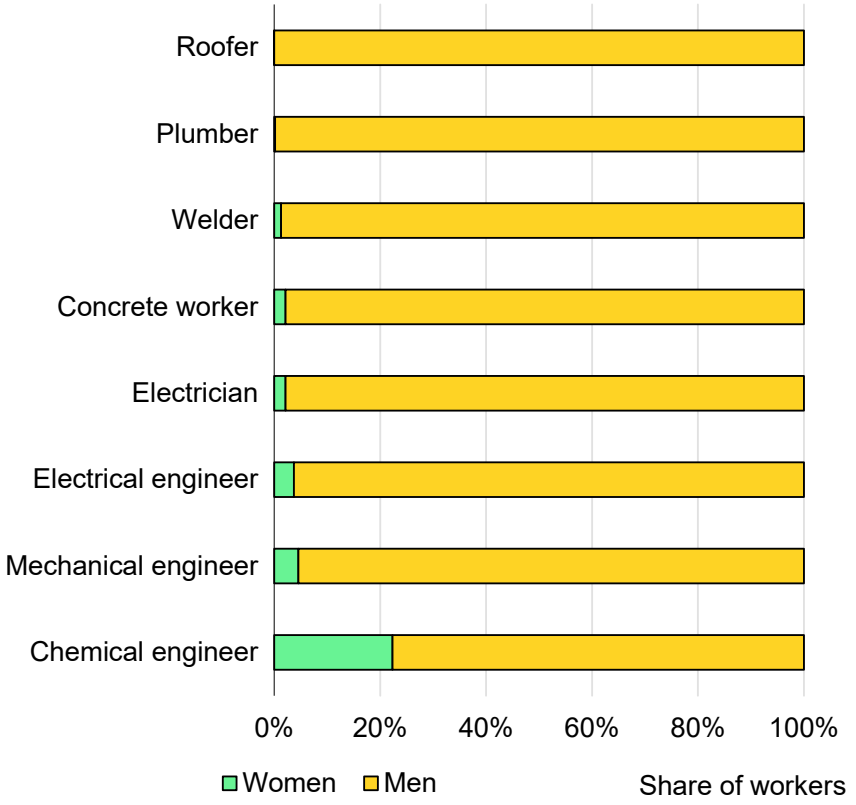
However, there are promising increases in the number of women pursuing education in fields needed in the energy sector, which could foretell future shifts. There has been a noticeable increase in women entering STEM fields in recent years. In 2022, after excluding biological and medical sciences – whose graduates are less likely to work in the energy sector – the share of women among STEM undergraduates averaged 29% in the United States, 34% in the European Union, and 44% in India.

Narrowing the gender imbalance depends also on increasing the number of women entering vocational programmes relevant to the energy industry. While 51% of jobs in the energy industry typically require some vocational training, the share of women in energy-related occupations remains well below the industry average. Studies show that occupations and industries that already have a high share of women have an improved ability to appeal to women students and other future employees, who perceive those companies, sectors, or occupations as more welcoming to women workers than others.

Narrowing the gender imbalance and raising the share of women in senior leadership positions depends also on increasing the number of women entering vocational occupations

Share of women in senior leadership by sector and in selected energy-related occupations, 2023





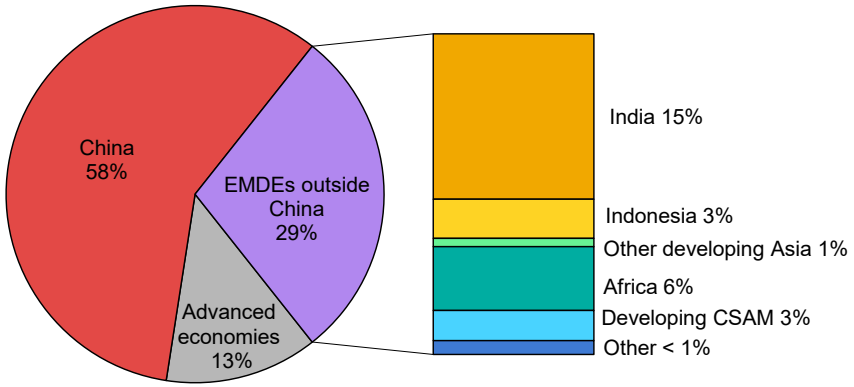
Note: Vocational occupations refer to skilled trades that require specialised training and hands-on experience, usually through apprenticeships or technical schools.
Source: IEA analysis based on data from the IEA Gender and Energy Data Explorer (Refinitiv Data) and the International Labour Organization. ILOSTAT 2023.

Clean energy employment in emerging markets and developing economies

Is the promise of clean energy jobs being delivered in emerging and developing economies?

Today, emerging markets and developing economies (EMDEs) other than China are home to over 13 million clean energy jobs, or approximately 38% of the global total.[1] This means clean energy makes up around 45% of total energy employment across these regions, compared to a global average of 52%. While this difference may seem insubstantial, it contributes to a perception among government, industry and labour leaders that the "promise" of the clean energy jobs resulting from the transition has not yet been fulfilled in these regions.

Share of clean energy employment growth by region, 2019-2023



Note: CSAM = Central and South America.

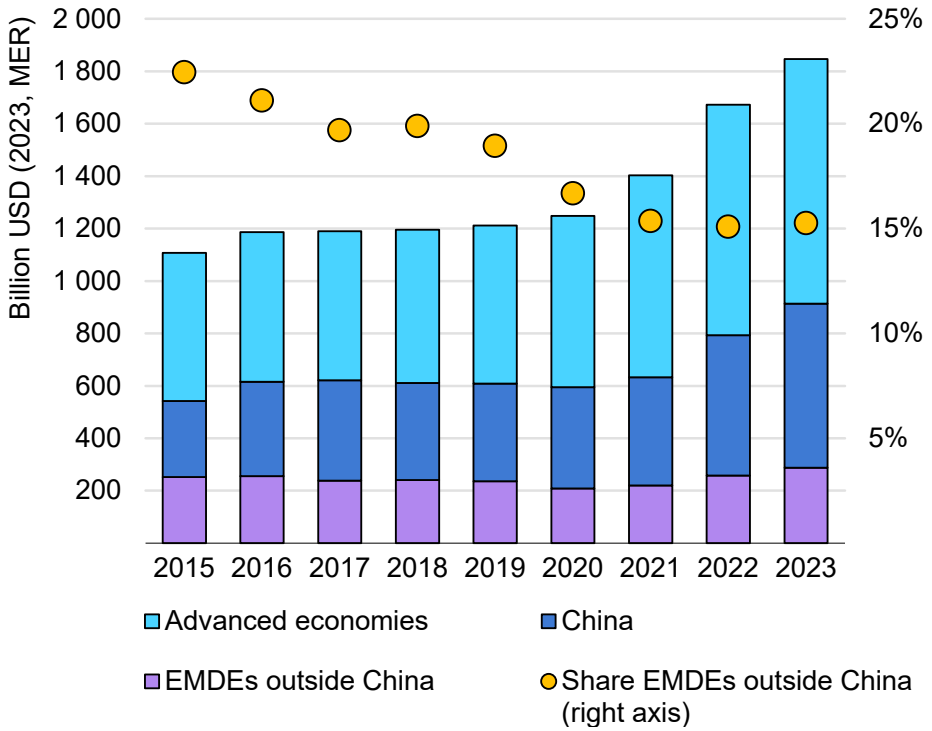
Indeed, IEA analysis confirms that many fast-growing clean sectors have not materialised at the same pace in most EMDEs as elsewhere in the world. As a result, substantial clean energy job creation and the associated economic boosts have so far failed to appear in many of these regions. Clean energy employment has grown 10% in EMDEs other than China since 2019, compared to 30% in China and 15% globally. Though the existing clean energy workforce in EMDEs is significant, most of the growth has taken place in just a few key markets in developing Asia Pacific, with India alone accounting for over half of the job additions since 2019. Overall, only 7% of global clean energy employment growth between 2019 and 2023 was in EMDEs outside of Asia Pacific, despite these regions constituting 28% of the global labour force in 2023.

Lower clean energy investment and deployment is the primary reason for slower clean energy employment growth in EMDEs. Since 2015, global clean energy investment has grown by nearly USD 700 billion, but just 3% of this spending has been in EMDEs other than China. This has in turn limited clean energy deployment, with just 6 GW of new solar PV and wind capacity added per hundred million people in EMDEs other than China over this period, compared to 51 GW in advanced economies and 67 GW in China. Investment is particularly lacking in Africa, with the entire continent accounting for less than 2% of global clean energy spending in 2023. The IEA

[1] The IEA considers China to be an emerging market and developing economy. However, the magnitude of China's role in clean energy supply chains and employment sets it apart from most other EMDEs. For this reason, analysis in this chapter may separate China from other EMDEs to avoid obscuring the clean energy employment situation in EMDEs other than China.

has long signalled the critical importance of scaling up clean energy investments in EMDEs, but more concerted action at both the international and national levels is needed to address these disparities.

Clean energy investment by region, 2015-2023



Note: MER = market exchange rate.

Most EMDEs have also struggled to capture significant portions of emerging new global supply chains for clean energy, such as manufacturing of solar panels or electric vehicles. Employment in clean energy manufacturing has grown by 1.4 million workers globally since 2019, with less than 15% of these new jobs in EMDEs other than China. Nonetheless, some success stories have emerged, such as India and Indonesia, where clean energy manufacturing employment has grown by over 35% each since 2019. Most other EMDEs have had greater success in upstream portions of the energy supply chain, notably in critical minerals mining and bioenergy supply. This is in large part due to the high-quality natural resource endowments in these regions, as well as the competitive value proposals they have been able to offer to both domestic and foreign firms.

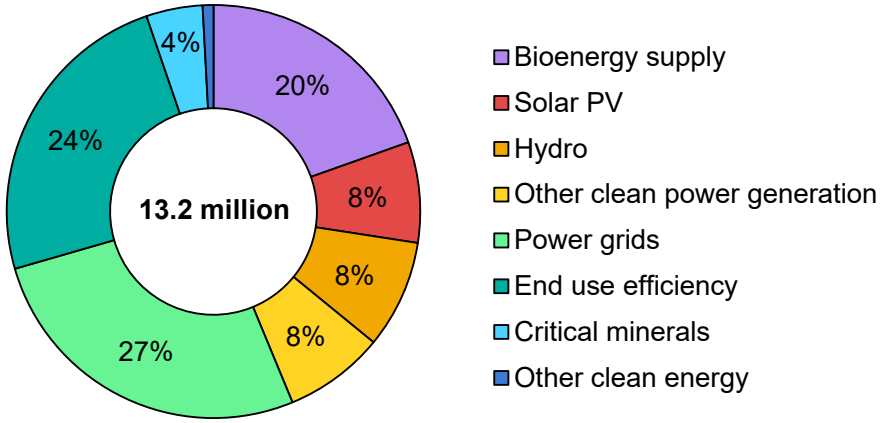
Currently, there are few indicators under today's policies that imply a radical shift in the future distribution of clean energy job growth. Although clean energy investment in EMDEs other than China is set to nearly double by 2030 in the IEA's Stated Policies Scenario (STEPS), this still represents only 20% of the global total compared with 15% today. As a result, EMDEs other than China maintain their current share of global clean energy employment, at just below 40%, through the end of the decade. A rising proportion of these jobs are in India and Southeast Asia, where clean energy employment grows at nearly triple the rate of the rest of the group, driven by new jobs in clean manufacturing and construction.

Nonetheless, clean energy jobs will become increasingly important in virtually all EMDEs in the coming years, especially as growth in fossil fuels employment slows in some regions. Historically, clean energy

and fossil fuel jobs have both grown steadily in EMDEs other than China, increasing by 3% and 4%, respectively, in 2023. This stands in stark contrast to many advanced economies, where transitions away from fossil fuels are well underway and clean energy job growth is outpacing increases in total energy demand. But looking forward, fossil fuel job growth is set to plateau in EMDEs other than China. Under current policies, fossil fuel jobs decrease by an average of 0.2% per year from 2024-2030 in these regions, compared to a 3.2% increase per year from 2021-2023. Though the specific changes to workforce size and composition will be highly dependent on local contexts, all governments and energy firms should brace for this uncertainty.

Clean energy jobs are already a significant driver of job growth in many parts of the world. In the European Union, Japan and the United States, for example, clean energy jobs represented 4-6% of economy-wide employment growth in 2023. The importance of clean energy to China's economy is even more impressive, contributing 11% to employment growth and accounting for about one-fifth of total GDP growth in 2023. This is not the case in most other EMDEs. Even in those that have experienced relative success generating new clean energy jobs, such as India and Indonesia, these additions represented less than 1% of economy-wide job growth in 2023. While these low numbers are in part attributable to growth elsewhere in these economies, they underscore why clean energy job growth is not perceived to be a major story in most EMDEs. Compounding this notion is the fact that nearly three-quarters of current clean energy employment in EMDEs other than China is in well-established sectors such as grids, bioenergy supply, and end-use efficiency, which are not witnessing the rapid growth of sectors like solar PV and batteries.

Clean energy employment in emerging markets and developing economies other than China by sector, 2023

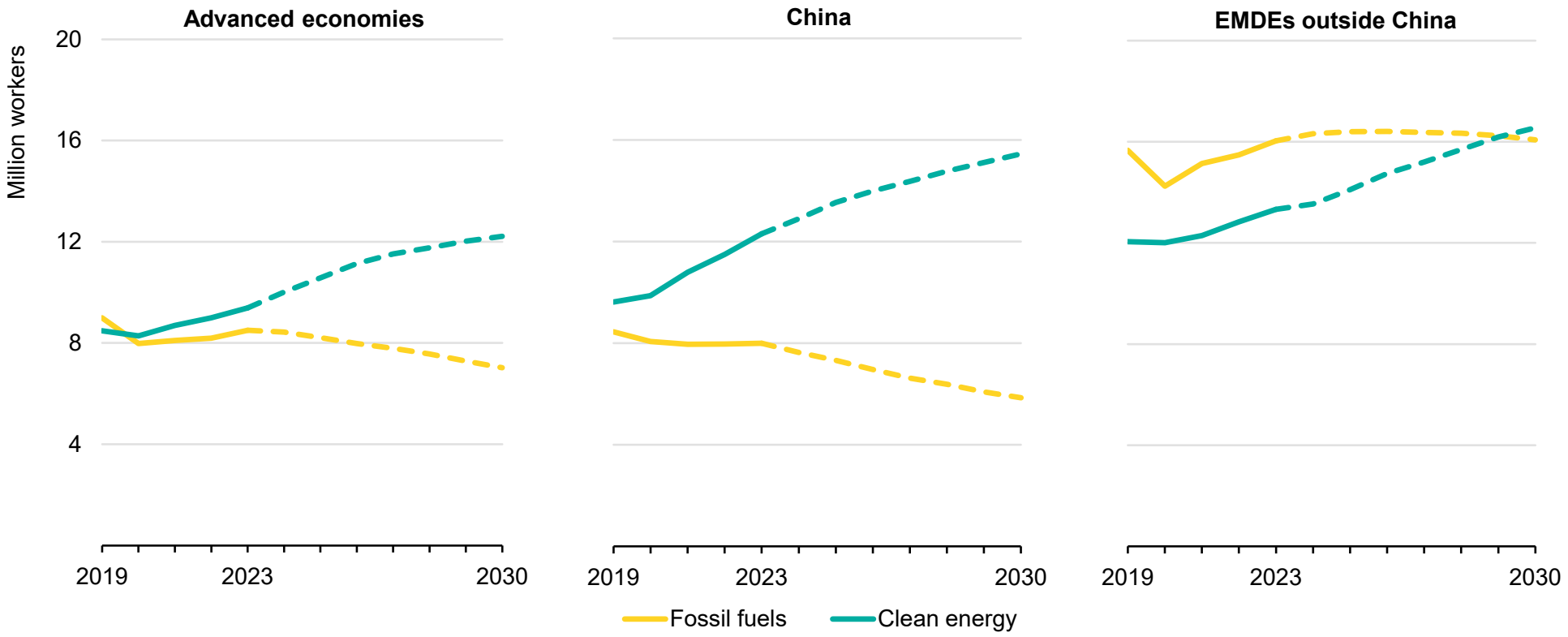


This trajectory is not set in stone. This chapter explores the steps that EMDEs other than China can take to better position themselves to increase domestic clean energy investments and attract foreign investment in clean energy supply chains. It also examines the sectors and regions in which EMDEs other than China have found success to date before assessing the obstacles to progress elsewhere, including transition pacing, wages, costs, and skills availability. Finally, it highlights measures that governments, firms and investors can take to increase the number and quality of clean energy jobs in EMDEs, in the context of broader economic and development objectives.

EMDEs

Both fossil fuels and clean energy jobs are expanding in most emerging markets and developing economies, but clean energy jobs drive growth elsewhere

Energy employment by sector and region in the Stated Policies Scenario, 2019-2030

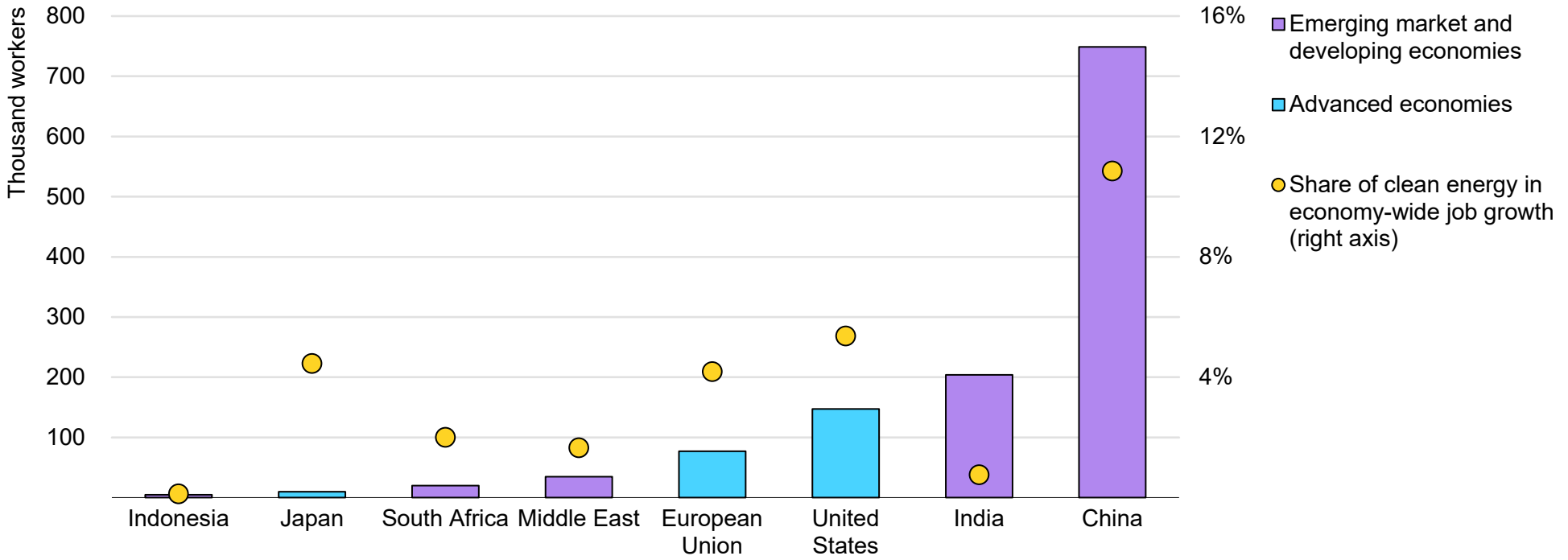


Note: EMDEs = emerging markets and developing economies.

EMDEs

On average, clean energy represents a smaller share of economy-wide job growth in most emerging and developing economies other than China or advanced economies

Clean energy job growth and significance in economy-wide job growth in selected geographies, 2022-2023



Emerging markets and developing economies find footholds in upstream clean energy supply

While clean energy employment growth has been more muted in most EMDEs than in the rest of the world, the upstream supply of raw materials for clean energy sectors, including bioenergy and critical minerals, has proven to be an important source of growth in EMDEs. While EMDEs other than China have accounted for 25% of clean energy employment growth since 2019, they captured nearly 80% of the job additions in the clean raw materials segment over the same period.

Thanks to large-scale palm oil and sugarcane plantations in regions such as Brazil, Indonesia, Malaysia and India, as well as strong policy measures including biofuel subsidies and blending mandates, over 60% of the growth in biofuel demand and production over the next five years takes place in these countries. Meanwhile, the Democratic Republic of the Congo accounts for two-thirds of the world's cobalt mining, while copper and lithium are mostly sourced from EMDEs in Africa, Central and South America, and Asia Pacific. The outlook for employment in upstream clean energy supply in EMDEs other than China remains strong, growing by 3% on average annually in the STEPS, with a robust pipeline of new critical minerals mining projects concentrated in these countries.

By contrast, EMDEs outside China have so far struggled to generate new employment opportunities in clean technology manufacturing, accounting for just 14% of these job additions since 2019. India and Southeast Asia have been the most successful in this arena, together having added nearly 200 000 clean energy manufacturing jobs between 2019 and 2023, equivalent to over 95% of net growth in this segment from EMDEs other than China. These two regions are already responsible for around 10% of global manufacturing employment in solar PV and wind turbines, a share which rises to 14% by 2030 in the STEPS.

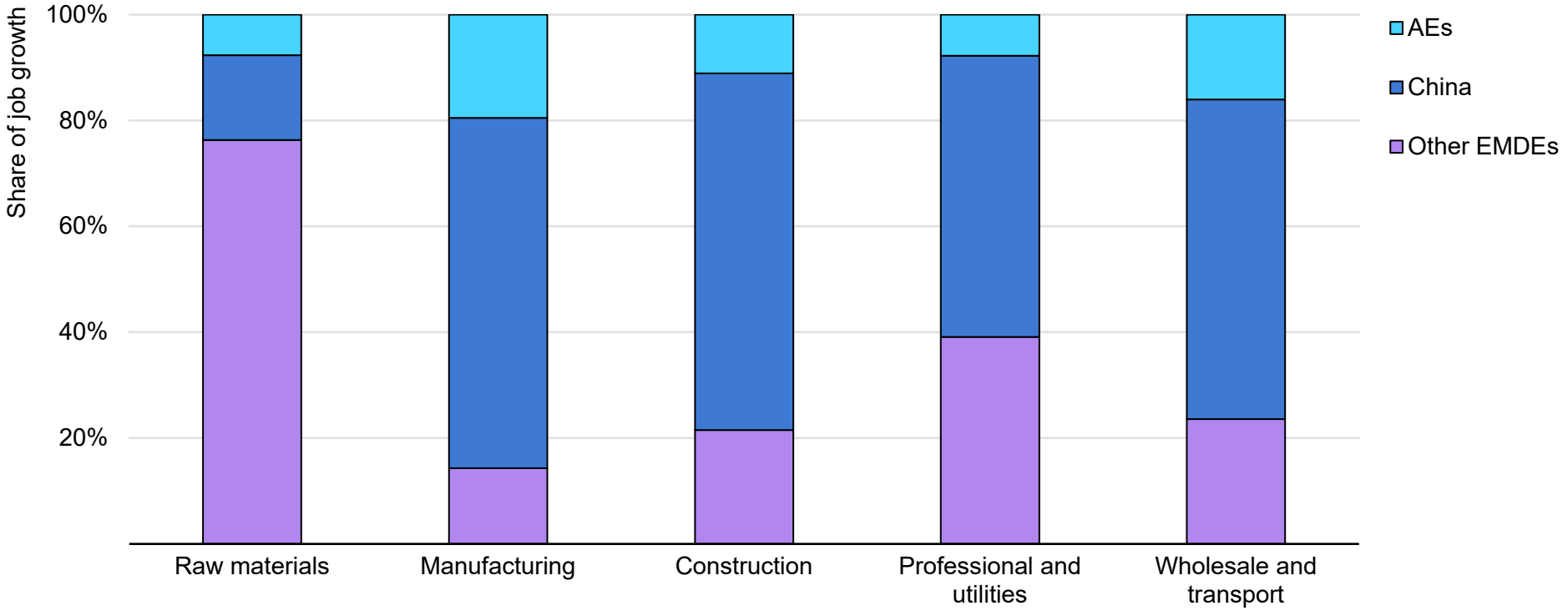
However, other EMDEs are beginning to gain ground in clean energy manufacturing and may soon see the associated jobs benefits. In Viet Nam, for example, local EV manufacturer VinFast is dominating the fast-growing domestic market and expanding into important export markets such as North America. Meanwhile, Brazil, Indonesia, Thailand and Morocco have all recently announced significant new foreign direct investment in domestic EV and battery manufacturing facilities.

Raw materials and manufacturing are both important export sectors that can provide an opportunity for EMDEs to expand their role in global energy supply chains and cultivate economic growth, regardless of the pace or scale of domestic clean energy adoption. But ultimately, the greatest employment potential lies in the development and operation of local clean energy systems and infrastructure; these sectors account for over two-thirds of clean energy jobs today. Realising this potential in EMDEs is therefore dependent on attracting new investment, cultivating an inviting regulatory environment and implementing stronger policies to substantially increase the number of clean energy projects in these regions.

EMDEs

Nearly 80% of recent clean energy job additions in raw materials were in EMDEs other than China, far outpacing their share of growth in other segments of clean energy value chains

Global clean energy job growth by activity and region, 2019-2023

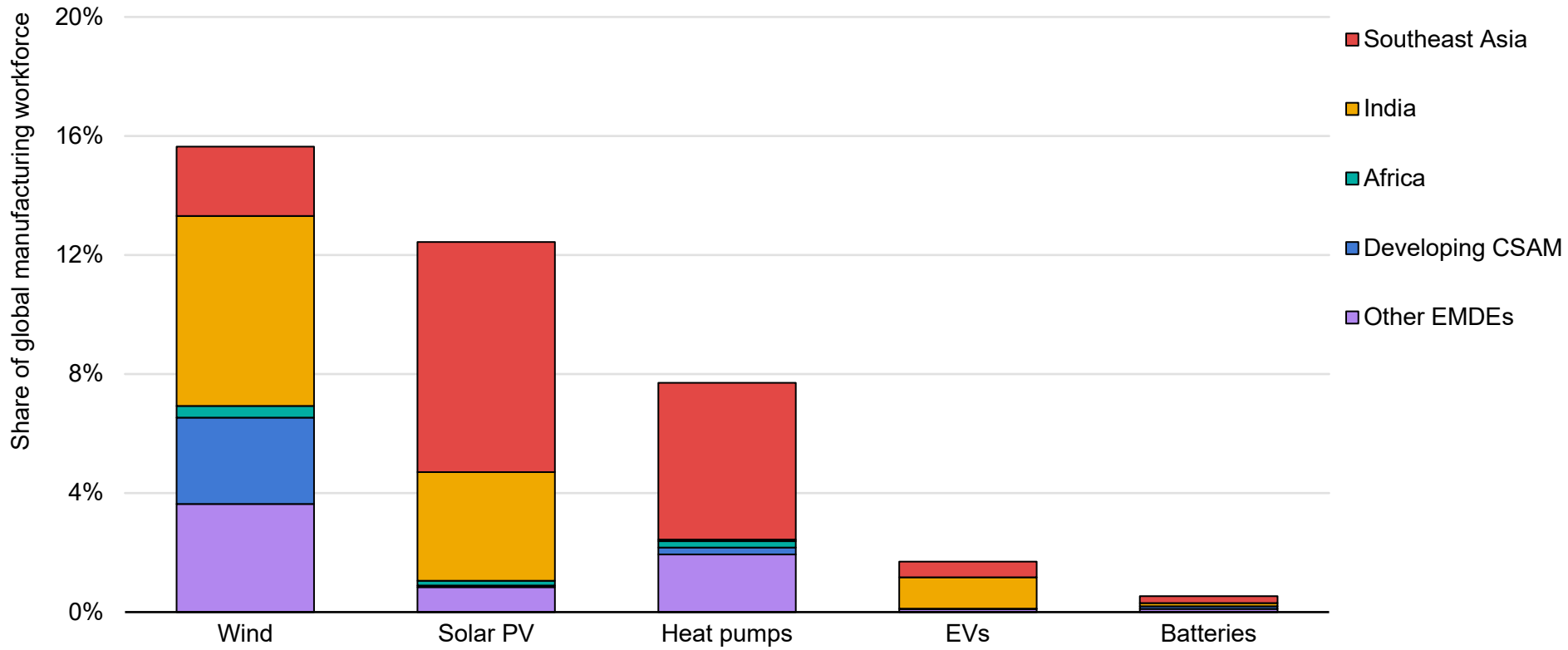


Notes: Other EMDEs = emerging markets and developing economies other than China. Clean raw materials jobs include the cultivation of bioenergy crops and the mining of critical minerals.

EMDEs

India and Southeast Asia constitute about 60% of clean energy manufacturing jobs outside of China and advanced economies

Share of global clean manufacturing jobs in emerging and developing economies other than China, by region and technology, 2023



Note: Developing CSAM = developing Central and South America, Other EMDEs = emerging markets and developing economies other than China.

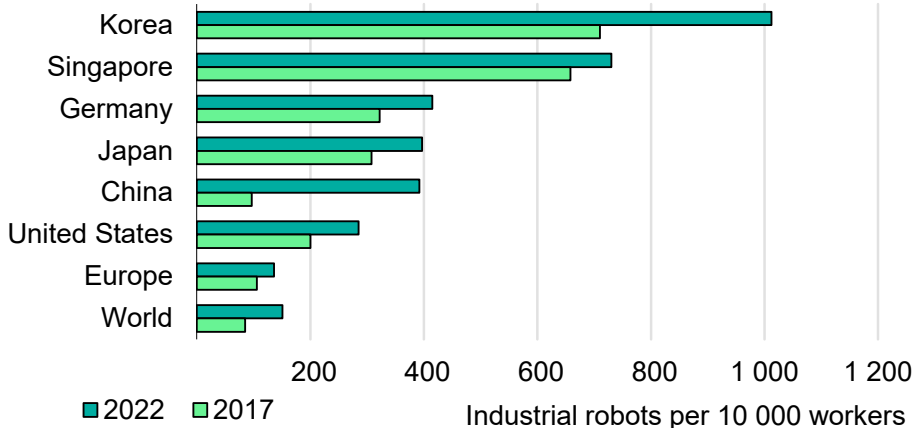
Labour cost advantages have not on their own been sufficient to attract manufacturing jobs

Much of the recent policy making on energy employment has focused on capturing new manufacturing jobs, a space where EMDEs are not finding a competitive footing despite their lower labour costs. Decisions about where to site new manufacturing facilities are influenced by a number of factors, including the size of the domestic market, local infrastructure and transport readiness, regulation and permitting regimes, among other issues. Operation costs, however, are a top consideration for clean energy firms, with energy, materials and labour together accounting for 70-98% of total manufacturing costs. EMDEs traditionally have an advantage of lower labour costs, with prevailing wages in the manufacturing sector on average roughly 50-70% below those in advanced economies, though there is significant regional and sectoral variation. For instance, the median wages for solar panel manufacturing workers in Indonesia are 40% of those in Japan or Korea and a quarter of those in the United States.

Higher wages in advanced economies can, to an extent, be offset by a greater degree of labour productivity, especially when boosted by mechanisation and automation. Korea and Singapore have some of the highest levels of automation in manufacturing today. However, rapid advances are possible, as illustrated by China, which has quickly automated its manufacturing industry in recent years to become the fifth most automated in 2022, up from the twenty-first spot just five years prior. This has added to China's significant labour cost advantage and helped improve quality control.

The relative importance of labour costs in siting decisions is shifting amidst a wave of domestic manufacturing incentives, rising transportation costs, and geopolitical uncertainty. For example, sizeable domestic markets for heat pumps have allowed Europe and North America to maintain significant market shares in their manufacturing, despite lower input costs elsewhere. Though this may erode one of the few incentives that EMDEs possess for attracting manufacturing jobs, a new asset is coming into focus: growing domestic markets. EMDEs outside China will account for a rapidly increasing share of energy demand in the coming years, providing a significant opportunity for firms to establish or expand manufacturing of clean technologies for domestic use as well as for export.

Concentration of industrial robots in manufacturing by region

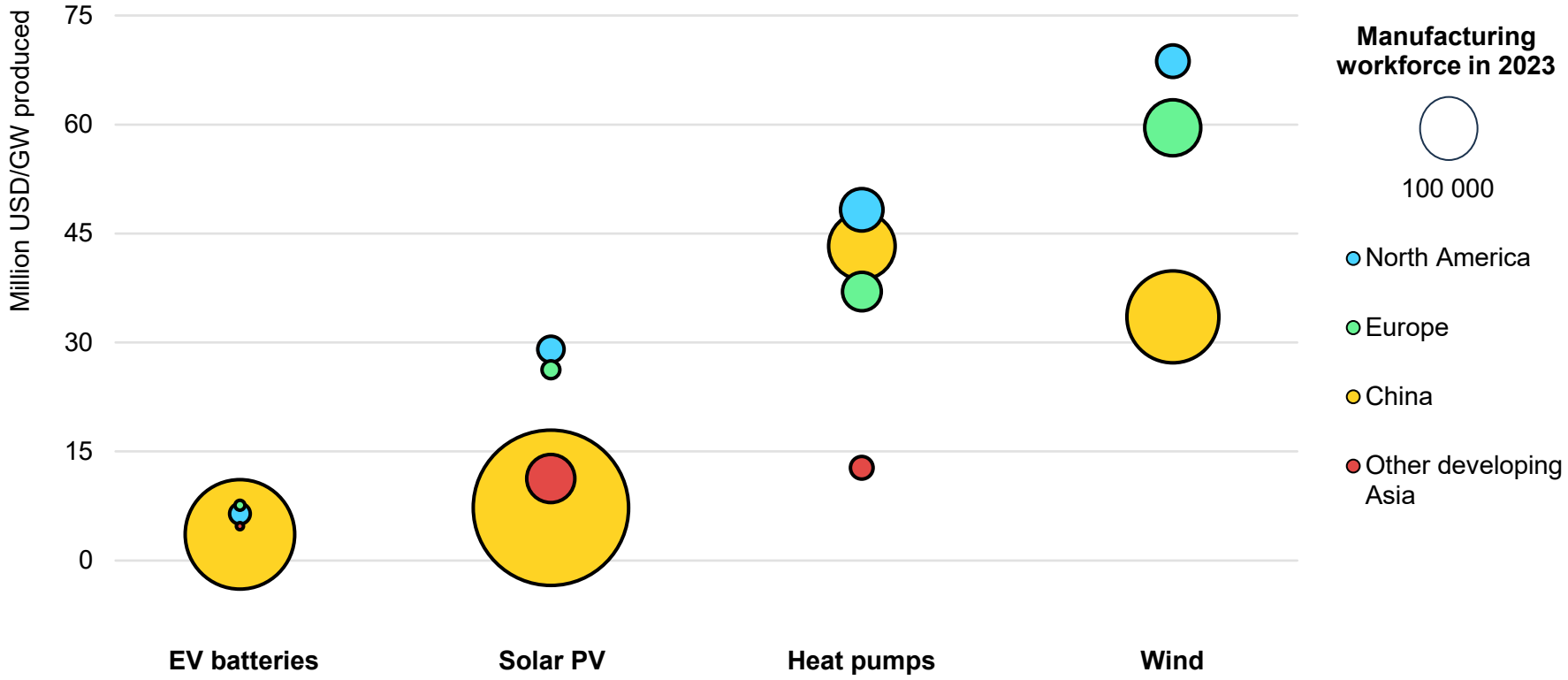


Source: IEA analysis based on International Federation of Robotics data.

EMDEs

Lower wages in developing economies are not always enough to compete with greater productivity, demand and policy support in advanced economies and China

Average manufacturing wage costs per GW produced and manufacturing workforce by region and technology, 2023

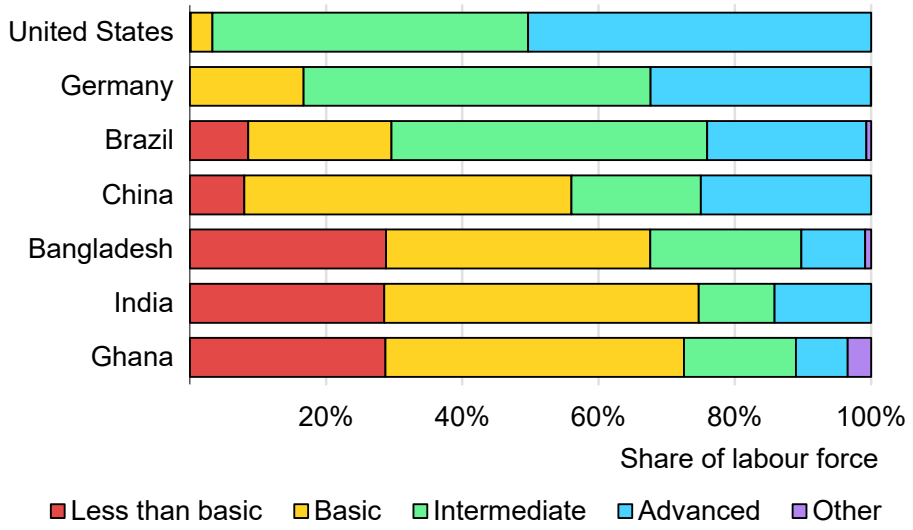


Notes: The wage cost estimates shown here may not represent the final net cost to manufacturers as they do not consider subsidies, tax credits, or other incentives that may reduce or offset the costs of labour. Regions with insufficient manufacturing capacity were excluded from this figure as the labour costs of production could not be properly assessed.

Skills availability works against emerging and developing economies for gaining energy jobs

In general, the populations of EMDEs tend to have lower educational attainment – which is broadly correlated with skill level – than those of advanced economies, presenting a challenge to energy companies looking to establish operations in these countries. The importance of skills availability varies by technology and supply chain segment. For example, only 15% of the workforce engaged in growing feedstocks for bioenergy must be highly skilled, but this share rises to around 40% for workers in bioenergy processing facilities. Other technologies, such as nuclear power and oil supply, have elevated skill requirements across all portions of the supply chain when compared with the overall energy workforce.

Labour force by highest level of education and country, 2022



As a result, employers in regions with lower-skilled labour forces face higher additional costs associated with onboarding and training workers. In the case of newer clean energy industries, there may also be a dearth of technology-specific skills. This leads to instances where, even if highly educated workers are available, they are unlikely to possess the specific skillsets and experience required to help build up clean energy industries, and are even less likely to be prepared to train others in those skillsets.

In some cases, international developers of clean energy projects have brought in their own workers from other countries to fill gaps. For example, one major hydropower project developed in Guinea by the China Three Gorges Corporation relied on imported labour for one-third of its workforce during construction. This approach is not exclusive to clean energy. For new oil and gas exploration projects, international oil majors may bring in experienced managers and engineers or import medium-skilled workers for support on drilling and rig work. In Namibia, for example, many workers developing new oil projects hail from Egypt and other parts of North Africa, while local employees are trained to the necessary degree.

But the most likely outcome is that clean energy jobs do not flow to areas where a skills base does not already exist. Economies that established clean energy industries early on, or even those with comparable industries, such as electronics, aerospace or fossil fuels, are at a clear advantage, as existing workforces with potentially applicable skills are a major draw for clean energy employers.

What can emerging markets and developing economies do to capture more growth in clean energy jobs?

The primary pathway for EMDEs to cultivate jobs related to the clean energy transition is to focus on developing domestic markets. Beyond this, manufacturing represents the largest opportunity to capture jobs related to clean energy deployment elsewhere in the world. Building the needed skills base is a critical step to attract both domestic and foreign investment across all portions of the supply chain. Skilling in EMDEs can be achieved through a combination of private and public, domestic and international efforts.

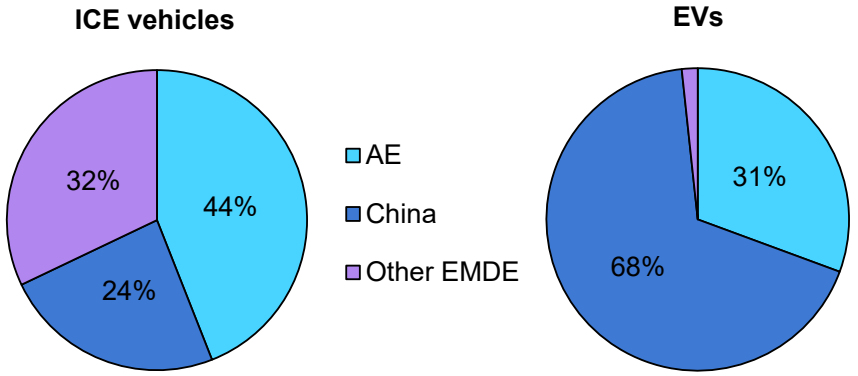
In the shorter term, project-level clean energy skill needs in EMDEs can be addressed via skills transfer mechanisms such as workshops, on-the-job training (OJT), and the build-operate-transfer (BOT) model agreements in which personnel from experienced energy firms train local workers during project development. These tools allow for clean energy work to commence without the time lag associated with training workers through formal education but are not a permanent solution due to the limited number of workers involved.

For the longer term, companies and governments in many EMDEs are already active in building out skills development initiatives, apprenticeships and vocational programmes to train workers for the clean energy industry. Access to certifications and education in emerging clean energy sectors tend to be less established than in traditional energy industries. However, close collaboration between private and public sectors can ensure the evolving skilling needs for clean energy technologies are reflected in new education and training programmes. For instance, the Tata Power Skill Development Institute (TPSDI) was established in India in 2015 to bridge the skill gap between the energy sector and workers. To achieve this, TPSDI established six training hubs across India, and supported skill development initiatives in Africa and Europe, providing vocational education programmes across key clean energy sectors, including solar PV, hydropower, wind, green hydrogen and grids. As of January 2024, over 275 000 workers have been trained. Energy skilling efforts can also benefit from connecting to education and initiatives within a country or region, which may offer more resources or mobilise a broader set of educational institutions. More examples of how international partners can help transfer skills and knowledge to clean energy workers in EMDEs are detailed in the table below.

In addition to enabling domestic deployment of clean energy, skilling efforts also improve the prospects of EMDEs seeking to attract greater clean energy manufacturing employment. While it would be challenging for any country to catch up to China's technological edge in the manufacturing of solar PV, EVs, or batteries, EMDEs can still take additional measures to encourage foreign manufacturers to locate new facilities on their shores. Depending on regional contexts, a mixture of financial incentives and optimisation of direct foreign investment or import/export regulations can make a difference once an appropriate skills strategy is undertaken.

Many EMDEs have already put financial incentives in place to attract manufacturing investment, such as Brazil's Green Mobility and Innovation Program or production-linked incentives with similar mechanisms as the US' Inflation Reduction Act (IRA) or the EU's Net Zero Industry Act. Brazil and Thailand, for example, have both announced new EV facilities are being established by BYD and Great Wall in the coming years, supported by policy measures such as tax incentives and the reduction of import and export tariffs. The recent United States-Kenya Joint Leaders' Statement announced the intention to collaborate on mechanisms to incentivise foreign investment in clean energy manufacturing in Kenya and the surrounding region.

Employment in ICE and EV manufacturing, by region, 2023



Notes: AEs = advanced economies; EMDEs = emerging markets and developing economies; ICE = internal combustion engine; EVs = electric vehicles.

Countries have also pursued non-incentive interventions to draw in new industries. Some EMDEs have imposed export restrictions on raw materials in an attempt to capture a greater share of midstream supply chain value. For example, Indonesia in 2020 implemented a ban on the export of nickel ore in hopes to build a strong EV battery manufacturing industry. This approach has allowed Indonesia to expand job creation and reap other economic benefits associated with its mineral endowment. However, the efficacy of these policies varies, and they should not be considered a blanket solution for other EMDEs. Indonesia was already the single largest producer of nickel at the time its export ban came into effect; most EMDEs do not possess a comparable degree of leverage over downstream industries. This approach also does not address the lack of skilled workers for downstream sectors, which has become an issue for Indonesia's critical minerals industry.

Governments can also benefit from focusing policy efforts on a few key sectors, where they may already have strategic advantages. For instance, countries that already have strong competencies in ICE vehicle manufacturing could court new contracts to produce EVs, or to expand to other parts of the vehicle manufacturing supply chain. Additionally, countries can enter different segments of the supply chain if they are geographically proximate to existing manufacturing hubs. For example, the Southeast Asia region could pick up additional assembly steps as components are shipped from East Asian manufacturing hubs to the rest of the world. This is, however, less likely to be applicable in Africa and Central and South America, which generally are more distant from global manufacturing centres.

Mechanisms for skills development in Emerging Markets and Developing Economies

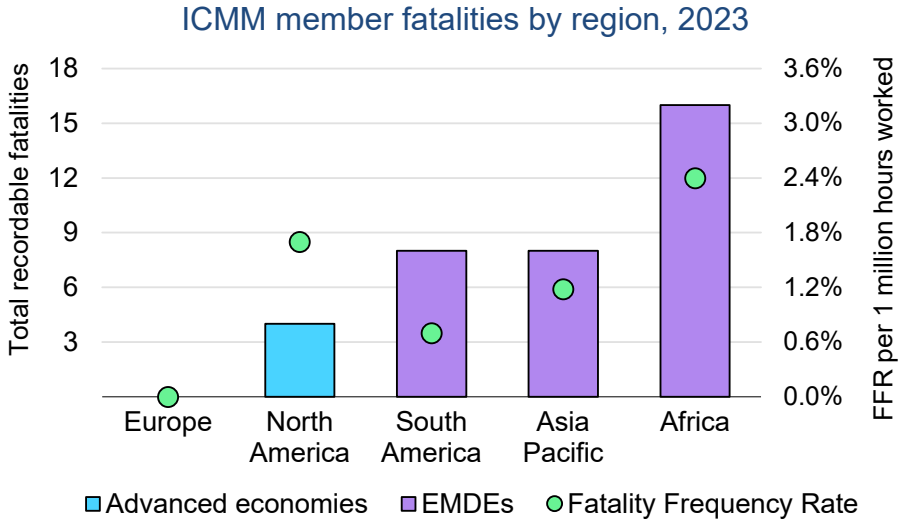
Mechanism	Description	Example
Degree conferrals	Governments select students for long-term training at partnering institutions, which may offer scholarships. These students ultimately earn advanced degrees and return to their home countries where they can further contribute to industry development.	The China-Laos Renewable Energy Development and Utilization Joint Laboratory, established by the governments of China and Laos, is hosted by Yunnan Normal University. It provides graduate-level training for workers from Laos in solar and biomass energy and offers advanced studies for professionals in Laos's renewable energy sector. Graduate students receive full scholarships.
Training programmes	Participants are awarded training certificates upon completion. A diverse array of organisations may operate these programmes, including governments, energy companies, and NGOs, and often involve multiple entities working together. These projects are vary in duration, with training ranging from a few days to several months.	The Netherlands Organisation for Applied Scientific Research and the Politeknik Negeri Bali with support from the Regional Government of Indonesia (Bali Province Government) are collaborating to develop a training centre for renewable energy on the island of Bali. This training centre will provide vocational education and certification to industry professionals and government officials.
Workshops and seminars	These short-duration trainings may be organised by a variety of entities. The main goal is to facilitate the exchange of knowledge and information among the participating parties.	The Techno-economic Considerations for the Design of Green Hydrogen Projects programme was a one-day training organised by the USAID South Asia Regional Energy Partnership in collaboration with the Skill Council for Green Jobs in India. In this programme, experts from USAID led several sessions focused on enhancing understanding of green hydrogen and green ammonia technology, including aspects such as sizing, economics and associated risks.
Certification and standard building	These standards are typically developed by international industry associations. They then work with other regional or national entities to establish local industry skill training standards and carry out various	The Global Wind Organisation (GWO) establishes international standards for safety training and emergency procedures in the wind industry. It hosts the GWO Safety & Training Forum and Awards to facilitate dialogue between manufacturers and operators, in addition to

Mechanism	Description	Example
	activities, collaborating with different training organisations to promote these standards.	recognising the teams of instructors and support staff who ensure safety in wind energy.
Curriculum design	These projects often involve collaboration between energy companies, industry associations, and educational or training institutions to design the content of the training programmes.	Enel Green Power and the Master Artisan Academy of South Africa collaborated to develop three skills PV-related skill training programmes: Photovoltaic Installer Course, Photovoltaic Entrepreneurial Course, and Photovoltaic Seller Course. They are offered in-person and free of charge to all qualifying participants.
R&D centres	These projects are typically collaborations between local governments, universities and energy companies to establish research and development centres, promoting long-term knowledge transfer and training.	TotalEnergies and Angola's state-owned oil company Sonangol are jointly establishing an R&D center in Sumbe, with the aim of supporting the skills development of Sonangol's R&D team in the fields of reservoir geology, process electrification and solar PV.
Joint ventures and the BOT model	These projects are primarily led by well-established foreign energy companies. Within the framework of joint ventures or BOT agreements, they provide skill and safety standard training to local personnel involved in a given project.	After the United Arab Emirates decided to develop nuclear power in 2008, it established a joint venture with Korea Electric Power Co. (KEPCO) to construct and operate the nuclear power plants while training indigenous staff to eventually take over operations. Taking advantage of experienced international expertise initially and transitioning to a local workforce over time has allowed the UAE to build a domestic skilled workforce while reaping the benefits of new nuclear power, instead of requiring a sequential skills-building effort before being able to build the plant. The Barakah nuclear power plant was connected to the grid in 2020, making the UAE the first Arab nation with nuclear power.

Governments have opportunities to ensure new jobs are high quality and create local value

Building up new industries with a focus on job quality is an opportunity for governments to generate greater benefits for local economies and improve citizens' livelihoods. In the energy sector, this time of transformation is ideal to address job quality indicators such as informality, wages, safety and union coverage.

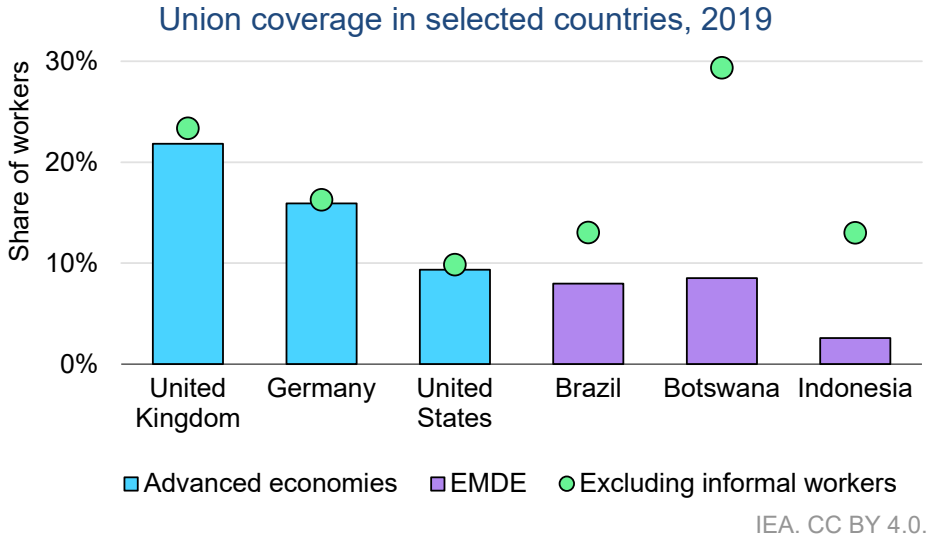
Today, levels of informal employment are elevated in many EMDEs, with over 80% of all jobs in countries such as India or Indonesia characterised as informal, compared with below 4% in most advanced economies. Informally employed workers generally lack social protections and employment guarantees and have fewer options in the case of harm or mistreatment. While levels of informality are often lower in the energy industries than in the broader economy, it remains a prominent issue in sectors such as coal and critical mineral mining, bioenergy harvesting and processing, coal plant operations, electricity meter reading, fuel delivery and vehicle manufacturing. In EMDEs, many of these sectors offer attractive wages to formal employees – a formally employed coal miner can earn nearly double the average salary of an industrial worker in Indonesia. For instance, informal workers receive much lower pay and often face greater risks and more adverse working conditions. This is especially true in illegal mining operations, where informally employed miners generally earn a fraction of what a formal worker makes and have little recourse against exploitative practices or dangerous working conditions. In 2019, informally employed miners globally included over a million children. Illegal mining is a prominent problem in critical minerals extraction in Africa, plaguing the cobalt industry and increasingly emerging as an issue for other minerals.



Notes: ICMM = International Council on Mining and Metals; FFR = Fatality Frequency Rate. EMDEs = emerging markets and developing economies
Source: IEA analysis based on the Safety Performance Report, 2023.

Unions and other collective bargaining mechanisms can also play a central role in achieving improved conditions for workers by enabling them to negotiate higher wages and better safety conditions, gain access to resources and training, and hold employers accountable for various infractions or abuses. Labour representation is particularly important in regions lacking strong or well-enforced legal regimes for worker safety. On average, the unionization rate across advanced economies is higher than in EMDEs, though there is significant

country-level variation. However, even in cases where union coverage rates in EMDEs are nominally similar, the rate, when accounting for informal workers, can be much lower. In general, while unionisation can improve job quality, it is not always a straightforward metric: the composition of the economy, cultural perceptions of labour movements, and the legal and social protections offered by governments all impact workers' preference and ability to unionise.



Notes: The trade union density reflects the percentage of unionised workers in the formal sector of the economy and does not account for informal workers. The adjusted trade union density assumes that informal workers have no union representation.

Source: IEA analysis based on ILO data.

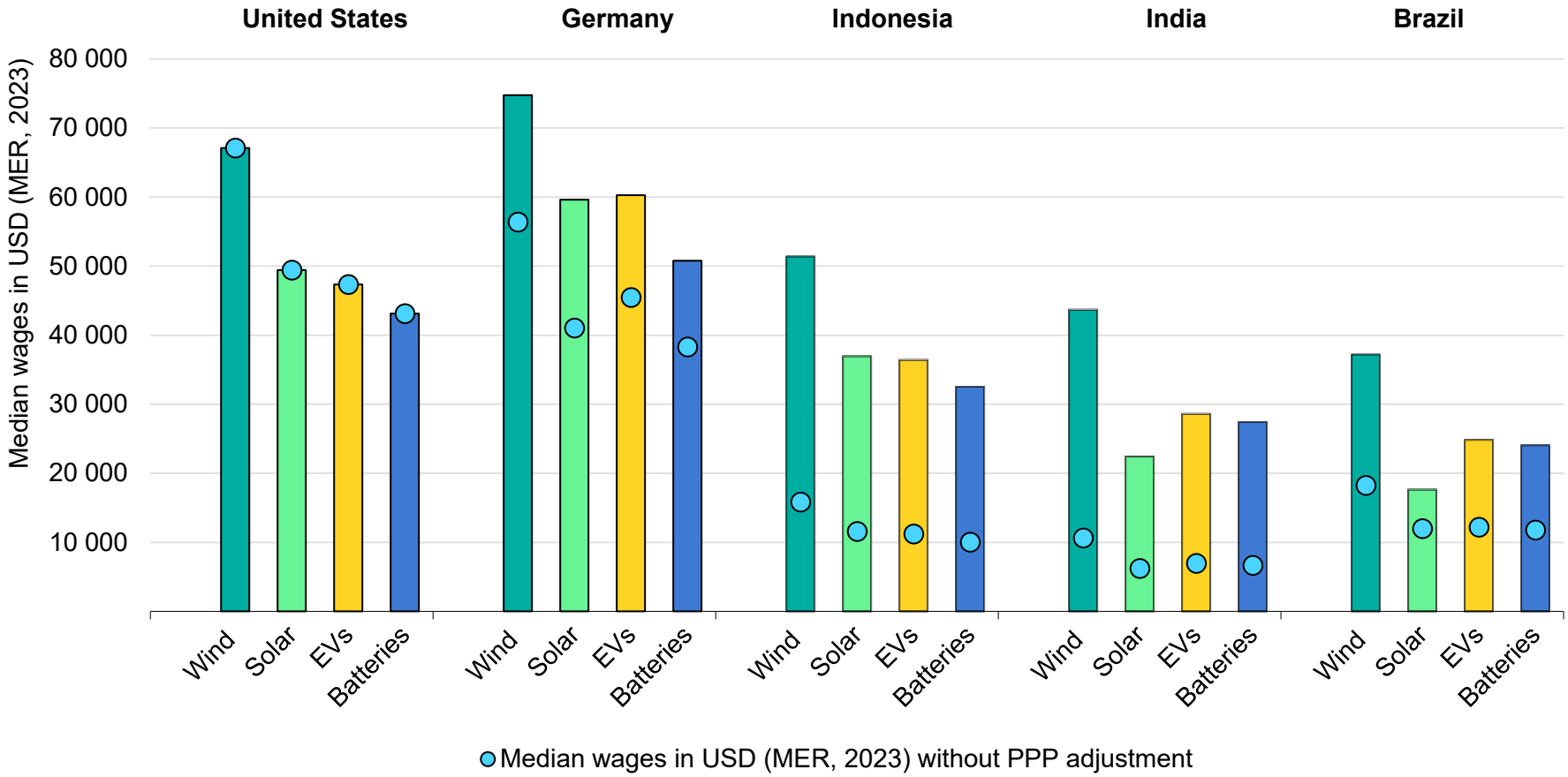
Higher wages have clear benefits for workers but are also important to ensure local economies accrue the maximum benefits from new industries. Yet IEA analysis finds that across four key clean energy sectors (wind, solar PV, EVs and batteries), workers earn on average 45% less in India, 30% less in Indonesia, and 54% less in Brazil compared to advanced economies, even after adjusting for local purchasing power parity. Real average wages are likely to be even lower due to the high degree of informality in many regions. Offering higher wages may also improve attractiveness to companies with ESG requirements stipulating fair wages in supplier networks, or those looking to safeguard against public perception risks regarding their supply chain's ESG performance.

Contract length is another aspect of job quality that can be important to attract workers, especially those in low-skilled construction or seasonal positions. Longer contracts provide greater job security for workers, but clean energy industries often offer shorter contracts than fossil fuel industries. This is in part because contracts in the solar and wind industry are largely project-based and linked to installation, which provides nearly a third of all clean energy jobs in EMDEs. Emerging renewables industries generally have less installed capacity than fossil fuel sectors, and therefore fewer workers in long-term operation and maintenance roles, further driving down average contract lengths. Multiple labour representatives and industry experts from EMDEs interviewed by the IEA echoed this concern, identifying the mobility demands of renewable energy projects as a particular challenge for workers with families, especially if these requirements are not reflected in higher compensation as they are in the oil and gas industry. Offering workers greater stability in employment is therefore a powerful lever to improve job quality and to attract new workers in an industry plagued by insufficient skilled labour.

EMDEs

Workers in emerging markets and developing economies have lower salaries in clean energy sectors, even after adjusting for local purchasing power parity

Median wages by country and sector with purchasing power parity adjustments, 2023



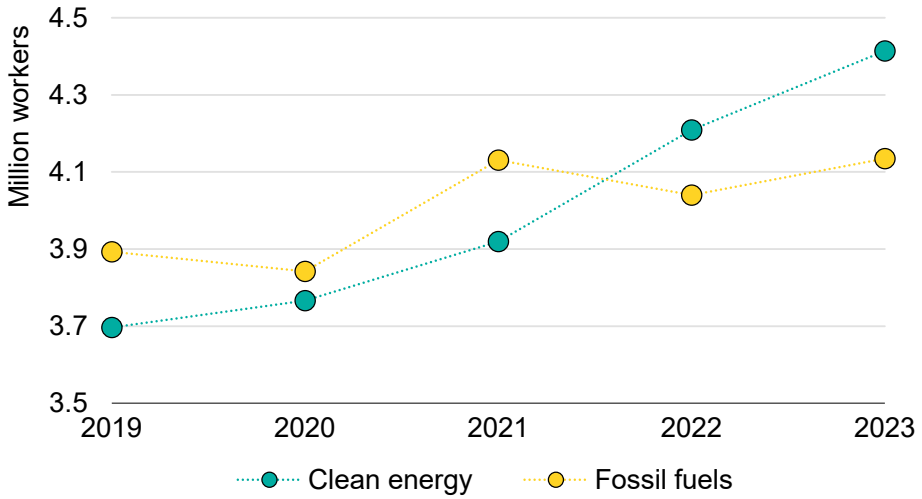
Note: PPP = purchasing power parity; MER = market exchange rate.

Regional focus: India

India's energy industry is on the rise, with clean sectors leading the growth

India is the world's fastest growing major economy, with rising employment across several sectors, including the energy industry. India's GDP has grown at a rate of over 7% for the past three years and is set to become the third largest economy globally by 2030, behind the United States and China. India's economy-wide workforce totalled approximately 566 million workers in 2023.

Energy employment in India by sector, 2019-2023



Total energy employment reached over 8.5 million in 2023, around 1.5% of the country's workforce, up by 3% year-on-year over the last five years. This growth has been driven by a rapid increase in energy investment, which grew by 6% in 2023, to meet India's growing energy demand. Clean energy investment has seen the largest uptick, rising 35% from the 2016-2021 average. At the same time, rising demand for fuel and electricity drove higher spending in conventional energy sources, with investment in fossil fuel supply up by 6% year-on-year in 2023. Employment in clean energy sectors rose by 5% in the same year, while fossil fuel jobs grew by 2%.

Over 3 million workers were employed in fuel supply in 2023. Coal supply had 1.6 million workers and was the second largest contributor to energy employment overall. Over half of these jobs were in the mining sector. The oil and gas sector had over 800 000 workers, with about 60% in midstream and refining activities. Nearly 700 000 worked in low-emissions fuels, led by bioenergy. This included both the emerging bioethanol industry, which is now the third largest globally, as well as the substantial, often informal, sector providing wood, woodchips, and charcoal to rural households.

The power sector employed 3 million workers, with jobs split roughly evenly between electricity generation and grids. The workforce involved in developing and operating power generation has grown the fastest in recent years, increasing by more than 20% since 2019, alongside a 18% rise in India's power generation capacity over that period. Solar PV and hydropower accounted for the largest share of this increase, together adding over 250 000 jobs since 2019. Jobs connected to developing and installing new power generation projects, which are more labour intensive than the traditional operations and maintenance of existing capacity, represented 60% of the labour force, up from 56% in 2019. Employment in the power

grids segment, which totalled 1.6 million workers in 2023, grew by 6% from 2019 to 2023, owing to rising electricity demand and transmission expansion to connect new renewable energy projects.

End use sectors accounted for around 2.5 million workers in 2023, with 1.3 million employed in the manufacturing of road vehicles and batteries. While employment in EVs and EV batteries manufacturing represented less than 1% of total energy jobs in 2023, the industry is gaining momentum in part thanks to government incentives. 1.2 million were employed in end use efficiency, including those working on government educational campaigns, carrying out building energy retrofits and industrial efficiency upgrades. Employment in efficiency has grown by 4% y-o-y from 2019 to 2023, driven by several state-led initiatives, including the Unnat Jyoti by Affordable LEDs for all programme.

Around half of India's energy workforce was employed in the manufacturing and construction sectors, totalling 4 million jobs, while 14% worked in the extraction of coal, oil, and gas, critical minerals, and agricultural production for bioenergy. More than 2.3 million workers were employed at utilities or in professional energy services, while wholesale and transport accounted for 900 000 jobs. The manufacturing and construction sectors also represented the bulk of energy job growth, increasing at a compound annual growth rate (CAGR) of 2% and 6%, respectively, since 2019.

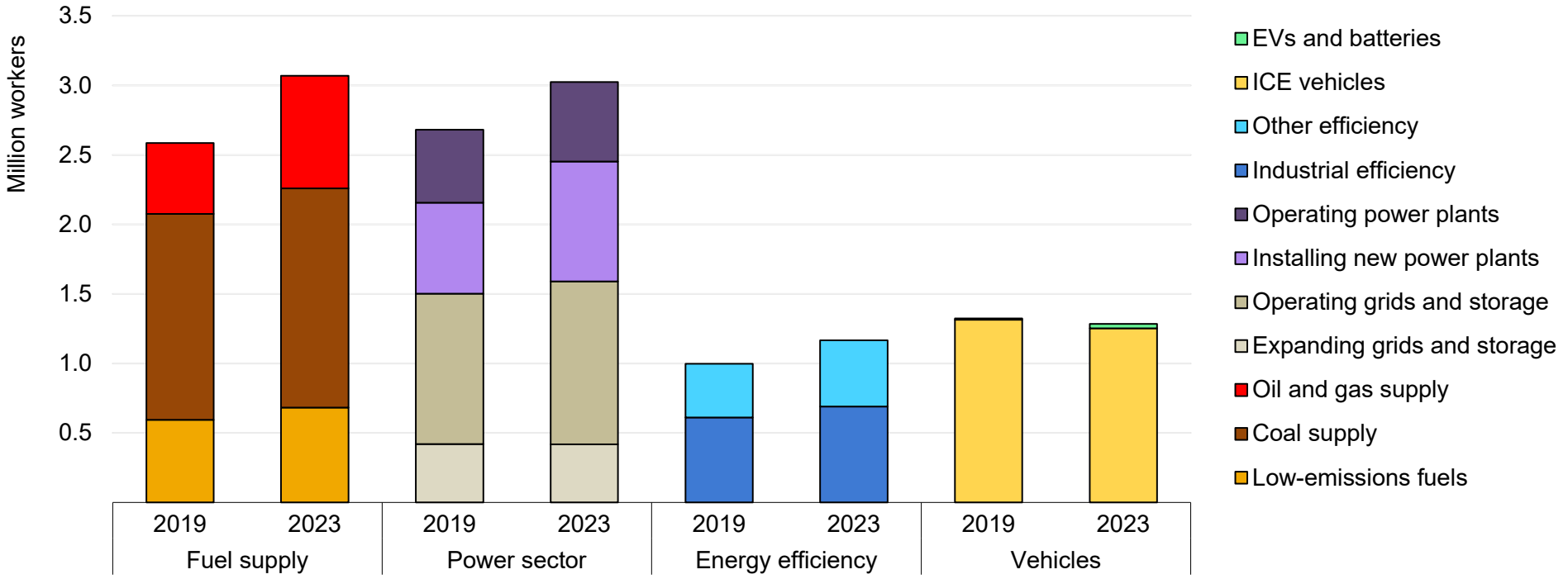
The clean energy manufacturing workforce has been increasing particularly rapidly. These trends are, in part, attributed to existing government incentives, like the Production Linked Incentives scheme announced in 2020, which aims to establish India as a clean manufacturing hub in segments such as solar modules and batteries. Firms have responded positively to the incentives. Ford, which had exited the Indian market three years ago, plans to repurpose its existing factory in Chennai to focus on EV manufacturing for export, and is expected to create over 3 000 local jobs. India's global conglomerate Tata Motors announced the construction of a 1.5 billion USD lithium-ion battery manufacturing plant in Gujarat, as well as extensive investments into the national EV infrastructure, and set a target of 50% EV sales by 2030.

Like many countries, India has a significant share of informal workers, including in energy. Based on government estimates, the informality rate can be as high as 60% in the manufacturing sector, 90% in the construction sector, and 45% in mining. IEA estimates indicate that coal mining, vehicle manufacturing, and the growing and gathering of bioenergy have some of the highest shares of informality in India's energy sector. A particular challenge resides in a large portion of the workers being hired as contractual or outsourced labour, often without direct employment benefits or formal skill development pathways. A lack of data on informal workers also complicates efforts to understand future workforce and skilling needs. Numerous government initiatives and schemes have been introduced to tackle high informality in the country. In 2021, the E-Shram portal was launched to create a national database of unorganised workers in an attempt to provide social security benefits and access to other government programmes, with around 280 million workers registered as of last year.

Regional focus: India

The number of energy workers in India grew by nearly one million since 2019, with the largest increases coming from fossil fuel supply, solar power and energy efficiency

Energy employment in India by sector and year, 2019-2023

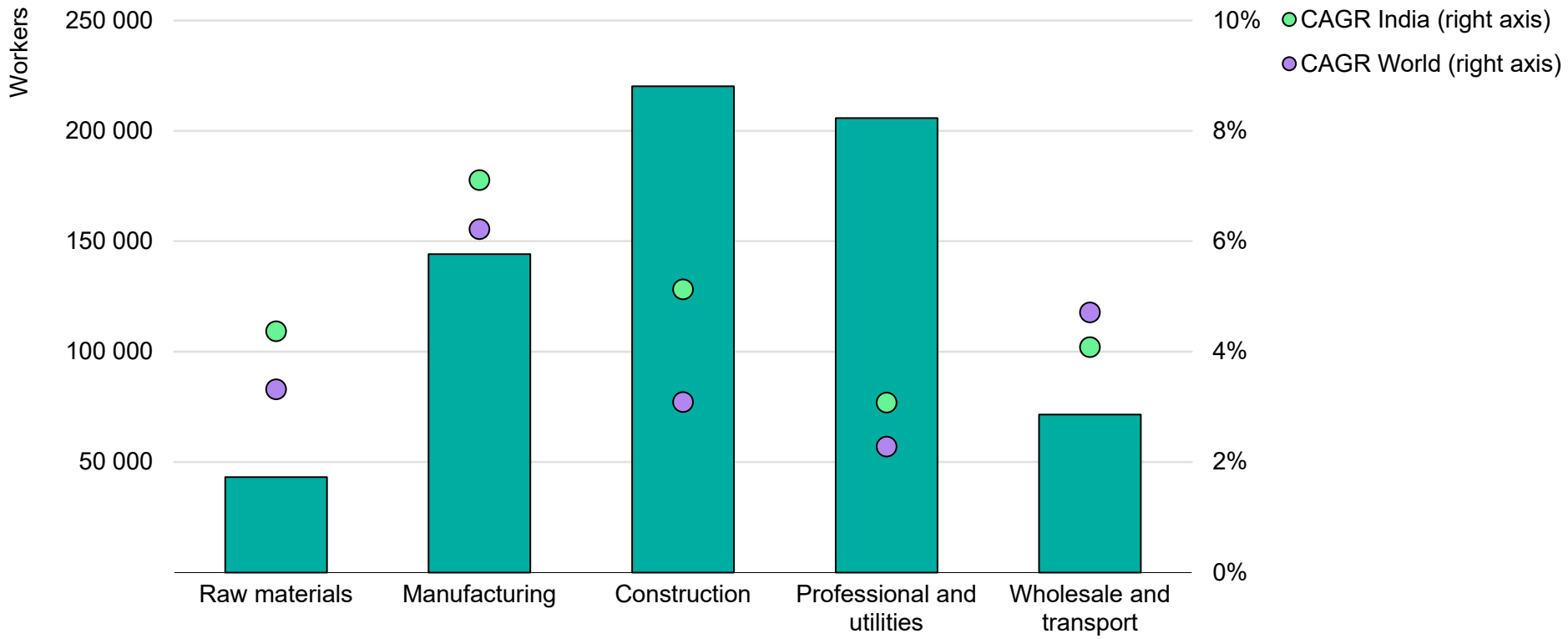


Notes: ICE vehicles = internal combustion engine vehicles; EVs = electric vehicles. Other efficiency includes building retrofits, heat pumps and other equipment, and appliances. Low-emissions fuels include bioenergy supply, nuclear supply, hydrogen supply and critical minerals.

Regional focus: India

India is emerging as a clean energy manufacturing hub, with rapid job growth in manufacturing and construction outpacing global averages

Clean energy employment change by economic activity in India, 2019-2023



Note: CAGR = Compound annual growth rate.

Energy employment in India is set to grow under today's policies, with a faster ramp-up needed to reach its goal of net zero by 2070

Energy employment in India is set to continue to climb under all IEA scenarios, with the magnitude and types of job additions dependent on the pace of the energy transition. The IEA's Stated Policies Scenario (STEPS) is shaped by today's policies and trends, while the Announced Pledges Scenario (APS) projects a pathway that would meet both India's near-term and long-term energy access and climate targets, including the goal of net zero carbon emissions by 2070 pledged at COP26 in 2021.

In the STEPS, energy employment in India grows by over 20% to reach 10.4 million jobs by the end of the decade. This growth is fuelled by expansion in the clean sectors, which add almost 2 million jobs, offset partially by a decline of 110 000 in fossil fuel sectors. The power sector is at the centre of much of the growth. Transmission and distribution add 360 000 new roles by 2030 as India endeavours to massively expand and strengthen its grid to enable integration of more than 500 GW of non-fossil-based capacity by 2030. Within power generation, the greatest gains are in solar PV, which adds a quarter of a million jobs and surpasses coal to have the biggest power generation workforce at 610 000 in 2030. The wind sector also sees substantial growth of 150 000 jobs by the end of the decade, with offshore wind in particular expanding quickly as the country begins development of its first offshore wind farms. Overall, renewables add 430 000 jobs through 2030, a 50% increase since 2023. Meanwhile, the unabated fossil fuel power workforce declines by one fifth over the same period, mainly as a result of a slowdown in coal capacity additions over the rest of the decade.

In the fuel and mineral supply sector, modern bioenergy is the largest area of growth, with 130 000 new jobs. The oil and gas supply workforce also expands by 90 000, with notable additions in the midstream segment, including the distribution of LPG driven by continued support from India's Pradhan Mantri Ujjwala Yojana (PMUY) programme. Despite rising output, coal supply employment contracts by 7% as efforts to automate and mechanise mining along with opening the sector to private sector participation set to contribute to a reduction in the labour intensity of coal production.

The implementation of government campaigns to improve efficiency will continue to provide substantial job growth in end-use efficiency, and help push total new jobs to 760 000 by 2030. The vehicles workforce grows by around 140 000 to 2030 in the STEPS, as sales of vehicles grow by one quarter. Increases in automation help improve labour productivity, with current rates of improvement set to gradually bringing India in line with other major global automotive manufacturers. India's vehicle electrification policies also shift the composition of the vehicle workforce by 2030, with around 320 000 workers connected to the manufacture of EVs and their batteries, up from roughly 30 000 workers today. This represents almost all of the job growth in India's automotive manufacturing sector to 2030.

In the APS, a stronger push for scaling up clean energy investment increases total energy employment needs substantially by 2030. Energy employment in the APS is 10.8 million, roughly 4% greater than in the STEPS. The power sector adds nearly 1.2 million jobs in the APS, compared to 700 000 in the STEPS – and represents the largest source of job additions of any sector in the APS. By 2030, both solar PV and hydropower surpass coal to become the top two employers in the power sector in this scenario. The majority of the increase comes from the installation and construction of new projects, whereas other segments of the business enjoy some benefit from economies of scale. Employment in power grids grows similarly in the APS as it does in the STEPS, with many of the same projects able to handle the increased deployment of clean power projects.

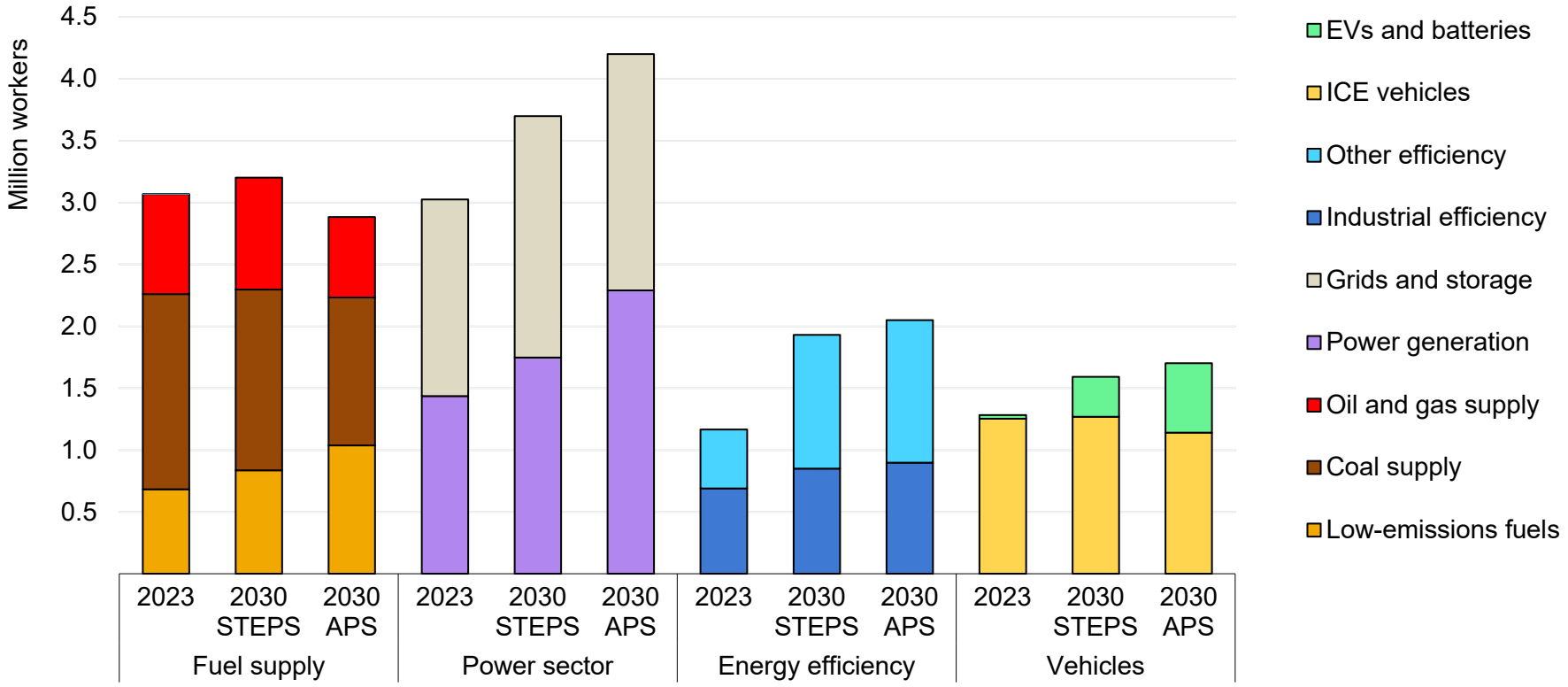
In the APS, the more rapid shift to EV manufacturing – both to meet rising Indian demand and greater demand globally for EV exports – implies a lesser focus on ICE manufacturing, decreasing labour needs in this segment by 1% per year by 2030. The number of workers involved in energy efficiency and end-use electrification grows slightly over the STEPS in the APS, but with greater focus on electrification investments, demanding more electricians, trained efficiency auditors, and process efficiency experts in particular.

If India was to implement further measures to accelerate toward its long-term climate targets, it would imply a shift in the trajectory for fossil fuel employment. While fuel supply employment grows to 2030 in the STEPS, in the APS it contracts. The largest decrease in labour demand would be in the coal supply sector, as improvements in labour productivity already present in the STEPS combine with a slower rise in coal production in the APS. Worker demand for developing further midstream oil and gas infrastructure also decline in the APS, decreasing by 20% by 2030. Growth in bioenergy employment offsets some of these declines in fuel production, as India triples consumption and production of biofuels over the next five years by moving to higher ethanol and biodiesel blends. Diversification becomes the watchwords for major fossil fuel-based employers in India given the spread of outcomes between the STEPS and APS, with many firms such Tata Power Solar, Renew Power and Adani Solar already developing thriving solar businesses. The APS provides greater upside potential for energy employment to 2030 than the STEPS, with net energy employment growing by 2.3 million, versus 1.9 million in the STEPS.

Regional focus: India

Labour demands will increase sharply in power generation as India accelerates its climate ambitions, with implications for fossil fuel supply

Energy employment in India by technology, year and scenario



Notes: ICE vehicles = internal combustion engine vehicles; EVs = electric vehicles. STEPS = States Policies Scenario; APS = Announced Pledges Scenario. Other efficiency includes building retrofits, heat pumps and other equipment, and appliances. Low-emissions fuels include bioenergy supply, nuclear supply, hydrogen supply and critical minerals.

India places focus on upskilling its workers, including in the energy sector

The Indian government has been making efforts to upskill its workforce. In 2014, the Ministry of Skill Development and Entrepreneurship was founded to co-ordinate skilling efforts across the country. A year later, the government launched the National Skills Development Mission of India, also known as Skill India, with the aim of training over 400 million people. These efforts are ongoing but are aiding progress – at the end of 2023, 73% of the Indian labour force had received a basic education or higher, compared to 60% in 2010.

Within these economy-wide efforts to increase worker skill levels, India has established energy-specific certifications and trainings. The Skill Council for Green Jobs (SCGJ), established in 2015, is a major organisation for clean energy job training, with over 550 000 workers qualified to date. Its main activities encompass skills gap analysis, occupational mapping, training of candidates across energy sectors, and the creation of centres of excellence. Sector specific government initiatives include the Jal Urja Mitra (hydropower), Suryamitra (solar) and Vayumitra (wind) skilling programmes. The private sector has also been contributing to skilling efforts, with firms such as Tata Power, Adani Power, and ReNew Power training thousands of workers across the energy sector.

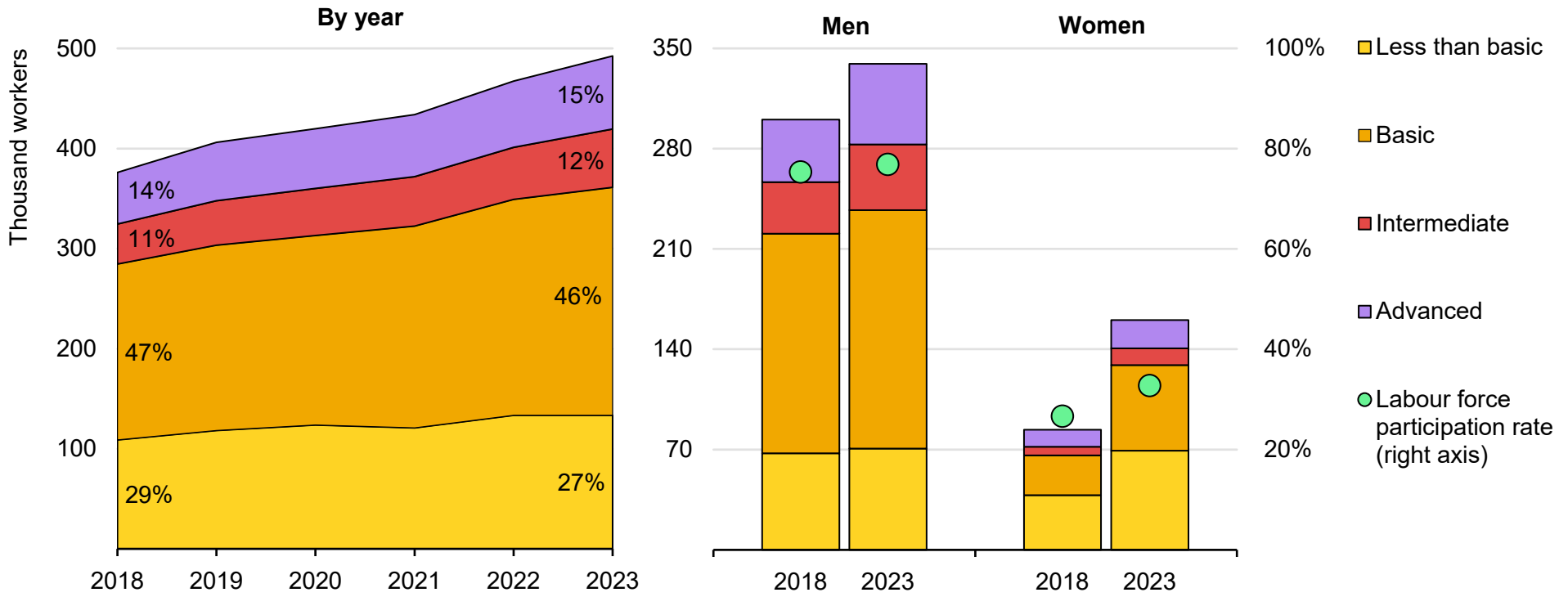
Similar initiatives could help workers acquire skills needed for emerging, high-tech sectors. In 2023, the union government approved the National Green Hydrogen Mission, ratifying three pilot projects for the use of hydrogen in steel production. The Ministry of Skill Development and Entrepreneurship is co-ordinating the development of skilling programmes and courses across the hydrogen value chain, including the manufacturing of hydrogen-producing and consuming equipment. In tandem, the Ministry of Education is encouraging the coverage of hydrogen technologies in existing curricula and building lab installations and experimental stations in schools to boost practical experience.

Despite efforts, Indian energy firms still report difficulty hiring skilled workers. In 2023, 72% of employers in the energy and utilities industry stated that they were experiencing talent shortages. This compounds with wider shortages for skilled manual labour. These shortages have contributed to project delays in a number of sectors. Industry has suggested greater standardisation in skills training and accreditation, which could improve training quality and facilitate better hiring. Still, industry is pushing for more involvement in shaping the skilling programmes to ensure their relevance to their business.

Within its skilling efforts, India aims to address low participation by women in the labour force. India's female labour participation rates lag other countries in Asia, such as Viet Nam, Indonesia and China, with only one-third of women formally in the workforce in 2023. Women are also less likely to receive education, with 43% of working women receiving less than basic education compared to 21% of working men. Government-sponsored programmes, such as Beti Bachao Beti Padhao (BBBP), aim to change perceptions of educated and working women, and are supported by organisations such as the National Creche Scheme, which provides childcare services.

The share of workers with higher-level education is growing gradually, as is the share of women participating in the workforce

Indian labour force by highest degree of educational attainment, year, and gender



Source: IEA analysis based on ILO data.

Deep dive: India's solar and hydropower sectors are rapidly increasing their workforce, with a particular pinch point in skilled construction roles

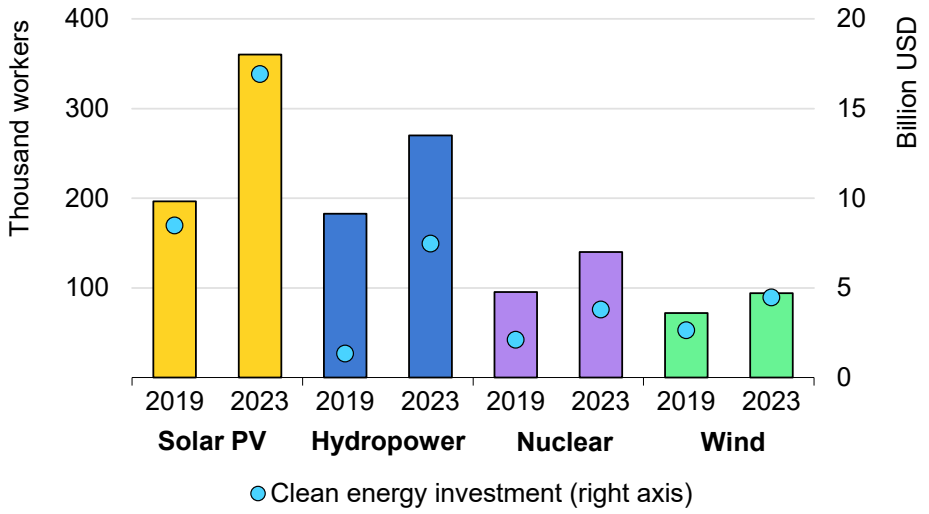
New policy initiatives, falling prices, public tenders, and improved grid infrastructure are contributing to India's strong growth in clean power investments, particularly renewables. Over the last 15 years, India clean energy capacity has grown by around 10% y-o-y, with a record 20 GW of new additions in 2022. The vast majority of new capacity is coming from solar PV.

Employment in clean power generation totalled over 930 000 workers in 2023, with hydropower and solar PV representing both the largest portion of that workforce and the greatest growth in recent years. The clean energy workforce rose last year by 10% y-o-y, with solar and hydropower accounting for over two-thirds of the increase. Demand for new workers, particularly for the installation of rooftop solar, is set to grow rapidly in the coming years on the back of strong new support from the PM-Surya Ghar: Muft Bijli Yojana programme.

Hydropower witnessed a sharp, 19% y-o-y growth in its workforce in 2023, driven by the addition of over 25 000 jobs connected to major hydropower projects currently under development, including new pumped storage hydropower (PSH) capacity, which expanded from a recent government push to develop PSH projects in the country.

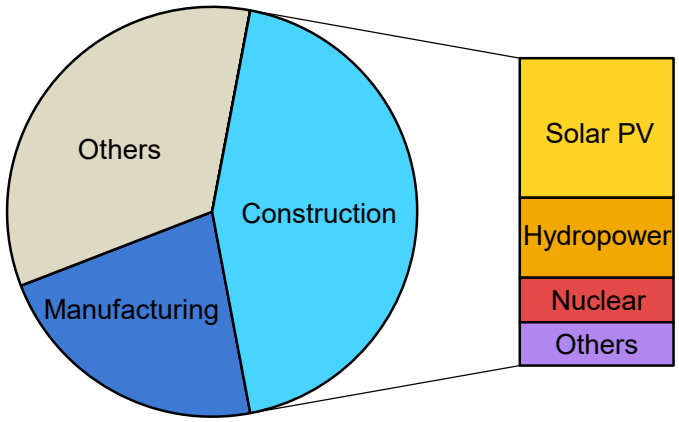
Similarly, the nuclear power workforce in India has grown by an average of 10% annually since 2019, with seven new reactors under construction on top of the country's 20 operating reactors.

Employment in power generation in India by selected technology and year



The construction sector is where most of these new clean power generation jobs are concentrated. Employment in the installation and construction of clean energy projects grew by 10% y-o-y in 2023, and represents around 45% of total jobs in clean power generation in India. Growth rates are even higher for some selected technologies, with the share of construction workers in solar PV representing over half of all solar PV jobs. Many contractors have been flagging economy-wide shortages of skilled workers for their sector, in particular in vocational occupations such as construction machine operators or welders.

Employment in clean power generation in India by economic activity and technology, 2023



Note: Others in the pie chart refers to the other economic activities "professionals and utilities" and "wholesale and transport". The Others category in the bar chart refers to the other technologies in clean power generation: wind, geothermal, concentrated solar power, marine and bioenergy.

The Government of India has placed particular importance on ensuring sufficient construction workers are available to support these growing industries. In an attempt to address skilled labour shortages and boost clean energy technology deployment, several state-led programmes have been launched, including in Gujarat, Maharashtra, and Rajasthan. The Suryamitra Skill Development Programme, implemented by the National Institute of Solar Energy, has been particularly important in increasing the number of skilled technicians, training well over 50 000 workers for the installation, operation and maintenance of solar PV systems. Similarly, the Jal Urja Mitra programme, initiated in 2022, focuses on reskilling workers in the hydropower industry.

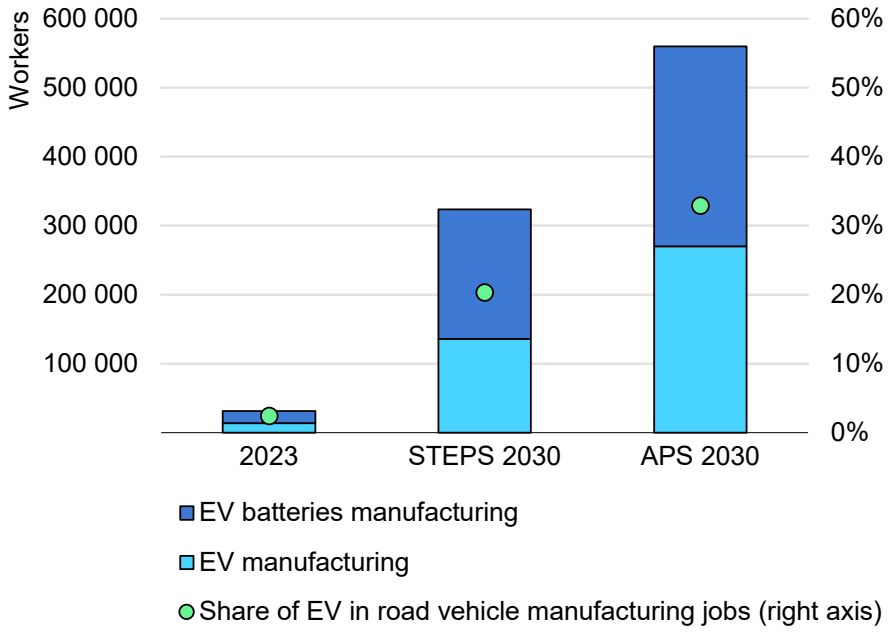
Training for construction workers in the nuclear industry tends to be much more intensive and project-specific than in other clean power sectors. India has a strong legacy of high-level nuclear education, including at the Department of Atomic Energy's Bhabha Atomic Research Centre Training School, which has trained scientists, engineers and technicians for the nuclear power industry since 1954. The Global Centre for Nuclear Energy Partnership, also under the Department of Atomic Energy, houses five schools for advanced nuclear studies and offers training courses and workshops in collaboration with the International Atomic Energy Agency. Ad hoc initiatives can also help fill specific skills sets needed for a nuclear power plant. For example, a training facility has been established at the Kudankulam Nuclear Power Project to train local youths in nuclear welding and other technical aspects of nuclear construction and maintenance. Students who complete the programme may then be hired to work on-site by Nuclear Power Corporation of India Limited or other companies involved in the project.

Deep dive: Employment in electric vehicles manufacturing represents less than 1% of total energy jobs in India, but the industry is gaining momentum

While employment in EVs represented less than 1% of total energy jobs in 2023, the industry is gaining momentum, and new manufacturing plants are creating opportunities for local employment. Policy support has boosted EV registrations in 2023, rising by 70% y-o-y, thanks to purchase subsidies under the Faster Adoption and Manufacturing of Electric Vehicles (FAME) Phase II scheme, tax benefits, the Go Electric campaign, and supply-side incentives. The FAME scheme provided subsidies to over 1.3 million EVs, achieving between 55-85% of its original targets across a range of vehicle types, including buses, passenger cars, and two- and three-wheelers. Under the PM Electric Drive Revolution in Innovative Vehicle Enhancement programme announced in 2024, the government seeks to incentivise the uptake of 2.8 million electric two- an three-wheelers and over 14 000 electric buses.

As the industry continues to expand, private companies are opening new manufacturing plants and generating employment. Viet Nam's VinFast, a leading electric vehicle manufacturer in Southeast Asia, opened its first integrated EV facility in Tamil Nadu in 2024, creating approximately 3 500 jobs locally. Tata Motors recently announced the opening of its USD 1 billion manufacturing plant in the same region, with the potential to create over 5 000 job opportunities. Efforts to onshore battery manufacturing are also ongoing, with the aim of reducing costs driving uptake, which is part of the government's Atmanirbhar Bharat Abhiyaan ("Self-reliant India") mission. Firms including Suzuki Motor Corporation and Tata Group have established plans to manufacture EV batteries in Gujarat, while Amara Raja Batteries Limited launched a USD 1.1 billion lithium-ion battery factory in Telangana.

Employment in EV and batteries manufacturing in India by year and scenario



Note: STEPS = Stated Policies Scenario, APS = Announced Pledges Scenario.

One of main challenges for private and international investment in new EV manufacturing facilities is finding experienced local staff to manage and operate them, which could pose significant obstacles to the industry's rapid expansion as well as India's ambitions to capture a growing share of the global EV and battery market. Many companies have turned to bringing in experienced workers from other leading companies in the EV and battery space to support their operations and train up local staff – a move aided by a relaxation of visa issuances for foreign workers in these and other sectors. Firms have also pursued joint ventures to gain experience and a foothold in the emerging industry, however direct foreign investment rules and other guidance present headwinds. Government changes to foreign investment regulations could play a role in attracting international firms and improving the pathway to building up a domestic skill base.

In parallel, both the public and private sectors are developing initiatives and partnering with educational institutions to build up a workforce with the know-how and technical abilities needed by the EV and battery industry. In addition to its multiple Learning Centres, where both internal and external workers across the supply chain can receive training, industry leader Tata Motors has partnered with universities and local colleges to offer courses for current and prospective workers. Similarly, the public Delhi Skill and Entrepreneurship University is working in consortia with others to design curricula related to EVs, starting with an EV mechanics training programme. Close and continuous updates to training curriculum remain critical as new innovations are rolled out across the production processes, including changes in engineering, assembly, electronics design and software. India has placed a particular focus on upskilling workers in micro, small and medium-sized enterprises (MSMEs) in manufacturing components and supporting EV assembly in the country. Existing initiatives include WRI India's MSME EV Skilling Program, which provides hands-on training for workers employed in MSMEs manufacturing EVs.

India's industrial and climate ambitions will require faster build out of EV and battery manufacturing than today's trends. In the APS, EV sales share in India scale up to over 65% in 2035 across all road vehicles modes, with rapid electrification of two- and three-wheelers leading the way. Accordingly, this faster trajectory will require rapid growth in EVs and EV batteries manufacturing employment over the coming years. By 2030, workers employed in the manufacturing of EVs and EV batteries total over 320 000 in the STEPS, and nearly 560 000 in the APS. The share of workers employed in EV manufacturing, including their batteries, compared to total ICE road vehicle manufacturing increases to 20% in the STEPS and 33% in the APS, up sharply from 2% in 2023. This would necessitate changing existing production lines today to electric vehicle assembly, and training current workers on these new production techniques. It also requires an expansion of other manufacturing segments in India, especially in light of the country's objectives to reduce the need to import key components for locally assembled solar PV, vehicles and batteries. Companies will need be proactive in designing recruitment and talent strategies for such ambitions and can benefit from close co-operation with government efforts to provide broader skilling support to the Indian population.

Deep dive: Rising productivity in coal mining is the major force shaping the coal employment outlook

In India, coal has an enduring and cross-sectoral importance as a major source of energy security, economic growth and social protection. India surpassed Indonesia in 2024 to become the second-largest producer of coal after China, and represents 12% of global coal demand, with the fuel accounting for around 75% of total domestic power generation in 2023. The government plans to continue expanding production and use of coal in the coming years. Coal production investment in India rose by 5% in 2023 and is set to expand by nearly 10% in 2024, to around USD 12 billion. New coal power final investment decisions (FIDs) in India doubled to 2 GW in 2023, the highest level since 2019, as the country seeks to meet strong growth in electricity demand. Based on the IEA Coal Transition Exposure Index (CTEI), which takes into consideration a country's energy and economic dependence on coal, level of economic development, and amount of existing coal-fired capacity that has not fully depreciated, India ranked among the top five most exposed countries as of 2022.

Coal supply, which excludes workers in coal-fired power, is a major employer in India. The country's coal supply workforce has grown 6% since 2019 to reach 1.6 million workers in 2023, equivalent to almost 20% of energy jobs in India and 25% of all coal supply jobs around the world. The government-owned Coal India Limited (CIL), which produces over 80% of the country's coal and is the largest government-owned coal producer in the world, is also one of the biggest employers in India, with a direct workforce of nearly a quarter of a million people in 2024, and many more workers on a part-time or contractual basis. The transport of coal fuel also represents an important source of revenue for the Indian rail system and has implications not only for employment in the sector, but also for the pricing for passenger rail – a primary mode of transit for tens of millions in India.

Coal mining in India, similar to other emerging market and developing economies, is less mechanised than in advanced economies. Today, around 14 times more workers are required per tonne of coal produced in India than in the United States, and 3.5 times more than in China. Continued improvements in mechanisation and automation in India's coal mines are diminishing the need for manual labour and at the same time substantially lowering costs and boosting efficiency. Some techniques have already gained ground: CIL is increasing automation and mechanisation in a number of job segments, including loading and transport, groundwater control systems and underground drilling. Early effects of these efforts are already evident: about 20% fewer workers were needed to produce one tonne of coal in India in 2023 than in 2019.

Mechanisation and automation also tend to improve safety and working conditions by minimising the number of miners underground. The safety profile of coal mining in India continues to improve. In 2023, CIL had 29 worker fatalities and 45 serious injuries, down from

an average of 53 fatalities and 170 serious injuries per year in the 2010s.

A series of policy reforms aimed at allowing greater private sector investments are attracting more capital to enhance the modernisation of mining techniques, another harbinger of labour productivity improvements. Today, India's ratio of coal production workers to output is roughly similar to the level of China in 2005, towards the beginning of the latter's long-term efforts to shut down illegal mines, consolidate operations and improve safety and productivity, all while increasing output. If India were to follow the same trajectory of rising output and productivity improvements as in China between 2005 and 2023, and assuming constant rates of growth, the country would lose over 320 000 coal production jobs by 2030 and nearly 680 000 by 2040, while increasing output by 4% per year on average. This production increase is actually greater than that seen in India under current policies. Pursuing these productivity improvements in tandem with India's goal of net zero carbon emissions by 2070 would have even more drastic effects on employment due to lower production growth, with over 500 000 jobs eliminated by 2030 and approximately 1.3 million by 2040.

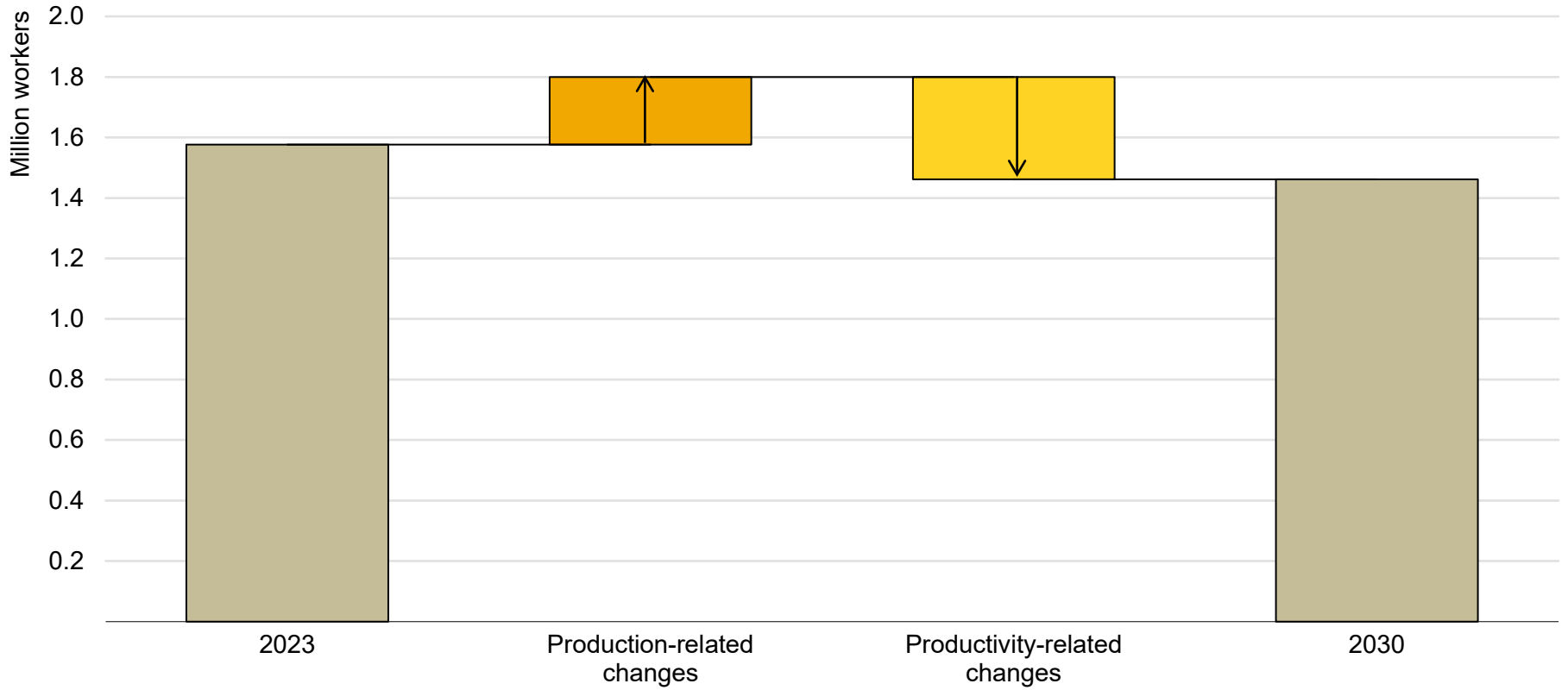
As a result of these advances, demand for coal supply workers in India falls while production expands in both the STEPS and the APS. In the former, production in 2030 is 16% greater than in 2023, nearly offsetting the job declines from productivity gains and leading to just 7% lower labour demand in the coal supply industry in 2030. In the APS, which assumes that India successfully meets its 2070 net zero target, the decline is larger. While production in 2030 in the APS is still 9% higher than in 2023, there is less growth to offset the effects of productivity gains, resulting in 25% less labour needed by 2030.

Careful advance planning is required to manage the employment shifts and socio-economic impacts resulting from productivity advances in the coal supply industry. The potential ramifications of these shifts and the ideal approach to managing them varies according to local circumstances and priorities. A report by NITI Aayog has already identified the key considerations and prerequisites for a just coal transition in India. These include the need for comprehensive mapping of the existing human resources and infrastructure in affected communities to understand the social and economic implications of changes in the coal sector, as well as to identify opportunities for growth. Falling labour demand in the coal industry can be partially offset by job additions in non-coal industrial sectors, such as steel and chemicals. In coal mining regions, promoting investment in other sectors can help diversify the local economies, which today remain concentrated in agriculture and mining. For instance, manufacturing jobs account for just 8% of total employment in Jharkhand and around 5% in Chhattisgarh, two major coal regions, while agriculture accounts for nearly 40% and 60%, respectively. One sector which may be able to draw upon the coal supply workforce for skilled labour is the country's growing critical minerals mining industry. The Geological Survey of India has already initiated hundreds of projects to explore the country's critical minerals resources, and in 2024 the Critical Minerals Mission was announced to support domestic production.

Regional focus: India

Rising productivity means coal employment in India declines, even as output grows

Change in coal supply employment by cause in India in the Stated Policies Scenario, 2023-2030



Fuel and minerals supply

Oil and gas supply employment grew around the world on a wave of new project developments

The oil and gas supply industry employed 12.4 million people in 2023, up from 11.8 million in 2022, with two-thirds of these workers engaged primarily with oil projects and the remaining one-third with natural gas. This 5% increase in employment is a slight deceleration from the 7% growth seen in 2022, with the hiring crisis persisting unevenly across firms and regions. The oil sector accounted for 360 000 of the 590 000 new jobs in 2023, while employment in natural gas rose by 230 000, with the liquefied natural gas (LNG) supply sector providing substantial gains. Total employment in LNG was estimated at 610 000 in 2023, continuing its yearslong upward trajectory fuelled by increasing investment. These estimates do not include workers in power generation or retail.

Job additions were spread across the world, with no one region dominating growth in 2023. Overall, about 60% of the oil and gas workforce is occupied primarily with tasks related to new capacity, such as drilling wells, manufacturing equipment and building infrastructure. Improved offshore economics catalysed a renaissance of drilling in the Atlantic Basin, contributing to growth in Africa as well as Central and South America, which together accounted for approximately a third of new jobs. Brazil, in particular, increased its oil supply workforce by over 15% in 2023. Jobs in Brazil are expected to continue to rise after state oil company Petrobras announced a year ago that it plans to expand its production.

Still, the Middle East region, which accounts for 32% of global oil supply and 17% of natural gas, remains the single largest employer and contributor to jobs growth, representing just over one-fifth of both the workforce and job additions in 2023. While most oil and gas producers laid off workers during the pandemic, petroleum employers in the Middle East implemented some of the most aggressive rehiring strategies after 2020. In Iraq, for example, data from LinkedIn indicates that average hiring activity in the oil, gas and mining sectors in the second quarter of 2021 was 230% greater than in the second quarter of 2020, whereas hiring in Norway was 63% higher. A year later, hiring was up another 69% in Iraq but just 5% in Norway.

LNG remains a key driver of employment growth in natural gas supply in several regions. The sector represents just 15% of all gas supply employment in 2023 but accounted for one-third of year-on-year growth. This follows an increase of 12% in LNG-related employment in 2022. In 2023, Europe ramped up LNG investment almost threefold to nearly USD 7 billion. With several regasification terminals, including floating storage and regasification units (FSRUs) under construction, job additions in LNG represented all gas supply employment growth in Europe last year. North America saw a similar magnitude of LNG jobs added in 2023, owing largely to the construction of new export terminals.

Refining is one segment of the oil and gas supply industry that is already experiencing the effects of a plateauing in oil demand. The refining industry has historically been fuelled primarily by strong demand for road transport fuels such as motor gasoline, however demand is set to continue to decline in China and advanced

economies, particularly in Europe, where one-fifth of vehicles sold today are electric and demand for gasoline and diesel fell by 2% in 2023. Global oil refining employment fell by 60 000 jobs in 2023 amidst plant closures in Europe, Japan and other countries, which in some cases had been planned for years but put on hold thanks to soaring margins after Russia's full-scale invasion of Ukraine.

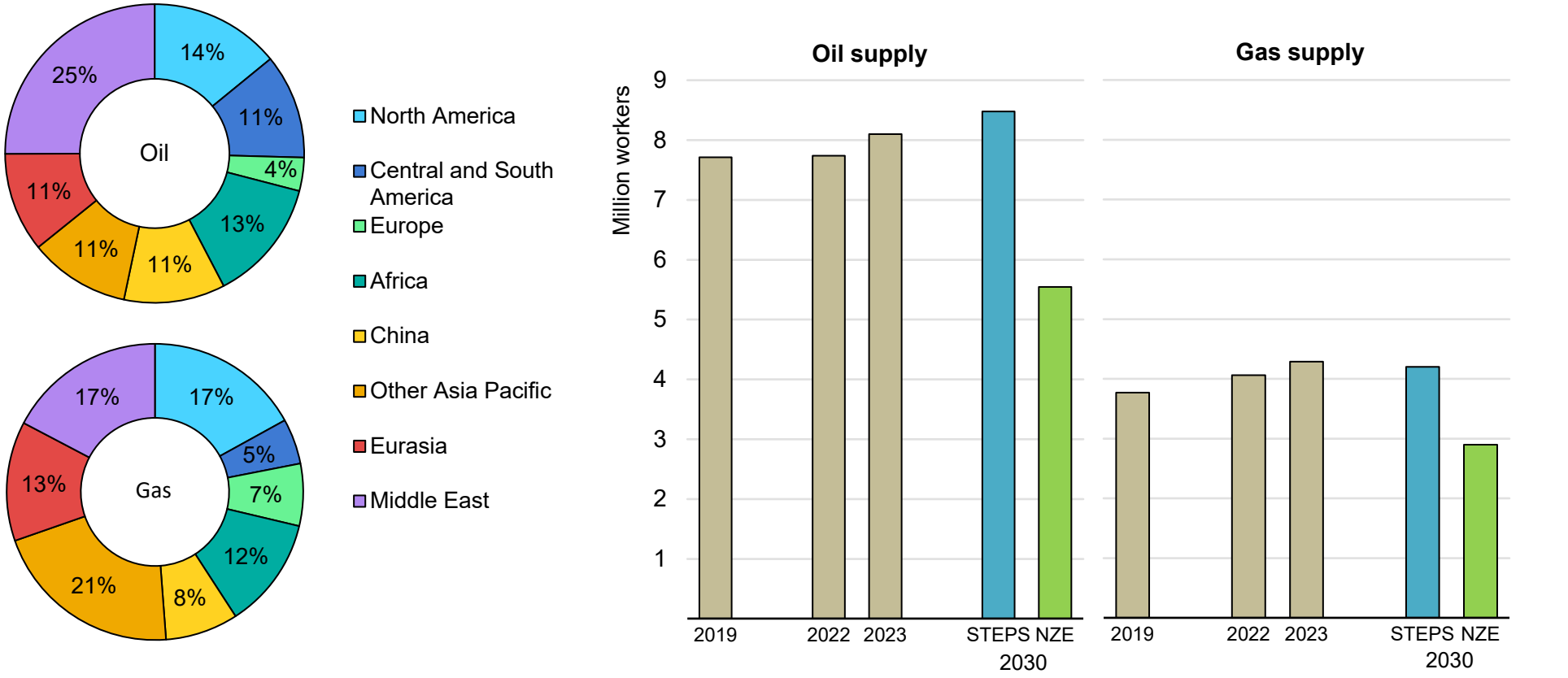
Going forward, the changes in oil and gas employment trends will depend on the pace of the energy transition. In all scenarios, there is a plateau in oil demand by 2030, limiting employment growth in the sector. In the STEPS, both oil and gas production are expected to slowly expand through the end of the decade, increasing by 1% and 5% by 2030, respectively, compared with 2% and 15% over the previous seven years. Employment rises alongside production, with about 290 000 new oil and gas jobs added for a total of 12.7 million in 2030. If the world were to align with the NZE Scenario, however, sharp falls in demand would require no new conventional oil and gas projects, leading to production declines of 22% in oil and 14% in gas in 2030, compared with 2023. This precipitates a similarly steep drop in oil and gas employment, with one-third fewer jobs needed by the end of the decade. Two-thirds of this decline is in oil due to its larger share in the workforce, but labour needs in both subsectors fall by about 30%.

Oil and gas producers are employing a variety of strategies to cope with this uncertainty. Despite potential declines in demand, many are actively hiring, and may in fact be struggling to replace a large portion of their workforce ageing out of the industry. To hedge against an uncertain future and attract employees, some major oil and gas companies are diversifying their portfolios into broader energy companies, though investments in low-emissions technologies have generally been small when compared to their core business, with some firms even selling off clean energy holdings in recent years. Nonetheless, this approach may offer a greater degree of internal flexibility surrounding career paths, with increased opportunities in renewables or alternative fuels such as hydrogen.

The mobility and advanced skills of oil and gas workers have made them some of the most sought-after employees in other energy sectors, especially those requiring similar skills such as geothermal, offshore wind, bioenergy, CCUS and hydrogen. In the NZE Scenario, about two jobs in clean energy sectors with directly overlapping skill needs will be created on average for every three jobs lost in oil and gas in a given region, indicating significant potential for oil and gas workers to become re-employed in clean energy sectors. However, oil and gas workers today benefit from some of the highest salaries economy-wide thanks to their elevated skill levels, large profits from oil and gas production, and well-established union representation, as well as increased compensation for occupational hazards, instability and mobility requirements. In the near term, most clean energy jobs are unlikely to be able to match the remuneration offered by oil and gas companies, implying a potential loss of income for workers whose positions are eliminated, even if they are immediately able to find new work in other energy sectors.

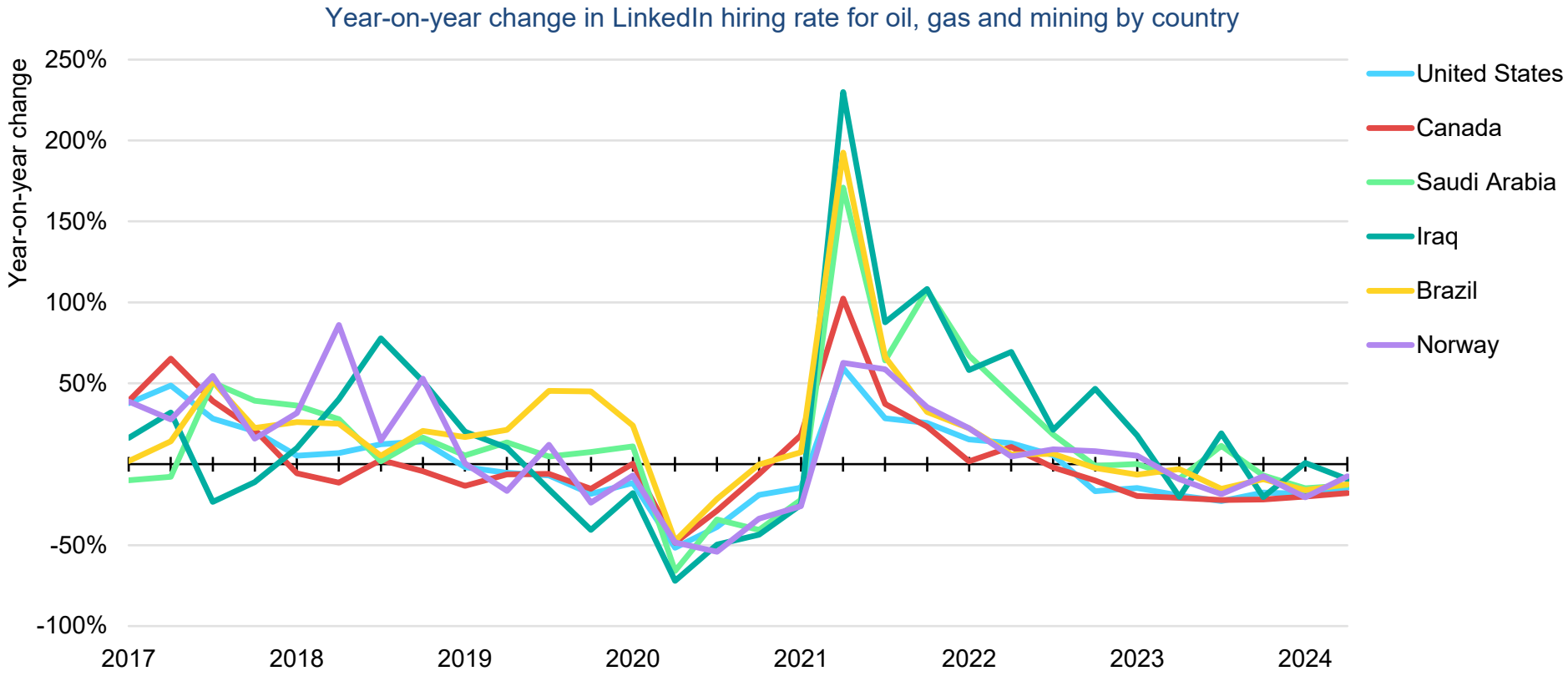
Oil and gas employment is stable through 2030 under today's policies

Employment in oil and gas supply by region in 2023 and by scenario in 2030



Note: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Post-pandemic rehiring in extractive industries was generally more aggressive and sustained in emerging and developing economies than in advanced economies



Notes: Year-on-year change compares the hiring rate of the same month across two consecutive years. The LinkedIn hiring rate represents the number of LinkedIn members who added a new employer to their profile in the same month a new job began, divided by the total number of LinkedIn members in that country. This number is indexed to the average month in 2016. Quarterly averages are used here for readability.

Source: IEA analysis of data from LinkedIn.

Coal supply employment stabilised in 2023 as production reaches record highs

In 2023, supply of coal reached record highs, the third year in a row of growth spurred by a recovery from the Covid-19 pandemic in 2021 and Russia's full-scale invasion of Ukraine in 2022. Nonetheless, continued pursuit of mechanisation and completed construction of over 30 new mines contributed to a slight decline in coal supply employment, which fell by 1% y-o-y, to 6.3 million in 2023.

China remains responsible for about half of the world's total coal supply and jobs, though its share of coal employment has fallen while its share of supply has risen since 2019. This is thanks to continuous nationwide efforts to consolidate hundreds of smaller, less-efficient mines and a subsequent focus on development of "intelligent mines," which rely heavily on automation and aim to minimise the number of coal miners underground. These efforts contributed to a 3% contraction in the massive Chinese coal workforce in 2023, equivalent to nearly 90 000 jobs. The next most important region for coal employment is India, which surpassed Indonesia in 2024 to become the second-largest producer of coal in the world following two years of record increases in production and plans to double coal output by 2030. India also opened four new coal mines in 2023; these tend to be more labour-intensive than new mines in China and therefore generate a greater quantity of coal supply jobs per unit of capacity. As a result, coal supply employment in India grew by approximately 30 000 jobs in 2023.

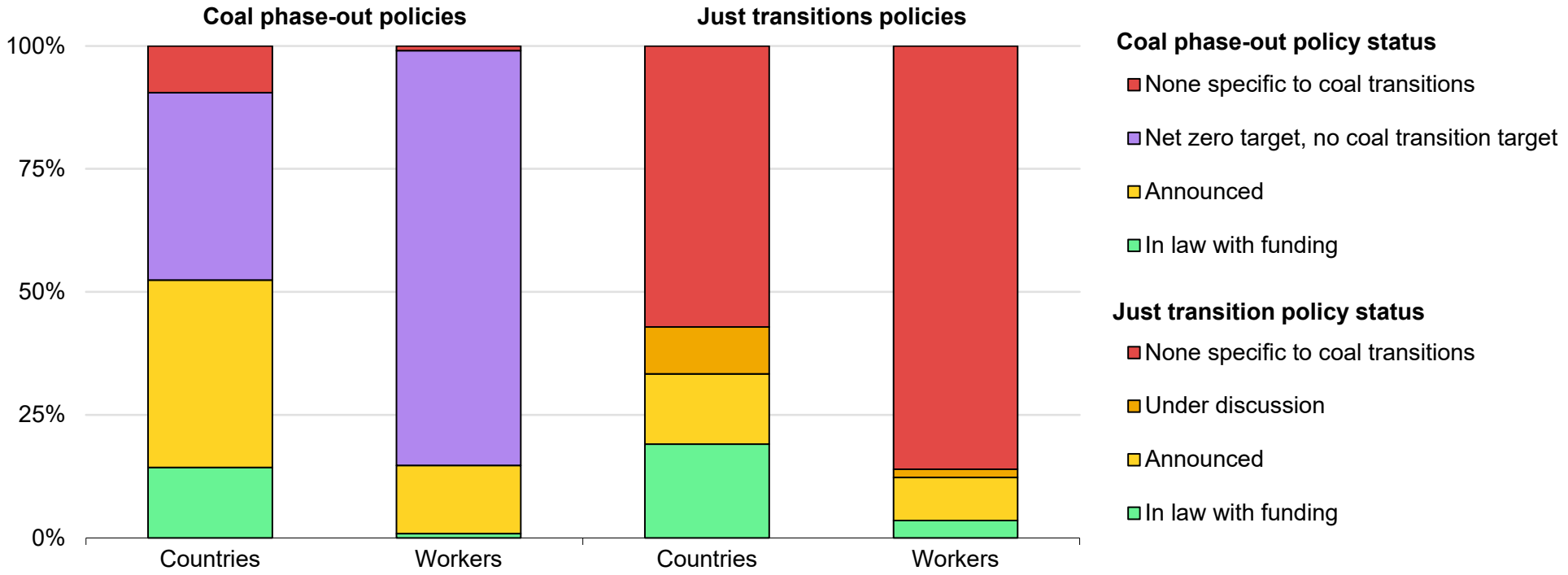
As an increasing number of regions move to end reliance on coal in the power sector, the primary driver of coal demand, production falls accordingly in all scenarios. In the STEPS, production decreases by 15% in 2030 compared with 2023, with employment declining by a few percentage points more. Not all the jobs lost are associated with falling production; coal employment would continue to decline even if production were held constant, thanks to the huge potential for labour productivity improvements. Coal mining is a prime candidate for automation due to its capital intensity, routine tasks, and the hazards it presents for workers. In India, growing involvement of the private sector in coal mining and a switch from an allocation system to an auction-based approach for developing new mines is likely to increase competition and improve labour productivity. In emerging markets and developing economies (EMDEs) outside China, over 80% of the decline in coal mining jobs by 2030 in the STEPS is due to labour productivity improvements. In advanced economies, on the other hand, high existing productivity rates and earlier coal phase-out targets mean that the majority of jobs lost are associated with falling production. Coal jobs fall even more rapidly in the NZE Scenario, with production and employment both declining by about 50% to the end of the decade. In this case, a greater share of the decrease is from falling production, as productivity growth tends to increase alongside the volume of coal mined.

Coal workers are among the most vulnerable during the energy transition, as many may not possess skills easily transferable to other energy sectors. Critical minerals mining is unlikely to be a significant area of re-employment for coal supply workers who lose their jobs,

as critical minerals job additions in regions with declining coal workforces are equivalent to less than 10% of the decrease in coal supply employment through 2030 in the NZE Scenario. It is therefore imperative that effective policy measures are implemented to support coal workers who lose their jobs, as well as communities which have historically relied on this income, to ensure a just and publicly acceptable transition. The specific policies enacted will depend on local context and priorities, but generally should focus on supporting affected workers as well as stimulating macroeconomic growth and enhancing social cohesion in declining coal regions. Governments around the world have utilised a combination of support mechanisms such as short-term income support, retraining and job placements, and regional industrialisation initiatives to achieve these priorities. However, across the 21 most coal-dependent countries, the IEA estimates that less than 14% of coal workers are covered by coal-specific just transitions policies, with only 4% in countries where policies were fully in law and funded. Nonetheless, this represents substantial progress over 2022, when just 4% were covered by any coal-specific just transition policy, including those announced or still under discussion.

Current just transitions policy coverage is insufficient to support coal workers, with only 14% of workers in the most coal-exposed countries protected by programmes

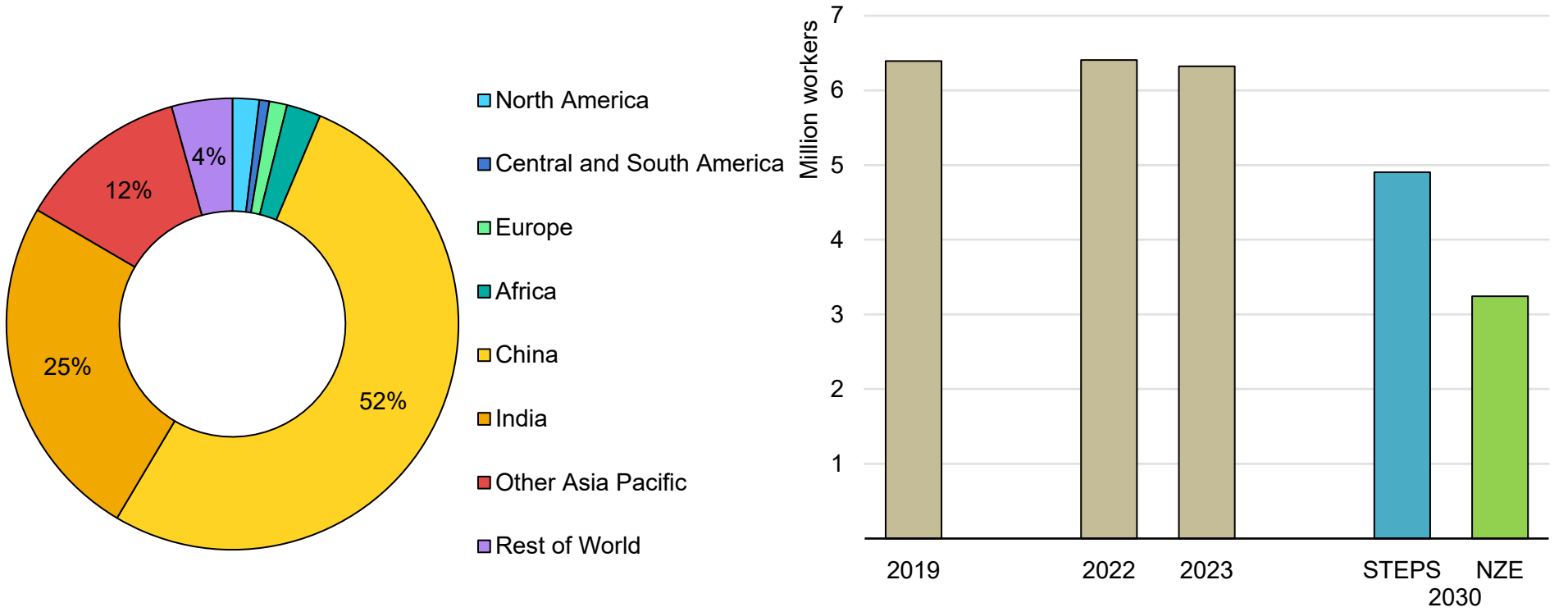
Coal phase-out and just transition policy coverage by status in the 21 most coal-dependent countries, 2023



Notes: Includes the 21 highest-ranked countries in the IEA Coal Transitions Exposure Index (see IEA, 2024, Accelerating Just Transitions for the Coal Sector, Chapter 1, Section 1.3). These countries provide over 95% of global coal production and global coal (supply and power) employment. Just transition policies here includes policies designed for coal workers faced with energy transitions, and not broader labour policies such as unemployment benefits. Net zero targets are included as they imply a likely transition away from unabated coal.

Coal employment cascades lower under today's policies as countries move away from emissions-intensive fuel and labour productivity improves in major producers

Employment in coal supply by region in 2023 and by scenario in 2030



Note: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Bioenergy employment continues to climb in anticipation of new blending mandates

Employment in modern bioenergy – which includes liquid biofuels, biogas and modern solid bioenergy – rose alongside production in 2023 to surpass 3.4 million jobs worldwide. Three regions account for approximately 20% each of the bioenergy workforce: Brazil, where biofuels such as bioethanol are prominent in the transportation sector; India, where abundant agricultural and organic wastes provide ample feedstock; and sub-Saharan Africa, where many industries and households utilise processed crop residuals. The United States is also a major player in global bioethanol and fuel wood production, and several Nordic countries provide woodchips and other forestry residuals to heating plants across Europe. Informal production of charcoal and fuel wood is not fully included in these estimates but is a major cooking fuel in emerging and developing economies, likely occupying millions more people in regions like Africa and developing Asia.

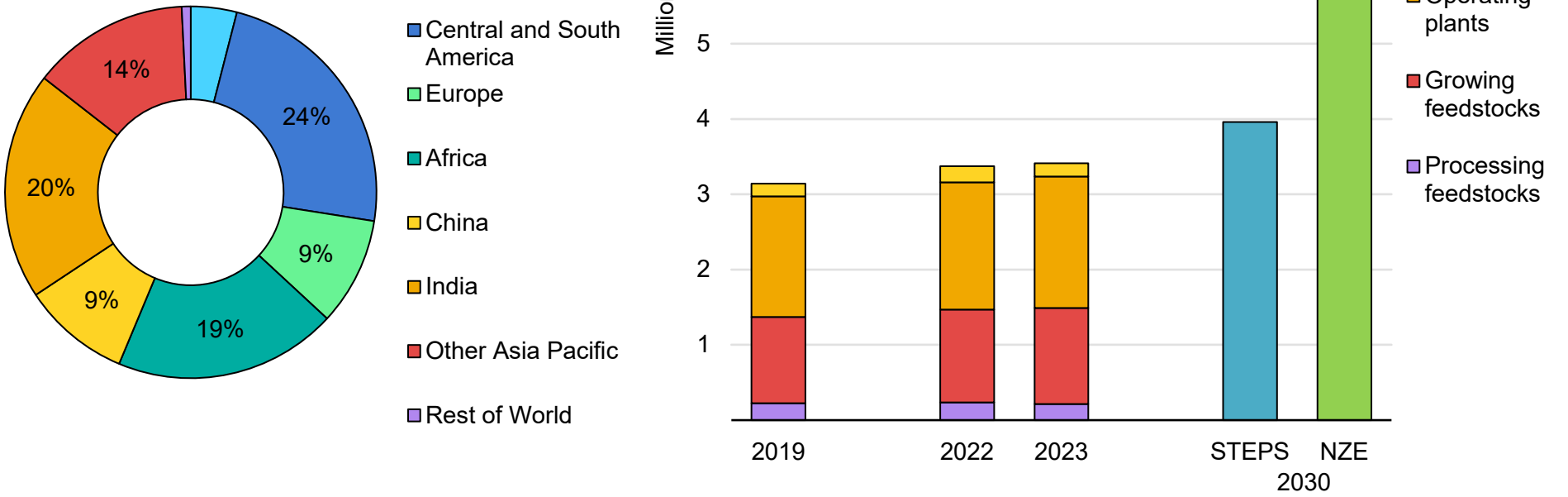
Biofuel blending targets have been increased in several regions, stimulating demand and employment growth. In 2023, Brazil raised the mandatory blend of biofuel in diesel from 12% in 2023 to 14% in 2024 and 15% by 2026. Indonesia also raised its biodiesel blending target to 35% from August 2023, and is considering an additional increase to take effect in early 2025. Others are implementing mandates for the first time, such as Ukraine, which introduced a 5% biofuel blending requirement for road transport fuels from June 2025.

New investment in facilities is also contributing to upstream jobs in manufacturing, as well as in installing equipment such as anaerobic digesters. In 2023, generation capacity of biogas and biomethane expanded by 4.4% globally, up from growth of around 3.6% the previous two years. This expansion has been supported by continued record-high investments in Europe, mobilised by efforts to reduce the dependence on Russian gas. European investments in biomethane and biogas supply hit a record high in 2022 and then nearly doubled in 2023 to reach USD 2.8 billion, equivalent to over half of the global total.

In the STEPS, global investment in modern bioenergy increases by over 60% by 2030, with EMDEs accounting for over half of the growth. As a result, demand increases by one-quarter and employment in bioenergy supply grows by over half a million to reach nearly 4 million jobs in 2030. In the NZE Scenario, demand growth in bioenergy is much sharper, particularly in industry and in households where traditional use of biomass is phased out by 2030 and often replaced with modern bioenergy solutions such as pellets from formalised bioenergy markets. This displacement allows modern bioenergy to provide a source of clean cooking for almost 1.2 billion people by 2030 and contributes to a near-doubling of the modern bioenergy workforce, which grows to over 6 million people.

Efforts to scale up modern bioenergy use contributes to huge workforce growth in the NZE Scenario by 2030

Employment in modern bioenergy supply by region in 2023 and by value chain step and scenario



Note: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Critical minerals mining employment grew by 7% in 2023 amidst an uncertain pricing outlook

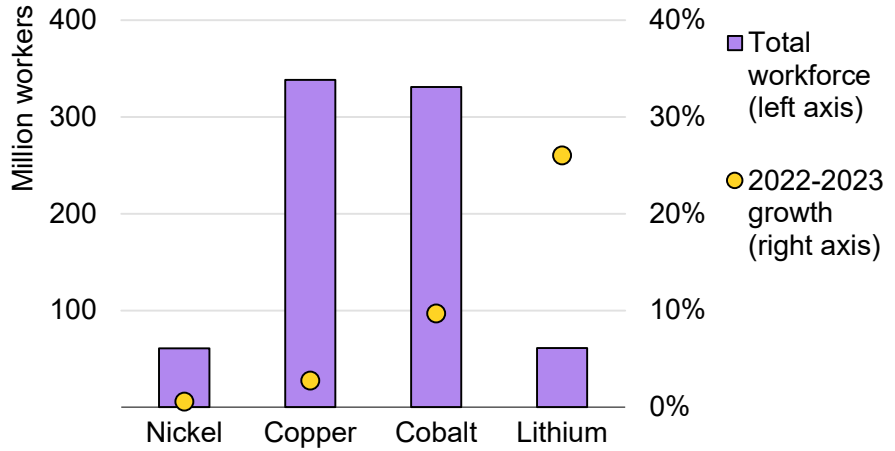
Demand for critical minerals experienced strong growth in 2023 and is expected to continue to increase despite fluctuating prices. Lithium demand rose by 30%, while copper, nickel and cobalt all saw demand growth ranging from 3% to 15%. As a result, employment in the mining of these critical minerals grew by 50 000 in 2023 to approximately 790 000 workers worldwide.

Declining prices have tempered investments in new mineral supply, but overall the industry is still growing. Investments in critical mineral mining operations rose by 10% in 2023, representing only a slight slowdown from growth in 2022. Investments in lithium saw the sharpest rise at nearly 60%, which contributed to a year-on-year increase of over 25% in the lithium extraction workforce. Exploration spending also rose by 15% in 2023, led by Canada and Australia, which increased their workforce by 2% and 6%, respectively.

With over 400 000 workers, Africa represents the largest employment base for critical mineral mining by a substantial margin. Central and South America is the next largest employer, with 130 000 jobs. Low-skilled, informal labour is prominent in the critical minerals sector in many EMDEs, as is the case with cobalt extraction in the Democratic Republic of the Congo. Informal workers there typically lack adequate safety training and equipment, endure substandard working conditions and receive low salaries compared to formal workers in the sector. The total number of workers in cobalt extraction in the DRC is hard to assess, with estimates as high as 250 000 and child labour believed to constitute around one-fifth of the workforce. Improving working conditions and ensuring decent jobs across the critical minerals industry is imperative for a just energy transition.

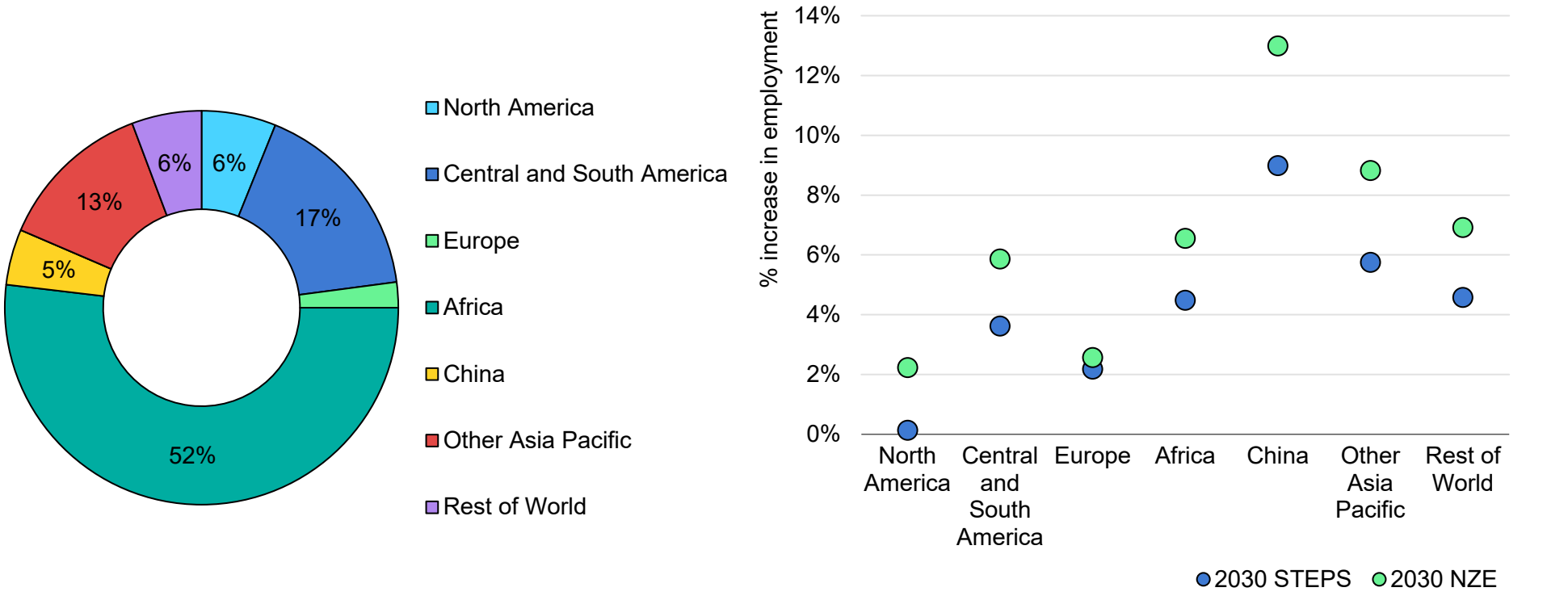
Employment needs continue to grow alongside expanding demand for critical minerals. In the IEA's inaugural Global Critical Mineral Outlook 2024 report, the pipeline of new mining projects under development are assessed by their likelihood of completion, providing an outlook to 2030. This project pipeline is insufficient to meet projected demand in the STEPS and NZE Scenario. Assuming sufficient supply to meet demand, annual average employment growth in critical minerals extraction in the STEPS is nearly 4%, with the total workforce surpassing 1 million by 2030. In the NZE Scenario, employment rises even higher, climbing by an average of 7% annually to reach 1.3 million jobs by the end of the decade.

Employment growth by critical mineral, 2023



Employment in critical mineral extraction represents a major source of energy job growth in emerging and developing economies in all IEA scenarios

Employment in critical minerals by region in 2023, and growth by scenario and region in 2030



Note: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Low-emissions hydrogen grows quickly from a small base

Employment in low-emissions hydrogen production represents just a small share of the total hydrogen workforce today. The vast majority of hydrogen production, which uses unabated fossil fuels and is consumed as an industry feedstock, is excluded. In addition, jobs producing the electricity used to make electrolytic hydrogen are counted in power generation estimates. At least 30 000 people work directly in low-emissions hydrogen supply, including manufacturing and installation of equipment, production, wholesale and transport. This represents more than a 20% increase in the workforce from 2022. This estimate rises to as much as 60 000 when considering research and development scientists or oil and gas workers who devote a portion of their time to low-emissions hydrogen.

Of the 97 Mt of total hydrogen produced in 2023, less than 1 Mt was low-emissions. Most low-emissions hydrogen is produced via steam-methane reforming with carbon capture and storage (CCS), while hydrogen production from water electrolysis remained below 100 kilotonnes (kt) in 2023. The largest portion of the jobs added in 2023 were in the construction and development of new facilities, with the global installed production capacity of water electrolyser hydrogen surpassing 1 GW for the first time. China was responsible for most of these capacity additions and, accordingly, is home to the largest share of low-emissions hydrogen employment today.

Employment in low-emissions hydrogen has already begun to benefit from a wide array of subsidies and incentives around the world. Jobs have grown steadily in the United States, where billions of dollars in funding and production credits for low-emissions hydrogen have been set aside by the Infrastructure Investment and Jobs Act and the Inflation Reduction Act in the last few years. The European Union has also witnessed rapid growth in the low-emissions hydrogen workforce, albeit from a small base, as it establishes plans to accelerate production and secure imports of renewable-based hydrogen throughout this decade.

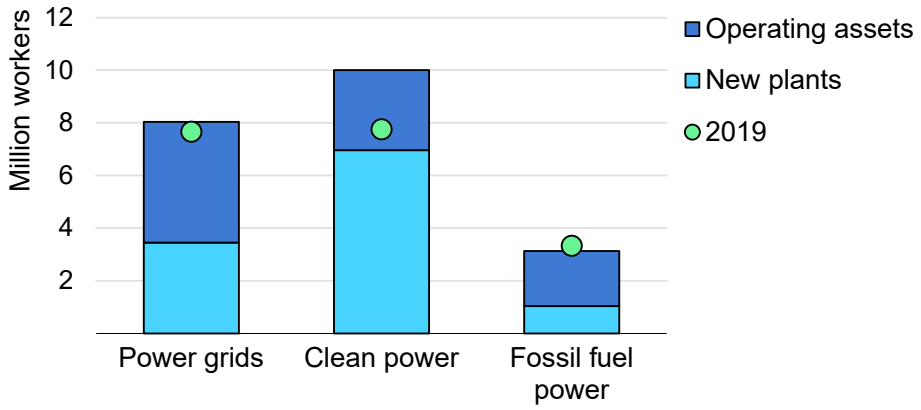
If all announced low-emissions hydrogen projects are realised, then cumulative production could reach 49 Mt by 2030, equivalent to nearly 75% of the total low-emissions hydrogen produced in the NZE Scenario. In reality, just a portion of these projects will likely come to fruition, which still leads the workforce to double by 2030 in the STEPS. In the NZE Scenario, labour demand from the low-emissions hydrogen industry soars as massive investments in manufacturing, production, infrastructure and end uses contribute to the realisation of the so-called global hydrogen economy. Achieving this vision will require commensurate levels of investments in training to build the needed workforce, but the low-emissions hydrogen industry has a substantial training capacity gap. Although workers with similar skills may transfer from the oil and gas industry, the sector lacks sufficient experienced instructors and institutions to train and accredit the huge quantities of new workers needed in a rapid scale-up scenario. Many initiatives have emerged to address this shortcoming, including UNIDO's Global Programme for Hydrogen in Industry and Germany's H2PRO research project.

Power sector

Power sector employment exceeds 21 million, with more than half of the workers involved in developing new projects

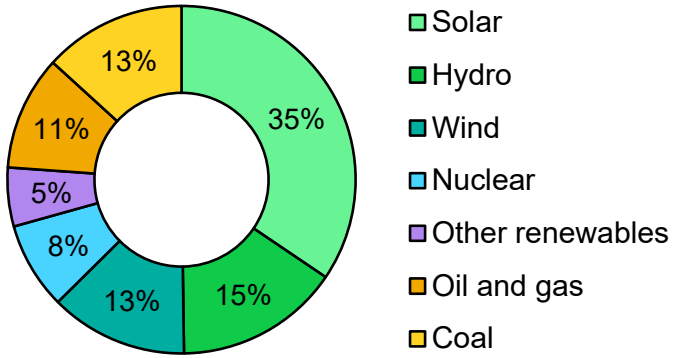
Global power sector employment exceeded 21 million in 2023, up 5% y-o-y. Power sector investment increased by around 15% from 2022 levels, to a record USD 1.3 trillion. Growth is set to continue in 2024 but at a more modest pace. While employment in grids and clean power increased steadily from 2019, fossil fuel power jobs maintained its flat to downward trend. Workers involved in the development and building of new projects represented more than half of all power sector employment at 11.5 million in 2023, with around 3 million in the manufacturing of system equipment, and over 6.6 million in the construction of power plants, damns, grids and mounting systems. Workers in the operations and maintenance of existing capacity totalled 9.7 million in 2023.

Employment by sector and asset type, 2023



More than three-quarters of the power generation workforce was employed in clean technologies in 2023. Solar PV jobs represented the largest share in the generation sector at 4.5 million, followed by hydropower at 2 million. Coal and wind power, including workers in onshore and offshore projects, both employed around 1.7 million each. While coal-fired power jobs decreased by 16% since 2019, coal workers still represent the third largest workforce in power generation in 2023, reflecting its importance in global electricity supply in many regions of the world.

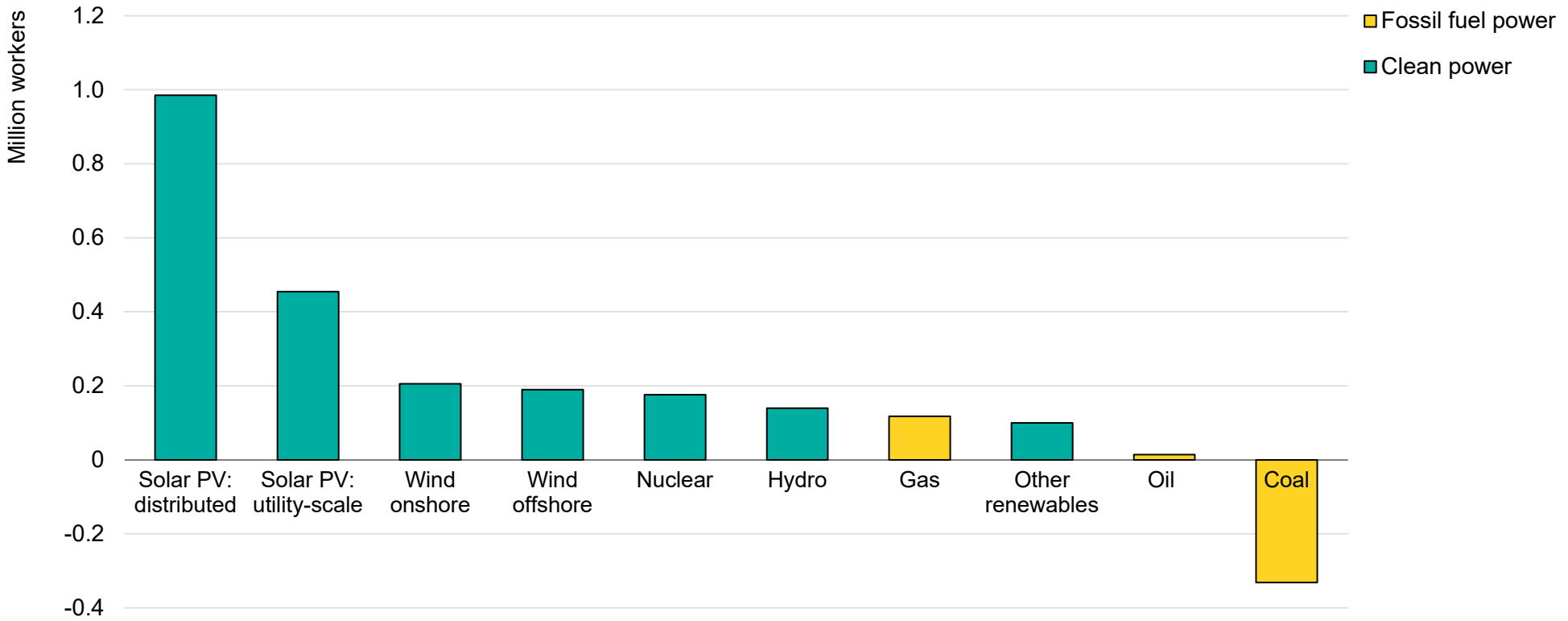
Employment in power generation by technology, 2023



Power sector employment totals over 24 million workers in the STEPS and 33 million in the NZE Scenario by 2030, with power generation employment accounting for 61% and 66%, respectively.

Clean energy employment in power generation added over 2.2 million jobs since 2019, while the fossil fuel workforce decreased by 6% over the same period

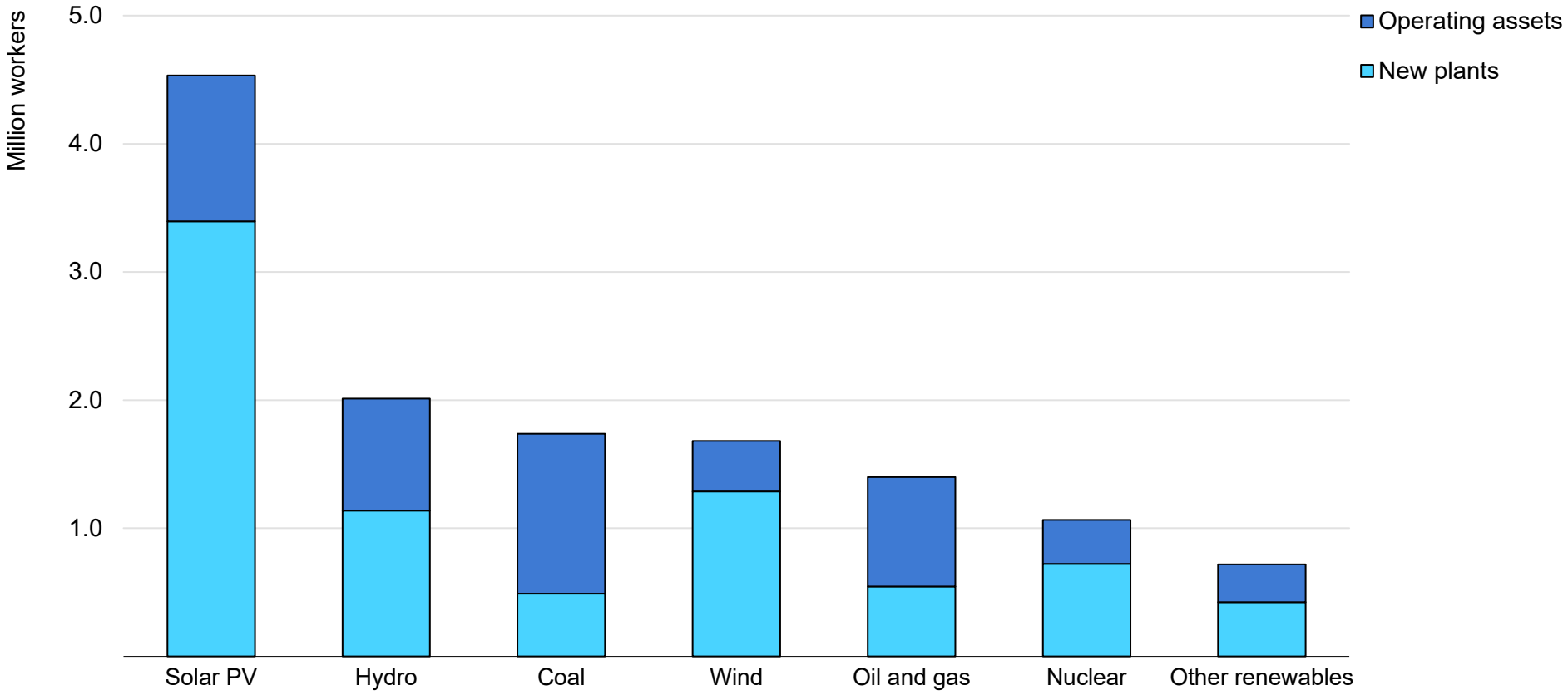
Employment change in power generation by technology, 2019-2023



Note: Distributed solar PV refers to rooftop, buildings and other small-scale installations. Utility-scale solar PV refers to solar farms, parks and larger commercial assets. Other renewables include geothermal, concentrated solar power (CSP), marine and bioenergy.

Over 85% of workers employed in the development and building of new projects are in clean energy sectors

Employment in power generation by technology and asset type, 2023



Note: Other renewables include geothermal, concentrated solar power (CSP), marine and bioenergy.

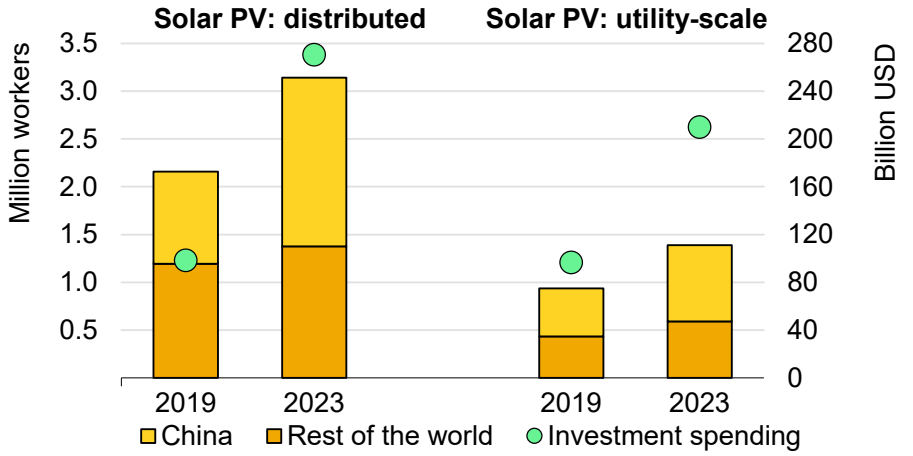
Solar PV employs more than 4.5 million workers, led by record investment spending globally

Solar PV solidified its position as the largest workforce in the power generation sector in 2023 at more than 4.5 million jobs, an increase of 13% y-o-y. Solar PV attracted a record USD 480 billion in spending in 2023, more than all other generation technologies combined, with China alone seeing solar PV spending jump by USD 70 billion to USD 220 billion.

Employment in the sector is concentrated in the installation of new capacity, with manufacturing and construction accounting for two-thirds of total solar PV jobs. Construction, which includes the installation of solar panels in both individual homes and utility-scale solar farms, is by far the largest contributor to employment in the sector, representing nearly half of all PV jobs worldwide. Manufacturing, which covers production of polysilicon, wafers, cells, modules, and inverters, as well as racking, mounting, and other components, represents nearly 20% of PV employment. China, where the vast majority of the world's solar panels are manufactured, accounts for nearly 85% of global manufacturing jobs and more than 50% of global construction. Nine out of the top twelve solar manufacturers in the world are Chinese companies, including JA Solar, Trina Solar, and Jinko Solar.

Around 70% of PV jobs today are associated with distributed solar (rooftop and other small-scale installations), which is more labour intensive per unit installed than utility-scale projects. Distributed solar PV installations total over 3.1 million jobs, a 13% increase from 2022 levels. This growth is driven by the increasing number of installations in industrial parks in China, contributing to the large increase of this part of the workforce.

Employment and investment spending in solar PV sectors, 2023

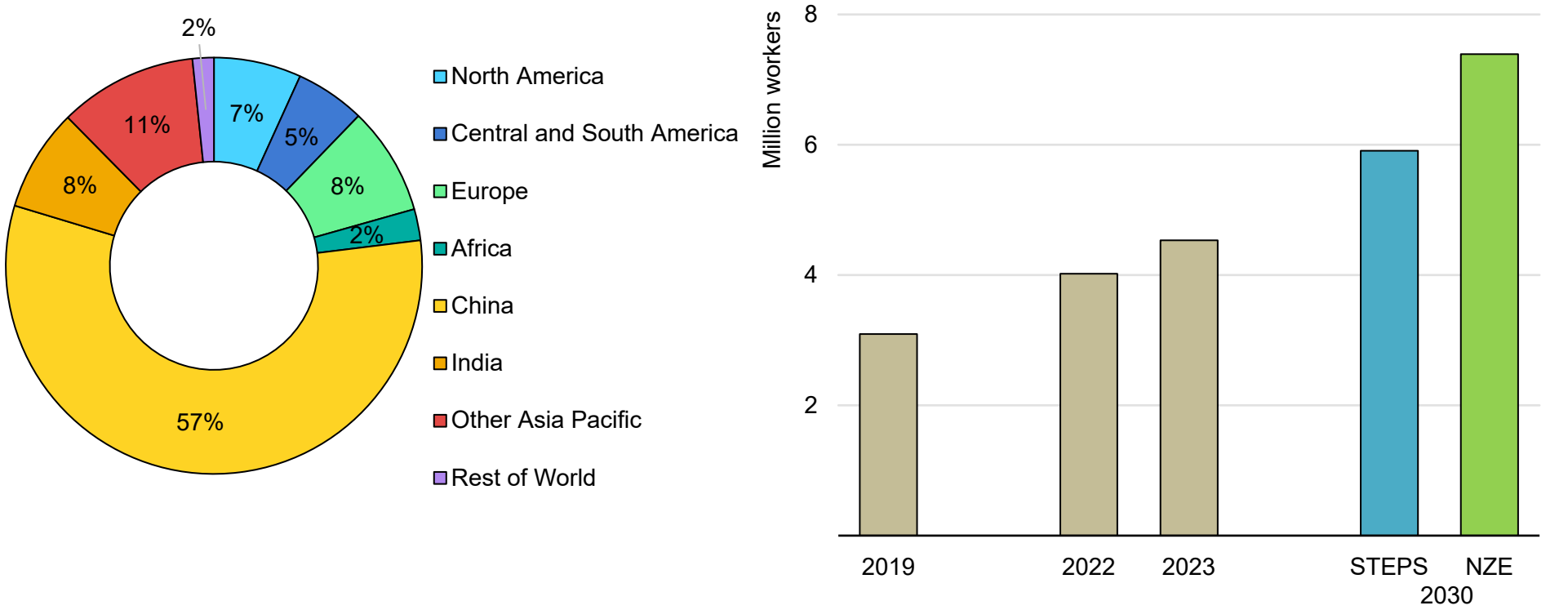


In regions without universal electricity access, off-grid solar home systems are playing an increasingly prominent role. In sub-Sharan Africa, nearly 10% of households with access to electricity rely on these systems, fuelling employment growth in the region.

While growth in investment spending may moderate slightly in 2024 due to falling prices of PV modules, capacity added will continue to increase as more is added per USD spent. In the STEPS, the solar industry reaches over 5.9 million jobs, while employment grows much faster in the NZE Scenario, to nearly 7.4 million by 2030.

China accounts for well over half of all solar jobs and is set to remain the largest employer as the workforce grows in the Stated Policies Scenario and NZE Scenario

Employment in solar PV by region in 2023 and by scenario in 2030



Notes: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Despite permitting delays, high interest rates, shipping costs and supply chain disruptions in offshore projects, employment in the wind industry grew by 8% year-on-year

Global employment in wind power was nearly 1.7 million in 2023, up by 8% y-o-y. Global wind capacity additions rose by 50% to 116 GW in 2023, with onshore wind projects accounting for over 90% of these additions. China alone captured 65% of global wind expansion, doubling its capacity additions since 2022. In advanced economies, growth has been slower, with 15.5 GW of additional capacity in the European Union, only 2% higher than in 2022. By contrast, US capacity rose just above 6.4 GW, down from a rise of 8.5 GW in 2022.

China leads both onshore and offshore employment with around 50% of total wind power jobs worldwide, followed by Europe with 20%, then other Asia Pacific with 14%, and North America with roughly 10% each. Onshore projects account for approximately three-quarters of all wind jobs, and grew 4% y-o-y. The majority of the workers are in the manufacturing and construction sectors, accounting for 28% and 36%, respectively. An estimated 27% is in the professionals and utilities sector, with workers involved in the design, planning and maintenance of projects, as well as the integration of wind-generated power into the electrical grid. A smaller 10% share is in wholesale and transport, responsible for the logistics of moving wind turbine components from manufacturing sites to construction locations.

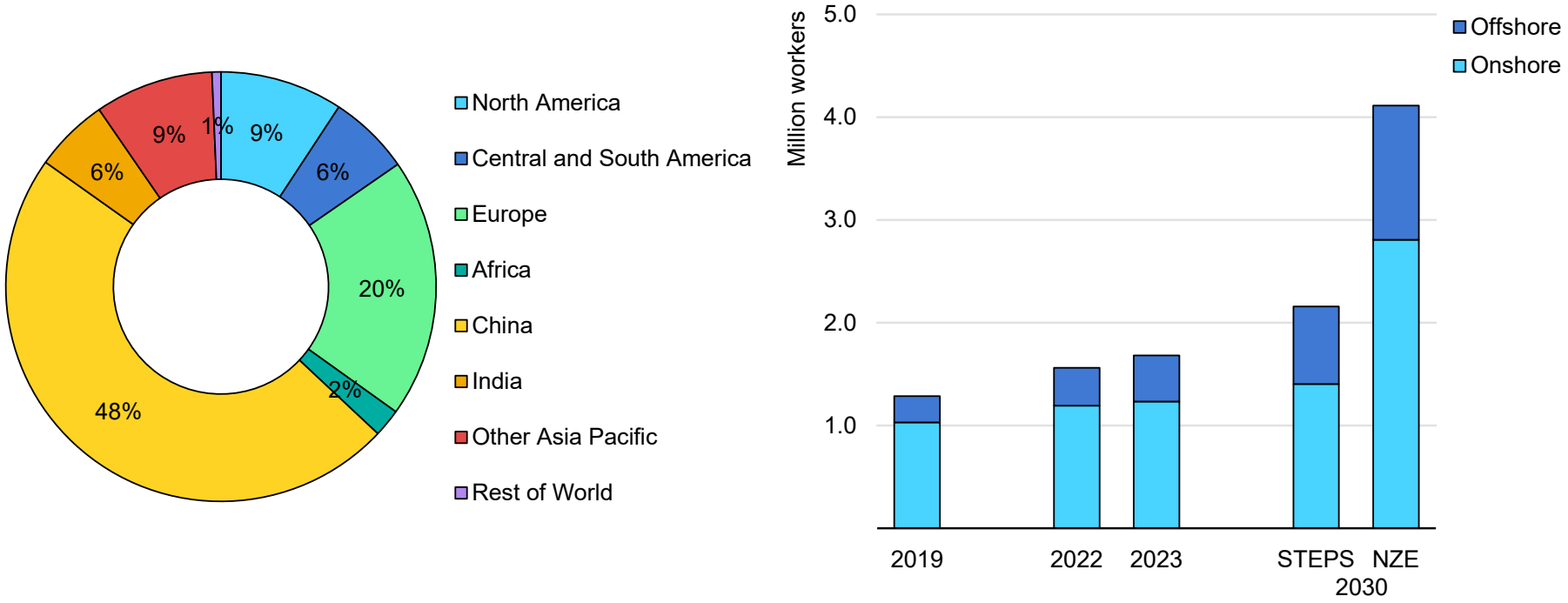
Compared to other sectors, construction jobs in the wind industry require more specialised skill sets, but a lack of skilled technicians has been a challenge for efficiently developing new projects. In the United States, 94% of construction employers reported at least some difficulty in finding qualified workers, while vacancy periods of six months were reported for wind technicians in Germany. In some regions like Europe the lack of homogeneity in training and certifications hinders the transfer of workers, which is particularly problematic in an industry that requires a mobile workforce due to the geographic limitations of wind farm localisations.

Growth in wind employment in 2023 masks headwinds faced by many major wind developers and original equipment manufacturers (OEMs), especially in the offshore wind industry. High interest rates, slower-than-expected project developments, international shipping costs, and supply chain disruptions put the industry under pressure and resulted in layoffs across the largest employers. Siemens Gamesa, General Electric and Orsted cut thousands of jobs in 2023, with offshore wind projects the most severely hit. Due to permitting delays and cost increases, contracts in wind offshore projects previously agreed at low prices saw cancellations in 2023. For example, 7 GW of planned capacity was cancelled in the United States, and 4 GW are under renegotiation at prices that are on average two times higher. Similarly, projects had to be cancelled in the United Kingdom, with the 2023 auction failing to attract offers, and prompting an increase of the strike price by 165% for its 2024 auction. As a result, growth in manufacturing jobs slowed down in Europe compared to previous years, and flatlined in the United

States. Still, China's wind energy jobs grew by more than 56 000 last year, representing almost half of global growth in wind employment.

Despite difficulties faced by the offshore wind industry, job postings for critical occupations are on the rise, particularly for wind-turbine technicians. Notably, in the United States postings for skilled technicians have increased sixfold since 2018 and are forecast to further rise by 60% over the next decade, according to the Bureau of Labor Statistics. The U.S. Energy and Employment Report (USEER) also noted a rise in wind jobs based on secondary labour surveys, confirming these countervailing trends. Wind jobs reach 2.1 million in the STEPS by 2030 and just above 4.1 million in the NZE Scenario. Onshore wind remains the primary employer in both scenarios, although the share of offshore jobs increases to one-third in the NZE Scenario and 35% in the STEPS by 2030, versus 27% today.

Employment in wind by region in 2023 and by scenario in 2030



Notes: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Hydropower is the second largest employer in the power generation sector, but ageing demographics and the lack of policy support jeopardise the future workforce

The hydropower workforce, including pumped hydro storage, was the second biggest employer in the power generation sector in 2023, after solar PV. Global employment totalled over 2 million jobs, a moderate 3% increase y-o-y. In many regions, negative public perception continues to hinder the development of new projects. Investment in hydropower fell slightly in 2023 and is expected to be even lower in 2024.

Growth in hydropower employment is driven mainly by new projects under construction, with jobs in that sector increasing by 6% versus 2022. These projects include, among others, a 2.4 GW Ituango project in Colombia, a 1.3 GW Mentarang Induk project in Indonesia and a 740 MW Zungeru project in Nigeria. The 2 GW Laucu hydropower station in Angola became fully operational in 2023. Although hydropower installations in Europe and North America are mature and little new greenfield conventional hydropower is expected, some countries have plans to expand their run-of-river hydropower and pumped hydro storage capacity.

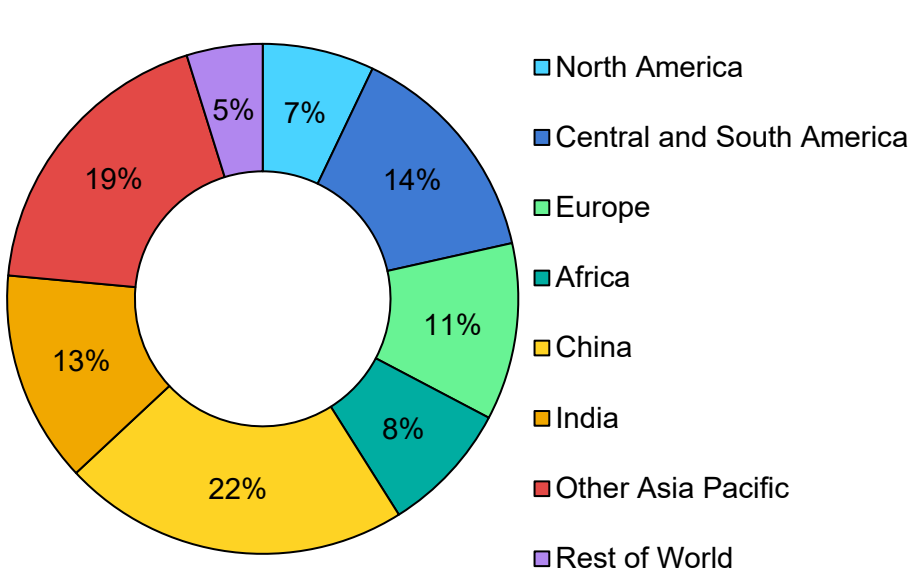
China remains the largest hydropower employer globally, with approximately 440 000 workers, followed by other Asia Pacific and Central and South America. A number of major hydropower developers in China also play a significant role in international project developments, like the USD 5 billion Santa Cruz River project in Argentina, financed 70% by the China Gezhouba Group Company. Additionally, repowering existing hydropower projects is contributing to employment growth in some regions, and can be quite labour intensive due to substantial dredging.

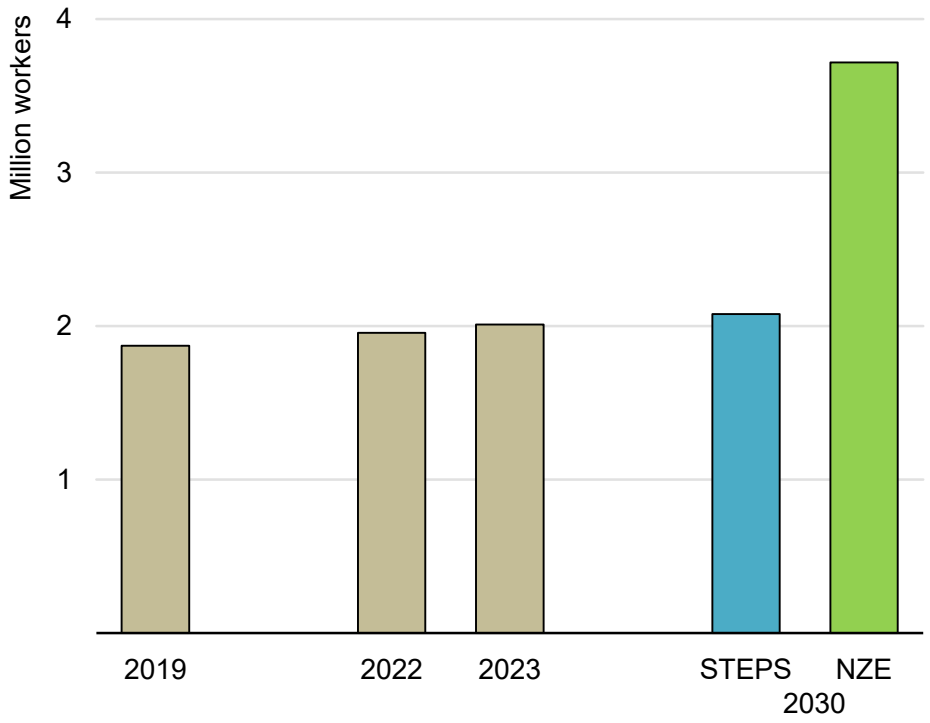
The industry faces demographic challenges, especially in the United States and Europe, where many workers are retiring. In the United States, about one-quarter of the current workforce is already eligible for retirement or will be within the next decade. However, the recruitment of new workers is challenged globally by the lack of hydropower-focused degrees and vocational programmes, as well as workers not wanting to relocate to work in remote locations. Redeveloping vocational programmes with the hydropower industry can help cultivate a new pipeline of skilled workers and change the perspectives on the sector. In an ongoing project in Georgia in collaboration with India's Tata Power Skills Development Institute, vocational schools were mapped out across the country and dedicated hydropower programmes were developed in schools located near plants. The hybrid format between in-class sessions and practical work at the plants aims to attract more young students.

Global hydropower employment grows by less than 1% y-o-y between 2023 and 2030 due to a moderate increase in new construction projects and unstable investments. In the NZE Scenario, several projects boost jobs in manufacturing and construction, including small run-of-river hydropower and pumped storage hydroelectricity, driving employment to 3.7 million by 2030, a 9% average yearly increase since 2023.

China remains the largest hydropower employer and is increasingly involved in the development of international projects, but global job prospects hinge on supporting policy

Employment in hydropower by region in 2023 and by scenario in 2030





Notes: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

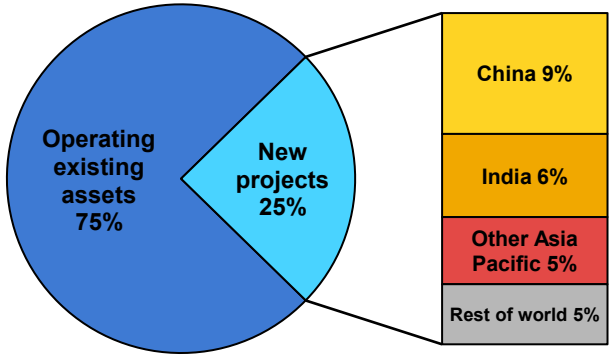
Despite record demand in 2023, productivity improvements lead to a drop in coal power jobs

Over 1.7 million people worked in coal-fired power generation, excluding mining and other supply jobs, in 2023, which saw the highest coal demand of all time. Coal remains the single largest energy source for power generation worldwide, accounting for 36% in 2023. After market disruptions and shortages led to record high prices in 2021 and 2022, countries that are very dependent on coal such as China and India invested heavily in both supply and new generation capacity. In 2023, these two countries added over 50 GW of coal-fired power capacity and account for nearly three-quarters of coal power employment. Nonetheless, the long-term pipeline for new capacity is drying up, especially following China's announcement in 2021 that it would stop building coal plants abroad. This, combined with productivity improvements, has led to a significant decline in jobs manufacturing coal power generation equipment, with employment in this category down by one-third from 2021.

Advanced economies have been reducing reliance on coal power, running plants less often or retiring them altogether. As a result, advanced economies accounted for 90% of the 26 GW of coal capacity retired around the world in 2023, and just 10% of coal power employment.

The use of coal for power generation, and therefore employment in coal-fired power, declines rapidly in all scenarios as efforts to transition away from unabated coal accelerate. New IEA analysis suggests that generation from renewables will surpass that from coal for the first time by 2025. In 2023, the central outcome of COP28 for the first time included an agreement to transition away from fossil fuels, including coal. About 60 national governments have joined the Powering Past Coal Alliance and committed to ending the use of unabated coal for power generation, and the G7 countries in April 2024 agreed to phase out it by 2035.

Employment in coal power by asset status and region, 2023



Coal power employment drops by nearly 330 000 jobs in the STEPS, equivalent to nearly 20% of the existing workforce. Employment is stickier at coal plants that maintain or scale down generation instead of ceasing operations entirely, as most workers at a given plant will still be needed even if its capacity factor declines. The job decrease in the NZE Scenario is greater, as achieving net zero emissions will essentially require a complete phase out of unabated coal power. This leads to a 50% decrease in coal power employment by 2030, with about 880 000 workers in coal power generation remaining at the end of the decade.

Gas-fired power generation employment growth slows as Europe reorients to alternative sources for electricity

Employment in gas-fired power generation, which does not include workers in gas supply, continued its upward trend from the pandemic to reach 1.2 million in 2023. The 4.7% y-o-y increase represents a slight slowing of growth from previous years: employment grew by 6% in both 2021 and 2022. The majority of workers, around 60%, are employed in the operations and maintenance of natural gas power plants. The remaining 40% are concentrated in manufacturing and construction, a higher share than for coal as gas plants require fewer workers for onsite operations and maintenance. The proportion of workers involved in building new plants and their components, which is more labour intensive than the operation and maintenance of existing capacity, is higher in emerging markets and developing economies than in advanced economies, at 45% compared to 33%.

Gas-fired power generation employment remains concentrated in Asia Pacific, the Middle East and North America, with employment growing by over 2.5% y-o-y in each region. Europe had the slowest employment growth of any major region in 2023, due to tight natural gas markets following Russia's full-scale invasion of Ukraine and resulting declines in gas-fired power generation.

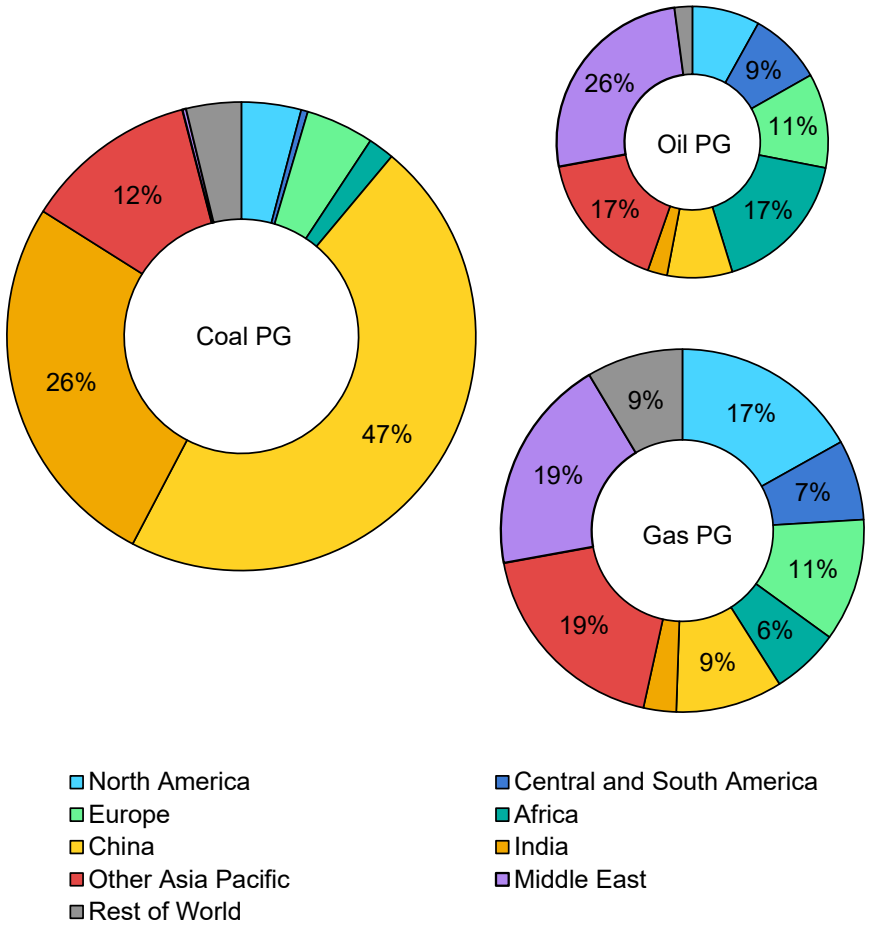
Global employment in the sector is set to decline slightly by 2030 in the STEPS as growth in capacity installed slows down, but this trend masks regional differences. In advanced economies, like North America or Europe, gas-fired employment decreases, while jobs in the Middle East and Africa increase by 2030 in the STEPS. Job prospects in all regions hinge on the acceleration of the pace of electricity demand growth, coal-to-gas switching, and delays of or reductions in renewables expansion.

Research and development efforts include the retraining and reskilling of workers as the transition progresses and a number of natural-gas fired power plants diversify to hydrogen-ready or ammonia-powered turbines. 2023 saw new project developments, with Siemens successfully operating a modified gas turbine with 100% hydrogen. Mitsubishi Heavy Industries is developing an ammonia-powered turbine, planned for commercialisation in 2025.

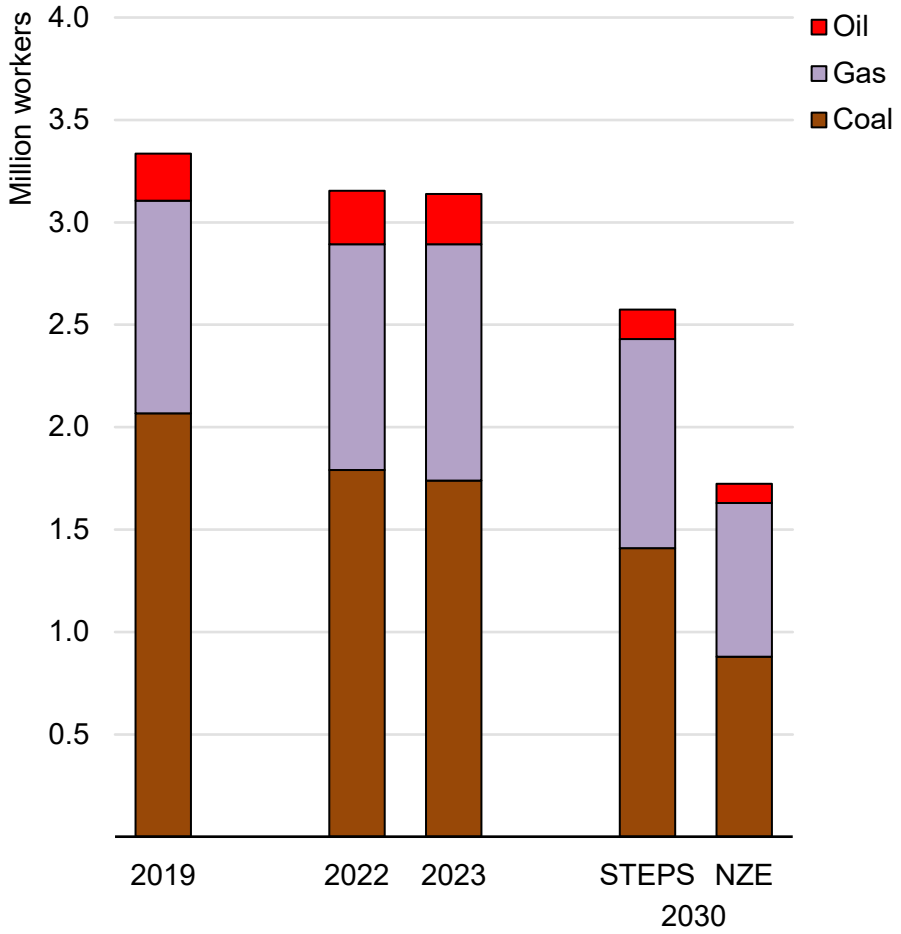
Oil-powered generation employment maintains its position as the smallest workforce of fossil fuel power, with around 245 000 jobs in 2023. Oil remains an important part of the electricity mix in some regions like the Middle East, accounting for 25% of total electricity supply. In Africa, over 40% of the population lacked access to electricity in 2023 and one in three with access experienced frequent outages, prompting many to buy off-grid gasoline and diesel generators. Diesel generators are also in high demand for use in remote locations and at construction sites, providing essential support for uninterrupted operations. Still, jobs decrease by 2030 in the STEPS, to 143 000, with centralised stations increasingly shifting towards natural gas, and distributed renewables and batteries gradually decreasing the prominence of back-up generators in remote applications.

Jobs in fossil fuel power continue to decline as the world commits to the energy transition

Employment in fossil fuel power generation by region, 2023



Employment in fossil fuel power generation by fuel and scenario



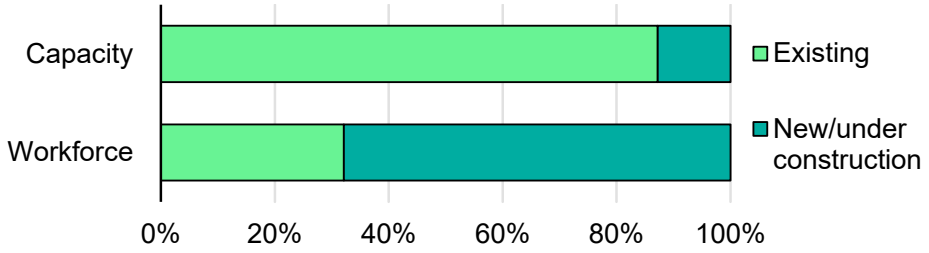
Notes: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Employment in nuclear power increases as investment grows steadily

The global nuclear power industry approached 1.1 million jobs in 2023, a 6% increase over 2022. Capacity additions were about 30% lower year-on-year, with five new reactors coming online in Belarus, China, Korea, the Slovak Republic and the United States. Despite the drop in capacity additions, growth in 2022 and 2023 was similar, with investment rising by 2% and long lead times for reactor construction tempering year-on-year fluctuations. Around the world, there were 59 nuclear reactors with a cumulative 61 GW of capacity under construction at the end of 2023, equivalent to a 15% increase in global nuclear capacity once all are brought online.

Nuclear energy has maintained a share of about 10% of global electricity supply for over a decade. Today, there are 415 nuclear reactors in operation in over 30 countries. Although existing nuclear capacity is over five times greater than the amount of capacity under construction, only about one-third of jobs in the nuclear industry are focused on operating existing plants. This means that countries such as the United States and Canada, which are not currently undergoing large-scale expansion of their nuclear programmes, do not constitute a large portion of nuclear employment despite their sizeable existing capacity. Manufacturing and constructing a nuclear power plant demands a significant number of highly specialised staff who generally require many years of training before working on projects for 7-12 years over the development, licensing, manufacturing and construction process. These jobs therefore tend to be highly paid, with nuclear employees earning about 50% more on average than workers in other power generation sectors.

Global nuclear power capacity and workforce by status, 2023

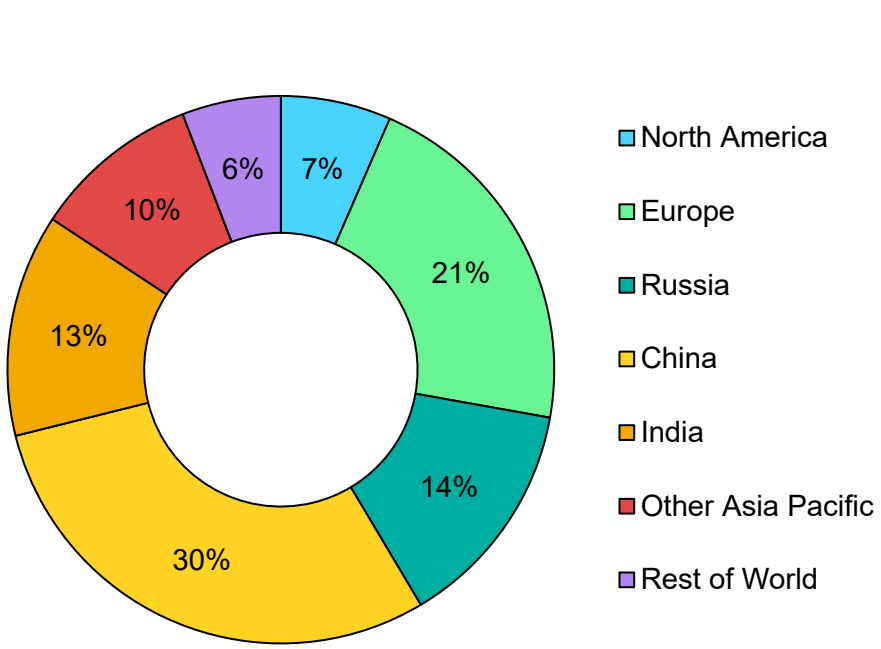


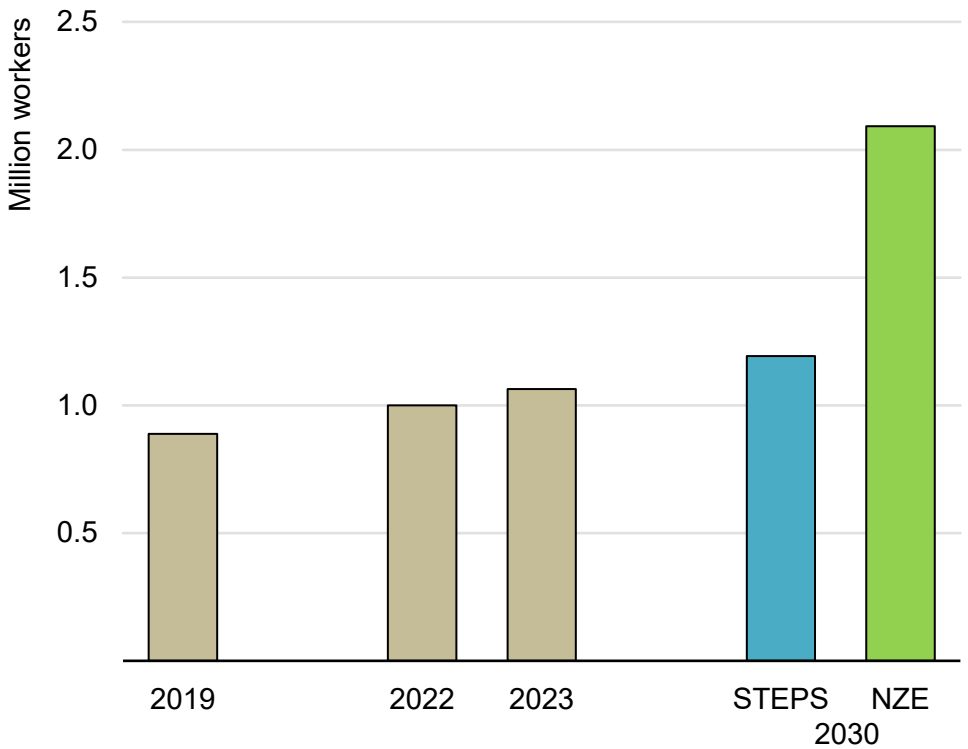
The dominant player in the nuclear supply chain is China, which is currently constructing 29 domestic reactors on top of its existing fleet of 56. China is also a major manufacturer of components for both domestic and foreign nuclear power plants, resulting in a higher-than-average share of manufacturing in total nuclear employment, at over 60%. As a result, China is the leading employer in this technology, home to nearly one-third of the nuclear workforce and around 60% of job growth in 2023. Europe and the rest of Asia Pacific follow at just over 20% each, with India representing over half of the latter's share.

Nuclear employment only moderately increases through 2030 in the STEPS but nearly doubles in the NZE Scenario, to reach 2.1 million jobs. This expansion is fuelled by new reactor construction and slower but steady growth in operating jobs, with annual capacity additions in 2030-2035 1.5 times the average in 2024-2029.

Nuclear power employment moderately increases in the Stated Policies Scenario but soars on the path to net zero

Employment in nuclear power by region in 2023 and by scenario in 2030





Notes: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

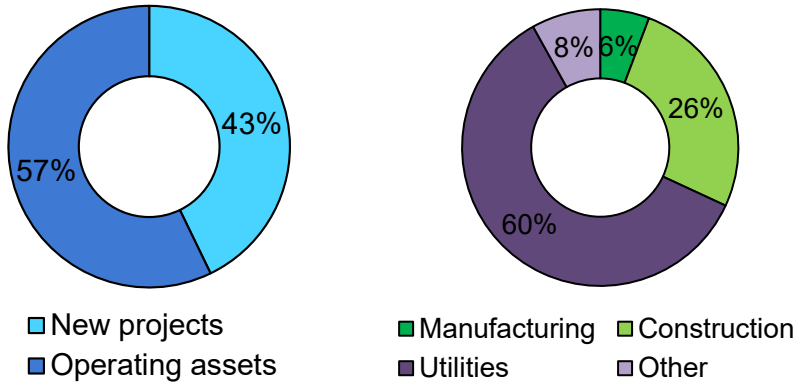
Employment in power grids is increasing, but the sector faces pressing skills shortages

Grid investment continued its rise in 2023 and is expected to reach USD 400 billion in 2024, with Europe, the United States, China and parts of Latin America leading the way. Employment in power grids is slowly but steadily growing globally, exceeding 8 million jobs in 2023. Growth in power grids employment remains regionally concentrated, with China and advanced economies representing more than half of total employment in the sector. Similarly, China and advanced economies lead investment in power grids, accounting for about 80% of global spending in 2023. While investment in EMDEs other than China is increasing, jobs have only slowly been picking up in Africa and Southeast Asia. However, objectives to achieve universal access to electricity are driving employment in Africa, in particular in the production of mini- and off-grid solutions.

Around 60% of jobs in the transmission and distribution segments are in the operation and maintenance of the grid, with workers responding to outages and customer connections, including meter reading. In countries that have experienced rapid expansion of their power grids, the share of workers in the manufacturing and construction sectors can be much higher. In China, for example, construction workers represent 42% of the workforce. Transmission and distribution jobs total 9 million by 2030 in the STEPS, a 1% increase from 2023. However, employment prospects vary from one region to another, and higher investment in robust and digitalised grids is needed, especially in EMDEs.

While they account for a small share of grids employment today, battery storage jobs have seen strong year-on-year growth, increasing by 20% since 2022. Sharply declining costs helped battery storage investment double in 2023 to USD 40 billion. As system flexibility needs increase, battery storage is set to be one of the fastest growing technologies in the power sector by 2030. In the STEPS, jobs more than triple by 2030, while employment grows by a factor of six in the NZE Scenario.

Global employment in grids by type of asset and activity, 2023



Note: Employment in grids include jobs in electricity transmission, distribution and storage.

Emerging and innovative technologies, such as drones, can help operators with maintenance activities by identifying potential issues with real-time, high-resolution data on the condition of the grid. In

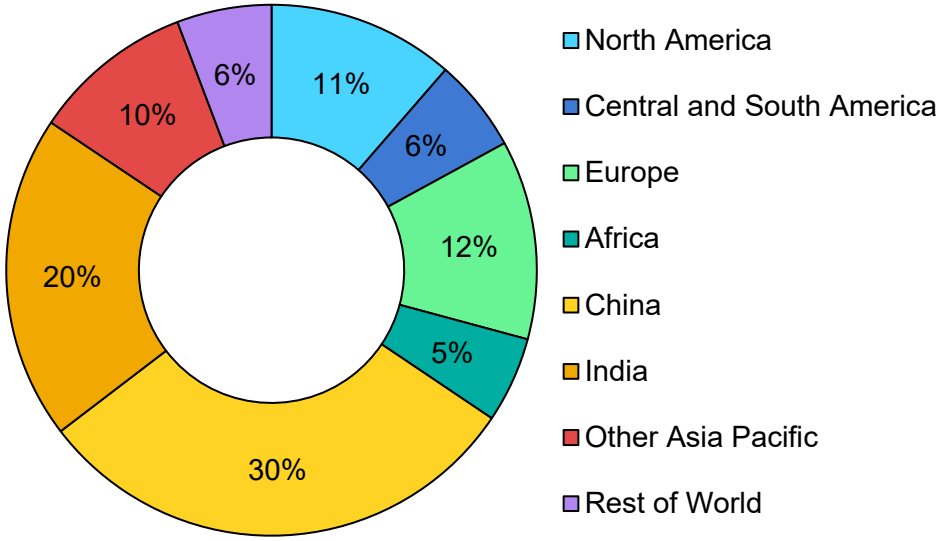
addition, advancements in the use of smart grids and artificial intelligence presents opportunities to improve workers' safety. However, more attention needs to be put on proper training of digital skills to ensure a smooth transition. In a survey conducted by the IEA with over 190 energy companies, utilities ranked digital skills such as data analysis, programming and digital literacy as the most important when hiring, ahead of both soft and technical skills. In addition, energy recruiters face cross-sectoral competition, with advanced digital skills in high demand across industries. Public utilities, in particular, must contend with strong interest from major technology firms and the financial sector, especially when targeting younger talent.

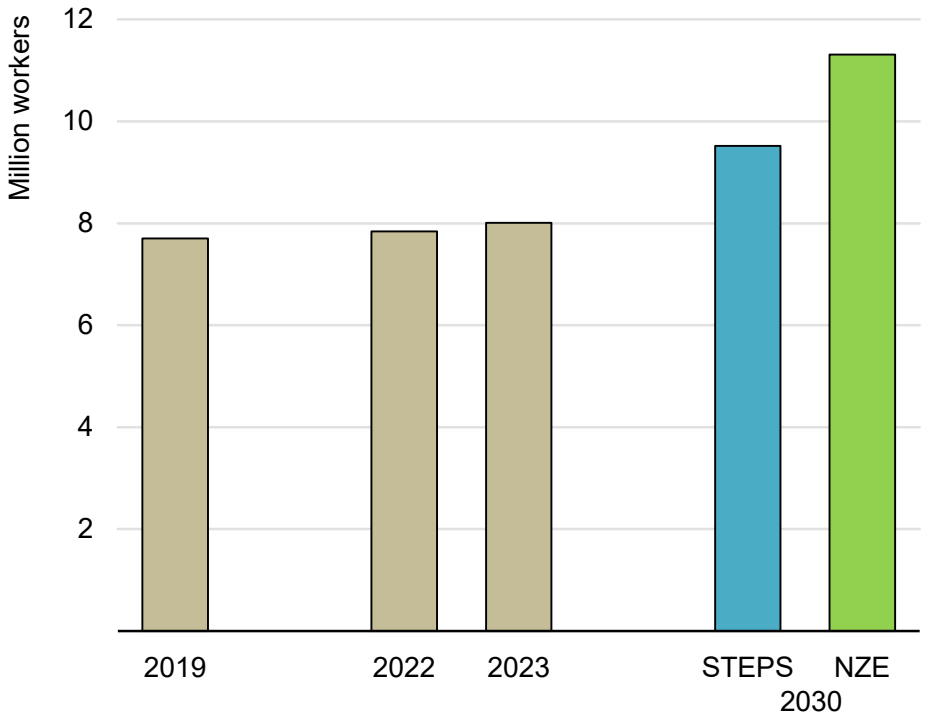
Ongoing labour shortages in the manufacturing of grid equipment, as well as a lack of specialised electricians, engineers and construction workers, has led to longer lead times for new projects, presenting headwinds for many countries who are urgently trying to address the lag in grid extensions to integrate new renewables. In the United Kingdom, a survey conducted by the country's leading energy union shows that 69% report tangible skills shortages, with engineers the principal concern.

Digital skills are also increasingly in demand for non-IT workers, necessitating rapid and profound adaptation of the workforce. In Europe, the electricity sector ranked among the highest for the percentage of online job postings requiring at least one digital skill, at almost 50% compared to 35% in 2019.

Employment in power grids rises in the near future in both scenarios, but higher investment in robust and digitalised grids is needed, in particular in emerging and developing economies

Employment in grids by region in 2023 and by scenario in 2030





Notes: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Innovation in digital tools, including artificial intelligence, are improving worker safety while creating new employment opportunities

Artificial intelligence has emerged as one of the most talked about innovations in recent years, with every industry trying to understand the implications and opportunities for their sector. The power sector has increasingly been employing new digital technologies to help improve system operation, performance, safety and efficiency, and is finding ways to employ artificial intelligence alongside other investments in digitalising grid systems.

Past digitalisation efforts have not historically led to large reductions in headcount, but instead promulgated meaningful improvements in performance, safety and efficiency. Launched in 2018 by Enel Green Power, RoBoost aims to widely implement ready-to-deploy robotic technologies for operations and maintenance (O&M) activities, primarily in wind and solar plants. One of the outcomes of the programme is the inspection of over 25 million photovoltaic (PV) modules (equivalent to more than 8 GW) using drones. Through the application of artificial intelligence algorithms, computers can detect potential repairs or optimisations that need to be made, helping classify various types of failures in PV plants, such as tracker misalignment, string outages, hotspots, delamination and cracks. By 2022, the number of robotic activities had risen to 16 000, including significant tasks like the robotic maintenance of wind turbine generators and internal blade inspections.

These technologies play an important role to enhance the safety of the workforce by identifying potential equipment failures or hazardous conditions, allowing for timely interventions. In transmission operations, the use of remotely controlled robots to trim vegetation near power lines and carry out safety inspection activities, allows operators to stay out of high-risk areas, avoiding electrical contacts, falls and object drops. Similarly, wind offshore employers such as Siemens Gamesa or Orsted use digital twins, a virtual replica of physical assets, to simulate maintenance and repair scenarios on offshore wind turbines. These practices allow for better planning and training to ensure workers perform tasks safely on-site. Recently, the European Union announced the Federated Digital Twins for Wind-Offshore (DTWO) programme to develop the technology and integrate existing models.

The development of these technologies can also facilitate the smooth transition of workers across non-linear career paths, as many digital skills acquired in one area of the sector are transferable to others. For instance, workers formerly employed in thermal power plants have been trained as drone operators for renewable energy plants. Additionally, new digital learning tools, including augmented and virtual reality, can expedite training while enhancing safety.

Vehicles and energy efficiency

Vehicle employment finally returns to pre-pandemic levels, with the share of autoworkers focussed on electric vehicles sharply rising

Employment in vehicle manufacturing and EV batteries reached 13.4 million in 2023 – surpassing pre-pandemic levels for the first time as sales recovered and supply chain bottlenecks eased. The vast majority of these jobs (10.8 million) remain focused on manufacturing internal combustion engine (ICE) vehicles and their upstream components, but EVs accounted for a rising share at 1.3 million and EV batteries at 1.4 million, with China representing more than 70% of these jobs.

Employment in EV manufacturing has been driven by immense growth in sales in recent years, with purchases of electric cars more than six times higher in 2023 than in 2018. Demand has been supported by robust policy incentives and falling prices for consumers, despite tight profit margins, volatile battery metal prices, high inflation, and the phase out of purchase incentives in some countries. Global EV jobs grew by 280 000 in 2023, representing a 28% increase on the previous year. 73% of these additions were in China, followed by 24% in advanced economies.

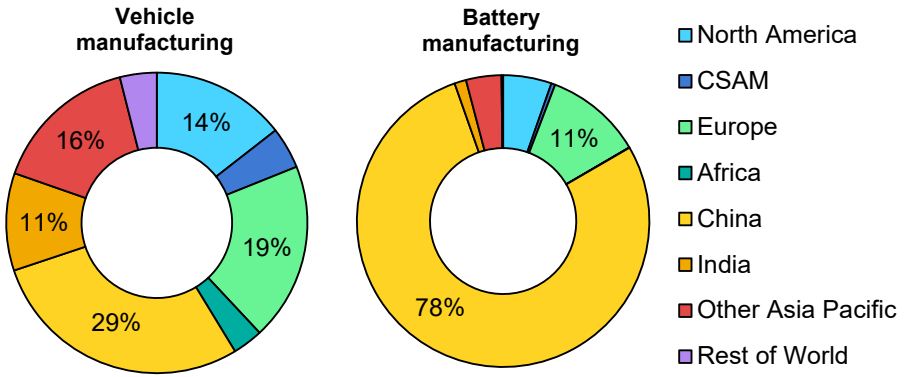
Much of the policy support for the rollout of EVs has come in the form of fiscal incentives, regulations, skills programmes and trade policy aimed at encouraging domestic production of EVs, as governments around the world target the onshoring of clean energy technology manufacturing. The US Inflation Reduction Act (IRA) requires vehicles to be assembled in the United States in order to qualify for the Clean Vehicle Tax Credit, spurring USD 126 billion of private investment in the EV industry in the two years following the IRA passing into law. In India, consumer purchase incentives have been supplemented by supply-side support via the Production Linked Incentive (PLI) scheme.

Despite these significant policy interventions elsewhere, EV production remains dominated by China, where one in three vehicles produced are now electric. This is fuelled both by continued strong demand, but also a rising global export market, with China surpassing Japan in 2023 to become the world's leading auto exporter. Growing EV sales in other EMDEs, particularly in Brazil and the Southeast Asia region, have proved to be a sizeable market for these exports, where cheaper Chinese models have begun to close the price gap with comparable ICE vehicles. Despite stronger domestic demand in these regions, local automakers struggle to compete with their Chinese rivals. As a result, EMDEs other than China account for less than 2% of jobs in EV manufacturing. While India has successfully protected domestic automakers through import tariffs, an alternative strategy adopted in many EMDEs has been to encourage Chinese companies to build factories locally, with new facilities notably announced in Thailand and Brazil.

Meanwhile, the European Union, supported by the Net Zero Industry Act and the relaxation of state aid rules, also shows signs of maintaining a substantial market share going forward, with 45 000 EV manufacturing jobs added in 2023, to reach 230 000, and

accounting for 18% of the global total. ICE vehicle manufacturing jobs make up around a quarter of energy employment in advanced economies, which may represent an opportunity for these regions to capture a sizeable share of the ascendant EV market, given that most vehicle manufacturing employment is in non-drivetrain-specific tasks such as assembly and manufacturing of other components.

Share of workforce by region, 2023



Note: CSAM = Central and South America

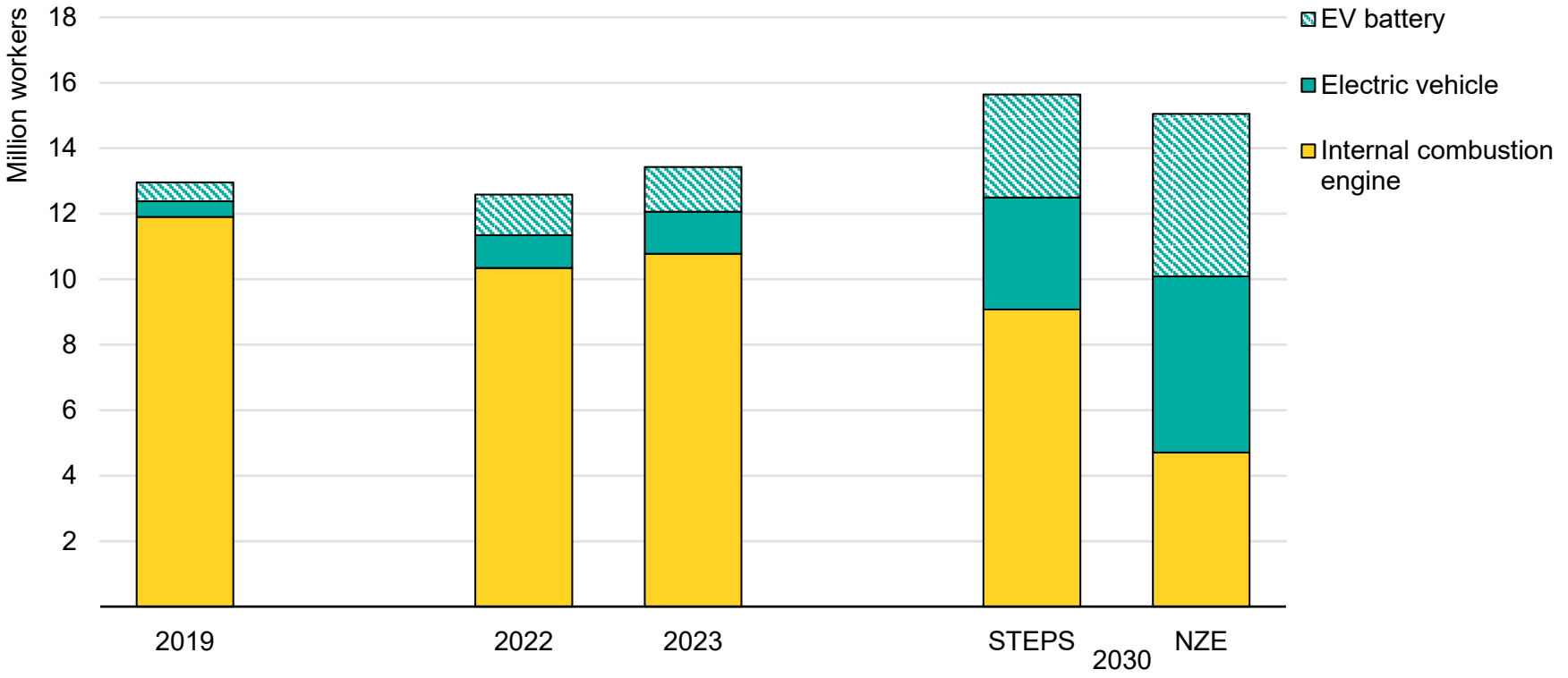
China dominates EV battery manufacturing to an even greater extent, surpassing 1 million jobs in 2023, or 78% of the global workforce. Battery manufacturing tends to be located close to the site of the demand (i.e. the EV production). The same is true in the European Union and North America, the other two major battery manufacturing regions, in each of which the battery workforce is expected to reach 120 000 in 2024. However, these regions also rely on EV battery imports from China. Growth rates in battery manufacturing have also been strong elsewhere, with many regions such as India, Southeast Asia and Africa seeing employment at least double in this sector between 2019 and 2023.

The recent expansion of EV demand has significantly cut into the market share of ICE vehicles. While the ICE vehicle industry has recovered 260 000 jobs since 2020, this still represents a decrease of 1.1 million workers involved in ICE compared to pre-pandemic levels. No region has escaped this impact, with all seeing at least a 7% fall in employment in the ICE vehicle sector since 2019. However, the countervailing gains in EV jobs have been much more unevenly distributed: only China has seen a net gain in vehicle manufacturing employment since 2019, as its large EV job additions have more than compensated for its ICE vehicle job losses.

The trend of rising shares of EV and battery jobs in vehicle employment looks set to continue in the medium term. Our analysis suggests that overall employment in the vehicle sector will continue to rise in the STEPS, from 13.4 million in 2023 to 15.6 million by 2030, but with a marked shift away from ICE vehicle jobs to the EV sector. ICE vehicle employment is projected to decline by 1.7 million to 9.1 million over the same period. These job losses would be compensated by an even greater number of EV manufacturing and EV battery job additions, which total 2.1 million and 1.8 million, respectively. This would represent a 150% increase in the workforce in the latter two categories.

A similar, but deeper, transition would occur in the NZE Scenario, where ICE vehicle jobs would fall to 4.7 million by 2030, compensated by rises in EV and battery manufacturing employment to 5.4 million and 5 million, respectively. However, total vehicle employment (including EV batteries) under the NZE Scenario is lower in 2030 than what would be seen in the STEPS. This is driven in part by economies of scale, but also because the NZE Scenario assumes a larger role for behavioural change and modal shift in helping to drive down emissions in the transport sector and, as a result, overall vehicle sales in 2030 are lower in the NZE Scenario than in the STEPS.

Global employment in vehicle and battery manufacturing by year and scenario



Notes: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

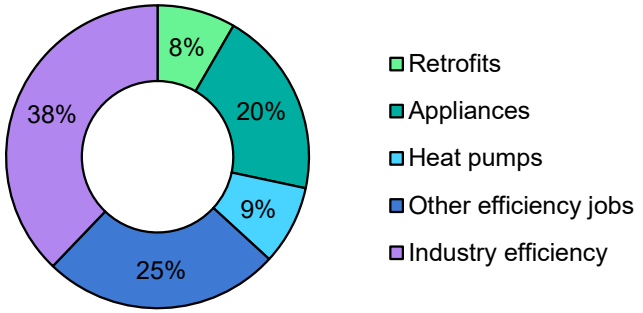
Energy efficiency jobs remained stable, largely due to weak investment in 2023

Energy efficiency investment in buildings and industry were affected by a worsening financial climate in 2023, with inflation and higher interest rates making it more difficult for end-users to invest in new energy-saving technologies and initiatives. Higher interest rates also narrowed governments' fiscal room to provide additional policy incentives for adoption of efficiency measures, however in most regions such incentives have remained available. Given these financial constraints, overall energy efficiency employment was roughly flat between 2022 and 2023, stabilising around 9.8 million, as more resilient investment trends in more labour-intensive regions shored up losses seen elsewhere.

Policy makers have continued to ramp-up buildings efficiency requirements, such as the new EU Energy Performance of Buildings Directive, Japan's revised Act on Rationalizing Energy Use, and South Korea's expansion of mandatory certification of zero energy buildings. Yet, despite these regulatory measures and a gradual easing of the interest rate environment, construction cost pressures and the winding down of fiscal incentives are proving strong headwinds for investment in the near term. Efficiency investment in the buildings sector fell by 7.1% in 2023 and is projected to fall by a further 3.8% in 2024. In this context, global employment in building efficiency measures remained flat at 5.3 million in 2023, including a strong decline in the European Union.

Industry energy efficiency investment also took a hit in 2023, with much of the decline driven by a 30% slowdown in China, the world's largest manufacturing hub. This continues a multi-year trend of stagnating efficiency spending in overall industry investment in China and elsewhere, despite high energy prices that would normally incentivise spending. Challenging economic conditions also led to investment flatlining in other parts of the world, with global employment in this sector falling by 1% to 3.7 million in 2023. Overall, employment in buildings and industrial efficiency contracted by 0.3% in 2023.

Employment in end-use efficiency by sub-sector, 2023

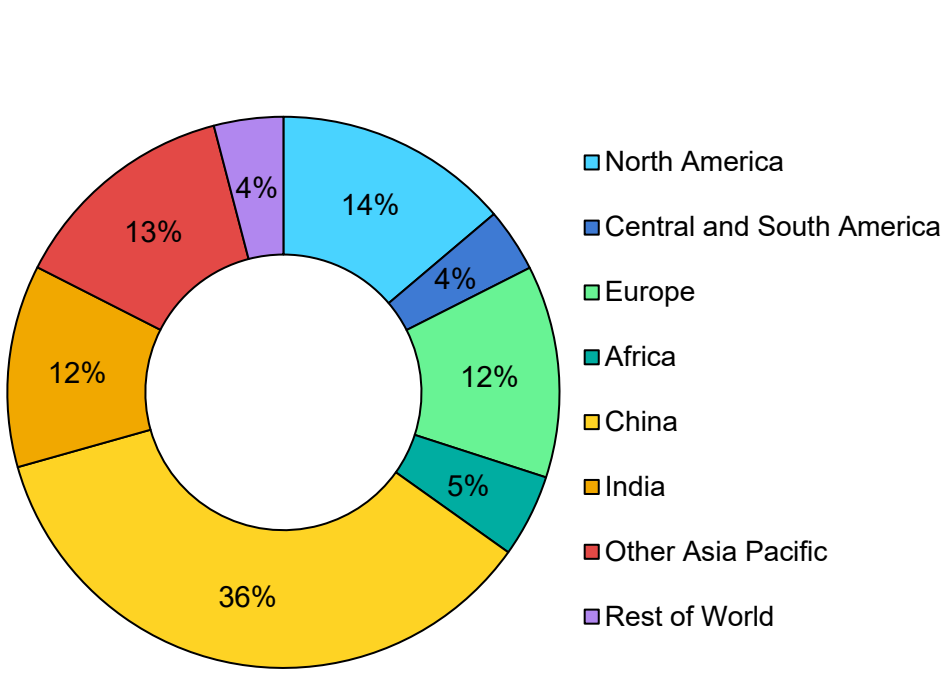


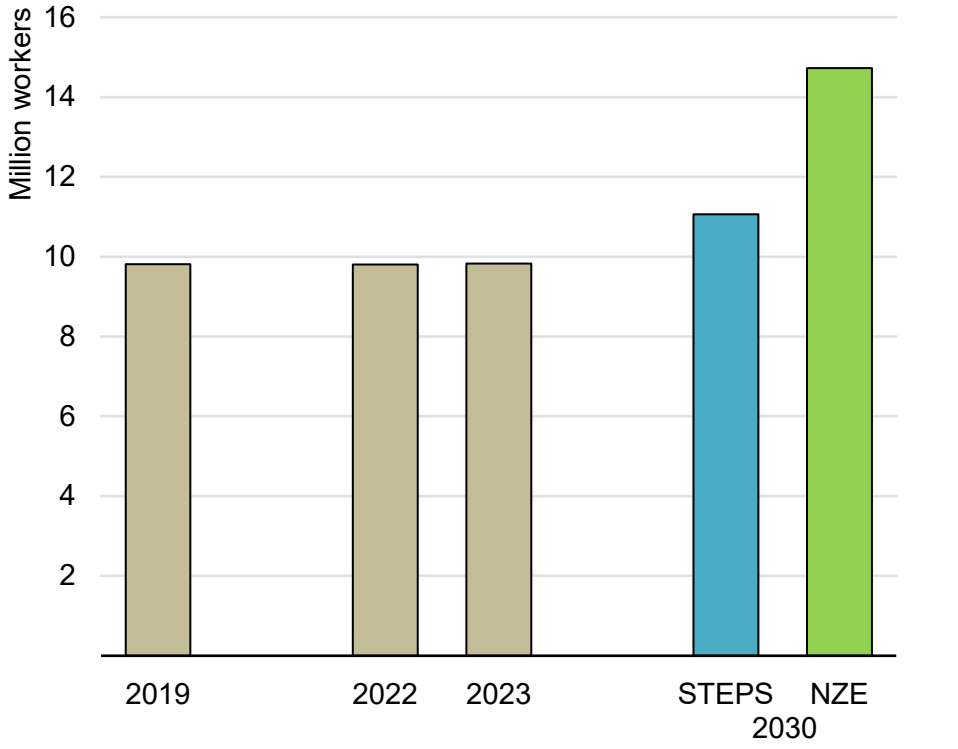
Sales of heat pumps similarly fell by 3% last year, as consumers struggled with cost-of-living increases and higher interest rates, leaving them unable to afford the upfront investment required. Additionally, following several years of double-digit growth in the heat pump market, many countries are seeing bottlenecks in the availability of skilled labour to fill demand, especially for installation. China was one of the few countries to see growth in heat pump sales, and this helped to generate a more modest increase in global heat

pump jobs than that seen in prior years, with employment in the sector rising by 7% to a total of 840 000 in 2023.

Our analysis suggests that a 2030 outcome consistent with a net zero global economy by 2050 would require much more rapid growth in investment and employment in this sector. In the NZE Scenario, efficiency employment grows from 9.8 million in 2023 to 14.7 million in 2030, representing a 5.9% compound annualised growth rate over that period.

Employment in energy efficiency by region in 2023, and by year and scenario





Notes: STEPS = Stated Policies Scenario; NZE = Net Zero Emissions by 2050 Scenario.

Annexes

Methodology

A note on historic revisions

Estimates for certain historical estimates (2019-2023) have been updated in the WEE 2024 relative to previous editions of the report and reflect the inclusion of the latest available data. These updates include new manufacturing data presented in the new Energy Technology Perspectives 2024 report, and the most recent data provided in the U.S. Energy and Employment Report (USEER) 2024.

The year 2022 sees the strongest revision, alongside the final estimates for 2023, which were presented as preliminary estimates in last year's report. Overall, the number of jobs in 2022 in the WEE 2024 are adjusted lower by 1.5 million, or 2.3%, than in WEE 2023, mainly due to revisions in energy-efficiency sectors and ICE vehicles production.

Approach

The data presented in the report are modelled benchmarks relying on the IEA's comprehensive energy data for calibration, including investments, capacity additions, existing stock, production, international trade flows of clean energy goods and services, and sales of equipment and appliances. The modelled estimates are then calibrated against data from national labour statistics, corporate filings, data from company interviews, international organisations' databases and academic literature. In addition, other valuable inputs include dedicated secondary surveys and studies on energy employment, such as the USEER, Canada's Labour Force Survey (LFS) and the United Kingdom's Low Carbon and Renewable Energy Economy (LCREE).

Prevailing labour costs in each region, industry and occupation are used to benchmark the number of jobs per energy project that would be consistent with the total investment, operating costs and earnings of different energy subsectors. Where labour costs are low, such as in India, building a project typically employs far more people than it would in the most advanced economies.

Modelling

Modelling is based on the IEA's energy balances as well as energy investment data, and calibrated based on a rich collection of employment data from the following sources:

- National statistics for all major countries.
- EUROSTAT data.
- ILO's employment database.
- UNIDO's IndStat and MinStat databases.
- Reports by international organisations and industry associations.
- Academic literature.
- Annual reports of major companies in each sector.
- Company surveys.

The data provided in this report represent our best estimates of employment across the energy sector based on the most recent available data. They are published to help governments and other stakeholders to understand the magnitude of the impacts of energy policy and investment on workers, but given the uncertainties that exist, they are clearly not the last word. These estimates will continue to be updated as new and improved data become available.

Where data was missing for certain years, energy subsectors, or countries, employment multipliers were applied based on the corresponding volumes and investment values in IEA energy balances. Regional multipliers were constructed based on wage differences. The steps included:

- **Identifying the cost contribution breakdown** for USD 1 million spent on new projects or products for regions with existing multipliers (e.g. 10% labour, 50% materials, 10% equipment costs). The breakdowns were derived using detailed manufacturer surveys, primarily from the US Annual Survey of Manufacturers data which provide information on the contribution to costs of average wages, labour and materials. Industry surveys were used to confirm breakdowns or provide more granular detail for specific technology types.
- **Adapting the cost contribution breakdown** to each region, taking specific account of how differences in wages and material costs shift the relative shares of labour and material. Average wages and basic material costs were indexed on the basis of US costs, and these were applied to the labour and material costs for a USD 1 million project or purchase to calculate how much that same purchase would cost to produce in a low-wage economy. Local wages, average cost differential of input materials, share of imports in production and the costs of those imports were considered to arrive at adjusted cost contribution breakdowns for various regions.
- **Finding average wages for relevant jobs** in a region by using national average salary information specific to a subsector. Where information on wages specific to a subsector was not available, average wages from salary reporting websites were used, splitting the labour costs to distinguish between those associated with production and manufacturing and those associated with overheads (e.g. research and development, procurement and marketing).
- **Calculating jobs per million dollars for the expenditure** by dividing the portion spent on salaries by average salaries. The indirect multiplier for advanced economies was used as a basis for indirect jobs, and the rectification multiplier for each country was applied to calculate indirect jobs.

The final employment multipliers were integrated with the IEA's Global Energy and Climate Model by applying the multipliers to the appropriate sector and regional investments.

Definition and scope of employment

The definitions used in this report are:

- Direct: Jobs created to deliver a project or product. These are counted in this report.

- Indirect: Supply chain jobs created to provide inputs to a project or product. Only inputs that are predominantly demanded by the energy industry are counted in this report.
- Induced: Jobs created by wages earned from the energy sector and spent in other parts of the economy, thereby creating additional jobs. These jobs are not counted in this report.

In this report's accounting, employment encompasses all direct jobs and the indirect jobs, from the development of energy-specific inputs to the construction, manufacturing and installation of new energy-supplying or energy-using facilities and devices. Other indirect jobs, such as basic building material inputs like cement, are excluded. Induced jobs and jobs that may be created from re-spend are also excluded. This sets a clear boundary around the jobs that the upfront investment would pay for to deliver the project.

Jobs are normalised to full-time equivalent (FTE) employment for consistent accounting. An FTE job represents one person's work for one year at regulated norms (e.g. 40 hours a week for 52 weeks a year, excluding holidays). Where data is available for hours worked, part-time work is considered proportionally. Otherwise, part-time employment is assumed as 0.5 FTE.

Employment numbers include informal workers, with the hope that our numbers reflect the scope of energy policy impact more completely. In alignment with ILO definitions, informal workers comprise own-account workers and all those employed in informal sector enterprises; contributing family workers; workers holding informal jobs; members of informal producers' co-operatives; and own-account workers engaged in the production of goods exclusively for their own final use by their own household. Estimates are based on a literature review of informality rates by region and sector.

This report does not address employment in the following energy sectors, among others, which will be covered in forthcoming reports:

- Coal transformation for blast furnaces and coke ovens.
- Fossil fuel downstream distribution, for example workers in petrol stations and workers in gas utilities.
- End-use renewables such as geothermal or solar heating for buildings or biomass boilers.
- Efficiency jobs related to appliances and lighting in buildings.
- Electrification of end-uses other than heat pumps.
- Manufacturing of non-road vehicles, as well as the servicing and maintenance of vehicles.

Economic sectors

Employment in this report is presented not only by energy sectors, but also by economic sectors (as defined by the ISIC Revision 4 classification system), with significant numbers of workers in the following sectors:

- Agriculture (code A), in particular for bioenergy production
- Mining and quarrying (code B)
- Manufacturing (code C)
- Electricity, gas, steam, and air conditioning supply (code D)

- Construction (code F)
- Wholesale and retail trade (code G)
- Transportation and storage (code H)
- Professional, scientific, and technical activities (code M)

Throughout the report, the economic sectors are aggregated into five groupings for simplicity:

- Raw materials (codes A and B)
- Manufacturing (code C)
- Construction (code F)
- Professionals and utilities (code D and M)
- Wholesale and transport (codes G and H)

Sample of ISIC codes referenced in employment modelling[2]

Code	Name
0510	Mining of hard coal
0520	Mining of lignite
0610	Extraction of crude petroleum
0620	Extraction of natural gas
0892	Extraction of peat
0910	Support activities for petroleum and natural gas extraction
1920	Manufacture of refined petroleum products
2710	Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus
2720	Manufacture of batteries and accumulators
2731	Manufacture of fibre optic cables
2732	Manufacture of other electronic and electric wires and cables
2733	Manufacture of wiring devices
2815	Manufacture of ovens, furnaces and furnace burners
2824	Manufacture of machinery for mining, quarrying and construction
2910	Manufacture of motor vehicles
2920	Manufacture of bodies for motor vehicles; manufacture of trailers and semi-trailers
2930	Manufacture of parts and accessories for motor vehicles
3510	Electric power generation, transmission and distribution
4321	Electrical installation
4322	Plumbing, heat and air-conditioning installation
4661	Wholesale of solid, liquid and gaseous fuels and related products
4930	Transport via pipeline

[2] While some of the codes listed correspond in scope directly to their respective energy subsectors, others are referenced with the understanding that only a subset of the workers enumerated under these ISIC codes work on energy infrastructure and value chains.

Skill levels

Employment in this report is also presented by skill level, in harmony with the ISCO-08 occupations in ILOSTAT. Skill level is defined by ILOSTAT as "a function of the complexity and range of tasks and duties to be performed in an occupation," considering:

- The nature of work performed.
- The level of formal education required for competent performance, as defined by ISCED-97.
- The amount of work experience and/or on-the-job training required for competent performance.

The following table illustrates the occupations, education level, and characteristic tasks typically observed at each skill level. In many cases, formal education is not an ideal method for approximating skill level, and as such the ISCED-97 level assigned is indicative of how workers of that skill level generally obtain the knowledge and skills required for competent performance. It is always possible that the appropriate degree of work experience and/or on-the-job training may substitute for the level of formal education indicated.

Skill level	ILOSTAT skill levels	Associated ISCED-97 levels	Associated ISCO-08 occupations	Characteristics
Low-skill	1	ISCED Level 1: Completion of primary education or the first stage of basic education may be required, along with possible on-the-job training.	9. Elemental occupations	• Performance of simple/routine physical/manual tasks • Literacy and numeracy, if required, are not a significant portion of work
Medium-skill	2	ISCED Level 2: Completion of the first stage of secondary education. ISCED Level 3: Completion of the second stage of secondary education, which may include a significant component of vocational education and/or on-the-job training. ISCED Level 4: Completion of vocation-specific education undertaken after completion of secondary educisraelation.	4. Clerical support workers 5. Service and sales workers 6. Skilled agricultural, forestry and fishery workers 7. Craft and related trades workers 8. Plant and machine operators, and assemblers	• Performance of tasks such as operating, maintaining and/or repairing machinery and electronic equipment; driving vehicles; manipulation and storage of information • Simple to advanced literacy and numeracy is generally required; some occupations may require significant manual dexterity
High-skill	3-4	ISCED Level 5b: 1-3 years of study at a higher educational institute following completion of secondary education. ISCED Level 5a or higher: 3-6 years of study at a higher educational institute leading to the award of a first degree or higher qualification; formal qualifications may be required for entry to the occupation.	1. Managers 2. Professionals 3. Technicians and associate professionals	• Performance of complex technical and practical tasks and/or complex problem solving and decision making, in either case requiring an extensive body of specialised knowledge • Extended levels of literacy and numeracy and well-developed to excellent interpersonal communication skills

Glossary

Clean energy: In power, clean energy includes generation from renewable sources, nuclear and fossil fuels fitted with carbon capture, utilisation and storage (CCUS); battery storage; and electricity grids. In efficiency, clean energy includes energy efficiency in buildings, industry and transport, excluding aviation bunkers and domestic navigation. In end-use applications, clean energy includes direct use of renewables; electric vehicles; electrification in buildings, industry and international marine transport; use of hydrogen and hydrogen-based fuels; CCUS in industry and direct air capture. In fuel supply, clean energy includes low-emissions fuels, liquid biofuels and biogases, low-emissions hydrogen and hydrogen-based fuels.

Fossil fuels: Includes coal, natural gas, oil and peat.

Informal employment: Includes all remunerative work (workers, self-employed workers) that is not registered, regulated or protected by existing legal or regulatory frameworks, as well as non-remunerative work undertaken in an income-producing enterprise in accordance with guidelines concerning a statistical definition of informal employment by the 17th International Conference of Labour Statisticians.

Induced employment: Jobs supported by wages earned in the energy sector but spent elsewhere in the economy. For example, a recently hired coal miner might spend their newfound wage income in a local shop, which could push the shop to hire a new cashier. Our energy employment estimates do not include these induced jobs.

Labour force: All individuals who fulfil the requirements for inclusion among the employed or the unemployed. The employed are defined as those who work for pay or profit for at least one hour a week. The unemployed are defined as people without work but actively seeking employment and currently available to start work.

Economic sectors

Construction: Refers to economic activities related to both general construction and specialised construction activities for buildings and civil engineering works; in alignment with ISIC Rev.4 section F. This includes electrical contractors.

Economic sectors: Refers to industry groupings such as mining and quarrying, manufacturing and construction, which are categorised in accordance with Revision 4 of the International Standard Industrial Classification of All Economic Activities (ISIC Rev.4) – the international reference classification of productive activities.

Manufacturing: Economic activities related to the physical or chemical transformation of materials, substances, or components into new products; in alignment with ISIC Rev.4 section C.

Mining: Economic activities related to the extraction of minerals occurring naturally as solids (coal and ores), liquids (petroleum) or gases (natural gas), as well as the supplementary activities aimed at preparing the crude materials for marketing; in alignment with ISIC Rev.4 section B named “Mining and quarrying.”

Professionals: Economic activities related to specialised services including legal and accounting, activities in head offices and management consulting, architecture and engineering, scientific research and development, advertising and market research, etc.; in alignment with ISIC Rev.4 section M titled “Professional, scientific and technical activities.”

Utilities: Economic activities related to the operation of electric and gas utilities, which generate, control and distribute electric power or gas; in alignment with ISIC Rev.4 section D that is named “Electricity, gas, steam and air conditioning supply.”

Wholesale: Economic activities related to wholesale and retail sale (i.e. sale without transformation) of any type of goods and the rendering of services incidental to the sale of these goods; in alignment with ISIC Rev.4 section G, named “Wholesale and retail trade; repair of motor vehicles and motorcycles.”

Regional groupings

Advanced economies: Australia, Austria, Belgium, Bulgaria, Canada, Chile, Colombia, Costa Rica, Croatia, Cyprus[1,2], Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel[3], Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Malta, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Republic of Türkiye (Türkiye), United Kingdom and the United States.

Africa: Algeria, Angola, Benin, Botswana, Cameroon, Côte d’Ivoire, Democratic Republic of the Congo, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Libya, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Tunisia, Republic of the Congo (Congo), Senegal, South Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Zambia, Zimbabwe and other African countries and territories.

Asia Pacific: Australia, Bangladesh, Brunei Darussalam, Cambodia, Chinese Taipei, Democratic People’s Republic of Korea (North Korea), India, Indonesia, Japan, Korea, Lao People’s Democratic Republic (Lao PDR), Malaysia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, People’s Republic of China (China), Philippines, Singapore, Sri Lanka, Thailand, Viet Nam and other Asia Pacific countries and territories.

Central and South America (C and S America): Argentina, Plurinational State of Bolivia (Bolivia), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Bolivarian Republic of Venezuela (Venezuela), and other Central and South American countries and territories.

China: Includes the People’s Republic of China and Hong Kong.

Emerging markets and developing economies: All countries not included in the advanced economies regional grouping.

Eurasia: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Russian Federation (Russia), Tajikistan, Turkmenistan and Uzbekistan.

Europe: Albania, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus[1,2], Czechia, Denmark, Estonia, Finland, France, Germany, Gibraltar, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kosovo, Latvia, Lithuania, Luxembourg, Malta, Montenegro, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Republic of Moldova, Republic of Türkiye (Türkiye), Ukraine and United Kingdom.

North America: Canada, Mexico and the United States.

Middle East: Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen.

[1] Note by Republic of Türkiye: The information in this document with reference to "Cyprus" relates to the southern part of the island. There is no single authority representing both Turkish and Greek Cypriot people on the island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue".

[2] Note by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

[3] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Acknowledgements

The *World Energy Employment 2024* report was prepared by the World Energy Outlook Division of the Directorate of Sustainability, Technology and Outlooks of the International Energy Agency. The project was designed and directed by **Laura Cozzi**, Chief Energy Modeller. **Daniel Wetzel**, Head of the Tracking Sustainable Transitions Unit, co-ordinated the analysis and production of the report. The lead authors were **Caleigh Andrews**, **Michael McGovern**, and **Rebecca Ruff**.

Key contributions were made by **Bruno Idini** (critical minerals and wages) and **Olivia Chen**. Other contributions were made by Arthur Biamouret (data), Ethan Burkley (GIS), Jianlan Dou (heat pumps), Konstantina Kalogianni (gender data), Aloys Nghiem (data), Leonardo Paoli (data), Jinglin Qui (skills), and Alessia Scoz (data). Marco Baroni oversaw the development and calibration of this year's energy employment model. Marina dos Santos, Reka Koczka, and Dylan Marecak provided other essential support.

Valuable comments and feedback were provided by senior management and colleagues within the IEA, including Elizabeth Connelly, Jane Cohen, Juliette Denis-Senez, Araceli Fernandez Pales, Carlos Fernandez Alvarez, Kavita Jadhav, Lydia Jayakumar, David Martin, Gergely Molnar, Brian Motherway, Jose Miguel Bermudez Menendez, Matthieu Prin, Mary Warlick, Hiroyasu Sakaguchi and Siddharth Singh.

Thanks also to Jethro Mullen, Acting Head of the Communications and Digital Office (CDO), and to CDO colleagues Liv Gaunt, Grace Gordon, Poeli Bojorquez, and Astrid Dumond.

Diane Munro carried editorial responsibility. Other valuable contributions from outside the IEA include Josh Oxby, Giulia Genuardi, Mirko Armiento and Maria Lelli.

The work could not have been achieved without the support and analytical contributions provided by the United States Department of State, Enel Foundation and the IEA Clean Energy Transitions Programme, the IEA flagship initiative to transform the world's energy system to achieve a secure and sustainable future for all.

Data from the International Labour Organization (ILO), United Nations Industrial Development Organization (UNIDO), India National Skill Development Corporation (NSDC), Economic Research Institute (ERI), and national labour statistics were essential for this analysis. Additionally, we are grateful to the 190 companies that provided essential feedback and shared valuable industry insights by participating in the 2024 World Energy Employment Survey.

Valuable perspectives were collected from industry experts, labour unions, and academia in deep-dive interviews, including Jonathan Bonadio (Solar Power Europe), Peter Wood (Shell), Carolin Widenka (Viessmann), Greet Velghe (Daikin), Mick Buffer (Glencore), Volker Kraayvanger (Uniper), Torben Brabo (Energinet), Akos Losz (Columbia University), Antonio Erias Rodriguez (Baker Hughes),

Candice Paton (Enhance Energy), Silvia Manessi (Acer Europa), Xavier Lorenzo (Snam), Gregor Pett (Uniper), Clair Osbourne (Delta), Hitoshi Sato (Panasonic), Caroline Cohen (Plateforme automobile), Debbie Gray (International Hydropower Agency), Iryna Petriashvili (International Hydropower Agency), Christian Preuss (Heidelberg Materials), Nana Tsertsvadze (BAG), Alok Prasad (Tata Power Skills Development Institute), Talvekar Mandar (Tata Power Skills Development Institute), Sachin Torne (Tata Power Skills Development Institute), Elly Rosita Silaban (Indonesian Trade Unions), Echezona Asuzu (Nigeria Labour Congress), Anton Ivanov (Confederation of Independent Trade Unions Bulgaria), Plamen Dimitrov (Confederation of Independent Trade Unions Bulgaria), and Donna Rowe-Merriman (Unison).

Many experts from outside of the IEA provided input and reviewed preliminary drafts of the report. Their comments and suggestions were of great value. They include:

Valeria Piazza	Permanent Delegation of Italy to the OECD
Andrea Garnero	OECD
Megan Gordon	Pembina Institute
Dave Jones	Ember Climate
John Ding	TrinaSolar
Siming Liu	TrinaSolar
Isabel Murray	Natural Resources Canada
Nina Nintai	Natural Resources Canada
Bert De Wel	International Trade Union Confederation
Camila Pereira R.	International Labour Organization
Christophe Lits	SolarPower Europe
Jonathan Bonadio	SolarPower Europe
Erin Mayfield	U.S. Department of Energy
Jay Rutowitz	University of Technology Sydney
Jenny Philip	Shell
Linda Kunertova	European Commission
Pablo Alvarez Jacome	European Commission
Carlo Napoli	Enel Foundation
Sam Harrison	Navius Research
Archana Patankar	National Skill Development Corporation
Prasad Alok	Tata Power Skills Development Institute
Amrita Goldar	Indian Council for Research on International Economic Relations
Jasper Van Loo	European Centre for the Development of Vocational Training
Stelina Chatzichristou	European Centre for the Development of Vocational Training
Hadrian Mertins-Kirkwood	Research Centre for Sustainable Development, Chinese Academy of Social Sciences
Linda Deelen	International Training Centre of the International Labour Organization

IEA Publications

International Energy Agency

Website: www.iea.org

Contact information: www.iea.org/about/contact

Typeset in France by IEA – November 2024

International Energy Agency (IEA)

IEA Publications
International Energy Agency
Website: www.iea.org
Contact information: www.iea.org/contact

Typeset in France by IEA - November 2024
Cover design: IEA
Photo credits: © Shutterstock