Global Wind Workforce Outlook

2024-2028

GWEC
GLOBAL WIND ENERGY COUNCIL

GLOBAL WIND ORGANISATION

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Training photography courtesy of GWO certified training providers: ENSA North America, SP Wind, OPS, RelyOn and Salvacon.

Design:

William Redfern Graphic Design, United Kingdom

Publication Date:

28 November 2024

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The tripling renewables target adopted at COP28 was a historic milestone for the wind industry, as it set out clearly that the adoption of wind energy, alongside other renewable energy sources, was key to achieving the landmark Paris Agreement. Last year, 2023, was a record year for new renewable energy installations, with wind energy alone reaching 117 GW. Despite record-breaking growth, the global effort to triple renewable energy by 2030 is falling short. The latest tracking report co-released by IRENA, the COP29 Presidency and the Global Renewables Alliance reveals a significant say-do gap in progress to meet the COP28 Consensus target, and keeping 1.5°C within reach.

This presents a unique opportunity, and a unique challenge, for the wind industry. To deliver the target, we need to rapidly accelerate annual wind installations to at least 320 GW, which would bring us to 3.5 TW of cumulative wind energy capacity by the end of this decade. The challenge is that it's now time for action! Streamlining permitting, building resilient supply chains, mobilising finance and investing in grids and storage are key to the required rapid scaling up of the wind sector. So too is building up the workforce; the skilled people who are ready and able to construct, install, operate and maintain the necessary infrastructure.

Global Wind Organisation and the Global Wind Energy Council are amplifying the call for change that addresses the industry's workforce challenges of how to scale up installation and reduce gaps. This jointly produced fifth edition of the Outlook offers a framework for workforce growth to support its forecast that at least 532,000 skilled technicians will be needed for C&I and O&M work in the global wind industry by 2028. In addition the Outlook also shows how the challenge of delivering this opportunity is heightened by the lack of new entrants and a natural attrition that widens the gap between available workers and the growing demand from industry.

For GWEC and GWO standardisation and international cooperation are the keys to scaling up at pace. Governments need to focus on three things. First, recognise and apply international best practices and standards as they are developed for the industry and by the industry through organisations such as GWO, GWEC, G+ and IMCA. The industry's large employers have a duty of care across multiple jurisdictions and use their deep understanding of the safety and technical issues to build appropriate best practices and standards. Secondly, invest in vocational education and training and use the best global practices to build local workforce that possess the appropriate skill sets to be readily employable and so deliver on our targets for energy transition. Finally, remove national and local regulation that doubles up on industry's own requirements, especially where local requirements unintentionally act as barriers to international mobility of skilled workforce. For most projects, teams mixing of experienced persons with local workers will be crucial to ensuring the safety of all workers and keeping to project timelines.

Developed in partnership by GWEC and GWO the Outlook is more relevant every year. This year our data and methodology are further revised to ensure a robust forecast that can allow for a clearer understanding of the workforce challenges facing our sector. We have considered the supply of labour in ten key markets and how public policy positions in those regions are supporting or hindering prospects for skilled and competent workforces. The message is loud and clear, let us refocus on people. Young job seekers and transitioning workers alike must be empowered to enter renewables. Business as usual won't be enough to stay within the International Renewable Energy Agency's 1.5°C scenario and avoid the worst effects of climate change.

Brian Allen, CEO, Beam

Lead sponsor

The wind industry stands at a historic moment of transformation. New global onshore wind power installations surpassed the 100 GW milestone last year and total installed wind capacity reached 1,021 GW. Technology and innovation are key enablers to unlocking the full potential of wind power, as rapid scaling will be essential to meet future energy demands.

At Beam we leverage AI, autonomous vessels, and autonomous underwater vehicles to deliver high-quality survey, operations, maintenance, and UXO services to offshore wind farms around the world. This technological innovation is crucial as the industry prepares for extraordinary growth, with global operational wind capacity to exceed 1,800 GW by 2028.

However, as advanced as our technologies may be, the true driver of our success lies in our people. This focus is particularly critical given the sector's workforce dynamics. By 2028, this Outlook forecasts the industry will need over 532,400 technicians, with offshore wind technicians expected to comprise 76,181 (14.3%). This is a dramatic increase from just 2.6% in 2018.

The GWO and GWEC Global Wind Workforce Outlook comes at a critical time, as the industry faces three fundamental challenges:

1. **Workforce development:** Exponential growth in wind energy construction, installation, operations and maintenance requires a corresponding investment in people and skills. From AI specialists to marine technicians, the industry needs a skilled workforce that can harness the technological advancements capable of overcoming the challenges faced. Only by aligning industry requirements with national industrial skills strategies to fund training and development can we bridge the growing skills gap.
2. **Diversity and innovation:** Creating an inclusive environment that draws talent from all backgrounds is essential for driving innovation and building resilience. Different perspectives lead to better solutions, making diversity not just an ethical imperative but a business necessity.
3. **Global collaboration:** These challenges transcend borders. Building a robust talent pipeline requires global cooperation in sharing knowledge, resources, and best practices. This collaborative approach is crucial for embedding globally standardised training and safety protocols across markets.

As we prepare to gather at the GWEC APAC Wind Energy Summit in the Republic of Korea, these workforce dynamics take on special significance for the Asia-Pacific region. This year's wind workforce outlook insights illuminate both the scale of the challenge and the transformative opportunities ahead. Successfully scaling wind energy deployments depends not only on technological advancement but on our ability to build, nurture, and retain a skilled workforce.

Looking ahead, Beam remains committed to investing in both technological innovation and human capital. While our autonomous systems and AI solutions make wind farm site characterisation, construction or O&M faster and more efficient, we recognise that our people, the workforce behind wind, are the true drivers of transformation. Through the collaboration and partnership with GWEC and GWO, we are working to create a stronger, more capable workforce that can accelerate the global transition to renewable energy.

Brian Allen
CEO, Beam

https://beam.global/

Chapter 1: Executive summary

In 2023 the world saw global new wind power installations surpass the 100 GW milestone for the first time following the integration of 105.6 GW of onshore wind and 10.8 GW offshore wind capacity. Thanks to this record installations, global cumulative wind power capacity passed the 1 TW milestone in 2023, showing year on year growth of 13%. Behind these figures lies an expanding workforce and it is these extraordinary people and their training needs that remains the focus of this report.

The Global Wind Workforce Outlook builds upon GWO's earlier Wind Workforce Model and leverages GWEC's global wind market intelligence as the primary inputs to predict the number of people required for the C&I and O&M segments of the value chain across global onshore and offshore wind from 2024 to 2028.

The model used for this Outlook focuses on two phases (C&I and O&M) of the full wind value chain where globally recognised training standards like GWO training are applicable. Manufacturing, decommissioning and repowering stages and ancillary services to the wind industry such as transport and logistics fall outside the scope of this report, but may be considered in future editions as data becomes available. The report's forecast for training needs is therefore a fraction (albeit a large one) of the expansive job opportunities which will be generated by the growth of wind energy worldwide. That said, the Outlook's focus areas are critical to the final stages of wind energy commissioning: the 'all hands on deck' period that sees projects move from planning into planning into operation. Addressing the workforce shortages in these areas can deliver immediate and tangible results, accelerating sector growth and supporting our industry's contribution to global climate goals.

This report examines four aspects of workforce development in the wind industry through the following guiding questions:

1. **Supply and Demand:** How many wind technicians will be needed in the coming years, and what will the future workforce structure look like? Where does the current workforce stand compared to future needs and what gaps must be filled to meet those demands?
2. **Policy:** What are the main factors driving global workforce demand, and how do policies in ten key countries shape workforce development? What policies are required to further support and foster industry growth?
3. **Challenges:** What challenges does the wind industry face in meeting workforce supply needs?
4. **Technology:** How do advancements in technology impact workforce requirements within the wind industry?

Key findings

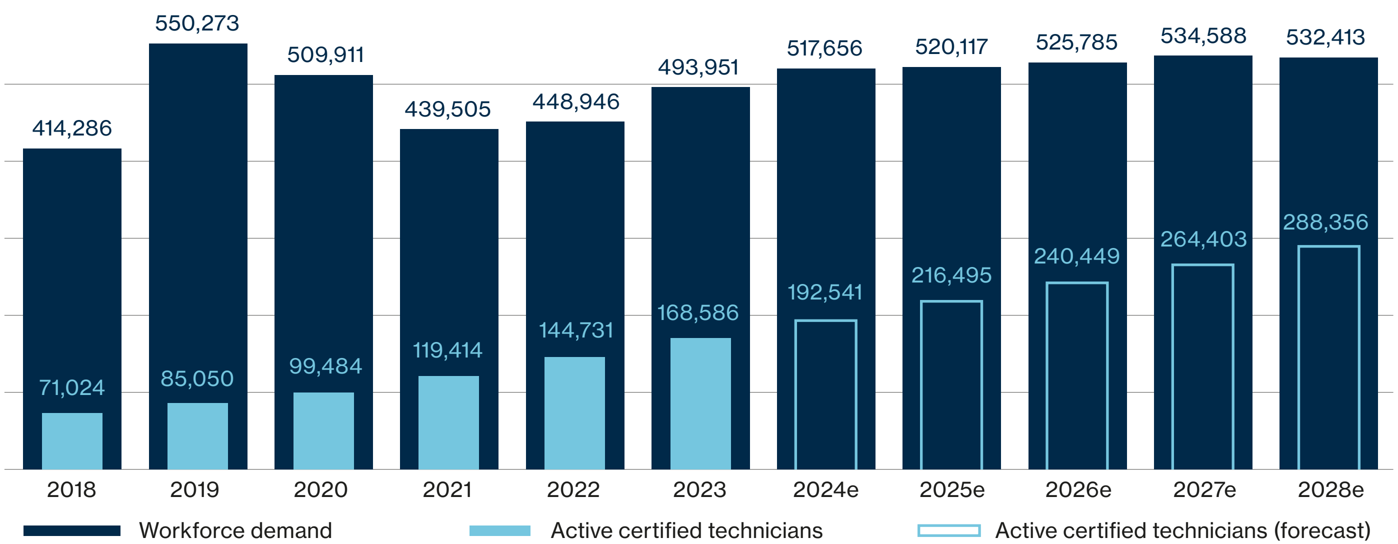
According to GWEC Market Intelligence, annual wind capacity additions are projected to grow significantly from 131 GW in 2024 to 182 GW by 2028. By the end of 2028, total global operational wind capacity is expected to surpass 1,800 GW. In line with this growth, the total number of technicians needed is expected to exceed 532,400. The number working in the Construction and Installation(C&I) segment is forecast to reach 307,790 by 2028, with 251,109 working onshore and 56,681 offshore. Similarly, the total number of Operations & Maintenance (O&M) technicians is expected to increase to 224,623, including 205,123 onshore and 19,500 offshore. Comparing the total workforce in 2018, when offshore wind technicians made up only 10,639 (2.6%), demand has grown significantly. By 2028, the number of offshore technicians is forecast to be more than seven times that number, at 76,181 (14.3%), reflecting substantial growth in both absolute numbers and share of the total workforce.

This global workforce supply challenge is amplified by technicians leaving the wind industry through churn. The typical churn rate for wind technicians in the C&I and O&M phases is 6%. However, based on GWO intelligence, the overall the offshore segment shows a higher annual turnover rate of 15%, posing a challenge for employers.

This has posed a critical challenge given the growing number of offshore wind projects and the increasing demand for a skilled workforce to meet commissioning targets.

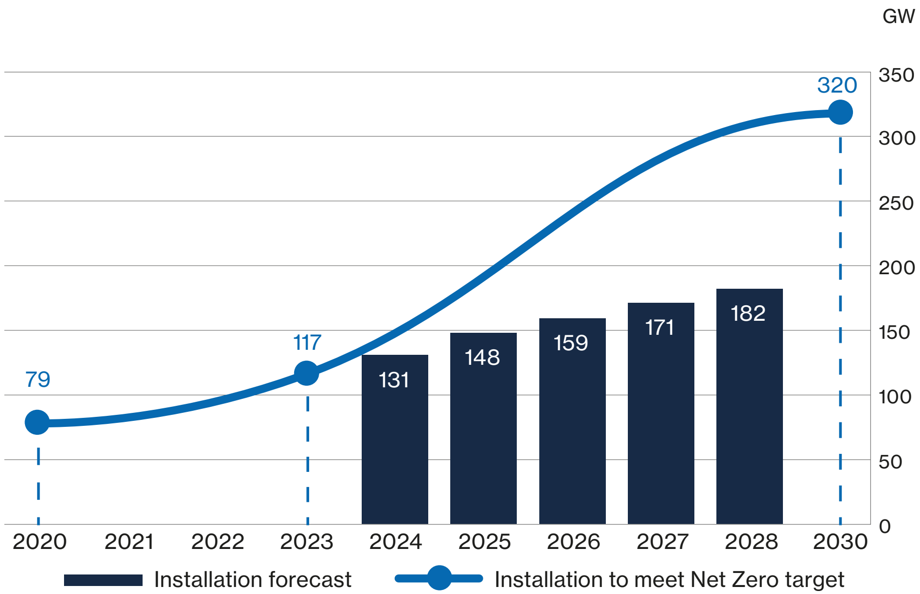
Assuming the workforce demand in 2023 was fulfilled, meeting the 2028 forecast means approximately 40% of the total workforce will need to be recruited between 2024 and 2028. If the growth of active GWO certified wind technicians continues at the current rate, we anticipate that 320,316 of them will be available in 2028. This will result in an unmet need of 212,097 new trained entrants to the workforce by this time (see figure 1).

Figure 1: workforce demand and active certified technicians (2018-2028)



Source: GWEC, GWO 2024

Figure 2: wind installation forecast falling short of IEA's net-zero pathway



Source: GWEC, IEA

It is important to note that the current forecast on wind installation falls short of IEA's net-zero pathway. To go beyond the 'business as usual' scenario and reach net zero by 2030, annual wind capacity additions must reach 320 GW with a corresponding stretch in workforce demand (see figure 2).

The wind industry has long reported challenges in finding enough qualified wind technicians to meet its operational needs. Despite the clear demand, there is currently limited reliable data available to quantify the actual shortage of technicians in the industry. This lack of visibility means the industry has an incomplete picture of the number of open positions or how this workforce gap aligns with projected future demand for technicians. As the leading body for wind technician training standards, GWO is well-positioned to fill this gap in knowledge. With a strong global presence, expanding training initiatives, and years of experience tracking workforce development across regions, GWO insights into available qualified technicians provide a robust foundation for the forecast. In the study period, the Workforce Forecast Model predicts that the global wind market will experience a shortfall of technicians for C&I and O&M roles, with approximately 6-8% of vacancies left unfilled. While this is not yet a critical issue for employers, rapid industry growth will increasingly result in a workforce with less experience and lower skill levels. This trend will be driven by technicians transitioning from other industries and a growing influx of young graduates entering the talent pool.

To meet global wind power ambitions, an efficient supply chain must be in place for all aspects, including workforce development. Government and industry-led initiatives for training and certification play an important role supporting a just and equitable energy transition away from fossil fuels, while offering win-wins that advance socio-economic opportunities, ensure safety and supporting stable growth within the wind industry. With these initiatives proliferating locally, nationally and globally, this Outlook (see chapter 4) takes the opportunity to review these and draw initial conclusions on the accumulating good practice now in evidence.

In particular, this report examines the policy and workforce outlook for 10 countries where wind power is on the rise: Australia, Brazil, China (excluding Chinese Taiwan), Germany, India, Republic of Korea, Philippines, Saudi Arabia, South Africa and the United States. These markets represent 76% (608GW, see table 1) of all new onshore and offshore wind capacity additions(791GW) expected worldwide over the five-year forecast period. Training needs in these 10 countries constitute 73% of the total number of C&I and O&M technicians in 2028. When setting targets for safety training 100% coverage of technicians in scope is a robust basis. Considering this assumption and accounting for technician turnover, over 320,000 new entry level technicians entering the industry by 2028 require standardised training in the 10 countries.

Table 1: forecast capacity installation, workforce demand and number of technicians requiring training

	New capacity (2024-2028)	Cumulative capacity (2023)	Workforce demand (2028)	New entrants requiring training (2024-2028)
Australia	9,500	11,479	5,715	3,636
Brazil	16,300	30,449	12,370	4,399
China	432,000	441,100	205,291	203,867
Germany	34,793	70,829	35,700	24,594
India	23,320	44,736	36,736	26,300
Republic of Korea	4,130	1,969	2,959	2,152
Philippines	3,380	593	1,917	549
Saudi Arabia	4,750	422	1,788	1,784
South Africa	4,700	3,442	2,561	1,230
United States of America	75,253	150,628	80,988	67,319
Total selected markets	**608,126**	**755,648**	**386,025**	**321,734**

Figure 3: forecast number of people requiring C&I and O&M training to meet wind energy growth as of the end of 2028.
(Additional C&I and O&M wind technicians requiring training from 2024-2028)

Chapter 2:
Growing demand for training and safety training standards

Since 2020, GWO and GWEC have worked together to produce the Global Wind Workforce Outlook. Now in its fifth edition, it continues to serve as a unique source for workforce and training volumes in the wind industry. In this edition two new elements have been added. First, a special feature discussing AI and its potential impact on wind technician employment and secondly; a summary of how public policy is being deployed to support workforce expansion.

The benefits of standardisation

The global wind industry collaborates through GWO, setting internationally recognised standards that address the most common activities, risks and hazards technicians encounter in their work. This approach reduces complexity, eliminates duplication, and enhances long-term productivity among wind technicians. Certification of GWO training centres and the upload of records into WINDA[1] ensures quality, enabling participants and their employers to verify technicians' training levels.

How are GWO training standards developed?

GWO training standards are developed through collaboration between safety and training experts from the world's leading wind industry employers. By combining their knowledge and data on the risks and hazards within the wind turbine environment, they prioritise standards that materially impact the largest possible number of wind turbine technicians. Their inclusive design process ensures that these standards are practical and fit for purpose.

The GWO training standards portfolio

The current GWO wind technician training portfolio is divided into 27 modules grouped into 11 standards. Some of the modules teach enduring skills that technicians practise every day at work, while other skills that are not used on a daily basis, such as practising first aid or rescuing an injured person from the nacelle, must be refreshed regularly.

In 2022, the OEMs and developers comprising GWO's membership aligned their descriptions for entry-level job profiles for wind technicians, and agreed on skills, knowledge and abilities that can be acquired through a training pathway known as the GWO Entry Level Framework. This combination of GWO courses for entry-level job profiles includes GWO Basic Technical Training and GWO Basic Safety Training plus a variety of additional courses specific to the task, site and employer. As GWO's remit has expanded, standards around instructor training and other aspects of the renewable industry have also been added to the portfolio.

The global community of training

GWO standards are recognised and used in 56 countries, and can be accessed at more than 570 training centres certified to deliver GWO courses. The course certificates (referred to as training records) are owned by the individual wind technician, and can be verified in an online global training records database. Using this central database to log training records establishes a mechanism for transparency and accountability for these core skills across the supply chain and for all teams working on a given site.

Growing demand for standardised training

The number of wind technicians worldwide holding a valid record in WINDA for at least one module has almost doubled, from around 100,000 in 2020 to over 190,000 in 2023. These 'Active Participants' demonstrate the growing trained workforce and allow employers to benchmark the available workforce that is trained according to internationally recognised standards. The number of technicians requiring GWO training is projected to exceed 500,000 in 2024. The high demand is expected to continue, necessitating a significant scale-up of training providers and educational facilities in wind markets globally. Compared with the previous forecast made last year, this number is lower due to a revision in the key assumption regarding the technician-to-turbine ratio, which has been adjusted downward for the onshore O&M segment (see elaboration in Chapter 4, page 14).

[1] WINDA is the Global Wind Industry Training Records Database designed with the primary purpose of verifying the certification status of GWO Certified Training Providers and the training status of Course Participants who have attended GWO certified training courses.

Marrying global standards with local market conditions

The role of employers in defining the training needs of individual wind technicians is paramount and GWO training standards are only ever recommended in step with local legal frameworks and employer specific training. To extend the specific applicability of trainings such as GWO's Entry Level Framework to individual labour markets during 2023 and 2024, GWO has worked with local wind industry associations to create tailor-made entry-level training guides for the United States (partnering with American Clean Power) and Japan (with the Japanese Wind Power Association). All guidelines are rooted in the GWO Entry Level Framework.

Table 2: GWO standards and modules applicable to onshore and offshore wind technicians

	Onshore, C&I	Onshore, O&M	Offshore, C&I	Offshore, O&M	Refresher
Advanced rescue training – all four modules	●	●	●	●	Yes
Basic safety training – first aid, fire awareness manual handling and working at heights modules	●	●	●	●	Yes
Basic safety training – sea survival module			●	●	Yes
Basic technical training – bolt tightening module	●	●	●	●	No
Basic technical training – electrical module		●		●	No
Basic technical training – hydraulics module		●		●	No
Basic technical training – installation module	●		●		No
Basic technical training – mechanical module	●	●	●	●	No
Blade repair (comprises single module only)	●	●	●	●	No
Control of hazardous energies – all three modules	●	●	●	●	Yes
Crane and hoist – basic user module	●	●	●	●	No
Crane and hoist – inspection and maintenance module		●		●	No
Enhanced first aid (comprises single module only)	●	●	●	●	Yes
Service lift – all three modules	●	●	●	●	No
Slinger signaller (comprises single module only)	●	●	●	●	No

Chapter 3:
Wind workforce dynamics

As total global wind power installations is projected to increase from 1,153 GW in 2024 to 1,810 GW by 2028 (a 57% growth) there is a pressing need for a skilled workforce to install and maintain this expanding wind fleet. This trend presents a significant opportunity for training providers and educators to expand and enhance their delivery of skilled workforce training.

The Global Wind Workforce Outlook is based on the latest intelligence available within the industry. The model's latest update is configured to use GWEC's Global Wind Report data as its primary input and focuses on the total number of wind technicians involved in the C&I and O&M phases of the onshore and offshore wind capacity installed globally each year from 2024 to 2028. These numbers represent the total number of people who will need to receive training to acquire or refresh their safety and technical skills during each year of the forecast.

Scope of forecast

Wind industry workforce needs outside of the C&I and O&M stages, that is, other segments of the wind project lifecycle, are excluded from this forecast. This wider wind value chain is therefore larger than the workforce eligible for GWO training identified in this report and covers research and development, procurement, manufacturing (traditionally the most labour-intensive segment in certain markets), transport, decommissioning and repowering. The GWO Wind Workforce Model will continue to be refined on an ongoing basis to build in more granular, country and industry-specific project data, progressively reducing the degree of uncertainty in the results. For instance, the current need for skills refresher training which lies within the scope of GWO standards is not considered in the forecast. Refresher training is an additional opportunity for training providers and educators. GWO is confident that continuously improving the GWO Wind Workforce Model will help the industry to better understand the volume of the C&I and O&M workforce and stimulate further discussions and research.

Getting a handle on workforce trends

The dynamics of workforce demand in Construction & Installation (C&I) and Operations & Maintenance (O&M) can vary significantly. Demand for maintenance has a linear relationship with the size of the installed fleet, with O&M employment having a steady but lower growth profile which proves resilient to year-over-year fluctuations in installed volumes. In contrast, demand for C&I activity is more volatile by nature, with employment patterns varying with the annual cycles of installation. While investment in new capacity requires intense C&I activity and has a substantial impact on employment during the early years of industry development, demand for O&M work starts to grow slowly but gains traction as the installed base becomes more significant. We estimate that on average, constructing and installing one onshore turbine requires around 12 full-time equivalents (FTEs), while approximately 18.4 FTEs are needed for the construction and installation of an offshore turbine.

Overall workforce growth is being influenced by three factors: technology improvements, the characteristics of the demand-side lifecycle and synergies with third-party service providers. Efficiency gains will also have a more significant impact on the onshore segment with all four factors contributing to the trend of requiring fewer technicians on average each year to maintain an onshore turbine.

Technological improvements

Over time, wind farm maintenance has become increasingly systematised, with a move away from primarily manual and labour-intensive practices towards predictive maintenance technology and remote monitoring systems that are now widely adopted in real-world conditions. Sensors on wind turbines, particularly those monitoring gearboxes, vibrations and temperatures, play a crucial role in detecting early signs of wear, enabling the successful implementation of predictive maintenance. This approach greatly improves labour planning and boosts productivity. As a result, some wind farms have achieved such high levels of operational efficiency that no human staff is needed for regular maintenance, relying entirely on automated systems and remote monitoring to ensure optimal performance.

Growth of third-party service providers

These companies supply skilled technicians who travel between wind farms to address maintenance needs, offering flexibility and specialised expertise. As a result, wind farms may hire fewer full-time, on-site technicians and rely on third-party providers to handle non-urgent or routine tasks. This approach allows wind farms to maintain a smaller core team to handle urgent issues while optimising maintenance efficiency by bringing in external technicians as needed.

Turbine lifecycle

The lifecycle of wind turbines is another key factor influencing wind turbine maintenance demands. Maintenance needs are higher during two phases: early in the turbine's life when frequent adjustments are required after installation, and later as the turbine nears decommissioning, when wear and tear lead to increased repair needs. In contrast, the middle phase of the lifecycle tends to see lower maintenance demand. With a typical wind turbine lifespan of around 20 years, the majority of turbines currently in operation worldwide are in this middle stage, where maintenance requirements are relatively low. This lifecycle pattern further reduces the need for a large, dedicated on-site maintenance workforce during this period. Considering all these factors, estimates suggest that an average of between 0.10 and 0.20 technician per turbine is needed each year for O&M, based on workload projections converted into full-time equivalent employees.

The impact of geography

The impact of automation and remote monitoring technologies has been felt sharpest on the offshore wind fleet, reducing some of the need for on-site personnel. Offshore wind turbines tend to be larger and more powerful, which can result in longer maintenance windows for each turbine. While fewer turbines may be required to achieve the same energy capacity as onshore farms, the maintenance demands per turbine can still contribute to a greater overall labour requirement.

Another significant location factor is the complexity and access challenges associated with offshore wind farms. Due to their remote locations and the harsher environmental conditions, accessing offshore turbines often requires specialised vessels, such as service operation vessels (SOVs) or helicopters. Travel time also plays a role here, again complicated by weather conditions. To compensate for lost time from travel and to ensure more rapid responses to operational issues, some large offshore wind farms maintain a permanent on-site maintenance crew, housed in accommodation platforms (APs). Such logistical complexity means that, even with technological advancements, offshore installations typically need more technicians per turbine compared with their onshore counterparts that benefit from quicker access and lower travel to the site costs.

While large markets are showing a trend towards localisation of wind technician pathways, the delivery of GWO training itself is following training provider market forces. One trend here is that ambitious training providers are offering participants training across national borders. This is particularly common with small local markets or during commissioning and installation stages in less mature wind markets, which can prime a local market while simultaneously potentially meeting local social justice and workforce objectives.

Impacts of building technician supply

Importantly, both C&I and O&M require significant access to skilled wind technicians, which requires planning for local recruitment and supply of training. The volume of wind technicians trained locally can also help to deliver socioeconomic benefits to the communities hosting wind projects and related infrastructure and facilities, and may provide a response to the potential displacement of workers from sunset industries associated with the fossil fuel sector.

Chapter 4:

Global Wind Workforce Outlook, 2024-2028

Workforce growth remains strong. The industry trend for significantly more offshore wind installation is a key driver of growth in workforce demand. Looking back to the situation in 2023, offshore wind technicians accounted for 10% (43,583) of the total workforce. This proportion is expected to increase to 14.3% by 2028, representing a total of 76,181 technicians. This strong growth continues to support a recommendation for targeted interventions to increase the workforce by the end of the forecast period in 2028, when the total C&I and O&M workforce demand is expected to exceed 532,400 technicians.

Looking at these trends in more depth, the total number of offshore technicians will grow more rapidly, with an expected increase of 50% from 2024 to 2028 and with offshore O&M technicians especially in demand forecast to grow 87% from 10,4k in 2023 to 19,5k in 2028. The pace of change will be tempered by fewer offshore machines needing a substantial presence of personnel on site, partly offsetting the efficiency gains achieved through higher turbine rating. In contrast, the number of onshore technicians is expected to remain nearly unchanged between 2024-2028 and 86% of technicians will still be located onshore by 2028. In 2024, the onshore demand is projected to reach 467,135 technicians, and 456,232 by 2028.

Revised coefficient

Continuous improvement is a core principle behind forecast generation. A review of key assumptions was undertaken in preparation for this edition of the Global Wind Workforce Outlook. This resulted in a revised, lower O&M coefficient* for the number of technicians needed per MW installed capacity. As a result, the overall workforce demand has decreased. This was due to technological advancements and lifecycle demands. Technological advancements, especially product development and automation, have significantly reduced the demand for turbine operation and maintenance (O&M). As this technology evolves, substitution of wind technicians by process automation and other technical support services, such as remote IT support, drone pilots and AI-powered subsea robot inspections, is nibbling into wind technician demand. We anticipate that in the next five years, the majority of the wind fleet will be in its midlife phase and consequently will have lower maintenance needs. This trend dampens the need for additional, new workforce as existing technicians are able to deliver the O&M needs of a larger number of midlife turbines. At the same time it reduces operational fragmentation, offers synergies across multiple wind farms and increases the efficiency of individual turbine technicians.

Strong demand remains

Comparing last year's report with the restated figure for the same year, the revision of the GWO Wind Workforce Model's O&M coefficient* has resulted in a 7% reduction in the headline figure. The challenge remains that although this figure refers to around 39,000 fewer wind technicians than previously forecast, the shortfall between the actual demand and the anticipated workforce in place in 2028 still offers significant challenges for the industry to obtain the skilled workforce it needs to deliver its objectives. By 2028, the labour gap is projected to exceed 33,808 vacancies, which represents a quarter of the available workforce.

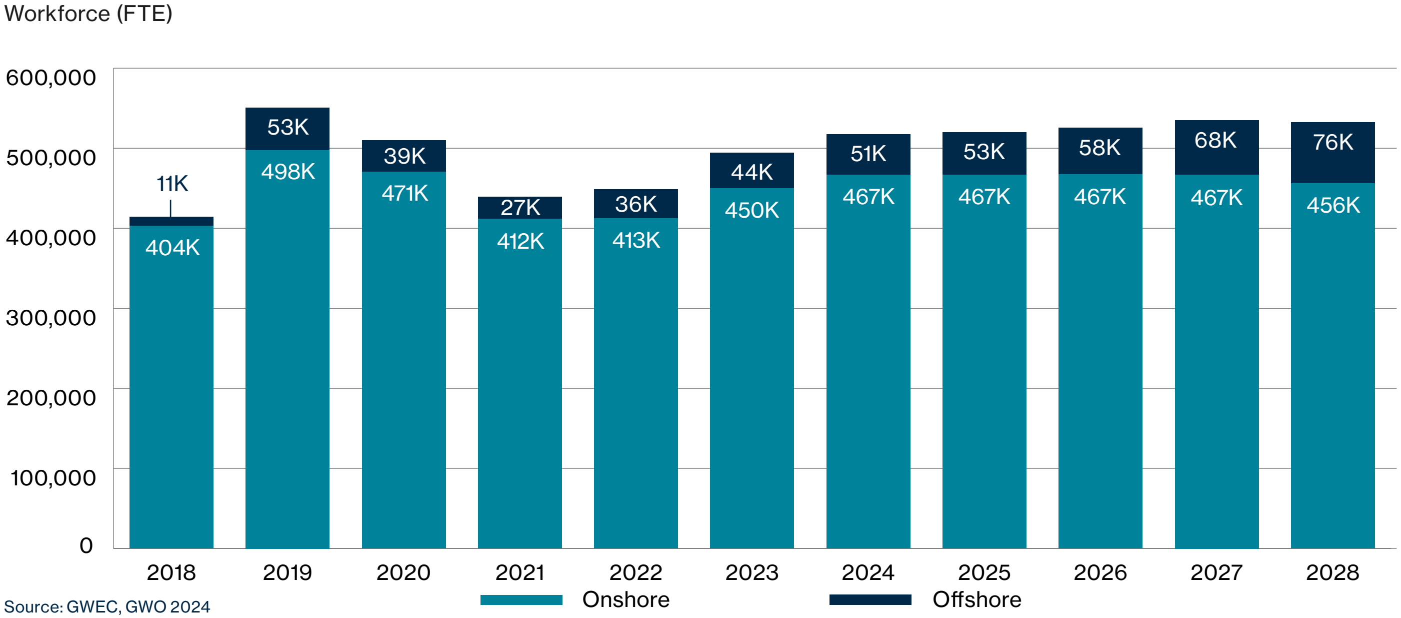
Despite this small dampening effect, workforce demand remains high, re-enforcing the need for the industry to collaborate with educators and governments to ensure that energy transition ambitions are aligned with workforce planning on a national and sub-national scale. Strategies to establish and support local education and training centres to target the recruitment and training of local workforces will continue to be a key approach to answering this demand.

Global workforce shortage

GWO has a strong global presence. As of the end of 2024, approximately 185,000 individuals held at least one valid GWO training certificate, which represents 35% of the estimated global technician workforce. Outside of mainland China, GWO-trained technicians fulfill over 60% of regional demand. This significant presence allows us to estimate the total number of available technicians by region, thereby facilitating an understanding of the gap between available technicians and industry demand.

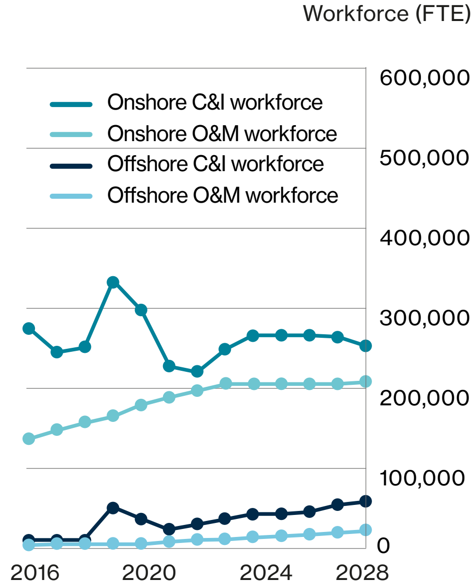
* **Note:** The estimation of labour shortage depends on GWO training records. Countries with very low GWO penetration (including China) have been excluded from our calculation of the total number of active technicians.

Figure 4: workforce demand by onshore and offshore



Source: GWEC, GWO 2024

Figure 5: demand by segment



Source: GWEC, GWO 2024

The estimated gap is calculated by comparing projected demand for technicians with anticipated supply, using GWO's training data as a benchmark. We select 2021 as the reference year, By 2021, we assume that the industry had sufficient workforce after a two year period workforce demand surge.

From this year, we project workforce availability based on a "business-as-usual" growth scenario, where the number of trained technicians continues to increase at historical rates of a given region. The aggregation of regional technician shortage reveals potential global workforce shortages in the wind industry. During the calculation period (2021–2028), the global supply of available technicians is projected to grow at a CAGR of 1.58%.

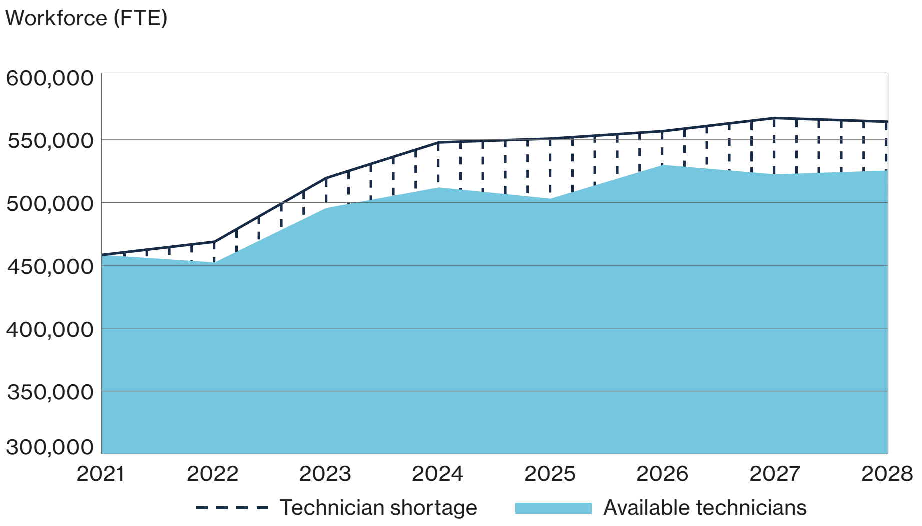
During the study period from 2024 to 2028, the projected labor gap is expected to represent approximately 6-8% of total total workforce demand (see figure 5).

It's important to note that this shortage is not solely driven by technician turnover (estimated 6%); employee churn occurs in every industry, and it is unrealistic to expect it to be eliminated entirely. In addition, the forecasts for wind energy additions, which is based on current stated policies, do not align with the roadmap needed to achieve net-zero emissions targets. According to the net-zero emissions roadmap, global wind capacity additions should reach 320 GW by 2030. However, the current projections indicate that only 182 GW will be added by 2028, resulting in a significant shortfall that could hinder progress toward these important climate goals. The anticipated workforce shortage underscores the need for the wind industry to enhance its strategies for attracting and retaining new talent.

The quantified 6-8% technician shortage (see figure 6) does not create an immediate crisis for employers. However, while this shortage is measurable, the issue of declining technician skill levels has not been fully quantified. To cope with rapid growth, employers are increasingly being forced to lower their recruiting standards, leading to a rise in under-skilled technicians.

Providing accessible training programmes is essential. Currently, there are over 570 GWO certified training providers in 56 countries. Growth in this network, and the availability of GWO training, is highly demand responsive to market signals at a national and local level from industry and governments alike. Further exploration of how demand signal and market stimulus packages are occurring across markets is discussed in Chapter 5, Country commentaries.

Figure 6: technician shortage – availability vs. demand



Source: GWEC, GWO 2024

Chapter 5:
Country commentaries

Despite lofty ambitions to triple renewable installations globally by 2030, alongside specific long-term decarbonisation and net-zero targets, the global race for clean power remains strongly influenced by conventional economic factors.

Overview and policy recommendation

For the wind sector, these targets will be simply unattainable if the required numbers of qualified, trained and experienced wind workforce are not available in time and place. Abundance of trained workforce is an economic 'must have'. Hence, it is crucial that all potential markets for wind have an integral wind or energy policy which not only signals long-term wind pipeline visibility but also assesses wind workforce needs. Such policies must also address workforce availability gaps (education, training, experience and safety) through investments and prioritise inclusivity through just energy transition measures. To put these at the centre of wind and clean energy growth plans, we recommend policy-makers take the following actions into account to fulfil the mid to long-term wind workforce needs:

- Set workforce targets as part of the national energy policy to support wind or renewable energy installation targets.
- Introduce education courses based on science, technology, engineering and mathematics (STEM) for preparing students to become the entry level wind workforce. For example; the Irish government has ramped up its support for STEM education in clean energy workforce creation by introducing the first "Irish STEM Policy".
- Investments and funding programs for workforce training, apprenticeships and upskilling to equip workers with the skills needed for wind and renewable energy jobs, especially offshore wind.
- Promote industrial policy and tendering criteria that foster wind installation growth through local jobs as much as possible.
  - Learnings could be drawn from these value chain localisation-based initiatives or policies for workforce opportunities: USA's Inflation Reduction Act, South Africa's draft South African Renewable Energy Masterplan (SAREM); India's Production Linked Incentives for solar and battery and Europe's Net-Zero Industry Act will facilitate the launch of European net-zero industry skills academies – including one dedicated to the wind sector to upskill and reskill workers.
  - There are examples of non-price criteria, especially for offshore wind, that include skilling and jobs creation in addition to community involvement and socioeconomic benefits: Germany's offshore wind auction for centrally pre-investigated sites includes non-price criteria that consider the contribution to the skilled workforce; The UK's Celtic Round 5 tender includes a range of plans for skills development, apprenticeship plan and volunteering plan; and Australia's offshore wind tender non-price criteria assessment would involve national policy objectives evaluations for local jobs creation.
- Facilitate the tailored retraining/reskilling pathways to promote transfer and upskilling of workers from carbon intensive industries to wind industry jobs.
  - For example, oil and gas and maritime workers can transition to offshore wind sector. Australia's mining sector has representation from First Nations peoples more strongly (3.4 per cent) in the traditional mining sector than they are in clean energy. Policy incentives and programs can deliver a similar trend in the clean energy sector.

- Promote diversity, equity and inclusion to resolve skill shortages by enhancing attraction and retention of workers to the industry.
  - ‘ILO Guidelines For a Just Transition: A Framework for Action’ elaborated action-based framework centered on four building blocks for achieving a just transition: Promoting inclusive, sustainable and job rich economies; Ensuring social equity; Managing the process; Financing just transition
  - The Just Energy Transition Partnership announced during COP26 is a classic example of a policy and financing instrument, here used to foster coal dependent counties’ just energy transition strategy. South Africa, Indonesia and other countries are leading on this partnership.
  - The Federal Government of Australia and the CEC have committed to Equal by 30, which aspires to deliver equal pay, equal leadership and equal opportunities for women in the clean energy sector by 2030.
- Make strategic policy improvement to address workforce imports, exports and dislocation
  - G2G agreements, public-private collaboration and policy provisions can supply the skilled manpower to other markets experiencing workforce shortages- this can provide civil safety, as well as highly paid employment opportunities for those who wish to migrate or are dislocated.
- Set standards and penalty provisions for operational health and safety for onshore wind and offshore wind workforce.
- Embrace the advantages of global standards and workforce initiatives, blending them to meet local conditions.
  - National wind power industry associations in the USA (ACP), Japan (JPWP) and, most recently, Brazil (ABEEólica) are partnering with GWO to establish industry-aligned guidelines for entry-level safety and technical training in their regions.
  - The International Renewable Energy Agency (IRENA) is also promoting Jobs4Re with key partners including Danish and Philippine Governments, GWEC and GWO, to build acceptance of international certification schemes like GWO, increasing certainty for stakeholders and driving workforce growth across all renewable sectors.

The wind industry experienced its most successful year on record in 2023, bringing the total global wind power installation to pass the first 1 TW milestone. The inclusion of a goal to triple renewables capacity by 2030 in the final COP28 text is unprecedented and historic for wind and other renewable energy technologies. The wind industry is becoming more optimistic about its short-term and long-term growth and more confident about its role in delivering the tripling target. GWEC Market Intelligence expects new installations to surpass the previous record and reach 130 GW in 2024. 791 GW of new capacity is likely to be added in the next five years under current policies. This equals 158 GW of new installations each year until 2028.

Global wind power growth in 2024-2028 will continue to be driven by ‘Grid parity’ scheme in China, tax credits in the US, auction/tenders elsewhere and corporate/private power purchase agreements (PPAs).

This section provides country commentaries for ten markets which are projected to add the majority of global wind workforce in next five years: China, USA, Brazil, Germany, India, Australia, Republic of Korea, Philippines, South Africa and Saudi Arabia. Although China, India and the Philippines have not explicitly committed to tripling their renewable energy output in line with the 2030 global target. However, they have equivalent national targets in place.

Australia

Albany Wind Farm, Western Australia

Australia aims for 43% reduction in emissions by 2030, an 82% renewable energy contribution in the national energy mix by 2030 and net zero by 2050. While there are no federal wind targets, various states (such as New South Wales, Queensland, South Australia, Tasmania and Victoria) aim to install wind projects in identified renewable energy zones under their gigawatts-based variable renewable energy installation targets set for 2050.

According to the Clean Energy Council (CEC), 2023 was a slow year for wind power in Australia. In 2023, there was only 942 MW of new onshore wind capacity installation and total wind capacity reached 1.5 GW. There were no new financial commitments announced for utility-scale wind projects in 2023 (compared with six in 2022). However, through the revamped Capacity Investment Scheme (CIS) announced in November 2023, Australia is set to double its large-scale wind and solar installations currently at 22.7 GW, which means 23 GW RE and 9 GW dispatchable capacity by 2030 with its latest efforts to step up spending on clean energy projects.

Based on announced project commissioning dates, GWEC upgraded its annual onshore wind installations outlook and expects 9.5 GW capacity of onshore wind to be added from 2024 to 2028. The growth momentum would be driven by three factors. First, the revamped CIS will hold biannual auctions from April 2024-2027. Secondly, more states have rolled out renewable tenders and installation zones to replace retiring coal plants. Thirdly, strong corporate PPA market driven by sustainability goals plus mining and heavy industries committing to use captive renewables and green hydrogen, and lastly, several transmission projects, such as Project EnergyConnect, VNI West and Marinus Link, are either approved or under construction.

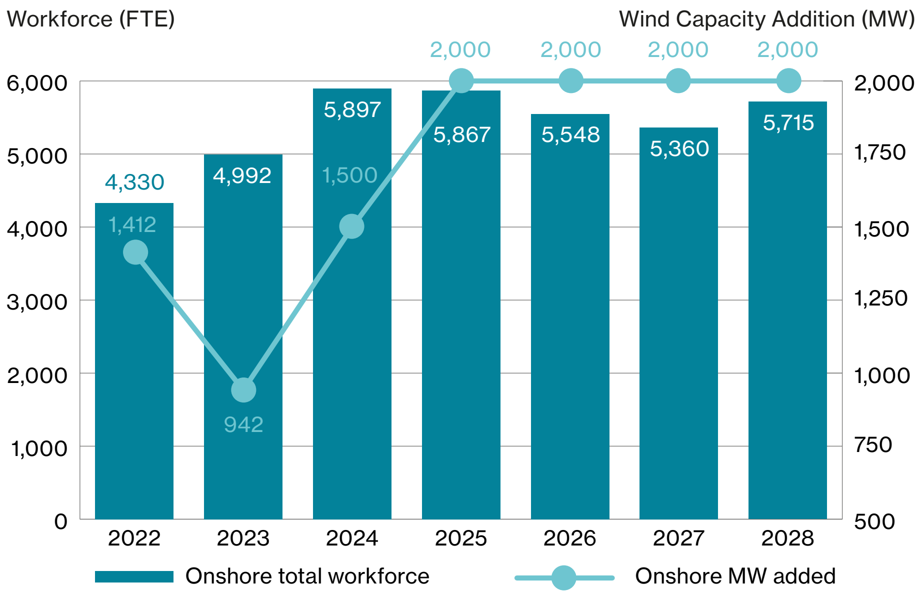
Australia is politically committed to adopting best practice for offshore renewable energy through forward-looking regulations, competitive license process and more flexible frameworks available. The federal government announced the establishment of several offshore wind zones around the country (Gippsland, Hunter Valley, Illawarra, Portland, Northern Tasmania, Perth and Bunbury), while Victoria has set up a one-stop-shop agency, Offshore Wind Energy Victoria (OWEV) for offshore wind development assistance.

While no offshore wind capacity is currently operational, the results of the Gippsland feasibility licencing process were released on 1 May 2024. This marked an important moment in Australia's offshore wind journey and a successful culmination of six years of collaboration between industry, federal government and its agencies. The first set of feasibility licences for six offshore wind projects off the coast of Gippsland in Victoria was granted with an intention to grant a further six licences. This would mean 25 GW of offshore wind playing into Victoria's energy mix, if all 12 projects are built.

Unlocking the full offshore wind potential would require Australia to ensure timely projects commissioning through grid connection, port infrastructure, market design, access to vessels, workforce development (including skills development training), investing in supply chain capacity development and tackling the rise of misinformation in the consultation process.

In addition to offshore wind, renewable hydrogen production is at the centre of the country's global decarbonisation strategies. Its National Hydrogen Strategy has a vision to be at the forefront of green hydrogen production through renewables and export, while the Queensland State Government has launched the Hydrogen Industry Workforce Development Roadmap 2022-2032.

Figure 7: Australia wind capacity addition and workforce demand



Source: GWEC, GWO 2024

There are skills shortage challenges in Australia. If unaddressed, the industry's growing project pipeline will exacerbate these pressures. According to the Australian Energy Market Operator (AEMO)'s 2024 draft Integrated System Plan (ISP), there is additional requirement of 24,000 direct clean energy jobs by 2030, an 81% increase on its previous projections.

Recognition of this challenge is also occurring at the state scale. Queensland's Energy and Jobs Plan will legislate renewable energy targets and define a pathway to deliver 22 GW of new wind and solar projects by 2035. According to the Queensland authorities, this will support 64,000 direct and indirect jobs in construction and operations and maintenance, and 36,000 jobs in the supply chain. The scale and pace of workforce change required for 2030 is urgent for Australia's clean energy growth and requires coordinated reforms. Without this, onshore wind-specific workforce requirement in next five years will be relatively lower.

This forecast, which focuses solely on the annual direct technician demand for C&I and O&M projects, estimates a need for 5,000 to 6,000 full-time equivalents (FTE) per year. This steady demand comes entirely from onshore wind projects, as offshore plans are not yet expected to materialise into finalised construction schedules.

Workforce training needs

The number of active GWO certified training centres in Australia grew significantly from two in 2018 to 17 in 2023, successfully addressing the training needs of a rapidly growing wind workforce. By the end of 2023, 2,660 people were certified in at least one valid BST module, up from 600 at the end of 2018. GWEC expects Australia's first offshore wind farms to reach commercial operations in 2031, with no impact on the workforce during the outlook period.

Brazil

Rosa Dos Ventos, Aracati, Ceará, Brazil

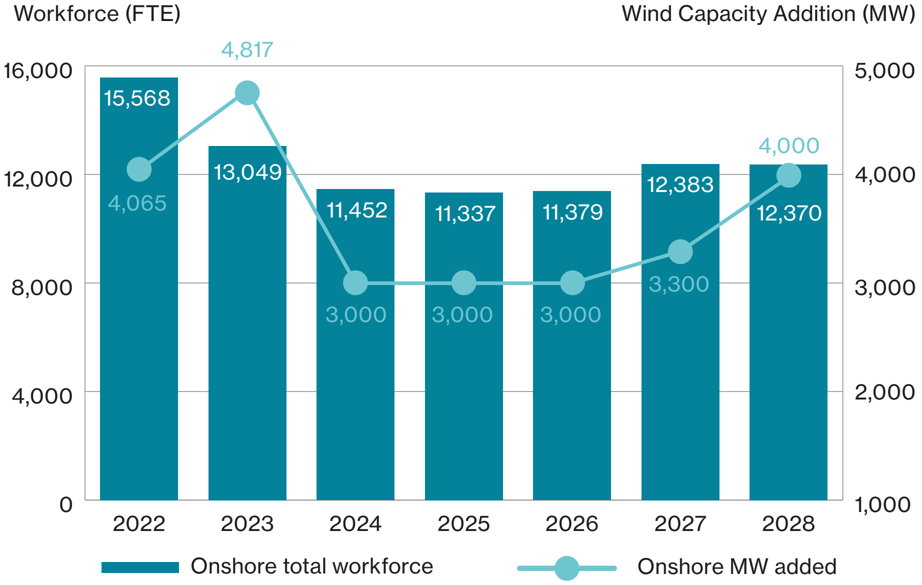
In 2023, Brazil reached a record of 4.8 GW new onshore wind installed capacity, driven strongly by long-term power purchase agreements settled under markets-based conditions. Wind has been recognised across Brazil's government ministries as a vector for a new Brazilian energy economy. There are more than 1,000 wind farms in operation surpassing 30 GW of total onshore wind installations. Currently, the renewables share of Brazil's electricity matrix stands at 84%.

This stable renewables growth is expected to continue due to the sustained investors' confidence and efforts of newly elected climate-friendly Brazilian federal administration. It signed the "tripling renewable energy by 2030" pledge at COP28 and decided to phase out unabated coal power. In 2024 Brazil plays host to the G20 presidency and Clean Energy Ministerial meeting, followed in 2025 by COP30 in Belém. COP30 is expected to focus on nature conservation/restoration and implementation of mitigation targets.

Wind projects in Brazil are expected to be developed mainly on the free market scheme (Corporate PPAs) based on three considerations. First, the dropping of regulated auctions after 2024 (no onshore wind auction capacity awarded since 2023); secondly, limited grid transmission infrastructure; and lastly, lower than expected electricity demand growth. The "New Industry Brazil", a new industrial policy aimed at boosting national development until 2033, includes provisions for investments of R$300 billion until 2026 to finance the neo-industrialisation process, which will drive the wind and renewable energy demand as part of the decarbonisation efforts of large corporate and industrial segments.

In terms of areas of improvement, Brazil needs an upgraded grid infrastructure for reliability and flexibility to avoid major blackout issues witnessed in August 2024. GWEC and ABEEólica are focusing on strengthening the Brazilian wind production chain, which has shown signs of weakening in the last three years. Manufacturers have downgraded production, largely due to a stop-go cycle of development in the country and challenging macroeconomic

Figure 8: Brazil wind capacity addition and workforce demand



Source: GWEC, GWO 2024

conditions. However, over the last year, macroeconomic variables such as inflation, job creation and GDP projection have begun to improve.

Offshore wind and green hydrogen are expected to be additional drivers for wind energy development in the coming years. According to the 'Roadmap Eólica Offshore Brasil', Brazil has a huge offshore wind potential of roughly 700 GW based on around 8,000 kilometres of coastline at less than 50 metres depth. Similarly, a World Bank study identified more than 1,200 GW of offshore wind potential. In addition, in late 2023 Brazil joined the Global Offshore Wind Alliance (GOWA), an initiative between GWEC, IRENA and the Danish Government to raise countries' offshore wind ambition.

As of the first half of 2024, The Offshore Wind Power Bill (PL 11.247 of 2018), which aims to build a regulatory framework for offshore wind, has yet to be passed for final approval in the Brazilian Senate. The development of clear policies, regulatory framework, marine spatial planning, investment in infrastructure and cooperation between the public and private sectors, and local communities will be crucial for capitalising on Brazil's offshore wind potential.

Workforce training needs

In the next two or three years, GWEC expects wind installation growth in Brazil to slow down as a result of a low power clearing price (the reference price in the free/bilateral energy market) as well as, relatively slow growth in electricity consumption due to the expansion of distributed generation. GWEC Market Intelligence expects a total of roughly 16 GW onshore wind installation from 2024-2028 at a relatively lower annual installation rate of 3.3 GW (figure 8 Brazil). This pace of onshore project commissioning seen in 2022-23, which drove C&I and O&M workforce in Brazil, is expected to decline in 2024, and then stay flat in 2025 in response to weaker onshore wind construction activity. The figures are forecasted to start growing in 2026 towards a trained workforce of 12,300, as onshore installations pick up again and companies prepare for the first offshore project scheduled for commissioning in early 2030s. GWO-trained workforce has grown from 600 in 2018 to 10,200 in 2023 with 27 training centres active at end of 2023, up from two in 2018.

China (mainland)

Changling Wind Farm, Jiujiang Lushan Haihui, Jiangxi, China

China retained its global leadership position, with 440 GW (43%) total wind grid-connected capacity in 2023. Followed by its ambitious '30-60' pledge[2] and a target to increase the share of non-fossil fuels in primary energy consumption to around 25%, China made its commitment to further expanding the role of renewables in its energy mix to more than 80% of total new electricity consumption by the end of the 14th Five-Year Period (2021– 2025).

Since 2021, China shifted from a subsidy-driven, feed-in tariff model to a 'grid parity' mechanism, whereby electricity generated from wind and renewable projects will receive the same remuneration as that from coal-fired power. After two years of relatively low growth, wind installations bounced back in 2023 and grid-connected wind capacity surpassed the 75 GW target (includes 6.3 GW offshore wind).

China's first batch of large-scale onshore wind and solar power bases in its northern provinces, with a total installed capacity of 45.16 GW is now online. The second and third batches have an approved total capacity exceeding 50 GW. In addition, (a) two integrated hydro/wind/solar giant bases are to be constructed in Southwest China, (b) transition from nearshore to deep-sea locations and from individual projects to large-scale bases is trending in the eastern coast areas and (c) in the central and Southeast regions, distributed wind projects are to be promoted, especially across villages in the vast rural areas.

It is estimated that from now to 2030, China's total repowering wind power capacity will reach 100 GW. In June 2023, the NEA issued the "Management Measures for the Renovation, Upgrade, and Decommissioning of Wind Farms," applicable to grid-connected wind farms for over 15 years, or have individual turbines with power rating below 1.5 MW. Provinces including Gansu, Ningxia, Fujian, Hebei and Zhejiang are accepting applications for project repowering or decommissioning. China's carbon market expansion will be another driver for wind and renewable energy expansion.

During the 14th Five-Year period (2021-2025), five large-scale offshore wind power bases (each with capacity

[2] Peaking carbon dioxide emissions by 2030 and achieving carbon neutrality by 2060.

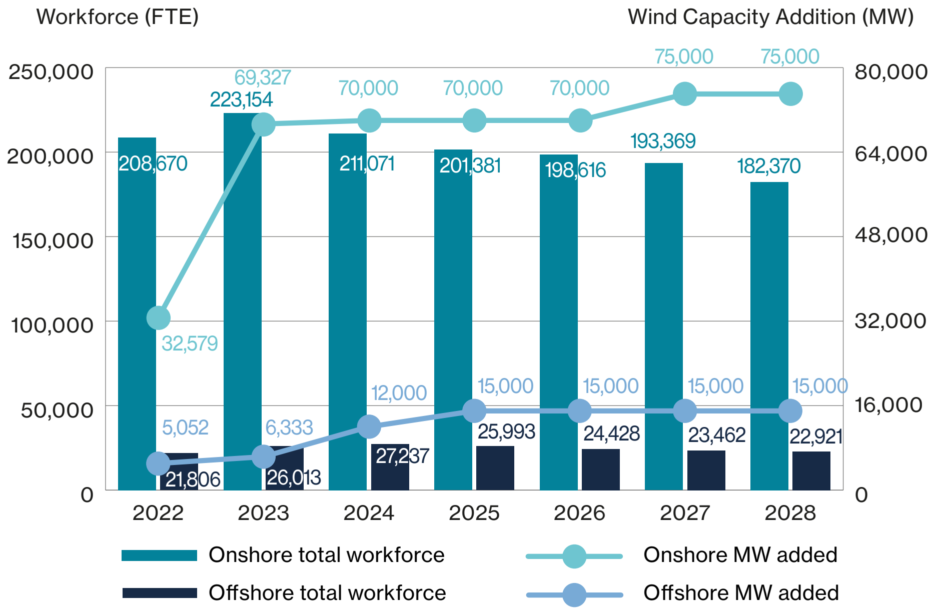
around 10 GW) are to be developed in the Shandong Peninsula, the Yangtze River Delta region, South Fujian, East Guangdong, and Beibu Bay. Through the decentralisation of offshore wind approval, so far, ten provinces have met the total 200 GW offshore wind development target.

China has a leading position in wind turbine technology and has the world's largest and most competitive wind supply chain. Amid fierce domestic price competition and global wind supply chain issues, it accounts for 60-70% of the global market share in wind turbine nacelles and key components production, and roughly 10 wind turbine manufacturers are active in China. At China Wind Power 2023, the Chinese wind industry announced the "Declaration on the Security of the Global Wind Power Industry Supply Chain". This underscores their commitment to building a safe, stable and sustainable industry supply chain, while recognising the need to diversify the global supply chain to improve resilience and support countries in benefitting from the energy transition.

Workforce training needs

With the world's largest sustained growth drivers and most competitive wind energy supply chain, clean energy has become a clear growth engine for the Chinese economy. As a result, GWEC Market Intelligence has upgraded its wind installations forecast for this market and now predicts that 360 GW of new onshore wind and 72 GW of new offshore wind capacity can be added to the grid in the next five years (figure 9 China (mainland)). The total technician workforce demand in C&I and O&M is projected to range from 182,000 to 211,000. This workforce projection is declining due to the increasing average turbine rating. GWEC expects that the average turbine rating for onshore wind in China will grow from 6 MW to 10 MW by 2028, while offshore turbines will increase from 10 MW to 18 MW, positioning China as a global leader. As a result, fewer turbines will need to be constructed, leading to a reduced demand for labour in turbine installation and related activities. The number of GWO-certified training centres established in China increased from six in 2018 to 23 in 2023.

Figure 9: China wind capacity addition and workforce demand



Source: GWEC, GWO 2024

Germany

Nordergrund, Near Bremerhaven, Germany

As defined in the revised Renewable Energy Act (EEG 2023) to reduce German reliance on Russian fossil-fuel imports, Germany aims for increased renewables' share to 80% of its electricity generation mix by 2030. This includes an estimate of about 115 GW of onshore wind capacity requirement to meet the installation target.

Germany is the third largest country globally for total onshore wind installation capacity, with 63 GW, as of 2023. Driven by the strong political will, as well as the improved situation on permitting, the country installed 3.5 GW of onshore wind and 257 MW offshore wind capacity in 2023, the best year for new installations since 2018.

In 2023, Germany's onshore wind auction awarded 6.4 GW, nearly double the volume awarded in the previous year, at the increased tariff rate range of 73.1 to 73.4 EUR/MWh through four under subscribed onshore wind bids. This under subscription was due to several challenges in project implementation; disrupted supply chains and the issue of transport permits; onshore wind permitting volumes were recorded at 7.5 GW in 2023 and 4.7 GW in the first half of 2024. This means that despite the under subscription of these scheduled onshore wind auctions, significant annual growth trend needs to persist and grow to 10 GW pipeline of permitted projects annually to meet country's expansion targets.

The Federal Network Agency of Germany is progressing well on its 2024 auction plan. This includes: first, four onshore wind auctions round each with 2.5 GW capacity to be awarded through a feed-in-premium mechanism. Secondly, two offshore wind auctions of 8 GW total capacity through negative bidding and non-price criteria, including contribution to decarbonisation, PPAs, noise levels and contribution to workforce development.

GWEC Market Intelligence expects Germany will continue to lead the regional market growth with more than 28 GW new onshore wind and 6.3 GW new offshore wind installation in the next five years. This will be mainly by auctions and PPA market drivers including:

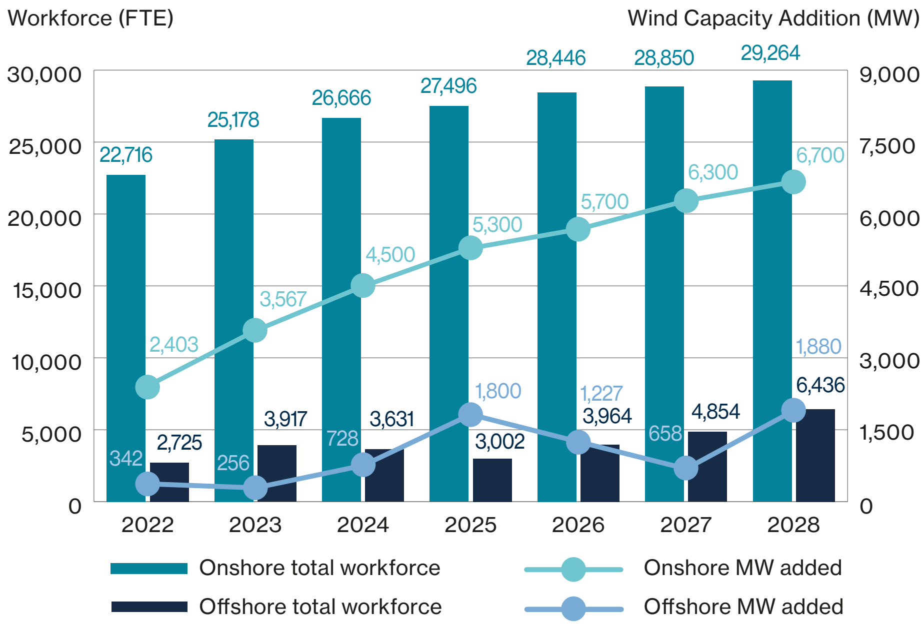
- A new "Onshore Wind Law" (WindLandG) passed in July 2022 as part of 'Easter Package', which allows the auction of 10 GW onshore wind capacity each year from 2025 and mandates German states to utilise 2% of their land area for wind energy generation by 2032. The law also to improves permitting and facilitates the permitting of repowering projects for exisiting turbines.

- Higher onshore bid price ceilings and the implementation of EU emergency measures that improve and streamline permitting.
- PPA market has seen strong growth in the last few years apart from auctions, providing other means for developers to secure fixed prices for electricity production.
- A clear offshore wind auctions schedule to offer 24 GW in both centrally and non-centrally pre-examined areas over the next five years to 2028.
- The preliminary targets set to increase offshore wind power capacity are 40 GW by 2035 and 70 GW by 2045. Germany is also a part of North Sea Energy Cooperation. In BSH's new area development plan, the agency has confirmed roughly 36.5 GW capacity areas for new offshore wind farms in the North and Baltic Seas, and specified the tendering timeline, commissioning and grid connection.
- Progress on green hydrogen would further accelerate wind power demand in Germany as green hydrogen is a very active space. One example is the "Wind H2" project at Salzgitter steelworks where seven turbines situated power electrolysers are producing green hydrogen.

Workforce training needs

Germany's onshore wind capacity is projected to continue its upward trend, leading to a growing demand for onshore workforce, despite an increase in average turbine ratings, which will result in fewer wind turbines. By 2028, over 29,000 technicians are expected to be required to meet the planned construction needs. In the offshore segment, growth is also anticipated from 2024 to 2028, with an average of over 1,200 MW expected to be added annually. This growth is projected to increase offshore workforce demand, ranging from 3,600 to 6,400 technicians. Strong policy drivers showcase a greater number of wind workforce requirement for both onshore and offshore wind growth in next five years. With an election called in Germany for 2025, it will be important that political change seeks to foster greater support for the energy transition and avoid any negative impact it may cause through new restrictions or rule changes, hence delays in installations. By the end of 2023, 15,350 people had already received training to BST through the 31 GWO training providers in Germany, compared with only 7,500 in 2018.

Figure 10: Germany wind capacity addition and workforce demand



Source: GWEC, GWO 2024

India

Kanyakumari, Tamil Nadu, India

India's wind energy growth plays a crucial role in shaping the pace of the energy transition across Asia. It ranks as the fourth largest global wind market, with 47 GW of onshore wind capacity installed by July 2024, and stands as the second largest wind turbine production hub in the Asia-Pacific region for component exports, as part of a supply chain diversification strategy. By August 2024, India had a total of 200 GW of operational non-fossil fuel-based power generation capacity (including large hydro) out of a total installed capacity of 451 GW.

Wind power is essential for India's efforts to provide 24/7 firm power, and meet round-the-clock and peak demands, while ensuring grid stability. Key strategic initiatives such as 24/7 energy access, poverty eradication, rapid urbanisation, and the "Self-reliant India" agenda through "Make-in-India", alongside decarbonisation or net-zero goals in the commercial and industrial sectors, are driving growing energy demands.

With a range of policy and institutional interventions from central and state governments, over 2.8 GW of onshore wind capacity was commissioned in India: the highest annual installation level since 2017. Wind power remains one of the most competitive renewable energy sources for the Indian grid. GWEC expects continued growth under a business as usual scenario and predicts 22.8 GW of new onshore wind capacity to be added over the next five years, accounting for half of the predicted additions in the APAC region in 2024-2028 at 411,732GW.

According to the central government's National Electricity Plan for the period ending 2032, India's installed wind capacity is projected to reach around 73 GW by 2026-2027 and 122 GW by 2031-2032. Until the 2030s, wind installations in India's highly competitive onshore wind market will primarily be driven by:

- A target of 10 GW of annual onshore wind bids from 2023 to 2027, through single-stage/e-reverse auction bidding from state, central, and public sector undertakings (PSUs), including tenders for firm and dispatchable renewable power supply, as part of an upgraded version of the round-the-clock tender for renewable and storage projects.

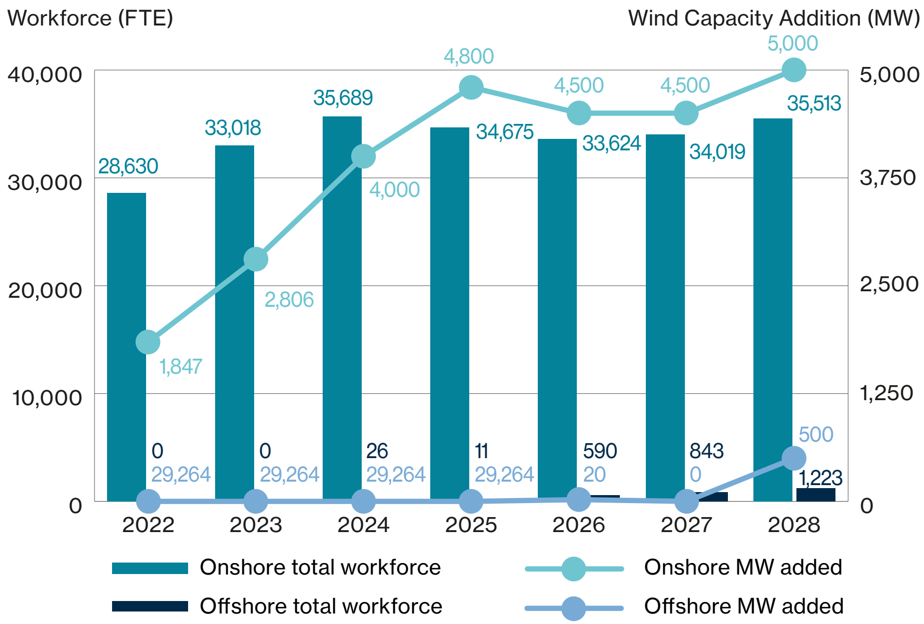
- Inter-State Transmission System (ISTS) charge waivers until June 2025 and transmission planning to integrate 48 GW of onshore wind capacity by 2030.
- Wind-specific Renewable Purchase Obligations (RPOs) from 2023 to 2030 and improvements in the timely disbursal of payments by DISCOMs.
- A mandated minimum share of renewable energy consumption for electricity distribution licensees (DISCOMs) and the ability for consumers to purchase green electricity.
- The revised 'National Repowering & Life Extension Policy for Wind Power Projects – 2023' to facilitate the repowering of wind turbines.

Although positive policy and regulatory momentum is in place, some challenges continue to hinder progress on onshore wind, which could result in a significant shortfall in meeting the 2030 onshore wind target. These include state-level operational issues such as delays in right-of-way permissions, grid connectivity, land procurement and payment delays in certain states.

In the offshore wind sector, the Ministry of New and Renewable Energy (MNRE) aims to harness an estimated 70 GW of offshore wind energy off the coasts of Gujarat and Tamil Nadu. The ministry has announced an auction trajectory for 37 GW of offshore wind capacity between 2023 and 2030, under the strategy paper for the 'Establishment of Offshore Wind Energy Projects' and the Offshore Wind Lease Rules 2023. From this trajectory, the Request for Selection (RfS) for the allocation of sea-bed lease rights for 4 GW of offshore wind projects in Tamil Nadu and the VGF-linked RfS for the development of a 500 MW ISTS-connected offshore wind power project in Gujarat (Tranche-I), are currently underway.

The successful allocation of offshore wind tenders by the government in the current financial year will mark the opening of a new offshore wind market in the region. Several key milestones are supporting the sector's progress, including Viability Gap Funding (VGF) approved for a 1 GW offshore wind project off the coast of Tamil Nadu and Gujarat, grants for two port

Figure 11: India wind capacity addition and workforce demand



Source: GWEC, GWO 2024

upgrades in these states, approval of 10 GW of grid infrastructure for offshore wind projects in Tamil Nadu and Gujarat by 2030, and ISTS charge waivers. The next steps for India will involve establishing a domestic offshore wind supply chain, addressing ground-level market barriers and implementing cost reduction strategies for the emerging offshore wind market.

Workforce training need

This remarkable progress in the wind sector highlights the growing need for a qualified workforce, particularly for offshore wind, towards the end of this decade in India. The National Institute of Wind Energy, a training facilitator and agency of the national government, has implemented the Vayumitra Skill Development Programme in nine onshore wind states in India. A surge in onshore wind workforce training, especially in the commercial and industrial sectors and in operation and maintenance (O&M), would only be expected if the volume of annual installations increases to between 6 GW and 10 GW in an ambitious scenario over the next five years.

The forecast projects a technician demand of approximately 35,000 people during the 2024-2028 period (figure 11 India) to reach a total of 36,736 by 2028. This is driven by consistent construction plans. In contrast, India's offshore segment remains limited in development compared to its onshore counterpart. By 2026, the offshore sector is expected to require around 500 technicians, with this number projected to grow to over 1,200 by 2028. The number of GWO trained people in India has grown steadily from 2,000 in 2018 to 17,300 in 2023 as GWO training providers in India increased from one in 2018 to 24 by 2023.

Philippines

Bangui Wind Farm, Bangui, Ilcos Norte, Philippines

The Philippine Energy Plan aims for a 35% share of renewables in the power mix by 2030 and 50% by 2040. Wind will play an important role in decarbonising the economy while reducing dependence on energy commodity imports. As of 2023 the total onshore wind installed capacity stands at 593 MW.

Presently, the Green Energy Auctions Program serves as the primary offtake mechanism for onshore wind, offering a transparent pipeline and tariff structure. In 2022, the inaugural auctions awarded 374 MW of onshore wind capacity at a ceiling rate of PHP 6.0584/kWh ($0.11/kWh).

The second round, concluded in July 2023, targeted 3.5 GW of onshore wind, but only 1.46 GW of bids were successful at a lower ceiling tariff of PHP 5.8481/kWh ($0.10/kWh). According to a GWEC survey at the time, developers were reluctant to participate due to tight timelines, low tariffs, stringent performance bonds and grid constraints.

In the offshore wind space, Philippines' growth is propelled by progressive policies streamlining permits, encouraging foreign participation and the introduction of a marine spatial tool. With plans for an enhanced Energy Virtual One-Stop Shop, developers anticipate smoother permitting processes for offshore wind projects. The Philippines Department of Energy (DOE) has already approved 63 GW of offshore wind sites and are processing more applications. It further expects 6 GW of offshore wind capacity to be commissioned by 2030 and plans to conduct the first offshore wind Green Energy Auction Program round in Q2 2025.

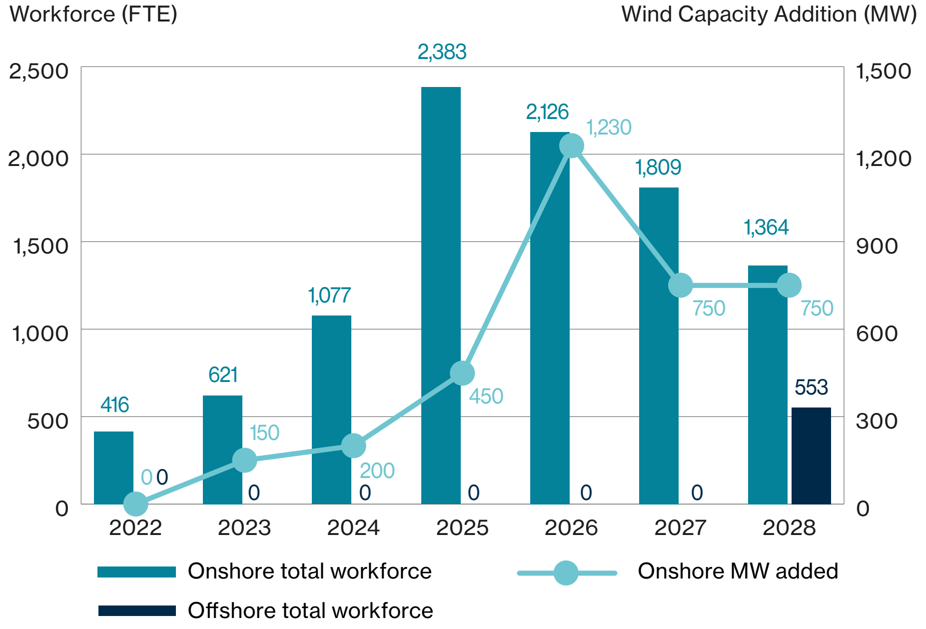
Having a separate auction for offshore wind will hopefully set clear capacity targets and price expectations for the medium- to long-term horizons. However, project de-risking measures are necessary, such as policy stability, long-term auction pipeline visibility, grid and port infrastructure, lowering performance bond requirements, mandating technical studies, indexed tariff against inflation and comprehensive cost mapping.

Despite the challenges ahead, there is optimism about wind energy development in the Philippines. With continued government support, favourable technical resources, technological advancements and strengthening market conditions, the sector is poised for growth. GWEC Market Intelligence predicts 3.4 GW of new onshore wind and roughly 500 MW offshore wind installation in Philippines between 2024 to 2028 (figure 12).

Workforce training need

During the next five years, the Philippines' wind workforce requirement will chiefly come from onshore wind installation. In 2025, the demand for onshore technicians is expected to peak at approximately 2,400 people (figure 12 Philippines), after which it will decline, due to a reduction in construction activities. Conversely, demand for the offshore workforce is projected to increase significantly in 2028 in anticipation of future projects planned for 2029 and 2030. Currently, there are three GWO training facilities in the Philippines.

Figure 12: Philippines wind capacity addition and workforce demand



Source: GWEC, GWO 2024

Saudi Arabia

Dumat Al Jandal Wind Farm, Saudi Arabia

The approach of the Kingdom of Saudi Arabia (KSA) is focused on the strategic initiative 'National Renewable Energy Program' (NREP) under Vision 2030 and the King Salman Renewable Energy Initiative. During the 2023 COP28 United Nations Climate Change Conference in neighbouring United Arab Emirates the KSA government announced a target of 20 GW renewable energy capacity additions annually up to 2030, as part of achieving 130 GW or 50% renewable generation by 2030. This sets out a roadmap to diversify local energy sources and provide sustainable economic stability.

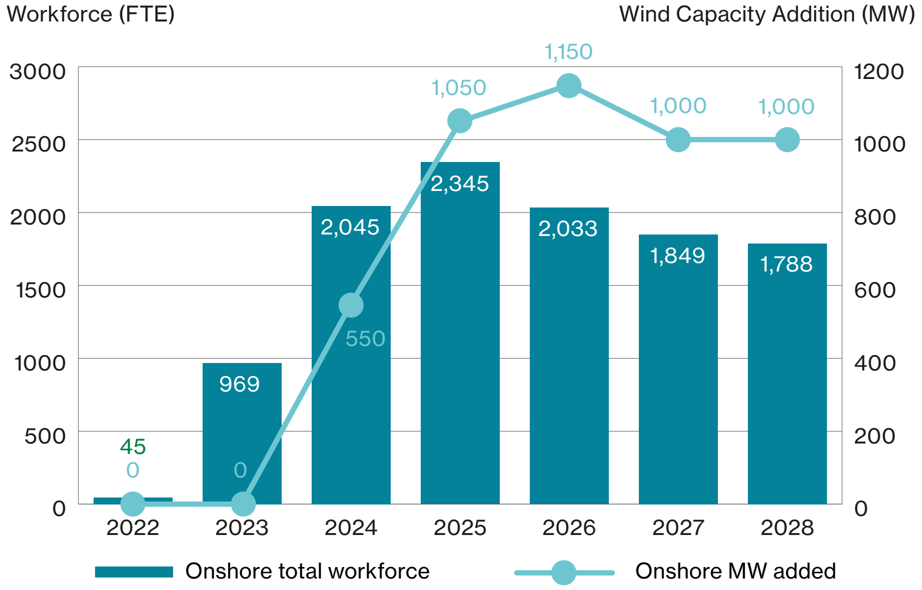
Today, Saudi Arabia's energy mix consists of <1% renewable energy, around two-thirds oil and around one-third gas. With wind speeds ranging from 6-8 m/s, Saudi Arabia's onshore wind potential is estimated at around 200 GW across seven different regions. The country operates a 400 MW Dumat al Jandal, its first utility-scale wind energy project located in the Al Jouf region, which recently reached its commercial operation date. It is owned by EDF (51%) and Masdar (49%) and consists of 99 4.2 MW Vestas turbines. This flagship project also boasts one of the lowest wind energy tariffs in the region, reportedly $19.9/MWh.

Large onshore wind project investments announced since last year include:

1. final procurement of three wind IPP projects (700MW Yanbu wind IPP, 600MW Al-Ghat wind IPP, 500MW Waad al-Shamal wind IPP) under NREP's fourth bid round with expected operations by 2026.
2. the 1.67GW wind turbine contract awarded to Chinese Envision Energy for the NEOM Green Hydrogen Project, expected to be fully operational by 2026.

According to the Ministry of Energy, there are 1,200 sites identified in various regions for pre-development preparation in the country to further initiate solar and wind projects. The next five years will be critical for evaluating Saudi Arabia's success in diversifying its energy production and investing in renewable energy industries such as wind and solar.

Figure 13: Saudi Arabia wind capacity addition and workforce demand



Source: GWEC, GWO 2024

GWEC Market Intelligence predicts around 4.7 GW of new onshore wind capacity addition from 2024 to 2028 (figure 13 Saudi Arabia); showcasing relatively buoyant onshore wind workforce requirements.

In addition, the offshore wind potential of Saudi Arabia's coasts is technically estimated to be up to 28 GW for conventional fixed-bottom installations and 78 GW for floating offshore wind installations. The launch of green hydrogen schemes and the potential to export green products, including green hydrogen derivatives, are encouraging for the development of both onshore and offshore wind. However, timelines for these plans are unclear, and there is a lack of transparency on the future projects, both onshore and offshore.

While Saudi Arabia boasts strong wind resources and optimistic renewable energy goals, its grid system will need to adapt to a higher share of variable renewable energy. At the same time the country's infrastructure for wind farms is still in its early stages, demanding specialised expertise and significant network development.

Renewable targets need to be coupled with sound national policies that facilitate the extensive roll-out of renewables and provide a conducive environment for further investments. If Saudi Arabia's model is successful, it will set a precedent in the Middle East for other oil-dependent countries to follow.

Workforce training needs

GWEC forecasts an addition of 950 MW of onshore wind capacity between 2024 and 2028. On average, around 2,000 technicians are required to support onshore wind development during this period. The peak demand for technicians is expected in 2025, after which the number of required technicians is projected to decline, in line with the slowdown in scheduled construction activities. There are currently no GWO-certified training providers in the country, with wind training happening in regional hubs in the EMEA region and India.

South Africa

Gouda Wind Facility, Gouda, Western Cape, South Africa

South Africa's energy mix relies heavily on coal, but ambitions for an improved renewable energy share in its power generation mix foresee a rise to 41% by 2030, driven by increasing onshore wind and solar installation capacity.

The allocation of wind procurement in the Integrated Resource Plan (IRP) of 2010 paved the way for utility-scale wind projects and, more recently, through auctions under the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP). A total of 3.4 GW onshore wind capacity has been awarded through REIPPPP auction rounds BW1 to BW4 up to year 2015.

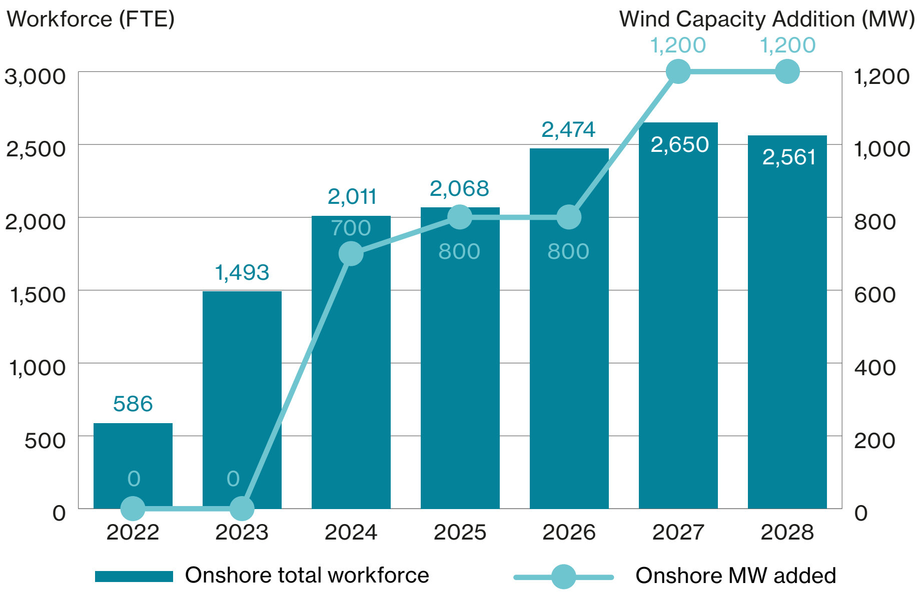
The revised, IRP 2019 further plans to allocate wind energy auction from 2021 to 2030 from which, the government has awarded two out of three planned new renewable energy auction rounds, totalling 6.8 GW under REIPPPP. Both auctions have been delayed. The first auction, BW5, awarded around 1.7 GW onshore wind capacity, which is expected to be commissioned by 2024/2025. No wind capacity was allocated through the second auction round, BW6, in December 2022 due to unavailability of grid capacity in Eastern and Western Cape.

The third round, BW 7 is delayed to 1H 2024 with undisclosed volume.

The two hybrid projects Oya 82.5 MW and Umoyilanga 77 MW awarded under 'Risk Mitigation Independent Power Producer Programme' were delayed and are at risk of cancellation, due to delays in its initial awarding phase; in reaching financial close and followed by project execution related delays.

However, the PPA market has gained popularity in South Africa, driven by the cheaper cost of energy compared with coal. The addition of these megawatts to the country's electricity system through private sector investment has positioned South Africa as a prime onshore investment destination in the region.

Figure 14: South Africa wind capacity addition and workforce demand



Source: GWEC, GWO 2024

By the end of 2023, South Africa's wind energy market showcased steady growth, with 3.4 GW of total onshore wind installed capacity. With projects awarded through the REIPPP Bid Window 4 auction coming online, in addition to delayed award of auctions and financing support needed for enough grid infrastructure creation, GWEC forecasts 4.7 GW onshore wind installation between the 2024-2028 (figure 8 South Africa).

South Africa's energy planning policies continue to evolve, with the Draft IRP 2023 released for public consultation in the first quarter of 2024. While onshore wind has been included in the envisaged energy mix, offshore wind is yet to be incorporated.

Workforce training needs

South Africa's onshore wind construction ambitions are increasing annually, driving a steady rise in the demand for an onshore wind workforce. By 2028, it is estimated that 2,000 to 2,500 technicians will be needed each year to support the growing capacity and expansion of onshore wind projects across the country. This upward trend reflects the country's commitment to scaling up renewable energy infrastructure. By the end of 2023, five GWO-certified training centres were in operation in South Africa with 1660 GWO-trained people in 2023, up from 275 in 2018.

Republic of Korea

Jeju Island Wind Power Plant, Jeju, Republic of Korea

Since 2017, the Republic of Korea's Government has demonstrated a strong interest in leveraging its renewable energy potential to contribute to its energy transition, and to reduce its heavy dependence on fossil fuel imports and energy price volatility. The Carbon Neutrality Act of 2021 targets achieving net zero by 2050. To realise this, over 60% of total power generation must be sourced from renewables. Under the 10th Basic Plan for Power Distribution published in 2023, the Ministry of Trade, Industry and Energy (MOTIE) announced a target of 21.6% of renewable energy in the total energy mix by 2030, with 5 GW onshore wind and 14.3 GW of installed offshore wind capacity target.

Currently, it is an emerging wind market with a relatively small footprint of wind installation, with 1.8 GW onshore wind and 144 MW offshore wind. The Republic of Korea's renewables portfolio system (RPS) was introduced in 2012 and remains in operation. Renewable energy suppliers can also obtain renewable energy certificates (RECs) in MWh units for offshore and onshore wind to meet the mandated RPS quota, while additional RECs can be traded on the spot market. The spot price of RECs has risen by nearly 50% from 2022 to 2023, prompting MOTIE to announce plans to stabilise the REC market in 2024.

The Republic of Korea's estimated 624 GW offshore wind potential is impressive and encompasses both fixed bottom and floating wind turbines. Its total offshore wind capacity with electric business licences (EBL) grants reached an impressive 20.8 GW by 2022. However, these projects faced bottlenecks from a lengthy bureaucratic/permitting process (under an open-door approach), grid constraints, local community acceptance, lack of policy support and regulatory clarity. For example, the 'one-stop-shop' offshore wind bill, which was due to introduce a dual-track system, has been pending for more than two years.

Hence, the Republic of Korean government has pushed for a variety of reforms. First, the introduction of government-led site selection and auctions to ease the costly and lengthy EBL-based project permitting process, which involves 29 licenses from different ministries. Secondly, focusing on capacity building and awareness raising initiatives to streamline the licensing process. Thirdly, assessing and communicating socio-economic effects through wider stakeholders' engagement to resolving specific fisher conflicts. The country's existing manufacturing competitiveness, development of port and infrastructure and a generous renewable energy credit scheme have also been a positive incentive for establishing a resilient offshore wind supply chain.

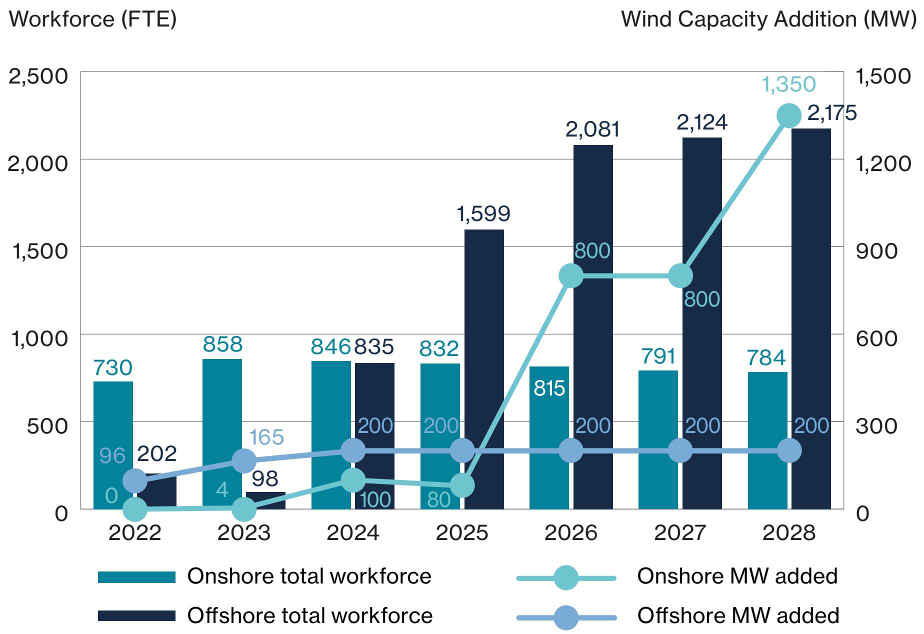
With these efforts, the country's first offshore wind subsidy auction with a confidential price cap was awarded in January 2024 to low-priced Chinese suppliers, although Vestas emerged as the biggest winner, securing 600 MW Wando Geumil Phase I & II and 396 MW Sinan Ui projects. Vensys (owned by Goldwind) and Mingyang secured 365 MW and 70 MW projects order respectively. This sparked a debate on the relative importance of minimising cost and fostering a local supply chain that can compete with global peers.

Workforce training needs

As part of Offshore Wind Power Competitive Bidding Roadmap, MOTIE launched the first in a series of offshore wind tenders in October 2024 for 1.5 GW capacity and will launch (at least) two more until the first half of 2026. In total, 7-8 GW of capacity is planned to be auctioned. With these impressive offshore wind progress, GWEC predicts new installations of 3.1 GW offshore wind and 1 GW onshore wind in next five-years (figure 15: Republic of Korea). This means larger wind workforce demand for offshore wind growth in the Republic of Korea. The Republic of Korea is the only country that follows an offshore-dominant pattern in all selected markets covered in this report.

With only 753 people with a valid BST certificate as of the end of 2023, training providers and educators could train an additional 2,000 people in the next five years. Wind growth patterns in the Republic of Korea suggest a workforce needed to install and maintain the onshore wind fleet will fluctuate around 800 people during the 2023/ 2028

Figure 15: Republic of Korea wind capacity addition and workforce



Source: GWEC, GWO 2024

period. With 3.1GW coming online from 2024 to 2028, offshore wind will drive workforce additions, with a surge in the total number of technicians needed to install and maintain assets growing from 800 in 2024 to 1,350 in 2028. The total number of C&I and O&M technicians in the Republic of Korea is expected to reach 2,900 people in 2028, driven by the buildout of new offshore wind assets.

USA

Windy Flats Wind Farm, Goldendale, WA, USA

As one of the world's leading wind markets, the USA exceeded 150 GW of total onshore wind installations by the end of 2023. The landmark Inflation Reduction Act (IRA) package was responsible for injecting widespread optimism into the future USA wind outlook.

A promising onshore wind outlook reinforced by IRA

After record installation levels in 2020 and 2021, 6.4 GW of new onshore wind capacity was installed in 2023, the lowest annual installation level since 2014. The low levels were due to market saturation in certain areas and delays caused by siting, permitting, supply chain constraints, inflation and long wait times in the grid interconnection queue. Instances of local oppositions to renewable energy projects, as witnessed in media reports, are also rising, suggesting a further source of delay.

The US onshore wind market has been typified as a tax credit-driven market. Presently, the IRA is providing a much needed investment landscape for long-term scale visibility for investors by upgrading the country's century old grid infrastructure into a modern, resilient grid system, while also stimulating clean power manufacturing. At least 22 high-voltage transmission projects are under development in the US; for example, the Gateway project and the Grain Belt Express project. In 2023, total wind assembly capacity increased by 15% on the previous year. As local capabilities have expanded imports of blades and hubs fell by 26%, the lowest levels of import volumes in the past 10 years.

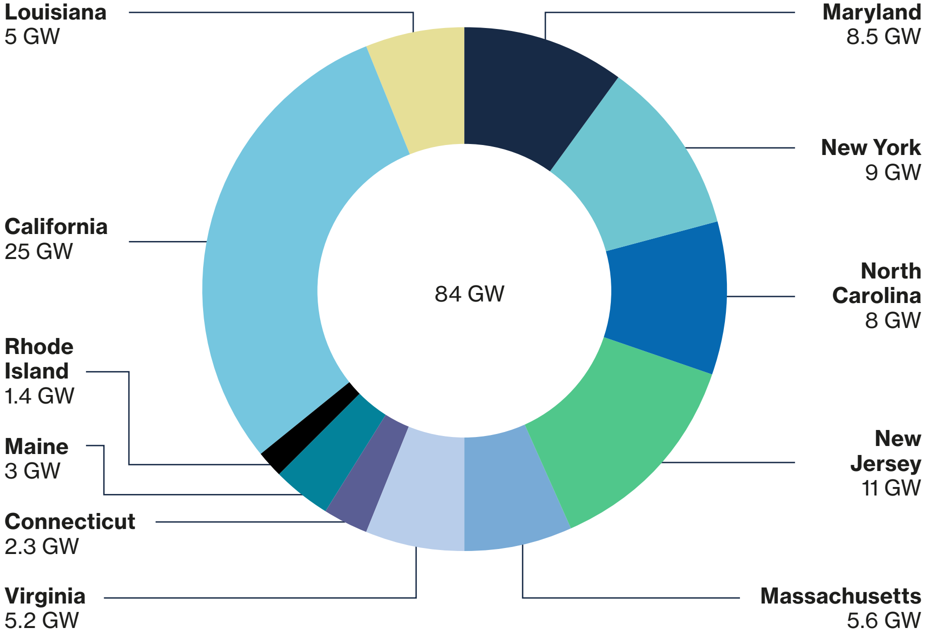
According to ACP, the US has 25.3 GW onshore wind pipeline by the end of Q1 2024, up more than 5 GW from the same time last year. With developers continuing to refill their pipeline in 2024, GWEC predicts that the US onshore wind market will be back in full swing from 2025/2026 and reach 16 GW by 2028.

A resilient offshore wind growth despite financial headwinds

With no new offshore wind installation in 2023, the US had 42 MW of total offshore wind capacity in operation by the end of 2023. The US Offshore wind market growth would primarily be driven by technology neutral tax credits and a country target of 30 GW by 2030 (30x30, to be largely met using bottom fixed technology). At the state level, eleven states have a combined offshore wind procurement target of 84 GW, including new offshore wind targets signed into law in Maryland, Maine, and California in 2023 (figure 16: US US State-level offshore wind procurement targets (Global Offshore Wind Report 2024, GWEC)).

During 2023, the US offshore wind industry experienced strong headwinds. Several projects encountered financial challenges due to inflation, interest rate increases, and supply chain constraints, including for vessels and foundations. Notably, nine projects, totalling 7.7 GW, have either had their offtake agreements terminated or seen the whole project development ceased, which triggered multi-billion dollar write down by large European and

Figure 16: US State-level offshore wind procurement targets*



Source: GWEC

*Announced plan, not yet signed by law

US developers. Hence, GWEC Market Intelligence has downgraded the US offshore wind outlook to 10 GW for the next five year from the 15 GW predicted in the previous year's outlook. This still makes it the largest offshore wind market after China and the UK in terms of new additions.

By 2024, a fresh start began with the commencement of a new offshore wind leasing rounds planning unveiled by the US Department of Interior in April 2024. This gave a new five-year schedule of offshore wind leasing rounds, aiming for up to 12 lease sales starting from 2024 to 2028, which would showcase a unique multi-state collaboration approach to procure offshore wind power. As of May 2024, four projects with a total 4.3 GW capacity are under construction, and another 50 GW projects are in the development and planning stages.

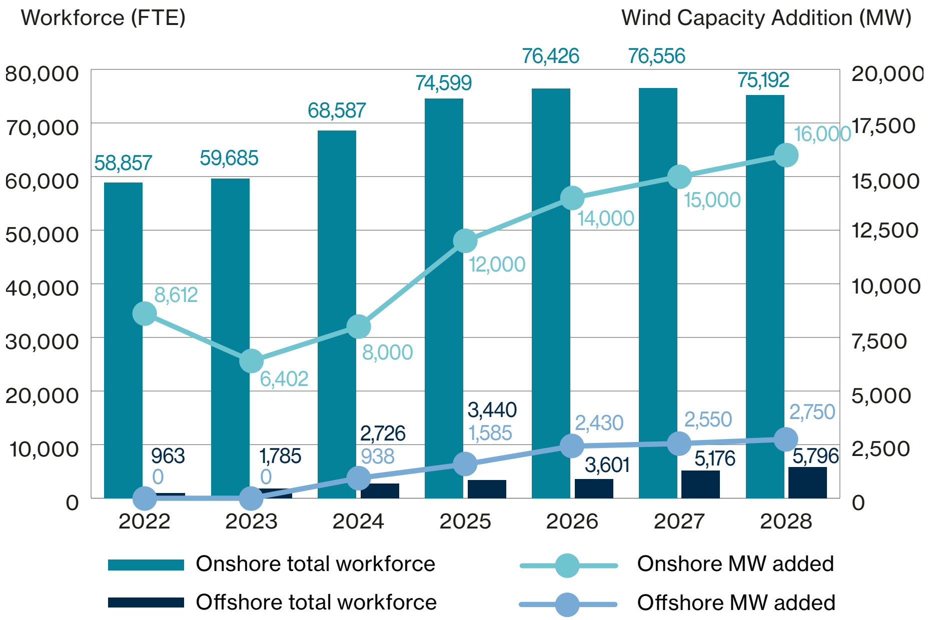
Additionally, the IRA package would continue to support offshore wind planning and permitting reform legislation, manufacturing, and clean job creation through five routes. First, tax incentives for wind projects up to 2032; secondly, $100 million for offshore wind transmission planning. Thirdly, domestic manufacturing tax credit for offshore wind components and an extension of the investment tax credit for vessel construction. Fourthly, offshore wind development in southern part of the US Atlantic coast, and lastly, inclusion of inflation adjusters in the bidding/project contracts.

To fully capitalise on promising onshore and offshore wind outlook leveraging IRA benefits, the USA will need to heavily invest in wind manufacturing, port upgrades, grid infrastructure and workforce trainings across the value chain including C&I and O&M. According to US Department of Energy (DOE), the U.S. wind industry currently employs more than 125,000 full-time workers (construction (>45,000) and manufacturing (>23,000). In order to reach the 30x30 goal DOE estimates an additional requirement of 44,000 workers in the offshore wind industry and an additional 33,000 in communities that would directly benefit from the industry.

The positive five-year outlook signals greater onshore and offshore wind workforce requirements across the value chain. To ensure the availability of skilled wind workforce, USA state, federal and private players are running a series of programmes and funding including:

- ‘Offshore Wind Workforce Education and Training Database’ to increase offshore wind training opportunities, and the ‘Wind Energy Technologies Office’ to address the wind industry’s workforce needs through various targeted investments.
- The DOE’s Wind Energy Technologies Office launched a $11.9 million investment in the offshore wind workforce in the form of the Academic Center for Reliability and Resilience of Offshore Wind (ARROW).
- The Maryland Energy Administration announced the Maryland Offshore Wind Workforce Training and Education Program for fiscal year, 2025 by providing grant funding up to $3,000,000 on a competitive basis for industry education and workforce training.

Figure 17: USA wind capacity addition and workforce demand



Source: GWEC, GWO 2024

- The State of New York aims to create more than 10,000 wind energy jobs through its 9 GW offshore wind commitment, with opportunities spanning 117 offshore wind occupations across the supply chain.
- In partnership with Rowan College of South Jersey, Ørsted’s Wind Power Ready: Atlantic City programme is training New Jersey residents to become wind turbine technicians.

According to NREL, to reach the 30x30 goal, average annual employment levels (full-time equivalent/year) are estimated at 15,000 and 58,000, based on 25% and 100% domestic content scenarios, respectively. Due to headwinds, several new wind-related factories announced in the USA have been delayed, stalled, or cancelled, cutting in the existing job total. This includes Siemens Gamesa's blade factory plan for Virginia, GE Vernova and LM Wind Power plans, Marmen and Welcon tower facility delays.

The time to deliver actions is now, hence, the offshore wind challenges have to be converted into a firm strong orderbook pipeline. This would create a strong wind workforce demand for C&I and O&M to realise the growth needed.

Workforce training needs

GWEC predicts a growing annual addition in both the onshore and offshore segments. It is projected that 65 GW of onshore wind capacity will be added between 2024 and 2028. In line with this growth and cumulative installations, an average of approximately 75,000 technicians will be needed each year for onshore wind, while around 4,000 technicians will be required annually for offshore wind. This positions the USA as the second largest country in terms of wind technician demand.

The workforce trained in GWO standards in the USA increased from 1,800 in 2018 to 15,198 at the end of 2023 while the network of local training providers grew from six training centres to 67 during the same period. The total C&I and O&M technicians is estimated at 80,900 people by 2028.

Special feature

Bridging the gap: AI innovation in offshore wind

By lead sponsor, Beam

Many nascent markets are emerging and racing to increase capacity. However, there are several hurdles that must be overcome for the industry to succeed – a growing workforce need is one of them. This year's Global Wind Workforce Outlook reveals the scale of this challenge, identifying that over 530,000 technicians will be needed to work in C&I and O&M by 2028.

To emphasise the urgency of addressing this workforce gap, regional targets, such as the European Union's ambitious goal of achieving 111 GW of offshore wind capacity by 2030 (compared to 34 GW installed in 2023) illustrates how formidable the challenge for the industry is. According to GWEC, aligning with WindEurope's projections, the EU requires an average of 8.5 GW of new installations annually until 2028. However, this pace falls significantly short of the average installation rate needed for the EU to meet its 2030 offshore wind target.

If the industry is to understand and tackle this gap between current capabilities and targets, we must look at solutions that can help address the workforce challenge too. In the offshore wind market, industry can utilise advanced technologies to improve efficiencies and facilitate a fundamental revision of how work is conducted. Beam, a leading deep technology company, believes AI and automation can help achieve this by using AI and autonomy on robotic ships and underwater robots to service offshore wind farms and improve existing capabilities.

Pioneering AI solutions: advanced autonomous technologies

In a significant advancement for the industry, Beam successfully deployed the world's first fully autonomous inspection of an offshore wind jacket at Scotland's Seagreen wind farm, a joint venture between SSE Renewables, TotalEnergies, and PTTEP.

The success of this deployment is a crucial milestone in the application of AI to offshore wind maintenance. The technology offers several groundbreaking capabilities, notably fully autonomous underwater inspections without human intervention.

This new approach to operations and maintenance work at offshore wind farms allows real-time data to be streamed directly to shore, provides advanced 3D asset reconstruction, as well as comprehensive visual data collection. It also allows for the automated monitoring of marine growth and erosion at foundations.

Transforming inspection efficiency

The significance of this type of technological advancement lies in the need to move away from the manual and labour-intensive processes that offshore wind typically relies on. Data from Beam's AI-powered operations shows this approach can reduce inspection timelines by up to 50%, reduce operational costs, and enhance data quality and accessibility. The success at Seagreen, the world's deepest fixed-bottom offshore wind farm, has demonstrated the technology's potential for large offshore wind superstructures.

Workforce revolution

This technological advancement is creating new opportunities to attract top talent, including from tech industries and the oil and gas sector, where many of the transferrable skills that offshore wind needs are held. By offering appealing, technology-driven roles with competitive compensation, the offshore wind industry can draw the best and brightest minds to accelerate the energy transition.

The transformation of traditional roles, underpinned by technology, brings many benefits. By taking on the repetitive, manual parts of a job, workers may shift their focus onto more complex tasks. We believe that a technician paired with AI can complete exponentially more work than they can alone. At the same time, unsupervised autonomy is allowing sea based vehicle operators to work onshore, now as autonomous fleet managers with associated mitigations of worker safety risks.

Building a sustainable future

An increasingly automated and digitalised workforce is much more than an engineering achievement. It's a blueprint for achieving the EU's dual objectives of climate action and economic growth, as these advancements show how we can help meet a climate goal, such as offshore wind capacity targets, while alleviating workforce supply issues.

This is vital, as the workforce challenge remains significant. With a workforce powered by this strategic deployment of cutting-edge technologies, the industry can better meet demands while creating more efficient, safer and more sustainable operations.

The future of offshore wind energy is reliant on the convergence of AI innovation, workforce transformation and clear environmental targets. Deployments such as Beam's at Seagreen, demonstrate how, through technological innovation and strategic deployment, we can collectively drive forward a sustainable energy future.

Chapter 6:
Methodology: the Wind Workforce Model

Number of technicians needed is projected based on wind capacity and technician-to-turbine ratios. The workforce demand for Construction and Installation (C&I) is projected based on wind capacity additions over the next two years, while demand for Operation and Maintenance (O&M) is based on cumulative wind capacity for the current year. The model assumes technicians should be available 1-2 years prior to construction. For both onshore and offshore C&I, the forecast includes 70% of the turbines projected for the upcoming year and 30% for the current year under study.

Using GWEC's input on total installed capacity and the rating of operational wind turbines, we estimated the number of turbines operating in each country. We then used annual turbine additions to project the volume of the cumulative installed turbines out to 2028.

GWO's forecast uses estimated technician-to-turbine ratios to estimate technician demand for onshore and offshore C&I respectively

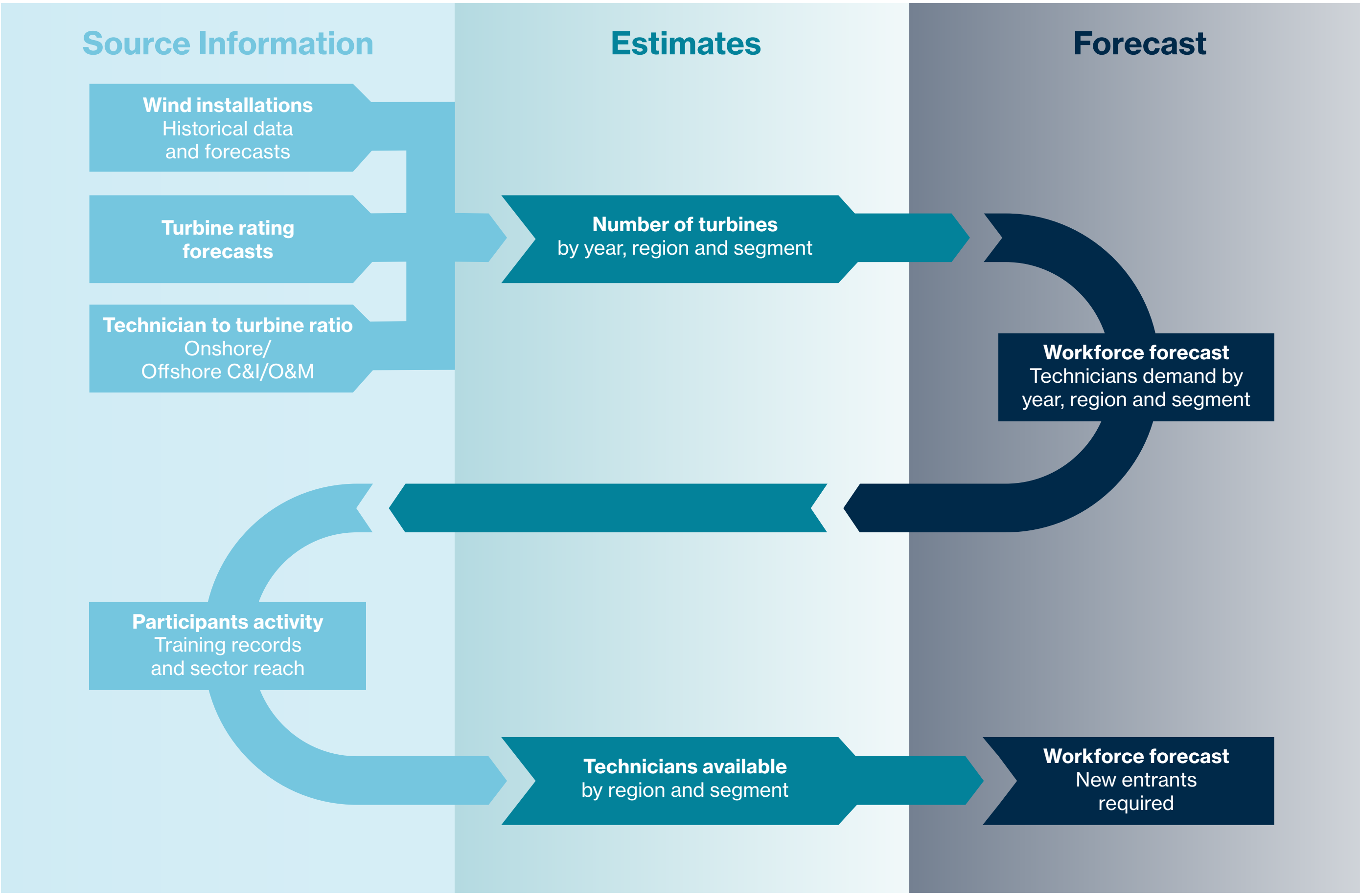
Technician-to-turbine ratio indicates how many technicians are needed for each turbine during its construction and installation phase. This ratio can vary depending on the complexity of the turbine, site conditions and other factors like specialised equipment.

Large-scale onshore projects with a high number of turbines typically enable developers to utilise fewer people on a per turbine basis, while the people/ turbine ratio tends to be higher for the buildout of smaller wind farms. Increasing turbine rating adds complexity to installations, and thus will raise the technician-to-turbine ratio. In the forecast period, the global average turbine rating increased from 5MW to 6,75MW. Taking all these factors into account, based on expert reviews and publicly available data, we estimate the technician-to-turbine ratio for onshore wind farms to be 12 technicians per turbine and 18 technicians per turbine for offshore wind fleets. By multiplying the number of turbines installed for a given year by the technician-to-turbine ratio, the model calculates the number of technicians required to construct and install wind assets during the outlook period.

In this year's forecast, GWO has revised its assumption regarding technician-to-turbine ratio for Onshore O&M

Using data on project O&M validated by GWO members and weighted by plant size, we estimated that the O&M of an onshore wind farm typically requires 0.45 people per turbine, as reported in the previous Workforce outlook 2023-2027. This assumption has been changed for this forecast. Our latest research indicates that the average number of technicians required for Operation and Maintenance (O&M) for one onshore turbine is now 0.15. This means that after erecting a wind farm with 100 turbines, approximately 15 permanent roles will be created for maintenance. From 2024 onwards, this figure will be used to project workforce needs. When multiplied by the total number of turbines in operation each year, it results in the forecast of the total number of technicians needed for onshore O&M, in addition to existing workforce data.

Figure 18: Wind Workforce Model forecast flow chart



Offshore O&M technician-to-turbine ratio is estimated on a country level, which considers the regional historical trend

Research on planned projects supports country-level assumptions regarding the ratings and number of turbines expected to be operational each year throughout the outlook period. The technician-to-turbine ratio is calculated by dividing the total expected number of technicians required at each site by the total number of turbines. This calculation is influenced by the capacity of the vessels expected to be utilised, based on the O&M strategy selected by the operator and the specific characteristics of the project. On average, the offshore O&M technician-to-turbine ratio is projected to increase from 0.69 to 0.87 during the forecast period, which is approximately 5 times higher than the onshore O&M assumption. This variance is attributed to the greater complexity involved in operating offshore wind fleets, which necessitates a higher number of technicians for effective maintenance and support. The ratio is multiplied by the cumulative number of offshore turbines to calculate the number of technicians required for each country.

These country-level estimates are then aggregated to determine the total workforce demand for offshore Operation and Maintenance (O&M) across all assessed territories

Historical wind capacity installations and GWO intelligence inform the business-as-usual case regarding workforce shortages in the forecast period

We use GWO training activities as proxies to estimate the growth of available technicians in a given region. A key assumption in estimating technician shortages is that, by 2021, workforce demand had been sufficiently met, indicating that there were no technician shortages at that time. The starting year for our analysis is 2021.

In a new industry like wind energy, the supply of professionals often lags behind demand. Between 2019 and 2020, the industry experienced a significant surge in workforce demand. Our assumption is that following this surge, the industry effectively responded and maintained a sufficient number of technicians in each region to meet the demands of 2021.

The resulting shortfall in technicians is reported as a global aggregate figure, reflecting a universal estimate of workforce availability. However, this assumption implies that workforce can move freely across borders without friction, which is more optimistic than the actual situation. As a result, this assessment may slightly underestimate the true extent of the overall technician shortage in the wind energy sector.

Definitions

Terms	Definition
ABEEólica	Associação Brasileira de Energia Eólica – Brazilian Wind Energy Association
BST	Basic Safety Training Standard (GWO Standard)
CoHE	Control of Hazardous Energies (GWO Standard)
C&I	Construction and Installation
COP 28 etc	Conference of the Parties (numbered in series)
DOE	Department of Energy (USA)
DISCOMS	Electricity distribution companies
Firm power	Mean power output during a certain critical period
FTE	Full time equivalent (a full time employee)
GW	Gigawatts
GWEC	Global Wind Energy Council
GWO	Global Wind Organisation
HSE	Health, safety and environment
IEA	International Energy Agency
IRA	Inflation Reduction Act (USA)
NEA	National Energy Administration (China)
NREL	National Renewable Energy Laboratory (USA)
MW	Megawatts
OEM	Original equipment manufacturer
O&M	Operations & maintenance
PPA	Power purchase agreement
REC	Renewable energy certificate
WINDA	GWO's online database of wind training records

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