GWEC | GLOBAL WIND REPORT 2025

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Jonathan Cole
Chair of Global Wind Energy Council

Time to focus on the long-term value and mission of wind energy

It might be fair to say that many people in the wind industry will not look back on 2024 too fondly. It was a year in which the impact of interest rate increases, inflation, supply chain pressures, investor confidence, regulatory inertia and political uncertainty all had a relevant impact across many key markets.

However, perhaps 2024 can be put into some perspective. After all, it was only one year in the long life of the Energy Transition, a 50-year programme to decarbonise our planet and safeguard its future.

For the preceding 20 years, wind energy had enjoyed a prolonged period of growth, achieving the historic milestone of 1TW of installed capacity in 2023 and growing into a major economic and industrial movement with over $200 billion of private capital being invested annually and over 1.5 million direct jobs being supported globally according to IRENA reporting. 2023 was also a record year for wind installations, with 116.6GW being installed globally (albeit heavily concentrated in a few markets).

With this in mind, despite so many headwinds, GWEC reports another record year with 117 GW of wind energy installed globally. It is also noteworthy that in 2024, 90% of all expansion in the power sector was in renewables, with 20% of that growth coming from wind energy.

However, if you look behind the headline numbers, four factors stand out:

1. We are not going fast enough – the rate of installation of wind energy needs to continuously increase, not hold steady or decrease, if we are to hit the important 2030 tripling up target, and modernise societies through electrification

2. We are still too concentrated in too few regions (86% of installations occurred in China, Europe and US).

3. Whilst Onshore wind continues to progress (growing from 105GW in 2023 to 109GW in 2024), Offshore Wind has not progressed as well (from 11GW to 8GW).

4. The underlying trends that have been undermining growth and confidence are stubbornly persisting.

On this basis, perhaps the key takeaways from the 2024 should be:

- We need to keep pushing to go faster in order to hit our important tripling up targets by 2030.

- Regulatory reform remains an urgent area of focus, in order to facilitate faster deployment and capital recycling to facilitate further growth, especially in nascent markets.

- Open and fair trade alongside healthy supply chains must be promoted.

- We should not lose sight of the long-term value and mission of wind energy, regardless of short-term political messaging. We must remain steadfast in fostering policymaking that is based on scientific and economic data and not on subjective opinion or disinformation.

- We must make more effort to sell the benefits of our sector to all aspects of the political spectrum, so that we can become less politically sensitive and can be seen as the force for good that we know ourselves to be.

Over the course of 2025, GWEC will be promoting a number of initiatives that address these key issues. Despite a difficult 2024, we expect 2025 to be another record year for wind installations and we are determined to play our part in helping wind energy through the current challenging environment. We look forward to working with colleagues across the industry in helping wind energy fulfil its vitally important potential.

A Tailwind of Progress, Navigating the Currents of Change

As we enter a new era in renewable energy, the Global Wind Report 2025 serves as a beacon of hope and a call to action for the global community. The journey of wind energy has been nothing short of remarkable, evolving from a niche technology to a mainstream source of power that is now integral to our energy transition efforts.

The year 2024 marked yet another milestone with 117 GW of new installations worldwide, bringing the global cumulative capacity to 1136 GW. This report not only highlights the impressive growth of wind energy but also underscores the immense potential that lies ahead. With the right conditions in place, the wind industry stands ready to triple its growth to meet the ambitious COP28 goal of tripling renewable energy capacity by 2030.

Our collective efforts have demonstrated that wind energy is not just a viable alternative but a necessary component of a sustainable future. China, United States, India and Germany top the charts while the Asia-Pacific region continues to lead the way. Emerging markets in regions such as Southeast Asia, Central Asia, and MENA are poised to become the next strongholds of wind energy growth.

However, the path to accelerated growth is fraught with challenges. Macroeconomic pressures, trade barriers, and supply chain disruptions threaten to derail our progress. It is imperative that we address these barriers head-on and implement solutions that will enable us to achieve the scale and efficiency required to meet our climate goals.

The Global Wind Report 2025 provides a comprehensive roadmap for overcoming these challenges. It emphasizes the need for enhanced international collaboration, streamlined permitting processes, and robust policy frameworks that support the rapid deployment of wind energy. By working together, we can turn targets into turbines and ensure that wind energy continues to play a pivotal role in the global energy transition.

As Vice-Chairman of GWEC, I am proud of the progress we have made and optimistic about the future. The wind industry has shown resilience and adaptability in the face of adversity, and I am confident that we will continue to rise to the occasion. Let us harness the power of the wind to create a cleaner, greener, and more sustainable world for future generations.

Girish Tanti
Vice Chairman, Suzlon Group

SUZLON
POWERING A GREENER TOMORROW

EXECUTIVE SUMMARY

The Data and the Story – Wind in 2024

2024 marked yet another record year for wind energy with 117 GW of new installations worldwide. Looking beyond the marginal increase from last year, this report tells the story of an industry increasingly pushing into new regions, the emergence of new wind power strongholds and a technology capitalising on the growing demand for a secure supply of clean electricity in an increasingly volatile world.

This year's Global Wind Report focuses attention on the moment wind energy currently finds itself – a maturing technology delivering value to governments, economies and people . The report recognises wind energy's broader value proposition, addresses the challenges holding the technology back, and the solutions needed to get back on to an accelerated growth trajectory so the industry can deliver its full potential. Last year's growth brings wind energy's global cumulative capacity to 1,136GW, spread across all continents, with new countries choosing to build wind energy every year. This year's report goes beyond installation data to capture the wave of growth expected from countries that have recently passed legislation, implemented policies and integrated wind energy into long term energy system planning.

A geographic breakdown of 2024 shows new wind energy was largely concentrated in the same top five markets as previous years - China, US, Brazil, India and Germany. Rising stars such as Uzbekistan, Egypt and Saudi Arabia had strong performances in 2024, representing the next wave of wind energy growth across an increasingly wider set of geographies, and served to counterbalance lower numbers in Brazil and the US.

The Asia-Pacific region continues to lead the way with China's installations making up 70% of the global total. Meanwhile, Africa & the Middle East had a record year, doubling onshore wind additions in 2024.

Our Markets to Watch section covers a range of maturing markets consolidating growth such as India, Germany and the UK, and important new regions poised to become wind power strongholds such as South Africa, North Africa, Southeast Asia and Central Asia.

Looking into wind energy's promising future, GWEC Market Intelligence expects new installations to surpass the previous record and reach 139 GW in 2025. 981 GW of new capacity is likely to be added till 2030 under current policies. This equals 164 GW of new installations each year until 2030, representing a projected compound annual growth rate (CAGR) for the 2025–2030 period of 8.8%. Growth in emerging markets in the regions of Southeast Asia, Central Asia and MENA is expected to gain momentum, with record installations expected every year in 2025–2030.

Promising future growth prospects aside, the global wind industry is prepared to build much more right now, and quickly. With the right conditions in place, the wind industry stands ready to triple growth to the 320GW necessary to reach the COP28 goal to triple renewable energy capacity by 2030, as a crucial climate change mitigation measure. With this level of ambition as the benchmark, the 2025 Global Wind Report focuses on the barriers to accelerated wind energy growth and the solutions required to remove them.

A Collective Call to Action from the Wind Industry

This year's report sends a clear message and call to action – wind energy needs to get back on to an accelerated growth trajectory. This is necessary for the energy transition to stay on track, for climate goals to be met, and to secure a prosperous future for wind as a globally dominant energy technology able to deliver its full value.

Ben Backwell
CEO, Global Wind Energy Council

Part One of the report covers key evolving trends and the challenges impacting wind energy growth. Global trends such as macroeconomic headwinds and trade barriers, and how they are interacting with wind energy are examined. Following these trends, the report dives into the challenges currently being faced by the global wind industry.

Finance and macroeconomic headwinds continue to challenge accelerated wind energy growth. Rises in commodity prices, in combination with rises in the cost of labour, logistics and higher costs of capital due to interest rates and risk premiums are all affecting project economics, resulting in project's stalling (especially on offshore) and undersubscribed

auctions. In emerging and developing economies, cost of capital remains relatively high based on risk perception despite strong investor appetite.

Trade barriers and fragmentation presents an increasing risk to wind energy's ability to accelerate growth through the efficiencies of a global, interconnected supply chain. The spread of protectionist policies, from tariffs to local content requirements, is gradually fragmenting the global trade regime with real consequences for the wind industry if trade-friendly industrial development policies are not followed.

Negative prices have emerged as a trend affecting how electricity markets remunerate renewable energy generation. Outdated market design, system constraints, lack of demand growth in some market, and technology imbalances are leading to a high degree of power price cannibalisation. Meanwhile, the excess of renewables in low-demand periods has created increasing periods of negative electricity prices. If this trend is allowed to increase over time, it has the potential to undermine the financial stability of renewable energy projects and discourage further investment. A combination of grid reinforcements, flexibility solutions, electrification and market design reforms are needed to reverse this trend.

The final trend, **factors affecting supply chain development,** is broken down into key factors and how they have contributed to a misalignment between the current supply chain footprint and the technology's accelerated growth trajectory. Lack of market volume and power price volatility, the 'rapid innovation curse' of ever-increasing turbine sizes and a political push for inflexible local content rules and other protectionist measures adding further uncertainty and additional costs are identified as contributing factors to this overall trend.

Moving on from these wider trends, the report delves into the specific challenges the wind industry is currently grappling with.

Auction mechanisms need to undergo reforms to reflect new market realities. Ensuring robust, flexible auction designs that accommodate evolving economic realities, safeguard project viability, and discourage speculative bidding will be critical to the long-term success of wind energy deployment. A more disciplined approach—where industry and governments work together to get risk-sharing right, setting achievable long-term revenue frameworks and support to de-risk projects—is essential for sustainable industry growth.

Grid infrastructure poses a set of challenges, requiring expansion and modernisation, streamlining of permitting and regulatory processes, congestion and curtailment mitigation, flexibility and a robust supply chain. Investment in grids must ramp up to alleviate significant queues to access grid connections around the world, ultimately causing governments to miss targets.

Social acceptance, increasingly fuelled by disinformation has become an important challenge to accelerated wind growth. The industry is seeing orchestrated disinformation campaigns financed by fossil fuel interest groups. The spread of false narratives about wind energy is exacerbating the persistent and multi-faceted issue of permitting bottlenecks, influencing policy decisions and eroding public trust in renewable energy solutions.

Mandatory and inflexible local content requirements (LCRs) are being utilised by governments in the context of wider national industrial strategies and protectionist policies. While LCRs can be used to stimulate industrial development and job creation in emerging markets, where utilized inflexibly they can also hinder investment and growth by restricting supplier options in countries which do not have a sufficiently developed supply chain, driving up costs and harming the very local industries they aim to boost.

The global race to new larger turbine platforms has turned into a

challenge itself for the wind industry to navigate. This trend has intensified cost pressures and raised quality concerns for OEMs, who are struggling to invest in larger and large turbine models before the current ones are amortised.

Solutions

Part two of the report puts forward solutions to be actioned by the wind industry and its partners across government, business and civil society, with a view to building the next terawatt on an accelerated growth trajectory.

Solutions to **achieving scale, meeting demand and de-risking investment** are addressed at the outset. Policy and regulatory measures designed to take advantage of increasing electrification, financial incentives such as subsidies, tax credits and other funding programs, infrastructure developments such as grid modernisation and electric vehicles charging networks and grid modernisation, are posited.

Industrialisation is an essential solution for the wind industry's long-term competitiveness and profitability. This section puts forward three critical pillars for successful industrialisation with a focus on efficiency – product strategy focusing modular designs and component standardisation, process strategy that reduces variability across manufacturing sites, and production strategy to optimise through automation.

Addressing issues related to **free, fair and open trade** requires intensified efforts to design trade-friendly green industrial policies that enhance competitiveness, drive innovation, and ensure secure, affordable energy while fostering economic growth. Coordination and dialogue between governments must triumph over fragmentation and competition for strategic investments, with global leaders leveraging multilateral institutions, bilateral engagements and regional forums to coordinate trade-friendly green industrial policies.

Finally, solutions to **winning political support and combatting disinformation** are addressed in a section focused on proactively engaging communities and shifting public narratives in favour of wind energy. Tactics such as 'pre-bunking' mis- and disinformation through community-driven messaging are put forward, coupled with policy recommendations on local ownership models and benefit-sharing schemes.

In the months leading up to the publication of this report we have seen significant progress in terms of government policies designed to drive wind energy growth across the world. This progress on policy and regulation, alongside a concerted effort from the wind industry and its partners to action the agenda outlined in this report, will make a significant contribution to getting wind energy back on to an accelerated growth trajectory.

INTRODUCTION - GETTING WIND ENERGY BACK TO ACCELERATED GROWTH

Introduction

Wind energy is at a critical moment in its history where the actions and measures taken today by the industry, policymakers, and other partners across business and civil society will have a significant impact on the technology's future growth trajectory. Record growth years are forecast for the foreseeable future, so the real question is how accelerated this growth will be, and how much value wind energy will be allowed to deliver to economies and people if barriers are removed.

Over the past four decades, wind power has evolved from a niche technology into a mainstream source of energy and a key pillar of the energy transition. It has proven its economic viability, becoming one of the most cost-competitive sources of energy globally. Where scale has been achieved, wind energy has lowered consumer power prices, created jobs and regenerated communities. Moreover, wind has a strong role to play in increasing a nation's resilience by reducing reliance on volatile and insecure fossil fuel imports.

Looking at the global energy landscape, there is a clear and encouraging meta trend taking the world over – electrification, or as the IEA recently termed it, ''The Age of Electricity''. Wind energy's role in this trend, changing energy systems around the world is clear, but it is up to us as an industry to step up to fully seize this opportunity. As it stands, wind and solar are already providing the bulk of new power coming online, although solar is deploying at a much faster rate. It is imperative that wind energy gets back to accelerated growth, for the energy transition to proceed in an orderly and balanced way, and so modern energy systems can benefit from their complementarity.

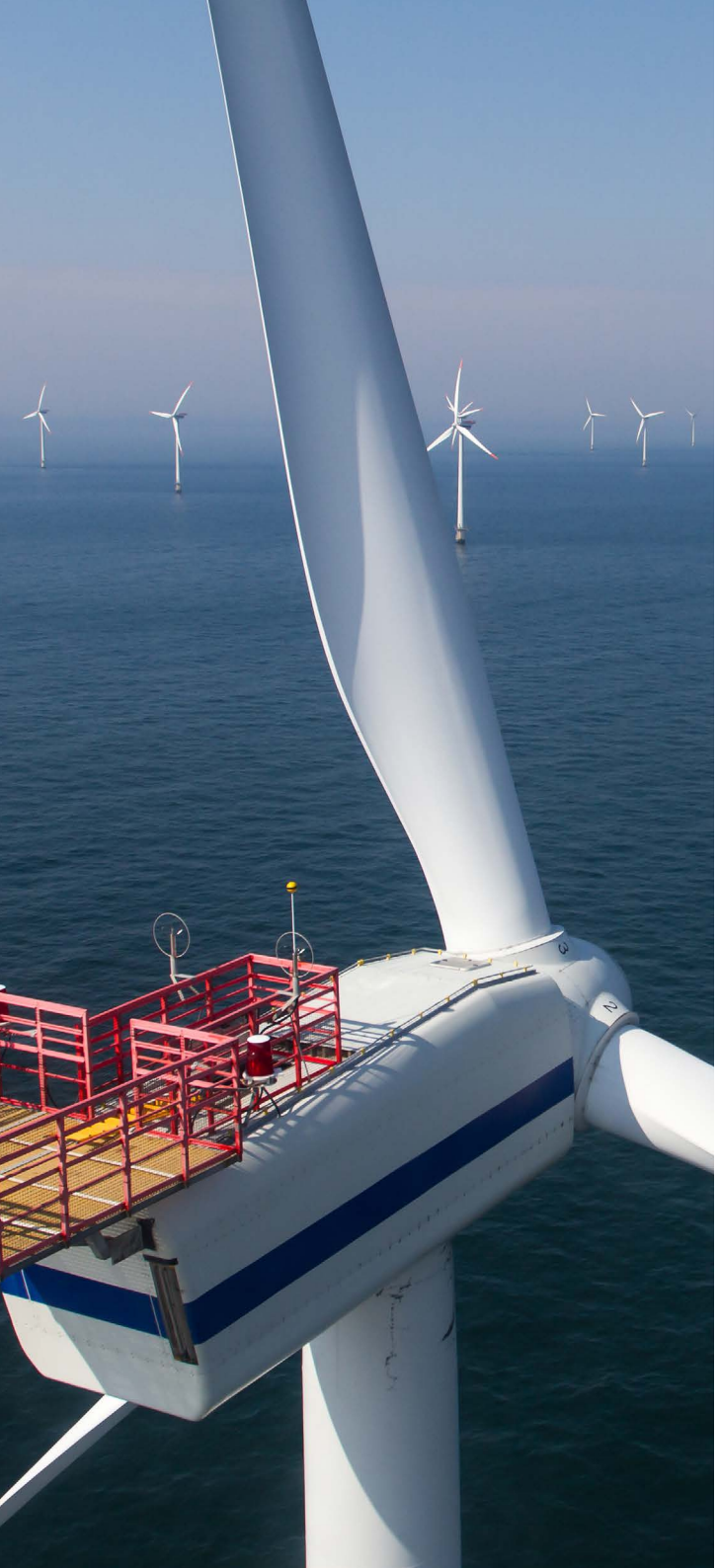
Across the world today, wind energy is helping economies grow. Countries harnessing their wind energy resources are benefitting from the stability of energy independence and security of supply to address vulnerabilities to geopolitical risks such as conflicts and trade wars. Large-scale, long-term investment in wind energy is contributing to local industrial growth, from the establishment of supply chain elements to the provision of affordable electricity for local businesses and consumers. In the UK in 2022 due to increased wind and renewable energy generation displacing £6.1 billion of gas, this led to a saving of around £221 per household.[1] Wind energy growth is also meaningfully benefiting societies across the world, through the creation of direct jobs – now at 1.5 million and counting worldwide – and cleaner air through the reduction of carbon emissions as fossil fuel generation is replaced.

But we could be delivering much more with scale. This year's report provides a pathway to getting there, with the goal of achieving 320GW per year needed to reach the COP28 goal to triple renewable energy capacity by 2030, as our north star.

Over the last few years, we have begun to see trends that threaten to derail the momentum that has been carefully built over decades. Macroeconomic pressures and rising commodity and capital costs have collided to make our technology more costly. On a national level, the uncertainty related to stop-start, inconsistent government procurement cycles has made long term supply chain investment difficult. In addition, the increasing fragmentation of global trade and implementation of protectionist policies is undermining the competitiveness of our globalised industry. Outdated market design bakes in distortions, which affect our business case. These trends constricting our industry's pace of growth need course corrections. While the direction of some of these trends is outside the industry's control, this report identifies the key challenges that the industry and its partners can address.

The focus right now, as outlined in this report, must be on getting wind back to accelerated growth by securing future demand and consolidating our position as a mainstream energy generation technology. Collectively, as

1. Energy UK briefing: Net Zero solution to the gas crisis - Energy UK



a global industry, and with our partners across government, business and civil society, addressing the challenges with the solutions proposed in the pages that follow is of paramount importance – this is our call to action.

The wind industry's relationship with governments around the world continues to strengthen, but there is still much work to be done to reduce complexity and streamline planning to deliver on targets and allow investment to flow at scale. Moreover, we are already seeing the damaging effects of trade tariffs to the global economy, highlighting the need for a globally interconnected industry safeguarding its competitive edge.

As an industry, we will continue to improve how we work together on manufacturing excellence and standardisation, how we work with governments on energy, industrial and trade policy, how we work with regulators and energy system planners to ensure grid and other infrastructure stays in lock-step with generation build-out, and how we work with communities by building trust and delivering fit-for purpose benefits.

There is a lot to be confident about when looking at the future of our technology and the opportunity in front of us. Despite the concerted effort from certain actors to undermine the case for wind energy, steady progress continues to be made. As the report shows, many countries around the world are doubling down on wind energy today - by increasing the volume of procurement rounds, passing legislations, and developing policies to prepare the ground for wind energy to play a bigger role.

2024 saw the UK enact a series of reforms aimed at delivering its ambitions for up to 50 GW of offshore wind and around 30 GW of onshore wind by 2030 as part of the Prime Minister's wider 'Clean Energy Mission.' Germany awarded nearly 11 GW of new onshore wind capacity in tenders – an all-time high representing a remarkable 70% increase year-on-year in support of the country's industrial base and energy security needs. The South African government recently published their seminal Integrated Resource Plan, where wind will ramp up yearly and become a cornerstone of the country's energy mix over the next decade. The Brazilian government's recently passed legislation on offshore wind, green hydrogen and 'new' industrialisation, will serve to create new opportunities in a country already considered a wind energy leader. Important policy advances were also recently made in the Asia-Pacific region as Japan, South Korea, Philippines and Australia progress their wind energy markets. And finally, Central Asia is emerging as the next region to harness its wind energy potential with large scale developments underway in Kazakhstan, Uzbekistan and Azerbaijan.

The global wind industry's confidence stems from the fact that we win where there is a level playing field. With the right long-term policy and regulatory conditions in place, we have seen investment flow, long term project pipelines develop, factories built, and jobs created.

We are an industry that has seen ups and downs and always emerged more resilient on the other end. We are an industry whose fundamental value proposition continues to strengthen as more governments and industries choose to power themselves with wind energy. And above all, we are an industry with a strong self-awareness and belief that we can and will get back on to an accelerated growth pathway. Our message from the wind industry to any governments currently back tracking on their commitments to wind and renewable energy is that this will eventually negatively impact your constituents in the long run.

The wind industry looks forward to the journey ahead, deepening its relationships with partners across governments, business and civil society under the common goal of getting wind back to accelerated growth so we can deliver full value to economies, people and the planet.

PART ONE: TRENDS TO WATCH

Finance and macroeconomic headwinds

Wind farms demand substantial upfront investments that render project economics sensitive to the cost of capital. The steep rise in the cost of capital in recent years has been compounded by fluctuations in interest rates and inflation, as well as high commodity and raw material prices.

However, the high upfront costs associated with constructing a wind project generally offset by lower operating expenses than fossil fuel plants – along with the absence of fuel costs.

Geopolitical tensions are likely to intensify existing disruptions in global supply chains and contribute to further market volatility. A particularly complex financial landscape exists for offshore wind projects, with project viability hinging on market realities and balancing risk with investor expectations.

The weighted average cost of capital is determined by the interest rates required by lenders and the return required by equity investors. Investment decisions are shaped by how much debt financiers are willing to extend based on the project's assessed risk profile and market conditions. Similarly, the target return on equity is determined by the developer's assessment of risk, and impacted by the electricity prices the market can sustain via a specific remuneration mechanism.

Utility-scale wind projects rely heavily on debt financing through limited or non-recourse project finance, typically covering 60-70%[2] of a project's capital structure. The cost of debt is heavily influenced by macroeconomic conditions such as prevailing interest rates, as well as real and perceived project and country risks, which affect the risk premiums that banks may apply.

While 2024 witnessed a decline in inflation and interest rates from their recent peaks, both metrics remain higher than the historically low-interest rate environment experienced globally since 2008[3].

The Secured Overnight Financing Rate (SOFR) surged to over 5% in H1 of 2023 following the US Federal Reserves' aggressive rate hikes, before easing slightly last year. Despite recent declines, SOFR remains higher than pre-2022 levels, resulting in high borrowing costs.

Due to their high upfront capital costs, interest rates have a more significant effect on the levelised cost of electricity for wind than for non-renewable energy sources. This is because a large percentage of the cost of fossil plants is the fuel cost incurred over many years[4]. Inflation rates, which typically precede higher interest rates, peaked around 2022 following after several global demand and supply shocks and imbalances. However, they have since stabilised as a result of monetary policies implemented by central banks.

The cost of materials, labour and logistics has increased due to strong demand and constrained supply post-COVID19. Additionally, the global economic fallout from the Russia-Ukraine war has raised overall project capital expenditures (Capex) for most developers globally. The rising costs of raw materials and components required for turbine production have increased both the manufacturing and upkeep costs that original equipment manufacturers (OEMs) need to bear. These price increases, in turn, have put additional pressure on developers who are already operating with narrow profit margins and constrained by wider project economics[5].

2. https://www.pfnexus.com/blog/wind-power-project-finance
3. https://www.ief.org/news/higher-interest-rates-pose-a-challenge-to-financing-renewables
4. https://www.iea.org/articles/what-is-the-impact-of-increasing-commodity-and-energy-prices-on-solar-pv-wind-and-biofuels
5. https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/offshore-wind-strategies-for-uncertain-times

Over 2023 and 2024, several offshore wind projects in the US and Europe defaulted due to unhedged costs and revenue-support schemes that were not adapted promptly to external market conditions. A flurry of offtake deal renegotiations put projects at risk of further delays[6].

The auction designs of the markets that suffered the most typically displayed a lack of capital allowances and appropriate revenue stabilisation measures, did not adequately share risk sharing between offtakers and developers, and resulted in bids that in hindsight were probably overly aggressive.

The lingering effects of a race-to-the-bottom mindset resulted in undersubscribed auctions where developers chose not to bid given the expected project economics.

While measures to control inflation and supportive policies such as the US Inflation Reduction Act and REPowerEU Plan were introduced, their continued implementation will ultimately depend on the political agenda and priorities of the ruling government administrations.

Risks differ significantly across countries and technologies, influencing how the financing of a project is structured. Some risks are easier to quantify, such as projected cash flow to service expected debt. Other risks are not easy to quantify, such as whether a government will default. Risk premiums are typically applied as an additional cost to manage the risk. During worsened macroeconomic conditions, currency volatility and inflation rate uncertainty can result in a higher risk premium[7].

In emerging markets, where higher perceived risks include factors such as weak offtaker creditworthiness, political instability and lack of sufficient regulatory frameworks, securing affordable capital financing becomes even more challenging.

The cost of debt remains high in emerging markets and developing economies (EMDEs), despite borrowing costs for emerging market firms tracking global interest rates more closely than they did in previous global financial crises[8].

This could result in reduced overall investment in EMDEs, which need it the most, as investors naturally gravitate towards more stable markets with lower risk premiums. Consequently, emerging markets face significant barriers in attracting the necessary funding for critical projects, which further widens the gap in global investment distribution.

For wind projects to succeed, the entire energy value chain – including transmission, distribution and port infrastructure – must be addressed. Persistent high capital costs may further strain financially limited utilities, transmission operators and governments, hindering their ability to invest in grid upgrades to match growing installed capacities. Similarly, since 2023, port operators have been under pressure to upgrade facilities to accommodate larger vessels to meet decarbonisation goals. At the same time they have faced declining demand due to the supply chain crunch.[9]

Nevertheless, in this evolving landscape, the wind energy industry is providing energy security, showing signs of resilience and progress. By addressing macroeconomic challenges, enhancing risk-sharing mechanisms and advancing supportive policy frameworks, the sector is well-positioned to strengthen its growth trajectory.

The wind industry had the record years in new installations in the past two years with annual installed wind capacity increased by 50% compared with 2022

These improvements are tparticularly promising for emerging markets, where the need for investment is greatest and where robust policies can serve as a strong foundation for sustainable development. With financing conditions gradually

stabilising, the global energy transition has a perfect opportunity to regain its momentum. The industry's adaptability along with the development of more effective policy frameworks, signals a positive shift.

6. https://about.bnef.com/blog/soaring-costs-stress-us-offshore-wind-companies-ruin-margins/
7. Baran Yeter, Yordan Garbatov, Feargal Brennan, Athanasios Kolios, Macroeconomic impact on the risk management of offshore wind farms, Ocean Engineering, Volume 284, 2023
8. IFC, How Emerging Market Companies Are Withstanding Global Interest Rate Shifts, 2024
9. https://commercial.allianz.com/news-and-insights/expert-risk-articles/shipping-safety-23-economic-outlook.html

Trade barriers and fragmentation

The risk of politically driven disruptions to supply chains is becoming increasingly relevant in global supply operations. The spread of protectionist policies, from tariffs to local content requirements, is gradually fragmenting the global trade regime. As a result, the economies of the key regions and hubs of the global economy are becoming increasingly disconnected from one another, even as intraregional economic integration deepens. Recent events, beginning with the creation of the most stringent tariff regime in recent U.S. history, have exacerbated and now threaten to accelerate this long-term trend, placing additional pressure on the stability of global wind power supply chains.

These dependencies and vulnerabilities are especially severe in the production and development of new key technologies for the green transition. Because their production processes are highly complex, they rely heavily on the efficiency of midstream processes, the availability of raw materials and the efficacy of logistical services that have been increasingly allocated in transnational supply chains.

By controlling access to raw materials and positioning themselves at the forefront of key value chains for renewable technologies, foreign firms have the potential to play a potentially destabilising role in the energy security of their trade partners. The urgency for a political response to such developments intensifies when a firm's advantage in critical sectors is perceived to stem not from market-based factors but from government support mechanisms that enhance the competitiveness of domestic firms over their foreign counterparts.

Beyond internal political drivers, the gradual fragmentation of supply chain links and trade relations is related to structural vulnerabilities embedded in the global economy. In certain strategic sectors, including renewable energy technologies, the market concentration of key processes in specific regions, firms, or states can lead to threatening dependencies that endanger the market position and long-term viability of other businesses operating at different stages of the supply chain.

Once developments in the sector come to be perceived as the result of unfair practices, market-distorting policies spread across borders. This process escalated in the aftermath of the COVID-19 pandemic, which exposed to policymakers and the public in Western societies the economic vulnerability embedded in global supply chains. The recent escalation of global trade tensions, driven by the new U.S. tariff regime, aligns with this broader trend, though it is further intensified by domestic political dynamics within the United States.

The extent of disruption these developments may cause to the industry will largely depend on how government officials and regulators in the affected markets respond to emerging vulnerabilities and politically motivated restrictions on international trade. If their responses involve policy measures that diverge from the market-based principles underpinning the efficient allocation of resources in global supply chains, the consequences could be increasingly detrimental.

The consequent fragmentation of the global trade regime threatens to result in isolating regional or bilateral trade regimes with contrasting, and sometimes contradictory, legal, technical and commercial standards in international economic transactions, both in terms of the exchange of goods and international investment.

Consequences for the Wind Power Industry

In the wind industry, the globalisation of supply chains for key components has not reached the levels of transnational integration seen in other highly globalised high-tech sectors such as replace smartphones with solar PV and electric vehicles. . However, the existing vulnerabilities in the global value chains of wind power remain significant due to three main factors:

- The component complexity of renewable energy technologies
- The strategic nature of energy industries
- The scarcity and geographical concentration of some key raw materials and processes for their production.

Consequently, the threat of trade fragmentation looms over the industry's ability to tackle the challenges of the coming decade. A dysfunctional trade system will imply significant risks for the industry in terms of both demand and supply.

- On the supply side, trade fragmentation threatens to undermine the cost efficiency of cross-border operations, undermining the ability of firms in downstream sections of the supply chain to access the most economically efficient suppliers and service providers in the market.
- On the demand side, the fragmentation of global trade and investment regimes will create market inefficiencies by restricting the ability of developers and manufacturers in trade-isolated regions to respond to each other's demand for wind power capacity expansion.

Responding to these challenges will require policymakers to safeguard the principles underpinning an open, fair and rules-based global trade system. As supply chain risks become increasingly apparent in global operations, it is imperative to enact effective incentive-based policies for supply chain development at the local level.

As shown in GWEC's 2023 Mission Critical: Building the Global Wind Energy Supply Chain for a 1.5°C World, which includes an analysis of future wind supply chain outlooks based on different collaboration scenarios, only an open-door scenario with strong regional collaboration on both supply and demand will enable the industry to reach its 1.5°C capacity targets. In this context In this sense, the international coordination of trade-friendly industrial development policies will play a crucial crucial supporting role in safeguarding the long-term expansion and profitability of the sector.

Negative prices

The rapid deployment of renewable energy is exposing the inadequacies in electricity market design.The phenomenon garnering the most attention is the increase in instances of negative power prices, which has emerged as a trend to watch for the wind industry, particularly in Europe.

Negative power prices occur when the wholesale price of electricity falls below zero, meaning generators earn no revenue – or may even pay – to supply power to the grid. While this is not a new or unusual phenomenon, recent years have seen a drastic increase in negative power prices, during periods of correlated wind and or solar output, especially outside of peak demand periods.

Without the relevant market design, or without appropriate de-risking tools, the wind industry could see investor confidence waver and financing costs increase. Prolonged bouts of zero or sub-zero prices threaten to derail commitments to renewables as governments and financers reassess the risks. This evolving trend is drawing attention to its causes, including electricity market design inefficiencies, auction design, marginal cost bidding as well as the factors outlined below.

One of the cases when negative prices usually arise is in the times of a lower demand level with a simultaneous oversupply of energy. Conventional generators decide on the pricing depending on their flexibility and the costs of shutting down and ramping up as compared to incurring short-term sales at negative prices. If the estimated losses from paying for their energy to be bought are lower than the costs of restarting the generator, then in order to minimize losses the energy will be offered at negative prices. This may also occur as some of the generators have contractual obligations to run during the times with negative prices.

Other factors include:

- End-user demand by households and businesses may not be flexible enough, or incentivised enough, to change consumption behaviour from high-cost periods to low/negative-cost periods.

- There may be insufficient batteries, pumped-hydro or other storage capacity to absorb excess electricity during negative-price periods. This lack of storage options means producers miss the opportunity to store power at negative prices and later sell it for profit.

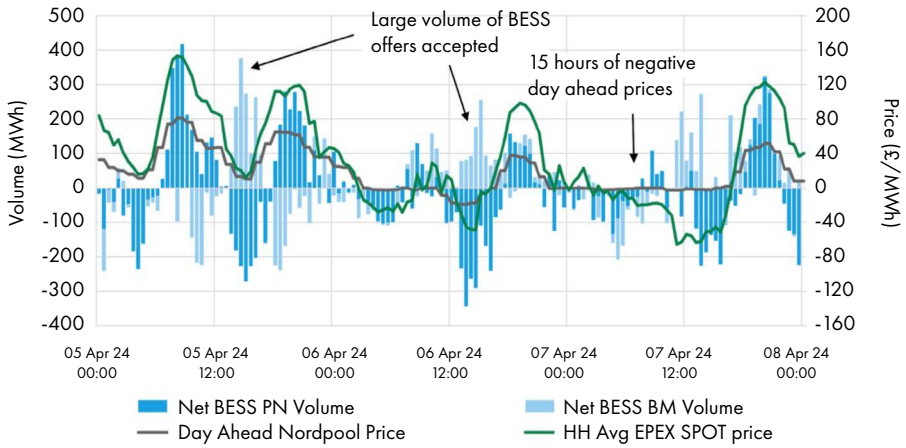
This chart shows a weekend in Europe in April 2024,t when a strong offshore storm in the UK led to high wind output and, at times, negative prices. The 'day ahead' prices are shown in black and in green are the spot prices reflecting short-term supply and demand fluctuations.

As prices start to go negative or just low enough, the battery storage system (blue bars) absorbs and stores the excess supply to then inject those electrons when prices are higher. This is a market functioning as intended, with negative prices being an inherent part of its design.

When grids lack flexibility or sufficient storage to absorb power during negative-price periods, negative pricing events become more frequent, particularly as renewable penetration continues to increase.

In the past few years, the number of negative power price hours has risen significantly in Europe and elsewhere. According to EU market monitor ACER and think-tank BNEF, there was a twelvefold increase in the occurrence of negative wholesale energy prices in 2024 – with the most instances taking place in Northern Europe. A similar trend is also occurring in Australia, which saw market prices dropping below zero 14% of the time in 2024.[11]

A week in the European market, April 2024



Source: Timera Energy[10]

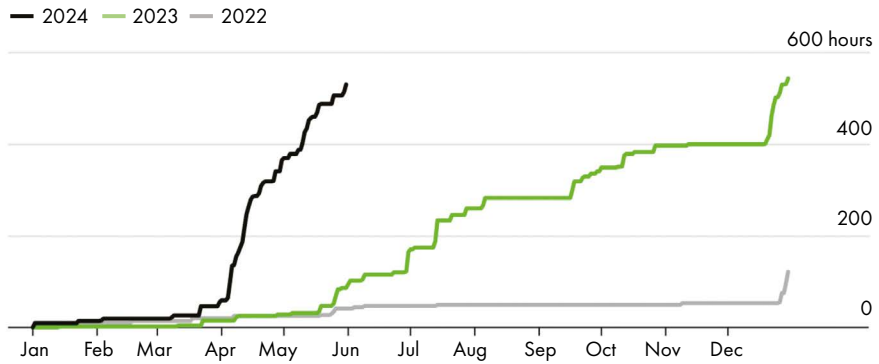
10. https://timera-energy.com/blog/negative-prices-and-high-bm-acceptance-drive-bess-revenues-across-the-weekend/

Addressing negative power prices

Electricity markets in regions such as Europe face the prospect of increasing negative power prices over the coming years if policy, regulatory and technological measures are not taken to safeguard wind energy's investment case and accelerated growth trajectory.

- **Battery storage:** Building out more energy storage—such as lithium-ion batteries, pumped hydro, or hydrogen—enables the system to absorb surplus power during periods of low or negative prices and release it when prices recover. This solution can range from compact, freezer-sized units for individual homes to expansive container-based systems in open fields. Battery storage will not only stabilise the revenue for renewable producers but also maintain grid balance as renewable penetration grows.
- **Technological innovation:** Developing hybrid projects (e.g., wind-plus-hydrogen or wind-plus-storage) allows surplus energy that would otherwise cause negative prices to be diverted into storage or alternative uses, mitigating price drops and enhancing overall system flexibility.
- **Grid flexibility through pricing and policy:** Implementing demand-response programmes, real-time pricing, and supportive market rules to encourage consumers and producers alike to adjust to changing supply and demand. Such measures reduce the incidence of negative prices by incentivising consumption shifts and bolstering flexible generation.
- **Flexible operation of conventional plants:** While the goal remains to phase out fossil-based generation over time, improving the ramping capabilities of existing coal or gas plants in the near term can help buffer sudden changes in wind or solar output—thus reducing negative price events.
- **Stable off-take agreements:** Updated or well-structured PPAs, Contracts for Difference and off-take contracts that guarantee predictable revenue streams for wind, reduce the investment risk and maintain project viability.
- **Increasing country and regional interconnectors:** An enhanced interconnection network has the potential to reduce market volatility by evacuating excess power generation. Bottlenecks still occur even in regions with high degrees of interconnections, highlighting the need for greater interconnection to ensure efficiency.
- **Revisit Capacity Market regulation:** Wind energy's eligibility from a system operator's perspective to provide this capacity presents another viable outlet for power generated.

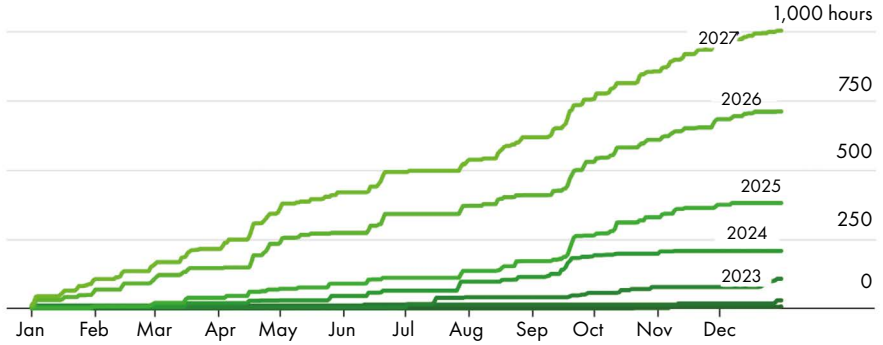
Europe is having record levels of negative energy prices



Source: EEX
Note: Data includes the total hours across Germany, France, Spain and the UK

Source: BloombergNEF[12]

Negative Electricity prices will increase tenfold in the years to come



Source: Modo Energy

Source: BloombergNEF[13]

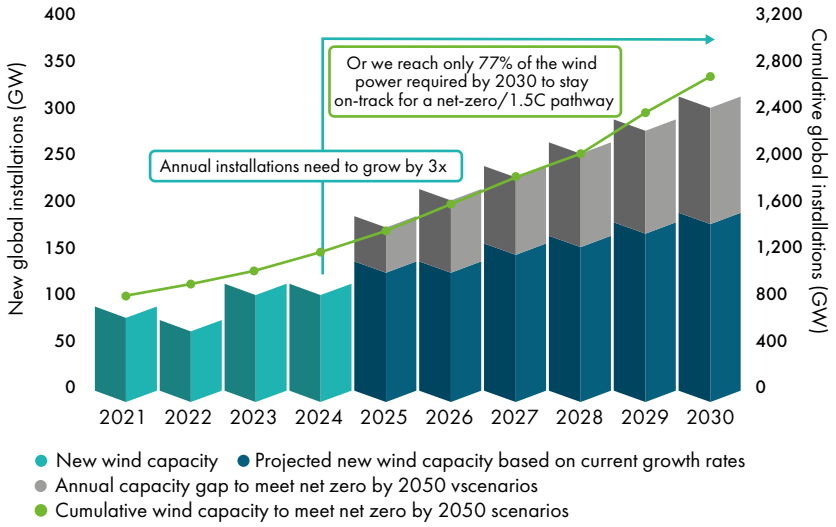
11. https://www.bloomberg.com/news/articles/2024-06-02/bursts-of-free-power-raise-red-flags-for-green-tech-investors?embedded-checkout=true
12. https://www.bloomberg.com/news/articles/2024-06-02/bursts-of-free-power-raise-red-flags-for-green-tech-investors?embedded-checkout=true
13. https://www.bloomberg.com/news/articles/2024-06-02/bursts-of-free-power-raise-red-flags-for-green-tech-investors?embedded-checkout=true

Factors affecting supply chain development

For the wind industry to reach its full potential, a robust and reliable supply chain is essential. GWEC's projections under current policy scenarios, which include stop start auction frameworks, indicate that wind energy will only reach about 77% of the capacity needed by 2030 to remain on a net zero pathway. To close this gap, annual installations must grow nearly threefold.

Wind manufacturing output will also have to grow in line with this rate of installation. At present, however, global manufacturing capacity is not yet on an aligned pathway. After decades of stop start auctions and procurement cycles, production of key components, such as nacelles, blades, and towers, has fallen behind other renewable energy technologies and remains below the levels required to meet net zero targets. In fact, a global study on the state of the wind energy supply chain entitled, ''Mission Critical: Building the global wind energy supply chain for a 1.5°C world'', produced by GWEC in partnership with Boston Consulting Group (BCG), shows that the manufacturing output from current supply chain is even below the levels required to meet the predicted market growth forecast under current policy scenario.

Wind power installations need to triple by 2030 in order to achieve a 1.5°C Pathway



Source: GWEC Market Intelligence

This shortfall not only restrains growth and undermines ambitious capacity goals but also threatens to stall the broader energy transition. Without significant investment to bolster manufacturing capacity across all regions, the gap in the world's net zero roadmap will only widen, jeopardising climate objectives that are dependent on the rapid expansion of wind power.

However, the wind industry is increasingly experiencing high demand-side volatility, hesitation towards scaling on the supplier side, and rapid technological innovations. These factors have fueled a 'race to the bottom' approach to costs combined with a 'race to the top' thinking on turbine size, leading to growing technical risk and a low level of serial production.

The wind supply chain is highly global in nature, with a strong focus in China given its sizeable domestic demand. But from Europe to the Americas, supply chain investment in some of the world's key regions has not been insufficient in recent years and has seen setbacks in its ability to make forward-looking investments in supply, mainly due to stop-start government policies, permitting bottlenecks and a lack of clarity and regular cadence for tenders. Market design and policy frameworks overly focused on power cost have unintentionally led to razor-thin or negative margins while failing to account for higher financing and material costs, making investment in supply chains unviable.

Four broader challenges are impacting today's global wind supply chain development:

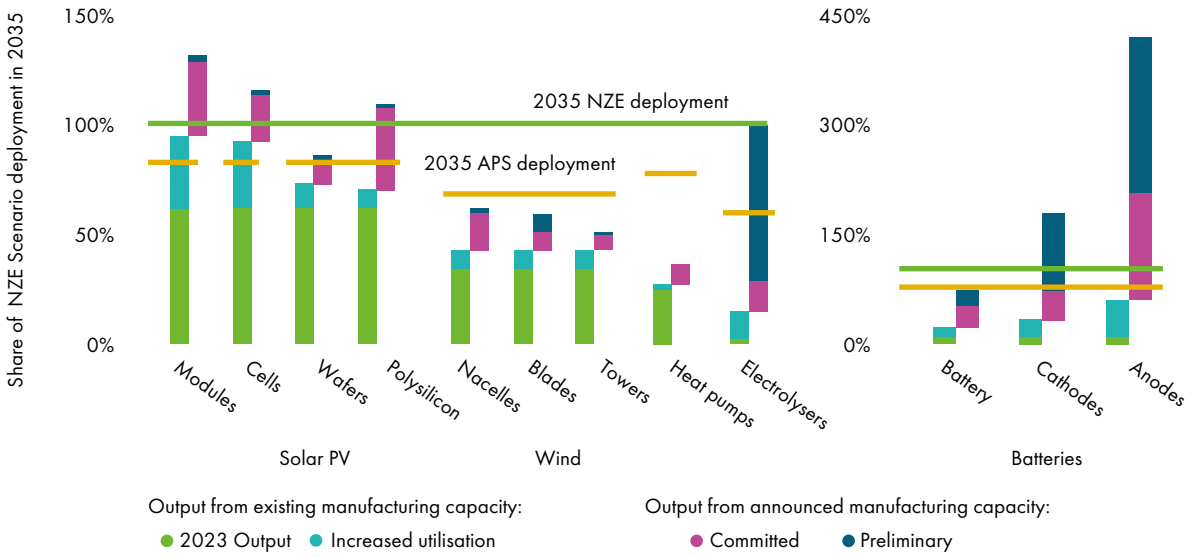
- Market volume and power price volatility is increasing in many markets. Failed auctions, project cancellations, inflationary impacts on supply chain components, shipping and logistics – as well as the rising cost of capital – are all impacting the investment case for wind energy.

- The 'rapid innovation curse.' The industry has reached a stage where ever-larger turbines are specialised in specific markets but less suited to the global market. At the same time, the core industry challenges created by the rapid increase in turbine sizes are becoming increasingly evident, including a shortened product development lifecycle that can lead to defects stemming from untested new technology deployments, large R&D spend for OEMs that they have not been able to recuperate, and a lack of industry standardisation pushing up costs.

- At the same time, ongoing trade disputes and protectionist measures add another layer of uncertainty, imposing additional costs on manufacturers and developers. The cumulative effect creates a less attractive environment for long-term investment, as businesses remain wary of unpredictable tariffs, fluctuating regulations, and geopolitical tensions that could stall or derail wind projects at any moment.

To further stimulate supply chain investment and meet ambitious net zero targets, the wind industry must leverage regional strengths, de-risk investments, simplify regulations, standardise processes and enhance global collaboration.

Announced annual manufacturing capacity as shares of deployment in 2035 by technology and scenario



Source: IEA. CC by 4.0. Notes: APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario. Battery demand here includes that for all electric vehicle types and stationary storage. Announced manufacturing capacity refers to announcements made by H1 2024 that could come online by 2030.

The challenges facing wind energy

Auctions

Wind energy auctions – challenges and recommendations

Auctions for long-term offtake contracts remain a key route to market for renewable projects globally. As of January 2025, the cumulative global auctioned clean energy capacity stands at 1,280 GW, with wind energy accounting for 31% of awarded capacity since 2003. Looking ahead, 68 GW of onshore wind and 97 GW of offshore wind (OFW) auctions are in the pipeline.[14] Table 1 shows a few commonly used competitive offtake mechanisms for wind energy.

Evolving challenges in wind energy auctions

What worked in the past may no longer be fit for purpose as renewable energy deployment scales up, and auction mechanisms will need to undergo reforms to reflect new market realities. Rising material costs, inflation, permitting delays and supply chain bottlenecks are testing the robustness of auctions to deliver realistic price discovery. Auctions increasingly incorporate non-price criteria, shifting from price-only competition to prioritising factors such as local supply chain development and sustainability commitments.

Policymakers must now balance multiple considerations to ensure auction mechanisms remain effective. This is particularly critical for capital-intensive, long-lead-time projects like offshore wind. Upon award, it typically takes around two to three years – sometimes longer – before projects reach final investment decision (FID),[15] when a developer formally commits to funding and proceeding with construction.

Challenging project economics

While renewable energy costs have fallen over the past decade, soaring capital costs, inflation and supply chain disruptions are driving up wind energy project costs.[16] Auctions that fail to account for evolving macroeconomic conditions risk project failure. Recent years have shown that fixing prices at the time of auction without mechanisms for inflationary adjustments can severely impact project viability, as global economic events have repeatedly overturned project economics post-award.

Wind energy (especially offshore wind) has long development timelines. With limited options at their disposal for price adjustments between auction award and project commissioning, developers often fail to use safeguard mechanisms to protect themselves from factors such as the fluctuating costs of key commodities, workforce expenses and other factors, as seen in the US and UK markets.

14. BNEF, Global Clean Energy Auctions Update 1Q 2025
15. To achieve Final Investment Decision (FID), the developer needs to secure financing, finalises procurement contracts, carry out engineering design, obtains final regulatory approvals to confirms the project's technical and financial viability.
16. BNEF, 2H 2022 Levelized Cost of Electricity Update

Table 1: Common competitive offtake mechanisms

Mechanism	Price allocation	Definition
Contract for Difference (CfD)	Auction	A financial mechanism where the government guarantees a fixed "strike price" for OFW energy; if market prices fall below this, the difference is paid to the producer, and if they rise above it, the producer pays back the excess.
Feed-in Premium (FiP)	Auction	A policy where OFW energy producers receive an additional premium payment on top of the market price of electricity.
Power Purchase Agreement (PPA)	Auction	A long-term contract between an energy producer and a buyer (typically a utility, corporation, or government) where the buyer agrees to purchase electricity at a predetermined price (may have linkages to an index), providing financial certainty for the generator and stable energy costs for the buyer.
Renewable Energy Certificates (REC)	Administrative process or Auction	Tradable certificates representing the environmental benefits of generating one MWh of renewable electricity, which can be sold separately from the physical electricity.

Case Study 1: Turbulence in the US offshore wind industry

In 2023, the US offshore wind industry was grappling with inflation, the rising cost of capital, permitting delays, grid connection challenges, and an urgent need to establish local supply chains. Many previously agreed offtake contracts became economically unviable, leading to contract renegotiations and cancellations. The levelised cost of energy (LCOE) for US offshore wind projects increased 50% from 2021 to 2023. The absence of inflation adjustments in the offtake agreements exacerbated financial challenges, eroding developers' revenue streams. While the Inflation Reduction Act (IRA) provides some relief, developers continue to advocate for inflation adjustment mechanisms in contracts and further investment incentives to mitigate risks and improve project viability.

The competitive nature of constrained volume auctions, coupled with the need to predict future market conditions and technology evolution, created a strong incentive for developers to submit aggressive bids . Colliding with aforementioned challenges around shifting macroeconomic climates, including changing market conditions and delays in ports and grid infrastructure, which are crucial for timely construction and project connection, this trend has caused some developers to withdraw after realising that their initial bids are no longer economically viable.

Further complicating the challenge, some governments have continued to drive down prices through unrealistic auction pricing strategies. For instance, Taiwan (China) has enforced a rigid price ceiling, limiting the developers' ability to establish a stable revenue stream through government PPAs, while Japan has implemented a zero-premium approach,

Case Study 1: Turbulence in the US offshore wind industry (continued)

encouraging bidders to bid at a Feed in Premium price level equivalent to zero subsidy to achieve the highest bid points.

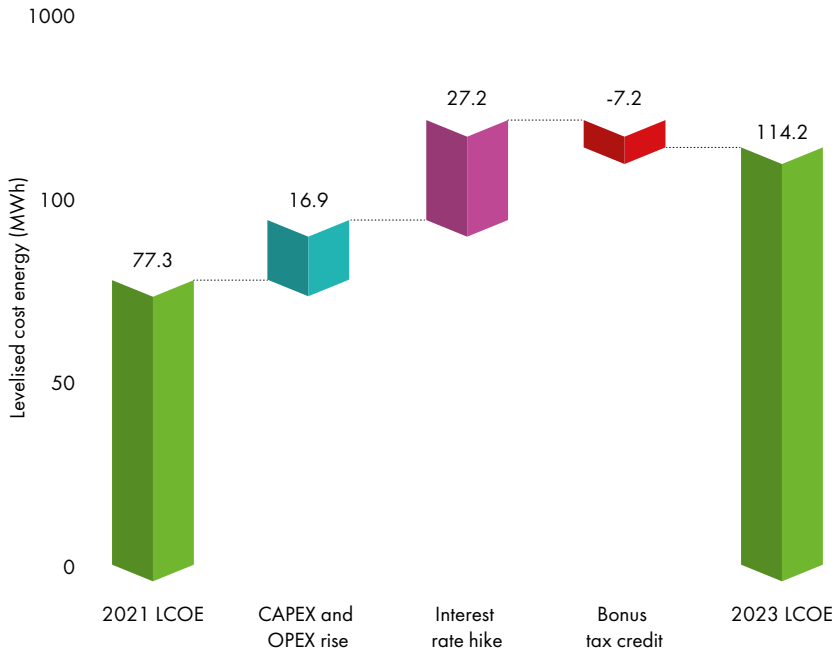
In both cases, some developers proceed with projects despite unsustainable pricing, hoping to secure long-term corporate power purchasing agreements (CPPAs) and close the gaps later. However, this approach may prove unfeasible after auction award if the tariffs required by the projects do not align with the price, terms and volume expectations of potential creditworthy corporate offtakers.

We encourage governments to recognise that the best way to ensure affordability and longer-term cost reduction in emerging markets is to put in place a long-term PPA framework that shares risks appropriately between governments and industry, accounting for macroeconomic risks, such as interest rates, inflation, foreign exchange and regulatory risk, that can arise between the auction award and FID.

There has also been a shift in the world as developers are now behaving more conservatively in bidding, which has led to what we have seen as undersubscribed auctions.

While auction mechanisms remain a crucial tool for wind deployment, they vary significantly across markets, making cross-country comparisons and policy harmonisation difficult. In emerging markets for wind, industry and government can work together to ensure the deliverability of the first stage projects that will pave the way for the widespread roll out of wind. We encourage the prioritisation of robust, flexible auction designs, which focus on appropriate risk sharing and long-term contracts that accommodate evolving economic realities, safeguard project viability. These factors be critical to the long-term success of wind energy deployment.

Impact of inflation, interest rates and tax credits on US offshore wind LCOE



Source: BloombergNEF, 2023.

Grid

Meeting the commitment to triple renewable energy capacity by 2030 and the Paris Agreement goals will require an unprecedented scale-up in electricity grid investments. Electricity grids must shift from being bottlenecks to becoming the backbone of the energy transition, ensuring energy security, economic resilience and industrial competitiveness alongside climate objectives.

The outcomes of COP29 underscored the pivotal role of grids in the global energy transition, with the **Grids and Storage Pledge** committing to add or refurbish 25 million kilometres of grids by 2030. However, analysis from the International Renewable Energy Agency (IEA) shows that an additional 65 million kilometres will be needed by 2040 to align with net-zero emissions by 2050. This pledge is not only about decarbonisation but also about enabling economic growth, job creation and the electrification of key sectors, to ensure that countries can meet rising electricity demand with clean and reliable power.

Governments and industry stakeholders have recognised that, without significant upgrades and expansion, grids will remain the bottleneck preventing the large-scale integration of renewable energy. Strengthening grid infrastructure is essential to improving energy affordability, fostering cross-border electricity trade and providing stable power supply to industries and communities.

While setting a global target acts as a guiding beacon, success in this effort depends on proactive national and regional actions that go beyond the Global Pledge. Countries must conduct comprehensive assessments of grid infrastructure, operational efficiency and regulatory frameworks to identify gaps and accelerate modernisation.

The need for grid expansion and modernisation

Grid expansion continues to lag behind the rapid growth of renewable energy sources. Despite setting ambitious renewable energy targets, many countries are not developing the transmission and distribution infrastructure needed to support them at the required scale and speed.

The IEA[16] reports that at least 3 TW of renewables projects are waiting in grid connection queues. This figure highlights grid constraints as a critical barrier to achieving net zero emissions.

Modernising grids is essential to unlocking the full potential of renewable energy, enabling greater flexibility, resilience and efficiency in electricity systems. Solutions such as Green Corridors and the development of Green Energy Zones can drive targeted infrastructure expansion, improve regional connectivity and support decentralised renewable integration. Additionally, micro and mini grids play a key role in extending electricity access to complex geographies and underserved areas, ensuring that clean energy reaches where it is needed most.

Accelerating grid expansion and modernisation will reduce congestion and curtailment, enhance energy security and increase the economic viability of new renewable energy projects, making clean power more accessible and reliable for all.

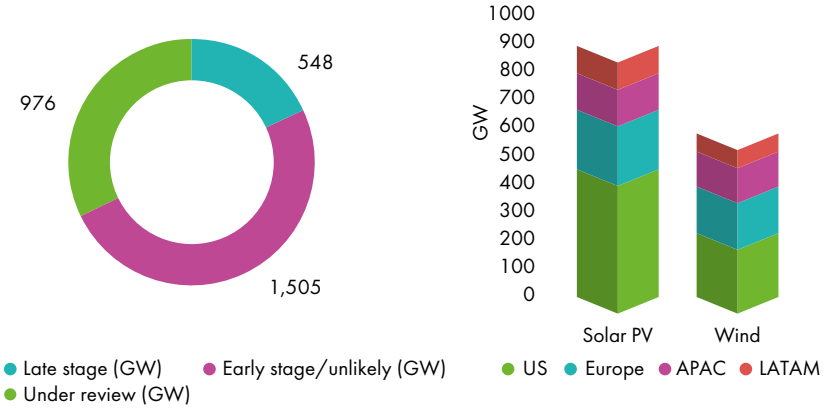
Streamlining permitting and regulatory processes

Streamlining permitting and regulatory processes is key to accelerating grid development and unlocking the full potential of renewable energy. COP29 emphasised the urgency of regulatory reforms to expedite approvals, ensuring that grid infrastructure projects can move forward at the pace needed to support the energy transition. By adopting best practices, such as clearer permitting guidelines, digitalised approval systems and stakeholder engagement frameworks, countries can significantly reduce delays while maintaining environmental and social safeguards.

Faster and more transparent permitting processes will also boost wind energy

Figure 1: Renewable energy capacity in connection queues[18]

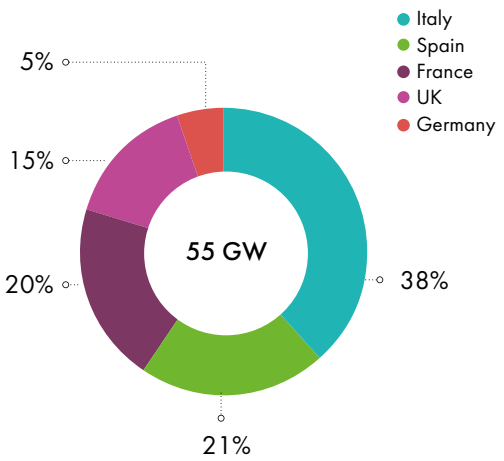
Renewable energy capacity in connection queues by project stage (left), and advanced-stage solar PV and wind projects by region (right)



Source: International Energy Agency

18. IEA, Renewables 202, 2024

Figure 2 – Permitting pipeline for onshore wind[19]



deployment. Currently, there are five times more wind projects in permitting than under construction in the EU. Addressing these bottlenecks with well-structured policies will create investment certainty, enabling a smoother and more predictable project pipeline.

Aligning regulatory frameworks with long-term renewable energy targets is crucial to bridging the gap between policy ambition and execution. Proactive policy changes that integrate anticipatory grid planning, enforce permitting deadlines and encourage cross-sector collaboration will accelerate grid expansion.

Mitigating grid congestion and the curtailment of renewables

Maximising the efficiency of transmission networks is essential to ensuring that renewable energy can reach consumers without limitations. The Grids and Storage Pledge highlights the need to reduce congestion and curtailment, ensuring that renewable energy capacity is fully utilised. Curtailment of renewable energy occurs when the power generated cannot be delivered to the grid due to technical constraints. In Spain, non-compensated curtailments accounted for over 1% of total renewable generation in both 2022 and 2023. Certain provinces experienced curtailment rates exceeding 10%, highlighting regional disparities in grid infrastructure[20].

Electricity market structures in many countries do not adequately incentivise optimal grid use. Without structural reforms such as locational pricing mechanisms, dynamic grid tariffs, capacity markets and congestion management tools, inefficiencies will persist. Addressing congestion requires not only new transmission investments but also better grid management and market design improvements.

Enhancing flexibility and system balancing mechanisms

A more flexible power system is essential to accommodate the variability of renewable energy generation. Investments in **energy storage, demand-side management and digital grid technologies** must be accelerated to ensure a resilient and reliable electricity network. While COP29 emphasised the urgency of energy storage deployment, widespread implementation remains slow due to high costs and regulatory uncertainty. Proactive policy measures and financial incentives are needed to drive adoption at scale.

Grid operators require a diverse set of tools to balance renewable generation effectively. Demand response mechanisms, interregional power exchanges and hybrid renewable-storage solutions can enhance grid flexibility and optimise energy distribution. Real-time grid management systems and AI-driven forecasting tools can improve operational efficiency and reduce reliability concerns as wind penetration increases.

Electricity markets must evolve to provide stronger incentives for flexibility solutions, including capacity remuneration mechanisms and ancillary service markets that fairly compensate storage and demand response participation. Scaling up grid flexibility measures will be crucial in maximising the potential of wind energy and ensuring a stable transition to a renewables-powered future.

Strengthening investment and business models for grid expansion

Grid infrastructure requires substantial capital expenditure. Existing business models often lack the necessary incentives for grid operators to innovate and expand, while regulatory frameworks in many countries do not sufficiently reward digitalisation, automation or efficiency improvements. Existing cost allocation methods often place a disproportionate burden on utilities and governments, limiting the scalability of investments.

Expanding Public-Private Partnerships (PPPs) and leveraging innovative financing mechanisms such as green bonds, climate funds and revenue-sharing models can help bridge the investment shortfall. Bringing in a wider pool of contributors, including industrial consumers and emerging market participants, can enhance investment stability and accelerate grid modernisation.

De-risking infrastructure in Emerging Markets and Developing Economies (EMDEs) is crucial for attracting private sector participation. Solutions such as credit guarantees, concessional financing and insurance mechanisms can lower financial risks, making grid investments more attractive.

19. BloombergNEF
20. https://auroraer.com/country/europe/iberia/evolution-of-grid-curtailment-in-spain/

Strengthening supply chains and workforce for grid expansion

COP29 acknowledged the pressing need to enhance supply chain resilience, particularly for key grid components such as transformers, high-voltage direct current (HVDC) cables, and substations. Addressing global shortages in these critical components is essential to accelerating grid expansion and ensuring timely infrastructure deployment. Investing in localised manufacturing capacity, strategic stockpiling and diversified supplier networks can mitigate delays and reduce system constraints.

Workforce development is also pivotal to scaling up grid infrastructure. Addressing gaps in high-voltage engineering, system planning and digital grid solutions requires targeted training programmes, reskilling initiatives and stronger industry-academia collaboration to build a robust talent pipeline. By strengthening both supply chains and workforce capacity, countries can ensure that grid expansion keeps pace with renewable energy deployment, fostering a more resilient and future-ready electricity system.

Turning pledges into action

While the Grids and Storage Pledge at COP29 was an important milestone, it is only the beginning. Implementation will determine whether these commitments translate into real-world impact. Scaling up investments, modernising regulatory frameworks and accelerating infrastructure deployment are essential to ensuring that grids can support the rapid growth of renewable energy.

A collective effort from policymakers, industry leaders and financial institutions is needed to drive coordinated action. Prioritising grid expansion, flexible market structures, streamlined permitting and supply chain resilience will unlock the full potential of renewables and enhance energy security. By taking bold and decisive steps now, grids can transition from being a bottleneck to becoming the backbone of a reliable, resilient and renewables-powered future.

Social Acceptance and disinformation

Wind energy's continued deployment across the world has meant that there is an increase in tissues related to social acceptance. This resistance stems not only from legitimate concerns but also from orchestrated disinformation campaigns financed by fossil fuel interest groups.

The spread of false narratives about wind energy is exacerbating the persistent and multi-faceted issue of permitting bottlenecks, influencing policy decisions and eroding public trust in renewable energy solutions.

Disinformation and the social licence to operate

The concept of the social licence to operate is fundamental to any infrastructure and energy development. This is especially true for wind energy, as the most targeted renewable energy technology in disinformation campaigns. Before diving deep into the implications of disinformation on wind energy, it is important to distinguish between disinformation and misinformation:

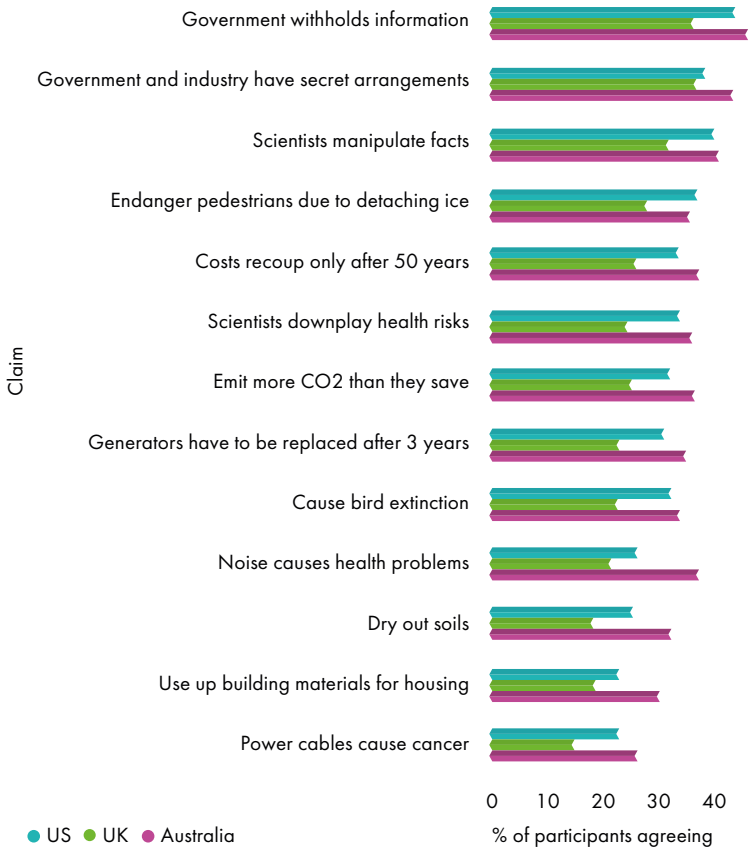
Disinformation: The term refers to concerted and deliberate efforts to spread false news and inaccurate or compromised information to the general public and local wind energy stakeholders. The are to introduce bias, increase opposition and undermine developments.

Misinformation: The term describes the propagation of false information without malicious and deliberate motivation. Often, misinformation is spread unknowingly by wind energy development stakeholders, such as community activists, ''concerned citizens'' or even NGOs. Many opponents of wind energy are biased, often without awareness of their misinformed views.

Recent research underscores just how pervasive both misinformation and disinformation about wind energy has become among the general public. A 2024 study published in Nature Communications found that nearly 30% of respondents in the United States, United Kingdom, and Australia agreed with half or more of the tested false claims about wind farms—ranging from health concerns to environmental harm. These beliefs are not isolated; they reflect a coherent, worldview-

21. Winter, K., Hornsey, M. J., Pummerer, L., & Sassenberg, K. (2024). Public agreement with misinformation about wind farms. Nature Communications, 15, Article 8888. https://doi.org/10.1038/s41467-024-53278-2

Figure 3: Public Agreement with Misinformation About Wind Energy[21]



Claims are sorted by decreasing the average level of agreement across countries. Exact wordings can be found in table 3. United States: N=1000, United Kingdom: N=1004, Australia: N=1004. Source data are provided as a Source Data file

Source: BloombergNEF

driven rejection of wind energy, often rooted in conspiracy thinking rather than a lack of scientific understanding.

This illustrates that misinformation and disinformation hinder progress towards global wind development targets and to decarbonising the energy sector. Approaching local communities and project stakeholders in good faith is essential for enabling any change in entrenched positions.

Without broad community support, wind projects face significant roadblocks that can lead to costly legal battles, stalled construction and, in some cases, project cancellation. Social acceptance is often shaped by a combination of real concerns about land use, environmental impacts, community engagement, involvement and benefits, as well as misinformation, which distorts facts and can lead to direct opposition.

Misinformation campaigns create a climate of uncertainty for developers and sometimes an outright hostile environment, making it difficult to engage with communities in meaningful ways.

Concentrated disinformation campaigns can take common misconceptions and amplify them, spreading them in an organised way through various media.

This is especially impactful in Emerging Markets. Here, misinformation has been weaponised to stall projects by fostering scepticism and resistance among local populations. False claims about land dispossession, economic harm and adverse health effects undermine community trust and discourage investment.

Without positive case studies to report in markets where developments are not yet frequent, it is increasingly difficult to counter existing narratives. Here, half-truths are often used to tell a one-dimensional story that may contain certain accurate elements, while adding misinformation.

For example, NGOs in the US have repeatedly claimed that whale deaths along the East coast are a direct result of offshore wind developments. While it is correct that cases of whale strandings along the East coast have increased, there is no scientific evidence to support statements that this is due to offshore wind developments. Expert opinion points to shipping and fishing gear entanglement as the most likely causes.

Despite the availability of this crucial information, public opinion remains heavily biased against offshore wind based on these concerns.

Figure 4: Types of Disinformation in U.S. Congressional Discourse on Offshore Wind (2023)[22]

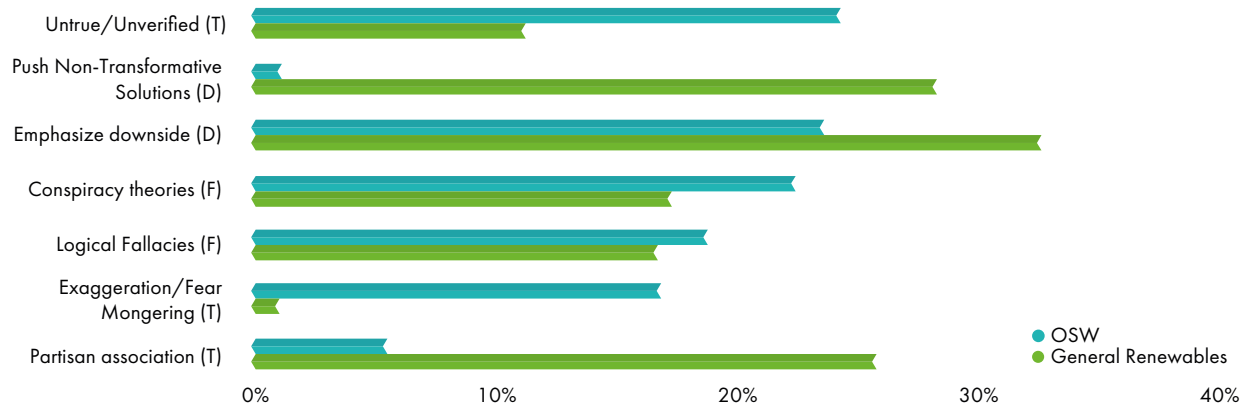


Table 1: Differences in frequency of negative claims between OSW specifically and renewables generally. For example, pushing non-transformative solutions was much more common when discussing renewables as opposed to OSW, appearing in 28% of general renewables claims. D=Discourses of Climate Delay; F=FLICC framework; T=This study.

Disinformation and misinformation about wind energy have substantial economic consequences. Widespread opposition – often rooted in misinformation – can substantially raise the cost of developing wind farms.

How misinformation undermines wind energy

Misinformation about wind energy manifests in several forms, often amplified through social media,

22. Garo, I. (2024, February 29). Spinning Negativity: Disinformation in U.S. Congressional Discourse About Offshore Wind. Climate and Development Lab, Brown University. Retrieved from https://www.climatedevlab.brown.edu

political rhetoric, and interest groups linked to the fossil fuel industry. Common falsehoods include:

- Environmental misinformation: ''Wind turbines kill whales!'', ''Wind turbines threaten local water quality.''
- Public health misinformation: ''Wind turbines make people sick!'', ''Wind turbines create harmful electro-magnetic fields and cause cancer!''
- Economic and grid stability arguments: ''Wind farms reduce adjacent property values.'', ''Wind farms negatively impact tourism revenue.'', ''Wind energy causes grid blackouts!''

A case in point is Brazil's recent offshore bill, enabling offshore wind developments in the country for the first time. Local campaigners falsely stated that offshore wind farms have negative impacts on coastal ecosystems and biodiversity. While scientific opinion does not support such blanket statements, the controversy led to community pushbacks and might result in permitting delays and financial losses for developers.

Disinformation: Implications for policy and the economy

The disinformation ecosystem targeting wind energy is linked to well-funded fossil fuel interests aiming to preserve the status quo, with talking points that find their way into the highest levels of policymakers and government officials – the very people that are often in direct control of regulatory bodies, frameworks and strategic planning for wind energy.

A Brown University study found that in just six months of US Congressional discourse, over 440 instances of misleading claims about offshore wind were recorded. This highlights how mis-disinformation is politically weaponised, creating issues that affect the entire wind industry.

Research in the UK found that fragmented local planning, driven by NIMBY (not in my backyard) attitudes, has increased the cost of deploying wind power by 10–29%, equivalent to an extra £8–23 billion ($10–29 billion).[23] Similarly, a modeling study in Ireland showed that strong public opposition can raise overall energy costs by up to 33% (including the cost of unserved energy). Even excluding extreme scenarios, investment and operating costs still rose by 5–6% under high-opposition conditions.

Dis- and misinformation can also negatively impact wind energy's 'social licence', with an inevitable knock-on effect of project delays that increase costs, which amplifies risk while making investments in wind energy less attractive.

Research by the Global Clean Energy Institute has shown that false claims linking offshore wind to whale deaths have directly resulted in permit moratoriums in key US states, costing the industry billions in lost revenue and delayed capacity expansion.

Social license is weakened by disinformation

Misinformation distorts legitimate concerns, overshadowing real discussions about how wind projects can benefit communities. Instead of addressing concerns about land ownership, revenue distribution and community participation, developers are forced into a reactive mode. Their focus on countering false claims can obscure meaningful dialogue with communities and stakeholders.

Additionally, disinformation erodes trust in institutions and regulatory processes, making communities hesitant to engage in discussions about wind energy developments in their vicinity and potentially associated benefits. This is particularly concerning in emerging economies where trust in governance, democratic processes and institutions can be already fragile.

Addressing misinformation and disinformation

Efforts to combat misinformation must be diverse, involving policy advocacy, positive storytelling, prebunking and debunking, proactive, early and qualitative community engagement, as well as industry collaboration.

Additional strategies can include:

- Strengthening transparency in project planning: Early, clear, and honest communication with communities about benefits and trade-offs.
- Countering false narratives with factual and positive storytelling: Wind energy success stories should be shared in accessible ways, featuring real community voices, rooted in actual projects.
- Building coalitions to push back against misinformation: Collaboration with local communities, NGOs, local leaders and journalists to ensure positive and constructive discourse.

The battle against mis- and disinformation is not just about protecting the wind industry – it is about securing a just and equitable energy transition that benefits all.

23. Jarvis, S. The Economic Costs of NIMBYism Evidence From Renewable Energy Projects, (2021).

Local content requirements and tariffs

As referred to in the emerging trends section, one of the most outstanding trends in global supply chains is the increase in politically motivated uncertainty in trade relations. Supply chain localisation, understood as positioning strategic stages of the supply chain within regions where key stakeholders or end-users are based, aims to account for these risks, mitigating potential disruptions while stimulating local industry development. However, if pursued with overly restrictive policies, it threatens to decrease cost-competitiveness and slow the expansion of renewable energy capacity.

Stringent or mandatory local Content Requirements (LCRs) and tariffs are particularly salient in this regard. The former requires foreign or domestic investors to source a percentage of goods or services locally, serving as an increasingly prominent form of non-tariff barrier (NTB) that often disadvantages foreign competitors in procurement processes. Their use has grown since the 2008 financial crisis, as governments across continents seek to bolster employment, safeguard local industries, and enhance economic security in response to increasingly pressing geopolitical risks.

Tariffs are a more direct method to restrict foreign access to domestic markets. By imposing duties on imports, they increase the price of foreign goods, with the goal of stimulating demand for locally produced alternatives across various levels of the value chain. Tariffs had significantly decreased over the past decades as part of the process economic globalization, but their popularity is on the rise again.

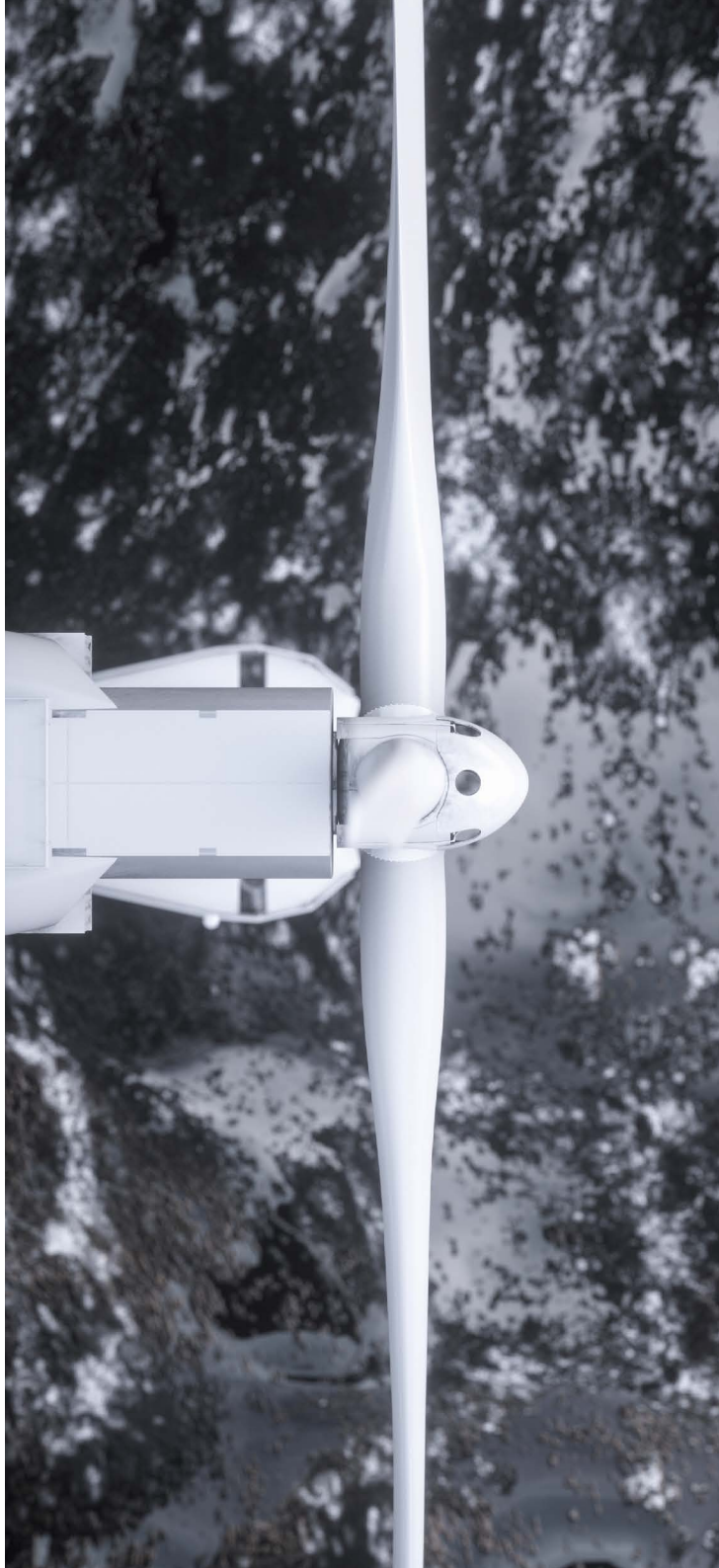
While LCRs and tariffs can stimulate industrial development and job creation in emerging markets, they also tend to hinder investment and growth by restricting access to foreign suppliers, limiting supplier options, driving up costs, and ultimately harming the very local industries they aim to support. Complementary policy initiatives, such as training programmes to build local skills, demand-side instruments, incentive-based industrial support schemes, and R&D funding for innovation, can help mitigate some of the negative effects often associated with such policies. Nonetheless, the industry recommends that if adopted, LCRs, tariffs and other restrictive policies should be an exceptional, time-limited measure, phased out as local industries become competitive on the global stage.

Regardless of whether they are implemented alongside these supporting frameworks, LCRs and tariffs should always be considered an ad-hoc, temporary, and time-specific policy approach. They may be deployed to support industrial development in developing regions where local industries genuinely lack the capacity to compete globally but should not be used to shield well-established industries from foreign competition. Therefore, the industry recommends that LCRs and equivalent measures be gradually phased out as local industries develop sufficient competitiveness and production scale to operate successfully in the global marketplace.

Supply chain localisation can and should be achieved without an over-reliance on market-disruptive measures. In this regard, several industry case studies illustrate how market-friendly policy principles advance localisation by creating favourable conditions that attract investment in local supply chain capabilities. The following key principles highlight the industry's preferred strategic framework for building local industrial capabilities:

Harness the benefits of international competition

The controversies surrounding the imposition of strict Local Content Requirements in China following the implementation of the 2021 Offshore



Wind Power Zonal Development Capacity Allocation Rules highlight the negative consequences of restricting access to global supply chains. Due to excessively restrictive LCRs, developers were forced to source essential components, services, and equipment from a small number of local companies—sometimes just a single supplier for certain components. This concentration of market power allowed these firms to drive up prices beyond levels that would be economically viable for most international developers. Following the EU's July 2024 WTO consultation request over Taiwan's offshore auction designs, the Taiwanese government has reached a preliminary agreement with the EU to ease Local Content Requirements and remove localisation rules in future wind project allocations.

Ensure policy coherence across domains and governance levels

Industrial incentive schemes are necessary to accelerate the development of economies of scale at the local level, but they are insufficient to ensure the creation of a sustainable and profitable local industry in the long term. In many instances, governments set ambitious renewable energy targets, but the absence of equally ambitious and well-coordinated grid expansion policies hinders their full realisation. This often results in supply and demand imbalances across multiple points in the supply chain, ultimately impacting both industry growth and end consumers. Additionally, misalignment between policy formulation and execution across different levels of government

can create further disruptions. To address these challenges, policymakers must ensure that renewable energy, infrastructure, and industrial strategies are designed to be complementary and mutually reinforcing at all levels, driving long-term success.

Focus on establishing continuity and predictability in the market

The 2015 delay of Round 4 of South Africa's REIPPPP highlights the importance of respecting long-term policy commitments to foster a favourable local investment environment. This unexpected halt eroded global investor confidence in South Africa's market, weakening the overall stability of the wind energy value chain. This case demonstrates that the success of wind energy capacity expansion initiatives depends on the sustained commitment of relevant authorities to support industry development. Ensuring that policy initiatives for capacity expansion remain in place over the long term is crucial for achieving investor confidence in the industry's long-term profitability.

Leverage local industrial strengths

Industrial incentives and other forms of government support for emerging local wind power industries must be pursued in a cost-efficient manner. This involves focusing support efforts on sections of the value chain that can leverage local competitive advantages, such as existing infrastructure, industrial expertise, and workforce capabilities. A prime example of this transformation is the repurposing of outdated offshore oil and gas port hubs for offshore wind development. Esbjerg, a port city on Denmark's west coast, exemplifies this shift, having evolved from a traditional oil and gas hub into a leading centre for offshore wind energy.

In addition the UK government published a road map for offshore manufacturing highlighting which components will be prioritised and which components can be provided by international supply chain.

Provide market incentives to attract investment

Incentive-based policies are always more effective in promoting local industrial development than restrictive measures such as LCRs. A case in point is Poland's 2020 Offshore Wind Act, which introduces flexible incentives for supply chain and local content development. The positive effects of this approach have been amplified by the launch of the country's National Reconstruction Plan (KPO), which provides further support through grants and direct loans for port infrastructure development and facilities for offshore wind construction and maintenance. This has resulted in an incredibly effective offshore wind power development strategy, positioning Poland as a leader in the European market for the second half of the decade.

Assess and empower the local workforce

Providing adequate capacity-building and training to empower the local workforce is crucial for developing a robust renewable energy industry. India has set a positive example by making significant strides in cultivating a skilled workforce for the renewable energy sector, particularly in wind energy, through initiatives like the Vayumitra training programme, managed by the National Institute of Wind Energy (NIWE). Since its establishment in 1998, NIWE has trained thousands of professionals and supported various programmes, such as the Skills Council for Green Jobs and the National Skills Development Mission. These efforts, in collaboration with industry, education, and civil society, have positioned India as a leader in wind turbine manufacturing, with over 17 wind equipment manufacturers exporting to Australia, Brazil, the USA, and Europe.

Consider regional collaboration

National authorities should foster regional collaboration within the wind power industry to build resilient and robust supply chains that mitigate vulnerabilities in global supply networks. By creating frameworks that align policies across trade, environmental, industrial, and

infrastructure sectors, countries can enhance supply chain resilience and capitalise on regional advantages. For example, in the U.S., regional initiatives such as the multistate cooperation framework between Massachusetts and Rhode Island for offshore wind development have successfully expanded capacity through coordinated procurement processes. Similarly, Denmark's early development of wind turbines in the 1980s, supported by the European Single Market, facilitated trade, knowledge transfer, and cross-border investment, strengthening both local and regional supply chains. The creation of the TetraSpar offshore foundation technology by European firms exemplifies how integrated regional efforts can drive innovation and accelerate industry advancements.

Race to new turbine platforms

Like any modern industrial sector, the success of the wind energy industry largely depends on continuous technological innovation. As wind energy expands globally, the industry is constantly enhancing its ability to adapt to local conditions and demands, striving to provide more reliable and efficient solutions for large-scale energy generation.

The intense competition in wind turbine design has also led to supply chain bottlenecks.

The trend of larger wind turbines is not a new development, but rather the result of gradual progress. Particularly in the offshore wind sector, the emergence of multi-megawatt turbines has been driving the industry towards higher efficiency. In the past year, major OEMs have continued to introduce higher-capacity turbine models. However, the balance within the wind industry has shifted. While efficient supply chains improve quality and reduce costs, intense competition has led to rapid innovation, accelerating the release of new technologies. This fast-pace technological advancement presents challenges in safety, reliability and cost control.

The major OEMs remain at the forefront of technological breakthroughs, consistently launching new turbines.

In European onshore wind sector, Nordex upgraded its Delta 4000 6.X MW turbine with a larger 175-meter rotor in Q3 2022 and expanded its N175/6.X series by introducing a hybrid tower with a 200-meter hub height. Vestas installed the prototype of its EnVentus V172-7.2 MW wind turbine at Denmark's Østerild test center in July 2024. Enercon launched the E-175 EP5 7.0 MW, featuring the newly developed E2 generator in March 2024, with the prototype installed in Wachendorf/Lower Saxony, Germany in April 2025.

In the Chinese market, the pace of wind turbine scaling has been even faster. SANY installed its SI-230150-15 MW onshore wind turbine last October, and other Chinese OEMs such as Goldwind, Envision, Windey, CSSC, CRRC and Sinovel all have 10 MW+ turbines in their product portfolios.

In the offshore wind sector, Vestas' V236-15.0 MW model has already secured over 6 GW in confirmed orders globally. In December 2024, it received its first order in the Asia-Pacific region. Meanwhile, SGRE's launched its SG21.5DD-276 offshore wind turbine last December with the prototype being installed in Denmark for detailed testing before commercial deployment.

Among Chinese OEMs, Dongfang Electric has announced a 26 MW offshore wind turbine – the largest power rating to date. Goldwind revealed details of its deep-sea 22 MW wind turbine at its Shantou manufacturing base, featuring a 300m rotor diameter and a swept area equivalent to 10 standard football fields. Mingyang installed its OceanX features a V-shaped dual-tower, dual-mainframe and dual-rotor design, combining two 8.3 MW offshore wind turbines for a total capacity of 16.6 MW, making it well-suited for deep-sea projects. As of the end of 2024, six Chinese OEMs had launched 20+ MW models.

Although this technical race trend has led to higher generation efficiency, it also presents significant challenges and development bottlenecks. Some existing wind turbine design standards no longer meet the design requirements of multi-megawatt units. Frequent issues such as blade fractures, blade tower strikes, and vortex-induced vibrations reflect deficiencies in blade design standards. Additionally, there are no industry standards for hybrid tower designs.

In manufacturing, rapid product iteration can lead to frequent design changes and technological updates, increasing uncertainty in the production process, disrupting the learning curve, and raising both production costs and operational complexity – making cost control difficult.

The intense competition in wind turbine design has also led to supply chain bottlenecks. Some Chinese OEM suppliers have expressed concerns about their ability to keep pace with rapid production acceleration, because component supplies cannot easily keep up with the pace of turbine development, threatening the sustainability of the supply chain.

Production and assembly processes

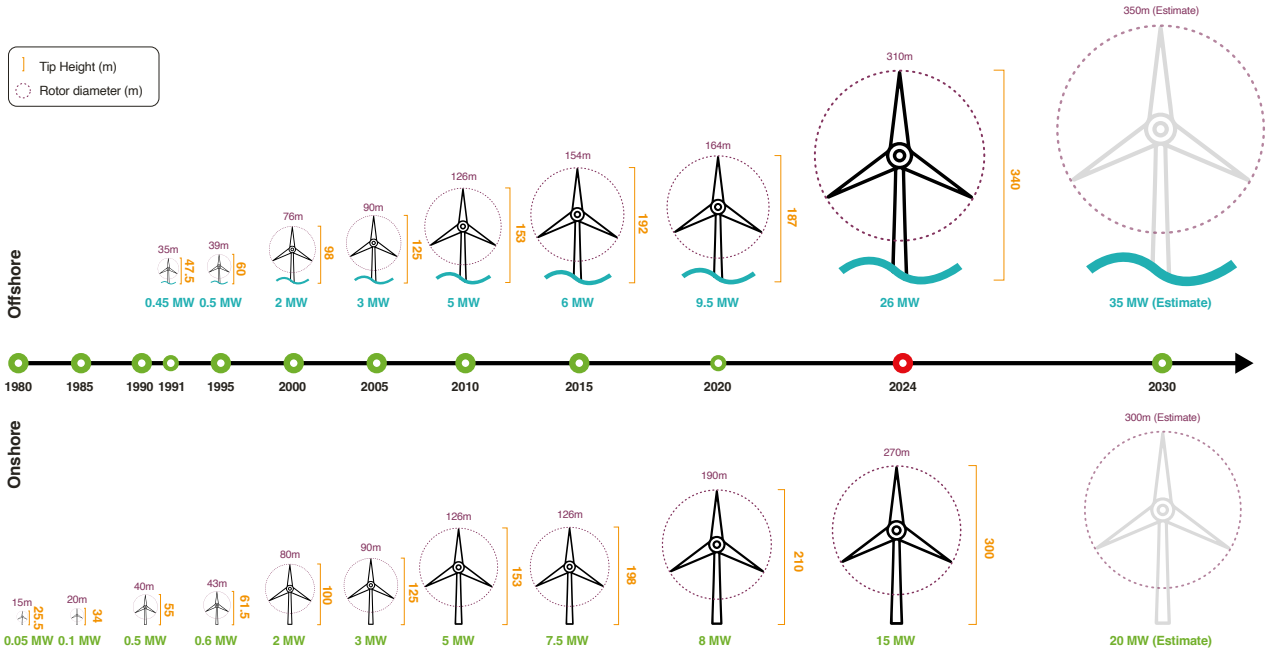
have not always evolved alongside technological advancements, leading to declines in manufacturing quality. Other parts of the industrial chain, including components, transport and installation, may not be fully compatible with the latest turbines designed by OEMs.

To support advancements in turbine technology, the entire supply chain must make technological progress, including innovations in key components such as blades, generators, gearboxes and main bearings. In the Chinese market, the wind industry "price war" sparked by the termination of feed-in tariffs has led to a pursuit of a larger market share and a desire to showcase technological strength. The ongoing race for larger turbine sizes has produced negative economic impacts, particularly on the financial sustainability of component suppliers. One of the main issues is the short product life cycle. As manufacturers compete to produce increasingly larger models, the lifespan of each turbine model becomes shorter. This forces component suppliers to invest in new designs and technologies for the next generation of turbines before they can fully realise a return on investment (ROI) from the previous models. As a result, suppliers are caught in a cycle of rapid product turnover, unable to recover costs and achieve profitability, which creates financial instability.

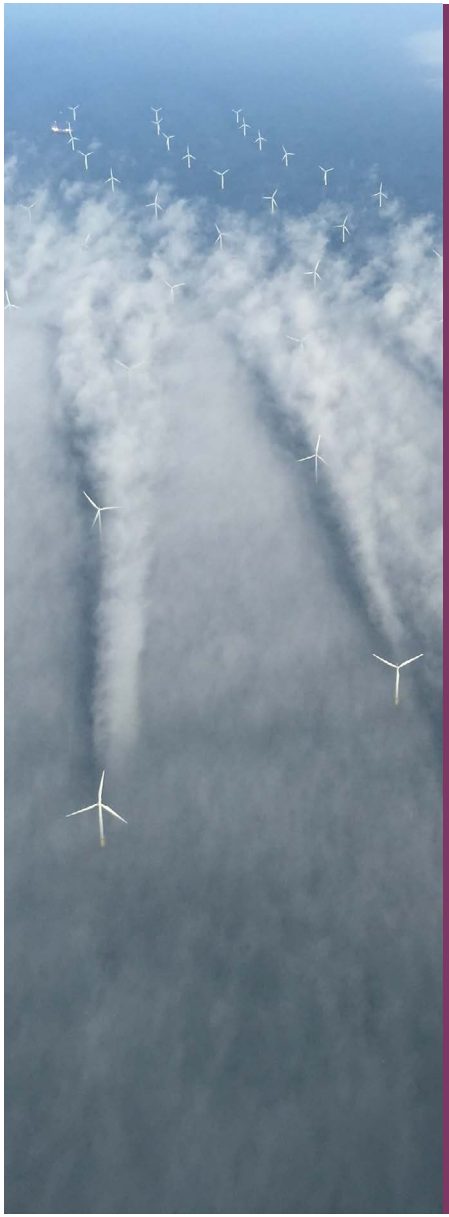
These pressures are felt not only by wind turbine component suppliers but also by developers. As the demand for larger turbines increases, developers are forced to continuously reinvest in new projects to accommodate the larger models. Thus, there are not enough opportunities to recoup costs already spent on earlier ones. Additionally, because some of those larger turbines have not been fully tested before the commercial installation, developers are exposed to the potential quality issues that could increase the OPEX and reduce the AEP.

As turbine sizes grow and technological designs become more complex, the costs of both development and manufacturing rise significantly. The short life cycle and constant race for larger turbines prevent suppliers and developers from achieving financial stability. With each new generation of turbines requiring large investments before the previous model's ROI is realised, the economic sustainability of the wind industry is at risk. If these issues are not addressed, the long-term health of the industry could be jeopardised, as both suppliers and developers struggle to remain financially viable in the face of constant innovation and rising costs.

Trend of onshore and offshore turbine size, 1980-2030



Source: GWEC Market Intelligence.



Case Study: Assessing the True impact of long-range wind farm wakes

Provided by: ArcVera, a Bureau Veritas Company

The wind energy industry has long grappled with the challenge of accurately estimating the energy production impacts of wind turbine wakes. While the effects of internal wakes within a wind farm are reasonably well understood, the magnitude and persistence of external wakes – those generated by turbines located more than four kilometres beyond the project boundaries – have been consistently underestimated by standard engineering wake models.

As a leading renewable energy technical consultancy with four decades of experience in providing finance-grade commercial and technical services for renewable energy projects, ArcVera Renewables, now Bureau Veritas' Renewables Technical Advisory arm, has recently shed light on this critical issue.

In the first case, ArcVera analysed four years of SCADA data from an onshore wind farm in the central United States. The normalised energy production data showed that the installation of a new, larger wind project 13 km to the north resulted in a 3.6% reduction in energy production at the target farm. However, two widely used engineering wake models had predicted negligible impacts, failing to capture even a small fraction of the observed wake losses.

Motivated by this finding, ArcVera turned to the Weather Research and Forecasting (WRF) model, which incorporates the Wind Farm Parameterisation (WFP) tool, to more realistically simulate the complex atmospheric interactions between wind farms.

In the second case study, the WRF-WFP model predicted external wake losses at the target project that were 16% higher than the SCADA-derived values, while the common engineering wake loss models, once again, vastly underestimated the impacts.

The third case took the analysis a step further, applying the WRF-WFP to hypothetical wind farm arrays in the New York Bight offshore wind lease areas. These simulations revealed dramatic long-range project-scale wake swaths extending over 50 km downwind, with specific examples showing 7% wind speed deficits 100 km away. When averaged over 16 days of predominantly southwesterly winds, the energy loss from external wakes at the target lease area was estimated at a staggering 28.9%.

These findings have profound implications for the wind energy industry. Existing engineering models that do not incorporate the WRF-WFP are primarily validated for internal wake losses and, perhaps for that reason, are – as these examples clearly illustrate – inadequate for assessing long-distance wake impacts, which may be significantly larger than previously accounted for in development planning.

The implications extend far beyond wind energy production estimates, impacting economic and project valuation risk, long-range asset performance and planning, hybrid project analysis, battery usage risk, and reliable around-the-clock renewable energy supply. Both onshore and offshore wind farms are impacted, and the extensive global plans for proximal deployment of wind projects should account for such impacts.

For more detailed information you can read the full ArcVera White Paper here: https://www.arcvera.com/arcveras-study-finds-long-distance-wake-losses-offshore-to-be-much-greater-than-expected/

www.arcvera.com
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PART TWO: SOLUTIONS TO BUILD THE NEXT TW

Scale, demand and investment de-risking

To make a meaningful impact on fossil emissions, rapid electrification of transport, heat and other end-uses via renewables must occur. This will not happen rapidly enough without targeted government support and public-private partnerships.

According to the IEA Electricity 2025 report,[24] strong growth in electricity demand is heralding a new **Age of Electricity,** with demand set to soar through 2027 and beyond. Most of this additional demand for electricity (85%) is expected to come from emerging economies, but electricity demand in developed economies is also set to grow. In advanced economies, electricity demand – both in total and per capita – has stayed relatively stable or even declined since 2009, even as these economies have continued to grow. However, it is now expected to start rising significantly, reversing the trend of the past 15 years. This demand for electricity driven by the deployment of electric vehicles, air conditioners, data centres and heat pumps, among other end-use technologies.

Already, wind and solar PV are the cheapest options to add new electricity generation in almost every country.[25]

On the supply side, renewables including wind, as well as solar and hydropower, are set to meet about 95% of the electricity demand growth in the IEA's forecast period. While this is to be celebrated, it also means that 5% of demand growth is met by other sources. **More critically,** it means that fossil emissions will not be significantly impacted, as existing fossil fuel plants are not being shut down quickly enough.

It is crucial to harness the long-predicted electrification of the global economy to ease regulatory bottlenecks, increase investments in grids and interconnection infrastructure and de-risk investments in renewables.

1. Greenhouse gas emissions reduction.
2. Improved air quality, both locally and globally.
3. Higher energy efficiency, as electric engines are often more efficient than internal-combustion engines on a full-energy-cycle basis.
4. Improved energy security as renewables is typically a domestic resource and cannot be blocked, cut off or used as political leverage.
5. More predictable electricity prices as the impact of volatility in fossil fuel prices is almost eliminated for end-users.
6. Job creation which is higher for renewables than for fossil fuels per

Tackling barriers to industrial electrification (World Economic Forum)

Industry electrification faces many barriers:

- Low fossil fuel prices compared with electricity.
- High upfront costs.
- The expectation of very short payback periods.
- Unfamiliarity with technologies.
- Concerns about disruption.
- Potential reconfiguration of industrial processes.

The diverse nature of these obstacles warrants a policy mix that combines different, complementary types of instruments and drives industry electrification at the needed pace.

24. IEA, Electricity 2025 report, (2025).
25. https://www.iea.org/news/massive-global-growth-of-renewables-to-2030-is-set-to-match-entire-power-capacity-of-major-economies-today-moving-world-closer-to-tripling-goal

MWh generated, with the increased costs of additional workers more than outweighed by avoiding lifetime fuel purchases.

7. Accelerated innovation and technological development, as electrification brings in new technologies and uses.

GWEC, the Global Renewables Alliance (GRA) and others have catalogued the many ways in which the growth of renewable energy can be facilitated: streamlined permitting, appropriate risk-sharing, expanded grids and others.

It is now time for governments globally to begin to actively promote the electrification of their economies.

The following are options to promote electrification:

Policy and regulatory measures

- **Undertake research:** Assess current and future electrification potential, distinguishing between commercially viable options and those requiring policy support.

- **Set electrification targets:** Establish clear goals for electrification in sectors such as transportation, industry and buildings. For example, many countries have targets for electric vehicle (EV) adoption and the expansion of charging infrastructure.

- **Mandates and standards:** Implement emission standards and efficiency requirements for vehicles, buildings and industrial processes to encourage the adoption of electric technologies.

- **Public-private collaboration:** Develop sectoral roadmaps in collaboration with industry stakeholders to coordinate decarbonisation strategies through electrification.

Financial incentives

- **Subsidies and tax credits:** Many countries provide financial incentives for EVs, installing charging infrastructure and adopting electric industrial processes. Replacing fossil heating systems with heat pumps is another logical early step in electrification. Industrial programmes will require a deeper understanding of available options, reinforcing the need for further research.

- **Funding programmes:** Provide grants for research, development and demonstration projects in electrification technologies. Examples include the EU's REPowerEU plan.

Infrastructure development

- Expand charging networks: Invest in EV charging infrastructure, including public chargers and curb-side solutions for urban areas.

- **Grid modernisation:** Grids in many countries are struggling to keep up with demand for connections by renewables projects. Grid modernisation will be critical to ensuring that the grid can handle the increased demand.

Awareness and education

- **Public campaigns:** Launch initiatives to educate consumers and businesses about the benefits of electrification. For example, India's campaigns promote EVs and electric cooking solutions.
- **Training programmes:** Provide training for workers in industries transitioning to electrification, such as mechanics for EV fleets.

Equity-focused Actions

- **Electricity access must be expanded:** Grid expansion can bring electricity to disadvantaged communities in EMDEs and elsewhere.

Electrification can contribute to de-risking renewable energy investment, which in turn brings down the overall cost of RE. Here are some key factors influencing this dynamic:

- **Long project pipelines:** If renewable energy developers plan a project but lose in an auction, they can still bid in subsequent auctions.

- **Scale:** If supply chain companies have a short-term sales outlook, they may not invest in a country or region. However, if long-term electrification

appears highly likely due to policy and other support, they will invest more, helping to drive down in-country costs.

- **Favourable government policies:** In a supportive policy environment, banks tend to be less concerned about delays that can disrupt a project. An abundance of offtake mechanisms such as auctions, corporate PPAs, and wholesale markets provides developers with ample opportunities to monetise their projects.

Electrification can be the lightning rod that catalyses the large-scale expansion of renewables. It will lead to significant de-risking of the industry – from supply chains to the cost of capital – further lowering renewable energy costs, increasing energy security, and stabilising prices in both mature and developing markets.

How Goldwind drives innovation in novel power systems

Provided by Goldwind

In 2024, Goldwind accelerated its mission to become a top-three global provider for new-type power system solutions. Leveraging its seven regional hubs and integrated capabilities in wind power, energy storage and hydrogen production, the company has been designing sustainable energy ecosystems worldwide. Its projects in Vietnam and Egypt exemplify this global strategy.

Vietnam: Hybrid synergy for industrial decarbonisation

Goldwind partnered with XCE Energy to deliver renewable solutions for the Xuan Cau Industrial Park and Free Trade Zone (LHF Project) in Haiphong. The project combines wind turbines, rooftop solar PV and energy storage systems to enable clean energy adoption by industrial users, supporting Vietnam's target to install 1 GW of renewable energy by 2030.

Since entering Vietnam in 2017, Goldwind has achieved the localisation of 66% of its wind operation teams, while 100% of its training coverage is localised.

Goldwind's Vietnam Solutions Factory won the "Smart Innovation Award" at the ASEAN Wind Energy Expo, demonstrating the company's commitment to nurturing local talent and advancing the energy transition.

Egypt: Wind power as a community catalyst

Goldwind's Gulf of Suez project Phase 2 – Egypt's largest wind farm – will generate 2 TWh annually, powering 800,000 households and cutting 1 million tonnes of CO_2 emissions.

The project drives localisation through the procurement of 35 tower sets and auxiliary materials locally, while creating more than 200 jobs with 70% participation by the local workforce.

Goldwind also collaborated with the Resala in Ras Ghareb charity to host culturally aligned community programmes, including Ramadan gift exchanges and skill-building workshops for orphans, strengthening social bonds.

Localisation: The bedrock of the global energy transition

Goldwind's localisation strategy embeds wind power projects into regional economies through technology transfer, supply chain integration and community co-development.

In Vietnam, the industrial park model sets benchmarks for low-carbon development, while in Egypt, the projects address both energy gaps and employment restructuring.

Operating across 42 countries, Goldwind transforms every unit of green power into momentum for regional growth, evolving wind farms into industrial incubators that empower local communities.

Through technological innovation and cultural synergy, Goldwind is accelerating the transformation of the global energy ecosystem with sustainable models, embodying its mission of "Driving Our Renewable Future".

Goldwind

Standardisation: Increasing competitiveness through manufacturing excellence

Beyond innovation: The wind industry on the path to industrialisation

As wind technology evolves, capturing the full value of industrialisation has become essential. Historically, industries like automotive have demonstrated that innovation alone is not sufficient and must be complemented by industrialisation for sustainable growth.

The wind sector often attributes its limited industrialisation to rapid innovation cycles. However, innovation is a prerequisite for industrialisation: **you can innovate without industrialising, but without innovation, industrialisation is impossible.**

Industrialisation directly influences speed-to-market and product quality, offering substantial economic benefits. In a recent example, a wind turbine generator yielded €400 million by accelerating market entry by two months.

Conversely, quality issues have challenged wind turbine OEMs significantly impacting profitability. While industrialisation cannot eliminate all quality costs, many OEMs could have minimised losses through more rigorous industrialised approaches.

While a focus on pure innovation was justified until a few years ago by the competition to make wind turbines more powerful, OEMs are struggling to make money in today's competitive market with stronger physical boundaries. The time is right to switch gears and focus innovation on industrialisation efficiency.

The three pillars of industrialisation

Successful industrialisation relies on integrating three critical pillars – product strategy, process strategy, and production strategy – well before large-scale implementation. Many companies rush innovative technologies to market without aligning these pillars, leading to costly redesigns and delays.

- **Product strategy:** Focuses on modular designs and standardising components early in development, significantly reducing complexity. Typically, wind turbines have nearly 80% new parts with each iteration; industrialisation aims to substantially lower this figure, emphasising the value of constraints early in the design phase.
- **Process strategy:** Ensures consistent, streamlined and scalable processes that reduce variability across manufacturing sites. This includes standardising processes to improve efficiency and minimise the risks inherent in rapid innovation.
- **Production strategy:** Entails optimising manufacturing setups through automated and pre-assembled components. Pre-assembling critical parts such as blade roots or nacelle sub-assemblies enhances efficiency, consistency and quality.

Historically, Ford's Model T illustrates this point: its revolutionary success was driven more by manufacturing process innovation than by the car itself.

A key indicator for industrialisation is the percentage of new or modified parts. In the automotive industry, a new model typically features 30–40% new parts, whereas in wind energy, this

Industrialisation captures the "value of constraints"

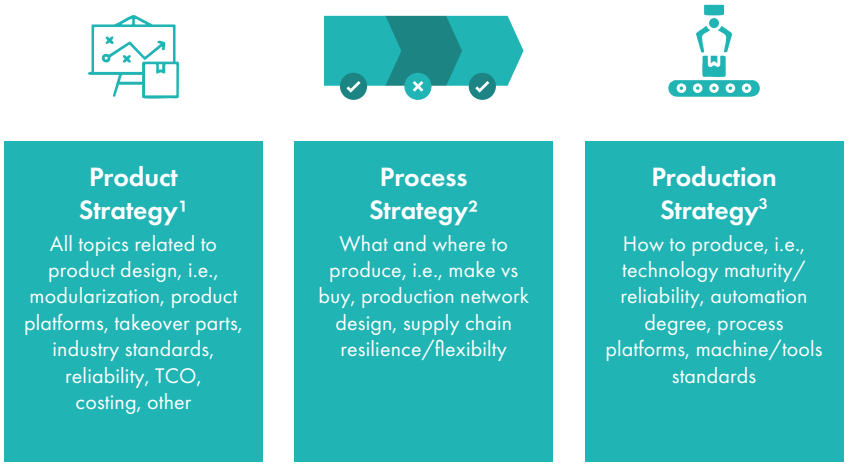


figure has reached as high as 80%—an extreme situation that industrialisation seeks to avoid. Industrialisation is a disciplined approach that must be embedded in the design process from the beginning.

A lean and agile framework

We have adapted the classic 14 principles from the 'Toyota Way' to suit today's wind industry context applying a lean/agile matrix. Developing the **best product strategy** required collaborative iterations within a multidisciplinary team including product R&D, suppliers, process engineering, manufacturing, quality, finance. In this context **Agile Delivery Units (ADUs)** represent the most efficient organisation model.,

Similarly, **process strategy** must leverage the specialised expertise of various engineering disciplines, with **Centres of Excellence (CoEs)** serving as key enablers. Meanwhile **production strategy** will be anchored in the time-tested Lean principles where **Lean Operation Teams** will be the strongest asset.

- **Agile Delivery Units (ADUs):** Where complexity is high, and customer proximity is key, we deploy "agile delivery units". Cross-functional teams focus on customer-centric products with high complexity. Structured into Tribes and Squads, ADUs rapidly deliver innovations through Agile sprints, ensuring products meet market demands effectively.

- **Centres of Excellence (CoEs):** Specialist knowledge structures are needed in the remote monitoring, second-level technical hotlines and commissioning teams. Specialised teams provide essential expertise on-demand. CoEs operate independently, supporting innovation and production through targeted knowledge without being constrained by organisational boundaries.

- **Lean Operation Teams:** The lean principles dominate in procurement and manufacturing. Optimise internal efficiency, supporting ADUs and CoEs by reducing overhead and streamlining administrative tasks using lean principles.

- **Customer Loyalty Teams:** Installation and the customer interface in operations will be performed by teams combining lean with a strong customer focus. Handle lower complexity, repetitive customer-focused tasks, maximising customer satisfaction through lean and flow-based methodologies.

Industrialisation is thus embedded into daily operations, rather than being isolated within special projects or initiatives. This disciplined integration requires new skill sets, prompting wind OEMs to increasingly recruit expertise from automotive sectors, where industrialisation is mature.

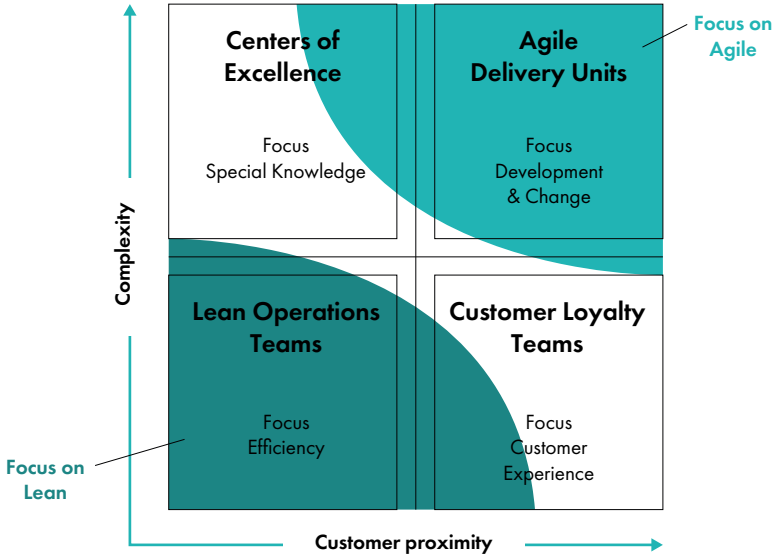
Speed and excellence through industrialisation

Industrialisation prioritises frontloading—addressing manufacturing constraints early in development—to achieve flawless quality without sacrificing speed. Applying Design for Manufacturing (DfM) processes with clear milestones and evaluations, such as Manufacturing Readiness Levels (MRLs), ensures timely and high-quality outcomes. Successful cases show industrialisation solving the trilemma of speed, excellence, and cost, indicating structured innovation enhances rather than hinders development.

Managing complexity through modularity and digital twins

Wind industry complexity arises from varied environmental, technical, political, infrastructure, and customer-specific requirements. To handle this complexity efficiently, companies adopt modular designs, standardising core components and customising only essential areas. Digital twins—virtual simulations of real-world performance—allow

Industrialisation using the Lean/Agile Matrix



Embracing industrialisation isn't optional; it's imperative for transforming the wind industry into a scalable, profitable, and future-proof sector.

predictive maintenance and streamlined development, significantly reducing time-to-market and maintaining rigorous quality control. For example, Formula One racing demonstrates how digital twin technology enables rapid, high-quality development despite very low production volumes.

Similarly, the aerospace industry provides valuable insights into managing complexity. Despite high customisation and stringent standards, aerospace manufacturers have successfully industrialised low-volume, high-complexity production. Their approach combines modular designs, automated production processes, and rigorous quality management, proving industrialisation is viable for wind turbine manufacturing as well.

Market-specific variants

The wind sector faces unique market-driven complexities—from extreme weather conditions to varying regulatory environments. Effective industrialisation requires flexible yet standardised manufacturing processes capable of adapting swiftly to such market dynamics. Modular product architectures, digital tools, and automated processes enable manufacturers to efficiently manage diverse market-specific variants while maintaining speed and quality.

The good news is that we have the tools and experience from wind and other industries to navigate this complexity in the development phase. The automotive sector is looking at more than 1000 customer preference dimensions. Nevertheless, we see a new model coming to market in 24 months. A new leading-edge gearbox in wind is available for serial production in 9 months, enabled by an agile team and a modular design approach

Disciplined New Product Introduction

A disciplined New Product Introduction (NPI) process embeds industrialisation strategies from the outset, optimising the path to commercialisation and maximising value creation. Clear milestones, standardized methods, and rigorous testing ensure that innovation translates smoothly into scalable production, reinforcing efficiency and innovation simultaneously.

Conclusion: Industrialisation—a strategic imperative

Industrialisation is essential for the wind industry's long-term competitiveness and profitability. Key priorities for the next phase of wind industrialisation include:

1. Leveraging innovation as an enabler for industrialisation.
2. Empowering agile delivery units with industrial discipline for product planning and development.
3. Continuously benchmarking future readiness in production, process, and product setups.
4. Prioritising speed and excellence through structured industrialisation.

Embracing industrialisation isn't optional; it's imperative for transforming the wind industry into a scalable, profitable, and future-proof sector. By applying proven industrial methodologies alongside structured innovation, wind energy companies can achieve rapid market entry, exceptional quality, and sustained competitive advantage.

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Notes/references from the 1st graph:
How to Deal with Exponential Complexity in Automotive Engineering, 2022 (BCG report)
Harnessing the Tectonic Shifts in Global Manufacturing, 2023; Building an Optimal Global Manufacturing Footprint, 2024 (BCG report)
Designing Factories That Are Built for the Future, 2023 (BCG report)

Innovative materials to improve the recycling of wind turbine blades

Provided by Goldwind

As wind energy capacity continues to expand, so does the disposal challenge for large wind turbine blades (WTBs) – the last piece of the puzzle to make a wind turbine 100% recyclable.

While efforts are being made to find more sustainable recycling methods, such as breaking the blades down for use in concrete or other products, the sheer volume of wind turbine blade waste is outpacing current solutions. For this reason, innovative materials, recycling technologies and sustainable blade designs are becoming increasingly critical to the future of our industry.

Blades are made of thermoset resins, which are not reversible or recyclable. Vitrimers are a new class of polymers that make thermoset resins reversible, and as such show significant promise for the future recycling of WTBs.

By using vitrimers, there is an opportunity to still benefit from the advantages of thermosets (high strength/durability, chemical/temperature resistance) while achieving the reversibility of thermoplastics.[1]

With vitrimer technology, the base chemistry of the blade resin, such as epoxy, remains unchanged. However, dynamic covalent bonds are inserted into the epoxy matrix like 'locks' that only open in the presence of a specific 'key' – a designed degradation solution.

This allows the blade manufacturing process to remain the same and continue to use familiar epoxy resin systems, eliminating the risk of a new, unknown chemistry that would require long-term testing. The recyclable resins degrade into oligomers to be re-used as chemicals or additives, while recovered fibers are reprocessed and used in new applications such as injection moulding of fiber-reinforced plastics (FRP) parts.

Techstorm's patent-pending recyclable resin systems allow for recycling at temperatures of around 100°C in a non-hazardous degradation solution while maintaining the design properties of epoxy resins in WTBs.

In 2024, we commercialised our vitrimer-based recyclable resin in the carbon fiber spar cap planks of wind blades with a few OEM customers. This enables recovery of carbon fiber reinforcements (rCF) at the WTB end of life, as well as the immediate recycling of waste from the manufacturing of spar cap planks and wind blades.

The same technology platform is being used to develop Techstorm's epoxy infusion resins, as well as urethane and acrylic-based structural adhesives. This would allow the recyclability of all parts of WTBs, including accessories that are bonded onto the blades, finally bringing the ambition of 100% wind turbine recyclability within reach.

TECHSTORM
Reliable Solution

1. The unique molecular structure of vitrimers features dynamic covalent bonds that can be 'reversed' under specific conditions such as elevated temperature and the use of suitable solutions. This allows the composite to be recycled via resin depolymerisation and enables the recovery of fiber reinforcements.

Enhancing trade and global collaboration to achieve scale and efficiency

The unparalleled levels of prosperity that have allowed for the expansion of global wind power generation capacity were founded upon a stable, predictable and expanding international trade system. However, the evolution of international politics in recent years is rendering each of these characteristics unattainable. In this new world, the uncertainty fuelled by a complex interplay between great power competition and state-led economic policy makes it increasingly difficult to establish fair, open and effective trade relations.

The rules-based trade order of the past decades is being overshadowed by complex transactional trade relations. As tariffs and barriers to trade are imposed across geopolitical divides, trade tensions and challenging environments in trade negotiations seem poised to become a driving force fragmenting global trade and supply chains in the coming years.

The ad-hoc use of tariffs will need to carefully balance domestic or international political pressures with the economic forces underpinning global trade relations. The extent to which political ambitions can align with economic realities remains a critical question, one that will significantly shape the future of global trade relations. In a world where uncertainty increases and a sense of intensifying global competition grows, the space for multilateral and regional trade agreements that prioritise sustainable economic growth will remain restricted unless there is a significant intervention at a national level. As geopolitical tensions rise, efforts to diversify and regionalise wind power supply chains must intensify for a more resilient industry. Third-party intermediaries between the competing global powers of our new multipolar world stand to gain significantly as businesses and governments seek alternatives to traditional energy sources. Emerging economies, such as Mexico, Vietnam, Turkey, Indonesia or India, must undertake the necessary reforms needed to feed their economies with the dynamism and socioeconomic impact that international trade and investment can provide.

Trade for security and sustainability

Wind power technologies rely on resilient, robust and efficient supply chains to provide secure, affordable and reliable wind energy for all. The complexity of key components in wind turbines calls for a free, fair and predictable trade system that allows for the efficient allocation of manufacturing processes across continents. Undermining such features of the global trade system will predictably create unnecessary cost drivers for wind power developers across continents.

The alternative to a trade regime that allows for the maximum possible level of efficient allocation of resources across the supply chain is a global economy kidnapped by a resurgent oil and gas industry. This will leave emerging economies vulnerable to the political predicaments and short-term interests of major oil and gas exporters, as well as the oil-driven geopolitical pressures that have caused so much desperation, war and suffering in the global south for decades.

Policy recommendations

A different path is possible, and it necessitates a sensible and efficient global trade system. The success stories of the wind energy industry in recent years highlight the critical need for a free and fair international trade framework to drive down costs and ensure a steady supply of renewable energy technologies. However, this is only part of the story.

Free and fair trade is necessary, but further initiatives are required
Cooperative trade relations not only boost the cost-competitiveness of green power but also facilitate technological innovation and promote necessary improvements in energy intensity. However, free and open trade is only one component of the broader action that the industry needs.

Wind power technologies rely on resilient, robust and efficient supply chains to provide secure, affordable and reliable wind energy for all

Green industrial policies must align with free and open trade to ensure a level playing field

- Free trade policies hold the potential to turn otherwise costly wind power components into widely accessible goods when cautiously integrated with incentive-driven industrialisation initiatives. This combination will allow wind energy firms to capitalise on local incentives for expansion, while leveraging the

cost advantages embedded in global trade relations.

Coordination, collaboration and dialogue must prevail over fragmentation, confrontation and competition

- Balancing fair trade practices with incentive-based industrialisation policies, while ensuring a level playing field that fosters efficiency gains and technological innovation, requires global leaders to maintain robust dialogue, both at a government level and also with industry representatives.
- Global leaders must, therefore, leverage the convening power and expertise of multilateral institutions and regional forums to coordinate the development of trade-friendly green industrialisation policies, creating conductive market conditions where wind power and other renewable energy industries can prosper.

Regionalisation is key, even though global dialogue must be preserved

- The current fragmentation of international political and economic relations cannot be ignored. Integrating a key strategic sector such as wind power in a global economy under siege by the forces of political division and conflict carries significant risks that need to be accounted for in government strategies.
- The effective regionalisation of supply chains offers a clear path out of the conundrum between energy security and economic efficiency. Strengthening regional economic cooperation can address political risks in global supply chains while allowing for local companies to leverage the advantages of the international allocation of processes according to each regional player's competitive advantage.
- Where regional capabilities are insufficient to meet market demand for critical components, materials and services, preserving strategic global supply chain linkages is essential. In this sense, policy efforts should focus on fostering redundancy and diversification across borders to enhance resilience and mitigate supply disruptions.

International Collaboration: Conference of Parties - UAE Consensus, Baku and Beyond

In order to establish a shared consensus around achieving climate goals and accelerating global wind energy deployment, it is essential that we facilitate enhanced international collaboration.

The Conference of the Parties (COP) is one of the few annual gatherings officially convened by the UNFCCC, where governments, the private sector, and key civil society actors come together to agree on a pathway forward for mitigation, adaptation, and many other workstreams needed to combat climate change.

A high degree of hope is placed on each COP. In 2023, the UAE hosted COP28, where 133 countries pledged to triple globally installed renewable energy capacity and double energy efficiency by 2030. UNFCCC and Carbon Brief analysis reported that the country hosted the largest-ever number of attendees (around 80,000) in COP history, making it one of the most inclusive and wide-ranging COPs to date. Year on year, the number of attendees has increased, except for COP29 in Baku, where the number of admitted participants decreased to around 70,000

To achieve the scale and efficiency required to deploy more wind energy, enhanced international collaboration will be key, and gatherings like COP will play a central role.

The Global Renewables Alliance (GRA) constitutes the combined forces of the Global Wind Energy Council, the Global Solar Council, the International Hydropower Association, the Green Hydrogen Organisation, the Long Duration Energy Storage Council, and the International Geothermal Association. It was established to speak with a unified voice on accelerating the energy transition.

Since COP28, the Global Renewables Alliance has jointly co-convened with the International Renewable Energy Agency a Global Renewables Hub in the Blue Zone of the COP process. This serves as a hub for public and private dialogues with key governments, private sector stakeholders, and civil society actors. During the two weeks of COP, the GRA advocates for progress on implementation and works to establish key steps to turn targets into turbines.

Without convenings like this, the essence of international and truly global collaboration would be lost and fragmented. Providing an international stage for these conversations breaks down barriers around market-specific challenges and allows us to pave the way forward through effective government engagement with the private sector at the table. The willingness of the host nation is key, and their support is imperative to secure bolder and more binding climate agreements.

COP30, hosted by Brazil, marks the next opportunity for the collective climate community to build on the $300 billion annual contribution pledged in Baku.

Winning support, building political support and combatting disinformation

Misinformation and disinformation pose some of the greatest threats to the continued buildout and growth of wind energy globally. Building public and political support, fostering trust with communities and embracing a proactive engagement to counter the effects of mis- and disinformation is the most effective countermeasure.

This section explores strategies to proactively engage communities, improve stability in wind energy policy and shift public narratives in favour of wind energy, while acknowledging that there is no 'one-size-fits-all' solution.

Shifting from reactive to proactive communications

Historically, the wind industry has responded to misinformation reactively, producing advocacy and communications campaigns after a narrative based on inaccurate claims had emerged.

A more effective strategy is to set the stage before misinformation even occurs, in a proactive and positive manner. No matter which techniques are chosen, solutions must be tailored to their specific – and often local – audience.

Besides being positive, messaging needs to fit the situation and align with people's perspectives on concrete and local issues – if authenticity is questioned, it can undermine the effort. Potential approaches include, but are not limited to:

- Prebunking: Publishing factual communications campaigns without reacting to a certain development, highlighting potential positive impacts of wind energy development for people or biodiversity as a way to "inoculate" communities against disinformation efforts not yet underway.

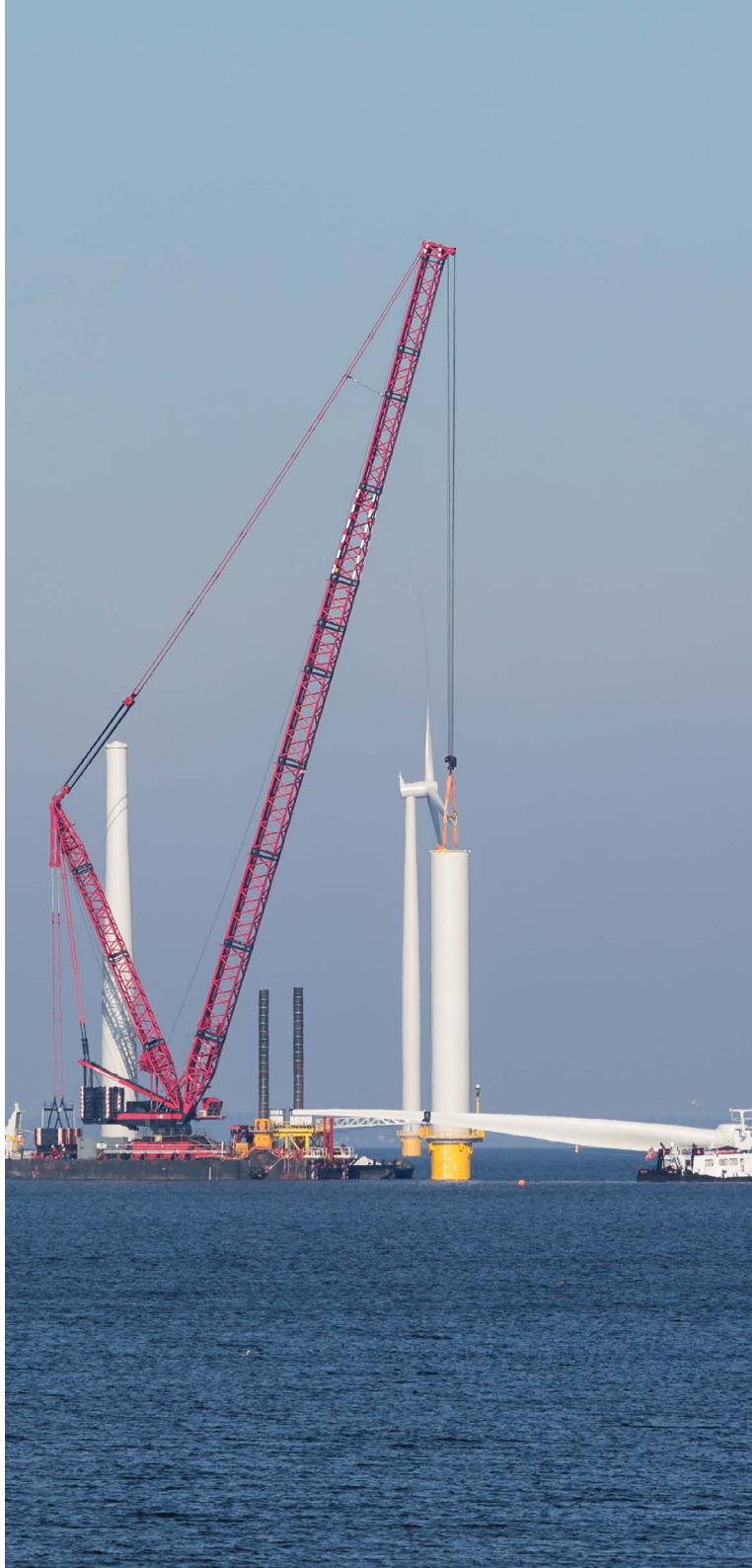
- Debunking: While in essence a reactive technique, it can prove useful to address recipients that are not overly distrustful of science, forming part of a package of approaches to mitigate the effects of misinformation. Debunking essentially refers to the act of proving that a certain piece of information is not true.

Potential underlying narratives for these techniques could be:

- Humanising wind energy: Featuring stories from local beneficiaries, workers and community members who have directly experienced wind energy's benefits. Human stories could centre, for example, around working conditions for local fishers being improved due to the donation of safety gear; improved health & safety training around offshore wind farms; children having access to after-school programmes funded by wind farm operators; or success stories of local restaurants and hotels due to the influx of workers to a community.

- Communicating economic and social benefits: Framing wind projects as economic opportunities that bring jobs, infrastructure and community investment. Potential examples could highlight successful use of community benefit funds, infrastructure improvements in local communities, an increase in full-time jobs in a wind farm's vicinity and the potential for nature conservation opportunities.

- Nature-inclusive and co-use designs: Highlighting ways of designing wind farms that have shown potential for creating spaces in which nature not only exists but can thrive – all while including local co-users. Potential examples could be wind farms acting as nature conservation areas with extensive agricultural use,



offshore wind farms enabling algae-farming, artificial reefs and artisanal fisheries applying non-ground invasive techniques

Community engagement and building trust

Social acceptance hinges on early and authentic engagement that follows high standards of good engagement

One effective approach to proactive messaging is to combine on-the-ground human resources with high-tech tools. For instance, GWEC is currently developing a Disinformation War Room—an AI-powered dashboard designed to provide real-time tracking of disinformation. It will also leverage pattern recognition, predictive modelling, and sentiment analysis to anticipate potential mis/disinformation in specific regions. When paired with insights from national wind energy associations, this platform can help craft targeted, preemptive strategies tailored to local contexts and audiences.

practice, in order to make a positive and lasting impression on communities.

Quality engagement relies not only on early communication but also on reflecting a developer's long-term commitment to working with a community. Representatives within the community should therefore be selected based on their ability to connect with local stakeholders and how relatable they are. A few examples of quality engagement strategies include:

- Local ownership models: Community co-ownership of wind projects increases buy-in and reduces resistance of local communities, providing an incentive to critically reflect on possible disinformation efforts.

- Benefit-sharing mechanisms: Ensuring that revenues from wind projects directly benefit local communities through infrastructure investments and local hiring is vital, since it enables communities to directly experience tangible benefits of the development.

- Educational initiatives: Collaborating with local schools, universities and civil society groups to improve energy literacy will raise understanding for the developers' position and the need for building wind energy as part of the energy transition. Most importantly, it serves as a way to prebunk and inoculate stakeholders against the false information that is likely to reach them at some point in the process.

Disinformation can be countered

The wind energy industry must recognise that winning political and public support is not a passive process: It requires strategic, sustained, practical and sensitive engagement. Over the past two decades, the oil and gas industry has spent more than $1.5 billion on advertising and lobbying to keep fossil fuels flowing—outspending clean energy groups by a staggering 27 to 1.[26] This financial firepower has given their messaging a massive reach, shaping public perception and policymaking in ways that directly undermine wind energy development. To counter these long-running campaigns, the wind industry must come together and commit meaningful resources to proactive, coordinated efforts that push back against false narratives. If we are to win the battle for public trust and policy support, the fight against disinformation must be met with equal determination and strategic investment from the renewables sector.

26. Christian Downie & Robert Brulle, Big Oil's allies spend big money on ads and lobbying to keep fossil fuels flowing, Pennsylvania Capital-Star, February 14, 2023. Available at: https://penncapital-star.com/commentary/big-oils-allies-spend-big-money-on-ads-and-lobbying-to-keep-fossil-fuels-flowing-analysis

PART THREE: MARKETS TO WATCH

Africa: South Africa

Authored by the South African Wind Energy Association

South Africa has made significant progress in integrating clean energy sources into its energy mix, with multiple policy directives prioritising renewable energy for connection to the national grid. In July 2024, President Cyril Ramaphosa established the Ministry of Energy and Electricity, led by Minister Kgosientsho Ramokgopa, to enhance energy security with a special focus on electricity."[27]

Reflecting on a decade of wind energy

South Africa remains a leader in renewable energy deployment on the African continent, with approximately 30% of the continent's installed wind energy capacity.

Over the past decade, wind energy in South Africa has grown steadily and is nearing maturity, with several utility-scale wind farms operational for more than ten years. Public policy, driven by the White Paper on Energy (1998) and the White Paper on Renewables (2003) kick-started the wind industry. These policies led to the Integrated Resources Plan (IRP) of 2010, which included allocations for renewable energy and directed Eskom to procure wind energy.

Under the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP) that emerged from the IRP2010, the first requests for proposals (RFPs) were published in 2011 and the first utility-scale wind farms became operational in 2014. Since then, REIPPPP has procured 4,287 MW of wind energy, with 3,344 MW already installed. While there was significant momentum in the early 2010s, procurement slowed towards the end of the decade. The last successful procurement window for wind occurred in 2021, with 1,608 MW of wind projects announced.

Half of these projects failed to reach commercial close due to global supply chain pressures, however, and only 784 MW of the 1,608 MW awarded are currently under construction. The new Department of Electricity and Energy intends to introduce reforms to restore the success of the public procurement model.

Private offtaker market stimulating the wind sector

Significant reforms introduced in 2022 under the Electricity Regulation Amendment (ERA) Act established an independent transmission operator, removed the 100 MW distributed generation limit and granted trading licenses to aggregators and traders, creating a liberalised energy market.

Since then, at least 15 private offtake projects totalling 1,943 MW have been announced and are either under construction or will begin later this year. The first private offtake wind project to deliver power through the national grid was the 69 MW Msenge Emoyeni Wind Farm, completed in October 2024, which supplies power from the Eastern Cape to a petrochemical's producer in the Free State.

Most private offtakers are in the mining and petrochemical industries and are looking at renewable energy as they seek to move towards decarbonisation. In addition, several wind projects have signed agreements with traders and aggregators, signalling the arrival of the power trading market, even in areas outside of the Cape Regions, such as Mpumalanga Province.

Mpumalanga has long been the heart of South Africa's coal power generation, hosting the majority of Eskom's coal-fired power stations. The construction of Ummbila Emoyeni[28], the province's first wind farm, signals a significant shift towards renewable energy.

27. https://sawea.org.za/news/sawea-welcomes-merging-ministries-electricity-and-energy-retaining-kgosientsho-ramokgopa
28. https://ummbilaemoyeni.com/

A bright future for wind energy

The 2024 South African Renewable Energy Grid Survey (SAREGS) identifies a pipeline of 53 GW of wind and wind-hybrid projects for development over the next 5–8 years, with 33 GW potentially completed by 2030.[29]

The Draft IRP2024 reflects this ambition, indicating that between 69 GW and 76 GW of wind energy will be needed between 2031 and 2050 across all considered scenarios. While the IRP was still under review as of February 2025, wind energy is expected to remain the preferred renewable energy source for long-term planning.

Wind deployment levels in both SAREGS and the IRP are significantly higher than current achievements, highlighting constraints such as land acquisition, logistics, financing, skills availability, and, most critically, grid capacity.

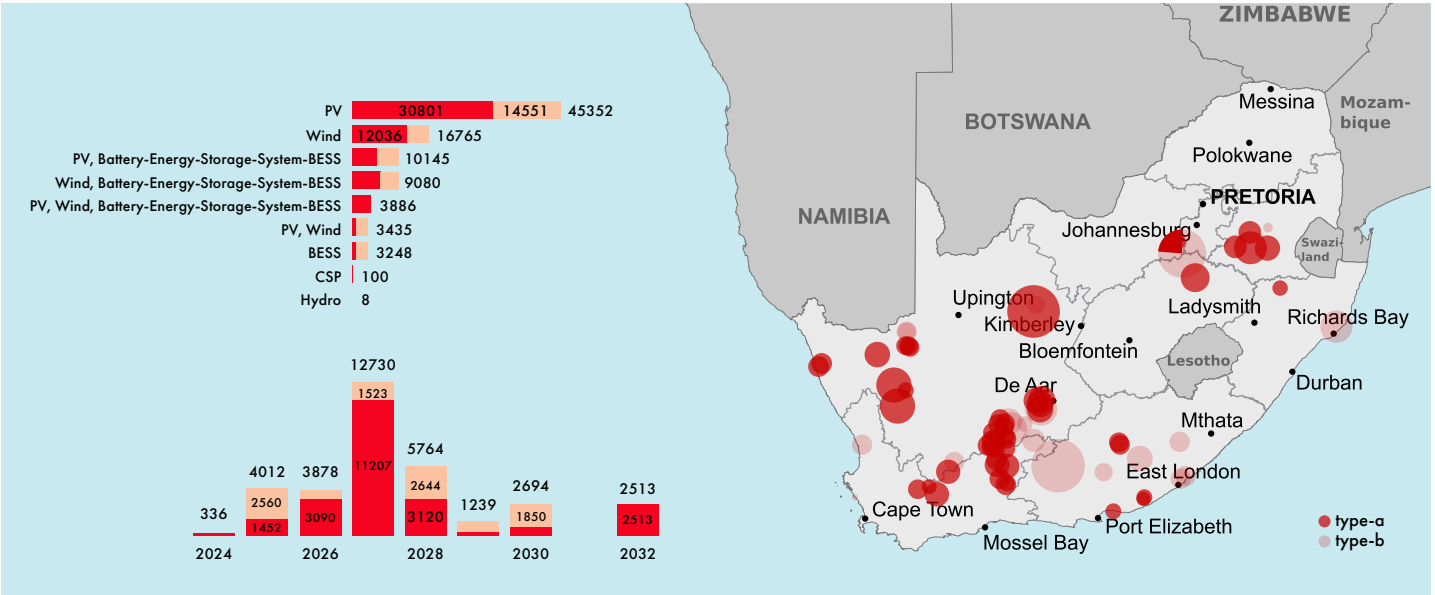
Resolving grid constraints

Grid connection capacity is a major obstacle to accelerating wind energy deployment in South Africa. The highest wind resource regions lack sufficient connection capacity, which has caused numerous projects to be stranded.

The National Transmission Company South Africa (NTCSA)'s 2025–2034 Transmission Development Plan (TDP) prioritises grid strengthening and expansion in these regions. However, there is a shortage of resources for the necessary scale of expansion. The National Treasury plans to use Independent Transmission Projects (ITPs) to involve the private sector in expanding the national grid.

29. https://www.ntcsa.co.za/south-africa-renewable-energy-grid-and-survey/

Figure 1: 2024 SA Renewable Energy Grid Survey – July 2024– Eskom NTCSA



Source: Eskom NTCSA

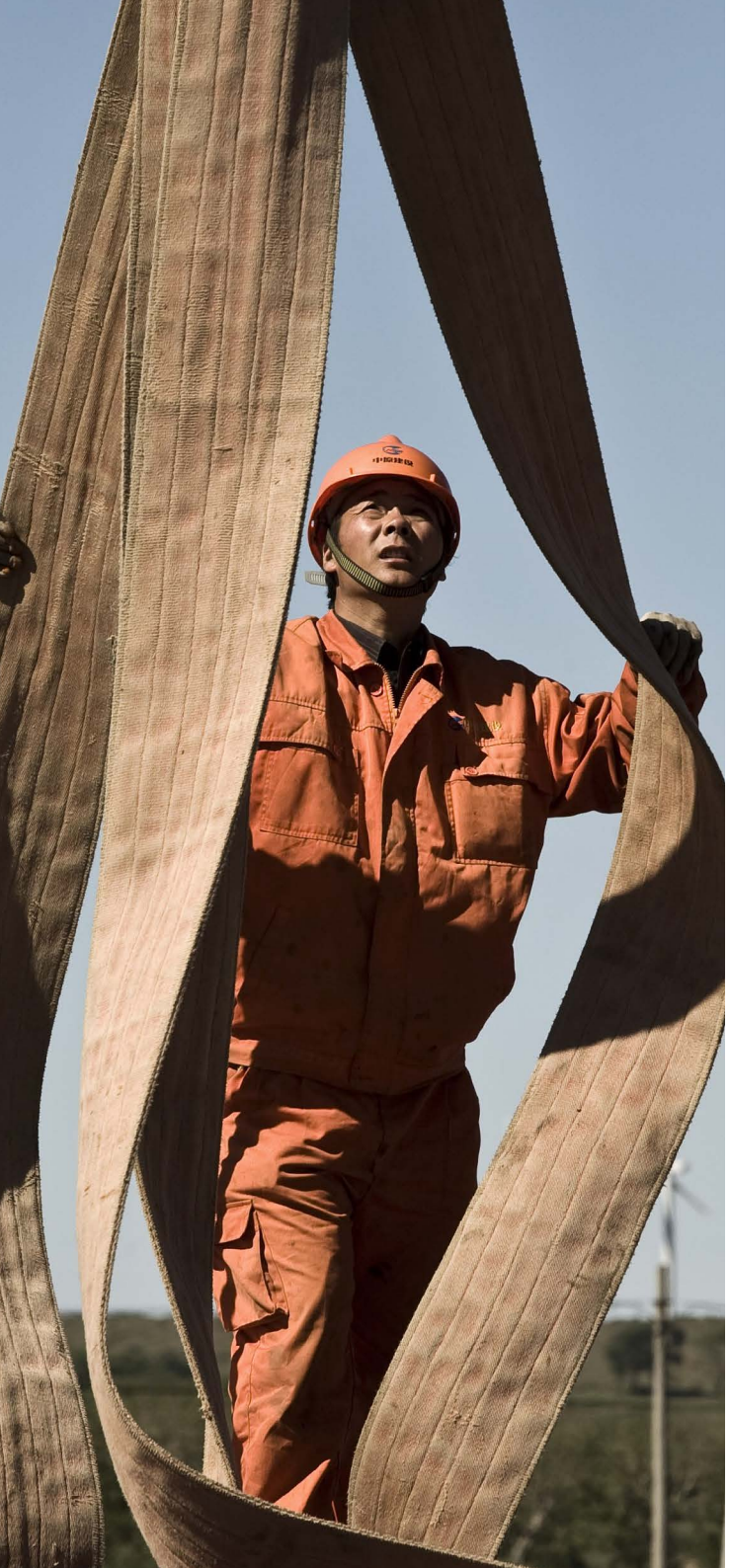
South Africa assumes G20 Presidency

In November 2024, the G20 Presidency was officially handed over from Brazil to South Africa. At the G20 Global Leaders' Summit later this year, the Just Energy Transition will be a key agenda item. During Working Group meetings preceding the summit, the wind energy sector will be discussed as a primary industry for reducing carbon emissions and a key player in achieving a Just Energy Transition.

2025 wind energy outlook

The Electricity Regulation Amendment Act (ERAA), signed into law in August 2024 and effective from 1 January 2025, sets the stage for accelerating power sector reforms in South Africa. The ERAA aims to establish structures for a competitive wholesale electricity market by April 2026, transforming the energy landscape and expanding the wind energy market both locally and through the Southern African Power Pool (SAPP).

In the short term, the wind energy industry awaits the revised IRP2024, which will provide direction for new electricity infrastructure over the next two decades and help restore investor confidence. The government is also planning to reform and restructure the REIPPPP to address current challenges, accelerate renewable energy procurement, and align with ongoing power sector reforms.



APAC: China, Australia, India, Singapore, Philippines, South Korea

China

2024 was a year of vigorous development for China's wind power industry, with remarkable progress in technological innovation, industrial scale expansion, policy environment optimisation, and market structure reshaping.

Installed capacity reaches a record high

In 2024, newly grid-connected wind power capacity in China was nearly 80 GW, surpassing the previous installation record set in 2023. Cumulative installed capacity was more than 520 GW, accounting for almost 50% of the total global wind power installed capacity. The installed capacity of wind power and solar PV power generation reached 1,400 GW by the end of 2024, surpassing the installed capacity of thermal power for the first time in China's history. Wind power accounts for one-tenth of the country's total power generation, making it the third-largest source of electricity after thermal power and hydropower. The clean energy sector (including renewables, nuclear power, electricity grids, energy storage, EVs and railways) contributed 10% of China's GDP in 2024. It has become the top driver of economic growth.

Increased policy support

The Energy Law adopted in November 2024 fills a gap in China's top-level energy system design and lays a legal foundation for achieving the country's "30-60" goals of carbon peaking by 2030 and carbon neutrality by 2060. The law specifies that the government supports the priority development and use of renewable energy. In August 2024, governmental guidelines were issued on accelerating green transformation in all areas of economic and social development, explicitly proposing to vigorously develop non-fossil energy. These regulations ensure the long-term development of renewable energy.

The government also introduced policies to support wind power. The "Thousands of Townships and Villages Embracing Wind Power Initiative", for example, promotes the construction of wind power projects in rural areas. The market potential driven by this initiative is estimated at 2,000 GW.

In 2023, the National Energy Administration (NEA) issued the "Wind Farm Renovation, Upgrade, and Decommissioning Management Measures" encouraging the renovation and upgrade of wind farms that have been in operation for over 15 years or have turbines with power ratings of less than 1.5 MW. To date, 15 provinces have issued implementation plans and launched pilot projects. In addition, the construction of the first batch of large-scale wind and solar power bases in the Gobi and other desert areas has been completed. The second and third batches are expected to solidify wind and solar power as the dominant sources of new electricity generation in the country.

Non-stop technological innovation

In 2024, the Chinese wind power industry achieved several technological breakthroughs, including the installation and operation of offshore wind turbines in the 18-20 MW range and the batch operation of 16 MW offshore wind turbines. Last October Dongfang Electric announced the world's largest offshore wind turbine with a nameplate capacity of 26 MW, while Goldwind rolled a 22 MW offshore wind turbine off the assembly line in December.

As for onshore wind power, 10 MW models have been installed on a large scale, and SANY installed a 15 MW onshore turbine prototype for testing in October 2024. Furthermore, the

world's highest wind farm, at an altitude of 5,200 meters, was commissioned in Tibet.

China has five pilot floating wind projects in operation. The most recent is Mingyang's 16.6 MW V-shaped OceanX, which was installed in waters off Guangdong. In 2024, CRRC launched its 20 MW floating turbine, which was installed at an onshore testing site in Shandong province in early 2025.

Mingyang introduced 143m wind turbine blades in February 2024, and the 147m blades manufactured by Goldwind and Sinoma Blades passed a static load test last September.

SANY commissioned the world's largest 35 MW "six-degrees-of-freedom" wind turbine test bench during China Wind Power 2024 in October. A 40 MW test platform is under construction in Shantou, Guangdong.

Building a sustainable local wind industry

Since 2021, competition in the wind power market has become increasingly fierce. At China Wind Power 2024, 12 turbine manufacturers signed a self-discipline convention to promote the stable and orderly development of the industry. Developers pledged to no longer solely focus on price in bidding, with some state-owned companies adjusting the bidding rules to gradually loosen the principle of awarding the contract to the lowest bidder.

Going global to support the energy transition

Over the past twenty years, China has forged the world's largest, most comprehensive and highly competitive wind industry. The Chinese wind supply chain is now actively expanding its global footprint. Goldwind's manufacturing base in Brazil has commenced operations in Camaçari, Bahia. Sinoma has established a blade factory in the same Brazilian city to supply Goldwind.

Sany is in the process of constructing an assembly plant in Kazakhstan. Envision has established production capacity in India and declared investments in Kazakhstan and Saudi Arabia. Mingyang has established joint ventures in South Korea and Italy to serve local markets. Shanghai Electric has announced a joint-venture plan in South Korea.

Renewable energy market reform with a growth mindset

To encourage further growth in the renewable energy sector, China's National Development and Reform Commission (NDRC) and NEA have recently issued a market-oriented pricing scheme. For projects commissioned before June 2025, the transition will follow a price-difference settlement mechanism, aligning grid connection pricing with current policy. New projects coming online after the deadline will have power purchase agreements adjusted dynamically, based on local renewable energy targets, with pricing set through competitive bidding.

The industry believes this setup will trigger an installation rush in the first half of this year. Since 2025 marks the final year of China's 14th Five-Year Plan, and more than 150 GW of wind turbine orders were made in 2024, 2025 is expected to be another record year for new installations. However, developers will be more cautious about future investments due to growing uncertainty about rates of return.

The Chinese wind industry has faced similar crossroads several times. GWEC Market Intelligence believes that the local industry is capable of coping with the challenges posed by market reform, and that China will continue to play an important role in promoting the global energy transition and responding to climate change.

Australia

Authored by the Clean Energy Council

Australia has some of the world's best onshore and offshore wind resources, and the sector is set to play a large role in the country's energy transition away from ageing coal-fired generation.

Wind power – all of it onshore – accounted for 33.5% of Australia's renewable power generation in 2024, providing 32,519 GWh of energy, making it the largest category of clean power supply in the Australian renewable energy sector. Overall, it supplied 13.4% of Australia's total power generation in 2024, while renewable energy represented 40% of Australia's total electricity generation mix, up slightly from the previous year.

Seven onshore wind farms were connected to the grid in 2024, with the largest – Tilt Renewables' Rye Park – coming in at just a whisker below 400 MW. Meanwhile several even larger onshore wind farms are currently under construction: the 414 MW Uungula in New South Wales, the 450 MW Clarke Creek and the 923 MW Macintyre in Queensland, and the two stages of the 1.33 GW Golden Plains in Victoria.

A resurgence in wind energy investment

Eight new onshore wind projects saw financial commitments in 2024, for a total 2.2 GW of new generation capacity, at an estimated value of AUD 5.9 billion ($3.71 billion). This marks a resurgence in wind energy project investment, following a slump in 2023 which was driven by higher equipment, construction, and financing costs, planning and environmental assessment bottlenecks, and policy uncertainty.

The federal and state governments have made focused efforts to streamline assessment processes and reduce commercial risks for new clean energy investments through the expanded 'Capacity Investment Scheme'. This competitive tendering process will provide revenue underwriting for 23 GW of new large-scale generation and 9 GW of dispatchable capacity by 2027. Such efforts appear to be boosting renewed investor confidence.

Likely federal elections in May 2025 could place this confidence at risk, however. The Federal Opposition – a coalition of the Liberal and National parties – has indicated a preference for nuclear energy development, rather than continued momentum in renewable energy generation and storage investment.

While a change of government would be unlikely to change the investment case for renewables, it could provide additional headwinds for projects in the development pipeline.

Offshore wind powers up

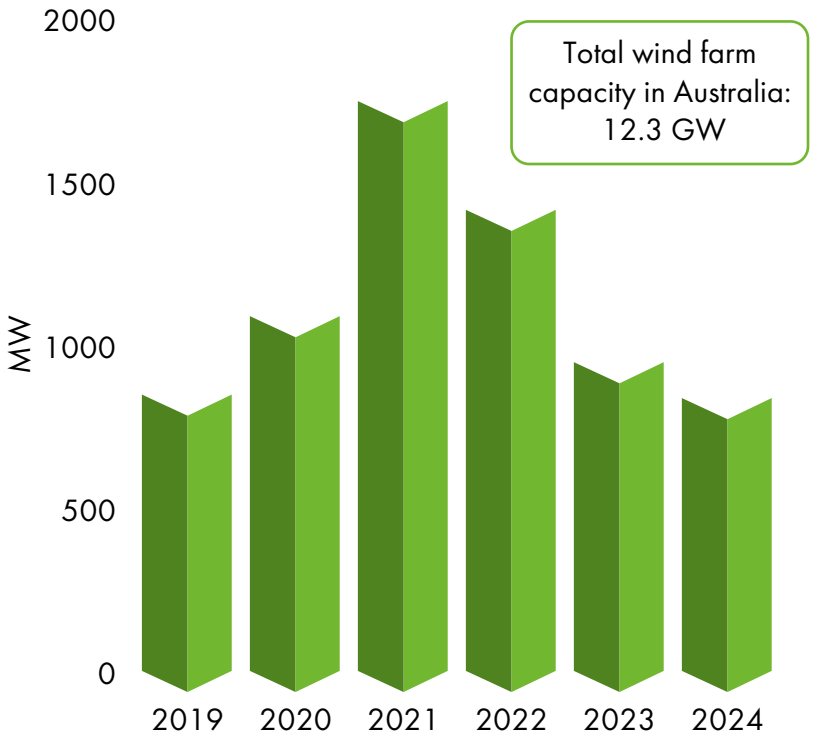
In 2024, the Australian offshore wind industry saw significant developments, with area declarations, awarding of feasibility licences, and increased regulatory support.

Outstanding consultations for proposed offshore wind areas were completed, with declaration processes finalised in 2024 for the Southern Ocean, Illawarra, Indian Ocean (Bunbury) and Bass Strait (Northern Tasmania) offshore wind areas. They join Gippsland and the Hunter as the six declared areas for future offshore wind development.

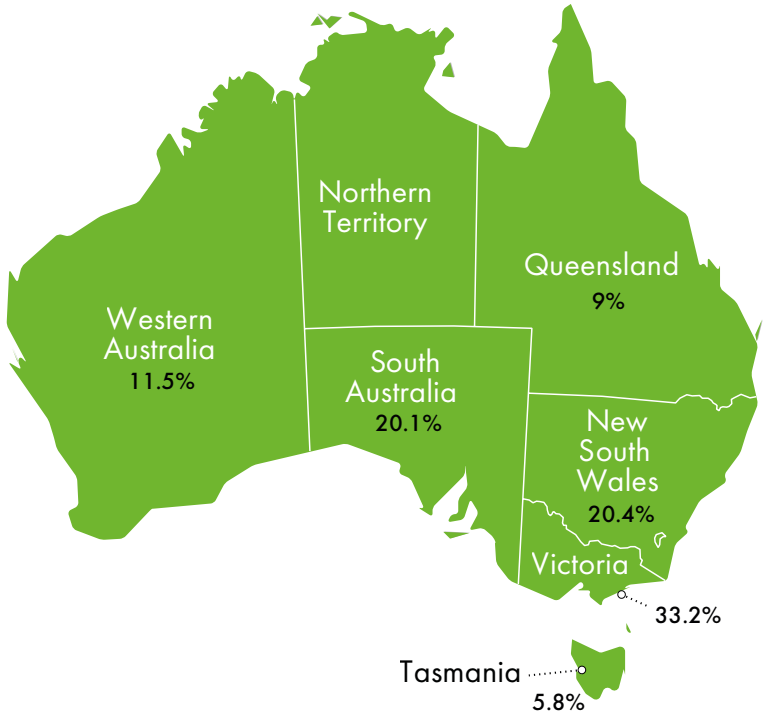
Following the awarding of 12 GW of feasibility licences across six projects

7 wind farms commissioned in 2024
836 MW new wind capacity added in 2024
AUD $5.9 billion (USD 3.71 billion)
new investment in wind projects in 2024
33.5% of total clean energy generated in Australia in 2024
13.4% of total Australian electricity generated in 2024

Annual installed wind capacity in Australia (MW)



Percentage of Australia's wind generation by state



in the Gippsland offshore wind area in 2023, an additional six licences were granted in July 2024 to the following projects: the 3 GW Aurora Green, 2.1 GW Greater Gippsland, 1.5 GW Navigator North, 2 GW (approximate) Kent, 2.5 GW Great Eastern, and 2 GW Gippsland 2. This brings the total feasibility licence capacity awarded in the Gippsland offshore wind area to 25 GW.

With licences secured, early survey works, such as geophysical and bird investigations, have commenced for several projects in the Gippsland region. Outcomes from these will contribute to the proponents' environmental impact assessments and, ultimately, their applications for commercial licences to construct and operate offshore wind farms.

In early 2025, the Federal Minister for Climate Change and Energy made formal offers for feasibility licences in the Hunter offshore wind area for the 2 GW Novocastrian project, and in the Southern Ocean offshore wind area for the 1+ GW Spinifex project. Pending acceptance of these offers, the total capacity of projects awarded feasibility licences in Australia could surpass 28 GW.

The Federal Department of Climate Change, Energy and the Environment published its Offshore Electricity Infrastructure Amendment Regulations 2024 in December, enabling the

Offshore Electricity Infrastructure Act 2021. These regulations detail the requirements for project design, and how proponents can carry out feasibility studies and prepare management plans.

Victoria sets legal targets for offshore wind

Following its announcement in 2022 of a 9 GW offshore wind target by 2040, with interim steps of 2 GW by 2032 and 4 GW by 2035, Victoria legislated the target under the Climate Change and Energy Legislation Amendment (Renewable Energy and Storage Targets) Act 2024 in March. This makes Victoria the only government in Australia with an offshore wind target.

VicGrid, which is responsible for the development of onshore connection points for Victorian offshore wind areas, opened a tender process last December seeking a public-private partnership for delivery of Gippsland's transmission infrastructure requirements. This includes selecting a development partner to design, build, finance, operate and maintain the transmission lines and connection hub linking Gippsland's offshore wind area to the National Electricity Market.

The expression of interest process for the Victorian government's first 2 GW offshore wind auction round, which was originally slated for Q4 2024, is expected in H1 of 2025.

Wind farms under construction or financially committed as at end of 2024

Commitment year	Project	Lead operator/owner	State	Installed capacity (MW)
2022	MacIntyre Wind Farm	Acciona	QLD	923
2022	Golden Plains Wind Farm East	TagEnergy & Ingka Group	VIC	756
2024	Golden Plains Wind Farm - Stage 2	TagEnergy & Ingka Group	VIC	577
2022	Clarke Creek Wind Farm Stage 1	Squadron Energy	QLD	450
2023	Uungula Wind Farm	Squadron Energy	NSW	414
2024	Lotus Creek Wind Farm	CS Energy	QLD	285
2024	Diamondy Wind Farm (Wambo) Stage 2	Stanwell and Cubico Sustainable Investments	QLD	254.2
2022	Diamondy Wind Farm (Wambo) Stage 1	Stanwell and Cubico Sustainable Investments	QLD	252
2024	Boulder Creek Wind Farm	CS Energy	QLD	228
2020	Ryan Corner Wind Farm	Global Power Generation	VIC	218
2022	Goyder South Wind Farm 1A	Neoen Australia	SA	209
2022	Goyder South Wind Farm 1B	Neoen Australia	SA	203
2024	Warradarge Wind Farm Stage 2	Bright Energy Investments	WA	108
2024	King Rocks Wind Farm	Synergy	WA	105
2020	Hawkesdale Wind Farm	Global Power Generation	VIC	96.6
2021	Crookwell 3 Wind Farm	Global Power Generation	NSW	58
2024	St Ives Wind Project	Gold Fields	WA	42
2024	Mt Weld Power Station - Wind	Zenith Energy	WA	24

India

India's wind energy sector is witnessing strong growth, with 3.4 GW of new capacity added in 2024 – the highest annual installation level since 2017 – bringing total capacity to 48.16 GW[30]. Most of the new installations were in Gujarat, Karnataka and Tamil Nadu.

With rising energy demand driven by industrialisation and urbanisation, wind energy is crucial to India's goal of achieving 500 GW of non-fossil capacity by 2030 and net-zero emissions by 2070. Achieving 10 GW of annual wind energy capacity additions by 2030 will be key to positioning wind power as a cornerstone of India's decarbonisation strategy.

Under the National Electricity Plan for 2022–2032, installed wind capacity is estimated to reach 73 GW in 2026–2027 and 122 GW in 2031–2032.[31] Sustaining this momentum, however, requires large-scale investment, enhanced grid infrastructure, streamlined regulations and technological innovations.

Driven by ambitious renewable energy targets and increasing electricity demand, India's wind energy sector is a key player in the country's energy transition. Offshore wind holds immense potential but faces infrastructure, policy and investment challenges. Onshore wind growth, while supported by newer kinds of tenders such as hybrid and firm and dispatchable renewable energy (FDRE), is hindered by land acquisition issues.

Greater grid integration is needed, as well as the repowering of ageing turbines and a secure supply of rare earth materials for wind turbine production to further boost India's wind energy strides.

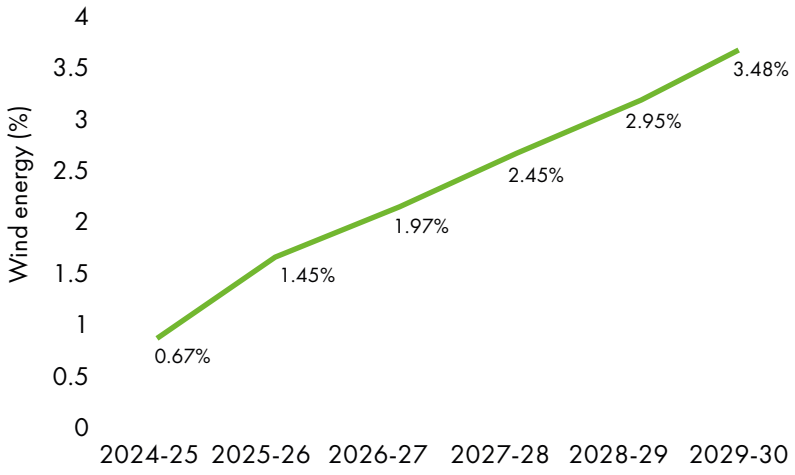
As the second-largest hub for onshore wind turbine assembly and key component production in the Asia Pacific, India is strategically placed for wind manufacturing expansion, reducing imports of large components such as castings and pultrusion carbon fibre.

The successful award of offshore wind tenders is likely to attract investments in domestic offshore wind manufacturing. The central government is exploring avenues to support local manufacturing and local content creation.

30. Times, T. E. (2025, January 9). India added 24.5 GW solar and 3.4 GW wind capacity in 2024, sets new records. Retrieved from The Economic Times: https://economictimes.indiatimes.com/industry/renewables/india-added-24-5-gw-solar-and-3-4-gw-wind-capacity-in-2024-sets-new-records/articleshow/117085849.cms?from=mdr

31. Anand, S. (2024, April 18). India's wind energy capacity to hit 122 GW by 2032 amid policy boosts. Retrieved from The Economic Times: https://energy.economictimes.indiatimes.com/news/renewable/indias-wind-energy-capacity-to-hit-122-gw-by-2032-amid-policy-boosts/109386717

Wind RPO trajectory from 2024 to 2030



Source: India's Ministry of Power

Onshore wind and repowering

Ranking fourth globally with 48.2 GW of installed onshore wind as of January 2025, India is the second-largest wind market in the Asia Pacific region after China.

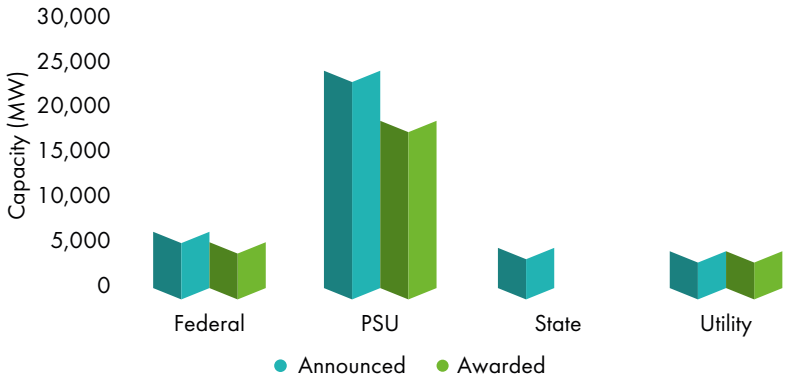
India's onshore wind sector is gaining momentum thanks to supportive policy, regulatory and infrastructure enablers. The central government is pushing to modernise transmission infrastructure through initiatives such as the Green Energy Corridor and HVDC networks.

Repowering ageing wind farms in key states such as Tamil Nadu, Maharashtra and Gujarat is likely to boost the country's generation potential.

Further enablers for accelerating onshore wind installations in this market include:

- An onshore wind auctions target of 10 GW annually over the 2023–2027 period
- Wind-specific renewable purchase obligations (RPOs) from 2023 to 2030 and high demand from the C&I segment
- Inter-State Transmission System charges waiver up to June 2025 (i.e., installation will peak in 2025)
- Plans to upgrade the transmission network to integrate 48GW onshore wind capacity by 2030
- Policy measures in support of wind power procurement

Wind Enrgy Auctions in India (2024)



Source - GWEC Market Intelligence.

- An established local onshore wind energy supply chain.

Auctions awarded and announced in 2024

Following the government's announcement that it was targeting 50 GW of renewable energy and 10 GW of onshore wind bids per year between 2023 and 2027 through single-stage/e-reverse auction bidding, last year saw a surge in activity. By the end of December 2024, nearly 27.3 GW of projects had been awarded, either as standalone wind or as wind components of hybrid projects. Gujarat, Tamil Nadu, Maharashtra, Rajasthan and Karnataka led the way for India's 2024 wind energy auctions.

Strategic push for offshore wind

India's offshore wind sector gained some momentum in 2024 with the announcement of a 4 GW tender in Tamil Nadu and a 500 MW project off Gujarat's coast[32]. To ensure financial viability and attract private investment, the government approved a INR 7,453 crore ($893 million) Viability Gap Funding (VGF) scheme in support of 1 GW of offshore projects and port upgrades[33].

32. Koundal, A. (2024, September 16). SECI invites proposals for 500-MW offshore wind energy project in Gujarat. Retrieved from Economic Times: https://energy.economictimes.indiatimes.com/news/renewable/seci-invites-proposals-for-500-mw-offshore-wind-energy-project-in-gujarat/113399102

33. Das, B. (2024, July 3). Is viability gap funding enough to power India's offshore wind dreams? Retrieved from Down To Earth: https://www.downtoearth.org.in/renewable-energy/is-viability-gap-funding-enough-to-power-indias-offshore-wind-dreams

These initiatives aim to leverage India's vast coastline and wind potential while reducing reliance on conventional power. However, sustained policy support, infrastructure expansion and technological innovation are all needed to scale offshore wind energy and achieve long-term renewable energy goals.

India must invest in grids, ports infrastructure, vessel availability, supply chain, secure blended and concessional finance, and leverage technological innovations for the seamless integration of offshore wind into the national energy mix.[34]

The wind industry in India is gaining momentum, with new opportunities emerging in areas such as supply chains, offshore wind and innovative tenders to harness wind energy. Progress in 2024 has raised ambitions, making it important to build resilience and introduce robust risk mitigation and support measures.

Onshore wind remains a key focus, with repowering initiatives in Tamil Nadu, Maharashtra and Gujarat enhancing efficiency. The C&I segment is booming with rising demand, and this is also evident from auctions that favour wind capacity additions. But challenges persist, including land acquisition disputes, transmission infrastructure limitations, and auction delays affecting Power Purchase Agreements (PPAs). Addressing these barriers through policy reforms, grid modernisation and investment incentives is critical for sustained growth. Strengthening regulatory frameworks, integrating advanced technologies and fostering private sector participation will be instrumental to cementing wind power's role as a cornerstone in the country's energy transition and India achieving its ambitious renewable energy goals.

34. https://www.connaissancedesenergies.org/sites/connaissancedesenergies.org/files/pdf-actualites/GOWR-2024_digital_final_2.pdf.

Singapore

Singapore is setting an example of regional collaboration within the APAC region, supporting the energy transition and contributing to the global net zero target. Despite having no domestic wind market, Singapore actively supports the buildout of global offshore wind capacity through providing critical products and services across the value chain, acting as a hub for project development and financing, and driving innovation and standards development.

In October 2024, Singapore announced plans to raise its low-carbon electricity imports from 4 GW to 6 GW by 2035, which will meet one-third of its energy needs. To date, the country has issued Conditional Licenses or Approvals for 10 projects, including a 1.2 GW offshore wind project in Vietnam jointly developed by Singapore's Sembcorp and Vietnam's PTSC.

A global financial centre for wind

Enterprise Singapore, the government agency supporting the growth of the offshore wind cluster in Singapore, estimates that over 40 Singaporean companies are involved in the supply chain of offshore wind projects in the US, UK, EU, Taiwan (China), Korea and Japan. These companies operate primarily in the fabrication of vessels, offshore structures including offshore substations, wind turbine installation vessels (WTIVs), construction support vessels, and service vessels. Singaporean companies have also invested in both onshore and offshore wind farms in overseas markets, further consolidating their role in the global offshore wind industry.

As a champion for sustainable development and ranked among the top three global financial centres, Singapore is leading the way in developing innovative financing tools and capabilities to serve as a catalyst for renewable energy financing. In 2024, the Singapore government announced a commitment of $500 million USD in concessional funding for the Financing Asia's Transition Partnership (FAST-P), launched by the Monetary Authority of Singapore (MAS) at COP28. This blended finance initiative, pooling public and private capital, aims to attract commercial capital and other sources of financing to support Asia's green transition, with a goal of raising up to $5 billion USD for the region's green and transition financing needs.[35]

Floating offshore wind and beyond

Innovation is crucial as the industry advances to floating offshore wind projects by 2030. The Technology Centre for Offshore and Marine, Singapore (TCOMS), a national R&D hub, is working with industry collaborators to test and validate concept designs for floating foundations, floating offshore substations and mooring solutions. In parallel, Singapore is also participating in international standards bodies to help shape design requirements for offshore wind turbines and electrical components.

This comprehensive approach – building a vibrant domestic and regional supply chain ecosystem, financial leadership, innovation in offshore wind technology, and standards development – positions Singapore as a key driver of APAC's energy transition journey through collaboration.

Philippines

The Philippines has rapidly emerged as a prime destination for renewable energy investments, ranking second among emerging markets in the Asia Pacific region, according to BloombergNEF's 2024 Climatescope report[36]. This rise from 30th place in 2021 underscores the nation's commitment to fostering a favorable environment for renewable energy development through robust policy frameworks and strategic initiatives.

The government has implemented key policies to accelerate wind energy deployment. The Department of Energy (DOE) revised its Renewable Energy Act to allow 100% foreign

35. https://www.mas.gov.sg/news/media-releases/2024/singapore-commits-us$500-million-in-matching-concessional-funding-to-support-decarbonisation-in-asia
36. https://www.global-climatescope.org/markets/philippines

ownership in wind energy projects. It has also facilitated Energy Virtual One-Stop Shop (EVOSS) improvements to expedite regulatory approvals and minimise bureaucratic delays for wind developers.

The Philippines Energy Plan (PEP) 2024–2050 sets out a roadmap for increasing renewable energy capacity, reinforcing wind power including offshore wind as key pillars of the country's future energy mix. For offshore wind projects, the signing of a Memorandum of Agreement (MoA) between the Department of Environment and Natural Resources (DENR) and the DOE aims to streamline offshore wind permitting processes – particularly seabed and foreshore leases – ensuring faster project approvals.[37]

The Power Development Plan (PDP) 2023–2050 outlines the vision of aligning transmission projects with future offshore wind capacity. The PDP underscores the critical need for timely grid planning and execution to support the country's ambitious renewable energy targets of a 35% share by 2030 and 50% by 2040. Achieving these goals requires a comprehensive approach to upgrading and expanding the country's transmission infrastructure.

Turning wind service contracts into operational projects

While collectively these policy advancements strengthen the Philippines' position as an attractive investment hub for wind energy, the transition from planning to execution is still challenging. Developers often encounter hurdles in both the pre-development and construction phases.

In the pre-development stage, securing permits remains a major roadblock. Developers must navigate multiple layers of approvals from both national and local agencies, leading to extended processing times. Grid connection approvals still take a long time to process, creating bottlenecks in project timelines. Additionally, while assessments have been conducted, granular data and clearer zoning guidelines are necessary to facilitate efficient site selection and planning.

During the construction phase, supply chain constraints pose a significant risk. The local manufacturing base for wind turbine components, installation vessels and port facilities remains underdeveloped, increasing reliance on imports. This dependence may lead to potential delays due to global supply chain disruptions. Furthermore, the lack of wind-ready ports and transmission infrastructure creates logistical bottlenecks, impacting project execution timelines.

The availability of skilled labour is another concern, as the offshore wind sector requires specialised technical expertise, which is in short supply in the local workforce. Additionally, contractual issues, particularly concerning liability and risk allocation, complicate negotiations between developers, contractors and financiers.

Financing remains another crucial barrier. Offshore wind projects demand high upfront capital, typically ranging from $3–4 million USD per MW[38], necessitating access to blended finance mechanisms such as concessional loans, green bonds and

37. https://doe.gov.ph/press-releases/doe-and-denr-sign-agreement-accelerate-offshore-wind-energy-development
38. World Bank Group

risk-mitigation instruments. Issues on the Renewable Energy Payment Agreement (REPA) bankability and an evolving regulatory environment may deter financial institutions, which seek predictable revenue streams and risk-sharing mechanisms such as tariff indexation and sovereign guarantees.

Recognising these challenges, the government has been taking steps towards a more holistic approach to accelerating offshore wind development. Efforts to streamline the permitting process are under way, with greater integration of relevant agencies into EVOSS and the establishment of a single-window clearance system aimed at reducing delays.

Public-private partnerships are increasingly being explored to enhance infrastructure readiness, particularly in port and transmission development to resolve logistical bottlenecks. Additionally, there is an increasing focus on strengthening local supply chains through targeted incentives, fostering local employment opportunities while reducing dependency on imports.

On the financing front, measures such as tariff indexation, hedging solutions and credit enhancement mechanisms are being considered to de-risk investments and bolster investor confidence. These coordinated efforts reflect a strong commitment to unlocking the full potential of offshore wind in the Philippines.

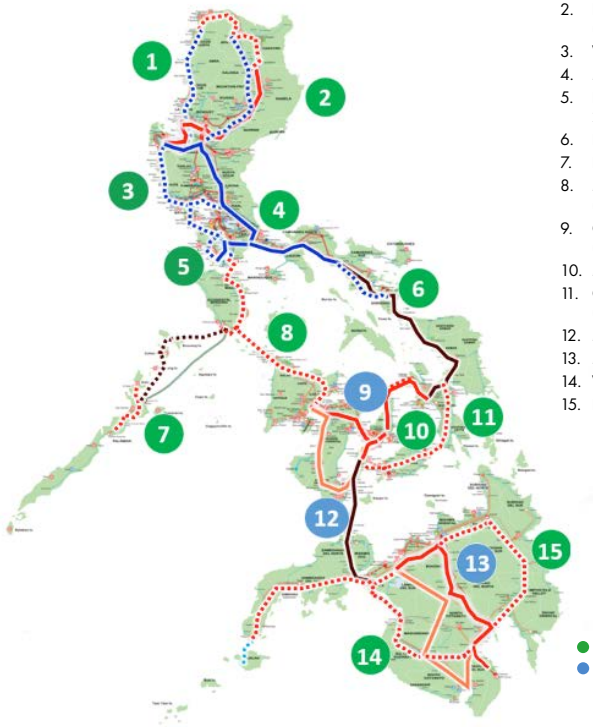
Infrastructure: Supply chain, grid, and port readiness

The successful integration of large-scale wind energy, particularly offshore projects, is heavily dependent on the readiness of grid and port infrastructures. Stakeholders have identified grid congestion and insufficient transmission planning as major barriers to accommodating additional renewable energy capacities. To address this, accelerated grid expansion plans, proactive investments in offshore transmission networks and clear policies granting grid access to renewable energy developers are essential.

Port infrastructure also requires substantial upgrades to support wind energy logistics. The Philippine Ports Authority (PPA) has committed to investing in key ports, including Subic, Batangas and Iloilo, to facilitate offshore wind development. These enhancements are crucial for handling the specialised equipment and vessels associated with wind installations. Encouraging private sector participation through PPPs can expedite infrastructure development and ensure projects align with the ambitious timelines of offshore wind initiatives. Additionally, the government is exploring co-financing port development with international investors, particularly through blended finance mechanisms that combine concessional funding with private sector capital.

Another key element is the development of localising the wind energy supply chain. The Philippines has the potential to build a robust manufacturing base for wind components, particularly in sectors like shipbuilding, steel and cement, essential for offshore wind construction. Government-backed

Transmission Development Plan 2024 – 2050, NGCP



1. **Bolo** - Lacag 500 kV Backbone (Mar 2028)
2. Nagsaag to Kabugao 500 kV Backbone (2041-2050)
3. Wester Luzon 500 kV Backbone (Stage 2: Dec 2025)
4. Metro Manila 500 kV Backbone Loop (2031-2040)
5. Batangas - Mindoro Interconnection (Stage 1: Sep 2027, Stage 2: Dec 2030)
6. Luzon - Visayas HVDC Bipolar Operation (Dec 2032)
7. Palawan - Mindoro Interconnection (Feb 2033)
8. Mindoro - Panay 230 kV Interconnection Project (2041-2050)
9. Cebu - Negros - Panay 230 KV Backbone (Completed)
10. Metro Cebu 230 kV Backbone Loop (2024-2050)
11. Cebu - Bohol - Leyte 230 KV Backbone (2024-2050)
12. Mindanao-Visayas Interconnection (Completed)
13. Mindanao 230 KV Backbone (Completed)
14. Western Mindanao 230 kV Backbone (2031-2040)
15. Eastern Mindanao 230 KV Backbone (2032)

incentives, in collaboration with private sector investments, can catalyse the establishment of local production facilities, reducing reliance on imports and fostering economic growth.

Beyond auctions: Creating a sustainable market design

The upcoming Green Energy Auction Program 5 (GEAP 5), to be released by the third quarter of 2025, will mark a significant milestone with the inclusion of offshore wind for the first time, reflecting the Philippine government's proactive approach to expanding renewable energy.[39]

DOE: DOE and PPA strengthen partnership for OSW development with port infrastructure upgrades | Department of Energy Philippines

The DOE and Energy Regulatory Committee (ERC) have demonstrated a strong commitment to collaboration by engaging with industry stakeholders via an established Offshore Wind Technical Working Group to refine the current framework, ensuring it aligns with market conditions. This openness to industry input sets the Philippines apart within the Asia Pacific region, positioning it as a model for public-private cooperation in offshore wind development – potentially serving as a case study in the coming years.

While the GEAP has played a significant role in securing commitments for wind energy, a diversified market approach is required to ensure long-term growth. The DOE's policy shift allowing 100% foreign ownership in renewable energy projects has significantly bolstered investor confidence, leading to substantial commitments in the sector.

To enhance market dynamics, the government should promote additional offtake mechanisms beyond traditional PPAs. Corporate PPAs allow private entities to directly procure renewable energy, diversifying revenue streams for developers. Furthermore, expanding carbon markets and renewable energy certificate (REC) trading can support wind project bankability.

A well-structured carbon pricing mechanism can provide a secondary revenue stream by monetising the

39. https://doe.gov.ph/press-releases/fifth-round-green-energy-auction-offshore-wind-projects-set-launch-3q-2025

avoided emissions from wind power generation. An expanded renewable energy market supporting both voluntary and compliance-based REC trading will help corporate buyers fulfil sustainability commitments while ensuring steady demand for wind power.

The road ahead for the evolution of renewable energy

The Philippines Energy Plan (PEP) and PDP reaffirm the country's commitment to wind energy through investments in infrastructure and market stability. A holistic approach—combining policy execution, infrastructure readiness, and industrial development—will accelerate wind energy deployment, enhance energy security, and create economic opportunities for decades to come.

South Korea

South Korea has demonstrated a strong commitment to renewable energy, as demonstrated by its COP28 pledge to triple renewable energy capacity by 2030 and its updated Nationally Determined Contributions (NDC) in 2021, which set a target to reduce domestic emissions by 40% below 2018 levels by 2030. While the NDC targets could be more ambitious, the 2021 update prompted the development of sectoral roadmaps outlining potential policy measures to achieve carbon neutrality.

In February 2025, the Ministry of Trade, Industry and Energy (MOTIE) finalised the 11th Basic Plan for Supply and Demand of Power. The draft outlines a plan to significantly expand solar and wind power facilities, increasing capacity from 23 GW in 2022 to 72 GW by 2030 and 115.5 GW by 2038. However, the target for renewable energy's share in the total energy mix by 2030 remains unchanged at 21.6%, consistent with the previous 10th Basic Plan[40].

South Korea has significant wind energy potential, both onshore and offshore, with a target of achieving a total cumulative installed capacity of 18.3 GW, as highlighted in its Offshore Wind Competitive Bidding Roadmap announced in August 2024. This includes 4 GW from onshore projects and 14.3 GW from offshore wind.

The Renewable Portfolio Standard (RPS) for Renewable Energy Certificates (RECs), which mandates large power generators to produce 14% of their power from renewable sources in 2025, is expected to be gradually phased out by 2026. This change is prompted by recent significant increases in REC prices as well as limited options for corporates to procure renewable energy through direct power purchase agreements (PPAs). Currently, the Korea Energy Agency will match power generators to award wind projects that have secured a 20-year fixed-price contract through a PPA. Nevertheless, it remains unclear what kind of remuneration system will replace the RPS system.

Due to the limited availability of suitable land for onshore development, the country remains focused on harnessing its 624 GW of technical potential for fixed-bottom and floating offshore wind. Between 2024 and 2026, South Korea intends to conduct competitive bidding tenders for offshore wind projects, targeting a capacity of 7–8 GW. Expanding offshore wind supports its goals for anchoring carbon-free energy for economic growth and energy security, given the country was importing 84.6% of its energy as of 2023[41].

While progress is being made through legislative reforms and greater collaboration between public and private stakeholders on challenges such as permitting, grid connectivity, and costs, there remains a pressing need to accelerate efforts to maximise impact.

The future of offshore wind permitting

On 27 February 2025, the National Assembly passed the Offshore Wind Power Promotion Act, commonly referred to as the 'OSS Bill', a significant milestone after years of extensive debate, stakeholder consultations, and multiple iterations of the proposed legislation.

40. Shin & Kim, Assessed: 17 Feb 2025 https://www.shinkim.com/eng/media/newsletter/2480
41. IEA, Korea Energy Mix, Assessed: 25 Feb 2025 https://www.iea.org/countries/korea/energy-mix

This landmark bill was part of a broader legislative package that included the National Backbone Power Grid Expansion Act, the Semiconductor Special Act and the High-Level Radioactive Waste Management Act. The simultaneous passage of these bills underscores the strong agreement and coordinated effort required between the political parties.

The OSS Bill is designed to address longstanding challenges in the offshore wind sector by streamlining the often lengthy and complex permitting processes. It introduces a centralised approach whereby the government designates offshore wind development sites and grants site exclusivity to selected developers. This aims to reduce delays and create a more predictable policy framework for project development. However, implementation of the OSS Bill will require careful planning to navigate the transition from the current system to the new centralised model.

A key aspect of this transition is the 'two-track process' accommodating both new projects under the centralised framework and existing projects that have already obtained Electricity Business Licenses (EBLs) and/or Offshore Public Water Permits (OPPWs). The latter will continue progressing under the developer-led approach.

The process for project developers who have previously obtained EBLs wanting to have their project location as a designated offshore wind zone will need to be considered. The dual-track system must acknowledge the realities of an implementation period that will take around one year. The priority is to ensure that the offshore wind sector can continue to grow in the meantime without disruption.

A potential supply chain leader for the region

Positioned as the next major supply chain hub after China and India, South Korea's wind supply chain is robust and well-positioned for growth opportunities, potentially even as an export market. The country has extensive expertise in shipbuilding, foundation manufacturing, submarine cables, offshore wind turbine production, the automotive industry, and electrical and electronic components. These capabilities provide a solid foundation for expanding into both the onshore and offshore wind sectors.

According to a study by GWEC Market Intelligence, South Korea's domestic supply chain can meet a significant portion of onshore wind demand through 2030.[42] However, further interventions are required for offshore wind. While domestic OEMs have already established a presence in the onshore wind market, greater collaboration with international players is needed to scale up local capabilities, particularly in manufacturing blades, power converters and castings. For offshore wind, South Korean OEMs are currently testing a 10 MW turbine, signifying an important step in strengthening their offshore wind supply chain capabilities.

To fully capitalise on South Korea's supply chain potential and position the country as an export hub, policy interventions are essential. The recent passing of the OSS Bill is a commendable first step, as it streamlines permitting issues – one of the key barriers to installation and investment in global markets.

Additionally, South Korea should seize the opportunity to attract international OEMs looking to establish manufacturing facilities, further solidifying its role as an offshore wind turbine supply chain hutb for the APAC region. The country can also leverage its shipbuilding expertise to address vessel shortages and enable the serial production of floating substructures to meet offshore wind demand domestically, across Asia Pacific and globally.

42. GWEC, 2024, Mission Critical: Building the Asia Pacific Wind Energy Supply Chain for a 1.5°C World

Central Asia: Uzbekistan, Kazakhstan, Azerbaijan

Uzbekistan

Uzbekistan's wind energy sector is growing rapidly, driven by government targets and favourable policies. Nearly 13 GW of wind projects have been announced, with a goal of reaching 20 GW of combined wind and solar capacity by 2030.

The Bukhara wind project, developed by ACWA Power, is now fully connected to the grid. It comprises of the Bash 500 MW and Dzhankeldy 500 MW wind farms. Chinese firm CEEC served as the EPC contractor, while Envision supplied 158 turbines. ACWA has also signed a $4.85 billion PPA with the government for the 5 GW Aral wind project, which is set to become Central Asia's largest wind farm.

Masdar's 500 MW Zarafshan wind project is under construction and due for completion this year. Sany has plans for a 1 GW project, and Sino-wind will build a blade factory to support the supply chain.

Most projects are being developed through PPP models, supported by investment-friendly government policies. These include competitive PPAs offering favorable terms to investors. Foreign also investors benefit from attractive financing options and tax incentives.

The country's ageing and overloaded grid infrastructure presents significant challenges, with frequent power outages hindering the integration of projects into the grid. In areas with strong wind resources, substations capable of absorbing and distributing the generated power are often located hundreds of kilometres away, particularly in remote regions.

Uzbekistan will continue to rely on the PPP model to drive the implementation of most projects while placing greater emphasis on the construction and upgrading of grid infrastructure.

Since August 2024, under a new "Law on Electric Power Industry", the JSC National Electric Grid of Uzbekistan has acquired full operational responsibility, which should help ensure reliable operation and balancing.

Kazakhstan

Kazakhstan has strong wind energy potential, especially in the central, northern and northwestern regions. Supported by competitive auctions and bilateral agreements that have attracted significant foreign investment, the country's installed wind capacity is approaching 2 GW.

ACWA Power and Masdar have each signed agreements for 1 GW, while TotalEnergies secured a PPA for Kazakhstan's 1 GW Mirny onshore wind project in the Zhambyl region.

Following Sany's investment plan last July for a nacelle assembly plant, Envision has partnered with Samruk Energy to develop a turbine nacelle and

energy storage facility. Construction work has begun, and production is expected to begin later this year for Sany and in Q3 2026 for Envision.

In November 2024, China and Kazakhstan signed a renewable energy cooperation agreement covering 1.8 GW of projects, including wind and solar. A 1.8 GW auction is planned for 2025, with 66% allocated to wind.

The Ministry of Energy aims for renewables to account for 15%of total electricity production by 2030. KEGOC, the state-owned grid operator, prioritises power suppliers with PPAs. To support investment, the government offers tax incentives and guarantees the purchase of all electricity generated, ensuring a stable investment climate for renewable projects.

Grid instability is a major issue, as the northern region generates excess electricity while the western and southern regions face shortages. This imbalance, coupled with a weak transmission network, hampers efficient power distribution.

Wind energy capacity will continue to grow, though grid limitations may slow progress. The government is promoting energy storage and plans to connect regional grids through a 500 kV transmission line, expected to be completed by 2028.

Azerbaijan

The economy of Azerbaijan, the host of the COP29 climate summit last year, has relied heavily on revenue from oil and gas exports for several decades, with Caspian Sea exploration a key activity since the 1990s. Fossil fuels generate nearly half of the country's GDP and over90% of reported export earnings.

Nevertheless, Azerbaijan has set a target of 6 GW of combined installed capacity for solar, wind and hydropower by 2030. This will boost the share of renewable energy in the country's power generation mix up to 30%.

ACWA Power is developing a 240 MW wind project under the Build Own Operate (BOO) model, while Masdar is working on a 1 GW portfolio, including one onshore wind and two solar projects. In November 2024, at COP29, Masdar, SOCAR and ACWA Power signed an agreement to jointly develop Azerbaijan's first offshore wind project, with a total capacity of 3.5 GW.

According to estimates by the Azerbaijan Renewable Energy Agency (AREA), the country's onshore wind energy potential is approximately 3 GW. While its technical offshore wind resources total around 157 GW – 35 GW fixed-bottom and 122 GW floating.

Along with harnessing the potential of offshore wind, the country needs the country needs significant policy reforms, infrastructure development, and investment frameworks. Azerbaijan must also address problems with its grid if wind projects are to be successfully integrated. Azerbaijan, Kazakhstan and Uzbekistan have signed multiple strategic agreements on green energy and are collaborating with international financial institutions to provide funding support. These agreements include the development of infrastructure, including grid systems, and the construction of international power transmission corridors to deliver surplus renewable energy to Europe.

Europe: Germany, UK

Germany

Authored by Bundesverband WindEnergie

Germany's wind energy market is experiencing an unprecedented boom, reinforcing the country's role as a European wind energy leader. This surge is underpinned by the former government's commitment to the energy transition, supported by broad societal consensus and a legal framework that has prioritised renewable energy expansion. Record-breaking figures in permitting and auction results in 2024 demonstrate the effectiveness of these efforts.

In 2024, nearly 11 GW of new onshore wind capacity was awarded in tenders – an all-time high. This represents a remarkable 70% increase year-on-year. North Rhine-Westphalia accounted for 28% of this capacity, followed by Lower Saxony with 14% and Brandenburg with 10%. Together, these three states were awarded 5,849 MW, exceeding the combined total of all other federal states (5,147 MW).

The rapid acceleration of wind energy expansion reflects deliberate action to remove barriers to development and prioritise renewables. **A key factor in this progress is the legal recognition of wind energy as being of "overriding public interest" under Section 2 of the Renewable Energy Sources Act (EEG).** This designation has streamlined permitting processes and reduced legal and administrative hurdles, enabling projects to advance more quickly.

Currently, the average project realisation period – the time from tender award to grid connection – is approximately 26 months. This means that the capacity awarded in 2024 will translate into new installations around 2026, **aligning with the targets outlined in the EEG. One of the most encouraging developments has been the surge in new permits.** In 2024, authorities approved approximately 2,400 wind turbines with a combined capacity of 14,000 MW – an unprecedented milestone. North Rhine-Westphalia led with 4,044 MW of newly permitted capacity, nearly 30% of the national total.

Germany's energy transition reflects a broad societal commitment to addressing climate change, strengthening energy security, and ensuring economic resilience. **This boom in wind energy development is also closely tied to the energy needs of Germany's industrial base.** Energy-intensive sectors such as steel and chemicals rely on affordable, renewable electricity to modernise production processes and remain competitive in a decarbonising global economy. Wind energy also underpins the production of green hydrogen, which is critical for enabling sector coupling and achieving deep emission reductions across industries.

Conferring upon wind energy the status of "overriding public interest" is of crucial importance to the achievement of the country's climate, security and economic resiliency objectives. Communities are increasingly benefiting from wind energy projects through financial participation and local economic development. The former government, elected with a mandate to advance the energy transition, delivered by implementing policies that aligned the interests of industry, communities and policymakers.

To reflect on these developments, at the beginning of 2025, VDMA and BWE presented data on Germany's onshore wind expansion in 2024. Nationwide, 635 turbines with a combined capacity of 3,251 MW were commissioned. Once again, North Rhine-Westphalia led the way with 748 MW of gross additions. For 2025, gross capacity additions are projected to range between 4.8 and 5.3 GW, with repowering projects playing a crucial role – a trend worth paying attention to. In 2024, 37% of capacity additions came from repowering, demonstrating

the potential to significantly increase efficiency and output by replacing older turbines with modern, high-capacity models.

Looking ahead, it is crucial that the next federal government maintains stable regulatory frameworks and prioritises investment certainty. Implementing the EU Renewable Energy Directive (RED III) into national law, further accelerating permitting processes, and modernising energy infrastructure will be essential to sustaining the momentum for wind energy expansion.

United Kingdom (UK)

Authored by RenewableUK

Following the election of a new government in July 2024, the UK has seen a series of reforms aimed at delivering its ambitions for up to 50 GW of offshore wind and around 30 GW of onshore wind by 2030. These targets are part of the Prime Minister's wider 'Clean Energy Mission' to achieve at least 95% low-carbon energy generation and build on the UK's successful foundations in electricity decarbonisation to date.[43]

Statistics published in January 2025 by the UK's National Energy System Operator (NESO) show that wind outperformed gas for the first year ever in 2024, providing a record 30% of Britain's electricity, up from 28% in 2023, while gas produced just 26.3%.[44] Clean power sources in total provided 58% of the country's electricity, with coal producing only 0.6%, as Britain's last coal-fired power station was decommissioned last September.

In just over 20 years, the UK has built a total of 43 offshore wind farms while, since 2016, the industry has invested over £50 billion ($64.6 billion) in new offshore wind farms. The country intends to show global leadership, particularly in offshore wind, by establishing a new Global Clean Power Alliance[45] and collaborating bilaterally with India, Brazil and others.[46, 47]

In January 2025, the government made its submission to the United Nations Framework Convention on Climate Change (UNFCCC), setting out a detailed list of policies and measures in the UK's Nationally Determined Contribution (NDC) to reduce greenhouse gas emissions by at least 81% by 2035 compared to 1990 levels, in the hope of spurring global ambitions.[48]

Onshore and offshore wind

The new government made its intentions clear early on by lifting England's de facto ban on onshore wind in July 2024, which had been in place for the previous nine years.[49] It later confirmed that onshore wind projects over 100 MW would be reintroduced into the Nationally Significant Infrastructure Projects (NSIP) regime this year, a decade after they were removed.

The budget for the country's most recent clean energy auction (Allocation Round 6) was increased to a record £1.55 billion, ensuring the UK's flagship Contracts for Difference (CfD) scheme was able to secure 9.6 GW of new renewable energy capacity for the country in 2024.[50] In total, 131 renewable energy projects won contracts, including Green Volt, the world's largest commercial floating offshore wind project.[51]

The recently launched Clean Industry Bonus allows offshore wind projects to access an additional £27 million per GW of capacity in revenue support to bolster industrial investment and low-carbon supply chains.[52] Looking ahead to the 2025 auction (Allocation Round 7), the data shows that at least 13 UK offshore wind projects are currently eligible to bid with a total capacity of 7.3 GW, though several more could become eligible if additional reforms are introduced.

Last year, the UK reached the historic milestone of 30 GW of wind generation capacity,[53] sufficient to meet the annual power needs of more than 26 million homes and reduce annual carbon emissions by more than 35 million tonnes.

Wind aspirations and policy reforms

In December 2024, the Clean Power 2030 Action Plan set out measures to expedite grid development and streamline planning decisions for renewable energy generation.[54] It includes targets across key technologies such as offshore wind, onshore wind and long duration energy storage (LDES), as well as a commitment to introduce measures to develop domestic supply chains in the government's upcoming Industrial Strategy, due for publication in summer 2025. New measures to support port infrastructure developments are expected to be brought forward by the National Wealth Fund.

43. https://assets.publishing.service.gov.uk/media/677bc80399c93b7286a396d6/clean-power-2030-action-plan-main-report.pdf
44. https://www.neso.energy/news/britains-electricity-explained-2024-review
45. https://x.com/10DowningStreet/status/1858982461364961443?t=jAjKGBFkwvx6jRCmmpcZdA&s=19
46. https://www.newkerala.com/news/o/uk-india-convene-4th-energy-dialogue-806
47. https://www.gov.uk/government/publications/international-climate-cooperation-joint-brazil-uk-statement/joint-brazil-uk-statement-on-international-climate-cooperation
48. https://unfccc.int/sites/default/files/2025-01/UK%27s%202035%20NDC%20ICTU.pdf
49. https://www.gov.uk/government/publications/policy-statement-on-onshore-wind/policy-statement-on-onshore-wind
50. https://www.renewableuk.com/news-and-resources/press-releases/wide-range-of-projects-win-contracts-to-generate-clean-power-in-latest-clean-energy-auction/
51. https://greenvoltoffshorewind.com/

In April 2024, RenewableUK, the Offshore Wind Industry Council (OWIC), The Crown Estate and Crown Estate Scotland launched the UK's Offshore Wind Industrial Growth Plan framework[55]. The framework aims to create jobs, triple supply chain manufacturing by focusing on nine regional areas and ultimately boost the economy by £25 billion gross value added (GVA).

The UK has established several new institutional structures to support the development of the sector. These include Great British Energy[56] as a state-backed investor in new renewable energy projects, Mission Control[57] within the Department for Energy Security and Net Zero to coordinate reforms across government, and an 'onshore wind taskforce'[58]. Additionally, NESO has been set up to advise on pathways to clean power by 2030 and produce the first iteration of a strategic spatial plan for energy in 2026. In recognition of the increasing skills requirements of the energy sector, the government has developed an Energy Skills Passport tool to help workers transfer from other energy industries.[59]

Addressing barriers to acceleration

Addressing consenting and grid barriers to enable the deployment and construction of onshore and offshore windfarms remains critical for the UK, where an antiquated first-come, first-served approach to grid connection applications has created a 700 GW backlog and left some projects facing decade-long delays to connect.

In February 2025, Ofgem, the UK's Office of Gas and Electricity Markets, set out its intention to approve NESO's proposed changes to the grid connections regime.[60] This should provide greater clarity for developers on faster timescales for connection and, if fully realised, could unlock up to £15 billion investment in offshore wind alone.

Last year also saw a transmission licence exemption granted to allow higher voltage array cables for offshore wind farms, laying the groundwork for updated offshore transmission policies to support the country's increased offshore wind ambitions.

In January 2025, the UK Government announced guidance for a Marine Recovery Fund to enable the introduction of measures to better protect biodiversity in UK waters.[61] This is part of a broader set of several strategic compensation packages to address the likely environmental impacts resulting from offshore wind developments.

As discussions intensify around the UK's future relationship with the EU, decisions will be forthcoming on the EU-UK Trade and Cooperation Agreement (TCA) and its provisions for energy exchange, the final shape of the EU Carbon Border Adjustment Mechanism (CBAM) and the importance of excluding electricity exports from it, and the work of the North Seas Energy Cooperation (NSEC) programme to advance development of offshore renewable energy. Across all these areas, the UK government is publicly committed to working towards closer collaboration with European countries to boost supply chain growth and resilience, support a robust electricity market, and lower barriers to electricity trading.

Progress in green hydrogen and LDES

The UK continues to diversify its renewable energy ecosystem, with the first wave of 11 green hydrogen projects progressing through the Chancellor's Autumn Statement and Hydrogen Allocation Round 1 last year, alongside confirmation of the introduction of a long-duration electricity storage cap and floor mechanism later in 2025.

52. https://www.gov.uk/government/news/new-industry-bonus-opens-to-support-good-jobs-and-low-carbon-manufacturing-factories
53. https://www.renewableuk.com/news-and-resources/press-releases/uk-wind-power-reaches-historic-30gw-milestone/
54. https://www.gov.uk/government/publications/clean-power-2030-action-plan
55. https://www.renewableuk.com/media/rqvlqzu0/offshore-wind-industrial-growth-plan.pdf
56. https://www.gov.uk/government/publications/great-british-energy-bill-factsheets
57. https://www.gov.uk/government/news/chris-stark-to-lead-mission-control-to-deliver-clean-power-by-2030
58. https://www.gov.uk/government/groups/onshore-wind-industry-taskforce
59. https://www.renewableuk.com/news-and-resources/press-releases/energy-skills-passport-goes-live-enabling-workers-to-build-new-careers-across-the-energy-mix/
60. https://www.ofgem.gov.uk/press-release/clean-power-2030-one-step-closer-proposed-new-fast-track-grid-connections-system-unveiled
61. https://www.gov.uk/government/publications/strategic-compensation-measures-for-offshore-wind-activities-marine-recovery-fund-interim-guidance/strategic-compensation-measures-for-offshore-wind-activities-marine-recovery-fund-interim-guidance

MENA: KSA

The development of the wind energy industry in Saudi Arabia is a central component of the Kingdom's strategy to diversify its energy sources and reduce its reliance on fossil fuels. This aligns with the broader objectives of Saudi Vision 2030 and King Salman's Renewable Energy Initiative, which aims to create a sustainable energy future while fostering economic diversification and green innovation. By 2030, Saudi Arabia plans to install 130 GW of renewable energy, with 50 GW generated by energy projects. The government has announced that it will be tendering 20 GW of renewable energy per year to reach the target set for 2030[62].

Operating and planned wind energy projects

Saudi's flagship wind farm is the 400 MW Dumat al Jandal project, developed and operated by EDF and Masdar in the northwestern region of Jazan.

In line with the Saudi Vision 2030 of reaching a 50% share of the energy mix for renewables by 2030, the National Renewable Energy Program (NREP) and the Saudi Project Procurement Company (SPPC) are managing the development of an additional 8.9 GW of wind across different regions in KSA[63].

Below is a list of operational and planned wind energy projects in Saudi Arabia:

Fast-tracking wind development

To fast-track the development of renewable energy projects, the kingdom launched a country-wide project to carry out geographical surveys for renewable energy sites – the first of its kind – under the umbrella of the National Renewable Energy Project (NREP). Saudi companies were awarded contracts to install 1,200 measuring stations across an area measuring 850,000 square kilometres. This initiative will allow investors in both wind and solar energy to reduce development times by 18–24 months[64].

High competition for renewable energy tenders

Renewable energy tenders have attracted developers from around the globe. In the latest SPPC Round 6 tender, a shortlist of 16 qualified developers included Masdar, Sumitomo and Al-Fanar[65].

In 2024, the Saudi Power Procurement Company (SPPC) awarded the 600 MW Al Ghat Wind project to Marubeni with a wind energy tariff of 1.56cents/ KWh, which is considered to be the world's lowest LCOE for wind energy projects[66].

62. https://www.zawya.com/en/business/energy/saudi-arabia-targets-130-gigawatts-of-renewable-energy-by-2030-minister-jkr4mbu0
63. https://renewable.vision/saudi-arabia-re/
64. https://www.moenergy.gov.sa/en/MediaCenter/News/Pages/Ministry-launches-groundbreaking-survey-for-renewable-energy-sites-in-Saudi-Arabia.aspx
65. https://www.saudigulfprojects.com/2024/09/saudi-arabia-issues-rfq-for-round-6-renewable-energy-projects-with-total-capacity-4500-mw/
66. https://www.zawya.com/en/projects/utilities/saudi-arabia-sets-world-record-for-lowest-cost-of-electricity-from-wind-power-xxry6126

Project Name	Capacity (MW)	Round	LCOE (cents/ KWh)	Phase	Developer(s)
Waad Al Shamal	500	SPPC Round 4	1.7	awarded	Marubeni, Ajlan
Gayal Wind	1200	ENOWA	N/A	tendered	NEOM
Dumat Al Jandal	400	SPPC Round 1	1.99	operational	EDF, Masdar
Al Ghat Wind	600	SPPC Round 4	1.56	awarded	Marubeni, Ajlan
Yanbu Wind	700	SPPC Round 4	N/A	tendered	N/A
NGHC (hybrid)	4000	Red Sea Global	N/A	N/A	ACWA power, Air Products, NEOM
Dawadmi	1500	SPPC Round 6	N/A	N/A	N/A

source: https://renewable.vision/saudi-arabia-re/#

Energy industry localisation

The Saudi government plans to reach 75% localisation of its energy industry by 2030. In line with this initiative, the Public Investment Fund (PIF), along with Vision Industries, has signed several strategic agreements with renewable energy suppliers, including Chinese wind turbine supplier Envision.

The agreement with Envision includes the local manufacturing and assembly of key wind equipment: blades, nacelles and hubs[67]. Saudi's long-term objective is to create a renewable energy industry hub in the kingdom, with the aim of becoming a key exporter to the rest of the Gulf Cooperation Council (GCC) and the MENA region.

Challenges: Reskilling and workforce preparedness

Saudi Arabia faces the challenge of preparing its workforce for this rapidly evolving industry. Key government stakeholders such as the King Abdullah City for Atomic and Renewable Energy (KACARE) and King Abdullah University of Science and Technology (KAUST), along with private sector players, are working to prepare local talent for renewable energy jobs through public-private partnerships (PPPs), training and research programmes and workforce localisation initiatives.

KACARE has launched a human capacity development division with the specific objective of developing workforce capabilities for the energy sector in Saudi Arabia, focusing on three areas: university students, vocational trainings and professional skills[68].

GWEC forecasts that around 2,000 technicians will be needed to support planned wind energy projects between 2025 and 2028.[69]

Looking ahead

The Kingdom of Saudi Arabia has set some of the most ambitious renewable energy targets in the MENA and GCC regions. Despite the growth required in workforce development, the country is on track to become the Middle East's leader in renewable energy and a potential hub for renewable energy manufacturing.

Saudi Arabia's growing focus on renewable energy may also inspire other oil and gas-dependent states in the GCC to follow suit and increase their own investments in clean energy, positioning the region as one of the fastest-growing renewable energy markets globally.

67. https://www.envision-group.com/news detail?id=66977acc8c6f4501ad86173f&lang=en
68. https://www.energy.gov.sa/en/Sectors/Pages/HumanCapabilityDevelopment.aspx
69. Global Wind Workforce Outlook. GWO-GWEC, 2024

Americas: Brazil

The Brazilian wind energy sector underwent a significant transformation in 2024, marked by a series of legislative advances that positioned the country as a key player in the global renewable energy landscape and finally opened up a Brazilian offshore wind market.

Installed capacity and future projections

At the close of 2024, Brazil's installed wind power capacity reached an impressive 33.7 GW, distributed across 1,103 wind farms and 11,720 wind turbines. Installed capacity increased with 3.3 GW of additions and 23.3 MW of repowering capacity. The most significant indicator of growth is the projected future capacity. By 2032, Brazil forecasts a cumulative new installed capacity of 56 GW, demonstrating its commitment to wind energy.

Supply chain developments

Despite a challenging economic environment in 2024 that saw high interest rates, a fluctuating GDP, reduced demand for new projects, an abundant energy supply and increased curtailment impacting operational projects, the wind energy supply chain witnessed notable developments.

Chinese wind turbine manufacturer Goldwind defied the prevailing trend by establishing its first factory outside of China, investing over BRL 100 million to produce models ranging from 5.3 MW to 7.5 MW. This move signals a strong vote of confidence in the Brazilian market.

Further highlighting the dynamism of the sector, Vestas, another leading turbine manufacturer, announced a BRL 130 million investment in its Ceará-based facility to produce the V163-4.5MW turbine. Vestas also formalised a Protocol of Intentions with the Government of Ceará to support new project development in the state and partnered with Banco Santander to offer more competitive financing options to its supply chain partners.

HINE do Brasil, a supplier of hydraulic systems, components and cooling systems, inaugurated a new service center in Parnamirim, Rio Grande do Norte, in May 2024. This BRL 4 million investment will support the growing demand for wind turbines and hydraulic systems in the region.

In response to the challenges faced by manufacturers and suppliers, the National Monetary Council introduced measures to improve access to financing. In December 2024, it adjusted the interest rates under the National Fund for Climate Change (FNMC) from 8.0% to 6.5% for wind energy projects, aiming to stimulate growth in this highly nationalised sector. Discussions are underway to increase the funds available for wind energy projects from BRL 500 million to BRL 1.5 billion.

The government is exploring additional incentives, including the regulation of tax benefits for green hydrogen plants and programmes to reimburse tax credits for energy transition projects.

Legislative advancements

In what was a landmark year for legislative developments impacting the wind energy sector, Brazil established a legal framework for low-carbon hydrogen in 2024, under the National Low-Carbon Hydrogen Policy and the Low-Carbon Hydrogen Development Programme. This legislation provides guidelines for the production, use and commercialisation of hydrogen from renewable sources, promoting decarbonisation and supporting Brazil's climate goals.

The Brazilian Emissions Trading System (SBCE) was also enacted, laying the foundation for a regulated carbon market in Brazil. This initiative positions the country strategically in the global transition to a low-carbon economy, offering legal certainty and stimulating innovation and competitiveness.

Complementing these efforts, the Energy Transition Acceleration Program (PATEN) was established to provide financial incentives for projects that replace fossil fuels, promote energy efficiency and drive technological innovation.

These legislative achievements collectively enhance Brazil's attractiveness as a destination for investments in the low-carbon industry.

Offshore wind energy: A new frontier

The approval and presidential sanction of Law No. 15.097/2025 on 10 January 2025 marks a watershed moment, establishing the regulatory framework for offshore wind energy projects in Brazil.

This law, originating from Bill No. 576/2021 authored by then Senator Jean-Paul Prates, governs the use of federal assets for power generation in marine environments under Union jurisdiction, encompassing the territorial sea, exclusive economic zone and continental shelf. It outlines procedures for authorisation or concession grants (depending on the process of the initiative), preceded by public calls or auctions and a technical qualification process, divided into evaluation and execution stages. Exploration is governed by usage cession contracts regulated by the federal government. This landmark legislation provides security and predictability for sector investments, crucial for Brazil's energy transition.

Brazil holds immense offshore wind potential, as highlighted in the World Bank's Offshore Wind Development Program: Scenarios for Offshore Wind Development in Brazil report. With one of the world's cleanest and most cost-competitive electricity generation matrices, the country boasts a technical generation potential of 1,200 GW, including 480 GW from fixed-foundation technology (for depths under 70 metres) and 748 GW from floating-foundation technology (for depths of 70 metres to 1,000 metres). These production sites are strategically located near energy demand centres, indicating significant long-term potential for integration into Brazil's energy mix.

The Brazilian wind energy market: A year of transformation

The Brazilian wind energy sector is poised for continued growth and expansion, driven by strong government support, strategic supply chain investments and recent legislative advances that create a favourable environment for the development of renewable energy.

There are high expectations that the first auction of areas for offshore wind will take place in 2025, before the COP30 climate talks in Belém do Pará, in the Brazilian Amazon.

The contribution of offshore wind projects to the country's energy matrix could provide impetus for the decarbonisation of Brazil's industrial and naval sectors. It could also attract new industries such as green hydrogen production, fertilisers and data centres, among others.

In addition to seeking to exploit its vast wind resources, the country is striving to decarbonise its industry by consolidating incentives. This makes Brazil a key player in the global transition to a cleaner energy future.

PART 4: MARKET STATUS

Overview

2024 was the wind industry's best year so far, with 117 GW of new wind power capacity added to the grid worldwide, bringing total installed wind capacity to 1,136 GW, an increase of 11% compared with last year.

New onshore wind installations surpassed the 100 GW milestone for the second year in a row, with the 109 GW connected to the grid in 2024 marking a historical peak. The offshore wind capacity commissioned in 2024, at 8 GW, was 26% less than the previous year and the lowest since 2021.

Thanks to explosive growth in China and a steady recovery of installations in India, the Asia Pacific region further consolidated its leading position in wind power development in 2024 with a 75% global market share, having experienced 7% year-on-year (YoY) growth.

Europe commissioned 16.4 GW of new wind power capacity last year, of which 12.9 GW is from the EU-27. Although wind power additions in the European continent and its global market share in 2024 declined by 10% and 2% YoY, the region remains the second-largest wind market.

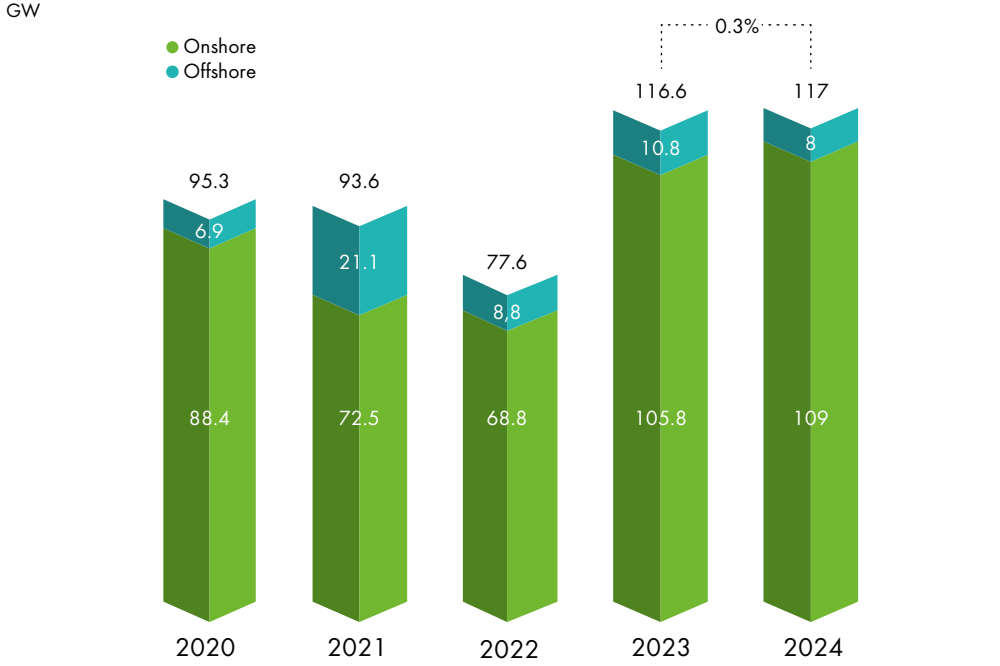
North America retained third place, but its global market share in 2024 declined by 33% YoY. This is primarily due to new onshore installations in the US dropping to the lowest level since 2013. Latin America was the fourth-largest market in 2024, but its market share decreased by 1% YoY because new commissioned capacity in Brazil dropped by 30% compared with 2023. Africa & Middle East remained the smallest market although wind additions doubled in 2024 compared with the previous year.

The world's top five markets for new installations in 2024 were China, the US, Germany, India and Brazil. Compared with 2023, Germany and India each moved up one position while Brazil fell two positions to fifth place. These five markets combined made up 81% of global additions in 2024, collectively 1% higher than the previous year.

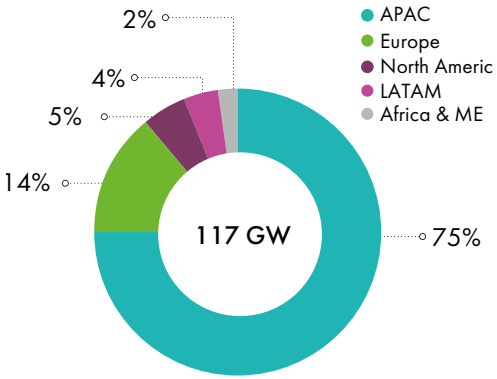
The top five markets by total wind power installations at the end of 2024 were China, the US, Germany, India and Brazil. Compared with 2023, the only change is that Brazil moved to fifth place, a position previously held by Spain. Together, the top five markets accounted for 73% of the world's total wind power installations in 2024, 1% higher than the previous year.

GWEC reports installed and commissioned new wind power capacity in the Global Wind Reports. According to GWEC Global Supply Side data, globally 127 GW of new wind power was mechanically installed in 2024, but only 117 GW was commissioned because more than 9 GW of new installations in China, India and the US were not grid-connected.

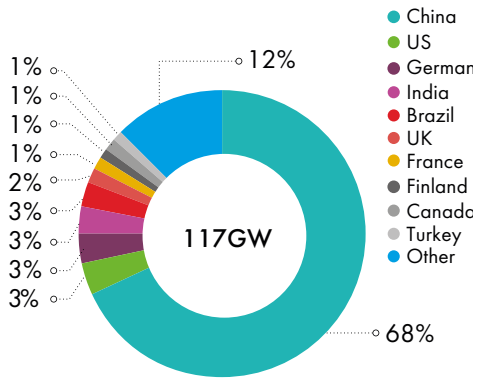
New installations
GW



New capacity in 2024 installed by region (%)



New capacity 2024 and share of top 10 markets (%)



Onshore Wind Market – Status 2024

2024 was a record year in annual onshore wind installations. With 109 GW of new onshore wind capacity commissioned last year, global cumulative onshore wind installations surpassed the 1,000 GW milestone for the first time, marking a YoY growth of 11%.

Asia Pacific and Africa & Middle East both had a record year, driven by China's remarkable performance, the ongoing recovery of the Indian market and strong performance in North Africa.

Meanwhile, onshore wind additions in Europe, Latin America and North America dropped by 5%, 25% and 35%, respectively, in 2024 compared with the previous year. The decline in Europe and Latin America was mainly due to the slowdown of onshore wind growth in Sweden and Brazil. In North America, the drop was driven primarily by the onshore wind market plunge in the world's second largest wind power market – the US.

China made up 70% of the world's total onshore installations last year. Since 2021, onshore wind development has been driven by a market support mechanism called 'grid parity', which remunerates the electricity generated from onshore wind at the same regulated price as coal power in every province. After two years of relatively low growth in 2021 and 2022, when installations were also affected by the COVID lockdown, onshore wind bounced back in 2023, with record additions of nearly 76 GW in 2024. Such explosive growth demonstrates that the country is seriously committed to its '30-60' targets of peak emissions by 2030 and carbon neutrality by 2060.

> With 109 GW of new onshore wind capacity commissioned last year, global cumulatiave onshore wind installations surpassed the 1,000 GW milestone for the first time.

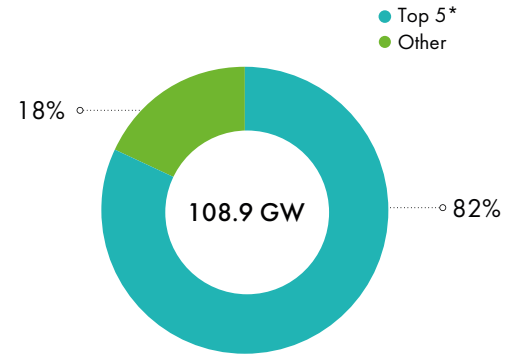
In the US, the Bipartisan Infrastructure Law and Inflation Reduction Act (IRA) propelled renewable energy investment across the country, with more than 40 US primary-component manufacturing projects across utility-scale wind, solar and storage supply chains coming online in 2024. However, less than 4 GW of new onshore wind capacity was commissioned last year – the lowest since 2014. The glacial pace of onshore wind project deployment in the US was chiefly due to challenges such as transmission congestion, long interconnection queues, inflation, the delayed guidance on tax rules and a list of projects delaying commissioning until 2025.

In addition to China and the US, the other onshore wind markets in the top five for new installations were India (3.4 GW), Germany (3.3 GW) and Brazil (3.3 GW).

'Grid parity' in China and auctions/ tenders remain the top two market support mechanisms behind the onshore wind capacity added in 2024, collectively accounting for a combined 91% market share, 2% higher than the previous year. Other support schemes including merchant and PPA contracts replaced tax credits as the third-largest driver of onshore wind growth last year. Feed-in Tariff support schemes lost 0.4% market share compared with 2023, despite Japan having a record year in onshore wind installations and new capacity being added in Israel and Kazakhstan.

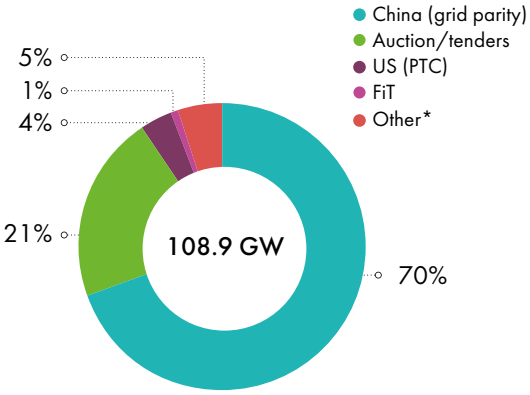
In 2024, excluding China, onshore wind capacity awarded worldwide through wind-specific, technology-neutral, renewable and hybrid auctions doubled from 2023. The total awarded capacity reached 53.5 GW, a record for the industry. More than half of this was in the Asia Pacific region – primarily in India – and nearly one-third was in Europe.

New capacity 2024 and share of top five onshore markets (%)



*China, US, India, Germany and Brazil

New capacity 2024 by market support mechanism (%)



*including merchant/PPA Basis

The current pace of annual wind power auctions in Europe is not fast enough and needs to gather pace if the EU is to achieve its energy security and climate targets.

The total onshore wind volume awarded last year amounted to 17 GW in Europe, 24% greater than 2023. This was mainly due to the onshore wind capacity awarded in Germany reaching 11 GW, which is 72% (or 4.6 GW) higher than the previous year. Improved permitting thanks to the implementation of the principle of Overriding Public Interest continues to accelerate onshore wind project development in this country. Nevertheless, the current pace of annual wind power auctions in Europe is not fast enough and needs to gather pace if the EU is to achieve its energy security and climate targets.

China approved 92.8 GW of onshore wind capacity under the 'grid parity' mechanism in 2024, triple what it achieved the previous year, paving the way for the country to achieve its '30-60' targets.

Offshore Wind Market – Status 2024

8 GW of new offshore wind capacity was grid-connected worldwide last year, bringing the total global offshore wind capacity to 83.2 GW by the end of 2024. New additions were 26% lower than the previous year, making 2024 the fourth-highest year in offshore wind history.

- China led the world in new offshore wind installations for the seventh year in a row. With 4 GW added to the grid, the country's total offshore wind capacity stood at 41.8 GW by the end of 2024. Last year was the third year since the Chinese offshore wind market entered the era of 'grid parity' – whereby the electricity generated from wind will receive the same remuneration as that from coal-fired power plants. Connecting 5 GW in 2022 and 6.3 GW in 2023 of new offshore wind without financial support from central government has demonstrated the resilience of the domestic offshore wind industry, but new additions dropped by 36% in 2024 compared with the previous year. This was primarily due to the delay caused by insufficient grid connections and complex maritime approvals and coordination, as well as a slower-than-expected transition from nearshore to deep-water offshore wind development.

- Europe commissioned 2.7 GW of new offshore wind from nine wind farms across four markets last year, accounting for one-third of offshore wind capacity connected worldwide in 2024.

- The UK connected 1.2 GW of offshore wind capacity in 2024 and recaptured the title as the region's largest offshore market in new additions. 88 units of SGRE offshore wind turbines were connected last year, of which 60 SG14-222 turbines at the Moray West offshore wind farm and 28 SG8.0-167 turbines at the Neart na Gaoithe wind farm. Last year saw further delays at the 1.2 GW Dogger Bank Phase A project, with only five GE Vernova Haliade-X turbines commissioned.

- Germany brought 730 MW of offshore wind capacity online last year, including 477 MW at the Baltic Eagle offshore wind project in the Baltic Sea and 253 MW at the Gode Wind 3 project in the North Sea. The Baltic Eagle project consists of 23 SGRE SG11-200 wind turbines, while Gode Wind 3 uses 50 V174-9.5 MW turbines supplied by Vestas.

- In the Netherlands, the 24 GE Cypress 5.5 MW turbines that replaced 28 Nordtank NKT 600kW wind turbines at Vattenfall's Irene Vorrink nearshore wind farm, in the IJsselmeer Lake, came online last March.

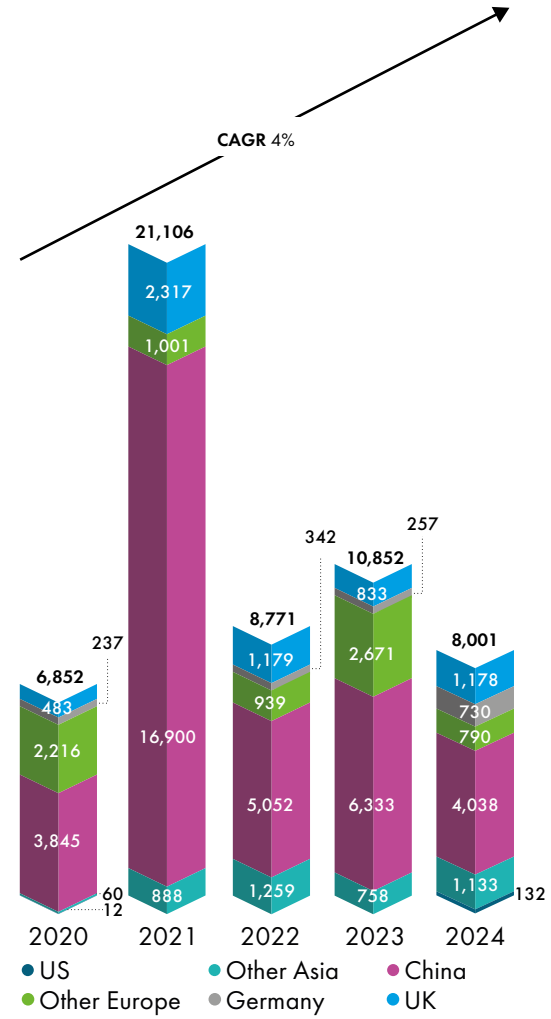
- France commissioned 658 MW of offshore wind in 2024. With the remaining 85 SGRE offshore wind turbines grid-connected at the Fécamp and the Saint-Brieuc wind farms, the two fixed-bottom projects achieved full operation in May 2024. In addition, the 25.2 MW Provence Grand Large offshore wind project, with three SGRE 8.4MW turbines, was Europe's only floating wind project to be commissioned in 2024.

- Elsewhere, Mingyang's 16.6 MW OceanX, a twin-rotor V-shaped floating turbine platform featuring two MySE8.3-180 hybrid drive wind turbines, was launched and installed in China. Altogether, a total of 41.8 MW of floating wind capacity was commissioned worldwide in 2024.

- Outside of China, three other markets commissioned new offshore wind capacity in the Asia Pacific region. Taiwan (China) commissioned 107 units (933 MW) of offshore wind turbines across the Yunlin, Greater Changhua 1 & 2a, Changfang Phase 2 & Xiaodao and ZhongNeng offshore wind farms in 2024.

- In Japan, the 112 MW Ishikari Bay New Port Offshore Wind Farm began commercial operations in early 2024. This project comprises 14 SGRE SG8.0-167 wind turbines. In South Korea, 18 units of Doosan's 5.56 MW

New offshore installations (MW)



The offshore wind market has grown from 1.6 GW in 2013 to 8.0 GW in 2024, bringing its market share in global new installations from 4% to 7%. GWEC Market Intelligence expects the global offshore wind market to continue to grow at an accelerated pace (for details, see Market Outlook).

offshore wind turbine were commissioned at the 100 MW Jeju Hallim Offshore Wind Farm, making it the largest commercial offshore wind farm in the country.

- The United States is the only country in the Americas with offshore wind turbines in operation. Although ten Haliade-X offshore wind turbines were installed by the early summer of last year, their commissioning at the 806 MW Vineyard Wind 1 wind project was delayed due to a blade failure reported in July 2024. However, the US commissioned the 132 MW South Fork Wind Farm, which consists of 12 SGRE SG 11-200 turbines, bringing the country's total offshore wind capacity to 174 MW.

- China is the absolute market leader for cumulative offshore wind installations, accounting for half of the global market share. The country took over the crown from the UK in 2021 and further consolidated its leadership in the past three years. Germany, the Netherlands and Taiwan (China) complete the top five. Offshore wind pioneer Denmark dropped out of the top five for the first time.

2024: A record year for offshore wind auctions

- 56.3 GW of offshore wind capacity was awarded worldwide last year. Excluding China, where 17.4 GW of offshore wind projects were allocated under the 'grid-parity' mechanism, the remaining 38.9 GW of offshore wind capacity was awarded through auctioning, with 23.2 GW in Europe, 8.4 GW in the US, 3.3 GW in South Korea, 2.7 GW in Taiwan (China) and 1.4 GW in Japan.

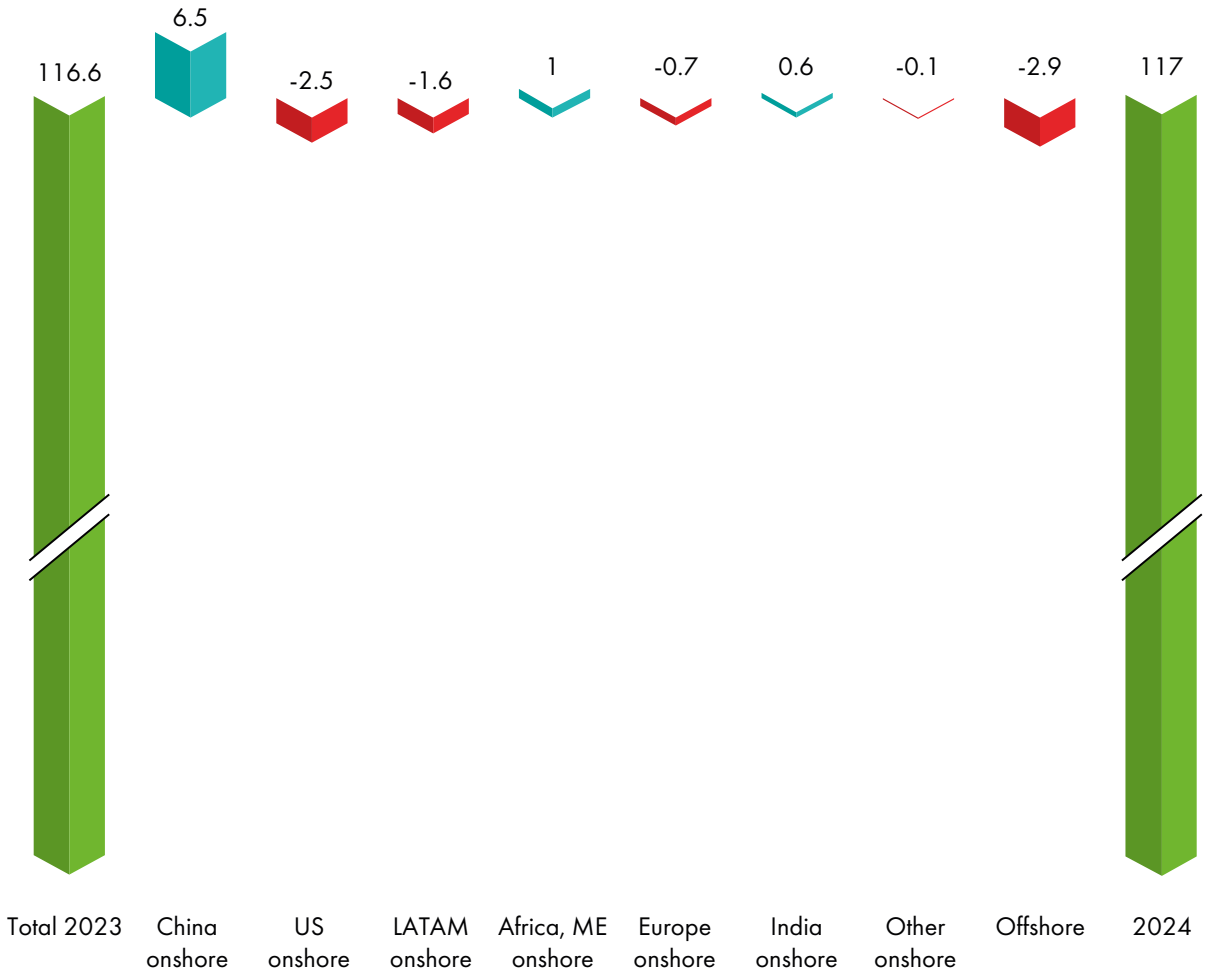
- In Europe, Germany and the Netherlands awarded 8 GW and 4 GW of offshore wind respectively via negative bidding, while the UK, Norway and France awarded 5.3 GW, 1.6 GW and 0.75 GW respectively via two-sided contracts for difference (CfDs).

- In the US, more than 8 GW of offshore wind capacity was awarded last year. In January, the New Jersey Board of Public Utilities (NJBPU) gave the green light to two large offshore wind projects with a combined capacity of 3,742 MW. In February, the New York State Energy Research and Development Authority (NYSERDA) selected Equinor's Empire Wind 1 (810 MW) and Ørsted and Eversource's Sunrise Wind (924 MW) in the state's fourth offshore wind solicitation. Both projects had previously secured agreements with the state and rebid in the latest procurement round to negotiate a new 25-year contract. In September, Massachusetts and Rhode Island published the results of their first multi-state offshore wind solicitation, selecting nearly 2.9 GW of offshore wind power.

- Of the total offshore wind capacity awarded in 2024, 1.9 GW was for floating wind, of which 750 MW in France through the AO5 and AO6 tenders across three floating projects, 750 MW in South Korea to the Bandibuli project and 400 MW in the UK via CfD Allocation Round 6 to the Green Volt project.

Only Asia Pacific and Africa & Middle East increased new installations

Changes in new onshore and offshore installations, 2023–2024 (GW)



Global wind market growth last year was flat with a YoY growth rate of 0.3%. Annual wind installations (onshore and offshore combined) increased in the Asia Pacific and Africa & Middle East regions, while North America, LATAM and Europe experienced a decline.

- Onshore wind: Asia Pacific and Africa & Middle East had a record year in 2024 with YoY growth rates at 10% and 107%, respectively, but new onshore wind capacity added in North America, LATAM and Europe last year declined by 35% (2.8 GW), 25% (1.6 GW) and 5% (0.7 GW) respectively. Last year both the US and Canada were accountable for the decrease of onshore wind installations in North America. The decline in LATAM and Europe was primarily due to lower installation in Brazil and Sweden compared with the previous year.

- Offshore wind: New commissioned offshore wind capacity decreased by 26% (2.9 GW) compared with 2023, mainly due to lower-than-expected installations in China, the UK and the US. This was caused by complicated maritime approvals and coordination, delays in grid connection and the supply chain, and component failures.

Actuals 2024 vs GWEC forecast

China onshore
After the Chinese market fully reopened following the COVID lockdown by the end of 2022, onshore wind installations quickly bounced back in 2023. The total capacity of onshore wind projects awarded through parity-based allocation and the order intake announced by Chinese OEMs in that year indicated that onshore wind development in China had moved to a stage of faster growth. The onshore wind capacity commissioned in 2024 is in line with GWEC's Q3 2024 Outlook.

USA onshore
Less than 4 GW of new onshore wind capacity was commissioned last year, although more than 16 GW of onshore wind projects were under construction by the end of 2023. The slow deployment in 2024 was due to transmission congestion, long interconnection queues, delayed guidance on tax rules and several projects delaying commissioning until 202**5.**

India onshore
India's onshore wind market continued to recover last year with 3.4 GW of onshore wind commissioned – the highest annual installation rate since 2017. However, the year ended lower than expected due to project cancellations caused by delays in grid connection and land acquisition.

Germany onshore
Driven by strong political will and improved permitting, 2024 was expected to be a better year than 2023. 4.3 GW of onshore wind projects were permitted in 2022. Considering a two-year lead time for construction, approximately 4 GW should have been connected in 2024. Installations, however, were delayed primarily due to last summer's partial shutdown of the A27 freeway in northwest Germany, which is a crucial route for rotor blades entering the country through the port of Cuxhaven.

Brazil onshore
The Brazilian wind industry had a record period for new onshore wind installations between 2021–2023. This strong growth was primarily driven by the free market through private PPAs. New installations were expected to slow down in 2024 due to grid transmission constraints, cancelled energy auctions and other regulatory issues.

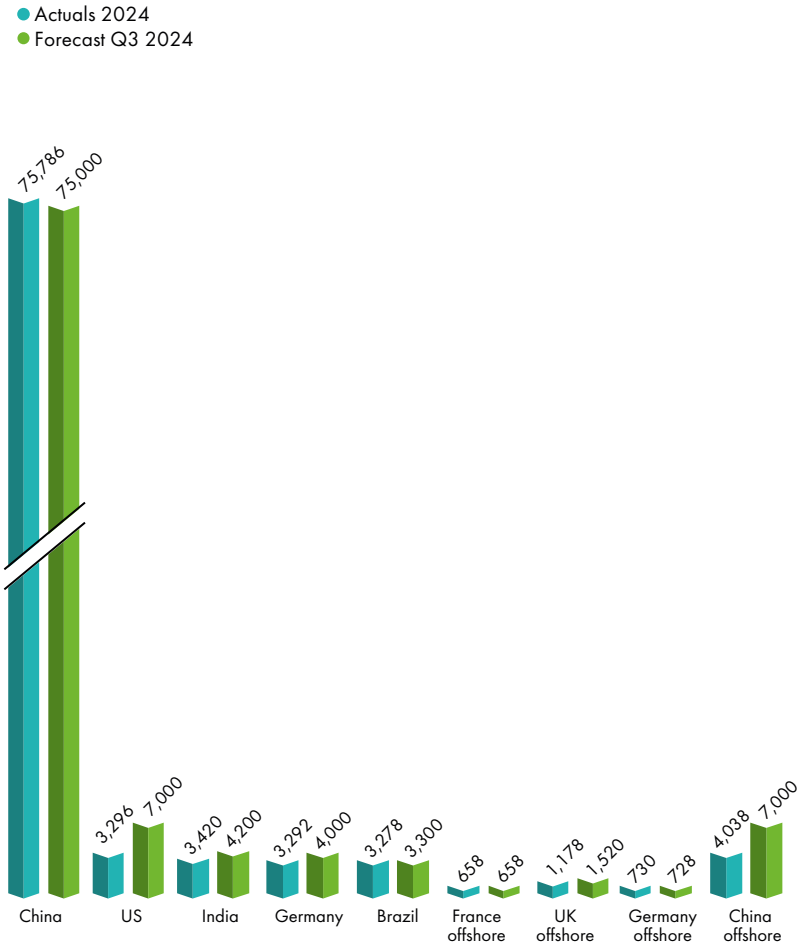
France offshore
In line with our projection, 658 MW of new offshore wind was fed into the grid in France last year, of which 633 MW came from two fixed-bottom projects – Fécamp and Saint-Brieuc – and 25.2 MW from the Provence Grand Large floating offshore wind project.

UK offshore
GWEC Market Intelligence expected the 882 MW Moray West offshore wind farm to reach commercial operation in 2024 and that half of the turbines at the 1.2 GW Dogger Bank A offshore wind project would be commissioned by the end of the year. Due to bad weather, poor availability of installation vessels and delays in the supply chain, only five of the wind turbines (63 MW) were commissioned at Dogger Bank A in the end, but 28 SGRE SG8.0-167 wind turbines achieved a grid connection at Neart na Gaoithe.

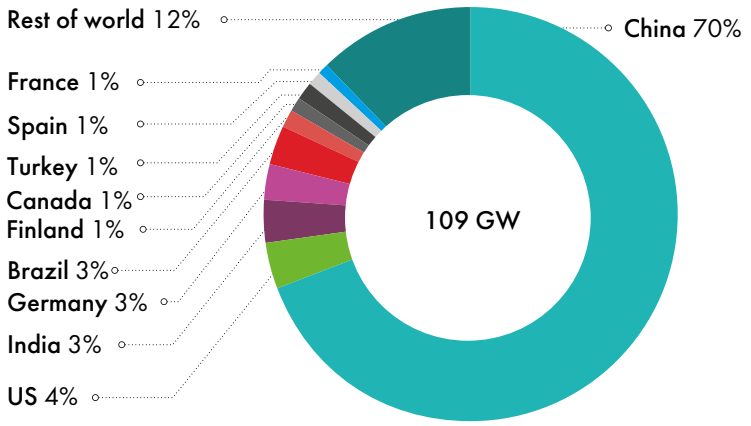
Germany offshore
In Germany, the 477 MW Baltic Eagle and the 253 MW Gode Wind 3 offshore wind projects came online last year, which was in line with our expectations. Although wind turbine installation at the 913 MW Borkum Riffgrund 3 offshore wind farm has been completed, the commercial operation date has been moved to early 2026 due to delays to the HVDC grid connection that links the project to the German onshore grid.

China offshore
China approved 18 GW of parity-based offshore projects in 2023 while more than 17 GW of offshore wind projects were under construction by Q1 2024, signalling continued momentum for offshore wind growth in 2024. Although 5.8 GW of offshore wind was mechanically installed last year according to CWEA, only 4 GW was commissioned. This is mainly due to delays caused by the grid connection in Guangdong and complex maritime approvals and coordination.

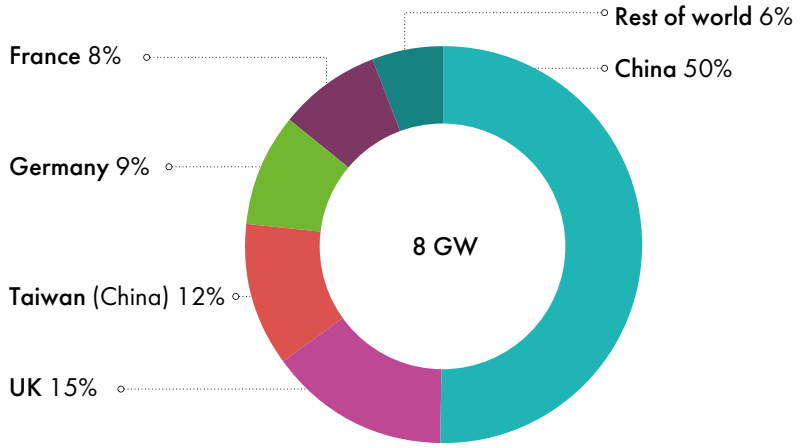
Actuals for 2024 vs GWEC forecast



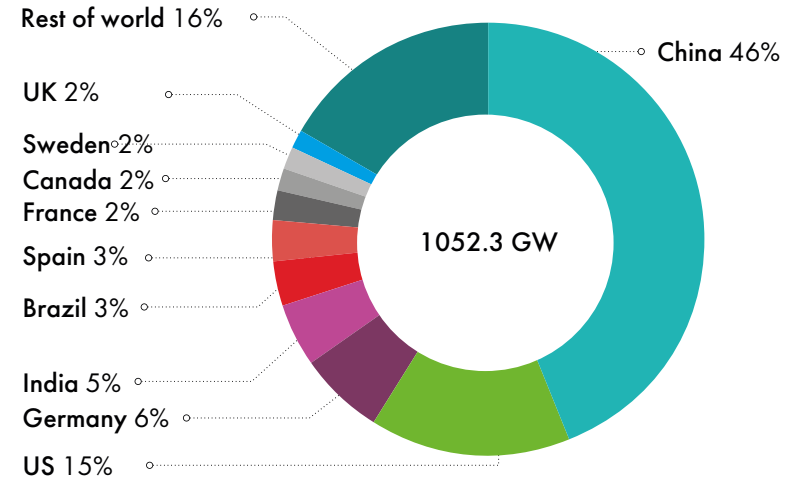
New installations onshore (%)



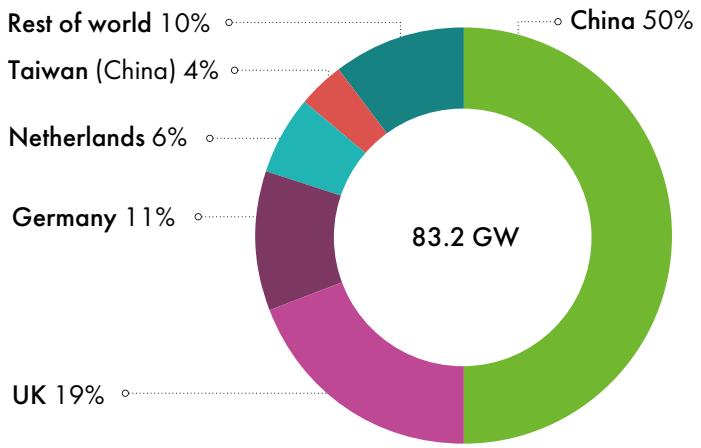
New installations offshore (%)



Total installations onshore (%)

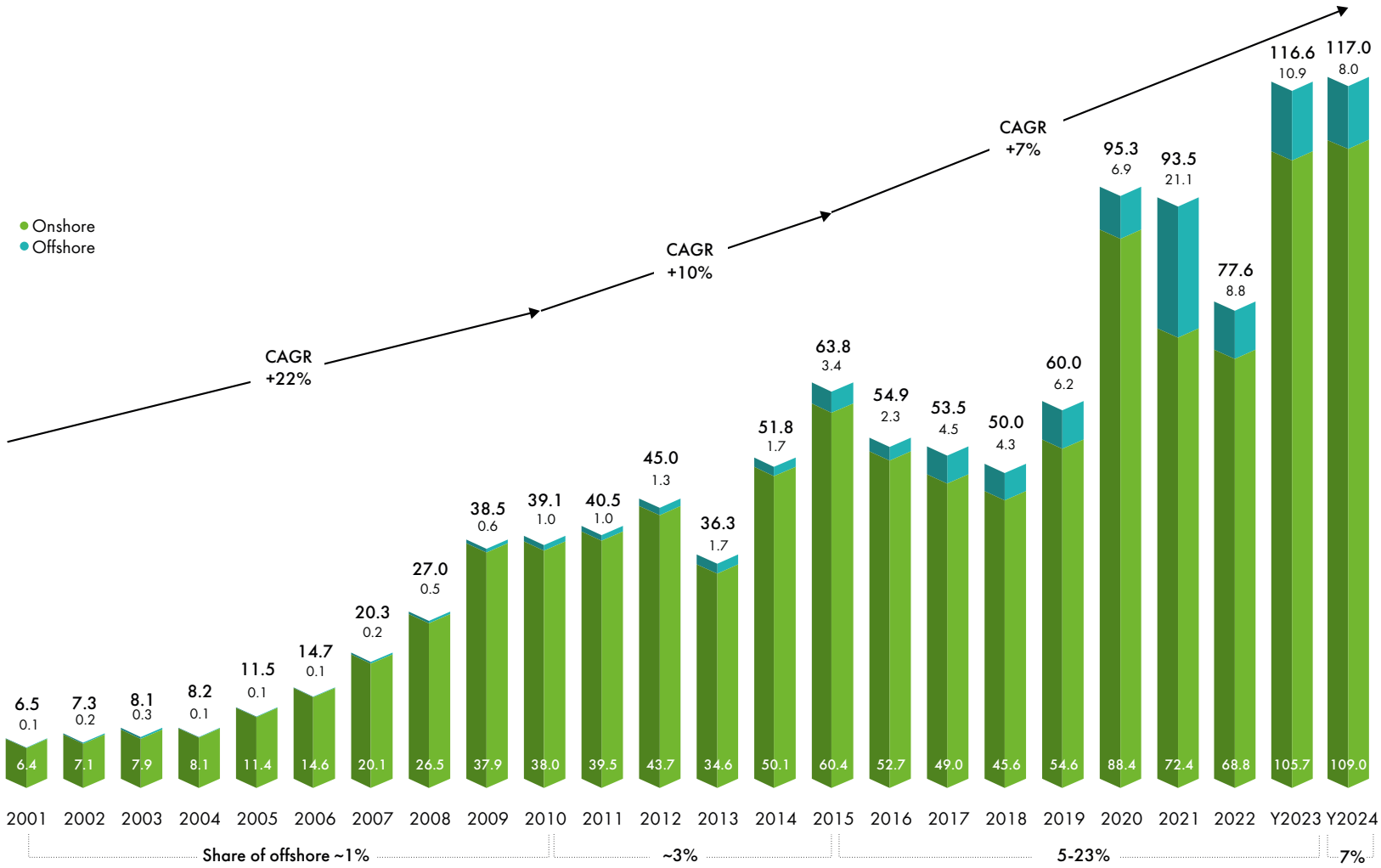


Total installations offshore (%)



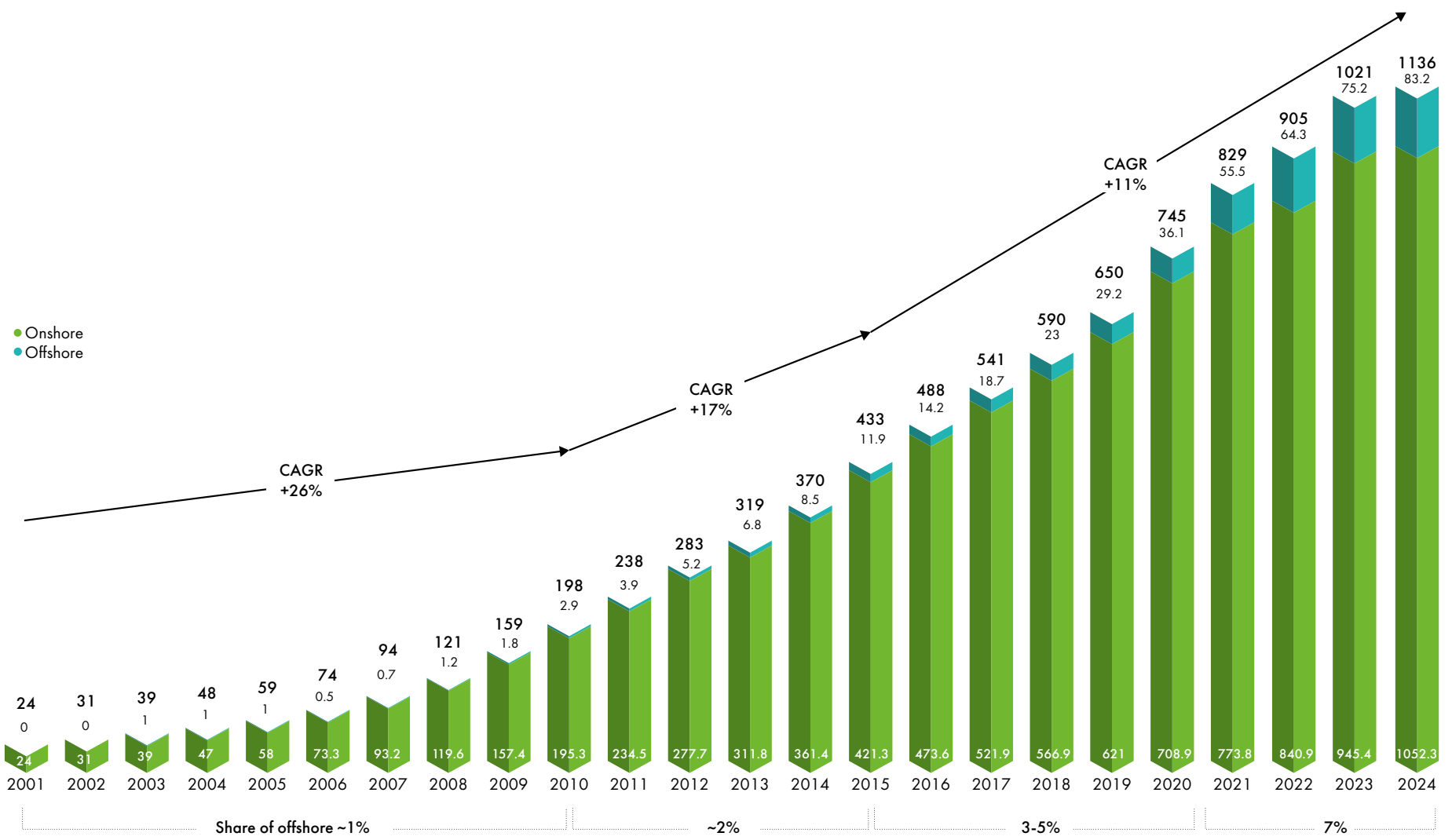
Detailed data sheet available in GWEC's member-only area. For definition of region see Appendix - Methodology and Terminology

Historic development of new installations (GW)



Footnote: GWEC made the adjustments to new installations and total installation in 2023 based on the updated statistics GWEC received. For details see Appendix -Methodology and Terminology

Historic development of total installations (GW)



GWEC made the adjustments to total installations based on the updated statistics GWEC received. For details see Appendix -Methodology and Terminology

Historic development of new and total grid-connected installations

MW, onshore	New installations 2023	Total installations 2023	New installations 2024	Total installations 2024
Total onshore	**105736**	**945449**	**108969**	**1052338**
Americas	**14418**	**218006**	**10047**	**227780**
USA	6402	150433	3926	154084
Canada	1720	16986	1387	18373
Brazil	4817	30449	3278	33727
Mexico	96	7413	369	7782
Argentina	395	3704	614	4319
Chile	688	4577	307	4884
Other Americas	300	4444	166	4611
Africa, Middle East	**959**	**10656**	**1981**	**12587**
Egypt	360	2062	793.5	2855.1
Kenya	0	425	0	425
South Africa	0	3442	69	3511
Morocco	110	1898	520	2368.28
Saudi Arabia	0	422	**390**	812
Other Africa	489	2407	209	2616
Asia-Pacific	**75836**	**478472**	**83152**	**561259**
PR China	69327	403325	75786	478787
India	2806	44736	3420	48156.23
Australia	942	11479	835.5	12314.7
Pakistan	0	1817	58	1874.8
Japan	572	5026	603	5589
South Korea	165	1821	198	2018
Vietnam	823	3924	239	4163
Philippines	150	593	0	593
Kazakhstan	161	916	127	1043
Other APAC	890	4835	1885	6719
Europe	**14524**	**238315**	**13789**	**250712**
Germany	3567	61139	3292	63719
France	1400	22003	1081	23071
Sweden	1973	16249	1015	17246
United Kingdom	553	14866	739	15604
Spain	762	30562	1183	31310
Finland	1278	6873	1414	8287
Netherlands	527	6754	161	6858
Turkey	397	12342	1310	13652
Other Europe	4067	67527	3594	70965

MW, offshore	New installations 2023	Total installations 2023	New installations 2024	Total installations 2024
Total offshore	**10852**	**75162**	**8001**	**83162**
Americas	**0**	**42**	**132**	**174**
USA	0	42	132	174
Asia-Pacific	**7091**	**41088**	**5171**	**46258**
PR China	6333	37775	4038	41813
Japan	62	188	100	288
South Korea	4	146	100	246
Vietnam	0	875	0	875
Taiwan (China)	692	2104	933	3037
Europe	**3761**	**34032**	**2698**	**36730**
United Kingdom	833	14751	1178	15929
Germany	257	8311	730	9041
France	360	842	658	1500
Netherlands	1930	4759	132	4891
Denmark	344	2652	0	2652
Belgium	0	2262	0	2262
Other Europe	37	455	0	455

GWEC made the adjustments to new installations and total installation in 2023 based on the updated statistics GWEC received. For details see Appendix -Methodology and Terminology

PART FIVE: MARKET OUTLOOK 2025-2030

Global wind energy market expected to grow 8.8% annually

Global outlook

Global energy markets are facing growing uncertainty in an increasingly complex world that continues to grapple with the Russia–Ukraine war, the crisis in the Middle East, and persistent high inflation. Trump's radical energy policies, coupled with trade wars with neighbours, allies and rivals, have further destablised an already fragile global landscape.

Although we have downgraded our near-term forecast for this year's global outlook, we remain optimistic and confident about the long-term growth of the wind energy sector. Ensuring energy security while addressing climate change through renewable energy remains a top priority for much of the world. As a result, the fundamentals underpinning the global energy transition remain strong, reinforcing our positive outlook for wind energy.

GWEC Market Intelligence expects new installations to surpass the previous record and reach 138 GW in 2025. A total of 982 GW of new capacity is expected to be added this year and in the next five under current policies. This would equate to 164 GW of new installations annually until 2030.

The projected compound annual growth rate (CAGR) for the 2025–2030 period is 8.8%, even starting from a level of installed capacity for 2024 that was the highest in history. The five pillars below we believe can support this level of success:

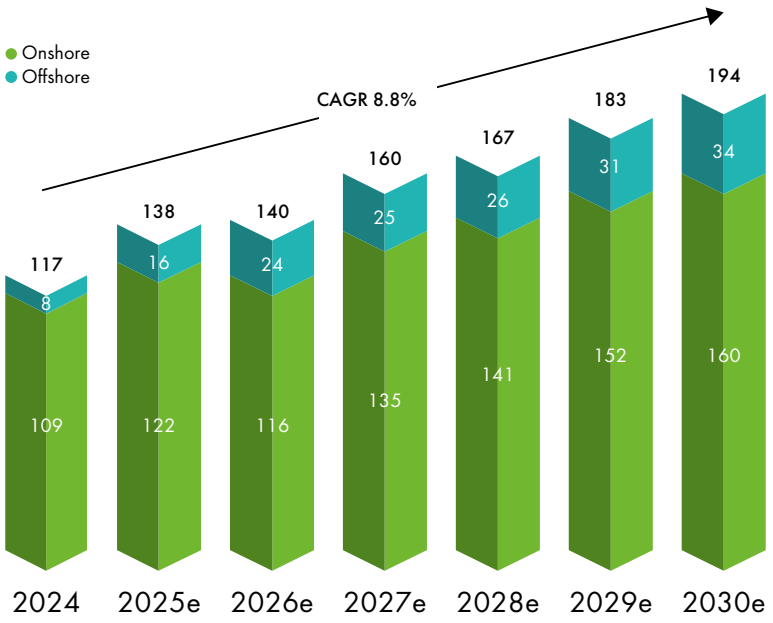
- As the global leader in renewable energy development and manufacturing, China made clean energy the top driver of its economic growth. Driven by the '30-60' pledge, the Chinese government has set a target for non-fossil energy sources to account for over 80% of total energy consumption by 2060.

- Europe is accelerating renewables development to achieve energy security in the aftermath of Russia's invasion of Ukraine. From 2023, the continent started turning its ambitious targets into actions. The Clean Industrial Deal passed early this year outlines concrete actions to turn decarbonisation into a driver of growth for European industries including clean energy.

- Although the Presidential Executive Order on wind energy has created uncertainty in the US, wind and other clean technologies remain the solutions to the need for more power generation capacity to support American advances in manufacturing and artificial intelligence.

- Despite the turbulence and Big Oil's green retreat, most governments and developers have maintained their commitments to developing offshore wind. Floating wind technology as well as power-to-X solutions will

New installations outlook 2025–2030 (GW)



GWEC's Market Outlook represents the industry perspective on expected installations of new capacity over this and the next five years. The outlook is based on input from regional wind associations, government targets, tender results, announced auction plans, available project pipeline, and input from industry experts and GWEC members. An update will be released in Q3 2025. A detailed data sheet is available in the member-only area of the GWEC Intelligence website.

further unlock offshore wind's potential to support the global energy transition.

- Growth in emerging markets in the regions of Southeast Asia, Central Asia and Middle East & Africa is expected to gain momentum, with record installations anticipated annually between 2025–2030.

Global onshore outlook

- The CAGR for onshore wind in the forecast period is 6.6%. Expected average annual installations are 138 GW. In total, 827 GW is likely to be added in 2025–2030.

- Growth in China and Europe will remain the backbone of global onshore wind development. Altogether they are expected to make up 73% of the total capacity to be built during 2025–2030. Due to policy uncertainty in the US, the Asia Pacific region excluding China is likely to overtake the US as the third-largest onshore wind growth driver in the period.

- China will continue to be the growth engine in the near term, making up 66% of total installations in 2025. But installations will accelerate in Europe, India and Australia from 2026, as well as in emerging markets in Southeast Asia, Central Asia and Africa & Middle East from 2027. Global onshore wind markets will become more diversified by the end of this

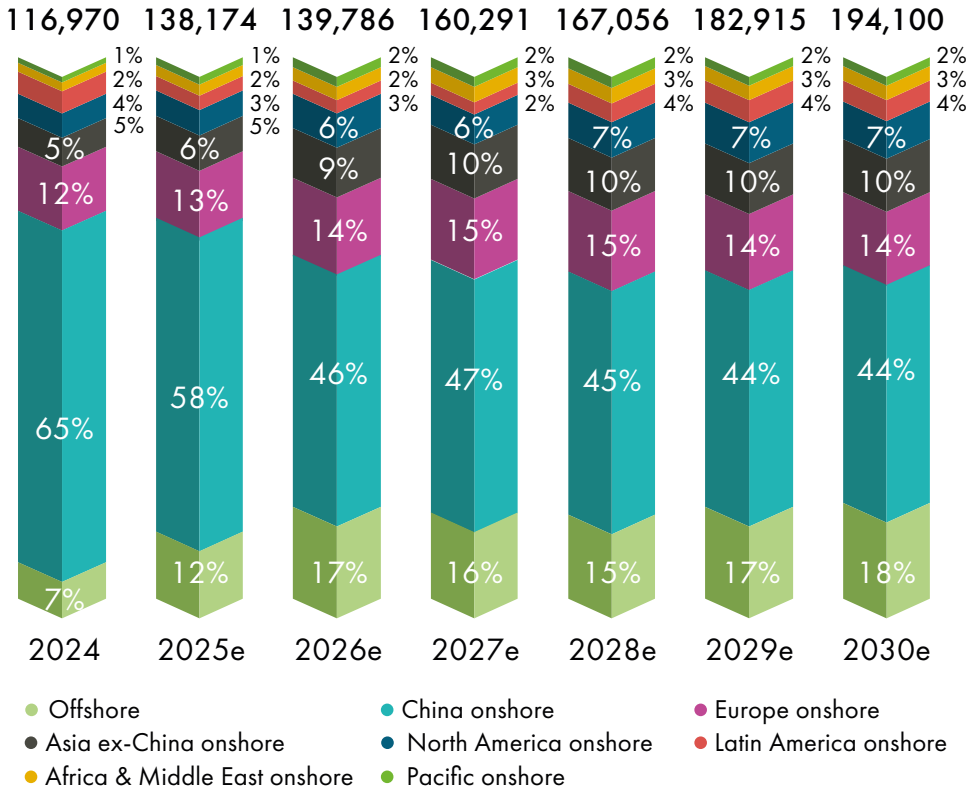
decade, with around half of the annual growth coming from markets outside of China.

Global offshore outlook

- The CAGR for offshore wind in the forecast period is 27%. As a result of such a steep growth rate, annual offshore wind additions are likely to quadruple by 2030 from 2024 levels.
- China and Europe will continue dominating growth in the near term with an 87% global market share in 2025, but offshore wind deployment is expected to gain momentum in the US from 2026 – assuming there are no delays for Revolution Wind and Coastal Virginia offshore wind projects – and in Asia Pacific's emerging markets from 2028. By the end of the forecast period, annual installations outside China and Europe are likely to make up more than 15% of total additions.
- With annual installations expected to average 26 GW, a total of 156 GW of offshore wind capacity is expected to be added worldwide in 2025–2030, of which 51% will come from China, 33% from the EU, 12% from Asia Pacific excluding China, and 4% from the US.

Onshore wind remains the growth engine and offshore builds up strength

New onshore and offshore installations outlook by region (MW, %)



Offshore wind

Despite the challenges brought by inflation, increased capital costs, supply chain constraints and grid connection delays – and the cloud that is hanging over the US market – global offshore wind capacity is expected to grow from 8 GW in 2024 to 34 GW in 2030. This would bring its share of new global wind installations from today's 7% to 18% by the end of the decade.

In Europe, more than 51 GW of offshore wind capacity is expected to be fed into the grid in 2025–2030, of which 42% is likely to be installed in the UK, mainly driven by the expected commissioning of projects from CfD Allocation Rounds 3, 4, 6 and 7, 22% in Germany, 12% in Poland, 11% in the Netherlands, 4% in France, and 3% in Denmark.

Although it underperformed in 2024, Chinese offshore wind deployment is likely to bounce back in 2025 and then accelerate once regulations for guiding and supporting project development in the deepwater locations are in place. The country is expected to retain its leading position in Asia with 80 GW to be added in 2025–2030, followed by Taiwan (China) (8.3 GW), Japan (5.0 GW) and South Korea (4.2 GW). No real offshore wind projects are likely to be commissioned in Vietnam before the end of the decade according to the revised PDP8 target.

In the US, a vulnerable local supply chain combined with macroeconomic challenges had already created a 'perfect storm' for the offshore wind industry before President Trump moved back into the White House in January 2025. Undoubtedly, the Presidential Executive Order to temporarily withdraw all offshore wind energy leasing within the Offshore Continental Shelf (OCS) will stop new offshore wind project development off the US coast. To compound matters, the very real threat of revocation hangs over project permits already awarded under the Biden Administration, as in the case of the 2.8 GW Atlantic Shores offshore wind project, planned off the coast of New Jersey. In addition, the industry may suffer from the tariffs that President Trump imposed on imports of goods from both allies and adversaries.

With all of this in mind, GWEC Market Intelligence has downgraded its US offshore wind growth projection to less than 6 GW of offshore wind capacity to be added from Vineyard 1, Revolution Wind, Coastal Virginia Offshore Wind (CVOW), Empire 1 and Sunrise offshore wind projects in 2025–2030.

China

China commissioned more than 360 GW of non-hydro renewable energy in 2024, which not only demonstrated the country's commitment to its '30-60' targets but proved that its local supply chain is ready to deliver this ambitious goal.

Although the market-oriented renewable energy pricing scheme released by China's NDRC and NEA in February 2025 may create uncertainty for returns on projects to be commissioned after 1 June 2025, GWEC Market Intelligence believes that the local industry can quickly adapt to the new pricing scheme, much as it did in 2021 when the grid parity-based pricing scheme replaced Feed-in tariffs as the support mechanism for wind energy.

Given that 2025 marks the final year of China's 14th Five-Year Plan and more than 150 GW of wind turbine orders were awarded last year, we believe that 2025 will be another record year. In total, 460 GW of new onshore wind could be added to the grid in China in 2025–2030.

Asia excluding China

The onshore wind market continued to recover in India in 2024. Given the expiry of the 100% inter-state transmission charge waiver (ISTS) in June this year, 2025 is predicted to be a record year. GWEC Market Intelligence believes that the growth momentum in this market will be sustained for the rest of the decade, with 41 GW of new onshore wind capacity expected to be added in 2025–2030. Our optimistic growth outlook is based on the following factors: 1) 10 GW annual onshore wind auctions target from 2023–2027; 2) nearly 27.3 GW of projects awarded by the end of 2024, either as standalone wind or as wind components of hybrid projects; 3) wind-specific RPOs from 2023 to 2030 and high demand from the C&I segment; 4) transmission planning to integrate 48GW of onshore wind capacity by 2030; 5) an established local onshore wind energy supply chain, with further investment announced recently.

In Vietnam, although state-owned Vietnam Electricity (EVN) has been negotiating PPAs with investors since January 2023 for installed projects that missed the 2021 COD deadline, only 1,062 MW of onshore wind projects have reached agreements with EVN over the past two years. This means that more than 1.5 GW of installed wind projects are still waiting for grid-connection approval. In our current policy scenario, we expect that most of this capacity will be approved in 2025 and that new onshore wind installations from 2026 will be driven by a new market support mechanism that the government has yet to confirm.

Elsewhere in this region, onshore wind growth is expected in Japan, the Philippines and emerging markets in southeast and central Asia. The Philippines, Kazakhstan and Uzbekistan are expected to become the region's rising stars. These three markets combined are likely to make up 13% of new capacity expected in APAC excluding China in 2025–2030.

Pacific
After a particularly poor 2023 for Australia, with no new financial commitments to utility-scale wind projects, onshore wind bounced back in 2024 with a total of 2,218 MW, worth almost AUD 6 billion, reached financial commitment. According to the Clean Energy Council's latest quarterly investment report, 19 onshore wind projects worth 5.8 GW were either under construction or committed at the end of 2024. Australia will need to add at least 6 GW of utility-scale generation to the National Electricity Market annually to meet the federal government's target of 82% renewables by 2030. The 6.4 GW of renewable projects (of which 3 GW is wind) awarded under the first national tender process under the Revamped Capacity Investment Scheme (CIS), announced in November 2023, has shown that the country is on track to achieve this target. As of Q1 2025, GWEC's Australia project pipeline shows that more than 70 GW of onshore wind projects are at different stages of development, including 16.5 GW that we believe will be added to the grid by 2030.

New Zealand commissioned 303 MW of onshore wind capacity across two projects last year, marking a record year for the country. Permitting, however, has slowed down onshore wind development. Currently, only two projects totalling 240 MW are under construction, with a 90 MW wind project recently securing consent.

Europe
Our onshore wind forecast for Europe is in line with WindEurope's recently released 2025–2030 Outlook, which takes account of the latest developments in EU regulation, national policies, announcements of signed power purchase agreements (PPAs), project development timelines and the ability of wind to secure further capacity in upcoming auctions and tenders.

Under WindEurope's central scenario, record onshore wind installations in Europe are expected annually from 2025 to the end of this decade, with 140 GW of new onshore wind to be built in 2025–2030, of which 81% or 113 GW is predicted to come from the EU. This equals 18.8 GW of new installations each year until 2030, which is much lower than the average growth rate the EU needs to meet its 2030 energy and climate targets. Based on onshore wind capacity that has already been awarded through auctions, Germany is likely to maintain its leading position in onshore wind development in this region, accounting for 27% of total onshore wind additions in the period, followed by Spain (9,3%), Turkey (9,0%), France (8%) and the UK (7%).

North America
Despite no shortage of projects in the pipeline, new onshore wind installations in the US continued to decline in 2024 as a result of challenges such as transmission constraints, increased interest rates,

delays in electrical components, and a lack of guidance on tax credit rules.

The American Clean Power Association (ACP) reported nearly 16 GW of onshore wind under construction and 9 GW in advanced development across 79 projects as of Q4 2024, positioning onshore wind to address growing demand for power from data centres. Although only a small portion of renewable energy capacity is on federal land – which could be impacted by President Trump's Executive Order – the uncertainty surrounding onshore wind development means that the US onshore wind market is unlikely to bounce back immediately.

Much anticipation surrounds possible new eligibility guidance under the IRA signed into law by the Biden Administration. Concerns abound over the impact of tariffs on the wind energy supply chain, even for projects currently under construction, given that the US onshore wind market still sources many components abroad. With all of this in mind, we forecast that 63 GW of onshore wind capacity in total will be added in 2025–2030 in North America, of which 88% will be built in the US and the rest in Canada.

Latin America

Brazil is the absolute leader in onshore wind development, accounting for two-thirds of the capacity added in this region in the past four years. Private PPAs drove the development of projects and the strong growth momentum in Brazil, enabling Latin

America to achieve a record year in 2023. However, onshore wind additions in the region dropped by 25% to 4.7 GW in 2024 when the region's growth engine slowed down.

GWEC Market Intelligence believes that annual installations in LATAM will continue to decline in the next three years as Brazil continues to face challenges such as lower than expected electricity demand, grid transmission constraints, missing demand from regulated new energy auctions, as well as the end of discounted transmission tariffs for renewable operators.

Elsewhere in the region, great progress was reported in Chile. With YoY growth of 236%, investments in renewables reached a record figure of USD 5,695 million in 2024. Non-hydro renewable energy sources already represent 51% in Chile's electricity generation mix, and an additional 6.7 GW of non-hydro renewable energy and storage are expected to be added in the next three years.

Despite market growth being hindered by an unconducive energy policy environment in Mexico and economic and political instability in Argentina, we expect new onshore wind capacity to continue to be built in both markets. In total, 32 GW of onshore wind capacity are likely to be added in this region during the 2025–2030 period, with Brazil, Chile, Mexico, Colombia and Argentina as the top five markets, collectively accounting for 95% of the additions.

Africa & Middle East

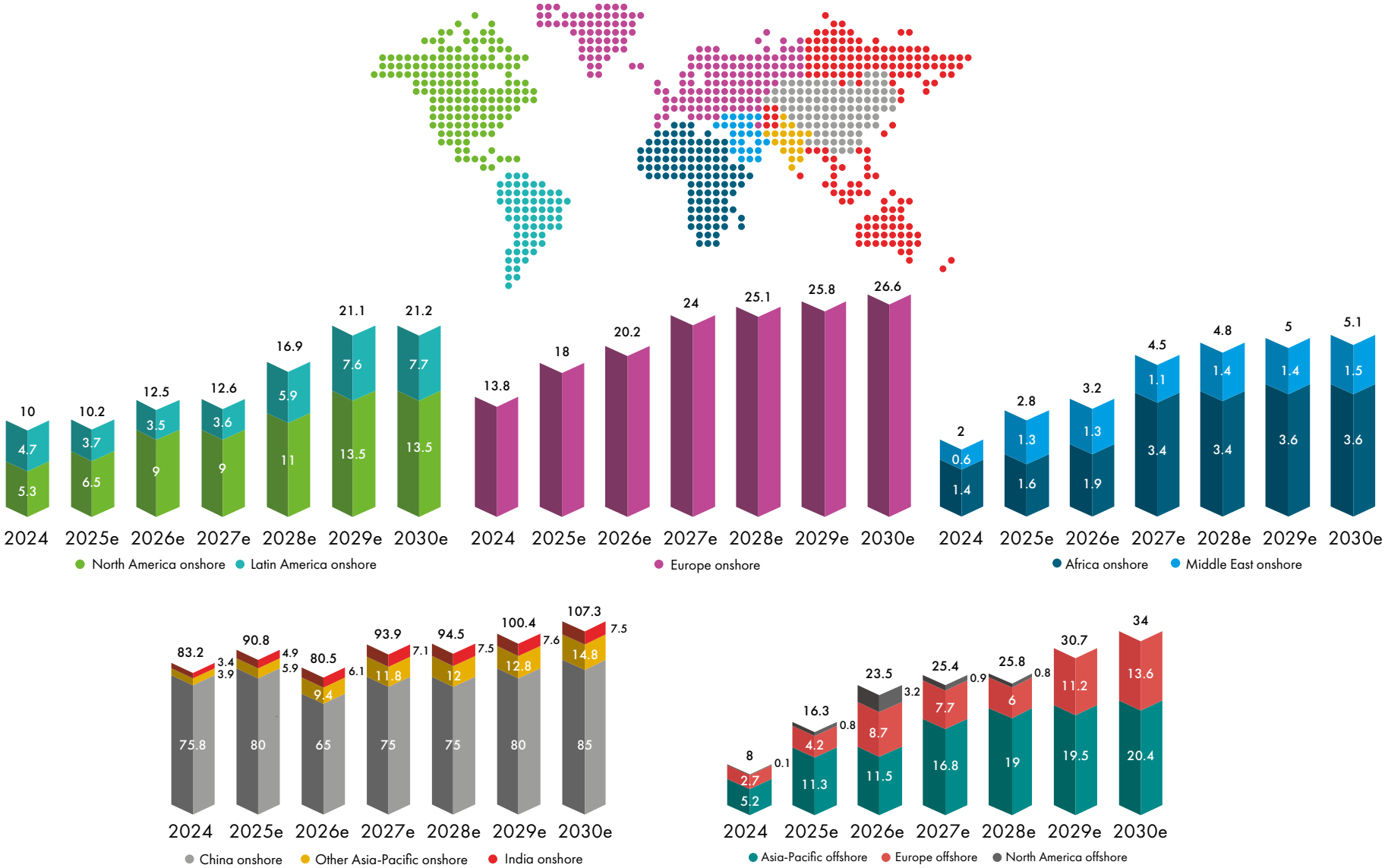
Africa & Middle East had a record year, doubling onshore wind additions in 2024. Although new commissioning

was disappointing in South Africa, the region's market leader in total wind installations, unprecedented growth in Egypt and Morocco made 2024 the best year in history for wind power in Africa. Given more than half of the capacity awarded through the REIPPPP Bid Window 4 auction are under construction, and nearly 2 GW of private-offtake projects have been announced since the 2022 electricity market reforms, we believe that South Africa will bounce back in 2025 with stable growth expected for the rest of the period to 2030. Considering that multi-GW onshore wind projects are currently under construction – or are ready to be built – in Egypt, GWEC Market Intelligence expects Africa to have record installations annually from 2025 to 2030.

In the Middle East, new installations were reported in Saudi Arabia, UEA, Israel and Iran last year, but only Saudi Arabia is likely to add GW-level onshore wind capacity in the period to 2030.

Given the expected strong growth in Africa, GWEC Market Intelligence predicts that new onshore wind additions in Africa and the Middle East will double the end of this decade compared with 2024. In total, 25 GW of new capacity is expected to be added during 2024–2030, of which 17 GW (69%) will come from Africa and the rest (31%) from the Middle East.

Regional onshore and offshore wind outlook for new installations (GW)



APPENDIX

Global Wind Report 2025 Methodology and Terminology

Data definitions and adjustments

GWEC reports installed and fully commissioned capacity additions and total installations. New installations are gross figures not deducting decommissioned capacity. Total installations are net figures, adjusted for decommissioned capacity.

Historic installation data has been adjusted based on the input GWEC received. GWEC made the adjustments to both new and cumulative installations in 2022 for all the markets where updated statistics are available.

Definition of regions

GWEC adjusted its definition of regions for the 2018 Global Wind Report and maintains these in the 2025 edition, specifically for Latin America and Europe.

Latin America: South, Central America and Mexico

Europe: Geographic Europe including Norway, Russia, Switzerland, Turkey and Ukraine

Sources for the report

GWEC collects installation data from regional and country wind associations, alternatively from industry experts and wind turbine manufacturers.

Used terminology

GWEC uses terminology to the best of our knowledge. With the wind industry evolving, certain terminology is not yet fixed or can have several connotations. GWEC is continuously adapting and adjusting to these developments.

Acronyms

Abeeolica	Associacao Brasileira De Energia Eolica
ACER	Agency for the Cooperation of Energy Regulators
APS	Announced Pledges Scenario
APAC	Asia-Pacific
AEP	Asset Earning Power
AUD	Australian Dollar
BCG	Boston Consulting Group
BNEF	Bloomberg New Energy Finance
BOO	Build, Own, Operate
BRL	Brazilian Real
CAGR	Compound Annual Growth Rate
CBAM	Carbon Border Adjustment Mechanism
CfD	Contracts for Difference
COD	Commercial Operation Date
CoEs	Centres of Excellence
CRRC	China Railway Rolling Stock Corporation
DfM	Design for Manufacturing
DOE	Department of Energy
EMDEs	Emerging Markets and Developing Economies
EPC	Engineering, Procurement, and Construction
ERA	Electricity Regulation Amendment
ERAA	Electricity Regulation Amendment Act
ERC	Energy Regulatory Commission
EV	Electric Vehicle
EVOSS	Energy Virtual One-Stop Shop
FiP	Feed-in Premium
FNMC	National Fund for Climate Change
G20	Group of Twenty
GRA	Global Renewables Alliance
GVA	Gross Value Added
GW	Gigawatt
GWh	Gigawatt hour
GWEC	Global Wind Energy Council
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IRA	Inflation Reduction Act
IRP	Integrated Resources Plan
KACARE	King Abdullah City for Atomic and Renewable Energy
KAUST	King Abdullah University of Science and Technology
KEGOC	Kazakhstan Electric Grid Operating Company
KPO	Krajowy Plan Odbudowy
LCOE	Levelised Cost of Energy
LCRs	Local Content Requirements
LDES	Long Duration Energy Storage
MAS	Monetary Authority of Singapore
MENA	Middle East and North Africa
MW	Megawatt
MRLs	Manufacturing Readiness Levels
NDC	Nationally Determined Contributions
NDRC	National Development and Reform Commission
NEA	National Energy Administration
NGHC	National Grid Hosting Capacity
NGO	Non-Governmental Organisation
NPI	New Product Introduction
NREP	National Renewable Energy Programme
NTB	Non-Tariff Barrier
NTCSA	National Transmission Company South Africa
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
OFW	Offshore Wind
PEP	Philippines Energy Plan
PFA	Power Purchase Agreement
PIF	Public Investment Fund
PPP	Public-Private Partnership
PPAs	Power Purchase Agreements
RE	Renewable Energy
RECs	Renewable Energy Certificates
REIPPPP	Renewable Energy Independent Power Producers Procurement Programme
REC	Renewable Energy Certificate
R&D	Research and Development
RFP	Request for Proposal
RPS	Renewable Portfolio Standard
SBCE	Brazilian Emissions Trading System
SAREGS	South African Renewable Energy Grid Survey
SAPP	Southern African Power Pool
SOFR	Secured Overnight Financing Rate
SPPC	Saudi Project Procurement Company
TCA	Trade and Cooperation Agreement
TCOMS	Technology Centre for Offshore and Marine, Singapore
TW	Terawatt
USD	United States Dollar
V	Used as part of Vestas turbine model names
VIC	Victoria
WTO	World Trade Organisation
ZEV	Zero Emission Vehicle

About GWEC Market Intelligence

GWEC Market Intelligence provides a seriesof insights and data-based analysis on thedevelopment of the global wind industry. Thisincludes a market outlook, country profiles,policy updates, deep-dives on global windsupply chain and offshore wind among manyother exclusive insights.

GWEC Market Intelligence derives its insightsfrom its own comprehensive databases, localknowledge and leading industry experts.

The market intelligence team consists ofseveral strong experts with long-standingindustry experience across the world.

GWEC Market Intelligence collaborates withregional and national wind associations as wellas its corporate members and MI subscribers.

Who can access GWEC Market Intelligence?

- GWEC corporate and association members
- Market Intelligence subscribers

Contact
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GWEC Market Intelligence Areas

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Market statistics, market outlook, auction updates, project pipeline

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Country profiles, policy updates, offshore updates

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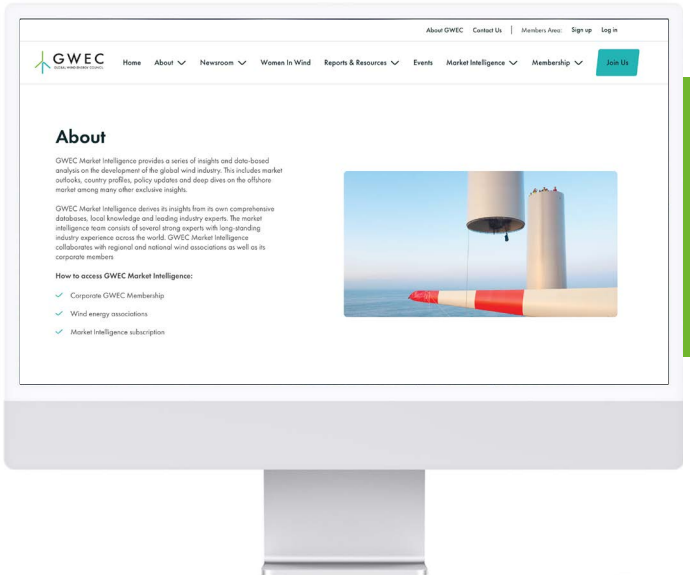
Wind turbine data, technology trends, component assessment, offshore wind installation vessels

Energy Transition
Shift to value-focused, new wind-based solutions, market design

O&M
ISP - OEM - Self Perform database for key markets



GWEC Market Intelligence is housed on a Members-only area on the GWEC website for our members and subscribers to have all of ourinsights on the global wind industry at their fingertips.

Click here to get your login

GWEC Market Intelligence Products in 2025

Product	Frequency	Expected Release date
1. Wind Energy Stats/Market Data		
Wind Stats 2024 (historic annual, accumulative, decommision data)	Annual	April 2025
Global Wind Report 2025	Annual	April 2025
Wind Energy Statistics (wind energy penetration rate, jobs)	Annual	April 2025
2. Country Profiles/Policy Updates		
Country Profiles Onshores/Country Profiles Offshore	Annual	April 2025 (onshore)/September 2025 (offshore)
Ad-hoc Policy Updates	Ad-hoc	
3. Market Outlook		
Global Wind Market Outlook 2025-2030 (Q1 and Q3) Database + Report	Semi-Annual	April 2025 (Q1 Outlook) November 2025 (Q3 Outlook)
India Market Outlook Report 2025-2030	Annual	TBC
4. Supply Side Data		
Global Wind Turbine Supply Side Data Report 2024 (by OEM, by technology, by turbine ratings, models and drive train, etc)	Annual	May 2025
5. Auctions/Tenders		
Global Wind Auction	Quarterly	Q4 2024 results - March 2025
Auction Trends and Learnings	Quarterly	Q1 2025 results - May 2025 Q2 2025 results - August 2025 Q3 2024 results - November 2025
6. Offshore Wind Market		
Global Offshore Wind Report 2025	Annual	June 2025
Market Entry Opportunities (database)	Annual/Quarterly	After each Global Offshore Wind Task Force meetting
Global Offshore Project Pipeline (database, in operation and under construction)	Annual/Quarterly	June 2025
Global Offshore Turbine Installation Vessel Database and Report	Annual/Quarterly	October 2025
7. Components Assessment		
Gearbox (Q4 2025), Generator (Q4 2024), Global Wind Supply Chain Deep Dive (Q4 2023), Blades (Q4 2020)	Special Report	December 2025
8. Wind Asset Owners/Operators		
Asset Owners and Operators Database (Onshore & Offshore Ranking)	Annual	July 2025
Asset Owners and Operators Status Report (including strategical trends)	Annual	
9. O&M		
O&M Service Provider Database (ISP - OEM - Self-perform)	Annual	February 2025
O&M Service Provider Status Report (including regional trends)	Annual	
10. Energy transition, Digitalisation, New Technologies		
Auction design, community engagement and social acceptance for permitting, localisation, industralisation, trade, supply chain and grid associated policy analysis	Special Report	Throughout the year

GWEC Global Leaders

The Global Wind Energy Council's Global Leaders are an exclusive leadership group of decision-makers and top-tier members who form the basis of the Association's Executive Committee, which drives the work programme and plays a major role in shaping GWEC's priorities for its efforts in the short and long-term strategy.

Siemens Energy
We are Siemens Energy – a global leader in energy technology. The energy transition is the greatest challenge our generation faces. How do we reduce emissions while also increasing energy supply? It is an uphill battle. And there is no silver bullet. But finding solutions has always been in our DNA. For more than 150 years our engineers have been spearheading the electrification of the world. Today we are a team of 100,000 sharing the same passion, vision and values. Our diversity makes us strong and helps us to find answers together with our partners. Located in 90 countries, Siemens Energy operates across the whole energy landscape. From conventional to renewable power, from grid technology to storage to electrifying complex industrial processes. Our mission is to support companies and countries with what they need to reduce greenhouse gas emissions and make energy reliable, affordable, and more sustainable. Let's energize society.

Ørsted
The Ørsted vision is a world that runs entirely on green energy. Ørsted develops, constructs, and operates offshore and onshore wind farms, solar farms, energy storage facilities, renewable hydrogen and green fuels facilities, and bioenergy plants. Moreover, Ørsted provides energy products to its customers. Ørsted is the only energy company in the world with a science-based net-zero emissions target as validated by the Science Based Targets initiative (SBTi). Ørsted ranks as the world's most sustainable energy company in Corporate Knights' 2022 index of the Global 100 most sustainable corporations in the world and is recognised on the CDP Climate Change A List as a global leader on climate action.

GE Vernova
Addressing the urgent need to build a more sustainable electric power system while improving the trajectory of climate change emissions are global priorities and we take our responsibility seriously. That is our mission at GE Vernova: continuing to electrify the world while simultaneously working to help decarbonize it. If we want our energy future to be different…we must be different. Our mission is embedded in our name. We retain our treasured legacy, "GE," in our name as an enduring and hard-earned badge of quality and ingenuity. "Ver" / "verde" signal Earth's verdant and lush ecosystems. "Nova," from the Latin "novus," nods to a new, innovative era of lower carbon energy that GE Vernova will help deliver. Together, we have The Energy to Change the World.

Iberdrola
With over 170 years of history behind us, Iberdrola is now a global energy leader, the number one producer of wind power, and one of the world's biggest electricity utilities in terms of market capitalisation. We have brought the energy transition forward two decades to combat climate change and provide a clean, reliable and smart business model, to continue building together each day a healthier, more accessible energy model, based on electricity

Vestas
Vestas is the energy industry's global partner on sustainable energy solutions. We design, manufacture, install, and service wind turbines across the globe, and with +151 GW of wind turbines in 86 countries, we have installed more wind power than anyone else.
Through our industry-leading smart data capabilities and +129 GW of wind turbines under service, we use data to interpret, forecast, and exploit wind resources and deliver best-in-class wind power solutions. Together with our customers, Vestas' more than 29,000 employees are bringing the world sustainable energy solutions to power a bright future.

Equinor
We are looking for new ways to utilise our expertise in the energy industry, exploring opportunities in new energy and driving innovation in oil and gas around the world. We know that the future has to be low carbon. Our ambition is to be the world's most carbon-efficient oil and gas producer, as well as driving innovation in offshore wind and renewables. We plan to reach an installed net capacity of 12-16 GW from renewables by 2030, two-thirds of this will be from offshore wind. With five decades of ocean engineering and project management expertise, focus on safe and efficient operations, in depth knowledge of the energy markets, skilled personnel and a network of competent partners and suppliers, Equinor is uniquely positioned to take a leading role in the offshore wind industry. From building the world's first floating wind farm to building the world's biggest offshore wind farm we are well underway to deliver profitable growth in renewables be a leading company in the energy transition.

Corio Generation
Corio Generation is a specialist offshore wind business dedicated to harnessing renewable energy worldwide. Our 20+ GW development portfolio is one of the largest in the world, spanning established and emerging markets, as well as floating and fixed-bottom technologies.

With our leading industrial expertise and deep access to long-term capital, we work closely with our partners in the creation and management of projects from origination, development and construction, and into operations.

Corio Generation is a Green Investment Group (GIG) portfolio company, operating on a standalone basis. GIG is a specialist green investor within Macquarie Asset Management, part of Macquarie Group.

CIP
Founded in 2012, Copenhagen Infrastructure Partners P/S (CIP) today is the world's largest dedicated fund manager within greenfield renewable energy investments and a global leader in offshore wind. The funds managed by CIP focuses on investments in offshore and onshore wind, solar PV, biomass and energy-from-waste, transmission and distribution, reserve capacity, storage, advanced bioenergy, and Power-to-X.

CIP manages ten funds and has to date raised approximately EUR 19 billion for investments in energy and associated infrastructure from more than 140 international institutional investors. CIP has approximately 400 employees and 11 offices around the world

SSE Renewables
SSE Renewables is a leading developer and operator of renewable energy, headquartered in the UK and Ireland, with a growing presence internationally. Its strategy is to lead the transition to a net zero future through the world-class development, construction and operation of renewable power assets and it is building more offshore wind energy than any other company in the world. Part of the FTSE-listed SSE plc, SSE Renewables is taking action to double its installed renewable energy capacity to 8GW by 2026 as part of its Net Zero Acceleration Programme, and increase renewables output fivefold to over 50TWh annually by 2031.

Envision Energy
Envision Energy is a world-leading green technology company, providing renewable energy system solutions for global enterprises, governments, and institutions. With the mission of 'solving the challenges for a sustainable future', Envision Energy continuously reduces the production, storage, and synergy costs of renewable energy through technological innovation. Encompassing three major business sectors - Smart Wind Turbines, Energy Storage, and Green Hydrogen Solutions, Envision Energy collaboratively constructs comprehensive solutions for energy transformation. It also manages Envision-Hongshan Carbon-Neutral Fund and owns Envision Racing Formula E team, who conquered the Formula E Teams' Championship in 2023.

Today, Envision Energy leverages its global network of R&D and engineering centers across China, the United States, UK, France, Germany, Denmark, etc. to continuously lead global green technology development. Envision Energy joined the Science Based Targets initiative (SBTi) and committed to achieving the "Business Ambition for 1.5°C" in 2021. It has achieved carbon neutrality across its global operations by 2022 and will achieve carbon neutrality throughout its value chain by 2028.

Envision was ranked second in Fortune's 2021 "Change the World" list and was ranked among the Top 10 of the 2019 'World's 50 Smartest Companies' by the MIT Technology Review.

Masdar
Abu Dhabi Future Energy Company (Masdar) is the UAE's clean energy champion and one of the world's fastest-growing renewable energy companies, advancing the development and deployment of renewable energy and green hydrogen technologies to address global sustainability challenges. Established in 2006, Masdar has developed and partnered projects in over 40 countries, helping them to achieve their clean energy objectives and advance sustainable development. Masdar is jointly owned by Abu Dhabi National Oil Company (ADNOC), Mubadala Investment Company (Mubadala), and Abu Dhabi National Energy Company (TAQA), and under this ownership the company is targeting a renewable energy portfolio capacity of at least 100 gigawatts (GW) by 2030.

Suzlon
The Suzlon Group is one of the leading renewable energy solutions providers in the world with ~20.7 GW* of wind energy capacity installed across 17 countries. Headquartered at Suzlon One Earth in Pune, India; the Group comprises of Suzlon Energy Limited and its subsidiaries. A vertically integrated organisation, with in-house research and development (R&D) centres in Germany, the Netherlands, Denmark, and India, Suzlon's world-class manufacturing facilities are spread across multiple locations in India. With over 29 years of operational track record, the Group has a diverse workforce of over 6,200 employees. Suzlon is also India's No. 1 wind energy service company with the largest portfolio of over 14.7 GW in wind energy assets. The Group has ~6 GW of installed capacity outside India. Suzlon offers a comprehensive product portfolio led by the 2 MW and 3 MW series of wind turbines.

Octopus Energy
At Octopus Energy Generation, we're building green power for the future. From large solar projects to wind farms which harness the abundant wind on land and at sea, to more localised, people-led renewables in the form of the Fan Club, the Collective and onsite generation connected directly to businesses - we're committed to driving the green energy revolution faster than ever before. We've invested in energy projects and energy transition companies spanning 20 countries and 18 technologies. As one of the largest renewable energy investors in Europe, we manage more than 270 large-scale green energy projects with a combined capacity of 3.9 GW. That's enough energy to power 2.6 million homes every year – and we're building more by the minute.

Mingyang Smart Energy
Founded in 2006, Mingyang Smart Energy Group (601615.SL, MYSE.L) is a leading smart energy provider with a diverse portfolio including wind, solar, storage, and hydrogen. We offer cutting-edge equipment, engineering, and services, and have built a robust eco-system for sustainable energy solutions. Recognized among China's top 500 and the global new energy elite, Mingyang partners with clients to drive technological innovation and support a green, low-carbon energy future. Mingyang is steadfast in its corporate mission of "Innovating Clean Energy for All." Leveraging the surging trend of global green and digital economic development, the company is committed to creating "new quality productivity." It reshapes technological innovation and the industrial chain layout, actively steering towards "global clean energy intelligence" and "inclusive clean energy." Mingyang is dedicated to building a comprehensive circle and a cohesive group, completing the layout of the entire industry, ecology, and globalization of new energy. By constructing a high-quality and sustainable industrial ecosystem, Mingyang expands application scenarios and creates a "new model" of energy transformation. This not only aids the green and low-carbon transformation of global energy but also propels Mingyang forward on the global track of the green economy, striving to become a world-class enterprise.

WOMEN IN WIND GLOBAL LEADERSHIP PROGRAM

Advancing Gender Equality in Wind and Renewables

The wind energy sector is a critical pillar of the global energy transition, yet as with the tradition energy industry it struggles with gender disparity. Women make up approximately 21% of the workforce in the wind energy sector, but their representation drops further in key areas, with only 8% in leadership positions and even fewer in technical roles. While gender equality is often framed as a moral or social issue, there is growing evidence that increased gender equality enhances business performance, innovation, and industry sustainability. This case study examines the state of gender diversity in the wind sector, the business case for inclusion, challenges to implementation, and real-world initiatives that are driving progress.

The Current State of Gender Representation in Wind Energy

Despite the industry's rapid growth, women remain underrepresented in key areas such as engineering, operations, and leadership. One challenge is the persistent "pipeline problem," where fewer women enter STEM fields, limiting their presence in renewable energy careers. However, this is not just a supply issue—systemic barriers such as workplace culture, lack of mentorship, and unconscious biases also contribute to gender disparities. Addressing these issues requires intentional policies and industry-wide collaboration.

The Business and Economic Case for Gender Diversity

Studies consistently link gender diversity with improved financial performance, innovation, and operational efficiency. According to McKinsey, companies in the top quartile for board-gender diversity are 27% (Dixon-Fyle, et al., 2023) more likely to outperform financially. Diverse teams bring broader perspectives, leading to better problem-solving, enhanced safety protocols, and stronger stakeholder engagement. Additionally, gender-inclusive workplaces tend to have higher employee retention, reducing recruitment and training costs.

Addressing Key Challenges and Industry Resistance

While the benefits of gender diversity are clear, resistance remains. Some argue that hiring quotas compromise meritocracy, while others cite the physical demands of field-based wind energy jobs. However, technological advancements have reduced physical barriers, making these roles more

accessible to all genders. Similarly, concerns about forced diversity initiatives can be addressed by focusing on skills-based hiring while expanding mentorship and training programs for women.

Another common criticism is that gender diversity initiatives do not yield immediate financial benefits. While some impacts may take time to materialise, long-term studies show that inclusive work environments lead to greater resilience, talent retention, and overall industry growth.

Case Study: Women in Wind Global Leadership Program

A leading initiative addressing gender disparity in the wind industry is the Women in Wind Global Leadership Program, launched by the Global Wind Energy Council (GWEC) and the Global Women's Network for the Energy Transition (GWNET). This program provides mentorship, leadership training, and networking opportunities for women in the sector. Many participants have gone on to take leadership positions in the industry, demonstrating the power of targeted support. The success of this program highlights the effectiveness of investing in gender-inclusive policies and capacity-building.

Recommendations for Industry Stakeholders

To accelerate gender equality in the wind sector, key actions include:

- Setting measurable gender diversity targets for hiring and leadership roles.
- Expanding STEM education initiatives to encourage women to enter renewable energy fields.
- Establishing mentorship and sponsorship programs to support career progression.
- Promoting inclusive workplace cultures through unconscious bias training and equal pay policies.

Gender equality is not just a social goal but a strategic advantage for the wind energy sector. By fostering inclusivity through initiatives like the Women in Wind Global Leadership Program, companies can unlock new opportunities for innovation, collaboration, and long-term sustainability. The wind industry must continue to champion diversity as a key driver of success in the global energy transition.

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