GWEC | GLOBAL WIND REPORT 2024

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Word from the Chairman

Jonathan Cole
CEO of Corio Generation and
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Meeting the challenge of our times requires ambition and courage: The ambition to be bold and think big in the pursuit of a clean energy future, and the courage to make the tough choices to fulfil that ambition.

When nearly 200 governments at COP28 in Dubai agreed the historic goal to triple renewable energy capacity, they demonstrated the ambition that will be needed to transition away from fossil fuels, limit the global temperature rise and avert the worst impacts of climate change.

Now comes the hard part. The part where we must take the bold decisions necessary to make this goal a reality.

Looking at this year's Global Wind Report, we can see strong progress by the wind industry in commissioning huge volumes of renewable energy. 2023 saw the highest number of new installations in history for onshore wind (over 100 GW) and second highest for offshore wind (11 GW). We passed the symbolic milestone of 1 TW installed globally and, at the current rate, we expect to hit 2 TW before 2030.

Nonetheless we must acknowledge, firstly, that this rate of growth still leaves us far short of the tripling target and, secondly, that our sector has been tested by the tough macroeconomic environment. Global inflationary pressures, rising cost of capital and fragility in the supply chain have affected our ability to ramp up in many regions.

Given the urgency of the action needed, we do not have time to retreat and wait for these problems to go away – we need decisive action by our political and industrial leaders to address the big challenges before us.

This means countries taking steps to derisk and accelerate deployment of renewables by prioritising early investment in the grid and transmission infrastructure and moving swiftly to streamline permitting processes.

It requires political leaders who are willing to spend political capital by sending clear signals to the market that the energy transition is inevitable, who pursue fiscal and practical measures designed to encourage supply chain growth, and who remove barriers to free trade that – whilst tempting in the short-term – are only likely to delay and increase the cost of the energy transition.

To incentivise new renewable energy projects, we need regulatory frameworks that measure the true value of the electrons we deliver, at a fair price, according to the full spectrum of services they provide: In addition to powering homes and businesses, the wind farms that GWEC members are building today will decarbonise the economy, reduce dependence on volatile fossil fuels, enhance security of supply, improve energy price stability, generate jobs and career opportunities, stimulate economic development and reinvigorate neglected communities.

Around the world, we are beginning to see the positive impacts of major policy interventions designed to incentivise new projects. Landmark legislative accomplishments such as the US Inflation Reduction Act, the EU's Wind Power Package and China's Five-Year Plan serve as recent exemplars of political statements being met with concrete actions.

When you consider everything we have already achieved, having the courage of our convictions feels much less like a leap of faith. Wind energy has never been more in demand and, with a little resolve and determination, I am certain this industry will emerge stronger, more resilient and more confident in its future than it has ever been before.

Building a confident wind industry in a 3X renewables world

Ben Backwell
CEO, Global Wind Energy Council

The wind industry is in a pivotal moment.
The historic COP28 adoption of a target to triple renewable energy by 2030 to accelerate the energy transition onto a Paris Agreement trajectory showed the extent to which the world is relying on wind energy to reach its climate goals.

Among policymakers and international institutions, there is a strong understanding that the world must accelerate installations of readily available technologies – namely wind and solar PV – if the world is going to move to a cleaner, modern and more flexible energy system in the timeframe required.

This places both a unique opportunity and a unique challenge in front of our industry. Essentially, as outlined in this year's Global Wind Report, we need to accelerate wind energy installations from a level of 117 GW in 2023 to at least 320 GW of annual installations by 2030. This tripling of annual wind installations would bring us to around 3 TW of cumulative wind energy capacity by the end of the decade.

It took us over 40 years to reach the 1 TW mark of worldwide installed wind power. We now have just 7 years to install the next 2 TW.

While this is possible, it will require an unprecedented level of focus, determination, collaboration and ingenuity to reach the goal.

Industry growth is speeding up, and once again the industry broke a new annual record in 2023. But so far, growth has been overly concentrated in the key markets of China, the EU, the US, India and Brazil.

An unprecedented number of countries have now established ambitious national targets – particularly those with strong offshore resources – including major industrial economies and large emerging markets such as Japan, South Korea, Australia, Vietnam, the Philippines and Kenya. Supporting these countries to push through regulatory complexity and scale up investment will play a big part in accelerating wind installations beyond 300 GW per year.

However, there are still many parts of the world where growth has been sluggish or non-existent, particularly in the Global South. Policymakers and investors will need to work hard to come up with better solutions for the millions of people in areas like sub-Saharan Africa to ensure that they too can play a role in the energy transition, and gain access to clean electricity and sustainable economic growth opportunities.

At present, market frameworks are still rewarding investment in fossil fuels, while companies in renewable energy and other key transition areas see thin returns and sluggish equity valuations. Concerted effort will be needed to ensure enough finance flows to renewables, to remove planning barriers, and to ensure that the supply chain can grow to the level needed to keep the transition moving.

But there is a strong case for optimism. Climate diplomacy is arguably the single most collaborative, action orientated, rules-based, multilateral discussion in the world right now. After 28 COP meetings, we are seeing the world sitting down seriously to discuss increasing climate action, preparing for fossil fuel phase out, and pledging to achieve 3X renewables and net zero. The push for 3X is slowly but surely filtering into targets, policy and regulation as governments look to the means

on hand – essentially wind and solar PV – to meet their climate commitments.

The Global Renewables Alliance – initiated by GWEC and the peer global renewable technology associations to create a combined voice – has found massive public and political support for its message of "Double Down, Triple Up, Time 4 Action."

Meanwhile, the three main emitting blocs, China, the US and Europe, are all taking unprecedented action to speed up emissions reduction and build green industries, with massive programs of policy, regulatory and financial support. This is already having a big effect, with record installations in China, an approaching installation rush for onshore and offshore in the US and positive effect of new regulatory urgency in the key European market of Germany.

GWEC is working hard with governments, stakeholders and companies to continue working through the bottlenecks in countries around the world – many highlighted in the Global Wind Report's Markets to Watch – through initiatives such as the Global Offshore Wind Alliance, the Ocean Energy Pathway technical assistance programme, Women in Wind, our work on supply chains and other activities.

The shift towards greater urgency and action is hugely positive. But at the same time, we face increased economic and social volatility, the predominance of geopolitics and a return to widespread military action. These days, as the UN Secretary General has lamented, countries seem to turn to force before thinking of the wider consequences.

Governments will need to find the right balance between national industrial policy on the one hand, and maintaining open global trade, competition and innovation on the other. We need to try very hard to make sure that healthy competition for leadership in the energy transition does not turn into rivalry, protectionism, trade wars, deepened inequity for the Global South and a race to secure materials at the expense of others.

International collaboration, dialogue and managed competition: these will continue to be the bedrock of economic growth and the energy transition in the coming period.

The alternative is a fragmented world and military conflict, and an inward-looking, more hostile political climate where extremist ideas and false narratives can run wild. In my view, this "dark domino" scenario would have dire impacts for the transition and renewable energy sector.

The wind industry can't fix all these problems, of course. But it can help fix the most important – runaway climate change – while injecting positivity and hope into society's discussion and providing a pathway to a fairer and more prosperous planet. We can push for collaboration across geographies and cultures, inclusivity, building new and unprecedented mega engineering projects that are truly awesome – these are some of the things which we can contribute as we expand and mature as a sector.

The challenges are many. But the important thing is put fear aside and take the concrete steps every day that are needed to overcome them.

Working together, we are confident that the wind industry will contribute to the building of the Confident Green World that we all wish to see.

Translating vision into reality

In the last few years, the world has awakened to the disastrous impacts of climate change, leading to global consensus by governments, industries and stakeholders across the value chain on committing to ambitious climate targets. As we shifted our focus from discussions to decisions, the global goal to triple renewables by 2030 emerged as a sustainable course of action at COP28, promising a triple bottom line of environmental, economic and social benefits.

> To realise the true potential of global supply chains, we must leverage regional excellence to uphold a unified purpose of locally made, globally sourced.

In unprecedented unison, more than 130 countries agreed to triple renewable energy capacity to at least 11,000 GW by 2030 to phase out fossil fuels and meet the 1.5°C global warming threshold. We need a similar collective resolve for the implementation strategies for this goal. This is a mammoth task demanding integrated multi-stakeholder action with a larger synchronisation of priorities, effort and innovative financing.

Amidst the passion for climate action, let's keep reminding ourselves that goal-setting is a long-term exercise. However, implementation requires well-aligned short- and medium-term decisions specific to countries, industries and resources.

The hour calls for policymakers and industries to work together to resolve bottlenecks and boost renewables adoption. This requires agility in local policy actions centred around project permitting, technology suitability, manufacturing preparedness, supply chain development and grid infrastructure readiness to support decentralised green power development and manage unstable market mechanisms (see Chapter 2).

Building a resilient supply chain

Since every country has a different set of challenges, including economic environments and manufacturing ecosystems, governments must champion domestic-friendly policies and systems based on their own regulatory and geopolitical scenarios to scale and maintain secure supply chains for renewables.

To realise the true potential of global supply chains, we must leverage regional excellence to uphold a unified purpose of "locally made, globally sourced." Arriving at that delicate balance of convergence and diversification to promote local interests, protect against geopolitical risks and enable the ramp-up of renewables should be a global priority.

Leveraging the Global South

Thus far, the green energy revolution has largely been driven by the Global North. However, the awakening of the Global South presents a momentous proposition of bringing in

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SUZLON
POWERING A GREENER TOMORROW

Renewables can help democratise energy through global trade and innovative climate action instruments.

enormous demand for clean energy to fuel rapidly growing economies. Countries in the Global South also have the potential to become the leading cost-efficient technology and supply chain partners.

At present, countries face the challenges of balancing global versus local supply chains, as well as the speed versus the price at which to develop renewables.

Green financing for tripling renewables

During the last five years, investments in renewables have outpaced those in other power sectors, reaching nearly $700 billion, according to the IEA. However, global investments in renewables, grid and storage infrastructure need to increase to around $2 trillion per year to realise the tripling renewables target (see Chapter 1).

Today, renewables are one of the cheapest energy sources in the world. With consistent and equitable financing, governments have the opportunity to revitalise their economies with manufacturing, power generation and green jobs, and also meet their energy security needs in the process.

Renewable energy is a great equaliser for countries less equipped to contribute to climate action, helping build competitive economies through distributed resources and decentralised generation. A catalyst for economic growth, renewables can help democratise energy through global trade and innovative climate action instruments, thereby uniting a fragmented world and offering an equitable, healthier future for all.

The world must now unite around action

COP28 concluded with the historic UAE Consensus, driving forward a global commitment on climate action. With this clear mandate, the world must now collectively unite around action, accelerating the energy transition by delivering clean energy solutions that support the tripling of global renewable capacity.

Wind energy is a critical component in reaching these ambitions, and it is against that backdrop that GWEC's Global Wind Report 2024 provides an important review of the progress that has been made in the global wind sector. With 117 GW added last year, installed wind power capacity worldwide has surpassed 1 TW, equivalent to the entire fleet of clean and conventional power of the US. Progress is being made and there is much to be proud of.

In line with the report's findings, 2023 was a record year for Masdar's growth in the global wind sector as well. It included an £11 billion landmark agreement with RWE to co-develop the 3 GW Dogger Bank South Windfarm in the UK, one of the largest planned offshore wind projects in the world, as well as a €15 billion strategic partnership agreement with Iberdrola to evaluate the joint development of offshore wind in the UK and other key markets like the US and Germany.

Closer to home, Masdar inaugurated the UAE Wind Program, bringing utility-scale wind to the UAE for the first time and leveraging innovative, state-of-the-art, low wind speed technologies that will pave the way for future projects in other low wind speed geographies.

It is clear that wind is continuing to generate great momentum in every corner of the globe. Yet, as this year's report outlines, the current trajectory in wind energy is not sufficient if we are to triple renewable energy capacity to 11,000 GW by 2030. The Global Wind Report 2024 highlights a similar trend in new renewable energy capacity in general, where a small number of nations are responsible for most new installations, predicating an unequal energy transition.

Investment must accelerate, supply chains need to be strengthened, trade barriers must be reduced, regulatory obstacles like licensing, permitting and auction design for both seabed rights and revenues must be addressed, grid infrastructure needs to be expanded and overall collaboration should increase so that industry can scale up at pace. Financing, particularly of projects in the Global South, must be a priority, supporting vulnerable communities, generating economic opportunities, and in turn, delivering social impact.

This is another area that Masdar is playing a leading role in through

It is clear that wind is continuing to generate great momentum in every corner of the globe.

Mohamed Jameel Al Ramahi
CEO, Masdar

Financing, particularly of projects in the Global South, must be a priority, supporting vulnerable communities, generating economic opportunities, and in turn, delivering social impact.

our platform Infinity Power, the largest pure-play renewable energy company on the African continent with wind projects across South Africa, Egypt and Senegal.

To get to where we need to go, the same resilience and determination that has resulted in wind power capacity passing the 1 TW milestone in 2023 is required. With global alignment under the UAE Consensus, we at Masdar are confident that nations and energy leaders around the world will put into practice the policies, regulation and investments needed to unlock the full potential of clean energy and help drive the energy transition forward.

EXECUTIVE SUMMARY

Joyce Lee
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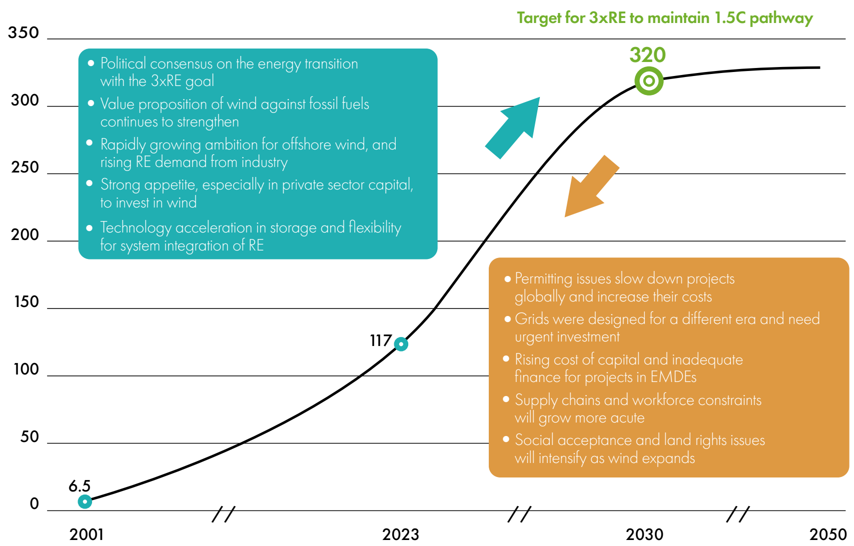
The Story: Wind energy and the global goal to triple renewables by 2030

When the gavel fell at COP28 at the end of 2023, a historic milestone was reached: Nearly 200 governments agreed on the need to triple renewable energy capacity globally and double energy efficiency improvements by 2030, to get on-track for a pathway that limits global warming to 1.5°C. Wind energy was also recognised in the final decision text as a key climate change mitigation technology, which has become increasingly cost-effective and available.

The last year gives cause for hope that wind energy can significantly contribute to this landmark goal. There is rising political ambition on the global energy transition, as well as recognition at the highest diplomatic and institutional levels of the urgency to close the "say/do gap" when it comes to implementing renewable energy targets. In 2023, a record-high 117 GW of new wind power was installed worldwide, representing a 50% hike from the previous year, which reflects the resilience of the industry even as it faced prolonged supply chain and macroeconomic difficulties.

The shift of clean energy into the heart of national industrial policy for major economies, combined with gathering momentum in offshore wind and promising ambition among emerging markets and developing economies (EMDEs), has prompted a more optimistic growth outlook from GWEC for total new wind additions through 2030 – increased by 107 GW, compared to last year's outlook.

Wind energy installations need to triple by 2030, but face competing pressures on growth in this crucial period



Source: GWEC Market Intelligence.

But the road to tripling global renewables in this decade is far steeper, to say the least, and lined with daunting challenges. **Global wind growth needs to rapidly accelerate, with annual wind installations roughly tripling to at least 320 GW over the course of the decade.** This pace of installation raises questions across the areas of investment and financing, supply chain, infrastructure buildout, land and seabed availability, social acceptance and more.

There are plenty of promising tailwinds, from strengthening demand signals for renewable power to technology acceleration that paves the way for large-scale system integration. At the same time, the global wind industry faces downward growth pressure from policy and regulatory areas like permitting complexities and timelines to grid bottlenecks to land rights issues around the world.

Widening wealth gaps between the Global North and South have been exacerbated by rising inflation and cost of capital. Trade distortions and geopolitical fissures have resulted in a fractious public discourse on building resilient global clean energy industries, and dimmed future forecasts for world trade growth.[1]

Like other industries, wind energy is still on the road to recovery from the reverberating impacts of COVID-19 and the invasion of Ukraine. This year, there are 2 billion people expected to go to the polls in presidential or legislative/parliamentary elections in more than 60 countries, which could send further shockwaves – some positive, and some less so – across the renewables sector.

Navigating these competing and multidimensional pressures on growth is an unwieldy task, but vital to keeping the narrowing 1.5°C window alive. A difference of a few percentage points of wind energy growth could make a material difference to the global warming trajectory – and that delta represents cleaner and more secure energy systems, as well as positive transformation for countless lives and communities.

Facing these choppy waters ahead, it will take courage, conviction and radical collaboration for wind energy to achieve its anticipated role in the tripling renewables goal, or get as close to it as possible. How the wind industry acts and advocates on increasingly complex issues, from global trade of clean energy to interactions with communities hosting projects, will determine whether we ultimately deliver a just and equitable transition.

Global Wind Report 2024 examines four areas – investment, supply chains, system infrastructure and public consensus – which will set the conditions for wind energy growth to take off through 2030 in pursuit of the tripling renewables goal. While not an exhaustive list, GWEC considers these domains as critical for meaningful engagement to mitigate the risks of an unstable and disorderly transition.

This year's report also delves into the potential pinch points that accompany the present-day technological era: a rapid innovation cycle in wind technology which undermines business profitability and risks product quality; interest groups actively using technology and social media to foment disinformation on climate change and renewables; robotics, artificial

1. IMF, World Economic Outlook Update, January 2024: Moderating Inflation and Steady Growth Open Path to Soft Landing, 2024.

intelligence (AI) and automation introducing further disruptions to labour and workforce planning; and a digitalisation gap between countries which impacts their capacity to allocate land, permit projects and operate smart, modern grids.

Each section includes a list of recommendations on improving the conditions for wind growth. The common thread among these recommendations is deeper and more robust forms of collaboration between the wind industry, policymakers, investors and communities, from enhanced cross-sector dialogue at the global level to embracing more flexible expectations at the community level.

Finally, the report builds on the need to ensure a significant and beneficial role for the Global South on the road to the tripling renewables goal. As such, we have expanded the Markets to Watch section, showcasing the growth opportunities for wind energy from Egypt to the Philippines.

Here are the top 12 takeaways from this year's Global Wind Report on the role of wind energy in achieving the global goal to triple renewables by 2030:

1. **Meaningful action is needed to mobilise larger volumes of investment into wind energy:** This will need an "all hands on deck" approach to shift market design into models that incentivise large-scale renewable growth and, especially in the case of EMDEs, to enhance public/private partnerships to mobilise investment. Without deliberate realignment of investment with the principles of equity and fairness, reflected in a balanced North-South distribution of capital, benefits, knowledge transfer and technology, the goal of tripling renewables will not materialise.

2. **Growth at scale comes with stable and ambitious policy environments that offer reasonable returns on investment:** Recognition of the wider societal and socioeconomic net benefits of wind energy can help to drive uptake of the technology, foster more sustainable remuneration schemes and secure higher project realisation rates.

3. **Collaborate to build a secure global supply chain with healthy, managed competition:** Governments can address domestic policy and regulatory barriers to support confidence in future supply chain investments. Policymakers should also adopt a balanced approach between pursuing supply chain diversification and strategic onshoring, while maintaining the global interlinkages of the supply chain, so as not to interrupt/delay project deployment or the wider energy transition.

4. **Trade policy should foster competitive industries, not push higher costs onto end-users:** Rather than pursuing defensive mechanisms which could enhance trade barriers, governments should focus on incentivising strategic segments of the domestic industry, creating a more attractive market environment by ensuring adequate pricing and returns, making competitive

finance available and removing bureaucratic barriers.

5. **New production models are needed to industrialise and decelerate the turbine platform race on size:** Cooperation amongst industry should shift into multilateral technical partnerships and taskforces which focus on innovation, standardisation and ESG assurance. The transfer of knowledge and technology from the North to the South is crucial for a just transition, and will require wide-ranging dialogue and agreements on "rules of the road" and fair partnerships.

6. **Ensure the advantages of AI and machine learning outweigh the drawbacks:** AI can be harnessed for supply chain efficiencies and siting optimisation, among other uses, but will impact workforce planning in the transition and carries attendant risks. Industry and authorities should collaborate on understanding the opportunities and risks presented to the clean energy sector, including good practice and risk management frameworks on cybersecurity and data-sharing.

7. **Close the gap on grids:** Grids must become a national and cross-cutting policy priority for countries to meet their energy security, climate and economic growth goals. This will require clearer targets for grid investment and system flexibility, anticipatory funding and investment in buildout, as well as public support for grid expansion. Cross-border grid integration also needs to be in the toolbox for implementing the tripling renewables goal and distributing its benefits.

8. **Scale modern and flexible power systems:** Policymakers should prepare to utilise storage, demand-side response and other flexibility solutions. Otherwise, disjointed efforts to build out renewables while underinvesting in grid and flexibility infrastructure could lead to power system inefficiencies and wider gaps in clean energy access, ultimately undermining the transition.

9. **Action to accelerate permitting of wind projects:** The expansion of wind energy will require early, extensive and effective engagement and a shared understanding of what that will mean for communities, nature and users of land/sea spaces. Policymakers, industry and communities can collaborate on a number of actions, from proactive dialogues to establishing centralised permitting authorities.

10. **Community engagement is more critical than ever:** Meaningful community engagement and respect for indigenous rights are of vital importance for the successful expansion of wind energy, while preserving cultural heritage and traditional ways of life. Participatory and inclusive engagement with impacted communities over wind farm lifetimes at project level is important to safeguard growth at sector level.

11. **Guard against misinformation and disinformation that sow doubt in wind and renewable energy:** Misinformation can reduce trust in the wind industry, at a time when the world needs an accelerated roll-out of renewables. Effective strategies

are required that push back against cynicism and turn the tide in favour of a renewable energy-powered world.

12. **The global wind industry must fulfil its role in delivering a just and equitable transition:** Scaling wind energy requires socioeconomic cohesion around the transition agenda. The industry can contribute by fostering a diverse, equitable and inclusive workforce, collaborating with governments on facilitating pathways for workers from carbon-intensive industries, and working with stakeholders on strong governance and decent work across the wind value chain, including in upstream mining and production.

Feng Zhao
Head of Strategy and
Market Intelligence, GWEC

The Data: 2023 was the wind industry's best year

The wind industry experienced its most successful year on record in 2023, with installations increasing by 50% year on year (YoY). Despite the world being fully open following the global health crisis sparked by COVID-19, 2023 remained an unusual year due to the challenging macroeconomic environment, rising and ongoing hostilities, the Red Sea crisis and prolonged supply chain disruptions stemming back to the time of Russia's invasion of Ukraine.

Connecting 117 GW of wind power capacity to the electricity grid in a single year not only demonstrates the remarkable resilience and adaptability of the wind industry but also shows that the world is moving in the right direction in combating climate change.

Market status

Thanks to the 117 GW of new wind power installations, global cumulative wind power capacity passed the first 1 TW milestone in 2023, showing YoY growth of 13%.

In the onshore wind market, 106 GW was fed into the grid last year, representing YoY growth of 54%. This milestone marks the first time that over than 100 GW of new onshore wind capacity was installed worldwide within a single year. At the country level, China and the US remained the world's two largest markets for onshore wind additions, followed by Brazil, Germany and India. Together, the top five markets made up 82% of global new installations in 2023, collectively 9% higher than the previous year.

After two years of relatively 'low' growth, onshore wind installations in China bounced back in 2023 with more than 69 GW commissioned, a new record. In the US, despite a last-quarter rush, with developers installing more new wind capacity in Q4 2023 than in the previous three quarters combined, only 6.4 GW of onshore wind capacity was added for the entire year, the lowest level since 2014.

At the regional level, Asia Pacific and Latin America had record years with more than 75 GW and 6 GW of onshore wind capacity added, respectively, mainly thanks to dramatic growth in China and Brazil.

New additions in Europe and Africa & Middle East did not surpass last year's record. However, both two regions still experienced their second-best years in terms of new onshore wind installations.

Total onshore wind additions in North America dropped to 8.1 GW last year, 16% lower than 2022. The decline was driven primarily by the slowdown of onshore wind growth in the world's second-largest wind power market – the US.

In the offshore market, 10.8 GW of new offshore wind was commissioned in 2023, bringing total global offshore wind capacity to 75.2 GW. Offshore wind additions were 24% higher than in 2022, making 2023 the second-highest year for new offshore wind capacity.

China led the world in annual offshore wind development for the sixth year in a row with 6.3 GW commissioned in 2023, making up

58% of global additions and bringing its total offshore wind installations to 38 GW, 3.7 GW (11%) higher than Europe. Elsewhere in the APAC region, three markets commissioned new offshore wind capacity last year: Taiwan (China) (692 MW), Japan (62 MW) and South Korea (4 MW).

Thanks to strong growth in the Netherlands, Europe had a record year in 2023, with 3.8 GW of new offshore wind capacity commissioned across six markets. This brought Europe's total offshore wind capacity to 34 GW by the end of 2023, 43% of which was in the UK and 24% in Germany.

The US had two utility-scale commercial offshore wind projects – Vineyard Wind 1 and South Fork Wind – under construction last year, but no offshore capacity was fully commissioned in 2023. Nevertheless, the US remains the only market with offshore wind in operation outside of Europe and APAC.

In total offshore wind installations, China took over the crown from the UK in 2021 and further consolidated its global market share in the past two years. Germany, the Netherlands and Denmark are the other three markets that make up the top five, as in 2022.

Although Europe relinquished its title as the world's largest offshore wind market in 2022, it remains the global leader in floating wind. The region commissioned 37 MW of floating wind capacity last year, making up 79% of floating wind additions in 2023 and bringing the region's total floating wind capacity to 208 MW, equal to 88% of global installations.

Market Outlook

The inclusion of a global goal of tripling renewable energy by 2030 in the final COP28 text is unprecedented and historic for wind and other renewable energy technologies. As a result, the wind industry is becoming more optimistic about its short-term and long-term growth, and more confident about its role in achieving the tripling target.

With a favourable political environment across the globe, GWEC Market Intelligence believes that 791 GW of new capacity is likely to be added in the next five years under current policies. This equals 158 GW of new installations each year until 2028. Five pillars will underpin this level of success in the next five years:

- Europe is accelerating development of renewables to achieve energy security in the aftermath of Russia's invasion of Ukraine. The continent has started turning its ambitious targets into actions from 2023.
- The US has implemented what has been called the largest investment in climate action the world has ever seen – the Inflation Reduction Act (IRA), helping to, not only, deliver new clean power over 2023-2032, but also to create a local supply chain, jobs and society-wide benefits.
- Clean energy has become the top driver of China's economic growth. Driven by the '30-60' pledge, the Chinese government has set the target that non-fossil energy sources will account for over 80% of total energy consumption by 2060.
- After a turbulent 2023, governments and developers have reaffirmed their commitments to develop offshore wind. Floating wind technology, as well as Power-to-X solutions, will further unlock offshore

wind's potential in supporting the global energy transition.

- Growth in emerging markets from Southeast and Central Asia to MENA countries is expected to gain momentum from the middle of this decade.

The compound annual growth rate (CAGR) for onshore wind in the next five years is 6.6%. We expect average annual installations of 130 GW. In total, 653 GW is likely to be added in 2024-2028. Growth in China, Europe and the US will remain the backbone of global onshore wind development in the next five years. Altogether, they are expected to make up more than 80% of the total capacity to be built in 2024-2028.

The CAGR for offshore wind in the next five years is 28%. In total, 138 GW of offshore wind capacity is expected to be added worldwide in 2024-2028. Annual offshore wind additions are likely to triple by 2028 from 2023 levels, bringing its share of new global installations from today's 9% to 20% by 2028. China and Europe will continue dominating the growth in 2024-2025. However, the US and emerging markets in APAC will start gaining sizable market share from 2026. By the end of the forecast period, annual installations outside China and Europe are likely to make up more than 20% of total additions.

GWEC Market Intelligence believes that the growth momentum will be retained beyond 2028. Compared with the 2030 global outlook released alongside last year's Global Wind Report, GWEC Market Intelligence has increased its forecast for total wind power capacity additions for 2024-2030 by 107 GW (YoY growth of 10%), primarily driven by the upgraded outlook in China and Europe.

GWEC forecasts that the milestone of a second TW is likely to be passed by the end of 2029, one year ahead of our previous year's projection – provided the anticipated growth materialises in the five key wind markets mentioned above. However, even this growth is not rapid enough to enable the world to achieve its Paris Agreement targets, and will leave a sizeable gap in the wind energy capacity required by 2030 to stay on track for the IEA's Net Zero by 2050 pathway. The areas of permitting, supply chain, finance and grids will remain key for forecast growth to materialise, and to ramp up growth beyond this for net zero.

WIND ENERGY: MEETING THE GLOBAL GOAL TO TRIPLE RENEWABLES BY 2030

Introduction

Where we are and where we need to go

2023 was a record year for renewables, with new installations of 510 GW – an increase of nearly 50% compared to the previous year.[1] It was also a historic year for wind installations, as the world added 106 GW of onshore wind and 10.8 GW of offshore wind. This brought the industry to record-high growth, even while facing notable challenges and headwinds around permitting timelines, grid availability and a volatile macroeconomic environment.[2]

However, even the pace set in this record year for renewables will not be enough to get the world on-track for a pathway that limits global warming to 1.5°C, nor to reach the global goal to triple renewable energy capacity to 11,000 GW by 2030, as agreed by nearly 200 countries at COP28 (see "How did countries commit to "Double Down, Triple Up" at COP28?" below).

By 2030, GWEC forecasts we are set to reach 2 TW of installed capacity under current policies. This will fall notably short of the volume of cumulative wind energy installations required globally to meet the goal of tripling renewable capacity.

International energy agencies and net zero roadmaps agree on the primary role of wind energy to meet this goal, though the figures vary slightly. IRENA's World Energy Transitions Outlook foresees 3,040 GW of cumulative onshore wind by 2030 and 494 GW of offshore wind by 2030, or about 3.5 TW of total wind installed by 2030.[3] The IEA's Net Zero by 2050 Scenario (2023) calls for 320 GW of wind installations in 2030, and a total of 2.75 TW of global wind capacity by that time.[4]

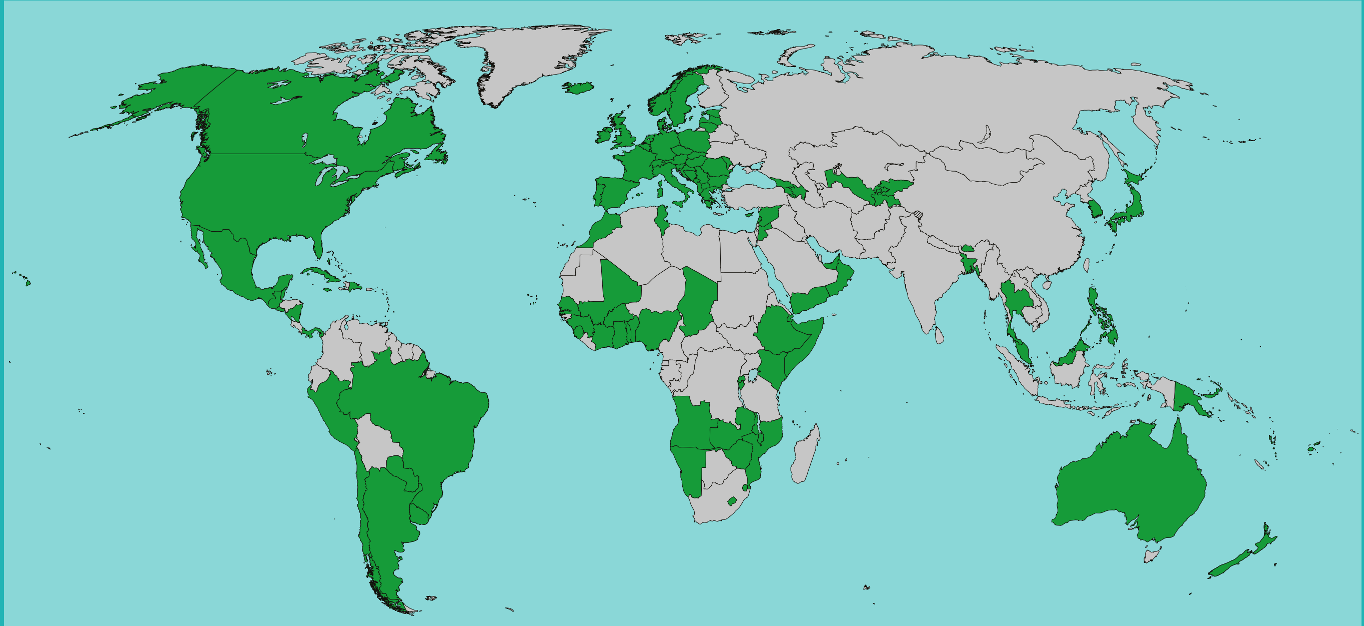
While the growth projections for wind differ, the conclusion is the same: **Global wind growth must rapidly accelerate to meet 2030 targets.** This will require annual wind installations to more than triple from current levels of 117 GW to at least 320 GW over the course of the decade.

So how do we get there? This report examines four areas – investment, supply chains, system infrastructure and public consensus – which will set the conditions for meeting the goal of tripling renewable energy capacity by 2030. While not an exhaustive list, GWEC considers these domains as critical for meaningful engagement and reform.

The global wind industry and policymakers must urgently collaborate (and in the case of public consensus, also establish better ways of working with communities) to resolve the bottlenecks to make progress in each of these areas. Only then will we be able to scale wind deployment at the necessary pace, creating a sustainable long-term pipeline of best-in-class projects that can meet global climate goals. This will also be a "win-win" for countries and communities by lowering energy prices, stimulating investment, economic growth and job creation, and supporting energy security.

1. IEA, Renewables 2023.
2. See GWEC's Global Wind Report 2023 and Global Offshore Wind Report 2023 for further detail on these challenges.
3. IRENA, World Energy Transitions Outlook 2023: 1.5°C Pathway, 2023.
4. IEA, Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach, 2023.

How did countries commit to "Double Down, Triple Up" at COP28?



132 countries signed up to the sideline Global Renewables and Energy Efficiency Pledge at COP28

The final outcome of the Global Stocktake (GST) process at COP28, which served as the cover text for the conference, called on Parties to COP to contribute to tripling renewable energy capacity globally and doubling the global average annual rate of energy efficiency improvements by 2030. This call, contained in Paragraph 28, recognised the role that tripling renewable energy plays in achieving the "deep, rapid and sustained reductions in greenhouse gas (GHG) emissions in line with 1.5°C pathways."

While the text itself is non-binding, it is still politically significant as Article 14 of the legally binding Paris Agreement outlines how the GST outcome should inform Parties in updating and enhancing their action on climate, including in international cooperation for climate action. Article 4 of the Paris Agreement specifies that this should include updates to countries' nationally determined contributions (NDCs) which are submitted every five years to communicate domestic climate actions, often including specific renewable energy targets and timelines.

By the time COP28 came to a close, 132 countries also signed up to the voluntary sideline Global Renewables and Energy Efficiency Pledge. This pledge recognised that global renewable energy capacity must triple to at least 11,000 GW by 2030, and energy efficiency improvements must double every year until 2030, to limit global warming in accordance with the Paris Agreement.

The 132 signatories committed to working together in this effort, accounting for "different starting points and national circumstances," and to take comprehensive domestic action to contribute to achieving the tripling target. This included collaboration in key areas like resilient value chains, expanding financial support and reducing cost of capital for renewable energy in developing countries, and accelerating cross-border grid connections.

Signatories also recognised some key enabling actions drawn largely from the report, "Tripling renewable power and doubling energy efficiency by 2030: Crucial steps towards 1.5°C," published by COP28, IRENA and the Global Renewables Alliance last year. These enablers include:

- Accelerate permitting of renewable projects and related infrastructure;
- Develop and expand grid

connections, and improve energy system integration;

- Provide clarity on market design and incentive schemes and strengthen market conditions and investment frameworks to facilitate investments in renewables and energy efficiency;
- Promote energy efficiency, electrification and energy demand management in all relevant sectors;
- Raise public awareness and encourage behavioural change;
- Encourage increased and meaningful, multiple-source private and public investments, particularly for developing countries;
- Enhance and scale new technological solutions, including through support in research, development and innovation.

Finally, signatories committed to reviewing progress towards this pledge annually until 2030. The countries which have committed to tripling renewable energy in this pledge, as of December 2023, are:

- Albania
- Andorra
- Angola
- Antigua and Barbuda
- Argentina
- Armenia
- Australia
- Austria
- Azerbaijan
- Bahamas (the)
- Bangladesh
- Barbados
- Belgium
- Belize
- Benin
- Bhutan
- Bosnia Herzegovina
- Brazil
- Brunei Darussalam
- Bulgaria
- Burkina Faso
- Burundi
- Cabo Verde
- Canada
- Chad
- Chile
- Colombia
- Comoros (the)
- Costa Rica
- Cote d'Ivoire
- Croatia
- Cuba
- Cyprus
- Czechia
- Denmark
- Djibouti
- Dominican Republic (the)
- El Salvador
- Estonia
- Eswatini
- Ethiopia
- Fiji
- European Union
- Finland
- France
- Gambia (the)
- Georgia
- Germany
- Ghana
- Greece
- Grenada
- Guatemala
- Guinea
- Hungary
- Iceland
- Ireland
- Italy
- Jamaica
- Japan
- Jordan
- Kenya
- Kiribati
- Kosovo
- Kyrgyzstan
- Latvia
- Lebanon
- Lesotho
- Liechtenstein
- Lithuania
- Luxembourg
- Malawi
- Malaysia
- Maldives
- Mali
- aMalta
- Mexico
- Micronesia
- Moldova
- Monaco
- Montenegro
- Morocco
- Mozambique
- Namibia
- Nauru
- Netherlands
- New Zealand
- Nicaragua
- Nigeria
- Niue
- North Macedonia
- Norway
- Oman
- Palau
- Panamá
- Papua New Guinea
- Paraguay
- Peru
- The Philippines
- Poland
- Portugal
- Romania
- Rwanda
- San Marino
- Saint Vincent and the Grenadines
- Senegal
- Serbia
- Seychelles
- Sierra Leone
- Singapore
- Slovakia
- Slovenia
- Somalia
- Republic of Korea (ROK)
- Spain
- Sweden
- Switzerland
- Syria
- Tajikistan
- Thailand
- Togo
- Tunisia
- UAE
- Ukraine
- United Kingdom
- United States of America
- Uruguay
- Uzbekistan
- Vanuatu
- Yemen
- Zambia
- Zimbabwe

Multidimensional challenges on the road to net zero
classrooms to climate forums at the highest international level, the transition to clean energy which is underway worldwide has been called "inevitable" or "unstoppable." Certainly, we have come further than ever before, and the pace of change seems to be accelerating.

It took nearly three decades for the countries of the world to reach a historic agreement that coal and fossil fuel subsidies needed to be phased out to combat harmful climate change, as noted in the COP26 cover text. Just two years later, countries agreed that wind power, solar and storage were the key mitigation technologies to keep 1.5°C within reach (see Chapter 1, "On the road to Baku and Belém: Looking ahead to COP29 and COP30").

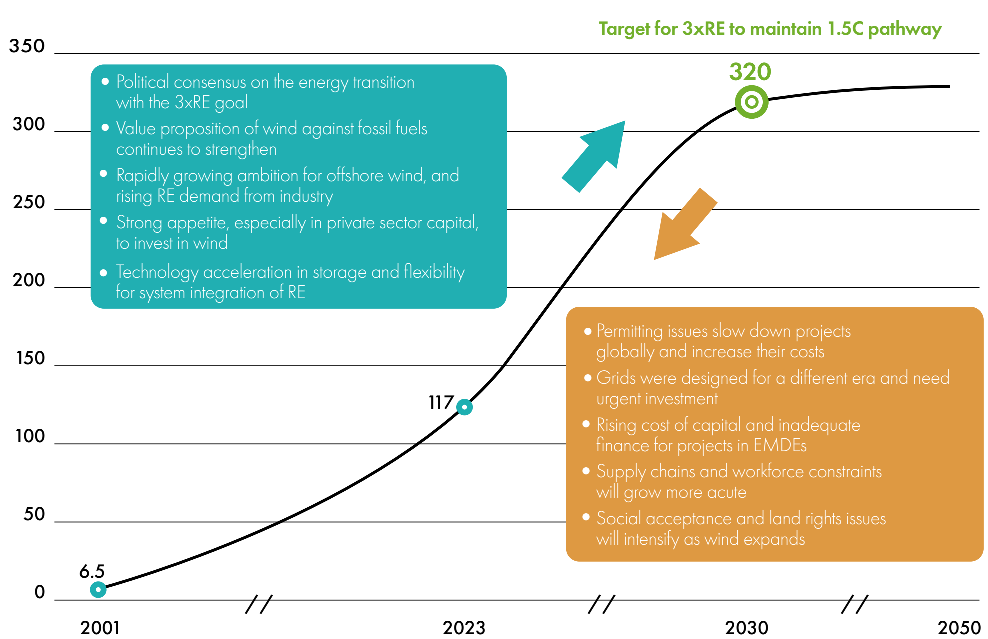
Major tipping points for change and exponential growth in the adoption of clean technologies have been identified across the highest-emitting sectors, from road transport to heavy industry.[5] This has been spurred by the widening availability of cost-effective, scalable wind and renewable energy, as well as increasing alignment among policymakers in pursuing electrification, sector-coupling and green industrialisation programmes to decarbonise their economies.

But the road ahead is a turbulent one. The global wind industry is still on the road to recovery from the reverberating impacts of COVID-19 related disruptions. There are 2 billion people expected to go to the polls in presidential or legislative/ parliamentary elections in more than 60 countries around the world in 2024.[6]

Not to mention the widening wealth gaps between the Global North and South exacerbated by rising inflation and cost of capital, the prospect of heightened trade barriers and fragmented supply chains, and fractious public discourse on the transition. Trade distortions and geopolitical fissures have resulted in lower-than-average world trade growth forecasts ahead, as well as a "resilient but slow" global growth picture, according to the IMF.[7]

The present-day technological era also brings its own challenges: a rapid innovation cycle in wind technology which undermines

Wind energy installations need to triple by 2030, but face competing pressures on growth in this crucial period



Source: GWEC Market Intelligence.

business profitability and risks product quality; interest groups actively using technology and social media to foment disinformation on climate change and renewables, robotics, AI and automation introducing further disruptions to labour and workforce planning; and a digitalisation gap between countries which impacts their capacity to allocate land, permit projects and operate smart, modern grids.

5. https://www.systemiq.earth/breakthrough-effect/
6. Anchor Change, Election Cycle Calendar, 2024; https://www.weforum.org/agenda/2023/12/2024-elections-around-world/
7. IMF, World Economic Outlook Update, January 2024: Moderating Inflation and Steady Growth Open Path to Soft Landing, 2024.

A 2024 survey of GWEC's wind and renewable industry association members around the world canvassed perceptions of short-term and long-term challenges to wind growth across areas like permitting timelines and grid bottlenecks. The outcome shows that the global wind industry is generally more optimistic about long-term growth prospects, and perceives the shorter-term challenges within the next five years as more acute.

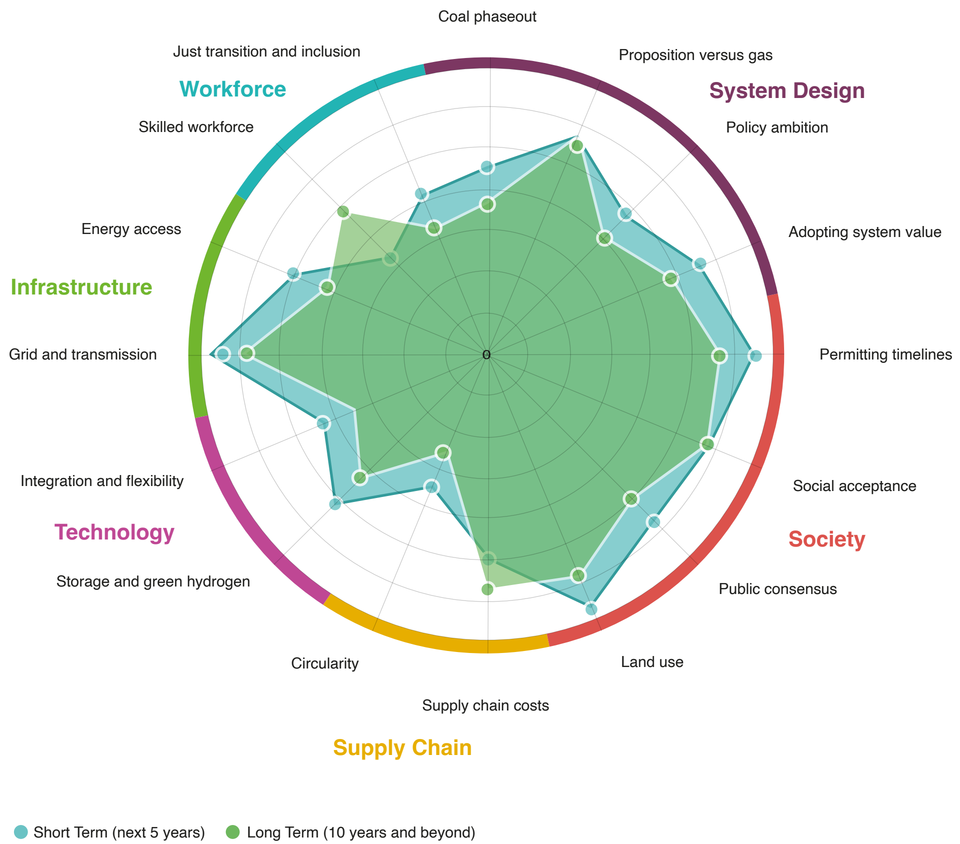
Long-term optimism on growth is driven by factors like growing renewable energy ambition, increasing competitiveness of wind vis-à-vis fossil fuels, strengthening public consensus on the transition, continued technology advancement and wider recognition of the need to undertake market design reforms as the transition progresses.

The exceptions, where challenges are perceived to intensify over time, are in the supply chain, where bottlenecks in production capacity and skilled workforce availability are expected to emerge in the medium to long term.

Compared with survey results in the Global Wind Report 2022, there are persistent challenges in competitiveness with gas, permitting timelines, land use and land rights issues, as well as grid availability. Optimism in short-term challenges has grown in the areas of circularity and storage technology, green hydrogen opportunities and system flexibility solutions.

This year's Global Wind Report 2024 explores some of the growth pressures facing wind energy, focusing on the vital areas of market economics and investment, supply chains, grids/storage infrastructure and public consensus for the transition. As we embark on the march towards the tripling renewables goal, **the global wind industry must collaborate with stakeholders across the energy transition to overcome these challenges and seize the growth opportunities ahead.**

Transversal challenges to wind energy's growth in the short and long term



Short term (within next 5 years) and long term (more than 10 years ahead) challenges which could slow down deployment of wind energy. Nodes closer to the outer circle are considered more severe challenges, while nodes closer to the centre are considered low or moderate challenges

Source: GWEC Market Intelligence and a survey of GWEC's national and regional wind and renewable energy industry association members, Q1 2024. This graphic is not inclusive of all challenges and factors impacting the growth of wind energy in different markets, and is meant to be used as a general guide to transversal issues.

System Design	**Coal phaseout:** The pace of countries exiting and retiring coal-based generation.
	Proposition versus gas: The enabling policy environment for wind energy versus natural gas/LNG, based on market and socioeconomic value.
	Policy ambition: The visibility and predictability of countries' wind energy growth targets, and the reflection in transparent and long-term procurement schemes and enabling market design.
	Price stability: The shift away from a "lowest cost approach" to wind procurement via revenue stabilisation and other mechanisms, and looking towards a system value framework.
Society	**Permitting timelines:** The ease of obtaining the necessary permits, licenses and approvals for wind project deployment, including legal challenges.
	Social acceptance: The scale of support versus opposition encountered by wind projects in host communities.
	Public consensus: Public education and awareness about climate change and the needs of the energy transition, including the impact of misinformation on social and political support for wind energy.
	Land use: Availability of land and seabed for wind energy projects.
Supply Chain	**Supply chain security:** The cost-effective and accessible supply of materials, minerals, metals and other inputs to the wind energy supply chain, as well as the efficient organisation of production capacity on a global basis, amid potential trade barriers and geopolitical factors.
	Circularity: The reuse, repurposing, recyclability and recovery of wind farm components including wind turbines, and the reduction of waste and environmental impacts generated in the wind project lifecycle in line with a circular economy approach.
Technology	**Storage and green hydrogen:** The pace of cost reduction and commercialisation of enabling storage and green hydrogen technologies, which will boost demand for wind energy.
	Integration and flexibility: The pace of cost reduction and integration of enabling balancing and flexibility technologies, such as demand-side response tools, which will enable large-scale integration of wind energy.
Infrastructure	**Grid and transmission:** The pace and scale of grid reinforcement, buildout and modernisation, ensuring sufficient grid availability to increase wind deployment.
	Energy access: The expansion of infrastructure to enable universal clean energy access and electrification of power and other sectors.
Workforce	**Skilled workforce:** The availability of a ready and able workforce with the necessary training and skills for the wind industry.
	Just transition and inclusion: The socioeconomic welfare of stakeholders concerned with the energy transition, and the development of a diverse and inclusive workforce which can harness all talents to grow the wind industry.

CHAPTER 1: INVESTING IN WIND TO MEET THE TRIPLING RENEWABLES GOAL

Investing in wind to meet the tripling renewables goal

The wind industry continues to face challenges regarding revenue stability and supply chain profitability around the world. This has led to slower growth and delayed investment decisions in the last three years – as well as some notable contract renegotiations or cancellations for a few large-scale offshore wind projects in 2023.[8a]

These challenges are symptomatic of policy and financing environments which are not fit-for-purpose if we are working towards a 1.5°C pathway where wind is to generate one-fifth of the world's electricity by 2030 and one-third of electricity by 2050.[8] This chapter of the report discusses how to build the investment environment for accelerating wind energy deployment in this decade.

Speedbumps, but not roadblocks, ahead

The world urgently needs more renewables, but there are many speedbumps ahead. A few of these are discussed below:

Major policy and regulation challenges

Permitting issues globally slow down project development and increase project costs – this is well understood and is being addressed in many countries, albeit still too slowly. Land/seabed rights for both onshore and offshore wind can be a big blocker on environmental, social and spatial planning grounds, whereas emerging markets and developing economies (EMDEs) may have fewer resources to ramp up the allocation of land for renewable energy and avoid conflicts with other interests while doing so.

Repowering offers a shorter pathway to additional capacity. But it is clear that to achieve climate goals, the wind industry needs more volume, and quality volume, on offer and that requires land and seabed.

Grids were designed for a different era that drew power from large, centralised power plants. These systems are no longer suitable in a world with more decentralised power generation, which will require additional investments for buildout, digitalisation and modernisation. The IEA notes that annual grid investment globally has been stagnant for several years and needs to double within this decade to more than $600 billion per year to meet net zero goals.[9]

Constrained supply chains

Recent increases in commodity, labour and logistics costs have put pressure on the supply chain (discussed further in Chapter 2). At the same time, the global wind supply chain must expand to meet the triple renewables pledge – this will require significant additional investment, while many supply chain companies, OEMs in particular, remain financially challenged in a post-COVID 19 environment.

It is certain that the stop/start nature of auction processes in many countries, the limited focus of these auction systems to support project realisation (for example, through the use of uncapped negative bidding in offshore wind) as well as insufficient volumes of

capacity available to achieve economies of scale in the supply chain, disrupts planning for investment in local industries, production capacity and human capital. These factors also increase the variability of demand, leading to volatility in pricing and lumpy growth pictures. Without clearer vision and collaboration on the

8a. BloombergNEF, Offshore Wind Investment Hit All-Time High in 2023, 2024.
8. According to the IEA's Net Zero Emissions by 2050 Scenario (2023).
9. IEA, Electricity Grids and Secure Energy Transitions, 2023.

scale of the supply chain needed, many actors will understandably hold back investment in future capacity.

The economics of wind power

Coal is almost impossible to finance now, and gas- and LNG-fired plants are facing increasing pressure on approvals and investment decisions. For instance, the Biden administration in the US recently announced a ''temporary pause'' on pending and future applications to export LNG from US plants, supposedly in response to climate activists and climate-oriented voter blocs.[10]

However, many EMDEs are growing fast and need more power generation to meet the needs of their economies – which leaves them struggling with the choices from the world's legacy energy system and its future one. Recent cost inflation and interest rate rises, while reversing or slowing somewhat in the second half of last year, have added further strain to the buildout of renewables and grids, though the cost-competitiveness of renewables versus fossil fuels is only strengthening.[11]

While interest rates globally are stabilising, access to low-cost financing remains critical for large-scale clean energy projects that carry high up-front investments and zero fuel costs (as opposed to traditional generation assets like coal or gas, which have lower up-front costs but high operating/fuel costs). Since most project analysis is done on a discounted cash flow basis, higher interest rates hit clean energy projects harder than fossil projects.

As the transition progresses, it is likely that markets will see increased volatility of commodities such as oil, gas, lithium, nickel, iron and other resources. The phase-out of fossil fuels and the simultaneous ramp-up of renewable generation and demand for a number of transition materials, from copper to neodymium, will lead to a turbulent supply-demand situation which will be reflected in comparative costs of wind versus fossil fuels.

Increased electricity prices could help fund much of the needed investments, but many EMDEs either cannot, or do not want to, implement cost-covering prices for electricity, even if it means the grid is more stable, demand is met, and economic growth can be accelerated. Some high-CAPEX renewable technologies, such as offshore wind, are ultimately cost-competitive with fossil fuel generation but will require more expenditure in the early stages of market development. This is particularly due to significant up-front concession payments, fees and costs related to the use of seabed.

Elevated cost of financing and commodity price volatility further underscore the importance of investment certainty. And in terms of market design, the prospect of price cannibalisation as penetration rates of renewable energy in a power market grow could jeopardise profitability for existing and future renewable projects.[12]

Access to capital in EMDEs

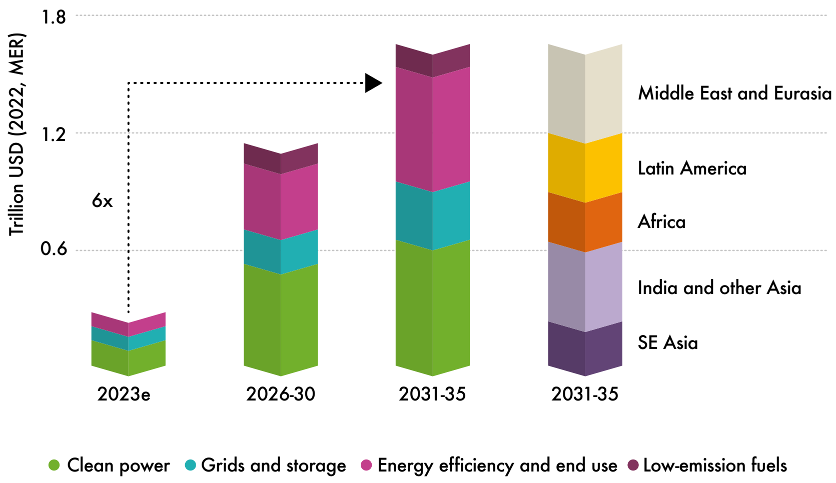
Globally, foreign direct investment (FDI) has fallen in the last two years due to confluent global crises, from the invasion of Ukraine to high energy prices to spiking national debt.[13] Add to this the relatively higher up-front CAPEX required for renewables and storage infrastructure, and the investment case for renewable projects in developing countries is hit hard by risk ratings and the high cost of capital.

From Mexico to Vietnam to India, the risk perceptions for wind projects in EMDEs centre around regulatory risk, land use, creditworthiness and financial viability of offtakers, transmission availability, currency stability, dispute resolution and other factors. Stacked up, these risks contribute to higher cost of capital for renewable energy investments.

During the period of lower-cost financing from 2019-2021, financing rates for onshore wind projects in industrialised countries hovered around 3-7% and often exceeded 10% in EMDEs – making a huge difference in returns for CAPEX-intensive projects like onshore and offshore

10. https://www.reuters.com/business/energy/biden-pauses-approval-new-lng-export-projects-win-climate-activists-2024-01-26/
11. IRENA, Renewable power generation costs in 2022, 2023.
12. Cornwall Insight, Wholesale price ''cannibalisation effect'' puts economics of renewables at risk, 2018.
13. Global FDI fell 12% in 2022, with particular declines to least developed countries. See: UNCTAD, World Investment Report 2023.

Annual energy transition investment in EMDEs required for net zero to 2035



Source: IEA, Reducing the Cost of Capital, 2024.

wind.[14] By 2023, financing costs increased, with global weighted average cost of capital (WACC) for new wind projects coming in at 6.4%.[15] In developing countries, WACC for solar and wind projects can be double or even triple the rates compared to mature renewable energy markets.[16]

Environmental, Social, Governance (ESG) standards and sustainability principles are increasingly mainstreamed in capital markets. But there is a widening gap in investment flows to developing countries for Sustainable Development Goal (SDG) activity, from energy to water and sanitation projects, which has grown from $2.5 trillion in 2015 to $4 trillion by 2023.[17]

As a result, **sub-regions of the world have largely been excluded from the benefits of the energy transition** to date: Only 2% of global investment in renewables in the last two decades were made in Africa, despite its vast technical wind and solar resources, and even then, investment activity largely targeted a handful of countries.[18] Least developed countries (LDCs) and small island developing states (SIDS) are among the groups which have seen the least investment activity in renewables.

Given the enormous volumes of capital required for EMDEs, most growth will come from private sources, although the mobilisation and strategic targeting of public funding are also crucial. Excluding China, annual investment in clean energy for EMDEs needs to scale from roughly $270 billion today to more than $1.6 trillion over the next decade, according to the IEA, to meet a net zero scenario. Approximately half of that investment would benefit renewable energy generation, grids and storage.[19]

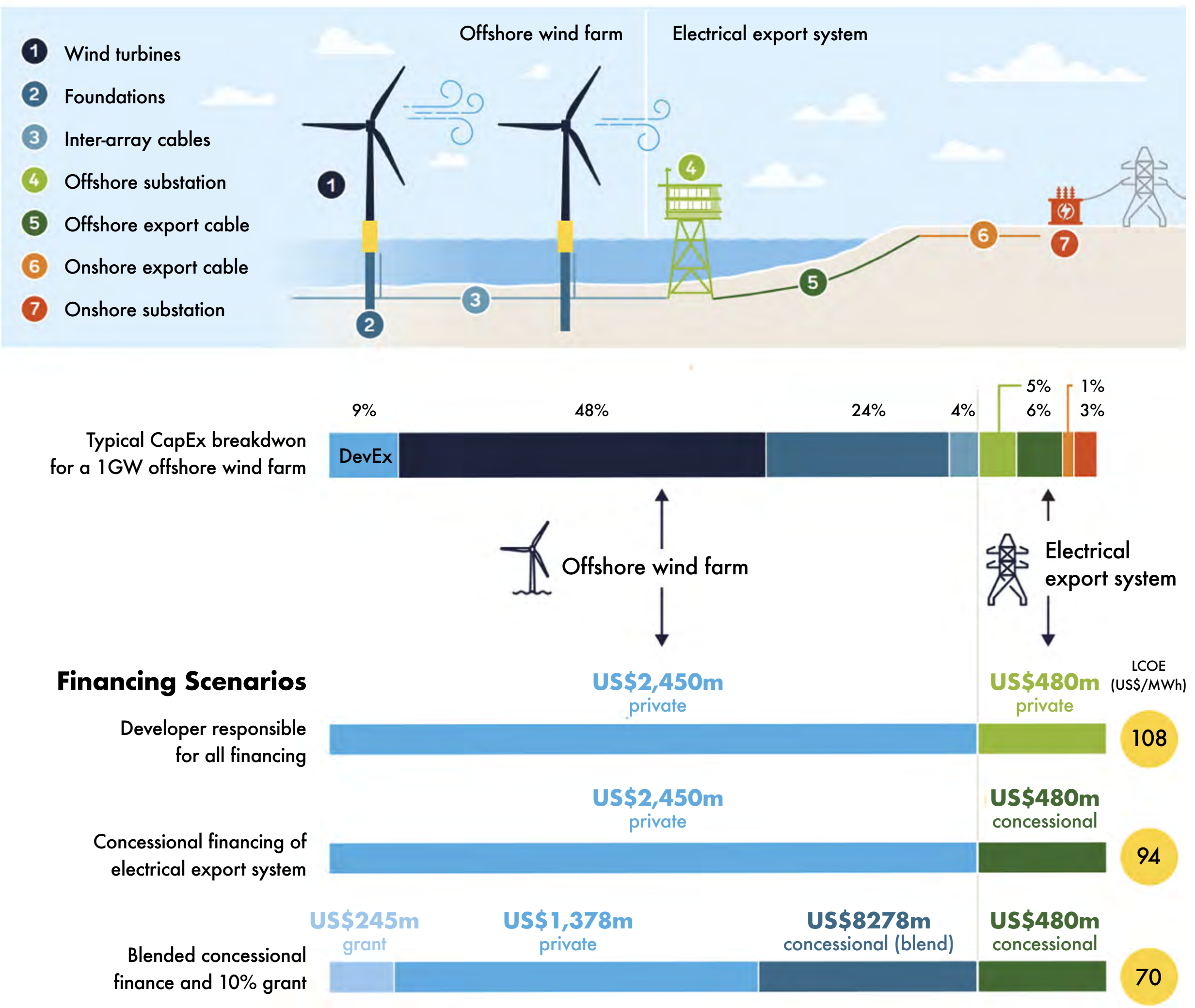
The way capital markets assess risk in EMDEs can be too risk-averse, but there is no clear view into how to realign the risk perceptions of capital markets (which tend to be very conservative, particularly among lenders). Still, it is vital to urgently lower the cost of capital for renewable energy projects in EMDEs and accelerate the transition for countries that may otherwise be left behind – and the savings are vast. The IEA calculates that narrowing the gap of cost of capital between EMDEs and advanced economies by just one percentage point would reduce annual investment needs in a net zero scenario by $150 billion globally.

Blended finance and partnerships will be increasingly important – UNCTAD has found that adding multilateral development banks (MDBs) to energy investments in developing countries will lower the spread on debt finance by 10%, while further combining this with government participation via public-private partnerships reduces the spread by 40%.[20]

In offshore wind, the World Bank has found that applying concessional public debt to the electrical export system of a 1 GW project, and covering the offshore wind farm with a blend of 40% concessional

14. IRENA, The cost of financing for renewable power, 2023; https://www.climatechangenews.com/2023/10/30/to-triple-renewable-energy-the-global-south-needs-finance/
15. https://about.bnef.com/blog/cost-of-clean-energy-technologies-drop-as-expensive-debt-offset-by-cooling-commodity-prices/
16. IEA, Renewables 2023.
17. UNCTAD, World Investment Report 2023.
18. IRENA, Renewable Energy Market Analysis: Africa and its Regions, 2022.
19. IEA, Reducing the Cost of Capital, 2024.
20. UNCTAD, World Investment Report 2023.

Impact of blended concessional finance on example offshore wind farm in EMDE



Source: World Bank Group, World Bank and ESMAP, Reducing the Cost of Capital, 2024.

finance, 10% grant finance and 50% private debt, would dramatically decrease the Levelised Cost of Electricity (LCOE) of a project from around $108/MWh to $70/MWh.[21] This is not a straightforward formula, as LCOE reflects multiple different factors of the project investment environment. But these findings indicate that offshore wind backed with blended finance in a developing country can compete with the cost of thermal generation on a long-term basis.

There is acute pressure to ensure the energy transition fairly distributes dividends and opportunities for growth. But the pace of the transition in comparison to climate mitigation targets, along with the uncertainty ahead (for example, uncertainty about when total oil demand will peak and decline), complicates planning for EMDEs in areas like infrastructure buildout and workforce development.

A transition that fails to address a widening wealth gap or prepare for the coming displacement of labour risks disorderly and protracted renewable energy

21. World Bank Group, The Role of Concessional Climate Finance in Accelerating the Deployment of Offshore Wind in Emerging Markets, 2023

On the road to Baku and Belém: Looking ahead to COP29 and COP30

In December 2023, following a year of diplomatic manoeuvring and global campaigning, nearly 200 countries adopted the final decision text of COP28. The world's largest climate conference achieved a number of historic outcomes: a conclusion of the first GST process by the UNFCCC which assessed collective progress towards the Paris Agreement; a decision to operationalise the Loss and Damage Fund, designating the World Bank as interim trustee and host of the fund for the first four-year period; and a first mention in the final decision text of "wind power and solar power and storage" as mitigation technologies that have become increasingly available and cost-effective.

For the year leading up to COP28, the Global Renewables Alliance (GRA, an umbrella association for the global industry associations for wind power, solar power, hydropower, geothermal, green hydrogen and long-duration energy storage, co-founded by GWEC) ran an international campaign to "Double Down, Triple Up," aiming to secure a global goal to triple renewable energy capacity and double energy efficiency improvement rates by 2030. This campaign included an open letter to policymakers signed by more than 300 industry, civil society and intergovernmental actors, representing a total of $12+ trillion in market value, as well as the publication of a report on the enablers to reach the tripling renewables goal co-authored by the GRA, the COP28 Presidency and the International Renewable Energy Agency (IRENA).

As a result of a huge diplomatic and multi-stakeholder effort, the final decision of COP28 recognised the need for "deep, rapid and sustained" reductions in GHG emissions, and called on countries around the world to contribute to the global effort to triple renewable energy capacity by 2030. This was a milestone achievement for the renewable energy industry, enhancing the recognition of wind power as a key solution to mitigating climate change. For wind, the tripling renewables goal translates into roughly tripling the annual wind installations from 2023 levels to 2030.

It should be noted that the final decision text of COP28 is non-binding, and the "UAE Consensus" had notable shortfalls in finance and means of support for developing countries. The Alliance of Small Island States (AOSIS) rejected the package after the gavel came down, noting that it failed to deliver sufficient commitments to phase out fossil fuels as well as financing for developing countries for climate change adaptation and mitigation. Nonetheless, COP28 gave the renewables industry and the wider global community a powerful signal to rapidly accelerate renewable energy within this decade to keep a 1.5°C pathway within reach.

Looking ahead to COP29 in Baku and COP30 in Belém, the three COP Presidencies have already formed a Troika to work on a roadmap to "Mission 1.5°C." It is expected that enhancing cooperation across three Presidencies will maintain momentum and urgency on the climate agenda, and in particular focus on climate finance and mobilising more ambitious NDCs, or countries' national commitments to climate action. The next round of NDCs is due in February 2025, with increased pressure on countries to submit their climate plans ahead of COP29 in November this year.

In Baku, countries will convene to agree on a New Collective Quantified Goal (NCQG) on climate finance flows to developing countries, superseding the existing pledge of $100 billion delivered from developed countries on an annual basis. The new quantum, and whether there may be sub-targets for types of funding or targets for funding, is yet to be determined. The IEA has noted that emerging markets and developing economies (EMDEs) excluding China only account for less than 15% of total clean energy investment; current investment in clean energy in these economies will need to grow sixfold to $1.6 trillion annually by the early 2030s to get on-track for 1.5°C. This leaves a vast gap to be filled by the NCQG, as well as other commitments which can de-risk and lower capital costs for EMDEs.

Beyond the "Finance COP" in Baku, COP30 in Belém is shaping up as an "Nature and Implementation COP" taking place during the year of updated NDCs and the UNFCCC's first synthesis report on Paris Agreement implementation. Given the setting in the Amazon, it will likely have a strong focus on nature protection, nature restoration and climate change adaptation issues, including encouragement of countries to submit and implement National Adaptation Plans.

development, ultimately pushing the global goal of tripling renewable energy capacity farther away.

There is no turning back

The speedbumps ahead to the tripling renewables goal ahead are formidable, but there is no turning back now.

The volatility in fossil fuel markets seen in the last few years is a reminder to governments of the energy security and macroeconomic risks associated with continuing reliance on fossil fuels – including the risks posed to attendant supply chains and industrial activity in a country. The demands for green power offtake in the public and private sectors – including targets to decarbonise industrial activity and benchmarks for emissions intensity that grow stricter with time – further weaken the investment case for long-term thermal generation.

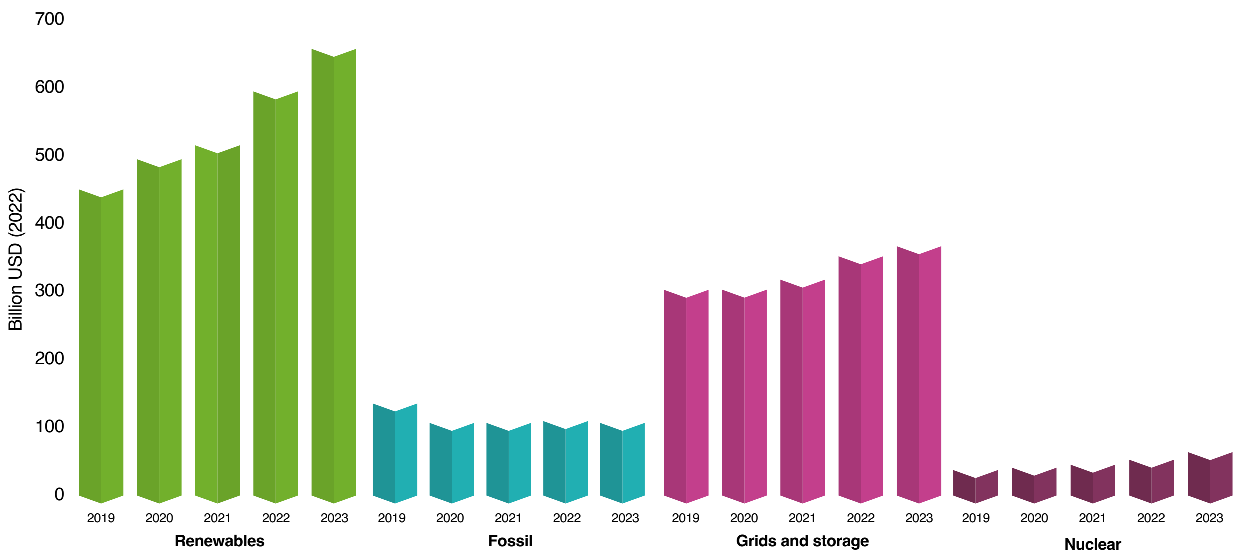
While coal currently provides more than one-third of the world's electricity, many (though not all) banks are pulling out of coal finance. The divestment policies adopted by banks – and strengthened by the 2015 Paris Agreement – have impacted more than half of lending activity into coal, and led to decommissioned and retired coal plants over the last decade.[22]

Gas- and LNG-fired power plants, while framed in many discussions as a transition fuel, are facing scrutiny from lenders. Investors are increasingly concerned that 12-15 years after this generation comes online (roughly around 2040, assuming a 3-year construction period after financing is closed), these plants may not be able to pay back their debt.

Global investment figures across the renewables, fossil, grids/ storage and nuclear power sectors over the last five years show that renewable energy has seen >20% growth since 2019. In contrast, investment in fossil fuels has been flat or even slightly declining.

And yet, in the public sector, global fossil fuel subsidies are projected to continue to rise from their nadir of $7 trillion in 2022, or about 7% of total global GDP.[23] More than four-fifths of current fossil fuel subsidies are non-explicit, such as undercharging for environmental costs like local air pollution and foregone consumption tax revenue. These subsidies are expected to increase

Renewables outpace other investment in power sector technologies over the last 5 years



Source: IEA, World Energy Investment 2023

22. Boris Vallée and Daniel Green, Can Finance Save the World? Measurement and Effects of Coal Divestment Policies by Banks, 2022.
23. Black, Liu, Parry and Vernon, IMF Fossil Fuel Subsidies Data: 2023 Update, Working Paper, 2023.

to meet the consumption needs of EMDEs, particularly in the Asia Pacific region where China provides the greatest volume of fossil fuel subsidies and the region as a whole accounts for half the global total.

Substantive energy subsidy reform in the public sector can help shift capital into areas where a formidable finance gap exists to meet the tripling renewables goal, such as modernising and expanding grid infrastructure, supporting governments to create legal, policy and regulatory regimes for the transition and building capacity in education and workforce training for the future energy system. Subsidy reform will need to be part of the toolbox for creating the conditions for massive investment into renewable energy, particularly in developing countries.

Still, for an increasing number of private investors, the most viable options today are wind, solar energy, storage (including batteries, pumped storage and other varieties), hydropower, as well as extensions to the lifetimes of nuclear and fossil plants. Green hydrogen and other new technologies may also be viable for the post-2030 period, though will not play a significant role in meeting the tripling renewables goal.

The wind industry in the mid-transition period

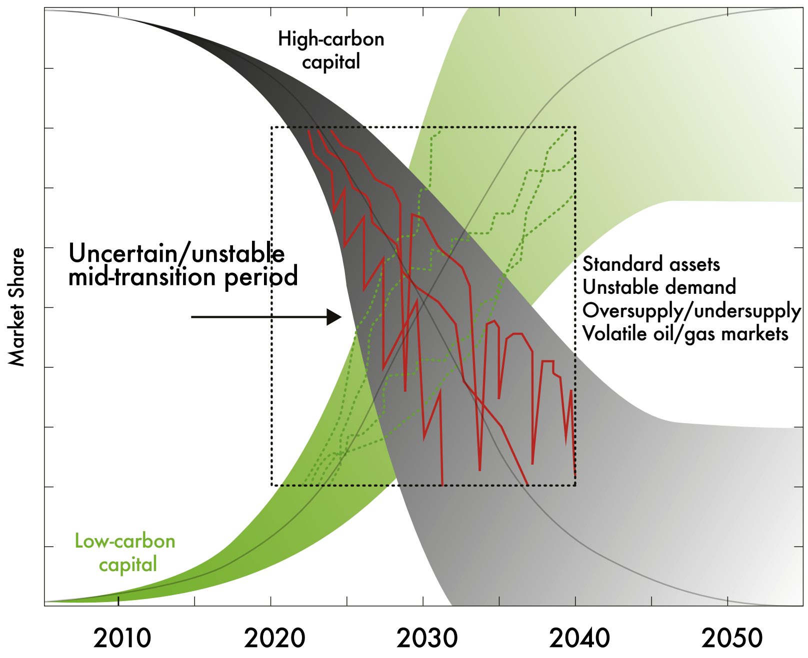
The transition is underway, and there is no going back to an economy fuelled mainly by fossil energy. However, careful consideration must be given to how this transition proceeds, whether as an orderly process, a disorderly one or something in-between.

An IMF working paper identifies our current period as one characterised by uncertainty, as markets wrestle with waning interest in traditional fossil investments (such as gas fields, power plants, regasification facilities, etc.) due to concern about future liabilities. Simultaneously this uncertainty is interacting with rising optimism regarding future demand for clean energy (including wind and solar projects, storage, electric vehicle charging stations, etc.).[24]

The instability of this period, which could be prolonged depending on our ability to navigate and manage the risks, will be characterised by decision-making under dynamic macro conditions. There may be excesses or shortfalls in supply of both renewable and fossil generation, cross-border price volatility exacerbated by climate damages, stranded fossil assets and unconnected clean energy assets, as well as uncertain demand signals.

For instance, the global wind industry is on a significant scale-up journey to ensureit can meet demand amid a volatile macro environment. Decarbonisation benchmarks for materials like steel and cement, along with the

Market shares for clean and fossil energy in the mid-transition period



Source: Espagne, Oman, Mercure, Svartzman, Volz, Politt, Semieniu, Campiglio, IMF Working Paper, Cross-border risks of a global economy in mid-transition, 2023.

24. Espagne, Oman, Mercure, Svartzman, Volz, Politt, Semieniu, Campiglio, IMF Working Paper, Cross-border risks of a global economy in mid-transition, 2023.

critical minerals like copper which will need to be mined in potentially fragile jurisdictions, exert further pressures on the wind supply chain.

It is a reality that some fossil fuels will be used to deliver clean energy for some time, whether in the context of existing worldwide shipping and logistics networks or the production of epoxy resins that coat wind turbine blades.

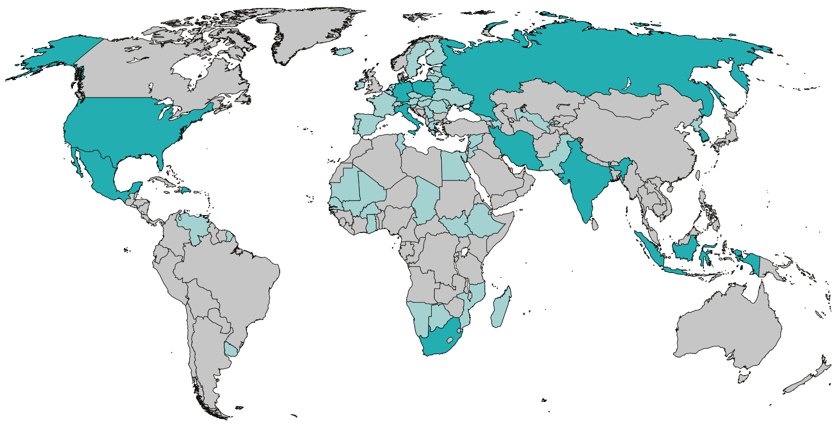
The risks of the mid-transition period are particularly pronounced for EMDEs, which tend to experience faster economic growth than developed countries, and need larger volumes of new power generation capacity to meet this demand. This requires larger relative percentages of GDP than in developed countries. For example, a 5% increase in power demand in Vietnam requires a larger percentage of GDP than the same power demand increase in a developed country.

In many developed countries with slower (as in the US[25]) or even negative (as in the UK[26]) electricity demand growth, renewable energy and storage installations typically displace power generated from existing fossil plants, or help to meet relatively low demand growth from sources like data centres and electric vehicles. Developed countries are also better positioned to invest in grid planning and buildout, although this is not happening fast enough.

Fossil fuel plant closures have been delayed – significantly in some cases, as evidenced by the recent spate of coal plant approvals in China. These delays are largely attributed to EMDEs struggling to scale up clean energy quickly enough to meet electricity demand for their economic growth trajectories. In industrialised countries, shutdowns of fossil generation have created employment dislocation and community impacts. It is crucial that shutdowns are well managed to maintain a public consensus on the speed and scale of the transition and to mitigate oppositional forces.

The physical/economic disruption and dislocation caused by the expansion of wind energy could become fodder for politicisation. However, on the flipside, political change could foster greater support for the energy transition.

More than 60 countries heading to the polls in 2024 – many among the top emitters globally



Light teal = Countries with presidential/legislative elections in 2024
Dark teal = Countries among the top 20 emitters worldwide with presidential/legislative elections in 2024
Source: Statista "Distribution of carbon dioxide emissions worldwide in 2022, by select country", Anchor Change 2023.

In 2024, nearly half of the world's population will head to the polls to vote in presidential or legislative/parliamentary elections in more than 60 countries around the world, including the European Union. Of these countries with elections this year, 11 are among the top 20 emitters globally, making this a banner year for the prospects of international climate action. These countries include: Germany, India, Indonesia, Iran, Italy, Mexico, Poland, Russia, South Africa, South Korea and the US.

The results of many of these elections will sway energy transition policy and reset renewable energy ambition – while we are unlikely to see overt U-turns, oppositional swings in office could slow down or speed up progress towards the tripling renewables goal. For instance, we could see a redistribution of renewables versus nuclear energy

25. https://www.eia.gov/outlooks/aeo/narrative/electricity/sub-topic-01.php
26. https://assets.publishing.service.gov.uk/media/6581b11eed3c3400133bfbb1/Electricity_generation_and_supply_in_Scotland__Wales__Northern_Ireland__and_England__2018_to_2022.pdf

in South Korea, or an isolationist approach to clean technology trade in the US, depending on election outcomes.

Delivering the energy transition in EMDEs

An estimated $2 trillion per year will be needed for the new renewable energy, grid and storage infrastructure through the end of this decade to meet the goal of tripling renewables.[27] There are many proposals for the industrialised countries responsible for most historical carbon emissions to contribute the lion's share of climate finance, whether in grants or recapitalisation of MDBs.

Many EMDEs are seeking a substantial quantum of grant funding to be included in the "blended finance" packages offered by MDBs, Just Energy Transition Partnerships (JETPs) and bodies like the Global Financial Alliance for Net Zero (GFANZ). But grants are still a minority share of donor finance. The Resource Mobilization Plan unveiled in late 2023 for Vietnam's JETP, for example, comprises around $8 billion in investment in the country's energy transition – about half of this volume comes from commercial development finance loans, while less than 4% comprises grants which have mostly been earmarked to specific projects.[28] It is expected that the plan will help to mobilise a further $7.5 billion from the private sector, coordinated by GFANZ.[29]

Climate finance is challenged by political realities. Domestic political pressures and a sombre economic outlook in many developed countries make such massive transfers of capital challenging. COP28 was able to mobilise a commitment of $700 million to the new loss and damage fund – a drop in the bucket of what is needed. Environmental organisation 350.org has called for as much as $200 billion in grants per year transferred from industrialised countries to benefit renewable energy in developing countries.[30]

MDB reform is high on the list of priorities for the global climate agenda, given that public funding in renewables in EMDEs could be strategically leveraged to crowd in private finance. The calls for reform include the 2022 Bridgetown Initiative promoted by Barbadian Prime Minister Mia

Mottley, which calls for, inter alia: emergency liquidity from the IMF; temporary suspension of interest surcharges to client countries; expansion of available MDB lending pools by $1 trillion; prioritising SDGs and climate resilience in concessional lending programmes; and a new insurance of $650 billion in special drawing rights (SDRs) or other instruments that can accelerate private investment in climate mitigation and post-disaster reconstruction.[31]

MDBs are responding to pressure to reform, but not quickly enough. The World Bank is eliminating its statutory lending limit, and simplifying its business guarantee products for renewable energy in a bid to triple its annual guarantee issuance to $20 billion

27. https://climateanalytics.org/press-releases/2-trillion-a-year-needed-to-triple-global-renewables-by-2030-double-current-investment
28. https://www.vietnam-briefing.com/news/vietnams-just-energy-transition-partnership-resource-mobilization-plan-unpacked.html/
29. https://www.gov.uk/government/news/international-agreement-to-support-vietnams-ambitious-climate-and-energy-goals
30. https://www.theguardian.com/environment/2023/dec/06/700m-pledged-to-loss-and-damage-fund-cop28-covers-less-than-02-percent-needed; https://350.org/press-release/powering-up-for-climate-justice-350-org-launches-report-on-global-renewable-energy-target/
31. https://pmo.gov.bb/wp-content/uploads/2022/10/The-2022-Bridgetown-Initiative.pdf

Case Study: Financing offshore wind in EMDEs

Provided by: The Global Offshore Wind Alliance (GOWA)

Projections show that offshore wind can deliver one-third of the required global power sector emissions reductions for a net zero world by 2050. To achieve that, the world will need 2,000 GW of offshore wind by 2050, according to IRENA's World Energy Transitions Outlook.

The World Bank estimates that there is over 71,000 GW of offshore wind technical potential globally. EMDEs such as Vietnam, the Philippines, India, Turkey, Azerbaijan, Romania, South Africa, Colombia and Brazil, to name a few, offer significant potential for offshore wind development. However, the challenges involved in delivering the potential look different depending on where you are in the world.

In the Global North, governments are focused on devising effective policy measures to stimulate private investment. This challenge is largely focused on managing the cost of finance rather than its availability. For instance, the recent increase in interest rates has resulted in a notable surge in the cost of borrowing.

EMDEs with a weaker macroeconomic risk profile are disproportionately impacted by the global rise in financing costs. They further face additional challenges in the up-front capital intensity of offshore wind. While in regions with mature offshore wind markets like Europe, intense competition and widespread deployment have driven down prices, experience has shown that early adopters of offshore wind have faced initial challenges such as higher transaction and delivery costs.

The larger scale of offshore wind projects presents hurdles, prompting private sector stakeholders to emphasise certain volume thresholds and for the market to demonstrate a sustained pipeline to justify the requisite infrastructure investment, including ports and associated facilities. To attract private investors, it is essential to ensure profitability, given the substantial costs involved. Hence, maintaining a focus on the financial viability and bankability of projects becomes imperative.

In this context, concessional finance has a key role to play, together with targeted efforts to ensure bankability and stable frameworks to attract investments and create a pipeline of projects, which is key in driving down costs.

However, at the macro level, the developing country requirement of funding remains far from being met. Grants and concessional loans accounted for less than 1% of global renewables financing last year.

Policy discussions convened by GOWA have indicated that governments can play a role in encouraging the financial sector to develop strategies and targets that align their financial portfolios with national climate commitments over time. As an example, national development banks can establish ambitious climate-related lending targets, particularly in the offshore wind sector. Flexible actions including indexation of revenue streams, a Feed-in Premium or Contracts for Difference (CfD) mechanism have also been raised.

A key focus has been on the provision of MDB-backed de-risking mechanisms to encourage private investment and finance, like blended finance solutions and guarantees. GOWA has further discussed development banks providing more support to local financing at preferential rates whenever possible.

Discussions have also highlighted that non-financial barriers hinder the bankability of projects, resulting in a misalignment between viable projects and available capital. The these include lack of policy clarity, onerous or unclear permitting requirements as factors which impede the "bankability" of a project.

Therefore, policymakers and stakeholders are encouraged to work collaboratively to establish a conducive environment that fosters offshore wind growth and recognises its true value in our transition to a sustainable energy future.

The Global Offshore Wind Alliance (GOWA) acts as a diplomatic global driving force for an ambitious uptake of offshore wind and contribute to achieving a total offshore wind capacity of a minimum of 380 GW by 2030 and an installed capacity increase of at least 70 GW per year from 2030. Recognising the importance of fostering collaboration among financial institutions, corporations and governments to expedite the required expansion of offshore wind, GOWA has been convening multistakeholder discussions focused on financing for offshore wind in EMDEs.

by 2030.[32] The European Bank for Reconstruction and Development (EBRD) removed its statutory lending limit in 2023, while the African Development Bank has proposed using SDR rechannelling to fund hybrid capital. The Asian Development Bank launched its Innovative Finance Facility for Climate in Asia and the Pacific in 2023 and is aiming to raise $100 billion in new funding over the next decade.[33]

Reforms are certainly underway, but implementation and capital mobilisation must drastically accelerate to keep pace with the investment needs for renewables by 2030.

Recommendations for financing the next era of wind growth

Without deliberate realignment of investment with the principles of equity and fairness, reflected in a balanced North-South distribution of capital, benefits, knowledge transfer and technology, the goal of tripling renewables will not materialise. Or worse, uncoordinated investment may foster conflict and uncertainty during the process of a grand capital reallocation for the energy transition in specific countries and regions of the world.

Reaching the tripling renewables goal in an orderly manner will require meaningful action in building finance and investment to scale wind energy. This will need an "all hands on deck" approach to shift market design into models that incentivise large-scale renewable growth and, especially in the case of EMDEs, to enhance public/private partnerships to mobilise investment.

GWEC makes the following recommendations for improving the investment environment for wind energy:

- **Strengthen policy and regulatory frameworks to make project timelines and approvals more certain**, as a means of reducing investment risk. This includes permitting frameworks which can simplify and accelerate the consenting process, prompting project realisation through auctions by stopping "race to the bottom" mechanisms, shortening grid connection queues and creating consistent, large-volume and long-term pipelines of wind and renewable energy capacity for allocation.
- **Integrate the perspectives of demand-side voices,** such as corporate clean energy buyer clubs like the Asia Clean Energy Coalition (ACEC) and the Climate Group/RE100. These groups can work with domestic industries to ramp up ambition for renewable power and collectively strengthen the demand signals for wind and solar additions, in addition to creating viable market opportunities for offtake.
- **Enhance inclusive dialogue and trust-building mechanisms on climate finance at international level**, using platforms under the G20, UNFCCC and MDBs to ensure support and financing facilities are in place for scaling wind industry infrastructure and supply chains, and for developing countries to accelerate renewables growth.
- **Accelerate MDB reform to enable different forms of donor finance to be more effectively and efficiently funnelled to clean energy investments in EMDEs**. Strategically targeting enabling infrastructure, such as by having public finance back the buildout of electricity export or transmission systems, can help to crowd in private capital for renewable generation. Working with the wind industry, MDBs can also enhance technical assistance on legal, policy and regulatory frameworks for renewable energy to reduce the perceived risks that lead to higher cost of capital.
- **International finance institutions should implement guarantee and credit enhancement mechanisms** for clean energy offtake agreements and supply chain investments, particularly in EMDEs. This approach can help to mitigate some of the present risks such as offtaker creditworthiness, currency fluctuation risk and revenue stability.

Capturing the value of wind energy

It took the wind industry over four

32. https://www.worldbank.org/en/news/press-release/2024/02/27/world-bank-group-prepares-major-overhaul-to-guarantee-business.
33. https://www.cgdev.org/blog/introducing-mdb-reform-tracker.

decades to pass the 1 TW milestone of global installations in 2023. This progress was largely driven by an attractive cost profile that makes wind generation more favourable than fossil fuels in many parts of the world.[34] However, with the goal of tripling renewables, the global wind fleet is now faced with the challenge of expanding by at least 2.75 times within the next seven years.

Accelerating the speed of deployment will be challenged by current policy and regulation, from overly long permitting timelines and slow grid/infrastructure build-out to a least-cost approach that risks fostering a "race to the bottom" in wind procurement. Auctions in many places compel developers to compete for small volumes of capacity by submitting extremely low or even negative bids. In uncapped seabed leasing tenders for offshore wind sites, developers face conditions that can generate unreasonably high bids, distorting CAPEX calculations.

It is important that governments look beyond price in energy auction schemes to promote the realisation of high-quality projects and maximise the benefits of wind energy buildout. There are various policy tools being deployed for these aims, from stringent pre-qualification stages to long-term industrial strategies; though unfortunately, even the most mature offshore wind markets are applying negative.

Many countries are also exploring non-price criteria (NPC) – also called qualitative or award criteria – in auctions to capture socioeconomic and environmental value from wind capacity. It is vital that NPC are considered with the broader investment picture for wind energy in mind, as well as the pace of growth required to meet climate goals.

Non-price criteria: A cautious approach

Typically, auctions begin with the notification of a pre-qualification stage, which sets out technical specifications and minimum-level competencies required for participation. Common criteria for this pre-qualification stage include: experience and track record; legal requirements; financial competence; good conduct; and geographic specifications.[35]

The next stage encompasses bidding, evaluation and selection. Contracts may be based on the most competitive bids by price or the best price-quality ratio. In the offshore wind sector, seabed leasing auctions are sometimes separate from the offtake auction. Depending on market conditions and maturity, some seabed leasing tenders may prioritise the highest bids, while others incorporate NPC.

While NPC can bring about additional value creation from wind energy, it also introduces a layer of complexity to the evaluation process. Given that onshore wind projects typically operate on a smaller scale with shorter construction timelines compared to offshore wind, **it is more effective to apply NPC in the offshore wind sector.** Offshore wind projects benefit from larger scales and longer planning timelines, allowing for better preparation to deliver NPC effectively, though not where auctions are using negative bidding.

Guardrails and guidelines for NPC in the wind sector

NPC expands the scope of auctions by procuring projects that

34. BloombergNEF, 2H 2023 LCOE Update, 2023.
35. Soysal, Emilie Rosenlund, Auctions for Renewable Energy Support: Effective use and efficient implementation options (AURES), Policy Memo 2: Pre-qualifications and penalties, 2016.

are efficient in pricing and deliver additional value. For instance, the EU Net Zero Industry Act directs authorities contracting net zero technologies to procure based on the best price-quality ratio, considering objective, transparent and non-discriminatory criteria that covers environmental sustainability, innovation, system integration and resilience.[36]

There is no universal template, and regulators must consider NPC through the wider lens of market conditions and the urgency to scale wind installations. In many cases, NPC will carry additional costs which should be reflected in auction pricing.[37]

In general, NPC can be categorised into three primary areas:[38]

Governments should adopt a cautious approach, carefully weighing the effectiveness of achieving political, economic or social objectives through auction criteria against the potential impacts on project economics. Authorities should carefully assess if the introduction of NPC would slow-down the build-out of renewables and inflate the cost of the energy transition.

Auction stages and potential application of NPC

Onshore Wind Auctions		Offshore Wind Auctions		
			Earlier application of NPCs is preferred for markets with a two-stage auction particularly at seabed leasing stage.	
Pre-Qualification Stage	Offtake Bidding Stage	Pre-Qualification Stage	Seabed Lease Bidding Stage	Offtake Bidding Stage
Ensure project feasibility and quality bids Sets out technical specifications and minimum-level competencies required for participation in a auction.	**Foster effective price discovery through a competitive process** Qualified bidders enter a primarily price-based competition for capacity and offtake agreements.	**Ensure project feasibility and quality bids** Sets out technical specifications and minimum-level competencies required for participation in an auction.	**Allocate seabed rights based on price and project value** Qualified bidders enter a competition based on price and, if NPC are applied, project value. It is beneficial to introduce NPC at an earlier stage to allow for project preparation.	**Award offtake contract through a competitive price-based process** Qualified bidders holding seabed rights enter a primarily price-based competition for offtake agreements.

Supply Chain and Industrial Strategy

Unlock supply chain investment and capture long-term local value creation

It is most effective to foster supply chain development through a wider industrial growth strategy, created in collaboration between government and industry, and aligned with anticipated schedules and volumes for procurement over a long term. This process of consultation, coordination and forward-planning provides visibility and certainty to investors and the wind value chain, unlocking investment and value creation over a long horizon. An industrial growth strategy should build on existing competitive advantages, drive innovation and complement auction design and criteria.

Source: GWEC, Position Paper: A global wind energy industry perspective on integrating non-price criteria in auction frameworks, 2024.

NPC's three primary areas

Sustainability	System Integration	Social Impact
• Environmental and ecological sensitivity in construction, operation and decommissioning • Nature-positive approaches to enhance biodiversity and ecosystem health • Limiting emissions intensity of projects • Enhancing circularity, recyclability and decarbonisation	• Integrating different technologies (such as storage, interconnections, transmission or ancillary services) to boost overall value	• Enhanced community and stakeholder engagement • Enhanced community welfare • Provision of infrastructure and public facilities

36. The EU Net Zero Industry Act has been provisionally agreed at the time of the report's writing. "Resilience" accounts for the proportion of products originating from a single source of supply. See: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52023PC0161
37. This is the reason why NPC should not be applied in an auction framework using negative bidding mechanisms.
38. GWEC, Position Paper: A global wind energy industry perspective on integrating non-price criteria in auction frameworks, 2024.

Case Study: Strict local content requirements in Taiwan (China) lead to higher costs

Taiwan (China) has emerged as one of the early movers of offshore wind in Asia. Its offshore wind ambitions are widely recognised, driven by ambitions to become a 'green economy' and a relatively open investment environment. Installed capacity targets of 5.7 GW by 2025 and a further 15 GW by 2035 have sent a strong market signal, requiring a steady buildout of roughly 1 GW/year to reach the long-term goal.

Localisation policy in the market's emergent offshore wind sector is expressed in a few ways. A supply chain plan must be provided in project applications for an establishment permit; fines or punitive measures on the feed-in-tariff (FIT) are imposed for missed delivery or delays on the plan. In the 2022 tender of the Round 3 Zonal Development Phase, the Industrial Development Bureau also qualified 25 items as key for development (including wind turbine components, engineering services and power facilities), and a longer list of items that qualified for bonus points. Bidders were required to locally procure the key development items for at least 60% of the proposed capacity. This created constraints around vessels, marine engineering and other segments, resulting in higher costs for offshore wind procurement and delayed projects.

As a result of relatively strict LCRs, the levelised offshore wind tariffs achieved in Taiwan (China) were nearly double those of subsequent auction rounds which eased localisation requirements, according to BloombergNEF. The implementation of more stringent LCRs in the market's growing offshore wind sector reflect the proportional relationship between local content and offshore wind costs. To achieve long-term cost reduction and a regionally competitive supply chain, especially in an early-stage wind market, policymakers should consider flexible and practical localisation approaches which reflect market conditions.

When considering the application of NPC in tender schemes, GWEC recommends the following guardrails:

General principles for wind energy procurement

- Establish supportive pricing, such as CfDs, and an enabling policy and regulatory environment;
- Deliverability, track record and financial capability should be elements of pre-qualification requirements for participation in the tender;
- Account for market maturity and conditions;
- If introducing NPC, provide an 'on-ramp' transition period to facilitate industry collaboration.

Application of NPC

- Ensure that NPC are transparent, reasonable, practical, and reflective of existing capabilities;
- NPC should be carefully selected to coordinate with broader policy frameworks;
- NPC should not increase legal or administrative barriers to an unreasonable degree and should be harmonised with existing frameworks and protocols as far as possible;
- For offshore wind, NPC is most effective at the seabed leasing stage (as applicable).

Evaluation of NPC

- NPC should be measurable, verifiable, comparable and quantifiable, if possible, without restricting flexibility in bidding;
- NPC require enhanced transparency in the evaluation and scoring process for tenders.

Industrial policy should adopt a broader, responsive and flexible approach

Focusing NPC on industrial development or local content requirements (LCRs) restricts the incentives to invest in a local supply chain to a small number of market actors with winning bids. This can hamper wider industrial growth and the ability for the wind supply chain to plan for efficient production, cost-effective procurement and economies of scale.

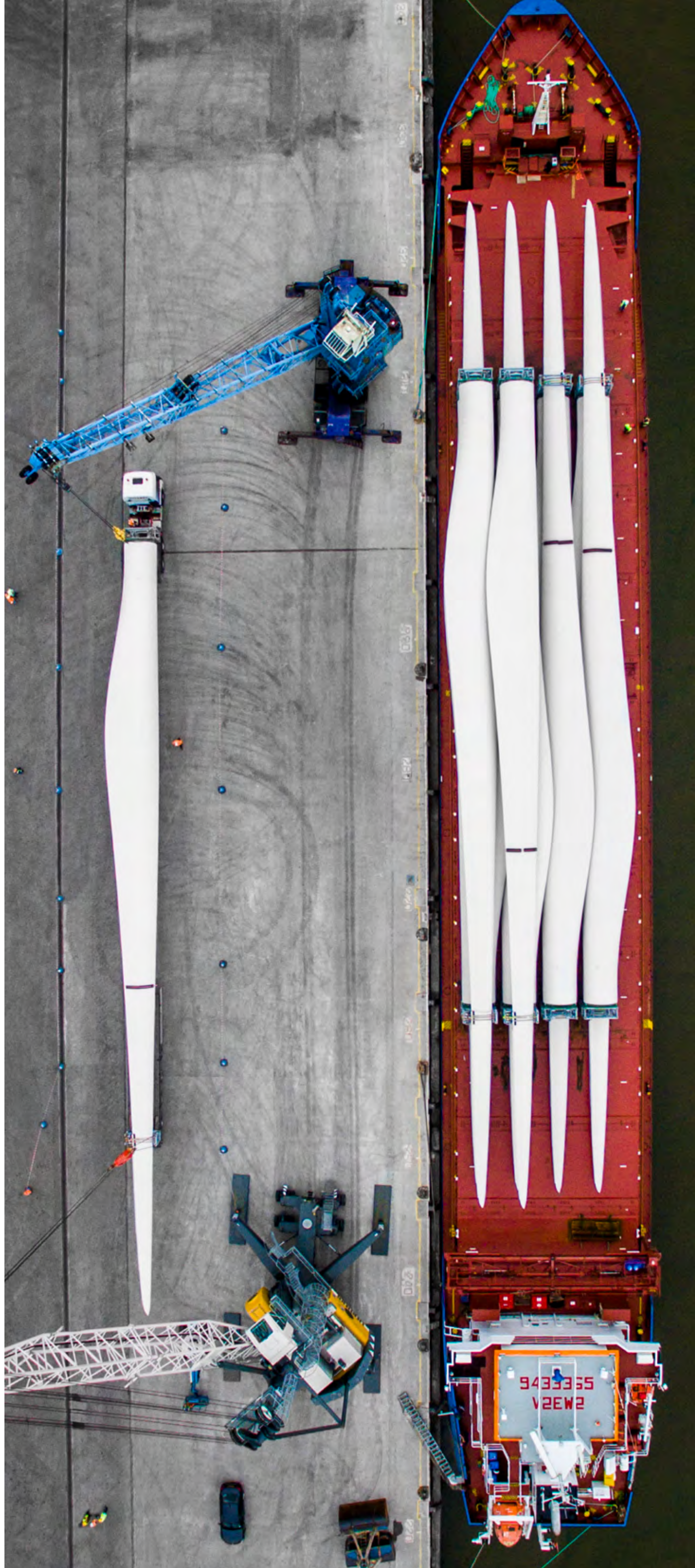
Policymakers should instead adopt a broader sector growth strategy that offers a practical timeline with milestone deliverables incrementally ramping up installed capacity and supply chain development, while driving costs down. A consultative process between government and industry is pivotal for creating an effective industrial strategy, taking into consideration the unique market conditions in each country and the wider investment picture for the supply chain.

Recommendations to maximise value from wind energy

The urgency of the global goal to triple renewable energy capacity by 2030 demands a shift beyond cost in wind energy development. Recognition of the wider societal and socioeconomic net benefits of wind energy can help to drive uptake of the technology and foster more sustainable remuneration schemes.

Ultimately, the industry needs stable and ambitious policy environments that offer reasonable returns on investment to achieve scale. GWEC recommends the following actions to capture the value from wind energy in power markets and auction schemes:

- **Avoid the pursuit of the "lowest**



cost possible" in energy procurement, considering the system- and economy-wide costs of alternatives to renewable energy, as well as the economic and stranded asset risks of fossil fuels, as discussed in the previous section.

- **Consider revenue-sharing mechanisms** instead of using uncapped negative bidding and other forms of "race to the bottom" auction mechanisms.

- **Undertake market design assessments now to prepare for the coming scale-up of renewables generation.** Renewables are currently the cheapest source of new generation in countries which represent around 82% of global electricity generation.[39] However, many countries, especially those with powerful state-owned vertically integrated monopolies or high levels of regulation, do not take economics fully into consideration when building out their generation portfolios. Industry can work with international institutions to encourage proactive power market design reviews to ensure that renewable energy is adequately incorporated, such as via implementing priority dispatch for low-carbon generation.

- **Design auctions that balance competitive price discovery and long-term delivery of affordable electricity and wider socioeconomic benefits.** This includes ensuring fair and sustainable remuneration mechanisms, as well as robust pre-qualification criteria to foster competitive and top-quality bids that will lead to a high project realisation rate.

- **Adopt a cautious approach to NPC in offshore wind auction schemes**, carefully weighing its effectiveness in achieving political, economic, or social objectives against the impact on project economics. This process should be undertaken in consultation with the industry, and with broader energy transition goals in mind.

39. BloombergNEF, Tripling Global Renewables by 2030: Hard, Fast and Achievable, 2023.

CHAPTER 2: BUILDING THE GLOBAL WIND SUPPLY CHAIN TO MEET THE TRIPLING RENEWABLES GOAL

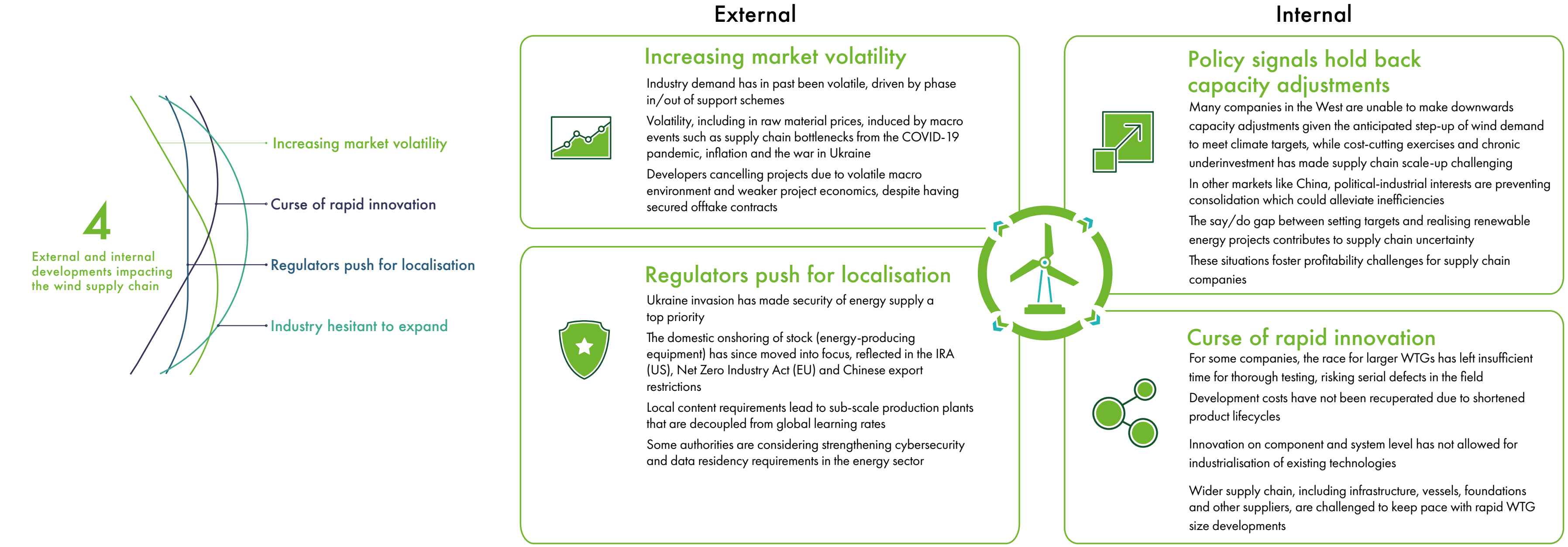
Building the global wind supply chain to meet the tripling renewables goal

To achieve the goal of tripling renewable energy and get on-track for a 1.5°C trajectory, the wind industry needs to roughly triple annual installations within this decade. By 2050, the global wind fleet needs to be roughly eight times its current size, reaching around 8 TW of installed capacity.

This will require a dramatic and sustained ramp-up in supply chain investment to build the necessary production facilities, infrastructure, partnerships, innovation and workforce to deliver new wind capacity.

However, while political ambition is growing for wind to become a backbone of electricity systems, in many key regions of the world, investment in the wind energy supply chain has been insufficient in recent years, with limited support from governments. From Europe to Americas, there has been chronic underinvestment in

External and internal challenges facing the global wind supply chain



Source: GWEC and BCG, Mission Critical: Building the Global Wind Energy Supply Chain for a 1.5C World, 2023; we note this graphic has been slightly updated by GWEC Market Intelligence as of Q1 2024.

future supply chain capacity (in onshore wind, current capacity is sufficient to meet near-term demand), which makes scale-up to meet the tripling renewables goal challenging.

In December 2023, at Trade Day at COP28, GWEC launched 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."[40] The report, produced in partnership with Boston Consulting Group (BCG), assessed the production capacity gaps across the full value chain for onshore and offshore wind to 2030, from critical minerals to transport and installation. GWEC and BCG also collaborated on a scenario-planning exercise, testing how four macroeconomic and geopolitical outlooks would impact energy transition policy, wind market growth, wind supplier margins and cost of wind power in this decade. The analysis and findings of this report are discussed in this section.

The wind supply chain under external and internal strain

In the external environment, the wind industry is experiencing **volatile policy and market demand**, which has led to underinvestment with regards to ramping up global supply chains. From Europe to the Americas, forward investment in scaling up production capacity has been stifled due to stop-start government policies, permitting bottlenecks and a lack of clarity and regular cadence for tenders.

At the same time, supply chain actors are rightly hesitant to adjust capacity downwards given the anticipated ramp-up in wind demand to meet climate goals.

Inflationary impacts have hit the price of commodities, labour and logistics, induced by macro events such as the COVID-19 pandemic and the invasion of Ukraine. Combined with rising cost of capital, this is also impacting the investment case for wind energy projects and supply chain capacity. Market and auction designs and procurement schemes that prioritise low cost of power have led to razor-thin or even negative margins, failing to provide the flexibility to adapt to a dynamic and volatile price environment.

Another external factor is the growing push for **domestic onshoring** which extends beyond securing the flow of energy supply, to now localising production activity. This shift in political agenda largely stemmed from the global energy crisis in 2021, Europe's reliance on Russian gas at the start of the invasion of Ukraine, as well as rising drought and coal price volatility in Asia. The initial focus was on securing energy supply and diversifying sources of fossil fuel generation (approving or restarting coal plants, building new LNG terminals), while initiating a ramp-up of domestic renewables deployment.

Since then, the discussion on energy security has shifted to prioritising local supply chains and industrial activity. In some of the leading wind production hubs of the US, Europe and India, policymakers are increasingly focused on domestic onshoring and reshoring. Large policy packages like the Inflation Reduction Act (IRA) in the US, Made in China 2025 and the EU's Net Zero Industry Act aim to expand industrial leadership in the cleantech sector. Some authorities are considering strengthening cybersecurity and data residency requirements in the energy sector.

But policies need to be carefully calibrated to create conditions for local supply chain growth while maintaining international trade, allocating capital efficiently and keeping prices competitive. As the wind supply chain is highly globalised, ill-considered policies pose a risk to the cost of wind power. Consequently, this jeopardises policy support and the necessary scale-up in volumes required to reach energy and climate targets.

Meanwhile, countries in the Global South often lack the financial and policy tools available to the major industrialised countries, and domestic onshoring strategies undertaken by major industrialised economies could result in them being locked out of the technology and value chain of the wind industry.

Moves towards a more protectionist environment for wind equipment could also undermine supply chain development in Global South countries such as India, which hope to position themselves as major equipment exporters and will be needed to support the global scale-up of production capacity for key components.

40. https://gwec.net/supplychainreport2023/

Internally, wind industry actors are hesitant to scale up production capacity, due to **uncertainty in future market growth**. Policy environments are not fit-for-purpose to incentivise deployment of wind energy at the necessary levels, marked by stop-start government ambition and auctions, and bottlenecks in project permitting, land availability and grid buildout. Cost of capital remains a significant investment barrier for projects and supply chain in EMDEs.

The prominent "say/do gap" between governments setting targets and actual realisation of renewable energy projects contributes to supply chain uncertainty and hesitancy to scale up. Maintaining overcapacity puts enormous pressure on supply chain players, particularly those with a client base more limited to wind (as opposed to bearing manufacturers or cable suppliers).

Meanwhile, local content and overarching industrial priorities are preventing industry consolidation in some markets like China, which would allow for a leaner and more efficient supply chain. There is adequate investment for scaling up to meet domestic growth targets, however political-industrial interests and competing priorities are similarly squeezing profitability of wind industry companies in China.

Finally, a distinct characteristic of the wind sector among other energy transition supply chains is the industry's **"rapid innovation curse."** The race for ever-larger turbines specialised for specific markets has shortened the product development cycle, leading to an inability for OEMs to recuperate their R&D spend, in addition to hampering the wider supply chain's ability to achieve economies of scale as other manufacturers, vessel-builders and logistics planners are challenged to adapt to ever-growing turbine models.

With continuous technological progress, the industry has reached a new stage with turbines growing larger and more specialised. For example, turbines have been designed for factors such as payload on highways (USA), environmental requirements (EU), climate conditions (Middle East), co-located plants (China) or grid limitations (Australia). A breakneck and bespoke development cycle also increases technical risk for turbines, leading to potential concerns over quality and defects if levels of serial production remain too low to refine turbine models over multiple generations.

These factors combined have fuelled 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.

Gearing the supply chain up for different macro scenarios

Given the turbulence of recent years, as we look ahead to meeting the tripling renewables goal by 2030, it is worth considering the various geopolitical and macroeconomic conditions that could impact the wind market and wider energy transition policy. GWEC and BCG jointly developed four such macro scenarios looking to 2030, and assessed each of their material effects on the wind supply chain.

1) **Open Door,** where major powers see the benefits of global cooperation based on established norms for trade and build regional supply chains that are competitive and resilient.

2) **Increased Barriers,** where domestic investment focus, trade conflicts and alliances lead economies to implement unilateral policies and trade barriers, reducing cross-border supply chain flows.

3) **Economic Downturn,** where the world is hit by the severe knock-on effects of an economic downturn with hyper-inflation, defaults and investment dry-up. A global recession and Chinese growth slowing down lead to a supply chain crisis and consolidation.

4) **Global Escalation,** where global markets are impacted by territorial, cyber or proxy war conflicts, resulting in powers pushing to restructure influence, fragmenting global supply chains.

Each scenario has a dramatic impact on energy transition policy, international cooperation and trade. Modelling each of these scenarios against three factors – additional wind market growth compared to a business-as-usual trajectory, supply chain actor margins and cost of wind power in LCOE terms – found that the Open Door scenario led to the largest market growth and additional wind installations, significantly stronger supplier margins and the most substantial decline in LCOE of wind. Conversely, the Global Escalation scenario where increased cross-border conflict reduces trade linkages leads to stagnant market growth, a dive in supplier margins and a spike in wind cost.

When modelling these four scenarios against the cumulative wind capacity required to meet a net zero pathway, **only the Open Door scenario has the positive climate and wind industry impact to deliver the additional capacity needed** to reach the roughly 2.75 TW of wind energy required by 2030.[41] This scenario's focus on open trade and the buildout of multiple price-competitive regions with backwards-integrated supply chains delivers wind growth in line with net zero.

In this scenario, strengthened climate change mitigation ambition and policy enable major world powers to recognise the need for cooperation to achieve a secure and cost-effective energy transition. This allows global supply chains to deepen, focused on LCCs (Low-Cost Countries) like

41. Cumulative wind capacity benchmark according to the IEA's Net Zero by 2050 scenario (2023).

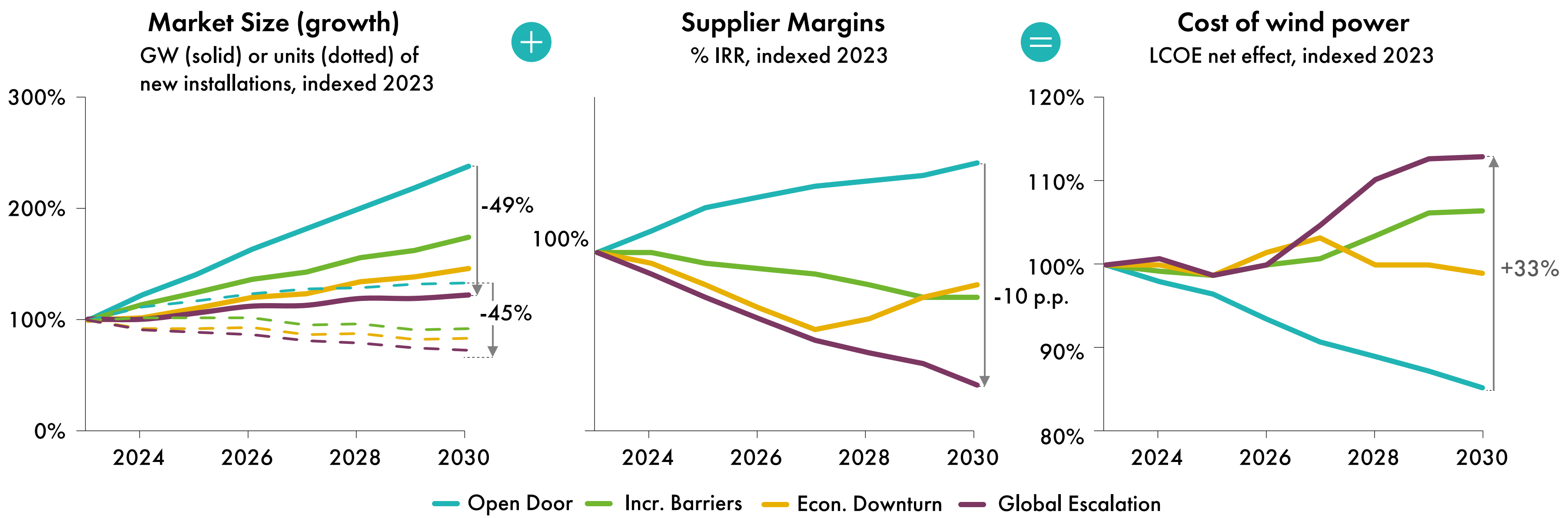
Four plausible futures with major wind industry impact

	Open Door	Increased Barriers	Economic Downturn	Global Escalation
	Push for collaboration facilitates more global approach to ensure resilient supply chainss and strong, stable demand Social and power market transformation delivering against 1.5° target with large global coverage	**More regional crises** lead gov. to focus on short term aids targeting consumers and industry Continued progress towards net zero in developed markets with focus on local production and investment; emerging markets see little progress	**Economic crises** shift focus away from decarbonisation and makes investment into wind challenging Affordability prioritised over sustainability, minimises investments in mitigation; inability to pay cost of adaptation	**International economic and conflict crises** lead to restructured areas of influence; net zero efforts largely cease Availability is highest priority in energy. The world reduces efforts to tackle climate change; rich economies focus on adaptation
Policy	Free trade focus, building multiple price-competitive regions with backward integration	Focus on protecting domestic players and limiting imports; trade conflicts lead to less decarb. focus	Low industrial activity leads to select player support, insolvencies and likely consolidation / mergers	High domestic resilience focus; only larger economies perform well while conflict limits trade
ET focus	Renewable demand growth due to emission taxes and fossil tech phase out; shared standards for trade	More focus on local quick-win solutions and energy flow resilience rather than decarbonisation	Focus on power access and price rather than decarbonisation; less investment into CAPEX-heavy tech	Availability risk from unreliable trade. Chinese mineral restrictions and price uncertainty raise costs

ET = Energy Transition

Source: GWEC and BCG, Mission Critical: Building the Global Wind Energy Supply Chain for a 1.5C World, 2023.

Global scenarios will impact wind market growth, margins and cost curves



Source: GWEC and BCG, Mission Critical: Building the Global Wind Energy Supply Chain for a 1.5C World, 2023.

China and India which can supply fast-growing demand. Regional hubs for supply chain allow for more efficient capacity utilisation and improved resilience.

Cross-border demand stimulation drives a large increase in the number of turbines produced and deployed, allowing for more sustainable growth of the wind supply chain – improved further by alignment within the industry on decelerating turbine platform growth and allowing for a degree of standardisation.

However, under current policies, **we are more likely to see an Increased Barriers scenario materialise**, reflecting the insufficient demand signals in Europe and other key regions, as well as the growing domestic onshoring agenda for wind supply chains. This scenario would set the wind industry to install just more than 2 TW by 2030, leaving a sizeable shortfall to a 1.5°C pathway.

GWEC and BCG also assess that it is likely some elements of the other two scenarios, **Economic Downturn** and **Global Escalation**, will resonate in global markets and energy policy to some degree. As a reflection of the macro volatility experienced in recent years, the wind industry must prepare to navigate a turbulent period ahead, remaining vigilant against the adverse effects of economic downturn, market growth lumpiness and escalation of trade tensions.

Bottlenecks are set to emerge across the global wind value chain

Industry data collected throughout 2023 reflects a risk of manufacturing bottlenecks from mid-decade onward for multiple key components in the wind value chain, in particular gearboxes, generators, blades, and offshore wind compatible castings, towers and foundations. Ports and installation vessels with sufficiently large crane capacity are also needed to scale offshore wind. In all regions except for China and India, nacelle assembly capacity will be insufficient (this includes India for offshore nacelle assembly), with the industry's thin margins currently deterring the expansion needed.

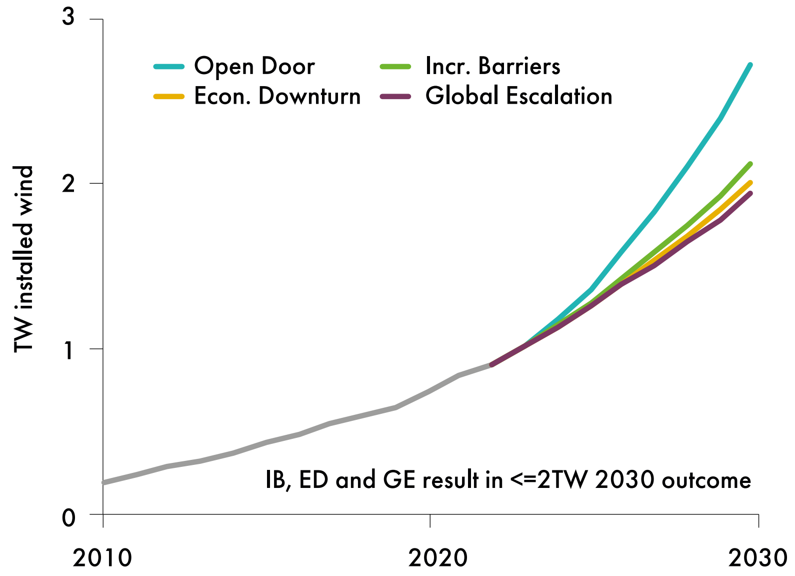
Mining for metals and critical materials such as iron, zinc and copper is centralised in a handful of countries. Broadly, mining for critical minerals needed for the energy transition is concentrated in Latin America, Africa and South East Asia: Chile and Peru are leading producers in copper; Chile and Argentina lead in lithium supply; Indonesia and the Philippines lead in nickel; while the Democratic Republic of Congo leads in cobalt and South Africa in platinum.[42]

However, the refining of critical rare earth minerals for wind turbine permanent magnets is handled almost exclusively by China. The natural resources and refining capacity for these materials are plentiful, but centralisation in both mining and refining makes trade restrictions a major risk for the global industry and renewables targets.

The wind supply chain is currently highly globalised, with a strong focus in China. Over the last decade, China has built up a scale-driven and backwards-integrated industry through steady market expansion. China leads the global market for material refining (steel, aluminium, rare earth materials), and manufacturing of key wind components like gearboxes (80%), converters (82%) generators (73%) and castings (82%).

Over time, most global OEMs have increasingly focused on core competencies such as design, engineering and assembly. Cost has become more important than proximity in supply chains; in the early 2010s, the supply chain was typically in the direct vicinity of the OEM, but now many suppliers have shifted production lines to LCCs. Today, global OEMs' assembly and supply chain have key footprints located in China and increasingly India.

Only an Open Door trade and cooperation scenario is sufficient for net zero



Source: GWEC and BCG, Mission Critical: Building the Global Wind Energy Supply Chain for a 1.5C World, 2023.

Concentration risk in China is not as high in the wind industry as it is in the solar PV industry, however, the concentration risk of these particular components is a concern due to historical patterns in key growth regions for wind – such as the US and Europe – to outsource gearbox, converter and generator manufacturing. These segments of the supply chain offer strategic targets for diversification and reshoring, to ensure more resilient wind scaling.

It is worth noting that most Chinese production is for China: While China holds 64% of the total value generated across the global wind supply chain, from mining to transport and installation, it will also install 58% of the expected new wind installations through 2025.[43]

42. IEA, The Role of Critical Minerals in Clean Energy Transitions, 2021.
43. Value-add based on estimated share of mining, refining, manufacturing, assembly and services with calculation done based on activity location. Installation outlook covering 2023-2025 is from GWEC's wind growth forecast (Q2 2023 Outlook).

Supply chain bottlenecks materialise by middle of the decade

Theme	Critical materials					Key components								Assembly		Offshore wind enablers		
Subject	Rare Earths*	Steel Plate*	Copper	Concrete	Carbon Fiber*	Gearboxes*	Generators*	Blades*	Power Converters*	Castings*	Towers*	Foundations*	Cables*	Onshore nacelles*	Offshore nacelles*	Installation vessels*	Ports*	Workforce
Global level criticality																		
Time to action ** – Europe	2023	-	-	-	2025	2024	2024	2024	2024	2023	2025	2025	2025	2024	2024	2025	2023	2023***
Time to action ** – North America	2023	-	-	-	2025	2023	2023	2023	2023	2023	2023	2023	2023	2024	2023	2023	2023	2023***
Time to action ** – China	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	***

Key findings

Critical materials

- General availability of needed materials at the global level, with copper mining/refining and concrete production available for all major regions
- Major centralisation for refining of rare earth materials, with close to no capacity outside of China today. First alternate refineries expected to be ready by 2028
- Carbon fiber production currently experiencing undercapacity; major capacity expansion has been announced in particular in China, with Europe and North America likely becoming reliant upon imports

Key components

- Risk of manufacturing bottlenecks before 2030 for multiple components at regional level, in particular gearboxes, generators, blades as well as offshore wind size compatible metal castings, towers and foundations
- Strong centralisation for some key components, especially gearboxes and castings. North America is generally fully dependent on imported components and is already today experiencing undersupply of especially components for offshore wind including offshore towers, foundations and subsea cables
- Supply chains will generally benefit from building out regional manufacturing hubs to ensure more resilient access to needed components while ensuring continued trade and global interlinkages to enable flexibility and address demand volatility

Assembly

- Onshore challenge expected only if trade exports from India/China are restricted
- Offshore assembly risks undersupply as uncertain industry outlook may lead to plant cancellations

Offshore wind enablers

- Offshore wind needs to scale both port capacity and wind turbine installation vessels with sufficiently large crane capacity
- US critically lacks vessels and ports while announced expansion plans and orders in other markets can address need to 2030; any cancellations will pose risks

Recommendations

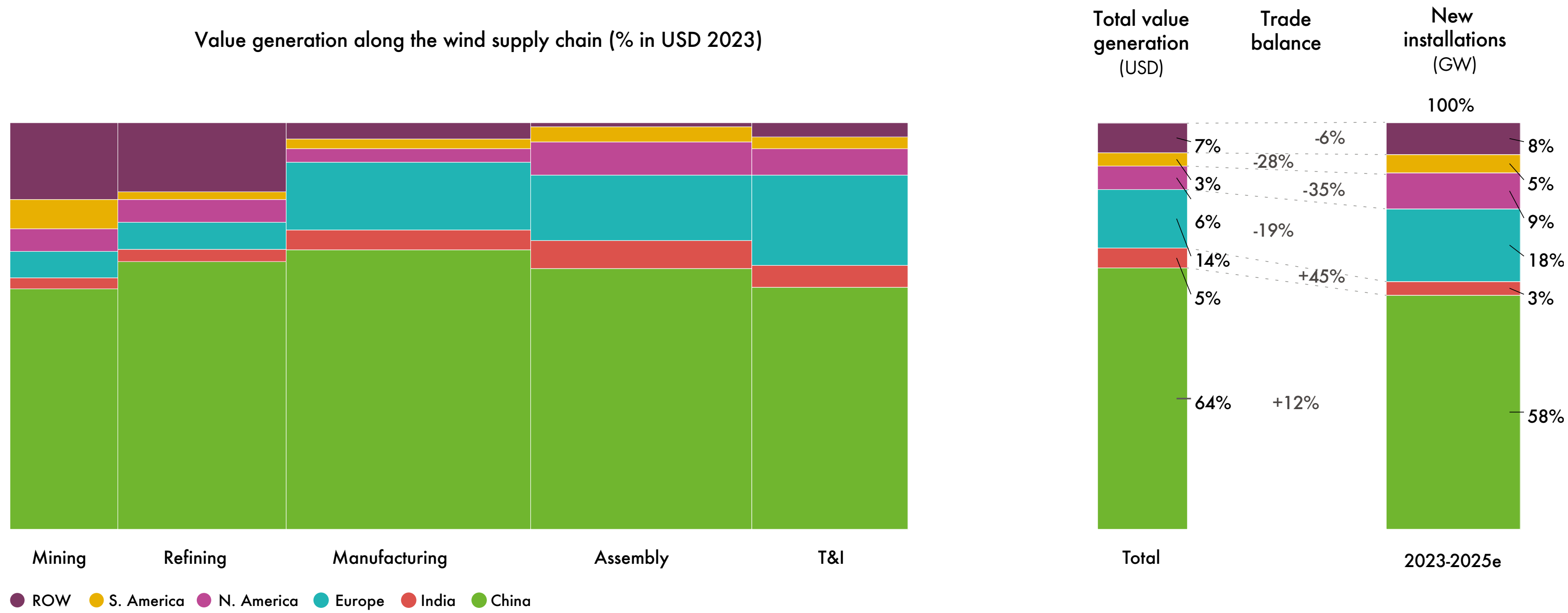
- Address basic barriers to wind industry growth in land, grids and permitting to increase volume and predictability
- Regionalisation will be needed to support growth and resilience, while maintaining a globalised supply chain
- Trade policy should build competitive industries, not push higher costs onto end users
- The wind industry must standardise and industrialise
- The market must provide clear and bankable demand signals
- Fundamental reform of the power market underpins further wind growth

No global bottleneck risk — Immediate global bottleneck

* Deep dive analysis provided ** Time to action denotes time when new capacity construction must be started to avoid bottlenecks in each region without trade
*** Workforce with major challenges, addressed in GWEC & GWO: *Global Wind Workforce Outlook 2023-2027*

Source: GWEC and BCG, Mission Critical: Building the Global Wind Energy Supply Chain for a 1.5C World, 2023.

Value generation varies by segment of the wind value chain; China and India are punching above their weight



Note: Analysis on location of value-add, not nationality of producer. Mining, refining and production split for wind use estimated based on national capacity, sourcing policy and trade patterns, and do not include major Chinese ownership in major mining markets such as Indonesia and Chile. Manufacturing includes sub-suppliers for towers and blades. Assembly includes OEM R&D.

Source: GWEC and BCG, Mission Critical: Building the Global Wind Energy Supply Chain for a 1.5C World, 2023.

Additionally, in terms of finished wind turbines, China's market share remains low. Out of the 90 GW of new wind installations in 2022, nearly 57 GW was produced and assembled in China – 88% was Chinese production for China, less than 0.2% was non-Chinese production for China, almost 9% was non-Chinese production for export and less than 3% was Chinese production for export. That said, there are clear signals that China intends to continue serving as the leading component manufacturer for the global wind industry, and further expand its market share in providing finished wind turbines to global markets.

Interestingly, in terms of trade balance (share of global total value generation relative to share of global new installations from 2023-2025), China holds a positive trade balance, but India's is even higher – showing that India is punching far above its weight as a production hub for the supply chain.

With large Indian conglomerates increasingly investing in the cleantech sector, in tandem with the national "Make in India" policy initiative for localisation of strategic industries, it is expected that India will strengthen its position as a global export hub for the wind industry. India's export opportunities are explored further in GWEC's report with MEC+ "Wind Energy Market Outlook 2023-2027: From Local

Case Study: Advancing the offshore wind supply chain in the Asia-Pacific (APAC) region

Provided by: The Global Offshore Wind Alliance (GOWA)

The summer of 2023 saw GOWA kickstart a series of closed-door roundtables bringing together high-level representatives from governments, offshore wind industry and stakeholders across the APAC region. The aim was to address supply chain challenges and explore opportunities for regional cooperation to advance the acceleration of offshore wind.

The alliance has so far convened representatives from Australia, the Philippines, Sri Lanka, India and Vietnam as well as the states of Victoria, Australia and the US state of California, who have shared insights into their respective offshore wind ambitions and challenges.

Conversations have emphasised the importance of aligning federal and state efforts to support regional collaboration. Some have showcased significant potential for offshore wind energy but highlighted regulatory complexities which are posing challenges in furthering market development. Whilst others have pointed to the need for cooperation with neighbouring countries and strategies to attract foreign investment as key to unlocking offshore wind potential.

Of note was the emphasis on the shortage of capital to support the development and scaling of the supply chain. There was recognition of the need for strategies to attract capital investment into the supply chain, which may include financial incentives, grants and investment-friendly policies.

The profitability of the offshore wind supply chain was central to discussions, particularly in the current challenging economic climate. The example of the collective action in the North Sea has been noted as an example for lessons learned.

Participants have identified various challenges facing the offshore wind industry in the APAC region, including inconsistent policies, capital shortages, technological gaps and a shortage of skilled human resources. However, they agree that strategic collaboration and the establishment of clear regulatory frameworks are essential for overcoming these challenges. Suggestions have included developing consistent policy frameworks, attracting capital investment, enhancing technological capabilities through R&D and investing in education and training programs.

Despite the challenges ahead, there is a sense of optimism regarding the industry's potential for sustainable growth through collaboration, addressing supply chain issues and focusing on community benefits. The APAC region has emerged as a promising hub for offshore wind innovation, demonstrating the transformative power of global cooperation in advancing renewable energy initiatives.

By bringing together key stakeholders and fostering dialogue, GOWA is laying the groundwork for future collaboration and innovation in supply chain development. As nations strive to meet ambitious renewable energy targets and address climate change, regional cooperation will be crucial in unlocking the full potential of offshore wind and meeting the global tripling renewables goal.

Wind Power to Global Export Hub.''[44]

Recommendations for securing the global wind supply chain

If we are to ensure a sufficiently large and stable demand for a net zero future, delivered at a highly competitive cost, industry and policymakers must actively collaborate on global renewable energy supply chains. The GWEC and BCG report, ''Mission Critical: Building the global wind energy supply chain for a 1.5°C world,'' makes six key recommendations for action:

- **Address basic barriers to wind industry growth in land, grids and permitting to increase volume and predictability.**

Parts of the supply chain are now loss-making and unable to invest in future production capacity. This is due to policy and regulatory barriers that lead to heightened uncertainty for project investments. These barriers include overly complex permitting procedures, grid bottlenecks and impractical pricing signals at auction. As a key energy and political priority, the wind energy industry must work with government and civil society to urgently address policy and regulatory barriers, in order to help improve its outlook.

- **The wind industry must standardise and industrialise.**

The wind sector must industrialise and scale, with designs becoming global and modular. To achieve this, turbine platform growth will need to slow down towards 2030 to the extent needed to ensure that OEMs can capitalise on their R&D investments and the supply chain can use equipment for more than a few years, as well as achieve economies of scale.

- **Regionalisation will be needed to support growth and resilience, while maintaining a globalised supply chain.**

With a growing push towards diversification, reshoring and regionalisation, the wind industry will profit from building out regional supply hubs to provide alternative sources for the materials and components needed to deploy additional wind capacity. This activity should focus on the strategic areas where global resilience is currently low and concentration risk in China is high – gearboxes, generators, power converters, castings and rare earth materials.

Measured reshoring activity must be accompanied by measures to keep trade flowing within and between regions, supporting individual nations in enhancing their capacity to deliver at scale, ensuring flexible access to needed materials, components and services, and providing stronger wind demand drivers across borders. This will be particularly important for the future growth of the offshore wind sector, where manufacturing, installation and O&M services all benefit greatly from regional collaboration and cross-border learning.

Governments should adopt a balanced approach between fostering regional supply chain security and accounting for the global interlinkages of the wind energy supply chain. Regions will need to pursue supply diversification strategies, reshore/onshore some segments and grow their own capacities. But this should not manifest in measures that outright block current trade flows and interrupt or delay deployment. The time needed to reshore or nearshore manufacturing must not be underestimated.

Regions will need to pursue supply diversification strategies, reshore/onshore some segments and grow their own capacities. But this should not manifest in measures that outright block current trade flows and interrupt or delay deployment.

- **The market must provide clear and bankable demand signals.**

Markets must develop credible build-out trajectories in the shape of concrete and transparent targets, as they will be key to supply chain investment. These must be stable, bankable and much stronger than

44. https://gwec.net/india-wind-energy-market-outlook-2023-2027-report/.

they are today. By stating clear targets and auction schedules or yearly capacity additions over a long horizon stretching beyond 2030, policymakers will be able to grow wind power demand as needed through communicated targets for electrification, decarbonisation, sector coupling and storage, involving the broader industry in building renewables ecosystems.

In addition, governments should look towards establishing public funding schemes that aim to scale the wind industry. While there are ample opportunities to acquire public funding for R&D or innovation activities, there is a notable lack of funding schemes dedicated to scaling up manufacturing and infrastructure.

- **Trade policy should aim to build competitive industries, not push higher costs onto end-users.**

Collaboration and trade must be protected to foster healthy future wind pipelines. Supply chain capacity utilisation remains key to cost reduction. This is only possible if resources can be shared across regions, with competitive cost positions and limited trade barriers. Markets will benefit from public investment into workforce skills and infrastructure, while prescriptive regulation against cross-border trade could reduce industry growth and increase costs. This will ultimately be paid for by households, commercial and industrial consumers, cities and other consumers of electricity.

Rather than pursuing defensive mechanisms which could enhance trade barriers, governments should focus on incentivising strategic segments of the domestic industry, creating a more attractive market environment by ensuring adequate pricing and returns, making competitive finance available and removing bureaucratic barriers.

- **Fundamental reform of the power market underpins further wind growth.**

In order to provide the certainty needed to attract investment, power market reform should be introduced to better address the requirements of renewable generation. Long-term operating margins must be ensured through awards based on solutions with higher system value – such as a better production profile – rather than strong competition for the lowest price per MWh. The broader societal benefits of wind energy could also be considered to further stimulate innovation and domestic value creation.

Creating secure and sustainable supply chains for wind power will allow the industry to continue to expand and create multiplier effects in sustainable employment opportunities, industrial growth and economic productivity around the world. This would not only bring us closer to the global climate change mitigation goal of tripling renewables, but also ensure that we provide incredible socioeconomic value along the way.

Pursuing industrialisation and standardisation

Like any modern industry sector, wind power owes a large part of its success to its drive to innovate. As wind energy has expanded to all parts of the world, the industry has also expanded its ability to adapt to local conditions and requirements, thereby identifying solutions that deliver larger volumes of energy more reliably and efficiently.

More recently, however, the balance between efficient supply chains capable of increasing quality and reducing costs on the one hand, and an innovation-hungry, highly competitive sector where new products are churned out at breakneck speed on the other, appears to have shifted towards the latter.

In February 2023, onshore wind turbines surpassed the symbolic double-digit mark in power ratings as Chinese manufacturer Envision unveiled its EN-220/10 MW model, for deployment in China's northern regions.

Most wind turbine OEMs have long offered models for onshore use with power ratings of 5-6 MW and above. Vestas upgraded its EnVentus onshore turbine from 5.6 MW to 6.0 MW in late 2020, and then boosted it to 7.X MW in 2022. Nordex evolved its Delta 4000 platform to power ratings of 6 MW and above; the N163/6.X model, with rotor sizes of up to 164 metres, has already made its mark in low- and medium-wind markets. A prototype with a larger rotor size, up to 175 metres, is expected this year.

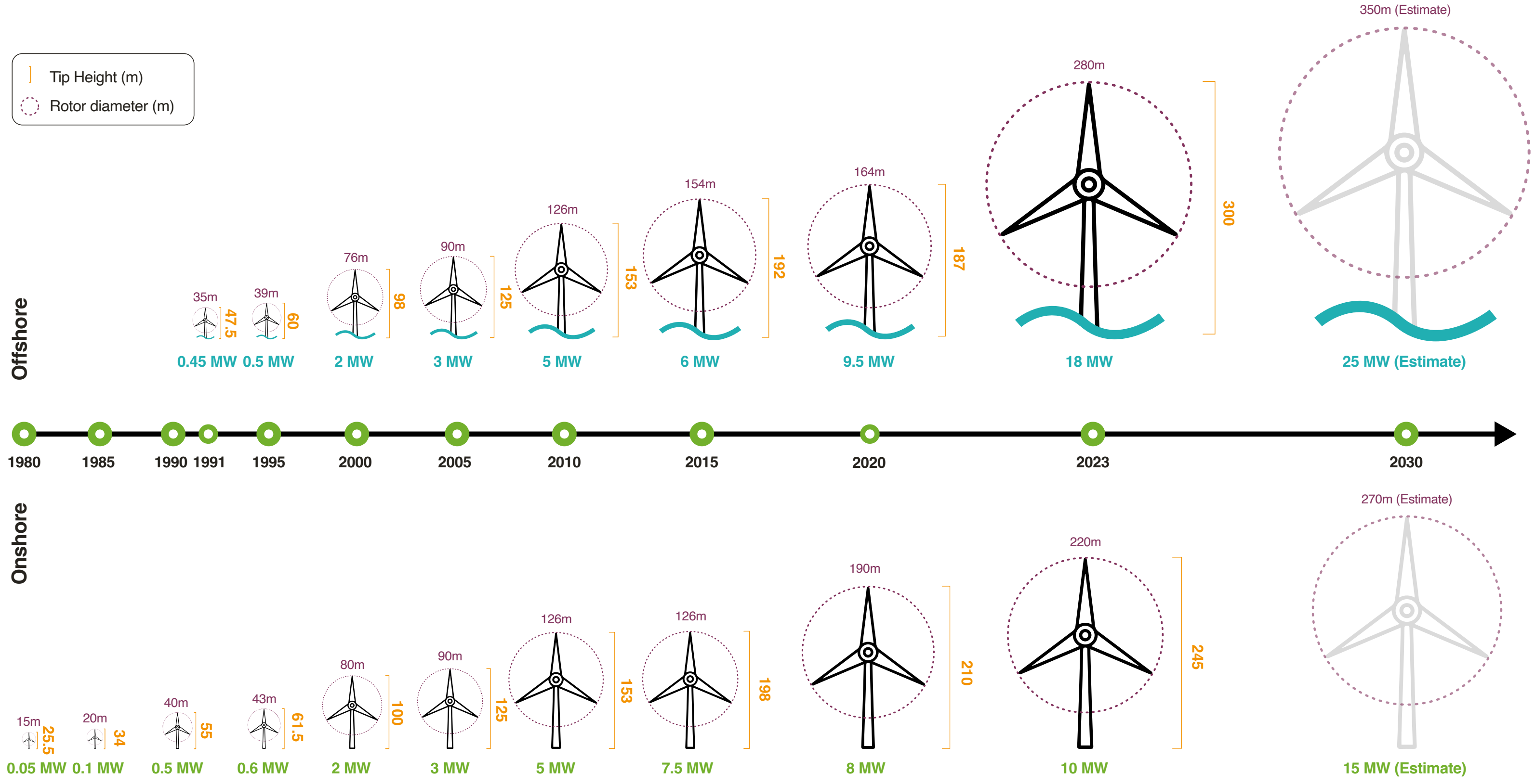
Other OEMs are now looking to make a mark in the 10+ MW territory. For example, Chinese company Sany's 919-series platform, featuring 8.5-9.0 MW models and launched in 2022, has been succeeded by the SI-230-100 variant, with power ratings of 11 MW and above, and rotor sizes of up to 230 metres. Other Chinese turbine OEMs who have also launched a 10+ MW onshore wind turbine include Goldwind, Mingyang, Windey, DEC, CSSC Haizhuang, SeWind, CRRC and United Power.

Super-sizing offshore wind

In the offshore wind sector, long-gone are the days of the Siemens 3.6 MW 'workhorse', with rotor diameters of up to 120 metres, dominating the sector. In early 2021, Danish OEM Vestas set new benchmarks for rotor diameter and nominal power rating with its V236-15.0MW offshore wind turbine. Its 236-metre rotor diameter and 43,743m2 wind-swept area easily surpassed the next-largest model up until then, GE's Haliade-X, with a rotor diameter of 220 metres and wind-swept area of 38,013m2.

While other European OEMs also

Trend of onshore and offshore turbine size, 1980-2030



Source: GWEC Market Intelligence.

Industry Spotlight: How effectively is wind energy generation capacity being utilised?

Provided by: HARTING Technology Group

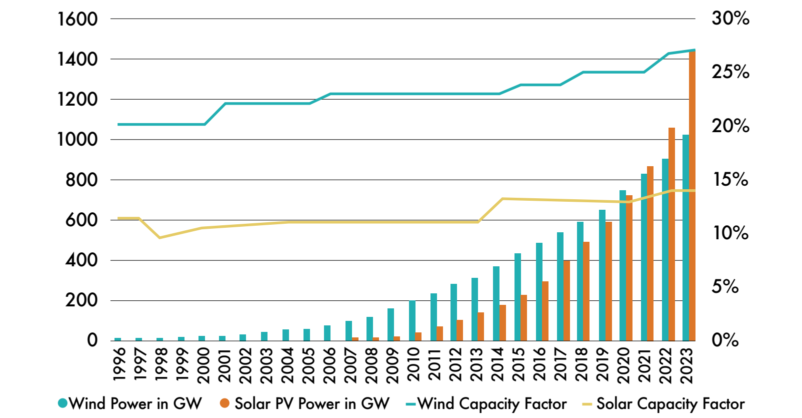
When travelling, people often encounter the striking sight of wind turbines. One common question is why some turbines are not rotating. After 40 years of development, the global wind industry has surpassed the impressive milestone of 1 TW in 2023 and is now on track to exceed 2 TW before 2030. To reduce friction on this huge growth trajectory, we need to address questions about the efficiency and effectiveness of wind energy generation capacity.

Wind energy generation varies according to location, weather conditions and turbine technology. In many countries, the electricity grid cannot absorb the generated wind energy, resulting in significant curtailment rates. All these factors affect the utilisation of wind energy generation capacity. But has utilisation improved consistently over time to keep pace with the expansion of wind power, and if so, what technological and economic factors have contributed to this improvement?

Capacity factor is defined as the ratio of the net electricity generated over a period of time to the energy that could have been generated at continuous full-power operation during the same period. This metric is commonly used to show power plant capacity utilisation across different countries and regions with varying generation technologies such as fossil fuels, nuclear, hydropower, solar and wind. The electricity generated can be metered, billed, absorbed in the grid or storage system or consumed by various electrical loads.

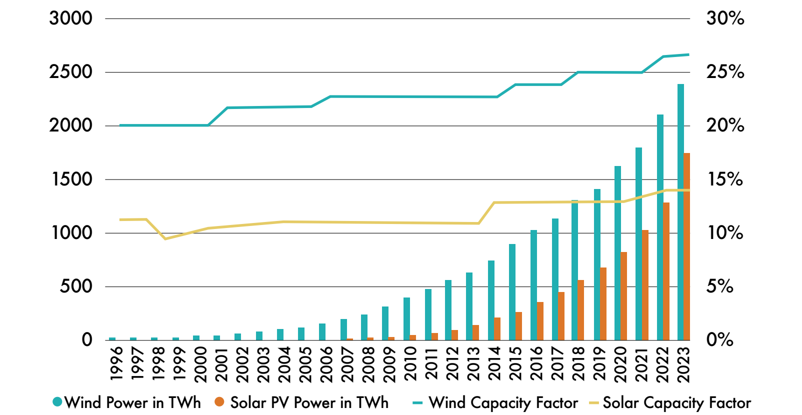
$$\text{Capacity Factor in Year xxx} = \frac{\text{Full-Power Generation Hours in Year xxx}}{\text{8760 (365 x 24 Hours)}} = \frac{\dfrac{\text{Generated Energy in kWh in Year xxxx}}{\text{Total installation Power in kW by Year xxxx}}}{\text{8760 (365 x 24 Hours)}}$$

Global Total installation Power in GW and Capacity Factor, Wind vs Solar PV



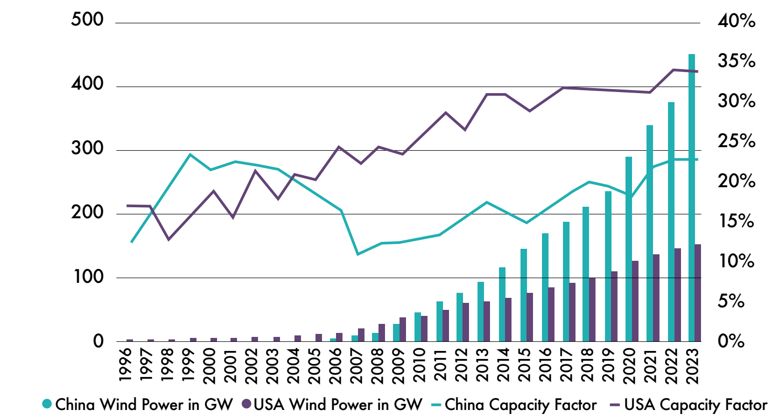
Source: GWEC, IEA, BP, Ember, 2024.

Global Yearly Generation in TWh and Capacity Factor, Wind vs Solar PV



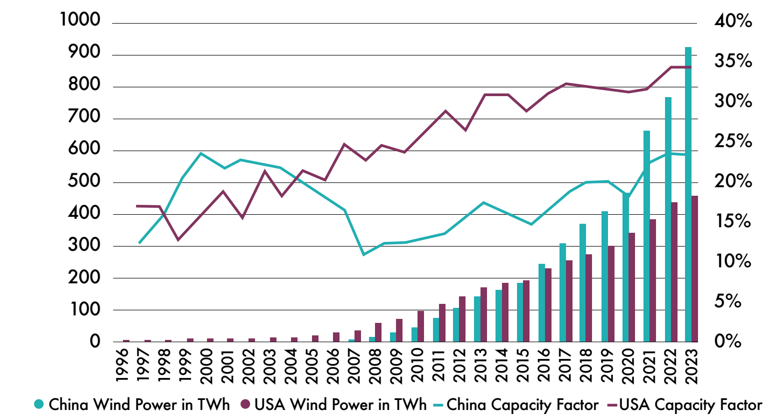
Source: GWEC, IEA, BP, Ember, 2024.

Wind Total Installation Power in GW and Capacity Factor, China vs US



Source: GWEC, IEA, BP, Ember, 2024.

Wind Yearly Generation in TWh and Capacity Factor, China vs US



Source: GWEC, NEA, ACP, EIA, Our Worl in Data 2024.

Use cases:
Wind and solar PV are currently the primary renewable energy sources that must grow at scale to meet net zero targets, and their capacity has been steadily increasing over the last decades. The graph below shows the global total installed capacity and corresponding capacity factor of wind and solar PV since 1996. While both capacity factors have grown, wind has a capacity factor double that of solar PV.

The reasons for continuous capacity factor improvement vary. The main driving factors are technological innovations of wind turbines and solar PV systems enabling the harvesting of as much wind and solar PV energy as possible, along with the continuous improvement of quality and reliability resulting from mass industrialised production.

From another perspective, comparing the capacity factors of the US and China – both countries located in the northern hemisphere and covering a large area across several latitudes and longitudes – shows that while China has had a higher total installed wind capacity since 2010, the US has had higher capacity factors since 2007 by about 10%. This corresponds to around 900 more full power generation hours per year in the US. Weather conditions may have played a dominant role in the differences, given the relatively similar wind turbine technologies in both countries. The relatively high level of grid curtailment in China is also a contributing factor.

Assessing efficiency and effectiveness of wind power through capacity factors offers a variety of use cases, which can be harnessed by the wind industry for continued improvement in building a highly reliable, long-lasting supply chain.

released offshore wind platforms occupying the upper range of the 10-15 MW range over the past few years, Chinese manufacturers took the "race to the top" to the next level.

Dongfang unveiled in July 2022 its D16000-2XX-S direct-drive offshore turbine with a turbine rating of 16 MW and 128-metre rotor blades – a wind industry record at the time.

In late 2022, giant conglomerate CSSC Haizhuang announced it was developing an 18 MW offshore wind turbine with a 260-metre rotor diameter. Mingyang's MySE 18.X-20 MW, released in late 2023, has flexible power ratings of between 18 MW and 20 MW. It supports rotor diameters of up to 292 metres and is designed for medium- to high-wind locations, including those prone to typhoons.

The OEM has already announced plans to produce an even larger offshore wind turbine, with a capacity rating of 22 MW and a rotor diameter of more than 310 metres.

The "rapid innovation curse"

Exciting as it may sound, the rapid upscaling of wind turbines is not a straightforward, efficient pathway to more cost-effective energy. A technology 'race' to develop new turbines is not only an expensive investment for R&D, but is also a risk to a sustainable supply chain. OEMs set the industry pace with their turbine designs, directly impacting the rest of the supply chain which needs to quickly adapt and follow suit.

Rapid wind turbine upscaling also compounds the pressure on cost-volatile raw materials and exacerbates issues related to logistics, transport and installation – ultimately making fierce and unmanaged competition a trap, rather than a foundation for sustainable growth.

While larger turbines typically result in higher capacity factors, other factors play a more significant role in reducing the cost of energy generated from wind farms over the long term. These factors include **adapting to specific site conditions, standardising components and streamlining supply chains.** Not to mention, the additional investment needed in the supply chain to deliver larger turbines may detract from the cost efficiencies achieved through larger turbines.

Facilitating sustainable growth through collaboration

In December 2023, Energy Cluster Denmark, a member-driven organisation to facilitate innovation collaborations, announced a new partnership between European OEMs Vestas and Siemens Gamesa to standardise tower transportation equipment for offshore wind turbines.

At the heart of the partnership is a desire to develop standards that allow for shared use of an expensive and scarce asset – in this case, installation vessels. This in turn allows the supply chain to transport components more efficiently and quickly.

Standardisation does not come without its limitations and downsides. In any industry sector, OEMs will seek to gain market share through their unique product offering and high-value intellectual property. The challenge is to identify the areas where meaningful collaboration can generate standards for components that benefit the sector as a whole without restricting the commercial opportunities available to any individual company or raising costs to an unreasonable degree.

Initiatives such as the Advanced Product Quality Planning Group for Wind (APQP4Wind) – that brings together turbine OEMs including Goldwind, Vestas, Siemens Gamesa and GE Vernova as well as developers such as Ørsted and Vattenfall, and supply chain companies – are a good example of how to make this happen. APQP4Wind has already produced an industry specification for fasteners, a straightforward domain to standardise and one with low levels of innovation.

Another approach to addressing the innovation and scaling challenges of the wind power sector is modularisation. This strategy could enable faster rates of assembly and deployment to meet growth targets. Additionally it could address some of the logistical issues associated with super-sized equipment, and tackle the variability of wind resources and geographic conditions as wind expands away from the 'ideal' sites where it first prospered.

As other industries including the automotive sector have demonstrated, modularisation can produce a variety of product configurations with few component changes per variant, creating

Industry spotlight: Innovation in the fabrication of offshore wind tower monopiles

Provided by: Bryan O'Neil, Director, Global Offshore and Power Generation, Lincoln Electric Company; Ken Mui, Specialist SAW Automation, Lincoln Electric Company

Achieving ambitious offshore wind targets requires rapid industrialisation and scale
When we reflect on 2023 and the current year 2024, worldwide offshore wind fabrication capacity has made significant investments in the supply chain to scale up the manufacturing base – both in capacity and scale. Across the world, from China to APAC, Europe and the Americas, investment in wind has hit record levels, particularly in new offshore wind factories for foundations.

While much has been accomplished, the offshore wind industry's key stakeholders and critical supply chain providers also agree more is needed. The collective global wind energy segment has an immense challenge and opportunity ahead to reach 2035 and 2050 targets. To achieve future installed capacity targets, the most rapid industrializations of energy supply chain and technology ever needed since the 1900s must happen.

This holds true across all fixed foundations but especially in monopile capacity, presently spinning up new capacity in 2023/2024 to reach new extremes never seen before. Larger diameter, weight and length capacity will be the core to supporting even taller towers and higher capacity turbines, together achieving record-breaking MW capacity.

The submerged arc welding process has been key to the industry's success, a proven process for many decades that now has new options for even higher productivity and quality. A step change in welding technology is needed to achieve a scale-up of offshore wind in the future.

Advanced technologies to accelerate monopile construction
As offshore wind turbines exceed 12 MW headed towards 20 MW, the required size of the monopiles is also increasing to over 12m (40 ft) diameter with up to 150mm (6'') wall thickness weighing in excess of 2500 metric tons.

To put this into perspective, a 9m (30 ft) diameter section can have a circumferential weld weight of over 600kg (1300 lbs.) of weld metal for a single joint. Total weld weight of a monopile can easily exceed 25,000 kg (55,000 lbs.) of weld metal. Due to the vast quantity of weld metal that is required, fabricators are looking to advanced technologies to help reduce welding time and metal to achieve greater efficiency in time and materials.

Typically, the SAW welding joint is 12° to 16° Narrow Gap groove, designed to reduce the required weld metal for each joint. Future welding solutions can be developed >12° down to 8° bevel, further reducing the required weld metal for each joint.

New welding techniques for heavy plate and vessel welding using submerged arc welding are required to meet the rapidly expanding global energy transition, including offshore wind. Fabricators across multiple industries using traditional submerged arc welding techniques can upgrade their current operations and potentially more than double the deposited weld metal using newer technology like Lincoln Electric's Long Stick Out (LSO) process with the relative simplicity of bolt on equipment. Advanced waveform control makes electrode stick out exceeding 150 mm (6 in) with 4 mm (5/32 in) wire possible. Combined with consumables capable of handling high amperage and voltages, fabricators can see up to 50% or higher decrease in welding time for the same material thickness.

To achieve further industry acceleration, continued collaboration on innovations like these in the welding segment must continue between industry supply chain, project owners, investors and local governments. Innovation and collaboration will provide the force and mass to achieve true rapid acceleration of wind energy.

Industry Spotlight: Risk mitigation strategies for wind supply chain scaling

Provided by: Bureau Veritas

Last year, Bureau Veritas completed a survey of more than 800 energy industry leaders to create the 2023 BV Energy Transition Report. In this report over 50% of respondents cite "Supply Chain Quality Issues" as their top supply chain concern and say they lack the resources to monitor components adequately in their supply chain.

Compounding this issue, the global wind energy sector aims to quickly scale its supply chain to meet the tripling renewables goal. The importance of standardisation in enhancing quality assurance and certification in risk management, now more than ever, cannot be overstated. These technical practices contribute to economies of scale, pushing efficiency through industry standards and best practices:

Quality Assurance in Production: Standardisation of production processes and certification of manufacturing facilities ensure consistent quality across the supply chain. For instance, Bureau Veritas works closely with manufacturers such as LM Wind Power to verify compliance with industry standards such as IEC 61400 series and ISO 9001. By certifying LM's blades and their manufacturing facilities and processes, we ensure that their components meet rigorous quality benchmarks, fostering reliability and trust in their products.

Risk Management Through Certification: Certification programs for components, equipment, and projects play a crucial role in risk management. Consider the certification of Offshore wind projects in the UK: Certifying these projects against international standards and regulatory requirements, conducted thorough assessments of structural integrity, safety protocols and environmental impact, is crucial. This process helps to identify and mitigate risks associated with overall project performance, ensuring safe and sustainable operations throughout the wind farm's lifecycle and maximising the bankability of the UK offshore wind industry.

Supply Chain Optimisation: Standardised practices enable supply chain optimisation, reducing lead times, improving efficiency, and enhancing competitiveness. Collaboration with supply chain stakeholders is needed to implement quality management systems, conduct audits and provide training, driving continuous improvement and scalability. The implementation of digital solutions will continue to be a major driver of wind supply chain optimisation.

Market Access and Compliance: Certification to recognised standards facilitates market access and regulatory compliance, essential for scaling operations globally. Consider the case of entering new markets such as in Southeast Asia. Certifications that are widely accepted in target markets are required, streamlining approval processes and ensuring compliance with local regulations. This market access enables companies to expand their operations internationally while maintaining high standards of quality and compliance.

Benefits and impact

- **Enhanced Quality and Reliability:** Standardisation and certification processes lead to enhanced product quality, reliability and performance, crucial for scaling the wind supply chain.

- **Risk Mitigation:** Certified products and projects reduce risks associated with operational failures, regulatory non-compliance, and reputational damage.

- **Efficiency and Cost Savings:** Standardised processes drive efficiency gains, reduce costs, and improve overall supply chain performance, supporting sustainable growth objectives.

- **Global Market Competitiveness:** Certification to international standards enhances market competitiveness, opening doors to new opportunities and partnerships in the global wind energy market.

Standardisation and certification are essential components in ensuring risk management and supply chain scalability in the wind industry. If we are to meet our "double down, triple up" goals, we need a supply chain that not just delivers the high production required, but also maintains the high levels of quality needed to ensure maximum supply chain efficiency.

economies of scale while providing highly desirable customisation as a result.

Within the automotive sector, a visible example of modularisation was provided in the late 1990s by the 'Smart' car collaboration between Mercedes-Benz and Swatch. While a typical car manufacturer would deal with around 200-300 suppliers, Smart uses 25 module suppliers, each providing components such as dashboard systems, body structure, braking control systems and seating modules.

One of the key benefits of this modular approach has been to transfer value-creating activities from the OEM to upstream suppliers, enabling OEMs to focus on core competencies while at the same time increasing their ability to accommodate new product variations in a shortened lifecycle environment and at lower cost.

Future-proofing the global wind supply chain

As the wind industry initiates a massive scale-up of production to meet the global tripling renewables goal, these collaborative approaches can drive environmental sustainability, low-emissions intensity and waste reduction in the supply chain.

That said, the challenge of coordinating the efforts of such a large number of companies operating across different geographies under a raft of vastly divergent regulatory and policy frameworks is hard to overestimate.

Initiatives such as the Global Offshore Wind Alliance (GOWA) – founded by Denmark, the International Renewable Energy Agency (IRENA) and GWEC, and officially launched at COP27 in November 2022 – aim to drive the uptake of offshore wind by garnering political support and helping to share knowledge between a global community of practice, including in supply chains. GWEC will also be undertaking work on a global ESG/sustainability and traceability framework for the wind supply chain.

As wind energy continues to expand to more countries, it is essential that the Global South is able to access and benefit from technology transfer and value creation. Targeting those areas of the supply chain that lend themselves to a more modular and standardised approach can provide opportunities for Global South countries to stimulate local production while avoiding damaging bottlenecks and counterproductive market restrictions.

Recommendations to enhance standardisation and scale up production

The development of new manufacturing and production models in the global wind supply chain is both necessary and desirable to achieve the ambitious target of tripling the world's installed renewable energy generation capacity to at least 11,000 GW by 2030.

GWEC makes the following recommendations for supply chain standardisation and production:

- **Cooperation must move from a high-level concept to the practicalities** of technical partnerships and taskforces. These collaborations should bring together international players in the wind supply chain with the specific goal of implementing effective solutions to real-world challenges. There is a need for more globally diverse clusters and workstreams that cooperate on areas of innovation, standardisation and ESG assurance.
- **A multilateral approach to industrialisation is needed** which can harmonise international standards for ESG, as a reflection of the wind industry's ambition to deploy best-in-class projects in every region of the world and the legitimate expectation of countries – across the Global North and South – to achieve wind targets in harmony with social cohesion and economic prosperity.
- **The transfer of knowledge and technology from the North to the South** must progress beyond sporadic and uncoordinated actions. Instead, it requires wide-ranging agreements on rules of the road and fair partnerships that pave the way for a just transition.
- **Within the context of a more standardised supply chain, a detailed mapping of the global supply chain is needed** to understand where countries and regions can localise content and add value. This mapping should also drill down to the regional level, to determine how strategic competitive advantages of economies in sub-regions of the world can be leveraged to diversify sourcing and production within a regional supply chain.
- **Focus efforts on the standardisation of existing turbine technology, instead of aiming for ever-larger wind turbines.** The largest offshore wind turbines with commercial readiness today are not yet deployed at sea. There is still work to be done to prepare the supply chain for this milestone – seeking even larger products at this critical moment of needing to scale wind installations globally would greatly hinder the supply chain's ability to standardise and deliver at the volume needed to meet climate and energy goals.

Balancing automation and economic benefits

Beyond the hype surrounding artificial intelligence (AI) and machine learning (ML) in mainstream media, there is little doubt that these technologies are already revolutionising many economic sectors around the world – wind energy included.

In a context where the global wind power industry needs to deliver a tripling of annual installations by 2030, developments in AI and ML can be game-changers in the collective race to ramp up production across the entire value chain.

AI technologies are already being deployed across the wind power project lifecycle: from providing the ability to analyse very large

Defining artificial intelligence and machine learning

The term "artificial intelligence" was coined in the 1950s referring to how machines can simulate human intelligence. "Machine learning" comes under the umbrella of AI and refers to the ability of software applications to increase in accuracy without being re-programmed to do so, thanks to the use of algorithms based on large amounts of data. The concept of "deep learning," a subset of ML, revolves around the use of AI to mimic how the human brain is structured, therefore replicating this type of learning in large virtual neural networks across which data is shared.

amounts of data for more effective site selection – and then generating virtual models during project design phases – to enabling better analysis of installation logistics in order to reduce costs.

Deploying AI and ML to improve project outcomes

Activities such as inspecting wind turbine blades can be both expensive and dangerous work. The Increased Blade Inspection Safety (IBIS) project, which was launched last year by Dutch research firm TNO, is an example of applying AI to a routine O&M task.

The project aims to fly two autonomous drones in tandem and apply X-ray technology to scan every inch of a blade. AI will be used to interpret and enhance the radiographic images from the scan, feeding the data into a 'digital twin' model – a digital copy of an existing turbine or wind farm – to predict maintenance needs.

In April 2022, GE Vernova announced the development of an AI-based tool to analyse installation logistics, promising a 10% reduction in expenses for wind turbine installation – a global cost savings that could reach a potential $25 billion over 10 years for the whole industry.

In the offshore wind sector, Autonomous Underwater Vehicles (AUVs) can be used for maintenance, repair of wind turbines and plan their decommissioning.

Meanwhile, the use of robots and large-scale automation in factories is well underway. Sany's 5G Smart Factory claims to have successfully used it to achieve a 28% improvement in quality and 40% improvement in efficiency compared with traditional factories.

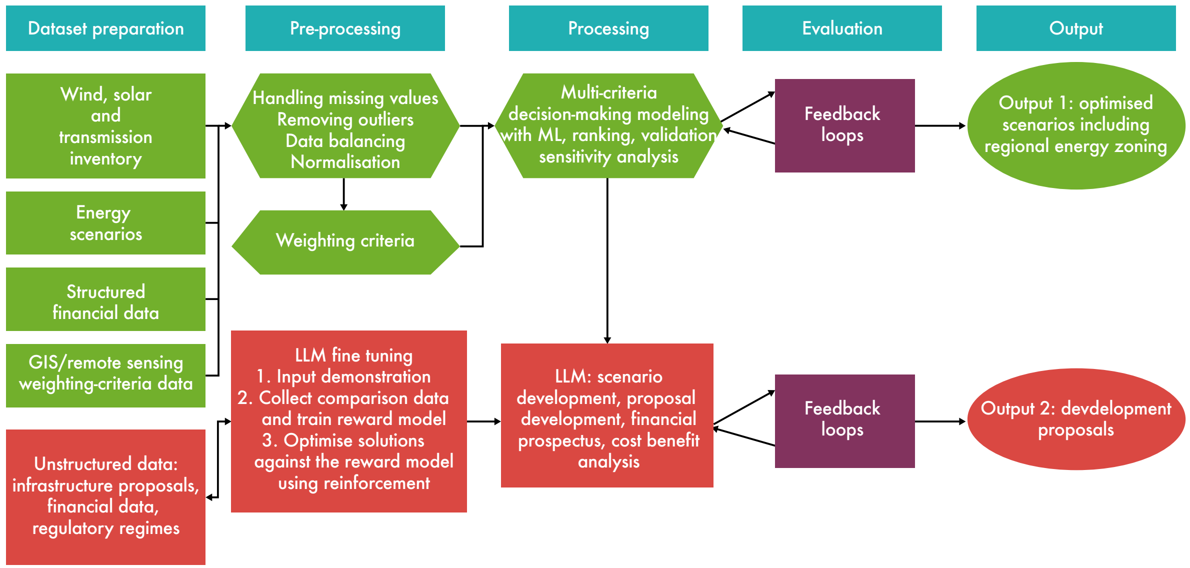
The untapped potential of AI

Forecasting models supported by AI and ML tools empower operators to balance supply and demand on the electricity grid, which results in meaningful reductions in LCOE. AI algorithms can predict energy demand based on historical data, weather patterns and other factors. This is widely used for demand-side management: For example, Indian company Infosys applies ML to the data generated by advanced sensors, smart metres and other devices to offer new services to consumers and retail electricity suppliers.

Work by the National Renewable Energy Laboratory of the US Department of Energy demonstrates that AI algorithms can inform wind turbine design, using more precise predictions of wind patterns that help engineers adjust the speed and angle of blades.

AI holds as yet untapped potential to

Potential project development flow with several AI applications



Source: Exponential Roadmap Initiative, A.I. for Clean Energy: Accelerating Project Pipeline Development Globally, 2023.

streamline regulatory processes across the world. It has been suggested that, by utilising a platform that harnesses generative AI and machine-learning, engineers, architects and technology companies could rapidly establish a global pipeline of hundreds of thousands of clean energy projects aligned with the 1.5°C target.[45]

Of course, this would not replace many aspects of the wind project lifecycle, including effective and meaningful engagement with host communities and impacted groups for wind farms, as well as many labour-intensive areas such as manufacturing, installation and turbine operation.

Dealing with the downsides

While there are opportunities for AI to optimise the wind value chain, reduce costs and support greater volumes of clean electricity generation, there are also concerns about its potential to disrupt the wind sector more broadly. There are attendant risks that need addressing, including cybersecurity, AI bias and error, the impact of AI on communication about the energy transition, as well as impacts

45. https://www.context.news/net-zero/opinion/ai-and-a-start-up-mindset-can-fast-track-clean-energy-projects

A risk impact matrix of AI integration in energy systems

Impact	Likelihood		
	1	2	3
1	LOW Low risk failures in AI control systems	LOW Out of control appliances and internediate storage (such as EV batteries)	MEDIUM Natural disasters, market dominance
2	LOW Lack of communication with and feedback from stakeholders	MEDIUM Biases & fairness, governance issues, robustness, complexity, price manipulations	HIGH Unintended systemic consequences, precision quality, decline of human autonomy
3	MEDIUM HIGH Practical use case experience availability	HIGH Privacy, lack of transparency	HIGH Cyber attacks, data quality, scarcity of skilled staff

Source: Navarra, Diego. Integrating artificial intelligence and sustainable technologies in strategic renewable energy and Power-to-X projects: A review of global best practices, risks and future prospects. Society and Economy, 2023.

on the workforce and the energy use of these technologies.

Cybersecurity is an important area of concern in the energy sector. An MIT study found that the energy sector is increasingly vulnerable to cybersecurity threats, with each attack costing an average of $6.4 million in damages.

Cyber threats have become both more frequent and more sophisticated, with a shift away from small and financially driven attacks to skilled operations that appear to be state-sponsored, raising national security implications. Germany has seen notable attacks on its wind power infrastructure, with turbines losing connection with satellites and internal IT systems also disrupted.

As with AI use in other fields, the unconscious bias of the technology developers, or its users, can lead to inequitable or even dangerous outcomes. There is also a risk that AI and ML may lead to forms of bias against certain technologies. This is an area where policymakers can play a significant role by promoting transparency requirements for algorithms. For their part, companies could allow for reviews or audits of model results by independent experts.

There are also issues around data privacy and data residency, and the understandable reluctance of companies to share sensitive data with other actors in the sector. What is particularly concerning is the absence of specific regulations that are agreed by all stakeholders across borders and regions, although this reflects the international fragmentation around digital sovereignty and governance.

Efforts are underway to enhance cooperation and partnerships to address potential vulnerabilities to AI-powered attacks. In August 2020, for example, the New York Power Authority (NYPA) partnered with Siemens Energy to form a centralised security effort involving 53 utilities.

While discussing these solutions, it is also important to be mindful of the risk of 'securitising' or 'militarising' wind farms due to threats that are not unique to the wind power sector. Efforts to legislate broadly for the infrastructure sector are welcome, but it would be sensible to remain cautious about wind sector-specific legislation, which may result in heightened national security scrutiny, social anxiety and permitting/siting challenges for projects.

Once again, collaboration rises to the fore as an essential driving force for the industry, with the potential to not only elevate the quality and quantity of technological improvements, but also the ability to bring the best ideas forward, avoid costly duplication and allay fears of unfair competition.

Putting people first in a new technological era

Beyond the technological and security dimension, it is important to consider the social implications of more widespread use of AI and ML. Among the most significant benefits the wind industry has provided to countries worldwide are the undeniable socioeconomic gains it has delivered, creating a multitude of jobs across the entire supply chain and beyond.

Innovating and investing in automated turbine assembly or repair can help improve process and cost efficiencies – and ultimately product quality – while mitigating human exposure to hazardous working conditions. But automation is accompanied by negative effects in job creation and potential labour dislocation in key parts of the supply chain.

As the wind industry increasingly embraces AI and ML, the spread of concentration of jobs across the wind value chain, where manufacturing is currently the most labour-intensive segment, will likely shift. O&M is another segment which will see some job displacement from the use of automation and robots. But these applications will also necessitate new jobs in design, development, engineering, testing, legal/compliance as well as risk assessment. Companies are already boosting the number of cybersecurity in-house experts, for example, and are likely to continue to do so.

Recommendations for AI and automation in the supply chain

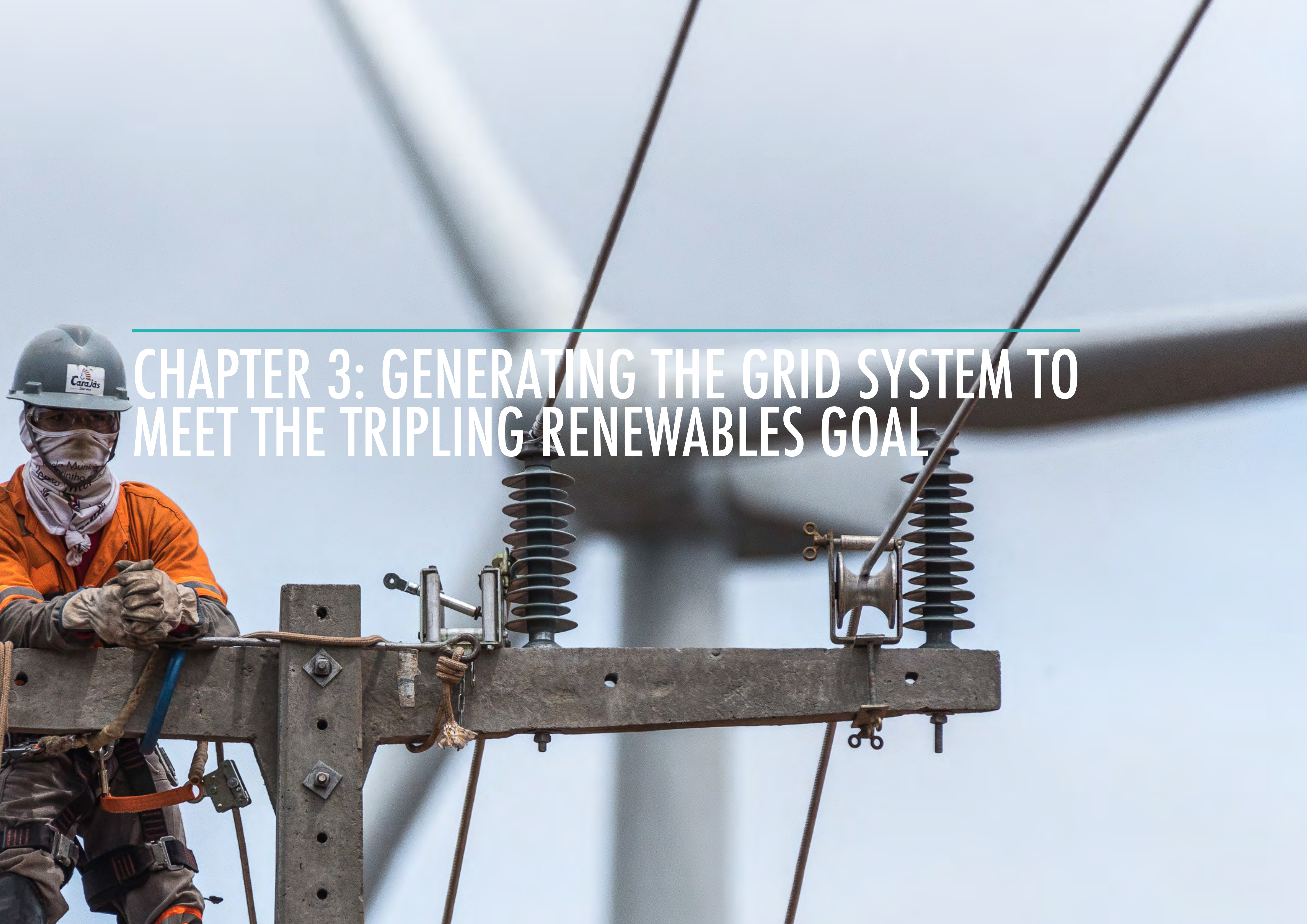
The upsides of a shift to AI and ML can outweigh the drawbacks, provided the right mindset of risk management is adopted and adequate measures are put in place to step up to the challenge. GWEC makes the following recommendations for AI in the global wind supply chain:

- **Industry players need to improve their understanding of the opportunities and risks presented by AI in the wind sector**. This includes avoiding premature investment and adopting a strategic approach to identifying which problems can be addressed with AI and considering the potential outcomes of its applications.
- Alongside overarching cybersecurity regulations and good-practice frameworks, such as those at the national level and covering broad large-scale infrastructure sectors, rather than the wind sector specifically, **cooperation at the national and international level should promote useful knowledge-sharing and strategies to prevent cyberattacks.** Greater cooperation is needed to produce data that is clean, standardised and well organised, so it can be more easily shared and used.
- **Policymakers should promote**

the de-risking of renewable energy, particularly in emerging markets in Asia, Africa and South America, by funding initiatives aiming to harness generative AI to generate off-the-shelf, practical roadmaps for national-level efforts towards net zero targets, helping to streamline regulatory processes.

- **The wind industry and policymakers should work together to put in place adequate workforce transition plans** – including STEM educational and skills development both for young people and the existing workforce – for displaced segments of the supply chain, as well as to rapidly identify areas of AI deployment that will require new skills and competencies.

CHAPTER 3: GENERATING THE GRID SYSTEM TO MEET THE TRIPLING RENEWABLES GOAL



Generating the grid system to meet the tripling renewables goal

Gaps in grid buildout for 1.5°C

The ambitious plan to triple renewable energy capacity by 2030 hinges on several elements moving forward into implementation, from creating favourable financing environments and streamlined permitting schemes to building a solid global supply chain and skilled workforce.

Equally important is the availability of the electricity transmission grid to transport the energy generated by wind farms and other renewable energy sources to the relevant demand centres and consumers.

Transmission grids include: the distribution grids that supply electricity through low- and medium-voltage lines to the majority of consumers; the high-voltage grid that connects utility-size generation, distribution grids and large industrial consumers; and the extra-high-voltage and ultra-high-voltage lines that transport electricity over longer distances.

Filling the gaps

It is difficult to overestimate the scale of the challenge to bring transmission grids up to the scale required for the task of decarbonising economies. According to the IEA, transmission lines doubled in length globally over the past 30 years, mostly thanks to the expansion of distribution networks.

Worldwide, grids have had to adapt to growing demand for electricity, alongside ballooning requirements for renewable energy integration, the implementation of digital and smart grid technologies, grid modernisation, enhanced grid resilience and security, and the integration of energy storage. **Modernised grids will be essential not only to respond to the demands of increased electrification, but also to improve resilience to extreme weather events caused by global warming.**

Ageing electrical assets present significant safety and reliability risks. But for many EMDEs facing fast-growing power demand, the combination of insufficient financing and tight supply chains threatens the progress of grid upgrades and modernisation. Grid investment in the Global South excluding China has even slowed down by an average of 7% per year in the past five years.

Grid modernisation and expansion will need to double over the course of this decade, from $330 billion in investment in 2023, for countries to meet their announced climate commitments. Given the scale of investment required, meeting the challenge will require new compacts and arrangements for channelling public/private financing into grid systems, as discussed in Chapter 1.

Building more and connecting together

While nearly all countries will need to build additional transmission lines to cope with the increased electrification of their economies, an even more significant step change is required to achieve modern, interconnected grids. For example, the EU estimates that 40% of its grid infrastructure is more than 40 years old.[46]

The advantages of interconnected grids include improved grid stability, increased energy security and enhanced flexibility in managing power demand and supply fluctuations. They are particularly well-suited to the integration of renewable energy sources like solar and wind, allowing regions with excess clean energy to transfer it to areas with higher demand or less generation capacity, as well as minimising the impact of variations of regional real-time production in the interconnected power system.

Offshore wind farms, which rely on the transport of huge volumes of electricity across significant distances, are increasingly looking to regional interconnection using meshed high-voltage direct current (HVDC) offshore grids. These grids link the generating facilities to various countries. In the European energy system, meshed offshore grids are expected to play a critical role in the next two decades.

Smart grids – electricity networks that can dynamically integrate the

46. The EU further assesses EUR 584 billion ($632 billion) will be required to invest in a more digitalised, decentralised and flexible grid system by 2030. See: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_6044.

actions of all the users connected to them – are an essential component of a modern transmission network. By incorporating digital technology into their design, they allow a two-way exchange of energy and information between energy generators and energy users.

In a smart grid, automated information and control systems respond to fluctuations in energy production and demand. This provides real-time information on energy consumption and on the status of each node, segment and element of the grid, ultimately increasing the efficiency and effectiveness of the transmission lines.

For instance, Thailand plans to roll out a national smart grid by 2036 that includes energy management systems, demand response, energy storage and improved weather forecasting. The government announced in 2021 a demand response demonstration project, driven by the country's Electricity Generating Authority (EGAT), to optimise the supply and demand balance on the Thai power grid. Multiple renewable energy forecast centres are being planned at EGAT substations in areas with potential for renewable energy development.

In Indonesia, the Ministry of Energy and Mineral Resources, together with the National Electricity Company PT Perusahaan Listrik Negara (PLN), have shared plans to build a smart grid to support greater use of renewable energy.

Overcoming barriers to buildout

Overcoming public perceptions about huge infrastructure projects like electricity networks is of crucial importance to laying the ground for the rapid buildout of renewable energy generation, and wind power capacity in particular.

As the experience of developing wind projects confirms, good projects and fair procedures are key ingredients in gaining public support. It is only by providing citizens with a clear prospect of what to expect on a practical level, while highlighting the overarching benefits, that electricity grid deployment can be successfully rolled out at value-for-money total cost.

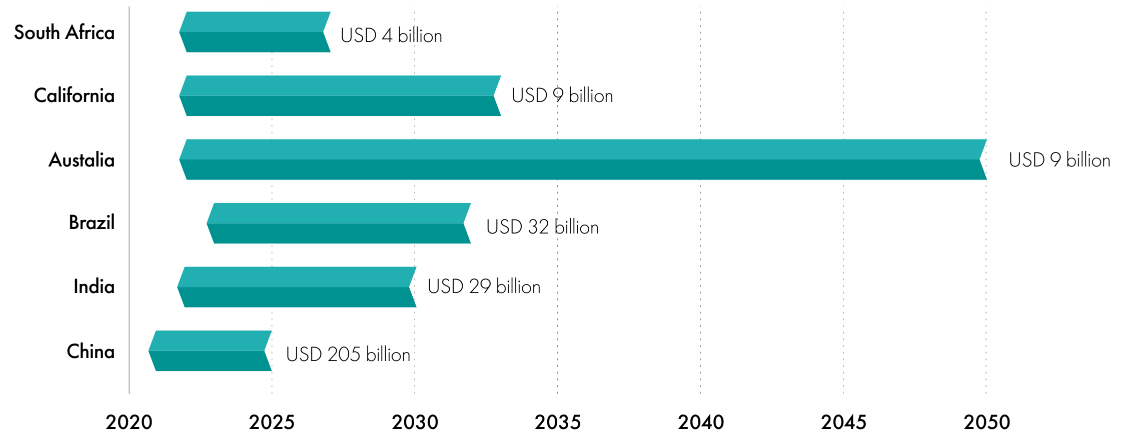
A lack of incentives for implementing grid investments is a major stumbling block. Grid operators, typically state-owned companies with limited competition, are often integrated with incumbent fossil fuel generators, leading to an inherent conflict of interest in promoting renewable generation integration. Ember highlights Poland as a case in point, noting a staggering 253% increase in grid connection declines amounting to 51 GW of capacity in 2022, as compared to 2021.[47]

As renewables are the newer actors on the stage, a false narrative can sometimes prevail suggesting that it is the responsibility of the renewable energy industry – rather than the whole of society – to invest in grid development. But these costs would ultimately be modelled into project CAPEX and reflected in offtake agreements and agreed power prices; in the worst-case scenario, they could jeopardise the competitiveness or viability of the entire renewables project. And if grid investments are wholly dependent on grid charges in consumer bills, it will be difficult for operators to raise the necessary funds at the urgency required.

A better approach would be targeted public and private

47. Ember, Electricity grids: Key policy actions, 2023.

Announced grid investment timelines by country



Source: IEA, Electricity Grids and Secure Energy Transitions, 2023.

funding for grid spend, with clear incentives for prompt delivery, and mandates for grid operators to include a decarbonised power scenario in planning. Authorities can also explore restructuring remuneration to grid companies, so they are incentivised to innovate, meet performance standards that align with market conditions and invest in modern technology and efficiency solutions, rather than merely recovering their costs for providing power from any source.

In the case of EMDEs, particularly sub-Saharan Africa, access to finance and high cost of capital are key barriers that call for international collaboration. For example, a high-voltage transmission line to export electricity from the Inga Dam III in the Democratic Republic of the Congo to South Africa has yet to start construction a decade after the two countries agreed to build it, due to the withdrawal of initial investors and a lack of support from local communities.

In Brazil, concessions have been used since 2004 as a mechanism to engage private entities in the expansion and operation of the transmission grid. As a result, state-owned Eletrobras has seen its ownership stake in the transmission grid decrease to around 40% by 2023, owing to the growing participation of national and international investors through competitive bidding processes. Brazil plans to increase its transmission line network from nearly 160,000 km to 200,000 km by 2032, with an investment of approximately $18 billion.

For jurisdictions with easier access to funding, such as Europe, the US and Japan, the most significant barriers often relate to public acceptance of new projects and adequate regulatory frameworks. Policymakers can make a difference by improving the rules around planning and by providing anticipatory investments and streamlined administrative processes.

Industry Spotlight: Balancing the grid with renewables buildout in California

Provided by: American Clean Power (ACP)

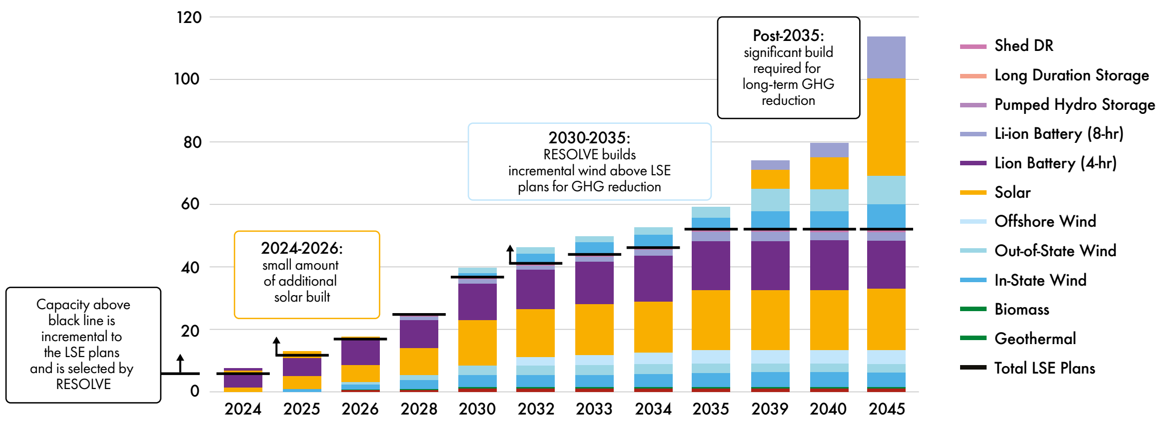
If California were a country, it would rank 5th globally in terms of GDP, with a grid that generates approximately 287 TWh of electricity per year – roughly equivalent to the total electricity production of Italy in 2022.

Over recent years, California has been at the forefront of climate change and the energy transition, seeing record-breaking heatwaves from 2020-2022 which brought wildfires, drought and electricity outages. These outages prompted Governor Newsom to direct the California Energy Commission (CEC), California Public Utilities Commission (CPUC) and California Independent System Operator (CAISO) to analyse the root causes.[1]

First, climate change-induced heatwaves resulted in unexpected spikes in electricity demand that exceeded supply. Second, planning for the transition did not adequately account for meeting energy demand in early evening hours (when solar production rapidly falls off, but demand does not).

In response, the Government of California and its energy authorities are modernising the state's grid and energy system. Resource planning has focused on grid reliability and the move towards a carbon neutral grid by 2045. Progress has been steady, with wind and solar capacity having more than tripled over the last decade to more than 23 GW by 2023, and innovative measures introduced.

CPUC 25 MMT Core Case – LSE Plans and model selected capacity



Source: California Public Utilities Commission, Rulemaking 20-05-003, Decision adopting 2023 preferred system plan and related matters, and addressing two petitions for modification, 2024.

Innovative energy system planning

California's latest preferred system plan, adopted in February 2024, utilises a long-term planning model that captures the reliability needs of a grid in transition.[2] The model core case largely depends on solar and four-hour storage capacity by 2030. By 2045, in order to create a reliable decarbonised grid year-round, the CPUC has found significant buildout of solar, out-of-state wind from New Mexico and Wyoming, offshore wind and eight-hour batteries will be needed for a total of 114 GW of clean energy capacity.

CAISO has already begun detailed studies on different offshore wind portfolios, including a base case with 4.7 GW of offshore wind, including 1.6 GW from the North Coast. CAISO will also use its analysis of higher quantities of offshore wind to inform its proposals and potentially enable future expansion.

At the same time, CAISO is considering significant changes

1. https://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf

to its process for studying interconnection requests and awarding deliverability. It has proposed a "zonal" approach to prioritising requests for study and indicated a desire to use existing tariff authorities to reserve deliverability on new transmission designed to serve a specific resource (e.g. north coast offshore wind).

In 2023, the California legislature passed AB 1373 which allows the CPUC to direct a state agency to procure diverse, long-lead-time resources like offshore wind upon a determination of need. This procurement option could provide greater market certainty for offshore wind developers and strengthen linkages between procurement and transmission planning and development.

Regional collaboration
Crucial to achieving its long-term decarbonisation goals, California's grid is entering a new phase of regional collaboration. Efforts to foster coordination in the American West began in 2014 with CAISO and utility PacifiCorp launching the Western Energy Imbalance Market (EIM), a real-time marketplace that allows for participants to buy and sell power close to the time electricity is consumed, giving system operators real-time visibility across neighbouring grids, resulting in improved balancing of supply and demand at a lower cost.

Since then, the EIM has grown to cover most utilities and balancing authorities across the Western Interconnect. The market has delivered $5.5 billion in savings, with $1.6 billion in 2023 alone, in addition to reducing renewable curtailment and gas generation.[3]

California provides an example of how to develop and operate a grid in a decarbonised energy system. Despite some short-term challenges, it remains clear that innovative up-front investments are paying off with net savings and affordable, reliable clean power for generations to come.

2. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M525/K918/525918033.PDF
3. https://www.westerneim.com/Pages/About/QuarterlyBenefits.aspx

Recommendations for closing the gap on grids

Addressing the present-day gaps in grid investment, cross-border and regional integration, storage solutions and system flexibility will be critical for developing the necessary infrastructure to achieve the goal of tripling renewables. Otherwise, investors in renewable energy will continue to face uncertainty around availability of grid and transmission infrastructure, the speed of grid connection agreements and the certainty of demand.

GWEC makes the following recommendations to scale financing on grids for the future:

- **Grids must become a national and cross-cutting policy priority** for countries to meet energy security, climate and economic growth goals. This will require countries to set targets for grid investment and system flexibility, as well as earmark funding mechanisms to meet targets. Importantly, there needs to be a regulatory approach of enabling anticipatory investment so that grids are available ahead of when connections are required, not just on a project basis, but to achieve wider wind energy goals.

- **Ensure alignment of planning, schedules, and assessments of grid investment requirements with long-term objectives for scaling up renewable energy deployment** and decarbonising end-use sectors, such as transportation and heavy industry.

- **Private investment in grid buildout** must be promoted through adequate and effective investment mechanisms, including adopting blended approaches that target donor finance for guarantees, credit enhancements and technical assistance on planning.

- **Effective campaigns are needed to mobilise public support for grid expansion**, alongside adequate siting approaches and the rollout of all possible measures, to gain the support of citizens for infrastructure and system transformation.

The next generation of integrated grids

Enhancing interconnection in grids not only drives the uptake of

Case Study: Connecting large-scale wind plants with demand centres using UHV transmission

In China, many areas with good energy resources are far away from load centres. For example, most of the hydropower resources are in the southwest, coal is in the northwest and wind and solar resources are in the west and north; however, the major load centres are concentrated in the eastern and central regions.

Additionally, the 500 kV electricity grid is limited in terms of long-distance and large-capacity electricity transmission, resulting in the expansion of coal-fired power projects in the middle and east areas of China. This aggravates the challenging situation for coal supply, transport and environment protection.

When energy shortages disrupted manufacturing companies in the early 2000s, the State Grid Corporation of China, which owns over 80% of China's grid, decided to invest heavily in ultra-high voltage (UHV) grid technology to transport energy thousands of kilometres from the resource areas to the main load centres.

UHV power grids are composed of 1,000 kV AC as well as ±800 kV and ±1,100 kV DC power systems. Compared with traditional high-voltage transmission (500 kV), the capacity of UHV transmission lines can be increased by more than two times, reduce losses by about 60% and increase transmission capacity per unit of line corridor width by 30%.

China completed the first commercial UHV project in 2009 and now more than 30 UHV lines have been installed. The total length of these lines is over 50,000 km, with the longest UHV transmission line being 3,300 km, and total transmission capacity is 200 GW. Currently China is the only country deploying UHV technology on a large scale. By 2030, the inter-provincial and inter-regional UHV transmission capacity will be increased to 350 GW.

The result is an emerging nationwide "super grid" that interconnects China's six regional grids and rectifies the geographic mismatch between where China; s clean power is produced and where it is consumed.

variable renewable energy (VRE) sources such as wind energy, but also increases flexibility in managing electricity supply and demand. Additionally, it facilitates access to renewable power in countries which face an electrification gap or a lack of renewable energy technical resource.

Interconnected grids can also reduce costs by flattening the load curve, and eliminating some of the expenses associated with enhancements to the transmission system. For example, since the inception of the ASEAN Power Grid, multiple projects have been built including the Trans-Borneo Power Grid Sarawak-West Kalimantan Interconnection Project in 2016 which connects parts of East Malaysia to Indonesian grids. This has since resulted in a reduction of electricity costs and replaced up to 130 MW of fossil fuel generation with renewables.

The ability to conduct cross-border power trading can also encourage FDI in addition to creating opportunities for exporting countries to benefit from income related to power sales. High-voltage interconnections between the Economic Community of West African States (ECOWAS) members, including an interconnector linking the national power systems of The Gambia, Guinea, Guinea-Bissau and Senegal and another connecting Cote d'Ivoire, Guinea, Liberia and Sierra Leone, have enhanced energy cooperation between this group of countries.

Across sovereign borders, grid integration fosters a more resilient and sustainable global energy landscape, with the potential to mitigate geopolitical tensions through interdependence, enhance energy security and increase collaboration on wider energy issues through mutually beneficial economic arrangements. Regional collaboration can be strengthened through the formation of 'grid communities', which create shared goals and a common regulatory order across the region.

Degrees and models of cross-border integration

There are several models of cross-border grid integration, with suitability dependent on the desired degree of integration, dictating the level of cooperation among participating jurisdictions. 'Bilateral integration' involves trade between two jurisdictions, sometimes unidirectional. 'Multilateral integration' involves three or more countries engaging in mutual trade. In 'unified models of integration', regional institutions take on responsibility for managing the power system across multiple jurisdictions.

According to the IEA, there are five degrees of cross-border integration, with greater integration offering potential benefits alongside increased organisational complexity:

Power pools foster cooperation and resource-sharing among neighbouring countries within regional energy markets. By coordinating electricity generation and distribution, power pools optimise energy utilisation and enhance grid stability. For example, SAPP member states collaborate on electricity generation and trading, promoting regional energy security and facilitating access to renewable energy sources.

Interconnectors provide physical links enabling electricity transmission between distinct power systems across countries. These infrastructure projects facilitate cross-border energy trading and bolster grid resilience. For example, connecting seven Central American countries, SIEPAC enables efficient electricity exchange and supports the integration of renewable energy across the region.

Degrees of cross-border grid integration

Form of integration	Example
1. Bilateral, unidirectional power trade	Singapore imports from Lao PDR
2. Bilateral, bidirectional power trade	California, USA with Baja California, Mexico
3. Multilateral, multidirectional trade among differentiated markets	Southern African Power Pool (SAPP), Central American Electrical Interconnection System (SIEPAC)
4. Multilateral, multidirectional trade among harmonised markets	EU Internal Energy Market, Energy Islands (Denmark)
5. Unified market structure, differentiated operations	Nord Pool

Source: IEA, Integrating Power Systems Across Borders, 2019.

Energy islands are self-sufficient and scalable energy hubs integrating various renewable energy sources to meet local demand and contribute to regional energy security. Denmark's energy island project in the North Sea, expected online around the turn of the decade, for instance, will harness offshore wind resources to create a renewable energy "powerhouse" to supply clean electricity to neighbouring countries.

Recommendations to integrate grids across borders

Cross-border grid integration will need to be in the toolbox for implementing the tripling renewables goal. But the broader economic challenge of integration lies in the allocation of benefits across participants. Countries that are rich in VRE may benefit more in electricity sales, giving them leverage to offset infrastructure investments and operational costs. At the same time, countries with limited technical resource for VRE may be able to meet decarbonisation goals and attract green supply chain investment via grid integration.

Achieving an equitable distribution of grid costs and benefits across markets necessitates transparent regulatory frameworks and fair pricing mechanisms. Regulatory alignment is crucial to ensure seamless cross-border energy trading and promote investor confidence.

GWEC makes the following recommendations to ramp up cross-border cooperation on grids:

- **Enhance multinational discussions and taskforces** aimed at fostering cross-border collaboration on grid systems, incorporating essential stakeholders such as regulators and power system operators, and if applicable, regional regulators.
- **Conduct advanced research on interconnection strategies** with a focus on enhancing power-trading capabilities in regions of the Global South, leveraging the potential for establishing multilateral or unified power pools due to proximity and terrain suitability.
- **Mobilise resources for long-term regional grid investments**, directing donor funding towards enhancing capacity and

infrastructure for integrating renewables into cross-border grid systems, and streamlining the permitting processes for new grid infrastructure projects and upgrades to existing transmission and distribution systems.

- **Develop modernised and decentralised grid systems**, incorporating digitalisation and smart applications for demand-side management, and fostering interconnections with neighbouring grid networks to enhance resilience.

Embedding storage and flexibility in future power systems

Meeting the goal of tripling renewable energy capacity demands innovative approaches to ensuring grid stability and flexibility in managing fluctuating supply and demand. The imperative for future grids, drawing from larger shares of VRE, is to embed storage and flexibility capabilities to propel cross-sector decarbonisation (such as transport and industry) via renewable electricity. Otherwise, electrification of emissions-intensive sectors will heavily draw on fossil fuel generation, resulting in an

Six phases of system integration of VRE

Phase	Description	Challenge to overcome	Relevance of storage initiative in mitigating the challenges	Relevance of DSR initiative in mitigating the challenges	Policy action needed
Phase 1	VRE has no noticeable impact on system operation (typically <10%)	-	-	-	Improve VRE forecasting, economic dispatch
Phase 2	VRE has a minor to moderate impact on system operation (typically <10%)	Minor changes to operating patterns	-	-	
Phase 3	VRE generation determines the operation pattern of the system (typically in between 10-20%)	Greater variability of net load	Use of existing storage, e.g. pumped-hydro	Advanced large industrial	Effective short-term wholesale markets, trade with neighbours
Phase 4	The system experiences periods where VRE makes up almost all generation (typically >20%)	Power supply robustness under high VRE generation	Battery storage	Commercial and residential	Reform of system services markets
Phase 5	Growing amounts of VRE surplus (days to weeks)	Longer periods of energy surplus or deficit	Medium-term storage	Tap new loads via electrification	Re-evaluate electricity taxation
Phase 6	Monthly or seasonal surplus or deficit of VRE supply	Need for seasonal storage	Long-term storage	-	-

Source: IEA, System integration of renewables, 2018; SHURA Energy Transition Center, Costs and benefits of options to increase system flexibility, 2019.

uncoordinated and disjointed transition across sectors.

Storage technologies and demand-side response

Currently, sources of flexibility vary in their capabilities and maturity. While conventional sources like fossil fuel power plants provide dispatchable power, they lack the sustainability needed for a low-carbon future. Advancing towards a more sustainable energy landscape requires progression across different verticals.

According to the IEA, there are six phases of grid integration of VRE as renewable penetration in a power system increases. Most countries are in a phase of <10% VRE penetration (e.g. Indonesia, Korea, South Africa), where VRE has either no or a minor impact on system operation; for this phase, storage and demand-side response (DSR) solutions are not yet required. It is sufficient to retrofit plants, reinforce grids and build interconnectors for flexibility, as well as make marginal changes to improve VRE forecasting and economic dispatch.

In the next stage of 10-20% VRE penetration (e.g. Morocco, Vietnam, Brazil) or even >20% penetration (e.g. Australia, Chile), investments in storage and DSR technologies are required to stabilise operation of the system. This includes effective short-term wholesale markets, power trading with neighbours and reform of ancillary services markets.

Some countries are currently in the later phases of >30% VRE penetration (e.g. Spain, Germany, Ireland, Denmark in particular). Policymakers must take action to prepare for these scenarios with greater shares of renewable energy as the world works towards the tripling renewables goal, as policy actions and system operation requirements intensify.

Examining long-duration energy storage solutions

Traditionally, pumped storage and hydropower reservoirs have been deployed to address supply-demand imbalances when VRE penetration is in the range of 10-20%. However, the energy storage landscape has evolved significantly, now encompassing various types such as electrochemical (e.g., batteries), thermal (utilising materials like rocks, bricks, or molten salts), mechanical (including compressed air, liquid air, or gravitational potential), and chemical storage (involving energy storage in compounds like hydrogen or its derivatives). These technologies are currently undergoing rapid advancements and innovation.

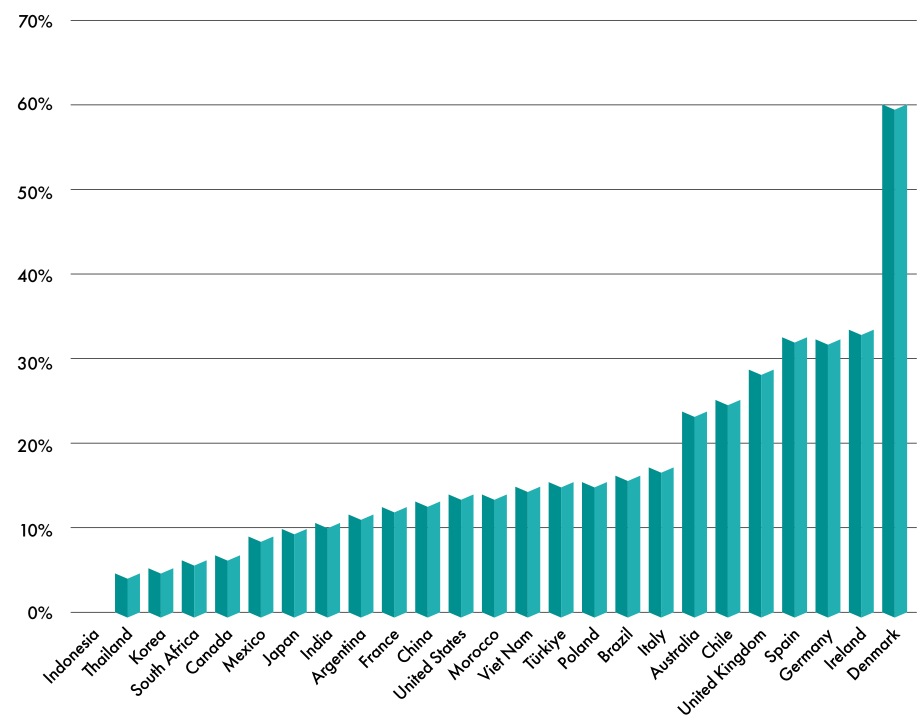
Long-duration energy storage (LDES) provides a solution for storing energy over extended periods, ranging from hours to seasons, especially during times of surplus renewable generation relative to demand. This differs from lithium battery storage or other shorter-duration energy storage typically benchmarked at four hours.

Stored energy can be released during periods of higher demand, effectively balancing the grid. For example, surplus energy from windy autumn days can be deployed during cloudy winter days. Storage technologies contribute to grid resilience by alleviating congestion, providing transmission services and ensuring reliability, especially amid prolonged extreme weather events.

These technologies also serve additional grid functions such as black start capabilities for restoring power in blackout situations and assisting micro-grids in maintaining power supply. Storage durations can extend to weeks or months, notably seen in pumped storage and reservoir hydropower systems.

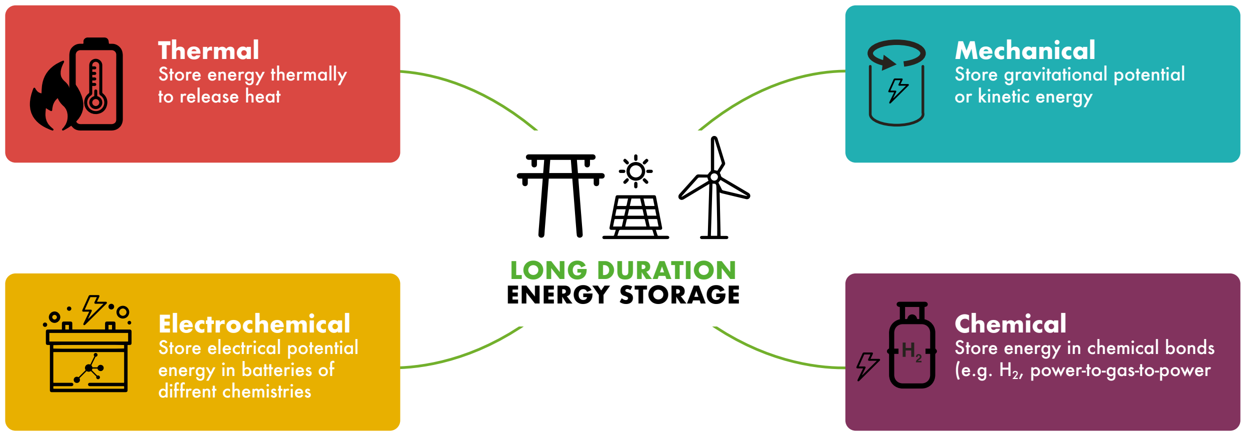
One emerging LDES technology is hydrogen storage, offering a

VRE share of power systems by country, 2022



Source: IEA, 2022.

Categories of long-duration energy storage technologies



Source: LDES Council and McKinsey.

unique capability to store energy for prolonged durations and in large quantities. As green hydrogen gradually replaces fossil fuels in various applications such as the production of chemicals and fertilisers, hydrogen storage could become increasingly vital for industrial and energy security, akin to the role of natural gas storage in many regions today.

Leveraging DSR to manage supply and demand

DSR encompasses a set of strategies traditionally aimed at reducing peak demand, but they are increasingly needed to incentivise consumption during periods of high VRE generation. This concept allows industrial consumers and households alike to participate in system operation by providing flexibility in response to price signals.

By adjusting electricity consumption during peak VRE generation periods, DSR can alleviate grid pressure, reducing the need for costly backup generation sources. Additionally, DSR contributes to grid stability by providing ancillary services like frequency regulation and voltage control, thereby enhancing overall system reliability.

As VRE penetration progresses, tapping into new loads becomes imperative to relieve grid congestion when conventional redispatch orders fall short. However, these services necessitate communication and competencies on both the system operator and consumer sides. Other DSR implementations can employ various strategies such as time-of-use pricing, response, critical-peak pricing and rebates.

Despite being a cost-effective flexibility option, DSR activation costs remain high in some regions and pose accessibility challenges, especially in the Global South. Underinvestment and limitations in physical grid infrastructure present significant obstacles, necessitating substantial investments in grid modernisation and expansion to enable real-time demand response. Moreover, digital technology gaps hinder DSR adoption, limiting access to advanced metering infrastructure and smart grid technologies.

Regardless of challenges, governments still recognise the importance of DSR initiatives. For instance, in South Africa, the Energy Efficiency and Demand Side Management (EEDSM) Programme aims to facilitate DSR exchange. In India, under the National Mission for Enhanced Energy Efficiency, agricultural and municipal DSR programs have been introduced to facilitate transactions.

Recommendations for scaling modern and flexible grids

Policymakers should prepare to utilise LDES, DSR and other flexibility solutions as countries transition to a net zero future with high VRE penetration. Otherwise, disjointed efforts to build out renewables while underinvesting in grid and flexibility infrastructure could lead to either green electricity surpluses (raising tough questions on compensation and system integration) or shortages (undermining decarbonisation goals and investment attractiveness in the economy).

In the international context, uneven investment in the system integration of VRE could widen the gap in access to renewable energy – and hence competitiveness in the new energy transition economy – between the global North and South.

GWEC makes the following recommendations to scale up modern and flexible grids:

- **Regulators should collaborate with the renewables sector** to enhance power market planning and ensure price signals, clear targets, and procurement incentivise investment in longer-duration storage. Grid planning should prioritise modernisation and DSR

Green hydrogen: Beyond storage to green industrialisation

The versatility of green hydrogen extends to a broad spectrum of applications, ranging from industrial processes to transportation. However, the deployment of green hydrogen must be guided by considerations of efficiency, cost-effectiveness and the availability of alternatives.

Currently, green hydrogen proves particularly valuable in decarbonising processes such as fertilisers, hydrogenation, hydrocracking, desulfurisation and methanol production, where viable alternatives are scarce. Additionally, green hydrogen demonstrates some competitiveness in shipping, aviation, chemical feedstock, steel production, and long-duration grid balancing.

Industries worldwide are increasingly focusing on greening their supply chains to produce competitive green products. The rise of green industrialisation presents opportunities for regions such as Africa and Latin America, endowed with abundant wind and renewable energy resources, to establish new export economies in the green energy transition.

These opportunities are particularly attractive given the coming proliferation of carbon pricing mechanisms, such as the EU's Carbon Border Adjustment Mechanism (CBAM), which has already caused consternation among the EU's trading partners for potential trade disruption and disadvantages for fossil-dependent Global South countries. The African Development Bank has warned that CBAM could cost African countries up to $25 billion annually based on the carbon price as of late 2023.

In Germany, the "Wind H2" project is utilising green hydrogen generated from wind power to produce green steel. Seven turbines at the site of the steelworks in Salzgitter power electrolysers which produce green hydrogen. The gas then replaces coal in the traditional blast furnace process through the implementation of direct reduction plants (these plants reduce iron ore to iron directly in its solid state using hydrogen, emitting water vapor instead of carbon dioxide).[1]

This innovative approach allows for a reduction of over 95% in emissions. The project's total cost, covering the construction of wind turbines, hydrogen plants and their integration into the existing supply network, amounts to approximately EUR €50 million with subsidies received from KfW bank.

Globally, similar initiatives are underway in countries such as Indonesia, Thailand, India, Japan, China and Namibia, aiming to utilise wind energy to achieve similar industry sustainability goals.

1. https://salcos.salzgitter-ag.com/en/windh2.html]

technology to close critical technology gaps as infrastructure expands.

- **Encourage investment and innovation in diverse storage technologies** to suit different users, such as by establishing research, development, and innovation (RDI) grant programs, encouraging public-private partnerships, and setting medium- and long-term capacity targets.

- **Developing economies can work with international finance institutions to explore innovative financing models** – such as blended finance – to mobilise investment in grid and DSR solutions.

- **Enhance data availability within the wider electricity system** to enable innovation in DSR and access to applications like smart metres by consumers and third parties.

- **Assess the cost-benefit of investment in DSR programmes**, accounting for energy and cost savings that can mitigate investment requirements for grid infrastructure expansion.

CHAPTER 4: FOSTERING PUBLIC SUPPORT FOR WIND ENERGY TO MEET THE TRIPLING RENEWABLES GOAL

Fostering public support for wind energy to meet the tripling renewables goal

In the pursuit of a sustainable future, social consensus and public support for the energy transition are imperative. Achieving shared buy-in to the scale, impact and planning process for the expansion of renewable energy is essential to mitigate conflict, anxiety and disenfranchisement stemming from wider impacts such as job dislocation and infrastructure buildout.

As we navigate the drive towards tripling renewables, maintaining social harmony hinges on inclusive decision-making processes that engage stakeholders at project and economy-wide levels.

This chapter of the report approaches the topic of building public support for wind energy's growth from four angles: speeding up permitting while mitigating the adverse impacts of projects; land rights issues in developed and developing countries; the risks posed by misinformation and disinformation; and the need to foster a just and equitable energy transition through workforce, diversity and value chain stewardship.

Accelerating permitting while mitigating project impacts

Despite, or perhaps because of, the drastic need to accelerate renewable energy growth, **opposition to wind power has become increasingly visible in many countries globally**. The roots of opposition to wind projects vary depending on local context, cultural values and socioeconomic factors. For example, a fishing professional may oppose an offshore wind farm due to concerns about navigation hazards, interference with fishing grounds or disruption to marine ecosystems. In contrast, groups presenting indigenous peoples may resist an onshore wind farm if it encroaches on traditional lands, sacred sites or areas of cultural significance.

One social psychology approach to anti-wind movements identifies three common frames for opposition: NIMBY (Not In My Backyard, driven by love, feelings of security, fear of disruption, and anger); populist (characterised by experiences of helplessness, fear, grief and anger); and environmentalist (rooted in concern and respect).[48]

For instance, opposition to offshore wind expansion in South Korea from the commercial fishing sector can be attributed to NIMBY framing, driven by fear of disruption and feelings of security. Opposition to wind growth in Finland from conservative movements stems from the populist frame, with clean energy conservatism focused on defending the Finnish countryside and opposed to pollution levies.[49]

Environmentalist framing may support wind power as a clean energy source, but criticise project impacts or the footprint of the supply chain.

Mitigating the adverse impacts of projects

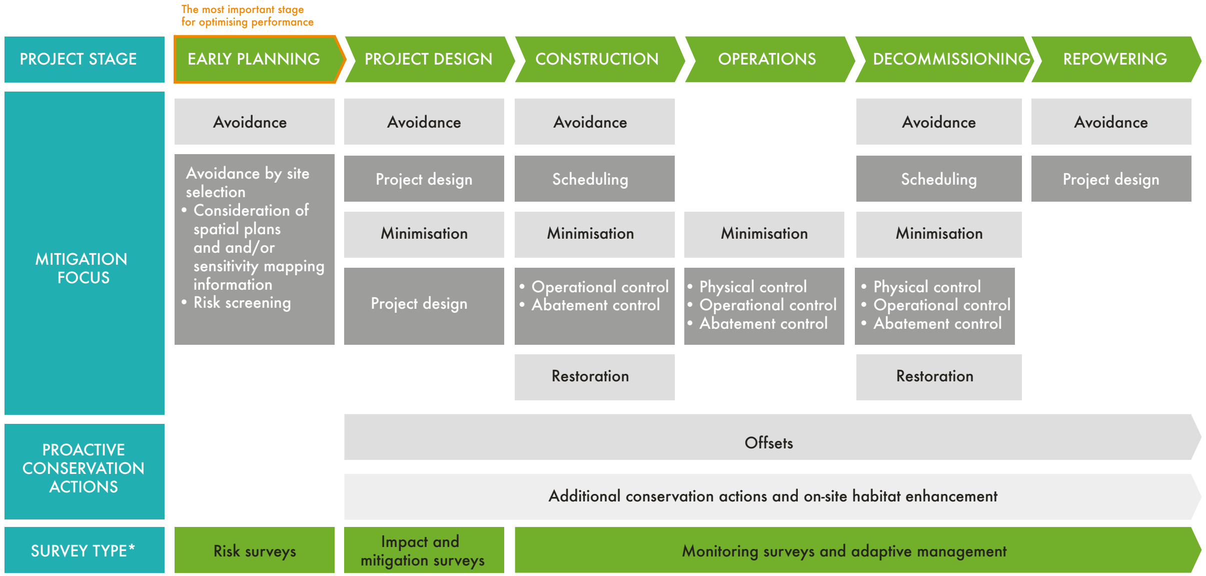
Onshore turbines are growing larger (see Chapter 2) and expanding to new sites, which makes them more prominent in landscapes. For example, natural landscapes and elements of natural beauty may be altered, and views may be disrupted.

In the ocean, offshore wind can impact marine ecosystems and the marine environment, such as in ecosystem changes through alteration of sediment movement. Ensuring the environmental sustainability of human activities at sea is an important task for the developing blue economy.

Along with supporting the restoration of biodiversity, wind farms can also benefit the surrounding ecosystem. Bees and other pollinators can find refuge in onshore wind farms that are properly maintained. A recent study of the Belgian North Sea indicated that wind farms have no negative impact on the abundance

48. Hanna-Mari Husu, The social psychology of framing: The emotional content of Finnish anti-wind power frames, Sociological Research Online, 2023.
49. Hatakka, Niko and Välimäki, Matti, The allure of exploding bats: The Finns Party's populist environmental communication and the media, "The Far Right and the Environment," 2019.

The mitigation hierarchy across the project development cycle



*The type of surveys needed to assess and monitor biodiversity risk, impacts and mitigation.

Source: IUCN and TBC, 2021.

of fish and invertebrates living on sandy bottoms, and that wind farms even increase the diversity of organism communities above the bottom.[50]

Understanding the mitigation hierarchy is important for wind energy development. According to the UN, avoidance and minimisation measures prevent or reduce impacts, while restoration and offset measures remediate impacts that have already happened. Preventive actions are preferable from an economic, social and ecological perspective.[51]

Avoidance is the most important step of the mitigation hierarchy, as it is based on measures taken to anticipate and prevent the creation of impacts. For example, to understand whether a location aligns with species at high risk of collision with wind power plants, protected areas or other regions of high biodiversity significance can be helpful to an investor's due diligence process.

Minimisation refers to measures taken to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided, as far as is practically feasible. For example, offshore wind developers can reduce noise emissions from pilings by using hydro-dampers and "air bubble curtains", which helps lessen the disturbances to marine life.

Accelerating permitting while maintaining public support

Planning and permitting forms one of the biggest barriers to renewable energy growth globally.[52] Challenges in wind energy permitting include lengthy bureaucratic processes and complexity of administration, lack of central authorities, lack of streamlined digital resources and lack of holistic planning to capture complex stakeholder interactions and lack of clear, shared understanding of the permitting rules between promoters and permitting entities.[53]

Permitting procedures must be appropriate for their intended use, keep up with climate change and renewable energy targets,

50. ILVO, Analyses of fishing activities in the Belgian part of the North Sea, Flemish Banks and proposed management areas for seafloor integrity, 2023.
51. Bennun et al, Mitigating biodiversity impacts associated with solar and wind energy development, IUCN and The Biodiversity Consultancy, 2021.
52. Energy Transition Commission, Streamlining planning and permitting to accelerate wind and solar deployment, 2023.
53. GWEC and IRENA, Offshore Wind Scale Up: Innovations in Permitting, 2023.

Case Study: Sensitive siting in renewable energy

Provided by: The Nature Conservancy (TNC)

The scale of renewable energy deployment needed to mitigate climate change will require a lot of land, which may result in land-use related environmental and social conflicts that slow deployment. To mitigate these conflicts, TNC is working to promote a nature- and people-positive energy transition by collaborating with partners to integrate climate, conservation, and community goals into energy planning, policies, and markets.

The Smart Siting Approach: In collaboration with partners, TNC has developed an innovative, science-based decision-support framework for utility-scale renewable energy siting. This approach helps to proactively identify low-conflict areas for wind and solar energy deployment – sites with high energy resource potential that minimise conflicts with environmental and social values.

By integrating these values into decision-making from the beginning, this approach can improve public support for renewables deployment, help reduce project costs and permitting times, and promote a rapid and responsible transition.

TNC has developed frameworks for key zones in the US, Europe and India. The development of the framework relies on four steps:[1]

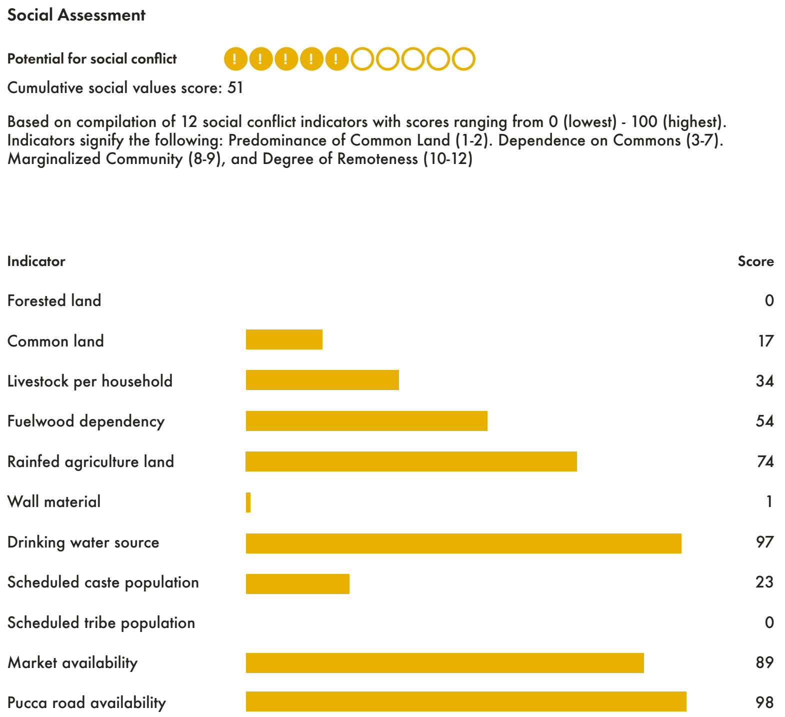
1. **Map lands suitable for renewable energy:** Identify areas with renewable energy development potential based on resource potential, existing energy infrastructure, administrative considerations like zoning and physical geographic features.
2. **Map environmental or conservation values:** Identify and gather data on critical ecological values like wildlife habitats, migratory routes and more.
3. **Map cultural and social values in the region:** Engage with local stakeholders to understand local values and concerns and identify how to spatially represent them with primary or secondary data.
4. **Synthesise information to identify low-conflict sites:** Assess data layers and conduct stakeholder review to develop a user-friendly tool that considers climate, conservation and communities.

It is important to note that, while this approach can support project developers in proactively screening projects to reduce siting conflicts, robust community and stakeholder engagement is still essential in project design and development.

For example, in India about 68% of solar and 22% of existing wind projects are sited on agricultural or natural lands, highlighting the potential impacts of renewable energy projects to biodiversity, community livelihoods, and future food security when not planned responsibly.

1. https://www.nature.org/content/dam/tnc/nature/en/documents/Europe_Energy_Practitioners_Guide.pdf

An example Social Values Index for a site in the SiteRight India tool



Source: The Nature Conservancy, 2024.

To address these concerns, a Social Values Index was integrated into the India siting tool along with energy resource potential and biodiversity indicators. This composite index aggregates 12 indicators, which can be considered individually, that serve as a proxy for socioeconomic vulnerability, as well as local and rural communities' dependence on common lands. Indicators were selected based on expert input and stakeholder focus groups and were compiled from government census data.

and meet high social and environmental impact benchmarks. Experiences from the public and private sectors indicate that best practices in permitting centre on: administrative consolidation; digitalisation; policy support; and public engagement.[54]

Creating dedicated, centralised authorities is one way to streamline this process by ensuring developers can refer to a single focal point. For instance, India recently introduced the National Single Window System (NSWS), which is a digital platform to provide guidance in identifying and applying for approvals according to business requirements. The platform gained popularity among investors when it enabled over 44,000 project approvals in a variety of industries since its launch in September 2022.

Collaboration with local communities can further strengthen the acceptance of wind energy projects. In Denmark, citizen-owned wind turbines account for approximately 75% of the country's total installed capacity, demonstrating the active participation of communities in the wind energy sector. This approach promotes local economic development and facilitates public acceptance.

tEasing the land acquisition and procurement process can expedite permitting processes. For example, in India the Ministry of Environment, Forests and Climate Change has placed solar and wind power projects under the 'White Category' of industries. As such, they are not required to obtain 'Consent to Operate' from the respective state pollution control board (SPCB / PCC) and an intimation to the board would suffice.

Recommendations to accelerate permitting of wind projects

The expansion of wind energy will require early, extensive and effective engagement and a shared understanding of what that will mean for communities, nature and users of land/sea spaces. GWEC makes the following recommendations to streamline permitting for wind energy

54. European Commission, Technical support for RES policy development and implementation – Simplification of permission and administrative procedures for RES installations, RES Simplify, 2023.

projects, while mitigating adverse impacts:

- **Mandate maximum lead times to permit wind plants.** Standard recommended lead times are 2 years for greenfield onshore wind projects, 3 years for offshore wind projects and 1 year for repowering projects – although these may be further reduced in light of energy security and climate goals.
- **Implement a clearing house mechanism for legal disputes** to prevent extended delays to critical infrastructure projects, and a structured and time-limited procesengagements for developers to provide evidence.
- **Dedicate centralised authorities and single focal points** to work with developers to streamline the siting and permitting process, such as through a "one-stop shop" model.
- **Invest in more staff and digital resources** for the various authorities which make decisions during the permitting process of a renewable energy and infrastructure project. Build digitised, searchable and up-to-date databases for land registrations and siting of projects, including an inventory of local ordinances and records of where energy projects have met community resistance, which can support zoning for projects.
- **Align land and ocean use guidance at national and sub-national level**, prioritising projects which support energy security, "Do No Significant Harm" principles, minimal impact to biodiversity and the green economy. This should also include a review of minimum distance requirements which are up-to-date with latest technologies.
- **Promote active dialogues between local authorities, communities and industry** to ensure a shared understanding of priorities and concerns. This is important to ensure a balance of interests across stakeholders and harmonious co-existence with other land/ocean users. An emphasis on early and continuous engagement with communities is necessary to obtain social license.
- **Industry actors should establish corporate commitments** that contribute to a nature-positive approach, including clear and ambitious conservation targets. Companies should monitor, assess and transparently disclose risks, dependencies and impacts on nature on a regular basis at company-wide level for new and existing developments.
- **Industry should also invest in innovation** of new technologies that help to avoid and minimise impacts of wind farms on the environment, or restore the conditions at sites.

As part of the GRA, GWEC has also contributed to the Planning for Climate Commission's plan in 2023 to accelerate permitting of renewable energy. This contains several recommendations covering effective administration to environmental safeguards.[55]

The Planning for Climate Commission's 9-point plan for fast and fair permitting

Source: Planning for Climate Commission, 2023.

55. https://gh2.org/article/global-commission-launches-recommendations-speed-permitting-address-climate-change

Industry Spotlight: Aurora Wind Power's impact on youth wellbeing in South Africa

Provided by: South African Wind Energy Association (SAWEA)

In South Africa, Aurora Wind Power has undertaken a comprehensive approach to foster the wellbeing of vulnerable youth living within a 50-kilometre radius of the 94 MW West Coast 1 wind farm. With a focus on education and skills development initiatives, Aurora aims to improve youth access to meaningful employment opportunities, thereby elevating their standard of living and ensuring easier access to housing, transportation, healthcare and nutrition.

Education programmes spanning life development stages

Aurora Wind Power's youth education initiatives encompass a broad spectrum of a young person's developmental stages, from early childhood development (ECD) to tertiary education. These programmes are designed to guide vulnerable youth towards quality education, which are crucial for securing meaningful employment in the future.

Early childhood development: In collaboration with Lerole Power and ELRU, Aurora supports two ECD initiatives in the communities of Louwville and Laingville, focusing on quality early childhood education. In 2023, these initiatives generated 10 local jobs, benefiting over 200 households, 24 ECD Centres, and 1,300 children aged 0-6 years.

Primary and secondary school initiatives: Through a partnership with HeyMath!, Aurora launched a digital Mathematics and Science improvement program at seven local public schools, aimed at enhancing learner participation and outcomes in these subjects. This program has reached over 100 educators and 6,000 learners, providing essential digital tools for education.

Grade 11 and 12: A leadership programme for Grade 11-12 learners at two local schools focuses on instilling values and leadership skills essential for future academic and professional pursuits. Additionally, an entrepreneurial skills development program has been initiated to support 20 aspiring entrepreneurs at a high school on the West Coast.

Bursary programme: Since 2016, Aurora's bursary programme has provided full financial support to deserving students from the West Coast for tertiary education in any field of study. To date, the program has aided 33 students, 67% of whom identify as female. Notably, 12 graduates from this programme have successfully secured employment in various sectors.

Impact and sustainability

In 2023, Aurora implemented six education programmes, significantly benefiting Black persons, aligning with the Broad-Based Black Economic Empowerment (B-BBEE) Codes of Good Practice. Over 4,000 individuals received training, with a majority being Black, demonstrating commitment to inclusive education and skills development.

The education programmes sponsored by Aurora have created a minimum of 17 jobs for individuals from the West Coast, further contributing to the local economy and community development. These impacts showcase the opportunities to empower vulnerable youths through education, ultimately fostering a brighter and more sustainable future for the community.

Who owns the wind? Navigating land rights in an era of expansion

The contentious nature of land[56] in the energy transition is underscored by political, historical, cultural and spiritual dimensions that extend beyond a project's physical footprint. Cultural heritage and traditions constitute foundational pillars for numerous indigenous communities, manifesting in a symbiotic relationship between land and identities.

Land's pivotal role in sustaining livelihoods, serving as an essential space for agriculture and livestock activities crucial to community well-being, further accentuates its contentious nature. Historical rights and land tenure, particularly prevalent in indigenous contexts, contribute to the complexity. Additionally, emotional and spiritual attachment to the land becomes a source of resistance, leading to legal battles and opposition against perceived disregard for cultural values.

This combination of cultural, economic, historical, and emotional dimensions highlights the significance of land, transforming it from a resource into a vital component of culture and traditions that communities seek to safeguard amid the energy transition.

When governments, developers and energy companies do not work in partnership with communities and landowners, these challenges persist and risk becoming a hindrance to renewable energy development. The unequal distribution of electrification benefits, which favours wealthier communities over less privileged ones, exacerbates the problem.

Given the critical role of land in the energy transition, this section examines experiences in Kenya, Norway and Mexico to highlight land rights challenges for wind projects as a global issue. In developing economies such as Kenya and Mexico, land rights issues often arise from the acquisition of communal lands belonging to indigenous communities. These communities have deep cultural and historical ties to the land, which is essential for their livelihoods, such as agriculture, livestock farming and fishing activities.

While challenges to wind farms in developed countries often stem from NIMBY, populist or environmentalist grounds, such as the visual impact of large wind turbines on the landscape, people displacement and indigenous rights can also pose a challenge in developed countries such as Norway.

The common thread is the necessity for developers to foster early, open and continuous communication, respect indigenous rights and address the specific needs and concerns of local populations. Inadequate compensation, lack of consultation and disregard for socioeconomic impacts have fuelled local opposition, posing substantial risks for investors and national energy ambitions.

Kenya

The construction of Africa's largest wind power plant at Lake Turkana faced significant challenges related to land, which was important for cultural heritage, cattle grazing and herding.[57]

Following prolonged legal battles,

56. In the wind energy context, the concept of "land rights" more broadly encompasses land and seabed. 50. https://www.climatechangenews.com/2023/09/04/kenyas-wind-power-troubles/.

a 2021 High Court ruling found that the land title deeds were acquired irregularly. The deeds were cancelled, and the four state defendants (the National Land Commission, Marsabit County Government, the Attorney General of Kenya and the Chief Land Registrar) who were enjoined with Lake Turkana Wind Power (LTWP) in the suit, were given one year to regularise the title acquisition process.[58]

If the acquisition wasn't solved within this timeframe, the land hosting the approximately $680 million project would automatically revert to the community. As no resolution was reached by LTWP within the given period, the land was returned to the locals in 2023. The four state agencies and LTWP have filed appeals.

In Nyandarua County, the $144 million Kinangop Wind Park (KWP) project faced community discontent, ultimately leading to its cancellation.[59] The project aimed to bring electricity to 150,000 Kenyan homes. However, KWP encountered issues due to insufficient community involvement during the land securing process. This led to conflicts with local landowners and farmers on compensation and negotiation procedures.

A major hurdle was the use of non-secured private land for infrastructure for installing turbines. Some groups around the project site were excluded from the land securing process, leading to complications at the start of construction. A local political leadership contest during the construction process also led to the wind project's impact becoming a campaign issue.

Initially, 38 land-owners entered into a lease agreement with the KWP project. However, problems arose when KWP relocated its equipment to the project site, prompting farmers to protest and demand proper community engagement and sensitisation, as well as compensation for those around setback areas. Concerns grew that the community might be

57. https://media.business-humanrights.org/media/documents/Lake_Turkana_Wind_Power_Judgment_October_2021.pdf; NIRAS Africa Limited, Socio-economic Impact of Lake Turkana Wind Power in Marsabit, 2020; https://ltwp.co.ke/category/resources-publications/
58. https://www.reuters.com/article/kenya-electricity-idUSL8N1620QG/.
59. Mike Iravo, Factors Influencing Community Participation in Implementation of Public Projects in Rural Areas: A Case of Kinangop Wind Park in Magumu, Nyandarua County Kenya, 2017.

forced to sell their agricultural land for the project to proceed. Local opposition gained momentum, fuelled by worries about coercion in land sales and fears of health problems caused by the turbines.[60]

KWP announced the project's cancellation, revealing that the protests had not only eroded the timeline but also depleted allocated funds. The cancellation had broader consequences for Kenya's energy goals, affecting the nation's pursuit of increased power generation capacity and energy security.

Based on the experiences from the LTWP and KWP projects, it is evident that land acquisition and engagement with landowners are critical factors that can determine the realisation of wind projects. The industry must continue to prioritise transparent and inclusive engagement with landowners and local communities, ensure fair compensation and resettlement processes, and establish robust conflict resolution mechanisms.

Failure to address these issues can lead to prolonged legal battles, costly delays and even project cancellations, jeopardising investments and hindering the

60. https://apnews.com/article/norway-sami-wind-farm-energy-indigenous-54f4cafbee29578dc9de1f206df3f9ff

development of wind energy projects.

Norway

In the heart of Norway's Fosen district, a clash unfolded over Europe's largest onshore wind farm, situated 280 miles north of Oslo.[61] The conflict centred on allegations of infringement of indigenous rights and the traditional reindeer farming practices of the Sami people.

The wind farm's construction, marked by 151 towering turbines, affected the centuries-old connection the Sami people maintained with the land through reindeer farming. The Supreme Court's verdict in 2021, siding with the Sami, underscored the tension between the push towards green energy and the preservation of indigenous rights. Sami activists mobilised, staging protests outside the Prime Minister's office, occupying the Ministry of Petroleum and Energy and strategically blocking entrances to various ministries.

After nearly three years of dispute, Norway reached an agreement with the indigenous community in 2024. This accord not only ensures the continued operation of the wind farm (and other onshore wind farms in Norway) but also acknowledges the importance of meaningful community engagement during the land securing process.

Under the terms of the agreement, the Sami will receive compensation, including a share of the energy produced by the wind farm. A new area for winter grazing will be provided, ensuring the preservation of their traditional way of life. To strengthen Sami culture, a grant of NOK 5 million ($475,000) was allocated. The Speaker of the Sami Parliament noted this was a turning point for the recognition of indigenous rights and reconciliation, laying a positive foundation for the future.

The agreement highlights the essential role of open communication, respect for indigenous rights and a commitment to finding sustainable solutions that balance environmental goals with the well-being of the communities affected by such projects.

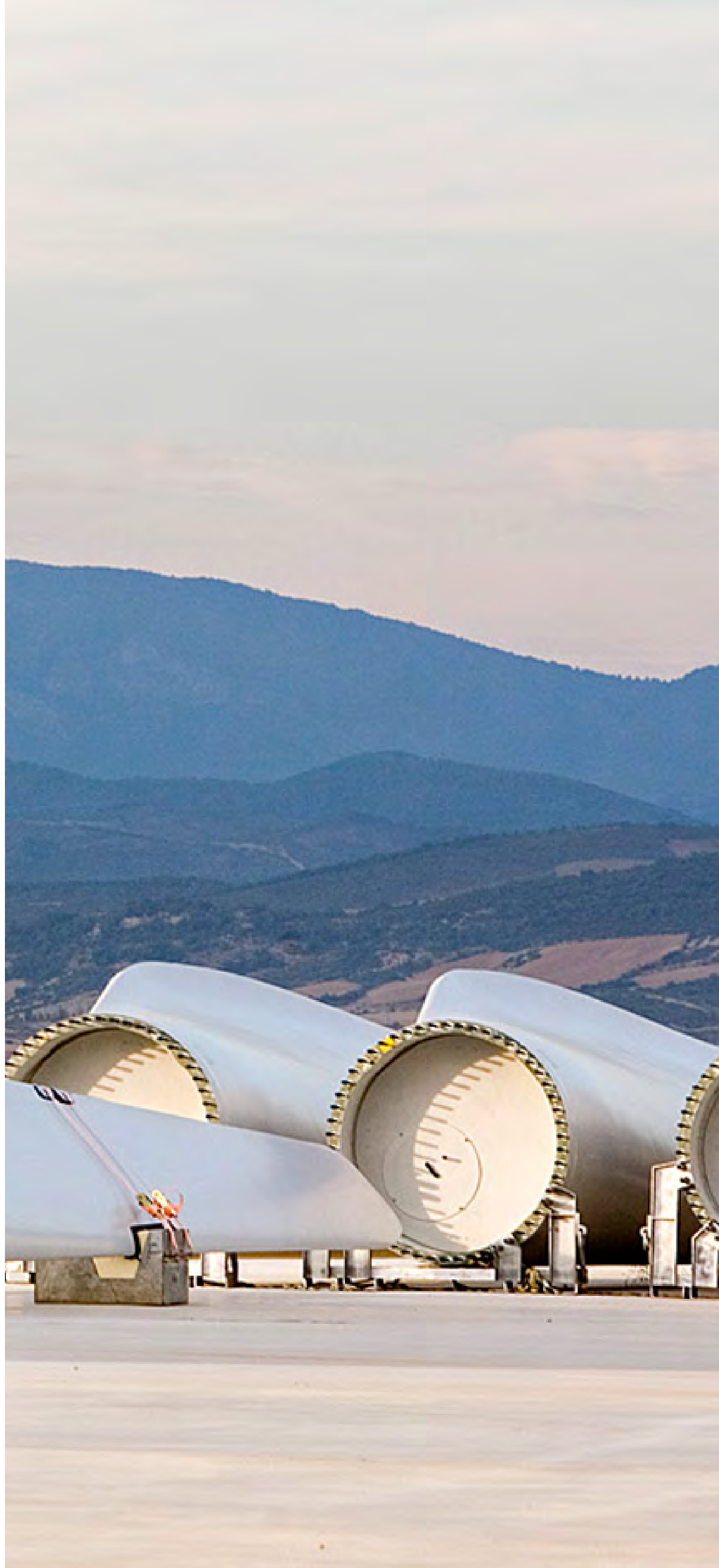
Mexico

In 2004, Mareña Renovables initiated a project to harness the unique wind conditions of the Isthmus of Tehuantepec in Oaxaca, Mexico. This region is predominantly inhabited by indigenous communities utilising communal land arrangements known as ejidos. Mareña Renovables acquired the rights to a 396 MW wind energy project, which would have made it the largest wind farm in Latin America at the time.[62]

However, the project encountered substantial opposition from indigenous communities, particularly Santa María del Mar and San Dionisio del Mar. The resistance stemmed from concerns related to the impacts of wind turbines on local biodiversity, fishing activities and their way of life.

The opposition gained momentum through the formation of the Assembly of Indigenous Peoples of the Isthmus in Defense of Land and Territory (APIITDTT) in 2007. The communities, supported by activists and neighbours, questioned the lack of

61. Armando Hurtado Sandoval, Wind Energy Development in Mexico A case study of the potential for local socio-economic benefits in Mareña, Lund University, 2015.
62. https://www.bnamericas.com/en/news/project-spotlight-mexicos-eolica-del-sur-finally-looks-set-to-be-built



transparency, consultation and respect for their autonomy during the negotiation process.

By 2013, following escalating clashes and court orders, the project stopped construction. It was relocated a few districts away and adopted a new project name, Eólica del Sur. The following year, the project initiated a Free, Prior and Informed Consent (FPIC) consultation process with local communities. Tensions with indigenous peoples and legal challenges continued, though Eólica del Sur was finally inaugurated in 2019.[63]

This case highlights the importance of involving local communities in the decision-making process and addressing their concerns during land securing, including alignment with FPIC protocols.

Recommendations to foster support for wind's expansion

Meaningful community engagement and respect for indigenous rights are of critical importance for the successful implementation of renewable energy projects while preserving cultural heritage and traditional ways of life.

GWEC makes the following recommendations to ensuring land can be secured for wind energy's growth while maintaining social harmony:

- **Respect for community rights** is an important principle for project development, as illegitimate land acquisition can lead to legal challenges, delays and project cancellations.

- **Participatory and inclusive engagement with local communities, particularly indigenous groups**, is crucial for project success. This should include early, continuous, in-person dialogue, and a conflict sensitivity approach which understands that conflicts will arise and that having a standing platform for open discussion and joint resolution is essential. This platform should be established during project development and last for the project lifetime, to mitigate potential tensions and violence, and ensure a smoother green energy transition.

63. Treen, Williams and O'Neill, Online misinformation about climate change, WIREs Climate Change, 2020.

- **Establishing fair compensation packages** is crucial for securing indigenous support and project continuity, and should be placed in context of potential disruption, economic displacement and cultural impact. Acknowledging and mitigating impacts on traditional practices, such as herding or grazing, is essential.
- **Flexibility in design and expectations** for both industry and impacted communities demonstrates a wiliness to move towards harmonious co-existence and accommodation of multiple priorities of local and national significance.

Guarding against the dangers of disinformation

Climate and renewable energy disinformation pose a formidable challenge to the global energy transition and the ability to achieve the global goal to triple renewables by 2030. Disinformation narratives can be difficult to recognise, let alone counter. They are strategically deployed by opponents to the expansion of certain renewable energy technologies in attempts to delay or halt projects, including wind energy.

Decades of experience have demonstrated that a successful renewable energy rollout will be contingent not just on robust policy and regulatory mechanisms and technological innovation, but also on the sustained support of local communities and broader society.

Large-scale wind, solar and transmission infrastructure projects are particularly vulnerable to challenges and blockages in the planning system, and disinformation-fuelled opposition only amplifies that. In certain places, community pushback can be among the biggest blockers to wind energy deployment. Targeted false narratives mislead communities, delay development, intensify investment risk and make informed debate difficult.

The importance of definitions

Climate misinformation is commonly referred to as "climate scepticism" and "denialism" as well as "manufactured doubt" that confuses the public, increases polarisation and stalls political action and public support for climate and clean energy policies.

Put simply, climate misinformation is well defined as statements and narratives that are "false, inaccurate, or misleading", or "presented out of context".[64]

Disinformation relates to narratives that have a "clear intent to cause harm or purposefully deceive others," whereas misinformation can be the result of an innocent bystander unknowingly perpetuating false information. Accordingly, disinformation is a subset of misinformation.

Importantly, not all critiques of wind energy are misinformation or disinformation, and instead may reflect fear of the unknown or genuine questions about the infrastructure.

However, disinformation does not represent arguments in good faith and has a distortionary effect on public debate. Disinformation was cited as the biggest short-term global risk in the World Economic Forum's 2024 risk perception survey among global business leaders, and is a risk only amplified by changing geopolitical landscape and a critical election year across several major economies.[65]

Intended or not, misinformation causes real harm. The impacts are felt at the aggregate level, such as

64. Treen, Williams and O'Neill, Online misinformation about climate change, WIREs Climate Change, 2020
65. https://www.weforum.org/press/2024/01/global-risks-report-2024-press-release/.

on the quality of public opinion and politics, and at the local level, when narratives collide and confuse scientific information to influence decisions, such as permitting and siting of infrastructure projects.

Misinformation discourses can influence the arguments deployed by communities and interest groups against renewable energy infrastructure, thereby influencing the parallel administrative decision-making processes – the results of which can negatively affect the development costs and timelines of wind projects.

Characteristics of misinformation

Because misinformation places information out of context, it can be especially difficult to counter. This has particular importance when considering that new methods of climate denial have moved on from attacking climate science to instead attacking climate policy solutions like renewable energy.[66]

Energy systems are highly complex and potential impacts of infrastructure projects can be difficult to assess even by subject-matter experts. **Misinformation exploits the complexity of the energy transition.**

Misinformation does not erupt spontaneously. Narratives are spread, in part, intentionally by opponents of renewable energy. Disinformation originates from well-funded vocal minorities.[67] Misinformation is then actively disseminated through traditional media, like newspapers and op-eds, and social media, like local Facebook groups.

In traditional media, climate reporting is characterised by false equivalence, where despite overwhelming scientific consensus, media gives disproportionate coverage to climate denialist positions in attempts to maintain balance; the result being that contrarian views are given disproportionately more airtime.

Misinformation is further spread on social media, amplifying local opposition. AI and algorithm-fuelled content-sharing poses a looming threat in amplifying disinformation, not just across climate policy but writ-large across debates on societal issues like human rights, healthcare, and elections. Critically, it is becoming easier to mass produce disinformation campaigns with even fewer resources.

What are the main narratives?

Analysis by GWEC shows identifiable patterns across misinformation narratives. The industry encounters four types of narratives across global markets: technological performance; economic impacts, quality of life impact and ecological impacts. Narratives are not random and instead reflect underlying values, beliefs, and concerns about the energy transition. Opponents rely on the selective use of information, frequently containing a grain of truth, to obfuscate and confuse policy debates along these four categories.

Technological performance

Narratives critique the technological performance of wind turbines, misrepresenting the capabilities of wind turbines and power systems reliant on wind energy. Common themes relate to reliability, sustainability and cost. These narratives are typical of climate delay discourse, since they criticise solutions and promtote inaction.

66. Center for Countering Digital Hate, The new climate denial, 2024.
67. https://www.volts.wtf/p/the-right-wing-groups-behind-renewable

- **Reliability:** Opponents suggest that the inherent variability of wind makes it an unreliable source of power and destabilises the power grid. However, wind energy is a reliable, predictable component of a diversified and integrated electricity mix. During the 2021 Texas winter storm, critics initially and falsely blamed wind energy for state-wide blackouts, when the root cause was later attributed to failures that began in the natural gas production system.[68]

- **Sustainability:** Opponents try to discredit wind energy on sustainability grounds, arguing that turbines are carbon-intensive and produce significant waste. While most turbine components can be recycled, there are challenges related to the end-of-life of turbine blades. However, these facts are decontextualised and fail to discuss the impacts of wind technologies in comparison to other forms of energy production. Electricity generated from fossil fuels has significantly higher embodied energy compared to renewable technologies like wind and solar, and fossil fuel extraction produces a dramatic amount of solid waste.[69]

- **Cost:** A common storyline is that wind is inefficient, requires subsidies to function and is therefore undeserving of special status. These claims draw on outdated information about capacity factors, not recognising that capacity factors globally for wind are among the highest for renewable energy, particularly for offshore wind.[70] These narratives overlook energy sector subsidies globally, where more than two-thirds of direct subsidies are currently benefiting fossil fuels.[71]

Economic Impacts

Others criticise and exaggerate the potential negative economic impacts of wind energy, emphasising the perceived economic losses to incumbent sectors who seek to defend their market positions, whether it is fossil energy or adjacent industries like fisheries and tourism. These narratives view wind energy through a lens of competition rather than co-existence.

- **Competing commercial interests:** Economic misinformation narratives relate to the potential harm to incumbent sectors like the fishing industry. Here, concerns related to biodiversity and marine life are used to discuss the economic productivity of the fishing industry, rather than

68. Busby et al, Cascading risks: Understanding the 2021 winter blackout in Texas, Energy Research & Social Science, 2021.
69. Pehl et al, Understanding future emissions from low-carbon power systems by integration of life-cycle assessment and integrated energy modelling, Nature Energy, 2017.
70. https://www.iea.org/data-and-statistics/charts/average-annual-capacity-factors-by-technology-2018.
71. Michael Taylor, Energy subsidies: Evolution in the global energy transformation to 2050, IRENA, 2020.

biodiversity itself. Opponents are concerned about diminishing returns for commercial fisheries and consequent job losses.[72] Narratives emphasise displacement of productive land for energy instead of its user for food or livestock production. Additionally, narratives about negative harms to tourism are prevalent.

- **Employment:** These narratives focus on job displacement or losses caused by the wind industry, particularly in regions with high reliance on fossil fuel industries for employment. Renewables are framed as coming in and replacing existing sectors.

Quality of Life Impacts

Impacts to human quality of life refer to narratives related to human health, community character and residential property values. Typical narratives relate to the perception of "damaged viewspaces" or "industrialisation" of pristine landscapes. These narratives single out wind energy from the wider built environment, like transmission lines and telecommunications lines. These narratives evoke emotional responses and are therefore the most difficult to counter with facts.

- **Human health:** Longstanding critiques include ideas that wind turbines cause noise-induced health problems. There is negligible evidence that turbines cause physical and mental health problems. When contextualised within the wider built environment, wind turbine sound levels are not found to be associated with health impacts, unlike higher levels of road traffic sounds.[73]

- **Community character:** A common objection is that wind turbines degrade landscapes and the character of a community. Opponents perceive a pristine landscape being invaded by an "industrial" object that does not belong and impairs the integrity of a community.

- **Residential property values:** A recurring narrative is that wind turbines cause negative impacts to residential property values, primarily as a by-product of undesirable views from homes. The research on the relationship between wind turbines and property values is complex. A 2022 study of offshore wind found that turbine views "do not specifically impact property values."[74] Interestingly, a Scottish study found a positive impact on house price growth in some cases, due to the additional economic or leisure benefits brought by projects.[75] The relationship between property prices and wind farms is not straightforward, but to suggest that wind farms directly lead to negative property valuations is disingenuous.

Ecological Impacts

The most well-known narratives relate to impacts on the natural environment, such as wildlife species and land. These claims are taken seriously by the industry, but many myths rely on outdated information. These narratives seek to undermine the green credentials of the wind industry but are also easier to counter with data. As newer technologies like floating offshore wind mature, debates around negative ecosystem impacts will abound and gaps in technological data could breed misinformation.

- **Impact to birds:** Early wind installations did present risks of turbine collisions due to siting issues, but modern wind farms significantly reduce the risk of avian collisions.[76] Fossil fuel plants are 35 times more dangerous to birds than wind energy, and

72. https://www.theguardian.com/environment/2023/nov/12/how-a-false-claim-about-wind-turbines-killing-whales-is-spinning-out-of-control-in-coastal-australia.
73. Radun et al, Health effects of wind turbine noise and road traffic noise on people living near wind turbines, Renewable and Sustainable Energy Reviews, 2022.
74. Luran Dong and Corey Land, Do views of offshore wind energy detract? A hedonic price analysis of the Block Island wind farm in Rhode Island, Energy Policy, 2022.
75. Heblich et al, Impact of wind tubines on house prices in Scotland, Climate Xchange, 2016.
76. Shifeng Wang and Sicong Wang, Impacts of wind energy on environment: A review, Renewable and Sustainable Energy Reviews, 2015.
77. Benjamin Sovacool and Pushkala Ratan, Conceptualizing the acceptance of wind and solar electricity, Renewable and Sustainable Energy Reviews, 2012.

nuclear plants are twice as dangerous.[77] Overall, bird mortality from wind turbines pales in comparison to deaths caused by vehicles, buildings, and cats.[78]

- **Marine life:** Misinformation narratives are one-sided and overlook the positive impacts offshore wind turbines can have on marine environments. For instance, offshore turbines have led to the creation of artificial reefs, and increased fish catch in some areas. Scientific certainty about the "magnitude" of negative impact is "relatively low."[79] Yet, misinformation about potential impacts to marine life is growing and provokes an emotional response in those unsure or already opposed to offshore development.

Misinformation narratives are notoriously complex and increasingly sophisticated. Yet recognising these patterns can help the industry and supporters of the energy transition to create responsive and proactive strategies. As policy complexity grows, misinformation evolves in response and will increasingly become a challenge across the policy decision making cycle.

Summary of wind misinformation narratives

Narrative Types	Sub-Narratives	Narrative Examples
Technological Performance	• Reliability • Sustainability • Affordability	• South Korea: "Many people believe that variability of renewable energy sources will destabilise the power system."[80]
Economic Impacts	• Sectoral impacts: fisheries, agriculture, tourism • Employment impacts • National identity	• Japan: "Residents are concerned the sight of wind turbines in the bay could have a negative impact on Ishikari's scenery, damaging the local environmental tourism industry."[81] • Greece: "Villages are trying to block wind turbines, arguing they will turn away tourists — Greece's main source of income."[82]
Quality-of-life Impacts	• Human health • Community character • Residential property values	• Spain: "As a local, I'm mostly concerned about the fishing... But also about the cultural spirit of Cadaqués, the landscape that inspired Dalí."[83]
Environmental Impacts	• Species: birds, marine life, etc • Weather patterns • Land conditions	• **United States:** "Despite a lack of scientific evidence, they have blamed a recent spike in whale deaths on exploration devices that use sonar to seek wind turbine sites."[84]

Source: GWEC.

Elevated risks of misinformation and disinformation

Misinformation leads to unpredictability at the policy and decision-making levels for wind energy projects – ultimately leading to more frequent project delays, incurring increased costs and reputational harm. In many cases, developers face regulatory uncertainty and constraints caused by misinformed opposition, such as being forced to change the scope of a project after approvals have been given.

In other cases, opposition narratives lead to fearmongering and partisanship, prompting local officials to instate large setbacks around private property. These local examples can compound into policy shocks, where governments may impose moratoriums or bans on renewable energy. For instance, in Ohio, a 2022 law granted local counties the ability to exclude wind and solar projects from certain areas.[85]

In another example, in August 2023, the government of the province of Alberta, Canada, instituted a seven-month moratorium on new renewables

78. Shifeng Wang and Sicong Wang, Impacts of wind energy on environment: A review, Renewable and Sustainable Energy Reviews, 2015.
79. Galparsoro et al, Reviewing the ecological impacts of offshore wind farms, npj Ocean Sustainability, 2022.
80. Adelphi, Promoting acceptance of wind and solar energy in Korea, 2019.
81. https://www.japantimes.co.jp/environment/2024/01/21/wind-power-environment-concerns/.
82. https://www.nytimes.com/2021/10/29/business/greece-green-energy-climate-eu.html.
83. https://www.nytimes.com/2022/07/19/climate/spain-floating-wind-farm.html.
84. https://yaleclimateconnections.org/2023/09/wind-opponents-spread-myth-about-dead-whales/.
85. https://ohiocapitaljournal.com/2022/08/23/nine-ohio-counties-ban-wind-solar-projects-under-new-state-law/.

development, citing concerns related to end-of-life and grid stability.[86] While the moratorium was lifted in February 2024, the government simultaneously introduced new restrictions for wind and solar to safeguard "future agricultural yields", "tourism dollars", and "breathtaking viewscapes."[87] According to the Pembina Institute, these restrictions do not apply to other sectors or land users, and have created heightened uncertainty for industry and investors in renewables.[88]

Unfortunately, misinformation also creates a risky environment for professionals on the frontlines, such as those in community and stakeholder engagement roles. Opponents not only attempt to discredit data provided by developers, but also attack climate scientists for being "alarmist" or those who are studying disinformation as suppressing free speech.[89]

Fundamentally, critics are questioning the motives of the messenger, leading to a cynical environment which reduces trust in the decision-making process, the political environment and ultimately, the energy transition. All these impacts serve to slow wind energy deployment.

Case Study: Offshore wind misinformation in Australia

In regions new to offshore wind development, misinformation can proliferate quickly. In the US, misinformation around whale deaths continues to cause anxiety and concern among policymakers, despite being debunked by scientists and experts.[1]

A recent report highlights the fact that the fossil fuel industry has long funded misinformation about renewable energy and that offshore wind is the latest target of nationwide campaigns.[2] Legitimate concerns are being swept up and stoked by funded interest groups.

As the offshore wind industry begins to grow in Australia, false claims about whale deaths took the industry and proponents by surprise. Misinformation is leading to confusion and uncertainty that could ultimately limit the growth of the sector. Campaigns opposing offshore wind deploy narratives related to the fishing and tourism industry; opponents circulate false claims on Facebook about the impact on whales and concerns that wind farms do not reduce GHG emissions.

Framing opposition through the lens of environmental concerns is a well-used disinformation tactic to confuse policy debates around renewable energy.

1. https://cleanpower.org/resources/oceanographic-effects-of-osw-structures-and-potential-impacts-on-the-north-atlantic-right-whale/
2. https://www.americanprogress.org/article/the-oil-and-gas-industry-is-behind-offshore-wind-misinformation/

Recommendations to guard against misinformation and disinformation

Wind misinformation narratives seed doubt, encourage inaction and are increasingly complex. These arguments attack the merits of wind energy and are constructed to shift the policy debate, using media strategically for amplification. Misinformation narratives continue to evolve and are fine-tuned to adapt to local social and economic dynamics.

Taken as a whole, misinformation can reduce trust in the industry, at a time when the world needs an accelerated roll-out of wind and renewable energy. To meet the global goal of tripling renewable energy, effective strategies are required that push back against cynicism and turn the tide in favour of a renewable energy-powered world.

GWEC makes the following recommendations to guard against the proliferation of misinformation and disinformation:

- **Recognise the narrative patterns** to help create responsive and proactive strategies. Narratives are storylines that simplify complex topics, allowing them to be widely shared and understood. As the energy transition

86. https://www.theglobeandmail.com/business/article-alberta-risks-losing-billions-in-renewable-energy-investments-with/
87. https://edmontonjournal.com/news/politics/alberta-ucp-danielle-smith-renewable-energy-restrictions.
88. https://renewablesassociation.ca/canrea-welcomes-end-of-alberta-moratorium/; https://www.pembina.org/media-release/alberta-hamstrings-renewables-sector-rules-not-required-other-industries.
89. Brysse et al, Climate change prediction: Erring on the side of least drama?, Global Environmental Change, 2013; https://www.nytimes.com/2023/06/19/technology/gop-disinformation-researchers-2024-election.html.

73. Adelphi, Promoting acceptance of wind and solar energy in Korea, 2019.

progresses and encounters more turbulence, creating narratives to combat misinformation and mastering the skill of utilising them will be increasingly important for the industry.

- **Engage with trusted local voices and leaders** to build trust in local decision-making and counter misinformation. People turn to those they trust to shape their beliefs, which in turn shapes public perception of social issues. Developing clean energy is no longer a purely technical exercise, but a political one, and often mediated by local officials.

Fostering a just and equitable energy transition

The just and equitable energy transition (JET) is indivisible from a successful pathway to global net zero emissions by 2050. People and workforces are at the centre of driving the energy transition forwards, and this means people and communities cannot be left behind in the effort to mitigate harmful climate change.

Definitions of a JET are broad and take into consideration many different aspects of the global energy transition. The pathway by which a JET is achieved will also

Industry Spotlight: Building public support for offshore wind with Ocean Energy Pathway

Scaling offshore wind means meeting climate ambitions, enhancing ecosystems, strengthening energy security and delivering transformative economic growth for local communities. Launched by GWEC in December 2023, Ocean Energy Pathway (OEP) is an accelerator that works to unlock the immense resource of offshore wind power across global markets.

Offshore wind is the most significant climate mitigation opportunity in the oceans. IRENA and the IEA forecast the need for 2,000 GW of offshore wind by 2050 to deliver net-zero emissions globally. To put this in context, by the end of 2022, 64 GW of offshore wind capacity had been installed worldwide, almost entirely in China and northern Europe.

Within the next 28 years, the offshore wind energy sector needs to expand so that it can produce 32 times its current energy capacity. This will require adding more offshore wind capacity between now and 2050 than has ever been installed.

Offshore wind is an energy and climate solution. It provides large volumes of clean, home-grown power to expand and sustain economic progress while displacing fossil fuels in the energy system. But scaling offshore wind will require enduring political support alongside massive public and private investment, civil society engagement, and international collaboration. While government and private sector actors play essential roles, civil society can provide the necessary flexible and catalytic support to accelerate responsible and durable development.

OEP fills a critical gap by working with policymakers and civil society. The provision of technical assistance bolsters governments' capacity to create a policy and regulatory environment conducive to developing offshore wind. Technical advisory will also support achieving high quality environmental regulations and other co-benefits of mature offshore wind sectors.

OEP invests in strategies that work with crucial place-based stakeholders critical to unlocking support for offshore wind development, such as convening industry and civil society on developing nature-aligned growth of the sector.

Industry Spotlight: Doing the maths on the global wind workforce

Provided by: Global Wind Organisation (GWO)

Hundreds of thousands of technicians will be needed for construction, installation, operation, and maintenance (C&I and O&M) of the world's wind fleet, especially when the world is aiming to triple its renewable energy capacity by 2030.

This vital human resource is analysed each year in the Global Wind Workforce Outlook, published by GWO and GWEC, which considers both the raw numbers in terms of total workforce required, and the availability of industry standard training programs in key markets to upskill technicians. As per the latest Global Wind Workforce Outlook 2023-2027 report, over 574,000 new technicians (87-90% for onshore wind and 10-13% for offshore wind) will be required within the next 5 years to deliver the world's forecast wind capacity growth.

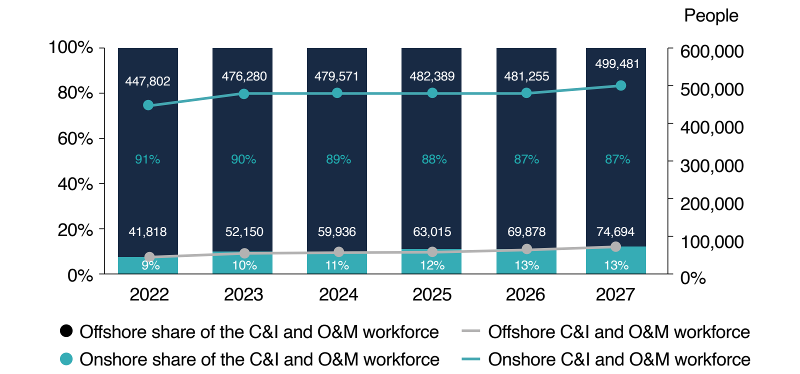
Importantly, by 2027, almost 43% of the total technician workforce would need to be new talent, given increases in MW capacity and standard attrition rates for employment. The technician needs are particularly acute in Australia, Brazil, China, USA, India, Japan, South Korea, Colombia, Egypt and Kenya. The high wind power ambitions of these countries must be reinforced by a strong culture of training standards, health and safety.

Policy support for workforce needs

This volume of workforce growth could be achieved by defining clear pathways into the wind technician workforce so people know what and how they should train to make the grade. Developers and OEMs agreed the GWO Entry Level Framework in 2022, which defines the recommended and task-specific training modules needed to ensure basic skills, knowledge and abilities of a new Pre-Assembly, Installation or O&M technician.

A huge milestone was passed in 2023, when the GWO Entry Level Framework was aligned with the

Global wind workforce needs in construction, installation, operations and maintenance



Source: GWO, GWEC, 2023.

American Clean Power (ACP) ANSI Wind Technician Entry Level Minimum Standard (ANSI/ACP 5000-2-2022). A new document, the ACP Guidelines for Entry Level Wind Technician Training, now demonstrates a clear pathway between the job role and an acceptable training pathway.

It is recommended that policymakers combine guidelines like this with workforce planning in their renewable energy policy. This will encourage investment for industry-standard training programmes. In the US, the message is starting to get through with several IRA-funded programmes supporting standardised training, and 60+ training providers by the end of 2023 compared to 25 in 2020.

The ACP model is inspiring other stakeholders to follow suit. Conscious of workforce needs to support its offshore wind pipeline, the Japanese Wind Power Association is also defining its own set of guidelines for entry-level wind technician training, which will be published in late 2024.

On a wider scale, the Jobs4Re initiative sponsored by the Danish and Philippine Governments, with support from IRENA, GWEC and

GWO, was launched at COP28 in Dubai. Initial steps are in place to build acceptance of international certification schemes like GWO, increasing certainty for stakeholders and driving workforce growth.

There is still much to do in terms of training the future wind workforce. Harmonisation of domestic safety and training regulations with international standards can pose a barrier to adoption. For instance, in Brazil national training regulations in "working at height" and first aid pre-date the creation of global wind industry training standards.

However, from all these examples, stakeholders are increasingly committing to aligning best practices. This, in turn, allows communities to share the benefits of a safe, available, and productive workforce as the wind industry expands.

vary from country to country, as transition pathways must consider the country's emissions, energy profile, fossil fuel dependencies, labour and welfare structures, macroeconomic conditions and financing needs.

As one of the protagonists leading the global energy transition, the wind industry is responsible for playing an active role in accommodating workers from carbon-intensive, sunset industries and encouraging their entry into new opportunities in the renewables sunrise industry. From the perspective of the global wind industry, **a JET can be approached as an energy transition which enables the socioeconomic welfare of all workers and communities concerned.**

Two of the main pillars of policy instruments can be leveraged to drive a JET: investment and education. Investment may be used to facilitate education, applied as support to workers displaced by the energy transition, or used along the supply chain to create demand for wind energy workers in the workforce. Education takes a variety of forms, from retraining or reskilling programmes to outreach to wider communities.

The role of the wind industry in enabling a JET

An effective JET must be undertaken at both the national and sub-national levels, to ensure local buy-in and value creation, so that the dividends of the transition to renewables can be distributed to all stakeholders. This is particularly important for communities facing economic or labour displacement from the transition away from fossil fuels, as well as for communities which host renewable energy projects.

> Over decades, the global wind industry workforce has grown to some 1.4 million people and counting.

Job creation in the global wind industry

Over decades, the global wind industry workforce has grown to some 1.4 million people and counting, spanning a wide variety of countries including China, the US, Germany, the UK, India, Brazil, Denmark, Spain, Mexico and the Netherlands.[90] The wind industry plays an active part in supporting investment and education for a JET at a national policy level, while ensuring local value creation in the form of clean energy job creation. Renewable energy employs people across all trades and levels throughout the entire value chain, from project planning to decommissioning.

Analysis by IRENA of the human resource requirements for the onshore and offshore wind industry shows that a typical 50 MW onshore wind and 500 MW fixed-bottom offshore wind project would generate around 261 Full Time Equivalent (FTE) jobs and 10,215 FTE jobs over the roughly 25-year course of the project lifetime, respectively.[91]

When considering the skills required for the deployment of wind energy facilities, analysis show that over 60% of the workforce in the onshore wind industry, and over half of the workforce of the offshore wind

90. IRENA, Renewable energy and jobs: Annual review 2023.
91. IRENA, Leveraging local capacity for onshore wind, 2017; IRENA, Leveraging local capacity for offshore wind, 2018. An FTE job is defined as one job for one person for one calendar year, based on a typical 260-working day year. 85. IRENA, Wind energy: A gender perspective, 2020.

Industry Spotlight: Empowering women in wind for gender parity by 2030

The wind energy sector has been predominantly male-dominated, with women comprising only 21% of the workforce and holding only 8% of leadership roles across the value chain. Recognising this imbalance as a barrier to innovation and sustainability, GWEC is committed to addressing and rectifying the underrepresentation of women in the wind sector.

Women in Wind (WiW)—a collaboration between GWEC and the Global Women's Network for the Energy Transition (GWNET)—has evolved into a global initiative. With a vision of attaining 50% gender parity in the wind sector by 2030, aligned with SDG5, WiW aims to foster a more inclusive and diverse wind industry through a series of initiatives:

1. EqualWIND Global Campaign: Launching in 2024, the seven-year global campaign aims to advance women's representation in the wind sector. By encouraging stakeholders to endorse the EqualWIND Pledge and commit to providing data that guides the sector towards achieving 50% gender parity by 2030, WiW sets a bold target for industry-wide transformation.

2. Women in Wind Global Leadership Program: Now in its sixth year, WiW established a leadership development programme to equip women with the skills and resources needed to excel in leadership roles within the wind industry. Through mentorship, training, and networking opportunities, women are empowered to take on key positions and drive change.

3. Global Ambassadors Program: WiW appoints global ambassadors to advocate for gender equality, raise awareness, and mobilise support for women in wind. These ambassadors serve as role models and champions for diversity, inspiring others to join the movement towards gender parity.

4. Local Network: The WiW chapter network strives to provide women in the wind industry with a platform for localised support through networking events, webinars, and mentorship programmes.

Backed by IMF evidence, global gender diversity is a key driver for economic growth and stability. It unlocks the full potential of human resources, fostering productivity and innovation. Beyond economic benefits, it plays a crucial role in addressing global income inequality and ensuring fair access to economic opportunities. Gender-diverse economies demonstrate resilience in the face of challenges such as climate change, offering adaptable solutions through diverse perspectives.

WiW's global and holistic approach prioritising empowerment, representation, and advocacy paves the way for a more equitable and sustainable future.

sector, require minimal formal training and could be filled via youth and apprenticeships, for example . Individuals with degrees in fields such as science, technology, engineering and mathematics (STEM) are required in smaller numbers (around 28% for onshore wind and 21% for offshore wind).

Highly qualified non-STEM professionals (such as lawyers, logistics experts, marketing professionals or experts in regulation and standardisation) account for roughly 5% and 20% of the workforce in onshore and offshore wind, respectively. Administrative personnel make up the smallest share (4% and 8%, respectively).

Fostering a diverse and inclusive workforce in the transition

Diversity, equity and inclusion (DEI) is an imperative across the wider energy sector. Diversity encompasses different dimensions, including gender, ethnicity and ability. As with the JET, countries will face different challenges and opportunities in this area, depending on sociocultural norms, demographics, public and private resource for DEI, and the existence of vulnerable or marginalised communities within the workforce already. One of the overarching inequities that exists is the gender imbalance in the energy workforce, with a greater majority of men than women in the overall workforce as well as in senior positions.

The proportion of women in the renewable energy workforce is approximated to be around 32%, with 21% specifically in the wind energy sector.[92] This compares unfavourably with the average 22% share of women in the oil and gas industry. As with the wider energy sector, there is a higher proportion of women in more junior parts of the value chain.

This is a systemic issue which reflects education access and sociocultural norms, as well as career and workplace opportunities and conditions. To address this, various tools such as mentorship programmes, normalising female leadership and targeting inclusion of females in STEM subjects in academia need to be expanded. These efforts are crucial for ensuring that women are more fairly represented in the wind sector.

Covering the whole of the supply chain

As the wind energy industry grows into new geographic and technological domains, its expansion will also impact the upstream segments of the supply chain, particularly rare earth elements (REEs) mining and critical mineral production communities. The increased demand for wind turbine components and rise in manufacturing capacity for wind energy will drive higher demand for specific materials, including REEs such as neodymium, dysprosium, and praseodymium as well as critical materials like copper, nickel and zinc.[93]

In order to ensure that the wind industry operates sustainably and with good governance across the wind supply chain, **sufficient policy interventions and regulatory frameworks need to be advanced to ensure the protection of mining and production communities as demand for these materials increases**. For instance, the Transition Minerals Tracker from the Business & Human Rights Resource Centre has identified 276 instances of human rights abuses across the mining practices for cobalt, copper, lithium, manganese, nickel and zinc from 2010-2020.[94]

The wind industry must also take responsibility for governing and stewarding its own highly globalised supply chain through consistent strong and consistent monitoring, high procurement standards that align with international benchmarks for good practice, regular auditing and other means of ESG assurance (see Chapter 2 recommendations).

Recommendations to secure a just and equitable transition

The conversation around JET continues to evolve among governments, civil society, industry and other stakeholders in the global energy transition, for example via the JETP initiatives, the IEA's People-Centred Clean Energy Transitions programme, the EU's Just Transition Fund and more.

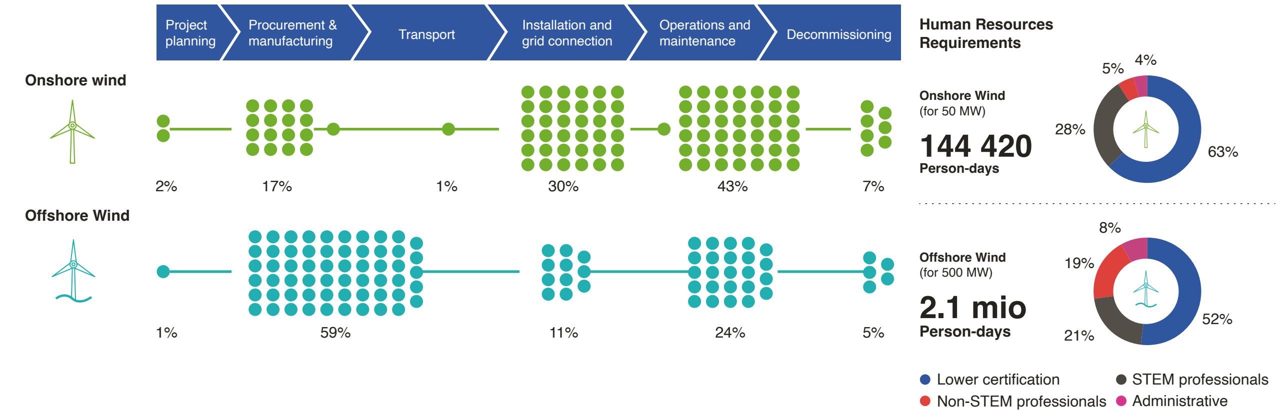
The following recommendations for action are not exhaustive, but provide a starting point for enacting a JET through enhanced dialogue, investment, education and governance:

- **The industry should increase outreach initiatives to foster a diverse, equitable and inclusive workforce.** It is vital that the wind sector is publicly recognised as an attractive and welcoming place to work by those at different career stages, from apprentices to graduates to executive talent. Interventions may be needed in company culture, recruitment practices, DEI guidance for companies, mobility and flexibility schemes, and other areas to leverage women talent as well as minority groups in the workforce.

- **Cooperate on enhancing social dialogue and stakeholder engagement on the energy transition at the national and local levels.** Creating space for social dialogue and increasing stakeholder engagement helps to support social cohesion around the transition agenda. Stakeholders include displaced workers, residents of host communities of local projects, and members of affected communities such as the fishing industry for offshore wind.

92. IRENA, Wind energy: A gender perspective, 2020
93. Global Wind Report, GWEC, 2022.
94 Transition Minerals Tracker, Business and Human Rights Resource Centre, 2021. https://www.business-humanrights.org/en/from-us/briefings/transition-minerals-tracker-global-analysis-of-human-rights-policies-and-practices/

Human resources and occupational requirements for 50 MW onshore and 500 MW offshore fixed-bottom offshore wind projects



Sources: Leveraging local capacity for onshore wind, IRENA 2017. Leveraging local capacity for offshore wind, IRENA, 2018.

National-level dialogue on the need for a JET should be sustained to ensure that the imperative for renewable energy is understood as a national priority for all, with the possibility of integrating JET objectives into climate/energy strategies.

- **Incentivise public-private collaboration to generate local value creation.** Subnational regions that depend on the production of coal, oil and gas for revenue may face economic displacement in the phaseout of fossil fuels. Governments should work with the wind industry to facilitate local industrial supply chain reviews and foster the creation of decent and productive jobs for workers, as well as appropriate plans for areas where fossil fuels-based economic activity will decline. This includes the creation of a viable local supply chain, with schemes to incubate businesses and local skills and capabilities for the wind sector, such as favourable loans and promotion of industrial clusters.

- **Tailored pathways to re-skilling or training for access to wind industry jobs from carbon-intensive industries.** Training and assistance to workers, including re-certification for wind industry occupations, could be designed under public-private collaboration to identify communities of need and match these with anticipated workforce gaps. Collaboration should aim to support career progression pathways for workers in the fossil fuel industry into renewable energy to encourage labour mobility and upskilling, in line with SDG 8.[95]

- **Public-private collaboration on governance and standards for mining and production communities in the renewable energy supply chain to ensure a safe and decent environment for workers.** At the international level, there should be alignment around the guidelines for working conditions and practices in mining and production communities that will be impacted by the increased demand for energy transition-related critical minerals, such as via the UN Guiding Principles on Business and Human Rights.

These recommendations will likely evolve as the transnational conversation on a JET engages new domains and communities. However, they represent an initial agenda for the global wind energy industry and a commitment that as the industry expands around the world, it must align with the concept and practices of a JET to ensure that wind energy retains sustainable development and social harmony as guiding principles.

95. SDG 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.

MARKETS TO WATCH

Australia

Australia has some of the world's best wind resources, with wind speeds reaching 12 m/s in offshore areas like the Bass Strait.[96] The country has 13.5 GW of installed onshore capacity, though the Australian Energy Market Operator estimates that twice the current amount of wind capacity will be required by 2030 to meet electricity demand.[97]

While no offshore wind is currently operational, the World Bank Group-ESMAP has identified more than 2,900 GW of offshore wind technical resource potential off Australia's shores. It is expected that 2 GW of onshore wind will be added annually from 2024 to 2030, with an additional 2 GW to be added in 2032.

Offshore wind holds immense potential to meet Australia's power demand and to transform the energy landscape in the country, and the wider region. If all of the proposed offshore wind farms are built, they would collectively be capable of producing more energy than all of Australia's remaining and ageing coal-fired power stations. Meanwhile, the Australian Climate Council reports that the deployment of offshore wind means 8,000 new jobs annually for Australian workers from 2031.[98]

Regional areas with significant energy infrastructure and skilled labour, such as the Hunter Valley, Illawarra, Gladstone, Port Kembla, Newcastle and Latrobe Valley, would see the creation of many jobs and economic prospects. Around 90% of those employed in the marine business and 70% of those employed in the traditional power generation sector already possess the fundamental skills required to work in offshore wind and would be able to transition to such positions with no training.[99]

Since 2022, the government has announced the establishment of many offshore wind zones around the country, including Gippsland (Victoria), Hunter (NSW), Southern Ocean (Victoria), Illawarra (NSW), Bass Strait (Tasmania) and Indian

96. https://www.ga.gov.au/scientific-topics/energy/resources/other-renewable-energy-resources/wind-energy.
97. Australian Energy Market Operator, 2022 Integrated System Plan.
98. https://www.climatecouncil.org.au/resources/offshore-wind-fact-sheet/
99. Star of the South, Making the move to offshore wind: A guide for workers, 2023.

Ocean of Bunbury (Western Australia). The first feasibility licensing process results of Gippsland, which kicked off in 2022, will soon be announced by the federal government.

Victoria moves to the next stage for offshore wind

With the announcement to join Global Offshore Wind Alliance in August 2023,[100] Victoria continues to spearhead offshore wind development in Australia. In December 2023, the state published an implementation statement for offshore wind, specifying a plan to achieve at least 2 GW of offshore wind by 2032, 4 GW by 2035 and 9 GW by 2040.[101]

The implementation plan provides greater certainty to industry on establishing local operations, and outlines several support areas for offshore wind:

- Parameters for the proposed support package for the first tranche of offshore wind projects in Victoria;
- An update on VicGrid's approach to the coordination of transmission using its Options Assessment Method that has been developed in consultation with landholders, communities and stakeholders. Preferred transmission project options will be announced in 2024;
- Workforce opportunities across all stages of offshore wind farm development, meaning jobs for Victorians in trade professions, engineering, administrative and other roles;
- A fit-for-purpose regulatory framework is also being developed to support the industry to ensure the environment is protected as the industry grows;
- A competitive procurement process to maximise local content while adapting requirements to reflect the early stages of the sector's development in Australia;
- Renewable Jobs Taskforce to be established, which will coordinate industry engagement and participation across offshore wind projects.

Stronger alignment to address concerns over wind expansion

The latest announcement for the Southern Ocean area was published by the Albanese government in March 2024. The announced area, however, was reduced in size significantly from the original proposed area, with maximum capacity decreased as a result from 14.6 GW to 2.9 GW.

This leads to several projects being placed on an uncertain future. For example, Bluefloat's Southern Winds project totalling 1.55 GW, located near port Macdonell, is outside of the declared area. Similarly, the 1.5 GW Cape Winds project off the coast around Cape Bridgewater and Portland is also outside of the declared area.

The decreased size is due to concerns about the impact of wind farm development on the fisheries industry in the area, particularly the $187.5 million ($123.7 million USD) rock lobster industry, as well as other marine life. The reduced zone was recommended by an environmental group, with the rationale of balancing cultural heritage protections and protection of sensitive ecosystems

100. https://www.premier.vic.gov.au/victoria-joins-global-leaders-offshore-wind.
101. Victoria State Government, Offshore Wind Energy Implementation Statement 3, 2023.

There is a need for more guidance for developers on how state and federal processes will coordinate.

such as the Bonnet Upwelling, a significant blue whale feeding area.

This is not the first setback for the industry. In January 2024, a renewable energy terminal at Port of Hastings was rejected by the environment minister due to concerns about "the large areas of wetland being destroyed or substantially modified by offshore windfarm development".[102] The Victorian government set aside $27 million ($17.8 million USD) in its last budget to progress the development of offshore wind, with a support of wind construction and delivery of up to 1 GW per year. However, according to the minister, this plan was deemed to damage the habitat of waterbirds, migratory birds, marine invertebrates and fish.

Efforts are underway to ensure positive support for wind energy. Industry association Clean Energy Council has created an initiative to facilitate greater communication between the industry and the communities. Under the initiative, a benefit-sharing scheme for renewable energy projects was initiated to integrate renewable energy developments into local communities in ways that are positive, rewarding and beneficial for both project proponents and local communities.

The Australian federal and state governments are highly supportive of wind power and are working together to grow the sector. Given that the federal government controls offshore territory while the state has jurisdiction over onshore matters, including decisions such as the rejection of the Port of Hastings as Victoria's port to be developed for offshore wind industry services, there is a need for more guidance for developers on how state and federal processes will coordinate.

The industry is committed to supporting the Australian governments at the national and state levels, as well as collaborating with local residents to ensure an enabling environment for wind energy development.

102. https://www.theguardian.com/environment/2024/jan/08/tanya-plibersek-blocks-victorian-government-port-hastings-wind-turbine-plan.

Azerbaijan

Azerbaijan's capital is set to host the UNFCCC-convened COP29 conference in November of this year. After some deliberation over the next host country, nations agreed on Baku as the location to progress global climate talks after the tripling renewables goal was set at COP28 in 2023.

The Minister for Ecology and Natural Resources in Azerbaijan, Mukhtar Babayev, previously an executive at the State Oil Company of the Republic of Azerbaijan (SOCAR), has been designated as President of COP29.

With wind energy referenced in the last cover decision as a key climate change mitigation technology, the wind industry is now set to stage a major intervention at the COP29 conference in Azerbaijan to promote the role of wind in driving decarbonisation through 2030 and beyond.

The Azeri energy transition
Azerbaijan's economy has relied heavily on revenue from oil and gas exports for several decades, with exploration of oil and gas in the Caspian Sea as a key

economic activity since the 1990s. Baku is a member of the OPEC+ and primarily exports its fuel supply to parts of Europe.

Azerbaijan owns one of the world's largest gas fields, Shah Deniz in the Caspian Sea, and is expected to extract 411 billion cubic meters (bcm) of gas over the next 10 years – with potential to emit the equivalent of all global aviation emissions produced in 2015.[103] The EU and Azerbaijan are mutually exploring the establishment of the Southern Gas Corridor to export gas via Georgia and Turkey to Europe.

The nation's reliance on fossil fuel energy sources is evident, constituting just under half of its GDP, just over half of government revenue and more than 90% of reported export earnings.[104]

The coming decades will present a challenge for the economy and energy system to transition to renewable energy generation. While no national net zero target has been agreed, Azerbaijan has pledged to cut its emissions by 40% by 2050 from 1990 levels, and is targeting 30% of power generation to come from renewables by 2030. It is not yet on-track to achieve these targets.[105]

Potential for offshore wind with deep reforms

There is hope for a less carbon-intensive profile for the incoming COP29 host nation. Current analysis identifies potential for offshore wind generation, although reaping this opportunity would require implementation of significant policy reforms, infrastructure buildout and investment frameworks.

According to the World Bank, Azerbaijan has technical offshore wind resource of around 157 GW (across 35 GW of fixed-bottom offshore wind and 122 GW of floating offshore wind), equivalent to more than 20 times its current installed electricity capacity.[106]

In a high growth scenario for offshore wind, an estimated 7 GW could be installed by 2040 if Azerbaijan pursues deep decarbonisation of its heat and transport energy demand, as well as upgrades its domestic transmission network. Critically, this offshore wind scenario would also necessitate grid and transmission infrastructure to export this power to demand markets in the wider region such as EU and Turkey.

As Azerbaijan's current electricity generation already covers the country's domestic demand, moving from technical potential to actual deployment of offshore wind will depend on long-term decarbonisation ambitions and a willingness to transition away from domestic fossil fuel resources.[107]

Despite most investment benefiting fossil fuels, in January 2023 SOCAR and the United Arab Emirates' state-owned developer Masdar entered a partnership on offshore wind and green hydrogen projects in Azerbaijan. Under a joint development agreement, they aim to develop offshore wind and hydrogen projects totalling 2 GW in capacity. The companies also signed joint development agreements on 1 GW of solar PV projects and 1 GW of onshore wind.

A raft of Memorandums of Understanding (MOUs) with the Ministry of Energy also focus cooperation on developing renewable energy, including: an agreement with ACWA Power for onshore wind, offshore wind and battery storage; with Fortescue for renewable energy and green hydrogen; with China's CGGC group for renewable energy; and with Total for onshore wind, solar and storage.[108]

As a country dependent on oil and gas exports, Azerbaijan faces an important moment as COP29 host to demonstrate commitment to climate action on the global stage. Offshore wind offers a potential platform to do so, but only if backed by political will to diversify the energy mix, long-term planning for cross-sector decarbonisation and an investment/collaboration framework for buildout of critical grid and infrastructure.

103. https://www.globalwitness.org/en/press-releases/cop29-host-country-priming-pumps-huge-hike-gas-production/.
104. https://www.france24.com/en/environment/20240107-former-azerbaijani-oil-executive-sparks-controversy-by-heading-cop29.
105. https://www.worldbank.org/en/news/press-release/2023/11/24/investments-and-policy-reforms-towards-low-carbon-transition-and-resilience-are-in-azerbaijan-s-economic-interest-says-w.
106. https://www.worldbank.org/en/country/azerbaijan/publication/offshore-wind-roadmap-for-azerbaijan.
107. IEA, Azerbaijan 2021 Energy Policy Review, 2021.
108. https://area.gov.az/en/page/beynelxalq-emekdasliq

Brazil

2023 was a pivotal year for the renewables industry in Brazil, characterised by the resumption of post-pandemic activities, a new national government and acceleration of offshore wind planning. However, it also presented significant challenges, including a major blackout in August and difficulties in restoring energy supply in São Paulo. These events highlighted the urgent need for Brazil to improve aspects of its electrical system, such as reliability and flexibility.

The country has garnered significant attention from the international community by placing the energy transition at the centre of its growth and diplomacy strategy. It is now preparing to host the G20 presidency and Clean Energy Ministerial in 2024, followed by COP30 in Belém in 2025. COP30 is expected to focus on nature conservation/restoration and implementation of mitigation targets.

Market status

For the third consecutive year, Brazil achieved new wind records, reaching 4.8 GW of new installed capacity, more than 1,000 wind farms in operation and surpassing 30 GW of total installations. The electricity matrix reached the mark of nearly 84% from renewable sources, establishing the country as an international reference in clean energy transitions.

Wind has been recognised across government ministries as a vector for Brazil's new energy economy, endorsed by important ministries such as the Ministry of Mines and Energy (MME), Ministry of Finance and Ministry of Development, Industry and Foreign Trade.

GWEC and ABEEólica are now focusing on strengthening the Brazilian wind production chain, which, in the last three years, has been showing signs of weakening. Manufacturers have relocated from the country or downgraded production, due largely to a stop-go cycle of development in the country and challenging macroeconomic conditions. However, over the last year, macroeconomic variables such as inflation, job creation and GDP projection, have begun to improve.

The evolution of offshore wind

The year 2023 was also marked by important progress regarding the

Offshore Wind Power Bill (PL 11.247 of 2018), which aims to build a regulatory framework for offshore wind. The bill has been approved by the Chamber of Deputies and is expected to pass final approval in the Senate in the first half of 2024.

In addition to the bill, Brazil sent important signals to the market by joining the Global Offshore Wind Alliance (GOWA, an initiative between GWEC, IRENA and the Government of Denmark to raise countries' offshore wind ambition), forming an interministerial council to discuss offshore wind regulation and signing up to the sideline pledge to triple global renewable energy capacity by 2030 at COP28.

According to the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama), 96 offshore wind projects have requested environmental licensing, representing the strong appetite for development in Brazil.

Looking ahead to the first seabed area auction in the second half of 2024, GWEC and ABEEólica are bringing international experience of good practices and case studies to support a robust auction design.

What to expect in 2024

After one year of the new government, the executive branch has created the Energy Transition Plan for Brazil led by the Minister of Mines and Energy, Alexandre Silveira, as well as the Ecological Transformation plan led by the Minister of Finance, Fernando Haddad, and the industrial plan called "New Industry Brazil" led by the vice-president and MDIC Minister Geraldo Alckmin.

In parallel, the legislative branch rushed to advance discussions on important issues for the country, such as the proposal that regulates the carbon market in Brazil (PL 2148/15), the bill which regulates production of low-carbon hydrogen (2308/2023) and the fuel of the future program (PL 4516/23).

2024 needs to be the year of implementation, where planning for the energy transition is put into practice. It requires close collaboration between the public sector and the private sector, as well as universities and civil society, to ensure that the wind industry, and renewables in general, can contribute with its full potential to an economic, ecological and social transformation in Brazil.

China

China has the world's largest renewable power generation system. According to the latest data from the National Energy Administration (NEA), the installed capacity of renewable energy in China had reached 1,450 GW by the end of 2023, surpassing the installed capacity of thermal power for the first time in China's history.

The newly installed capacity of renewable energy such as hydropower, wind power, and photovoltaic power generation in China hit a record high of 290 GW in 2023, accounting for over 80% of the country's newly installed power generation capacity and contributing more than half of global added renewable capacity.[109]

The installed capacity of wind and solar power reached just over 1,000 GW, up by a third from 58 GW in 2022 and contributing 15% of total electricity generated in the country in 2023.

In 2023, renewable energy generation investments accounted for 80% of all power project investments. This marks a new era where clean energy (including renewables, nuclear power, electricity grids, energy storage, EVs, and railways) is becoming a top driver of China's economic growth.

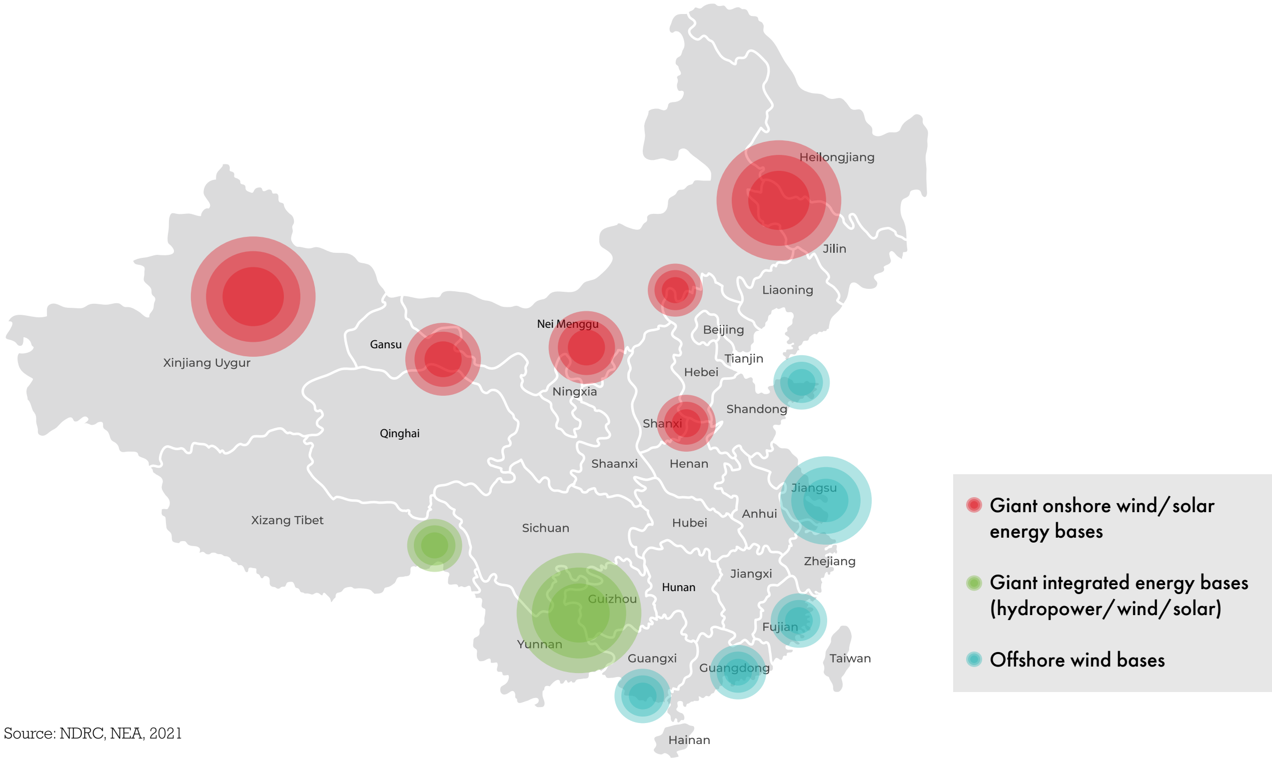
Retaining global leadership in wind energy development

In 2023, China added 75.9 GW of new wind power capacity into the grid, representing year-on-year growth of 102%. This surpassed the previous record set during the installation rush in 2020, prompted by the phaseout of the FIT regime. By the end of 2023, China's cumulative installed wind power capacity reached 440 GW, or 43% of the total wind installations worldwide.

China began planning large-scale wind and solar power bases in its northern provinces in 2021. Most of those power bases are in harsh environmental conditions, such as the Gobi and other desert areas. Now, the construction of the giant bases is steadily advancing.

As of December 2023, the first batch of these mega bases has

China's 14th Five-Year Period Renewable Development Plan



Source: NDRC, NEA, 2021

109. IEA, Renewables 2023

been completed and connected to the grid with a total installed capacity of 45.16 GW. The second and third batches, with approved total capacity exceeding 50 GW, are expected to further solidify the dominant position of wind and solar power in the country's new electricity generation capacity.

In addition to these mega onshore wind bases in the northern provinces, two integrated hydro/wind/solar giant bases will be constructed in Southwest China. In the eastern coast areas, offshore wind power is trending to transition from nearshore to deep-sea locations and from individual projects to large-scale bases.

The regulation for offshore wind development in deep-sea waters is expected to be released in 2024. A new round of offshore wind project planning and approvals has been completed in coastal provinces, including Guangdong and Zhejiang.

The industry anticipates that the newly installed capacity for offshore wind power will exceed 10 GW in 2024, and growth momentum will be maintained through 2030. In the central and Southeast regions, distributed wind projects will be promoted, especially across villages in the vast rural areas. This is also a crucial initiative for the rural vitalisation strategy under China's 14th Five-Year Plan (2021-2025).

Repowering and growth in line with sustainable development

In June 2023, the NEA issued the "Management Measures for the Renovation, Upgrade, and Decommissioning of Wind Farms," encouraging the renovation and upgrade of wind farms that have been connected to the grid for over 15 years or have individual turbines with power rating below 1.5 MW. The first wave of wind project decommissioning will gather momentum in the coming years as wind turbines operating in the early 2000s reach the end of their lifespan.

Provinces including Gansu, Ningxia, Fujian, Hebei, and Zhejiang are accepting applications for project repowering or decommissioning. It is estimated that from now to 2030, China's total repowering wind power capacity will reach 100 GW.

One month later, the National Development and Reform Commission (NDRC) and other authorities jointly issued the "Guideline on Promoting the Recycling of Decommissioned Wind Power and Photovoltaic Equipment." The policy mandates that companies operating wind and solar power generation assets must take responsibility for disposing of their decommissioned equipment in compliance with the relevant regulations.

In the disposal process, equipment should not be disposed of in landfills or without proper authorisation. Instead, companies are required to carry out ecological environment restoration and ensure harmless disposal. By 2030, up to 30 million tons of waste from decommissioned wind and solar power equipment will need to be recycled.

Stricter carbon emission policies

China's national carbon emissions trading market commenced operations in July 2021. The current trading system covers 2,200 large emitters responsible for roughly 4.5 billion tons of GHG emissions per annum.

Before the carbon market expansion kicks in from May 2024, with aluminium and cement producers expected to be included, the State Council has released its "Interim Regulations for the Management of Carbon Emission Trading." These regulations aim to toughen rules for industrial polluters participating in its national carbon market, including larger fines for entities found to be falsifying data on emissions reductions.

China's carbon market expansion can ensure the country reaches its ambitious '30-60' target to reach peak emissions by 2030 and carbon neutrality by 2060. Additionally, it assists Chinese suppliers to comply with the international environmental standards for industrial production. This is particularly important for Chinese industrial players to meet global regulatory requirements on ESG as well as the newly enforced EU CBAM.

Overcoming growing pains

More than 10 wind turbine manufacturers are still active in China. Although the domestic market is huge, competition has become increasingly fierce, with record-low bidding prices repeatedly reported every quarter since 2021.

Price pressure has been a driver of technology innovation and bigger turbines, as it has in the West. Chinese OEMs continue to launch new turbines with greater power ratings and bigger rotors to remain competitive.

OEMs like Mingyang, Haizhuang, Goldwind, Dongfang, Windey and Envision have already rolled out offshore turbines in the 16–18 MW range, with Mingyang most recently launching its 22 MW turbine model, setting a new record for offshore wind. In February 2023, Envision launched the EN-220/10 MW model, and two weeks later, SANY rolled out the 230/8-11MW prototype in Beijing – at that time, the largest onshore wind turbine in the world. SANY broke its own record when a 15 MW onshore model was launched at China Wind Power 2023. Onshore turbines of 10 MW level and offshore turbines in 16-18 MW range have appeared in the latest auctions.

China's wind manufacturing industry has made significant advancements, but it is not immune to the challenges faced by the rest of the industry (see Chapter 2). The combination of declining power prices and a race towards bigger turbines have undermined

margins, and by late 2023, some of the leading companies were showing negative EBIT margins and significant losses for their wind turbine manufacturing business.

To survive the domestic price war, Chinese OEMs continue to explore opportunities overseas. According to CWEA, Chinese wind turbine manufacturers exported 5 GW of wind turbines to overseas markets in 2023, doubling the volume reported for 2022.

At China Wind Power 2023, the Chinese wind industry announced the "Declaration on the Security of the Global Wind Power Industry Supply Chain" to underscore commitment to building a safe, stable and sustainable industry supply chain, as well as recognise the need to

diversify the global supply chain to improve resilience and support countries to benefit from the energy transition.

Driving towards the tripling goal

Guided by its "30-60" goal, the Chinese government has set the target that non-fossil energy sources will account for over 80% of total energy consumption by 2060. Wind and solar PV capacity is expected to be 10 times bigger than 2020 levels by that time. The industry trade body Chinese Wind Energy Association (CWEA) estimates that China's newly installed wind capacity will be at least 75 GW in 2024 and potentially reach 150+ GW by 2030.

While China did not sign up to the sideline pledge to triple renewables at COP28, President Xi Jinping did issue a joint statement with President Biden following a bilateral meeting at Sunnylands, California, in November 2023.

In the statement, both countries noted that they "support the G20 Leaders Declaration to pursue efforts to triple renewable energy capacity globally by 2030 and intend to sufficiently accelerate renewable energy deployment in their respective economies through 2030 from 2020 levels so as to accelerate the substitution for coal, oil and gas generation, and thereby anticipate post-peaking meaningful absolute power sector emission reduction, in this critical decade of the 2020s."[110]

China's scale and pace of wind growth have been major contributors to cost reduction and innovation in the wind sector to date. As the world's largest renewable market and the largest supply chain hub for renewable technologies, China is expected to play a crucial role in helping achieve the global goal of tripling renewable energy by 2030.

110. https://www.state.gov/sunnylands-statement-on-enhancing-cooperation-to-address-the-climate-crisis/.

Egypt

Turbulent conditions impacting offtake

Today, renewable energy makes up about 11% of Egypt's total installed capacity, but this is set to change. Egypt has ambitious targets to reach 42% renewable energy by 2035, and the government recently announced plans to increase this to 60%.

At COP27, Egypt signed off on several large investments in the wind sector, however given the current economic and political turmoil in the region, it is unclear whether the agreed projects will be implemented in the next 3-5 years as planned.

The recent devaluation of the Egyptian pound, an expected second round of devaluation, combined with reduced foreign currency inflows from tourism and the Suez Canal, have all combined to create a shortage of dollars and other hard currencies. In addition, the war in Ukraine and the Gaza-Israel conflict have added further strain on the geopolitical situation in the region.

Most renewable energy projects in the country have long-term government offtake PPAs with dollar-denominated tariffs. The Egyptian Electricity Transmission Company (EETC), the sole electricity offtaker, is now less willing to agree to additional dollar-based contracts. The Central Bank of Egypt has also set restrictions on transactions in dollars and the Cabinet of Ministers is requiring the Central Bank's prior approval for any future government foreign currency contracts.

Market status

Egypt's current installed wind capacity is over 1.6 GW, comprising the 262.5 MW Ras Ghareb Wind project, 250 MW West Bakr, 580 MW Gabal el Zeit, and Egypt's flagship wind project, the 545 MW project in Zaafarana. The Ras Ghareb wind project, awarded by public tender, was the first privately owned wind project in Egypt, developed by a consortium including Orascom Construction, Toyota Tsushu and ENGIE. The second privately owned wind project was developed by Lekela Power, since acquired by Infinity Power Holding (IPH).

The Egyptian New and Renewable Energy Authority (NREA), the government's primary body responsible for promoting and developing renewable energy, developed both the Gabal el Zeit and Zaafarana wind projects. In 2023, the Egyptian government announced a plan to sell 32 state assets, including these two state-owned wind projects.

In late 2023, an initial agreement was reached between British investor, Actis, and the Egyptian government for the sale of Gabal el Zeit, which Actis plans to expand. The first four phases of Zaafarana, which are nearing their 20-year end of life, have been offered to Maesrk, which is

investing heavily in Egypt for a large-scale e-fuels project and on the lookout for renewable energy sources. Although not confirmed, the earlier phases of Zaafarana are expected to undergo repowering – a first-of-its-kind project in the Middle East. The government plans to sell phases 4 to 8 of Zaafarana to investors in the green hydrogen field, however no buyers have been confirmed yet.

BOO scheme: Projects in the pipeline

There are several government offtake projects in the development and construction phase in Egypt, under the government's Build, Own, Operate (BOO) scheme. The Orascom consortium is constructing its second wind project in the Gulf of Suez region, the 500 MW Red Sea Wind Energy project. The project is sourcing its wind turbines from Goldwind, which is the Chinese supplier's first project in Egypt.

The Emirati-owned AMEA Power is constructing a wind project in Egypt, the 500 MW Amunet wind project, using Envision wind turbines, also a first project for the OEM in Egypt. Saudi's ACWA power, along with its local partner, Hassan Allam Utilities (HAU), signed a PPA and Usufruct Agreement with the government for a 1.1 GW wind project, across two separate locations in the Gulf of Suez region. IPH, a consortium of Infinity Energy and Masdar, are inching closer to agreeing on a 25-year PPA for a 200 MW wind project.

Finally, Siemens Gamesa Renewable Energy (SGRE) has an MoU with the government for the development of the NIAT 500 MW wind project and are looking to partner with another wind developer to take this project forward.

Scaling up wind, hydrogen and grid

At COP27, the Egyptian government signed over 20 GW worth of MOUs for large onshore wind and green hydrogen projects. Progress on the large onshore wind projects have been somewhat slow and have not advanced beyond the MOU stage.

Most green hydrogen projects will depend on both solar and wind projects to make the best use of Egypt's renewable resources. Land has been allocated in the West of Nile area for the pilot phases of the renewable energy projects for green hydrogen. Although the area has relatively good wind resources, it has significantly lower capacity factors than that of Gulf of Suez. In addition, the grid infrastructure in the West of Nile area is yet to be developed, which may delay plans for these projects come online.

In 2022, Egypt announced plans to construct the 'Green Corridor', a parallel electricity network connecting all renewable energy sources with a capacity reaching 70 GW. Although the timeline for this project remains unknown, it is expected that all wind farms serving green hydrogen projects in the country will be connected via the green corridor once constructed.

The government is also in talks with Greece and Italy on possible interconnections through HVDC subsea cables to export green energy to Europe. Although discussions are at an early stage, a number of developers have expressed their interest such as Copoulozos Group, Siemens Energy and Prysmian Group. An export route to Europe will encourage future wind and solar developments in Egypt.

Market outlook

Given the economic circumstances in Egypt, EETC is unlikely to enter into agreements for new government-offtake wind projects in the near future. Furthermore, there is market speculation that EETC is aiming to shift its role from offtaker to Transmission System Operator (TSO).

In a separate market development, EETC has been working closely with the EBRD on setting a structure for wheeling charges to facilitate private bilateral offtake contracts, which will be used for the upcoming green hydrogen projects. Once this wheeling charge structure is in place, the private offtake market is expected to unlock new opportunities for wind energy in Egypt.

India

Driven by an overarching vision under Prime Minister Modi, India is on a path to become a 'Developed Nation by 2047'. To achieve this vision, India has introduced several strategic initiatives, such as: "Self-reliant India" through "Make-in India"; targeting 500 GW of renewable energy capacity by 2030, including 140 GW of wind; reaching net zero by 2070; and a 'National Green Hydrogen Mission', among others.

While thermal power continues to dominate the power generation mix, India is expected to more than double its onshore wind and solar PV capacity by 2028 and achieve its milestone of 50% non-fossil fuel generation before 2030.[111]

Onshore wind recovering from a growth slowdown

Globally, India ranks fourth in total wind installations, with 45 GW of installed onshore wind as of January 2024. It is the second-largest wind market in the Asia Pacific region after China.

In 2023, due to a range of policy and institutional interventions by central and state governments, over 2.8 GW onshore wind capacity was commissioned – the highest annual installation level since 2017. GWEC expects continued recovery and has revised its onshore wind outlook for 2024-2028 to 22.8 GW. As per the National Electricity Plan of the central government for the period ending 2032, India's installed wind capacity is estimated to amount to around 73 GW in 2026-2027 and 122 GW in 2031-2032.

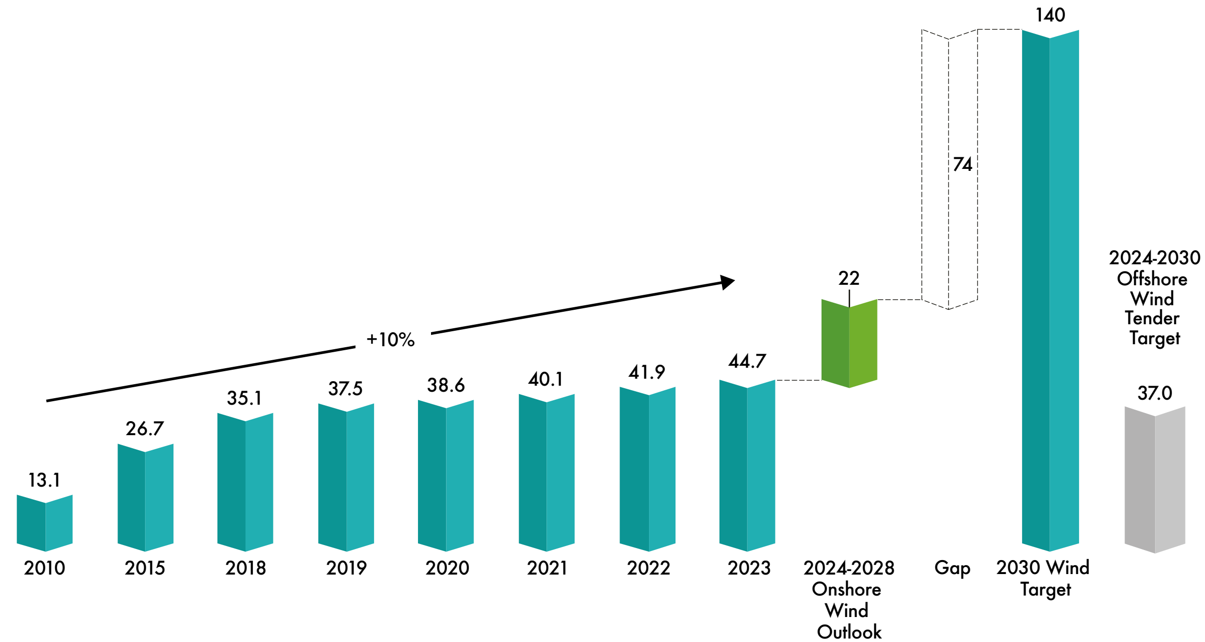
Concluded wind and hybrid tenders affirm that there is a pipeline of more than 13 GW of wind projects in India, as of September 2023. To advance the attainment of targeted volumes of annual wind and renewable auctions, the central government has provisioned administration of auctions by public sector undertakings (PSUs) such as NHPC, NTPC, Indian Railways, SJVN and PTC. State utilities have announced standalone wind, RTC, FDRE and hybrid auctions totalling 21 GW of capacity in 2023.[112]

The step-upt in wind demand will accelerate onshore wind growth, alongside other policy enablers:

- 10 GW of annual onshore wind bids targeted from 2023-2027 through single stage/e-reverse auction bidding;
- Inter-State Transmission System (ISTS) charges waiver up to June 2025;
- Wind specific renewable purchase obligations (RPOs) from 2023 to 2030;
- Announced firm and dispatchable renewable power supply tenders, as an upgraded version of the round-the-clock tender for renewable and storage projects;[113]
- Mandated minimum share of renewable energy consumption for the electricity distribution licensees (DISCOMs)[114] and the ability for consumers to purchase green electricity.[115]

111. IEA, Renewables 2023.
112. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/04/2023040359.pdf.
113. 'FDRE gives a truly viable alternative to coal, hydro and other dispatchable power-based technologies for power procurement. The key differentiator of FDRE tenders from RTC/ESS tenders, is the enhanced clarity for the project developers on the quantum, duration and PPA schedule aiding the developers in efficiently sizing the system and tariff discovery.
114. https://pib.gov.in/PressReleasePage.aspx?PRID=2004184
115. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/10/202310052144833558.pdf

Total onshore wind installations and gap to reach 2030 wind target (GW)



Source: GWEC Market Intelligence

- Improvements in the timely disbursal of payments by DISCOMs;
- Transmission planning to integrate 48 GW onshore wind capacity by 2030;
- A revised 'National Repowering & Life Extension Policy for Wind Power Projects - 2023' to facilitate repowering of wind turbines.

Despite positive policy and regulatory momentum, the current onshore wind forecast through the end of the decade still leaves a sizeable gap between wind market growth and the government's 140 GW target of installed capacity by 2030.

A few challenges continue to deter progress on onshore wind, including state-level issues for right of way, PPA sanctity and delayed payments, as well as land allocation. The industry is also experiencing increased turbine prices due to commodity price inflation and higher cost of financing.

Addressing market barriers is key to enabling offshore wind

Good progress has been made to finalise the first offshore wind seabed tender, including the publication of the revised 'Strategy Paper for Establishment of

Offshore Wind Energy Projects' showcasing three models to award 37 GW of capacity through 2030.[116] The offshore wind lease rules have been released as well, and in early February 2024, the central tender agency, SECI, announced offshore wind seabed leasing of 4 GW capacity in Tamil Nadu.

Viability gap funding (VGF) has also finally been approved for an initial 1 GW of offshore wind capacity, in addition to an ISTS waiver up to 2032. GWEC's India Offshore Wind Working Group has been proactively contributing industry inputs on offshore wind developments to authorities.

There is intense interest among PSUs to forge partnerships and JVs, for example between ONGC and NGEL, L&T and Navantia, NGEL and Gujarat Pipavav Port as well as Stiesdal and L&T for floating wind and an energy island. The Asian Development Bank (ADB) and World Bank are reportedly exploring low-cost financing for offshore wind in India too.

To achieve offshore wind installation progress, India needs to address key market barriers such as readiness of ports and grid infrastructure, availability of vessels, supply chain or import strategy, assurance for offtake, streamlined permitting and clearances, community partnership and the availability of a local skilled workforce.

Gearing up as an export hub

As the second-largest hub for onshore wind turbine assembly and key component production in the Asia Pacific, India is strategically well-placed for wind manufacturing expansion. It can benefit from a "China + 1" approach adopted by many major supply chain actors. Domestic manufacturing is sufficient to meet India's own onshore wind demand through 2030, leaving additional export and trade value ahead if India can significantly scale up manufacturing capacity.

India can make additional efforts to reduce imports of a few large components such as castings, generators and pultrusion carbon fibre. For example, in January 2024 at the Vibrant Gujarat Summit, Reliance announced that it would set up India's first carbon fibre facility at Hazira, Gujarat, for use in blade manufacturing in the wind sector.

Additionally, the successful award of offshore wind tenders is likely to attract investments in domestic offshore wind manufacturing. The attractiveness of financial and non-financial incentives offered by the central and state governments will be a determining factor in this regard.

116. https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/09/202309271030958532.pdf

Japan

In 2023, Japan achieved its second-highest wind power installations in the last decade, marking a significant milestone. With cumulative installed wind capacity of 5,213 MW from both onshore (5,026 MW) and offshore (187 MW) wind projects, Japan has solidified its position as a key player in the Asia Pacific wind landscape.

This growth momentum was bolstered by two developments: First, the results of the Round 2 offshore wind power tender announced in December 2023 played a critical role. This tender attracted major international developers, with RWE emerging as the first international developer to win a project in Japan, signalling growing confidence in the market. Second, the Japanese government's increasing focus on floating wind presents opportunities for market expansion. With intentions to expand offshore wind beyond territorial waters into its Exclusive Economic Zone (EEZ), Japan is poised for further growth.

Japan's Round 2 offshore wind tender results

No.	Sea area	Winners	Output (MW)	FiP (JYP/ kWh)	OEM	Operational date	Base port
1	Murakami-city/Tainai-city, Niigata Pref.	• Mitsui&Co., • RWE Offshore Wind • Japan, Osaka Gas	684	3	GE Haliade -X, 18 MW	June 2029	Niigata Port
2	Enoshima Saikai-city, Nagasaki Pref.	• Sumitomo Co. • TEPCO Renewables	420	22.18	Vestas V236, 15 MW	August 2029	Kitakyushu Port
3	Oga-city/Katagami-city/ Akita-city, Akita Pref.	• JERA • J Power • Itochu • Tohoku Electric Power	315	3	Vestas V236, 15 MW	June 2028	Akita Port or Noshiro Port
4	Happou-cho/Noshiro-city, Akita Pref.		To be announced in March 2024				Akita Port or Noshiro Port

Source: GWEC Market Intelligence.

Round 2 tender results boost confidence in offshore wind market

The Round 2 offshore wind auction results announced in December 2023 marked another significant milestone for the Japanese wind energy market, injecting a shot of optimism for international developers. This auction, the first conducted under the Feed-in Premium (FIP) scheme, saw three out of four projects successful awarded. All three successful bids are bottom-fixed offshore wind projects scheduled to start operation by August 2029 and with a total capacity of 1,419 MW.[117]

The auction was a historic win for a consortium led by Mitsui & Co, German energy giant RWE and Osaka Gas, securing a 684 MW wind farm off the coast of Niigata prefecture. This marked the first successful bid by an international developer in the Japanese offshore wind sector and was followed by RWE's announcement of further planned expansion in Japan.

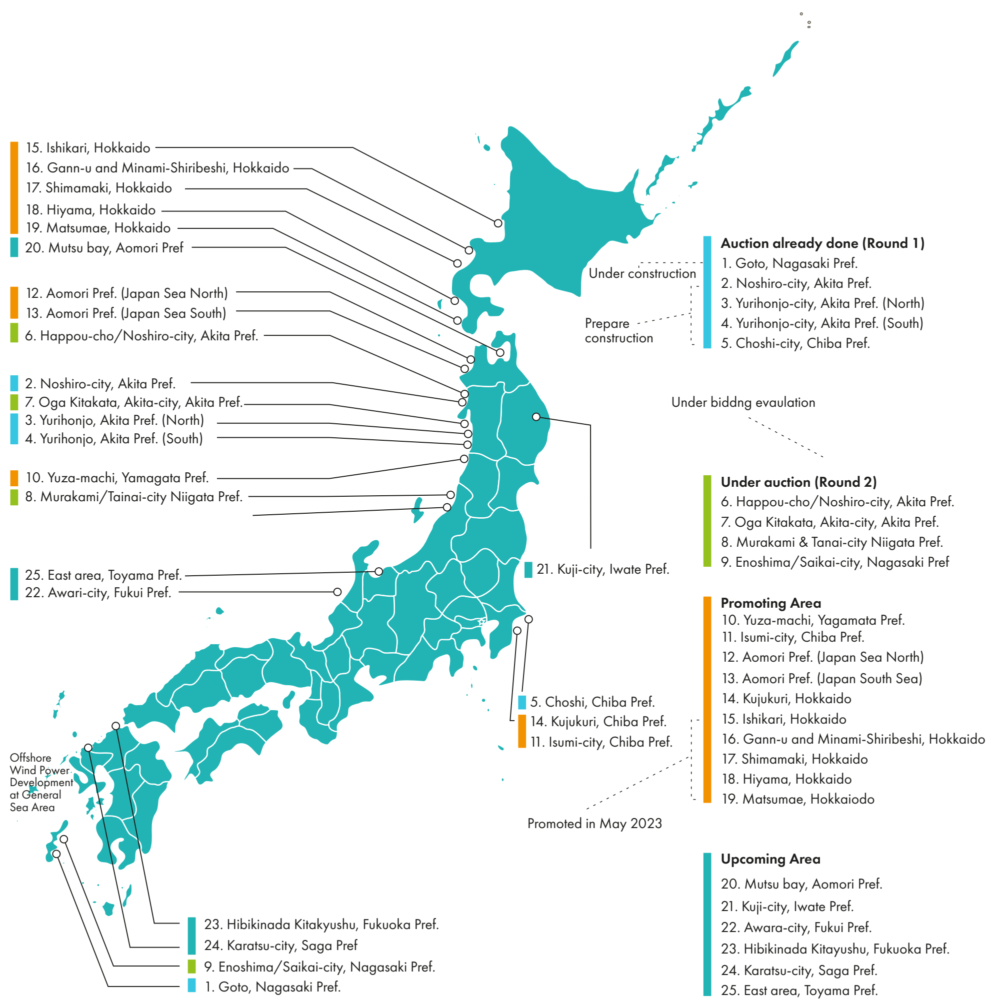
The tender results revealed highly competitive price bids, with two out of the three winning bids at "zero-premium level" of 3 yen/kWh. It is likely that these projects will need to secure revenue from corporate offtakers. While this indicates increasing financial viability without relying solely on government subsidies, it is important to acknowledge that the low FIP amount presents a challenge for many players and may jeopardise long-term project sustainability and profitability. This can in turn hamper innovation and broader value creation for offshore wind projects.

The Round 3 tender guidelines were announced in November 2023, and are expected to feature an even lower FIP. The tender focuses on the designated promotion zones in Aomori Prefecture South (600 MW) and Yuza Town Yamagata prefectures (450 MW).

Venturing beyond territorial waters

Currently, offshore wind development in Japan primarily takes place within its territorial waters, which extend up to 12 nautical miles from the coast and cover approximately 430,000 square kilometres. However, Japan's EEZ,

Japan Offshore Wind Development Areas within Territorial Waters



Source: Japan Wind Power Association, 2024.

117. The winner of the remaining 356 MW farm off the coast of Happo-Noshiro in Akita prefecture will be announced in March 2024, as revisions to the plan are needed due to overlapping use for port facilities by another Akita project.

spanning a significant 4.47 million square kilometres – the sixth largest in the world – offers vastly more space for both bottom-fixed and floating wind farm development.

The government has recently concluded that constructing wind power facilities within the EEZ is technically feasible, provided they are backed by appropriate domestic legal frameworks. This positive assessment paves the way for the government's planned framework for responsible and sustainable wind energy development in the EEZ.

Regulatory clarity and a clear development roadmap will be necessary to ensure the effective and swift deployment of offshore wind projects. The proposed legislation or a legal revision is expected to move forward around the same time as the country's marine strategy update in May 2024.

Accelerating commercial-scale floating wind

In October 2023, the government announced four candidate areas for demonstration floating wind projects (Phase 2) with approximately 30 MW per location, supported by the Green Innovation Fund (GIF). About JPY 150 trillion ($1 trillion) of public and private investment is targeted for industries including automotive, storage batteries and renewable energy.[118]

However, the broader green investment policy currently lacks alignment with the overall carbon neutrality goal, as funding is also being allocated towards technologies which are debatable in terms of long-term decarbonisation potential such as ammonia co-firing with coal and LNG-fired power generation. With current MW-scale floating wind projects, the industry has continued to advocate for bigger floating wind projects to ensure cost-effectiveness and competitiveness.

As the government continues to move forward with its plans, Japan's wind energy market is poised for continued growth and innovation, further contributing to the country's clean energy ambitions.

118. https://www.reuters.com/markets/carbon/japan-needs-invest-12-trln-decarbonisation-over-10-yrs-industry-ministry-2022-05-13/

Kenya

Kenya has become a renewable energy champion for the African continent, under the leadership of President Ruto and with flagship platforms like the inaugural Africa Climate Summit hosted in Nairobi in September 2023. It was at this summit that African Heads of State and governments agreed on the Nairobi Declaration on Climate Change and Call to Action. This Declaration called upon the international community to contribute to increasing Africa's renewable generation capacity more than five-fold, from 56 GW in 2022 to at least 300 GW by 2030.

Wind power is expected to play a significant role in supporting the renewable energy goals of the Nairobi Declaration, and is already a major source of generation in Kenya.

Market status

Wind energy in Kenya accounts for more than 12% of the installed power generation capacity in Kenya (grid and captive), as of June 2023. In terms of generation, wind power provides around 17% of Kenya's electricity, a 7% increase from the previous year, making it the third most important source of generation behind geothermal and hydropower.

The 310 MW Lake Turkana project alone is the largest plant of any technology on the grid, as well as the largest wind farm in Africa, providing nearly 13% of the electricity generated in Kenya. The other wind farms in the country are the 25.5 MW Ngong Wind and 100 MW Kipeto Wind projects.

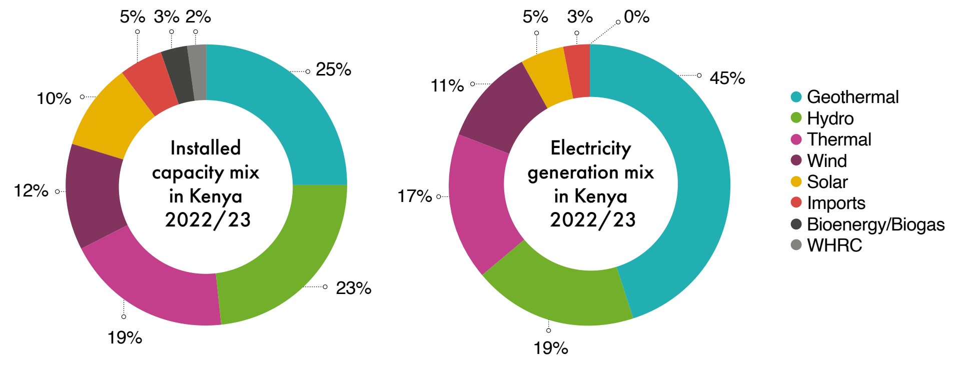
There have been changes in the ownership structures of the two private wind farms with Biotherm renewables, owner of the Kipeto wind farm and itself owned by Actis, being purchased by a consortium of Engie and Meridiam. The Lake Turkana wind farm has also seen the entry of Milele Energy and Blackrock Group, with the exit of Finfund, Norfund, IFU, Vestas and other shareholders.

A promising outlook for wind power

There have been announcements of new large-scale wind projects ahead, although the next projects are not due for commissioning until 2026. State generator KenGen announced plans to build a 1 GW wind park in Marsabit County with an initial capacity of 200 MW. This area is close to the Lake Turkana project, with a similar high capacity factor expected. Independent power producers (IPPs) are expected to add an additional 150 MW by 2027. Plans are also underway for the expansion of the Kipeto and Lake Turkana Power projects.

However, the plans for new-build and expanded projects will be limited by the securing of offtake and the availability of sufficient transmission capacity and capabilities.

Kenya's installed capacity and generation mix, as of June 2023



Source: Electricity Sector Association of Kenya (ESAK)

> Wind power is expected to play a significant role in supporting the renewable energy goals of the Nairobi Declaration.

There are developers working on wind projects targeted at distant loads via the transmission system. The Energy and Petroleum Regulatory Authority is aiming to introduce regulations for wheeling of electricity in the Kenyan grid. These are expected to spur the captive wind industry, where several projects are being

planned to supply Power-to-X initiatives and directly supply large industries.

With around 22% of installed capacity coming from VRE in Kenya, for wind power to continue expanding there is a need to support the grid in ensuring stability and providing related ancillary services. This has been procured from legacy hydroelectric plants and thermal plants to date, though there is a push to install battery energy storage systems (BESS) to supply ancillary services. KenGen has been appointed as the implementing agency of the Kenya Green and Resilient Expansion of Energy (GREEN) programme, which will see the generator build grid-scale battery storage by 2026.

The Philippines

As one of the countries most vulnerable to the adverse impacts of climate change, the Philippines has continuously affirmed its dedication to energy security, self-sufficiency and the acceleration of investments in renewable energy.

To underscore this, the Philippine Energy Plan (PEP) aims for a 35% share of renewables in the power mix by 2030 and 50% by 2040. The latest iteration of the PEP includes scenarios for offshore wind that project a low-growth scenario of 19 GW and a high-growth scenario of 50 GW by 2050. These projections emphasise the expected impact of offshore wind in addressing the escalating energy demand of the Philippines while supporting renewable energy and socioeconomic goals.

Market status: Onshore and offshore wind

The Department of Energy (DOE) has already approved 85.6 GW of wind service contracts as of December 2023, 63 GW of which are for offshore wind. Total onshore wind capacity stands at 443 MW, though recent auctions committed around 1.7 GW of new onshore projects through 2026.

The Philippines has been exploring offshore wind potential since 2020, although progress in this area has been slower compared to other renewable energy sources. Despite strong technical potential, there are hurdles in regulation, seabed lease acquisition, grid connection, ports and supply chains. Additionally, environmental impact assessments and community engagement are critical considerations for wind energy projects in the Philippines.

The DOE, supported by the executive branch, has established specific frameworks and action plans to drive offshore wind development. In 2022, the Marcos

Priority workstreams underway to boost offshore wind development:	
Permitting and Marine Spatial Planning	With funding from the Energy Transition Partnership (ETP), the DOE has commenced with two important projects that will 1) produce a marine spatial planning (MSP) tool to identify and map constraints in sea areas for offshore wind; and 2) develop a streamlined permitting process for offshore wind developers.
Infrastructure	The DOE, National Grid Corporation of the Philippines (NGCP) and Philippines Ports Authority (PPA) are addressing port and transmission challenges, supported by the ADB. An ongoing assessment is evaluating 10 existing ports for expansion and upgrade to support offshore wind construction. Massive upgrades to the grid are also essential to accommodate capacities from renewable energy projects. Initiatives such as the Smart and Green Grid System (SGSS) aim to develop a parallel grid capable of handling significant VRE capacities, notably offshore wind. These infrastructure developments are exploring Public-Private Partnership (PPP) arrangements to expedite investments
Supply Chain and workforce	In 2024, GWEC is undertaking a study on offshore wind supply chain readiness in the Philippines, which will aid industry and policymakers in identifying strategic investment opportunities to scale up manufacturing and workforce.
The Department of Environment and Natural Resources (DENR) Environmental Compliance Certificate (ECC) Guidelines	In February 2024, DENR released the latest guidelines for offshore wind developers to secure ECCs. Developers are now required to apply for an interim ECC for the pre-development stage and then the enhanced ECC for the actual development phase. The interim ECC covers a checklist of requirements specific to resource assessment, geotechnical studies and environmental baseline surveys.

Market development mechanisms for renewables in the Philippines

Renewable Energy Market (REM)
Established by the DOE to facilitate the compliance of the Mandated Participants with the RPS On-Grid Rules

Enhance Net Metering
Allows end-users to generate electricity from RE-based systems up to 100kW for own use and sell their excess to the grid

Green Energy Auction Program (GEAP)
Competitive electronic bidding of RE capacities

GEA-1 (17 June 2022)

RE Resource	Awarded Capacity (MW)
Solar	1,490.38
Biomass	3.4
Wind	273.20
Hydro	99.15
Total	1,866.13

GEA-2 (3 July 2023)

RE Resource	Awarded Capacity (MW)
Solar-Ground	1,878.982
Solar-Floating	9.390
Biomass	90.000
Wind (onshore)	1,462.384
Total	3,440.756

GEA —3 will invile Geothermal, Impounding Hydro, Pumped-Storage Hydro and Run-of-River Hydro

Green Energy Option Program (GEOP)
Provides end-users the option to choose RE resources as their source of energy

Preferential Dispatch
RE preference in wholesale electricity spot market dispatch

Must dispatch
Solar, Wind, ROR Hydro (FIT or Non FIT)

Priority Dispatch
Biomass, Geothermal or impounding Hydro

Renewable Portfolio Standards (RPS) for On-Grid Areas and Off-Grid Areas

On-Grid
Mandates load-serving entities to source a minimum percentage of RE in their respective power supply portfolios

2.52% starting 2023

Off-Grid
The minimum RE requirement is based on the optimal power supply mix an off-grid area

Source: DOE 2023 Energy Investment Forum, Energy Sector Updates and Investment Opportunities

administration removed foreign ownership restrictions, enabling 100% foreign-owned companies to invest in renewable energy development. Subsequently, Executive Order 21 was issued, streamlining the permitting process through a whole-of-government approach. This policy framework empowers the DOE to enhance permitting efficiency by integrating all permits into the Energy Virtual One-Stop Shop (EVOSS) platform. The DOE has since released implementing guidelines delineating OSW development stages and permitting requirements.

In February 2024, the DOE published a draft Omnibus Guideline detailing governance and administration procedures for offshore wind contract awards, including a provision for a maximum five-year Certificate of Authority period for developers to secure permits and conduct pre-feasibility studies.

Considerations for future offshore wind offtake

Sustaining momentum in the wind

sector hinges on a robust offtake regime. The Green Energy Auctions Program (GEAP) serves as the primary offtake mechanism for onshore wind, offering a transparent pipeline and tariff structure. The inaugural auctions in 2022 secured approximately 2 GW of renewable energy capacity, with delivery commitments spanning 2024 to 2025. Notably, 374 MW was allocated to onshore wind at a ceiling rate of PHP 6.0584/kWh ($0.11/kWh).

The second round, concluded in July 2023, saw 3.581 GW of committed capacity, with deliveries scheduled from 2024 to 2026. This round, however, was undersubscribed with only one-third of allocations awarded; 3.5 GW of onshore wind was targeted, but only 1.46 GW of bids were successful, due in part to a lower ceiling tariff of PHP 5.8481/kWh ($0.10/kWh).

Developers were reluctant to participate in the last auction round due to tight timelines, low tariffs, stringent performance bonds and grid constraints, according to a GWEC survey.

As a new sector in the Philippines, offshore wind will require a stable revenue outlook to attract investment. The DOE expects 6 GW of offshore wind capacity to be commissioned by 2030. Collaboration between the DOE and NGCP is crucial to identify suitable substation connection points – future offtake designs should consider a location-specific capacity approach.

Another key consideration is balancing competition with fair and sustainable remuneration for developers. Comprehensive cost mapping, incorporating input from stakeholders and financial institutions, is vital for project viability.

Lowering performance bond requirements and mandating technical studies can alleviate financial burdens, allowing focus on project de-risking. Tariffs should also be indexed to maintain financial viability over the contract term.

Despite the challenges ahead, there is optimism about wind energy development in the Philippines. With continued government support, favourable technical resource, technological advancements and strengthening market conditions, the sector is poised for growth.

Saudi Arabia

The Kingdom of Saudi Arabia (KSA), the world's second-largest oil producer, is on an ambitious path to diversify its economy and energy mix. This path is part of the KSA's effort to become a regional hub for the energy transition, leading in investment and innovation in particular.

Growth prospects for wind energy in KSA are strong, driven by the increasing energy demand associated with its growing population and energy-intensive water desalination programme. By 2040, Saudi Arabia is expected to desalinate around 30 billion m^3 of water daily.[119] Additionally, wind energy is poised to support the country's new large-scale infrastructure projects such as NEOM.

In 2016, the government launched Saudi Vision 2030, a national plan to diversify its economy and reduce dependence on oil. Renewable energy, with wind playing a leading role, is a central pillar of this strategy. Recognising the environmental concerns associated with fossil fuels and the potential for cost-competitive wind technology, the government has set ambitious renewable energy targets.

Today, Saudi Arabia's energy mix consists of <1% renewable energy, around two-thirds oil and around one-third gas. By 2040, the country aims to generate half of its energy supply from renewable energy and reach net zero by 2060. In 2021 it was estimated that the Ministry of Energy's spending on power and renewable energy projects would reach $293 billion by 2030, which is now expected to increase as KSA has since doubled its renewable energy targets.

From nodding-donkeys to nacelles

With wind speeds ranging from 6-8 m/s, Saudi Arabia's onshore wind potential is estimated at around 200 GW across 7 different regions.[120] In addition, the technical offshore wind potential off Saudi Arabia's coasts is estimated to be up to 28 GW for conventional fixed-bottom installations and 78GW for floating offshore wind installations.[121]

In 2016, Saudi Arabia's wind energy industry was practically non-existent. Today, the country operates a 400 MW wind farm and plans to reach 3.17 GW of installed capacity within 3 years.[122]

The 400 MW Dumat al Jandal is Saudi Arabia's first utility-scale wind energy project, recently reaching its commercial operation date (COD). Located in the Al Jouf region, it is owned by EDF (51%) and Masdar (49%) and consists of 99 4.2 MW Vestas turbines. This flagship project also boasts one of the lowest wind energy tariffs in the region, reportedly $19.9/MWh.

Dumat al Jandal is set to be the first of many utility-scale wind farms in Saudi Arabia. The National Renewable Energy Program (NREP) launched the Round 4 tender for three wind energy projects – Yanbu (700 MW), Al Ghat (600 MW) and Waad al Shamal (500 MW). In 2022, the Saudi Power Procurement Company (SPPC) shortlisted 18 companies, including major energy players such as Masdar,

112. GWI, Global Water Market 2017, 2016.
120. Allhibi, Chowdhury, Zaid, Loganathan and Alam, Prospect of wind energy utilization in Saudi Arabia: A review, Energy Procedia, 2019; https://www.acwapower.com/news/saudi-arabia-is-unlocking-the-potential-of-wind-energy/.
121. https://gwec.net/wp-content/uploads/2021/06/Saudi-Arabia_Offshore-Wind-Technical-Potential_GWEC-OREAC.pdf.
122. https://masdar.ae/en/renewables/our-projects/dumat-al-jandal; https://www.saudigulfprojects.com/2022/12/saudi-arabia-announces-pre-qualified-bidders-for-3-3gw-round-4-renewable-energy-projects/.

Sumitomo, and Marubeni. A few large Saudi Arabian developers, such as ACWA Power and Alfanar, have also been shortlisted. Projects are expected to reach operations by 2026.

NEOM, the futuristic smart city, is at the forefront of the renewable energy push in Saudi Arabia. NEOM is developing a 2.2 GW green hydrogen project in Tabuk, northwest Saudi Arabia, using a combination of wind, solar and storage to cater to the project's energy needs. The Neom Green Hydrogen Company (NGHC) is a joint venture between NEOM, ACWA Power and Air Products. The project's 1.37 GW wind farm is currently in its construction phase and expected to be fully operational by 2026, with the first batch of Envision turbines delivered at the port of NEOM in October 2023.

While Saudi Arabia boasts strong wind resources and optimistic renewable energy goals, the country faces several obstacles in realising its wind energy potential. Its grid system will need to adapt to a higher share of VRE, and the country's infrastructure for wind farms is still in its early stages, demanding specialised expertise and significant network development. There are also environmental impact challenges to mitigate, including the potential impact of wind farms on bird migration and local wildlife.

The growth outlook for wind

In December 2023, the KSA government announced a target of 20 GW renewable energy capacity additions annually up to 2030, as part of achieving 130 GW or 50% renewable generation by 2030. According to the Ministry of Energy, there are 1,200 sites identified in various regions for pre-development preparation in the country to further initiate solar and wind projects.

The next 3-4 years will be critical for evaluating Saudi Arabia's success in diversifying its energy production and investing in renewable energy industries such as solar and wind. Renewable targets need to be coupled with sound national policies that facilitate the extensive roll-out of renewables and provide a conducive environment for further investments. If Saudi Arabia's model is successful, it will set a precedent in the Middle East for other oil-dependent countries to follow.

South Korea

South Korea has demonstrated a strong interest in leveraging its renewable energy potential to contribute to its energy transition. Its 57 coal-fired plants are a major source of air pollution, and its heavy dependence on fossil fuel imports and energy price volatility strengthens the country's need to step up its clean energy pursuit.

Since 2017, the South Korean government has introduced several key initiatives to reduce energy generated from coal and support the growth of renewable energy. The Carbon Neutrality Act in 2021 locked in South Korea's commitment to achieve net zero by 2050. To realise this, over 60% of total power generation must be sourced from renewables.

Under the 10th Basic Plan for Power Distribution published in 2023, the Ministry of Trade, Industry and Energy (MOTIE) announced a target of 21.6% of renewable energy in South Korea's total energy mix by 2030, and 14.3 GW of installed offshore wind capacity. At the same time, the current administration under President Yoon Suk Yeol's position on a "feasible and balanced power mix" has also revived nuclear power to achieve carbon neutrality.

Offshore wind market status

South Korea boasts an abundant 624 GW of technical potential for fixed-bottom and floating offshore wind, largely concentrated in the West, Southwest, South and Southeast regions, as well as on Jeju Island.

Current operational capacity stands at 133 MW, or just 1% of its 2030 installation target, suggesting urgency to speed up the development and construction timelines. Significant challenges related to the permitting legislative framework, local consensus, grid connectivity and infrastructure are hindering the efficient deployment of offshore wind. Wider supply chain challenges and increasing costs could also lead to delays.

Permitting challenges and the "One-Stop Shop Bill"

The key regulatory frameworks governing the renewable energy sector in South Korea include the "Electricity Business Act" and the "Act on the Promotion of the Development, Use and Diffusion of New and Renewable Energy". The permitting process is complex and lacks transparency, with project owners being required to navigate through 29 different laws from 10 different government ministries and authorities with little criteria guidance.

Although a Marine Spatial Plan has been in place since 2020, the areas allocated to energy development are limited, and it remains up to the project owners to select sites viable for project development. However, site exclusivity granted by the authorities through a Public Water Permit will only occur once the project receives an Electricity Business License (EBL).

As authorities assess the level of local consensus garnered, significant delays have been attributed to opposition from local communities and the fishing industry. As of December 2023, 22.6 GW of EBLs had been issued, out of which only 203 MW of projects have reached a final investment decision, demonstrating the severity of this roadblock.

The Offshore Wind Power Promotion Act, more commonly referred to as "OSS Bill", has had three iterations proposed by representatives from both main political parties seeking to streamline the permitting process and introduce government-led site selection. While it is clear that MOTIE recognises the need for reform, the bill has not yet passed.

A 'two-track system' is likely to be implemented, given the bulk of projects that will contribute to the 2030 target will be developer-led. However, the government has not ruled out disqualifying licenses for projects that are assessed as inadequate for development, for example for projects that have not gained local consensus.

Current procurement schemes

The renewable portfolio system (RPS) replaced South Korea's FIT in 2012, mandating power generating facilities with installed capacity over 500 MW derive a minimum proportion of their power through renewable sources. Renewable energy suppliers obtain renewable energy certificates (RECs) in MWh units, the value of which differentiates between offshore and onshore wind.

RECs are purchased by generators according to their mandated RPS quota; additional RECs can be traded on the spot market. The spot price of RECs has risen by nearly 50% from 2022 to 2023, prompting MOTIE to announce plans to stabilise the REC market in 2024.

In December 2023, the second round of tendering by KEPCO for fixed-price contracts for onshore and offshore wind concluded. Four successful offshore project bidders with a cumulative 1.5 GW capacity are expected to enter into a REC sale and purchase agreement with the RPS obligator within 36 months. There was an emphasis on price highlighted in the evaluation criteria (60 out of 100 points), and ambiguity remains on the non-price factors worth 40 points.

Continuing wind power momentum

Excessive focus on reducing costs and the lack of strategic support for supply chains in qualifying for subsidies may have longer-term implications for South Korea's supply chains. In addition to realising wind power potential, the country needs strategic industrial planning and incentive-based approaches to facilitate an industrial transformation that serves the growing needs of the renewable energy sector.

This should ultimately include strategic support for supply chain networks, as well as the upgrade of grid and port infrastructure to make them suitable for the large volumes of onshore and especially offshore wind in development.

Increasing awareness of the economic benefits associated with the deployment of wind energy and stronger inter-ministerial and bipartisan collaboration would also unlock challenges associated with gaining local consensus for projects and keep existing projects on-track.

A 'two-track system' is likely to be implemented, given the bulk of projects that will contribute to the 2030 target will be developer-led.

The US

The historic Inflation Reduction Act (IRA) package has propelled the US to the forefront of the energy transition, creating a ripple effect throughout the world, impacting supply chains and the renewable energy investment landscape. Domestically, the IRA is transforming the American energy system, from grid modernisation to highlighting the need for permitting reform and transmission expansion.

While it is clear the IRA – and its significant investment incentives – cannot be replicated by most countries in the world, its present and future achievements serve as real-time case studies for the socio-economic benefits of deploying more clean energy. Tracking its progress and its pitfalls, including what effect a potential Trump presidency would have, is an essential exercise when analysing the future of the wind industry.

Taking stock of IRA-related progress

Due to the IRA, power market consultants such as BloombergNEF, S&P Global and Wood Mackenzie now expect 408 GW of utility wind, solar and storage to be built in the US over the next 7 years, compared to the expected 390 GW in February 2023. Breaking this figure down, onshore wind represents 23% of the market, growing from 7.5 GW in 2024 to 16 GW in 2030 and offshore wind expectations are approximately 14 GW by 2030.

Utility-scale solar accounts for 53% of the forecast, from 25 GW in 2024 to 36 GW in 2030, while the energy storage market, in which standalone storage can now claim the Investment Tax Credit (ITC), expects to add 81 GW by 2030, capturing 20% of the market.

One the primary objectives of the IRA is to develop domestic renewable energy supply chains. To date, 123 new manufacturing facilities or facility expansions have been announced since the passage of the legislation.[123] This includes 12 onshore wind power manufacturing facilities, 9 offshore wind facilities, along with 78 solar facilities, 20 grid-scale battery storage facilities or facility expansions and 4 grid connection facilities. From this total, 44 facilities have either completed or are currently under construction. Once all in operation, these 120+ facilities will support nearly 42,000 new manufacturing jobs.[124]

Focusing on the US' domestic wind market shows the IRA is building on a solid foundation. At present, there are 16 active primary (blades, towers, nacelles) wind manufacturing plants located across 12 states. Moreover, there are over 450 wind-related manufacturing facilities in the US supporting more than 20,000 manufacturing jobs.

GE Vernova, Siemens Gamesa and Vestas have a combined capacity to assemble approximately 15 GW annually. This is 15% higher than the previous year, primarily due to GE Vernova's newly inaugurated nacelle manufacturing facility in Schenectady, New York, from where the company's largest onshore turbine will be rolled out for the US onshore wind market.

The US still depends on specific imports to meet domestic demand, trading primarily in the wind sector with Mexico, Germany, India, Spain and Denmark. In 2023, the US onshore wind industry imported $1.5 billion of wind equipment across five product areas: blades and hubs, generation parts, generation sets, nacelles and towers. It is worth noting that blades and hubs hold the dominant share with over $900 million imported in 2023. However, imports fell 34% in 2022 and a further 26% in 2023 – marking the lowest levels of import volumes in the past 10 years as local capabilities have expanded.

Addressing the IRA's key growth enablers

While the IRA injects optimism into the future wind outlook, 2023 saw a decrease in installation growth marking the lowest level since 2014. The US installed 6.4 GW of wind in 2023, just less than half the volume it had installed two years earlier in 2021.

Cumulative operating onshore wind power has now reached above the 150 GW mark, but wind installations are experiencing a slowdown due to market saturation in certain areas, and permitting and development delays in others.

Recent reports and analysis from American universities and media outlets show rising local opposition to renewable energy projects. According to analysis from USA Today, at least 15% of all counties in the country have effectively halted new utility-scale wind, solar or both.[125] These blocks come as the result of outright bans, moratoriums, construction impediments and other conditions standing in the way of renewables projects, posing a significant barrier to the federal government target to achieve 100% renewable energy by 2035.

Despite financial headwinds, a resilient offshore wind market

Offshore wind is an essential technology for the country's clean energy future due to its scale and high-capacity factors. In 2023, several US offshore wind projects under development encountered financial difficulties due to inflation, supply chain constraints, interest rate increases and other macroeconomic factors.

Many projects had locked in contract prices prior to the pandemic, the unprecedented inflation that followed it and the higher cost of commodities. Furthermore, the first generation of offshore wind energy contracts did not include inflation adjustment factors, despite being 20- to 25-year contracts. This combination of factors, plus permitting delays, created serious economic issues for contracted projects that had not yet reached construction.

Despite a tumultuous year for the American offshore wind market, the outlook is still positive. The next tranche of offshore wind contracts will be able respond to today's economic landscape by including inflation adjusters and taking a regional approach to procurement,

123. According to American Clean Power.
124. https://cleanpower.org/investing-in-america/.
125. https://eu.usatoday.com/story/news/investigations/2024/02/04/us-counties-ban-renewable-energy-plants/71841063007/.

as pioneered by the states of Massachusetts, Connecticut and Rhode Island.

The Biden administration has a goal of approving 16 Construction and Operation Plans (COPs) by 2025. As of February 2024, six COPs have been approved. To achieve current market projections of 42.3 GW of offshore wind energy by 2035, 12 COPs need to be approved by the end of 2024.

New York awarded 4 GW of offshore wind offtake in October 2023 and announced in February 2024 the selection of two 'shovel-ready' re-bid projects in the fourth offshore wind solicitation, sending a positive signal to the industry that a recalibration of expectations between public and private sector has been achieved.

New Jersey awarded 3.7 GW in January 2024 and has upcoming solicitations this year. Massachusetts, Connecticut and Rhode Island will award capacity for a joint solicitation in August 2024. Maryland has a solicitation in July 2024. Maine, California, Carolina and Louisiana solicitations have yet to be scheduled.

Investing in a modernised, resilient, renewables-based grid

The electricity grid in the US is more than a century old and in need of modernisation. Many of the cables, towers, substations and other components are 50-70 years old and past their useful lives. These outdated and stressed systems have left the grid vulnerable to blackouts during increasingly common extreme weather events such as drought, extended heatwaves, wildfires and extreme cold conditions.

Progress is being made on grid buildout and modernisation in parallel to the significant pipeline of renewables projects. There are at least 22 high-voltage transmission projects in development across the country, such as the Gateway project that will transport electricity from wind energy from Wyoming to Southern California and the Pacific Northwest. The Grain Belt Express project, which was recently awarded 'FAST 41' status by the Federal Permitting Improvement Steering Council, will deliver renewable energy generated in Kansas to neighbouring power pools.

In yet another example, the Federal Energy Regulatory Commission (FERC) recently granted Mid-Atlantic Offshore Development's (MAOD's) petition seeking transmission rate incentives for its 230-kV substation and adjacent land required to interconnect up to four HVDC converter stations. This $193 million transmission project is meant to connect offshore wind with an onshore substation in the Pennsylvania-New Jersey-Maryland interconnection.

Reconciling progress with pitfalls

The world's most significant piece of climate legislation in recent years was never going to have an easy road for implementation, but early indicators are positive. The response to the investment signal sent by the IRA has been strong, spurring record investment into wind and renewable energy projects and factories as well as grid infrastructure.

The biggest single challenge remains winning over the hearts and minds of the American public, and disentangling an evidence, science and economics-based energy transition from culture wars and identity politics. The coming year, including the election period ahead, will be a true test of the strength of the IRA, and the resilience of the American energy transition.

Vietnam

Following a difficult year for wind in 2022 in Vietnam, 2023 showed some positive developments.

Early in 2023, Vietnam issued a new price ceiling for "transitional projects" (projects which have a PPA but missed the October 2021 FIT deadline), which resulted in 822 MW of onshore and intertidal projects being commissioned by year-end. While the tariff is considered too low by most developers, their choices were few (some cash flow versus no cash flow).

The government also issued the long-awaited Power Development Plan VIII (PDP 8) in May. The PDP 8 sets the energy strategy for the country for the period of 2021-2030 with a vision to 2050. It includes a target for onshore wind of 21.8 GW by 2030, up from the roughly 5 GW of installed capacity by end of 2023. The target for offshore wind is 6 GW by 2030 (with no installations currently), rapidly increasing thereafter to 91 GW by 2050.

These ambitious targets for wind energy reflect the commitment of Vietnam to transition to net zero by 2050, a pledge made by the Prime Minister at COP26 in 2021. The next step is to have a PDP 8 Implementation Plan and detailed regulatory framework to turn these targets into reality.

Market status: Onshore and intertidal wind

In addition to the roughly 5 GW of onshore and intertidal projects installed by end of 2023, there is another 3 GW of transitional projects in the process of PPA negotiation with Vietnam Electricity (EVN). The Ministry of Industry and Trade (MOIT) issued the price ceiling for these projects (about 20-25% lower than the previous FIT prices) and each project must renegotiate a new PPA with EVN.

The terms of the new PPA are viewed as less favourable for developers. For example, MOIT only allows projects that have all necessary permits to dispatch during the negotiation process and they will enjoy a tariff of only 50% of the ceiling price in this period. The difference between the 50% tariff and the final tariff will be paid once the negotiations are finished.

The government needs to issue new policy and legal frameworks before any new onshore and intertidal wind projects can be constructed. The PDP 8 Implementation Plan is being drafted by MOIT and the government aims to approve it within the first half of 2024. New wind projects must also enter into a PPA negotiation process with EVN to determine the price – a process which will remain until MOIT issues a new auction mechanism for wind projects in the coming years.

Market status: Offshore wind

Vietnam does not have any real offshore wind projects, only intertidal projects located near to the shore. The 2030 target for offshore wind in PDP 8 is very ambitious, divided by region: 2,500 MW in the North, 500 MW in Centre, 2,500MW in South Central and 1,000 MW in the South.

In addition, the PDP 8 also has a target for offshore wind projects for export. While there isn't a specific volume designated for offshore wind, the total electricity export capacity for renewable energy is estimated to range between 5-10 GW by 2030. One project has already been identified and received a site survey license: PTSC & Sembcorp, linked to the governments of Vietnam and Singapore, respectively, was approved as a special case by the Prime Minister.

The regulatory framework for offshore wind in Vietnam is under-developed. Coupled with the typical development and construction timeline of 6-8 years for offshore wind projects, achieving the connection of the first generation of offshore wind by 2030 will be challenging.

The development of the new legal and regulatory frameworks is time-consuming, and potentially new law(s) are needed, which in Vietnam typically takes 2-3 years. Many of the new regulations also cross multiple ministries and government departments. Recognising these hurdles, GWEC has been advocating for the establishment of an inter-ministerial task to accelerate the process – a measure which the government initiated in late 2023.

GWEC has proposed a type of fast-track or pilot mechanism to be applied for the first offshore wind projects. The government has signalled that it is open to a pilot scheme, but what shape this will take is still unclear.

Challenges with grid management

Vietnam is a relatively fast-growing economy with rising electricity demand. The government has been struggling to keep up with power demand and in the period of May-June 2023 in the northern region of Vietnam there were blackouts. According to the World Bank, these blackouts caused manufacturing companies to lose approximately $1.4 billion, or 0.3% of the country's GDP.[126]

The main reasons for the blackouts were hydropower plant operational issues due to El Niño causing low rainfall, as well as large thermal projects down for maintenance. In addition, while there was more than 20 GW of new wind and solar projects built from 2018-2023, MOIT highlighted that most renewable energy projects are concentrated in the central and southern regions. Furthermore, the capacity of the grid system is not sufficient to transmit the energy from south to north when needed.

The government has recognised these problems and has made a strong commitment to ensuring sufficient electricity supply in the northern region in 2024. Policies now include reserving water in the hydro dams, and preparing fuel and maintenance plans for the thermal power plants. The government also started the construction of a $1 billion, 519-km 500 kV grid line to connect the south with the north, due to be finished in June 2024.

The entire grid needs significant upgrades to be able to absorb new wind, solar and other projects. As such, grid investment of approximately $3 billion annually until 2030 was identified in PDP 8.

COP28 and the Just Energy Transition Partnership

At COP28 in Dubai, the Prime Minister of Vietnam issued the Resource Mobilization Plan (RMP) for Vietnam's JETP, which includes offshore wind as a focus area. The RMP lays out the strategy to deploy the $15.5 billion committed by the International Partners Group (IPG) to support Vietnam in its energy transition journey, half of which will be mobilised among private investors.

Vietnam was also one of the 132 countries to sign up to the sideline pledge to triple global renewable energy capacity by 2030. GWEC is working closely with the international community to support Vietnam in its achieving its goals, including the country's journey to net zero by 2050.

126. World Bank, Taking Stock: Making Public Investment Work for Growth, 2023.

MARKET STATUS

Overview

116.6 GW of new wind power capacity was added to the power grid worldwide in 2023, 50% more than in 2022, bringing total installed wind capacity to 1,021 GW, a growth of 13% compared with last year.

New installations in the onshore wind market passed the milestone of 100 GW while new offshore wind capacity commissioned last year reached nearly 11 GW, making 2023 the highest and the second-highest year in history for new wind installations for onshore and offshore, respectively.

Thanks to the strong rebound of new installations in China and India, Asia Pacific consolidated its position as the world's largest wind market last year with 71% global market share, experiencing a 15% YoY growth compared with 2022.

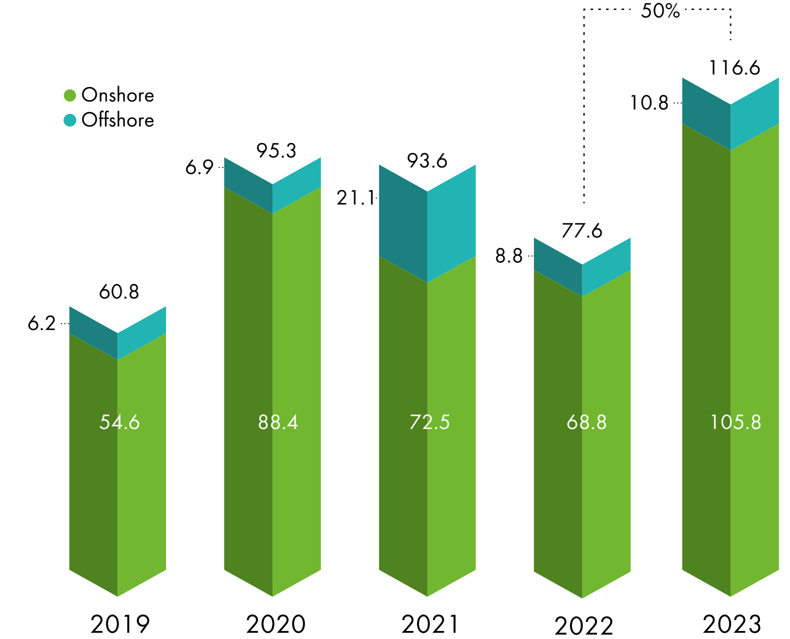
As the second-largest market, Europe commissioned 18.3 GW of new wind power capacity, of which 16.2 GW in the EU-27, representing a record amount for the bloc. However, Europe's global market share declined by 9% YoY in 2023.

Despite North America retaining third place, its market share decreased by five percentage points due to onshore wind installations in the US dropping to their lowest level since 2014. Brazil had a record year in 2023 and Latin America remained the fourth-largest market with a 5% global market share in 2023, followed by Africa & Middle East (0.9%).

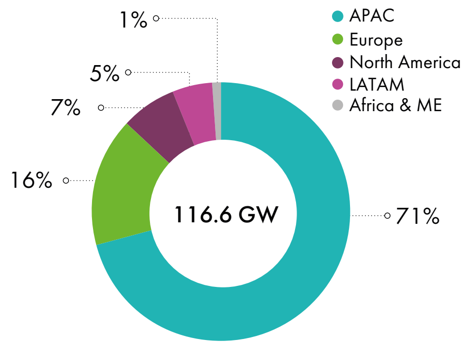
The world's top five markets for new installations in 2023 were China, the US, Brazil, Germany and India. Compared with 2022, the only change is that India overtook fifth place, a position previously held by Sweden. Together, the top five markets made up 80% of global new installations in 2023, collectively 9% higher than the previous year. This is primarily due to China's global market share surging by 16% points compared with 2022.

The top five markets by total wind power installations at the end of 2023 remained unchanged: China, the US, Germany, India and Spain together made up 72% of the world's total wind power installations in 2023, the same percentage as the previous year.

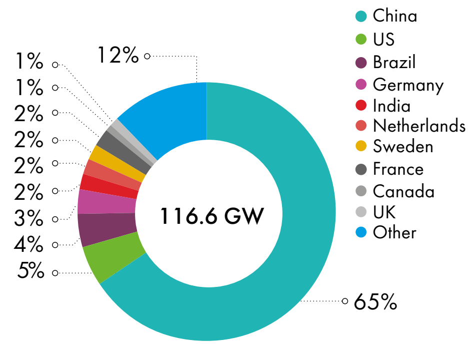
New installations
GW



New capacity in 2023 installed by region (%)



New capacity 2023 and share of top five markets (%)



Onshore Wind Market –Status 2023

2023 saw annual onshore wind installations surpass the 100 GW milestone for the first time. With 105.8 GW of new onshore wind capacity added to the grid last year, global cumulative onshore wind capacity reached 945 GW, a YoY growth of 12%.

Asia Pacific and Latin America had a record year mainly due to the outstanding performance of China and Brazil. Although Europe and Africa & Middle East did not beat the previous record, the two regions still experienced their second-best years in new onshore wind installations last year.

Total onshore wind additions in North America, however, dropped by 16% in 2023 compared with the previous year. The decline was driven primarily by the slowdown of onshore wind growth in the world's second-largest wind power market – the US.

Since 2021, China's onshore wind development has been driven by a market support mechanism called 'grid parity', meaning that electricity generated by onshore wind would be remunerated in every province with the same regulated price as coal power. After two years of relatively low growth, onshore wind installations in China finally bounced back in 2023 with grid-connected wind capacity surpassing 69 GW, a new record. Such explosive growth has demonstrated that the country is on track to reach its '30-60' target of peak emissions by 2030 and carbon neutrality by 2060.

In the US, the IRA propelled renewable energy investment across the country, including in the domestic wind supply chain. Developers installed more new wind capacity in the fourth quarter than the previous three quarters combined, and only 6.4 GW of onshore wind capacity was added last year, the lowest level since 2014. After record installation levels in 2020 and 2021, the amount of new capacity entering the onshore wind pipeline has stalled. Wind installations last year were depressed by market saturation in certain areas and delays caused by permitting, supply chain constraints, inflation and grid interconnection. However, the situation is expected to change in 2024, with a strong onshore market expected to return from 2025.

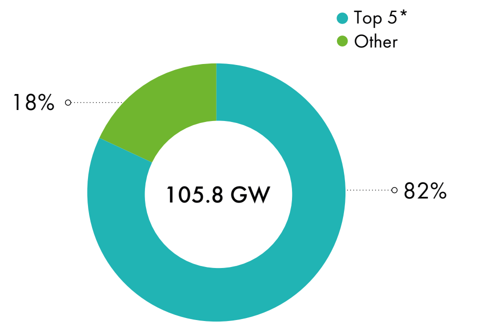
In addition to China and the US, the top onshore wind markets were Brazil (4.8 GW), Germany (2.4 GW) and India (2.8 GW).

'Grid parity' in China, tax credits in the US and auction/tenders elsewhere remain the top three market support mechanisms behind the new onshore wind capacity added in 2023, collectively accounting for a combined 95% market share, 4% higher than the previous year. Feed-in Tariff support schemes gained a small amount of market share compared with 2022, mainly due to Japan achieving a record year in onshore wind installations.

Excluding China, in 2023, onshore wind capacity awarded worldwide through wind-specific, technology-neutral, renewable and hybrid auctions increased by 73% compared with 2022. The total reached 23.7 GW, of which more than half was in Europe.

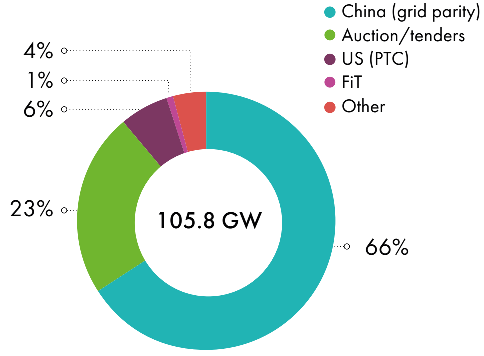
The total onshore wind volume awarded in 2023 amounted to 6.4

New capacity 2023 and share of top five onshore markets (%)



*China, US, Brazil, Sweden and India

New capacity 2023 by market support mechanism (%)



The total onshore wind volume awarded in 2023 amounted to 6.4 GW in Germany, nearly double the volume awarded in the previous year.

GW in Germany, nearly double the volume awarded in the previous year. This progress is credited to a higher bid price ceiling and the implementation of EU emergency measures that improve and streamline permitting to further accelerate renewable energy projects. However, to shed the EU's dependence on Russian fossil fuels while meeting climate targets, the current volume of annual wind power auctions in Europe is not enough and their pace needs to speed up further.

China approved 27.5 GW of onshore wind capacity under the 'grid parity' mechanism in 2023, with another 51 GW of announced onshore wind capacity under the same support mechanism expected to be approved by the provincial governments this year.

Offshore Wind Market – Status 2023

10.8 GW of new offshore wind capacity was fed into the grid worldwide last year, bringing the total global offshore wind capacity to 75.2 GW by the end of 2023. New additions were 24% higher than the previous year, making 2023 the second-highest year in offshore wind history.

- China led the world in annual offshore wind developments for the sixth year in a row with 6.3 GW added in 2023, bringing its total offshore wind installations to 38 GW, 3.7 GW (11%) higher than Europe. Last year was the second year since the Chinese offshore wind market entered the era of ‘grid parity’. Following a 70% YoY decline in new installations in 2022, GWEC Market Intelligence predicted that the offshore wind growth momentum would return last year. This was based on around 15 GW of offshore wind contracts having been awarded to wind turbine OEMs in 2022 and more than 30 offshore wind projects, totalling 14.8 GW, being under construction in China by Q1 2023. However, last year ended up being relatively flat. This was mainly due to an intervention from the central government, starting in Q2 2023, to ensure that the offshore wind industry would develop at a healthy pace.

- Europe had a record year in 2023, with 3.8 GW of new offshore wind capacity from 11 wind farms commissioned across six markets accounting for most of the new capacity.

- The Netherlands commissioned 1.9 GW of offshore wind capacity in 2023, replacing the UK as the region’s largest market in terms of new additions. More than 170 units of SGRE’s SG-11 DD offshore wind turbines were connected across the zHollandse Kust Noord (760 MW) and the Hollandse Kust Zuid 1-4 (1.5 GW) wind farms.

- The UK connected 833 MW of capacity offshore, of which 820 MW from the remaining wind turbines at the 1.1 GW Seagreen and 13 MW from the 1.2 GW Dogger Bank (phase A) projects. Seven Haliade-X 13 MW offshore wind turbines were mechanically installed at the latter last year, but only one unit was commissioned.

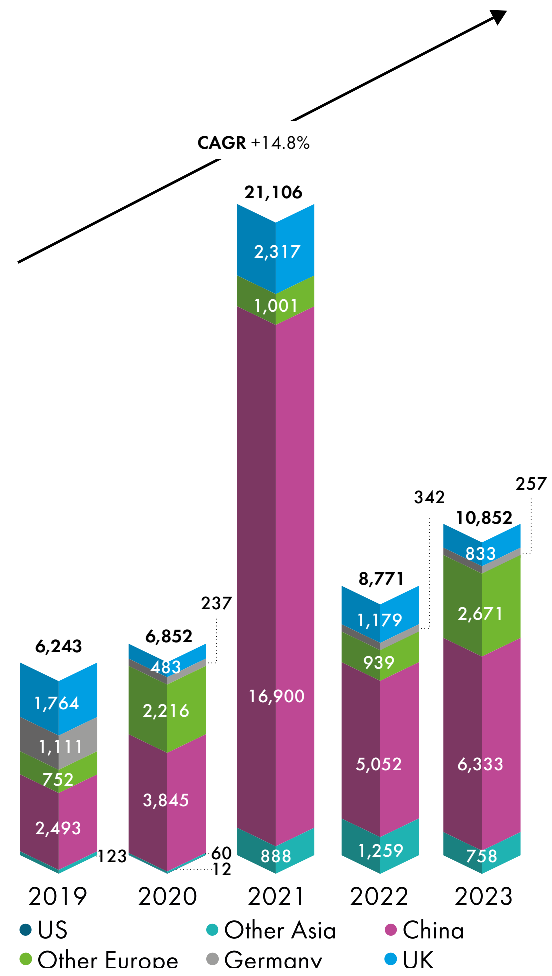
- France commissioned 360 MW of offshore wind in 2023. At the Fécamp (250 MW) and Saint-Brieuc (496 MW) wind farms, 49 SGRE offshore wind turbines were grid-connected. The remaining turbines (84 units) are expected to be commissioned later this year.

- Denmark installed 41 units of SGRE’s SG-8.0-167 DD wind turbines at the Vesterhav Syd and Nord wind farms in the North Sea last October, with the two small projects fully commissioned at the beginning of this year.

- In the German Baltic Sea, the Arcadis Ost 1 offshore wind project comprising 27 Vestas V174-9.5 MW offshore wind turbines was fully connected to the grid before the end of 2023.

- In Norway, the remaining four SGRE SG-8.6-167DD wind turbines, which were installed on a concrete SPAR-type floating foundation at the 94.6 MW Hywind Tampen floating wind project, were connected last year,

New offshore installations (MW)



The offshore wind market has grown from 1.6 GW in 2013 to 10.8 GW in 2023, taking its market share in global new installations from 4% to 9%. GWEC Market Intelligence expects the global offshore wind market to continue to grow at an accelerated pace (for details, see Market Outlook).

making it the world's largest floating wind project.

- Elsewhere, a total of 13 MW of floating wind capacity was commissioned in 2023. It included a 2MW floating demo, DemoSATH, in Spain and two units – a 7.25MW anti-typhoon machine from Mingyang and a 4 MW wind turbine from Shanghai Electric – installed on three-column semi-submersible floating platforms in China.

- Outside of China and Europe, three other markets commissioned new offshore wind capacity last year. Taiwan (China) commissioned 692 MW of offshore wind turbines across Formosa II, Yunlin, Greater Changhua 1 & 2a and Changfang Phase 2 in 2023. In Japan, all the turbines at the 140 MW Akita Noshiro Port wind farm were installed by the end of 2022, but the 55 MW Akita Port project was not commissioned until the end of January 2023. Additionally, the Nyuzen offshore wind project, consisting of three units of Mingyang's MySE 3.0MW typhoon-proof wind turbines, was completed last October. In South Korea, one unit of 4.2 MW offshore wind prototype was installed by Hanjin last year.

- The US is the only market with offshore wind in operation in the Americas. GE Vernova installed six Haliade-X 13 DD offshore wind turbines at the 806 MW Vineyard Wind 1 wind project, and SGRE also installed a few turbines at the 130 MW South Fork Wind project before the end of last year. However, no offshore turbines were commissioned in 2023 according to American Clean Power (ACP).

- In total offshore wind installations, China took the crown from the UK in 2021 and further consolidated its global market share in the past two years. Germany, the Netherlands and Denmark are the other three markets that make up the top five, as was the case in 2022.

Allocation mechanisms

With 39.4 GW of offshore wind capacity awarded worldwide, 2023 was a record year. Excluding China, where 18.2 GW of offshore wind projects were allocated under the 'grid-parity' mechanism, 21.2 GW of offshore wind capacity was awarded through auctioning, of which 15.5 GW in Europe, 4 GW in the US, and 1.4 GW in Japan.

In Europe, Germany awarded 8.8 GW of offshore wind via a zero-subsidy tender. Out of this, 7 GW across four sites was centrally pre-surveyed and featured a 'dynamic bidding' system. The remaining 1.8 GW awarded across four sites was not centrally pre-surveyed. Ireland awarded 3.1 GW of offshore wind capacity through its first offshore wind energy auction, ORESS 1. Following suit, France awarded 1 GW of offshore wind for the Centre Manche 1 site, and Lithuania awarded 700 MW from its first offshore wind auction.

No energy companies submitted bids to the UK's CfD Allocation Round 5 (AR5) auction last year, primarily due to the strike prices being too low and not reflecting rising costs. In response to the challenges facing the wind industry, however, the bid price ceilings under CfD AR6 were increased to £73/MWh (€83.9/MWh) for bottom-fixed offshore wind and to £176/MWh (€202.3/MWh) for floating offshore wind.

Moving beyond the turbulence in 2023

In 2023, a 'perfect storm' battered the offshore wind industry. Challenges such as inflation, increased capital costs and supply

chain constraints including for vessels created uncertainty in the sector, forcing developers to renegotiate signed project contracts and, in some cases, to even terminate offtake agreements and stop project development due for construction in the next five years (2023-2027).

In addition to the 1.4 GW Norfolk Boreas offshore wind farm that had won the UK's CfD AR4 auction in 2022, ten offshore wind projects totalling 10.9 GW off the east coast of the US were affected by supply chain and financial challenges. Of these, five projects totalling 5.5 GW – Ocean Wind 1&2, Commonwealth Wind, Park City Wind and SouthCoast Wind – saw their offtake agreements terminated or the whole project development cancelled.

Four projects located in New York tried to renegotiate their PPA price last year, but their request was denied by the New York State Public Service Commission. However, the state launched its fourth, expedited offshore wind solicitation in December 2023 and allowed projects that previously petitioned the Commission for financial relief to participate.

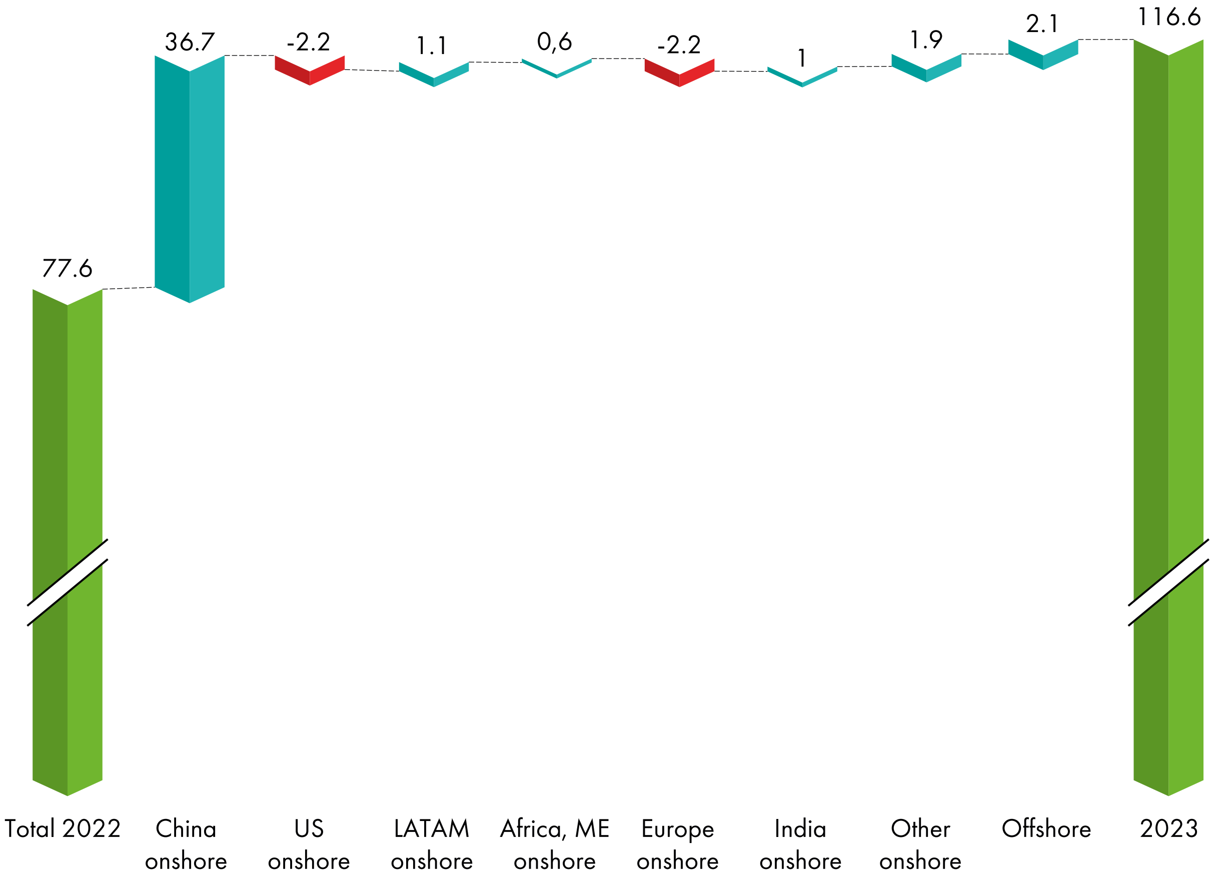
Despite all the turbulence experienced in 2023, governments and developers have retained their commitments to develop offshore wind. It is the industry's consensus that the worst has passed, and the offshore wind sector has entered 2024 poised for a new wave of growth.

In the US, the New York State Energy Research and Development Authority (NYSERDA) selected in February 2024 Equinor's Empire Wind 1 (810 MW) and Ørsted and Eversource's Sunrise Wind (924 MW) projects in the state's fourth offshore wind solicitation. Both projects had previously secured agreements with the state and re-bid in the latest procurement round to negotiate new 25-year contracts.

In the UK, the government announced in March 2024 that it would provide GBP 800 million (EUR 936 million) to support offshore wind in the CfD AR6, which is expected to procure approximately 4-6 GW of offshore wind. According to GWEC Market Intelligence's global wind auction database, 2024 will be a record year in offshore wind auctions, with more than 60 GW of offshore wind capacity expected to go through auctions and lease processes.

All regions increased new installations, except North America and Europe

Changes in new onshore and offshore installations, 2022–2023 (GW)



Annual wind installations (onshore and offshore combined) increased in all regions except North America and Europe in 2023, with a YoY growth rate of 50.3%.

- Onshore wind: Asia Pacific and LATAM had a record year in 2023 with YoY growth rates of 106% and 21%, respectively. Last year also saw onshore wind installation in Africa & Middle East increase by 182% compared with 2022, while new onshore wind capacity added in North America and Europe in 2023 dropped by 15.6% (1.5 GW) and 13.4% (2.2 GW), respectively. New installations in Canada increased by 71% last year, but US onshore wind installations went down to their lowest level since 2014. The decline in Europe was primarily due to lower installations in Finland, Spain, Turkey and Sweden compared with the previous year.

- Offshore wind: New offshore wind installations increased by 24% (2.1 GW) compared with 2022, which was mainly due to the recovery of the Chinese offshore wind market (25% YoY). Additionally, the Netherlands set a record with nearly 2 GW of new capacity commissioned in 2023.

Actuals 2023 vs GWEC forecast

China onshore
After the Chinese market was fully reopened by the end of 2022, we expected onshore wind installations in China to bounce back in 2023, as more than 80 GW of onshore wind capacity was awarded to Chinese turbine OEMs through auctions in 2022. Although installation activities were slowed down due to government's intervention in Q2 2023, recent Chinese NEA statistics shows that almost 70 GW onshore capacity was grid-connected last year.

USA onshore
Although the IRA signed into law in August 2022 has propelled the renewable energy investment in the US including the investment in domestic wind supply chain, only 2.7 GW of onshore wind capacity was added in 9M 2023, the lowest since 2018. After record installation levels in 2020 and 2021, the amount of new capacity entering the onshore wind pipeline has stalled. Additionally, some onshore wind project development was delayed last year due to the clarification on domestic content bonus credit guidance was not released until May 2023.

India onshore
Onshore wind market continued to recover in India in 2023. The country installed 2.4 GW onshore wind power in the first 10 months of 2023. However, the new onshore wind installations in 2023 is still lower than our Q3 2022 projection, which is primarily driven by grid related delays as well as a 200 MW project cancellation caused by litigation..

Germany onshore
Germany aims for increased share of renewables in electricity generation to 80% by 2030 as per the revised Renewable Energy Act (EEG 2023) to reduce reliance on Russian fossil-fuel imports. Driven by the strong political will as well as the improved situation on permitting, the country installed 2.5 GW of onshore wind capacity in the first three-quarters and added another 1 GW into the grid in the last one, making 2023 the best year in new installations since 2018.

Brazil onshore
The Brazilian wind industry has demonstrated a strong resilience during the COVID 19 pandemic and the political turbulences. New onshore wind installations record has been reported every year since 2021. Same as the previous years, the strong growth in 2023 was primarily driven by the free market through private PPA..

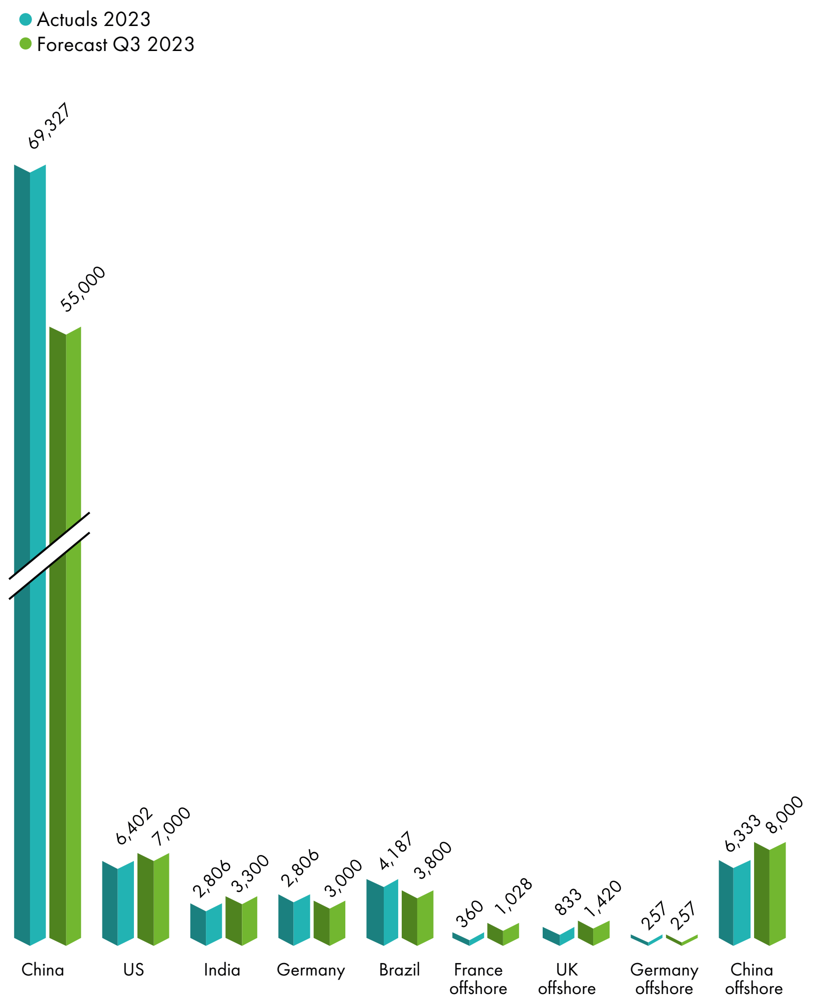
France offshore
According to project plans, the 496 MW Saint Brieucoffshore wind project and the 497 MW Fécampoffshore wind project were expected to be commissioned in 2023. Although all the turbines have been installed at Saint Brieucproject by end of 2023, only 136 MW was commissioned. The Fécampoffshore wind farm did start producing the first electricity last July, but only 224 MW were commissioned by the year end according to turbine supplier SGRE.

UK offshore
GWEC Market Intelligence expected that the remaining offshore turbines (totalling 820 MW) at the 1.1 GW Seagreen, offshore wind farm would reach commercial operation in 2023 and half of the turbines at the 1.2 GW Dogger Bank A offshore wind project would be commissioned by the year end, but only 7 units of wind turbine (91 MW) at Dogger Bank A were installed, of which only one unit is commissioned last year.

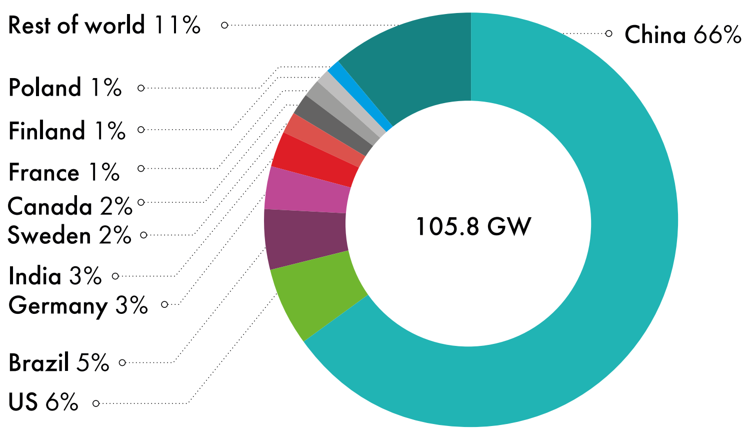
Germany offshore
The 257 MW the Arcadis Ost 1 offshore wind farm reached the commercial operation in German Baltic Sea, which was in line with our expectation. Although the 242MW GodeWind 3 project and the 476 MW Baltic Eagle offshore wind project also commenced the offshore construction work in 2023 but no wind turbine has been installed by the end of year.

China offshore
As around 15 GW of offshore wind capacity was awarded in China in 2022, GWEC Market Intelligence predicted that the offshore wind growth momentum would return in 2023. However, actual offshore wind installations is 1.7 GW lower than our projection, which is mainly due to the central government's intervention to ensure a health industry development.

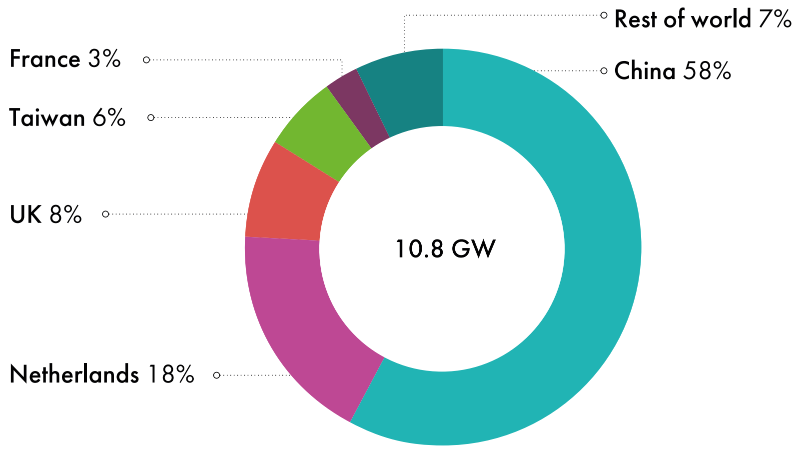
Actuals for 2023 vs GWEC forecast



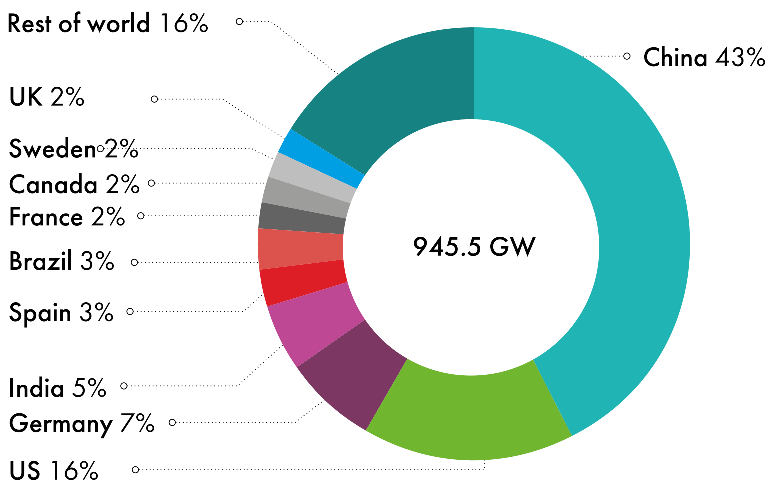
New installations onshore (%)



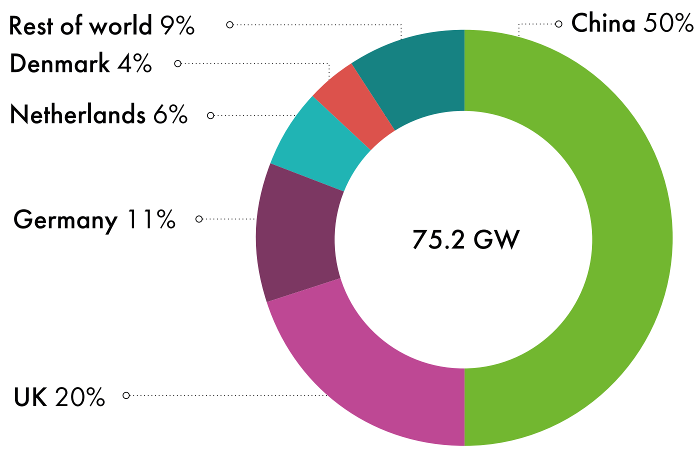
New installations offshore (%)



Total installations onshore (%)

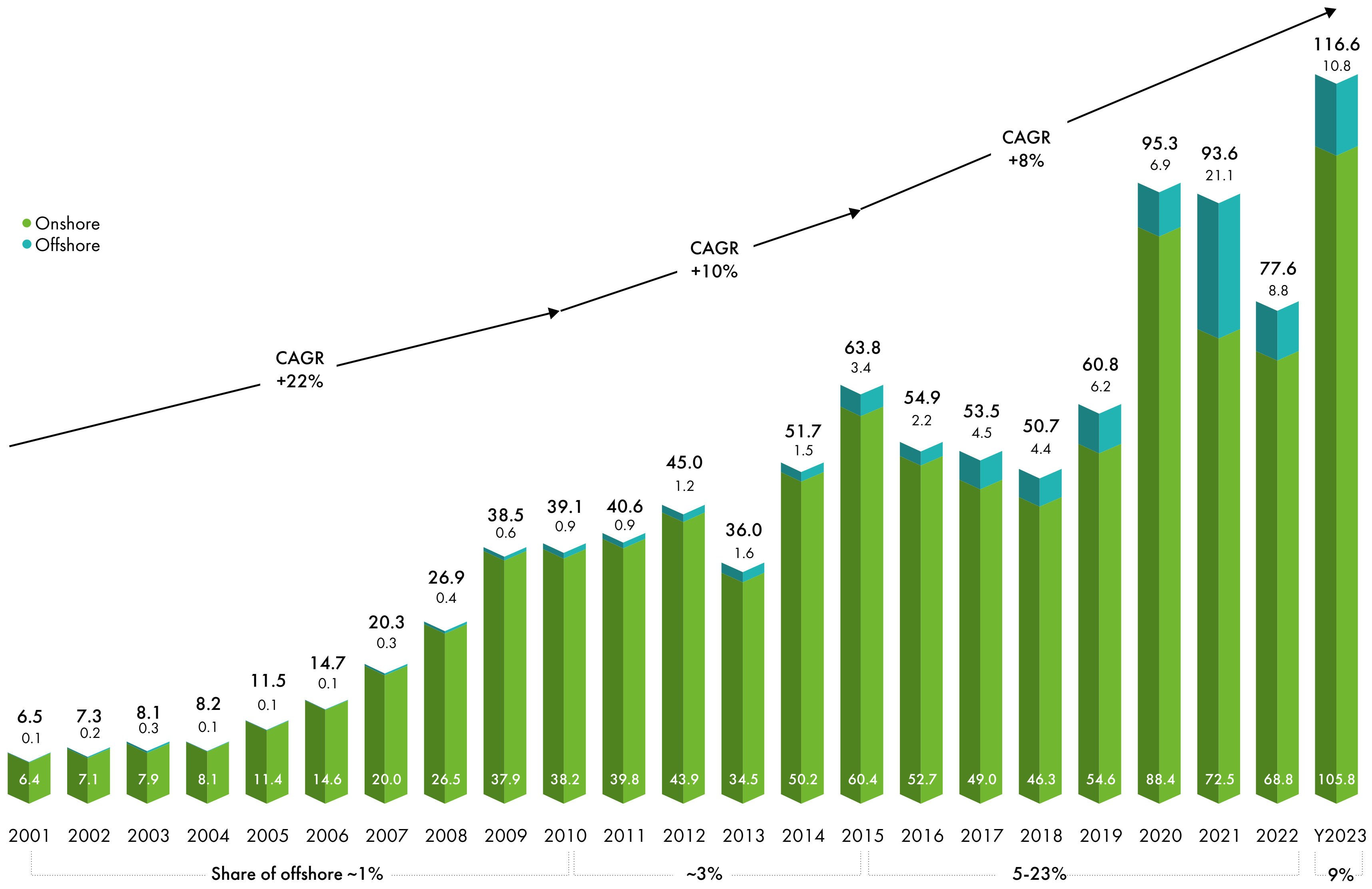


Total installations offshore (%)

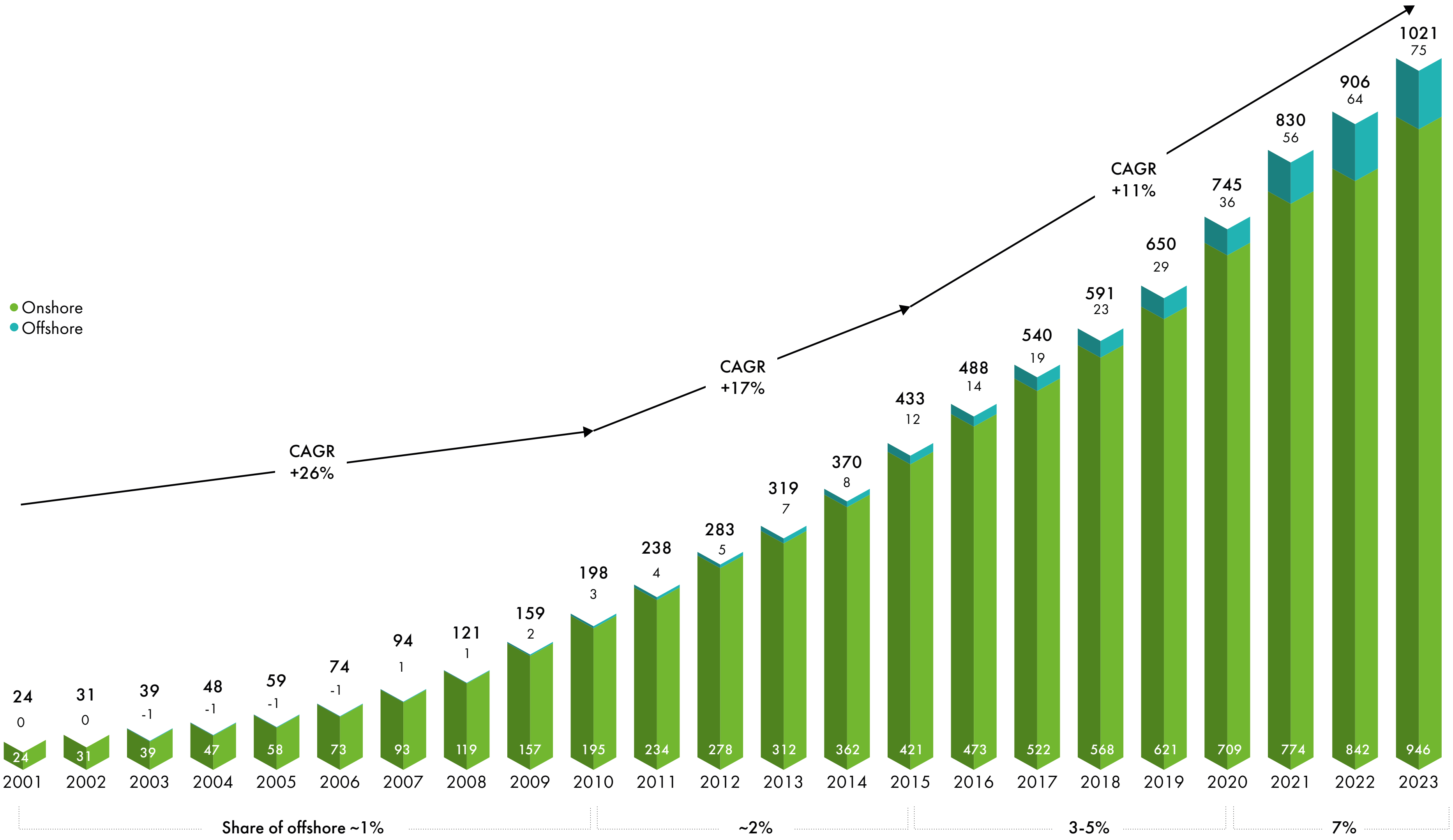


Detailed data sheet available in GWEC's member-only area. For definition of region see Appendix Methodology and Terminology

Historic development of new installations (GW)



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 2022	Total installations 2022	New installations 2023	Total installations 2023
Total onshore	**68811**	**840873**	**105764**	**945477**
Americas	**14829**	**203934**	**14417**	**218006**
USA	8612	144356	6402	150433
Canada	1006	15267	1720	16986
Brazil	4065	25632	4817	30449
Mexico	158	7317	96	7413
Argentina	18	3309	395	3704
Chile	824	3889	688	4577
Other Americas	146	4164	299	4444
Africa, Middle East	**349**	**9698**	**987**	**10684**
Egypt	0	1702	360	2062
Kenya	0	435	0	425
South Africa	0	3442	0	3442
Morocco	276	1788	138	1926
Saudi Arabia	0	422	**0**	422
Other Africa	73	1909	489	2407
Asia-Pacific	**36860**	**402713**	**75836**	**478472**
PR China	32579	333998	69327	403325
India	1847	41930	2806	44736
Australia	1412	10537	942	11479
Pakistan	301	1817	0	1817
Japan	149	4528	572	5026
South Korea	96	1658	165	1821
Vietnam	0	3102	823	3924
Philippines	0	443	150	593
Kazakhstan	418	755	161	916
Other APAC	58	3945	890	4835
Europe	**16773**	**224528**	**14524**	**238315**
Germany	2403	58106	3567	61139
France	1590	20653	1400	22003
Sweden	2441	14278	1973	16249
United Kingdom	502	14575	553	14866
Spain	1659	29800	762	30562
Finland	2430	5607	1278	6873
Netherlands	933	6227	527	6754
Turkey	867	11945	397	12342
Other Europe	3948	63337	4067	67527

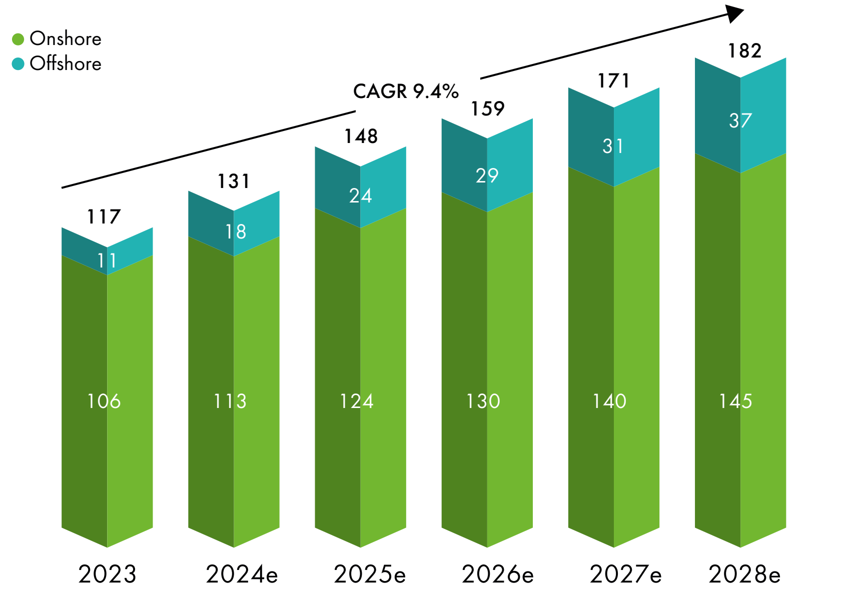
MW, offshore	New installations 2022	Total installations 2022	New installations 2023	Total installations 2023
Total offshore	**8771**	**64320**	**10852**	**75162**
Americas	**0**	**42**	**0**	**42**
USA	0	42	0	42
Asia-Pacific	**6311**	**34006**	**7091**	**41088**
PR China	5052	31442	6333	37775
Japan	84	136	62	188
South Korea	0	142	4	146
Vietnam	0	874	0	874
Taiwan	1175	1412	692	2104
Europe	**2460**	**30272**	**3761**	**34032**
United Kingdom	1179	13918	833	14751
Germany	342	8055	257	8311
France	480	482	360	842
Netherlands	369	2829	1930	4759
Denmark	0	2308	344	2652
Belgium	0	2262	0	2262
Other Europe	90	418	37	455

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

MARKET OUTLOOK 2024-2028

Global wind energy market expected to grow on average by 9% each year

New installations outlook 2024–2028 (GW)



GWEC's Market Outlook represents the industry perspective for expected installations of new capacity for 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 2024. A detailed data sheet is available in the member only area of the GWEC Intelligence website.

Global outlook

The inclusion of a goal to triple renewables capacity by 2030 in the final COP28 text is unprecedented and historic for wind and other renewable energy technologies. The wind industry is becoming more optimistic about its short-term and long-term growth and more confident about its role in delivering the tripling target.

GWEC Market Intelligence expects new installations to surpass the previous record and reach 130 GW in 2024. 791 GW of new capacity is likely to be added in the next five years under current policies. This equals 158 GW of new installations each year until 2028.

The projected CAGR for the next five years is close to 10%, even though the level of installed capacity for 2023 was the highest in history. We believe there are five pillars that will underpin this level of success in the next five years:

- Europe is accelerating renewables development to achieve energy security in the aftermath of Russia's invasion of Ukraine. The continent has started turning its ambitious targets into actions from 2023.
- The US has implemented what has been called the largest investment in climate action the world has ever seen – the IRA, helping to not only deliver new clean power over 2023-2032, but also to create a local supply chain, jobs and society-wide benefits.
- Clean energy has become the top driver of China's economic growth. Driven by the '30-60' pledge, the Chinese government has set the target that non-fossil energy sources will account for over 80% of total energy consumption by 2060.
- After a turbulent 2023, governments and developers have retained their commitments to develop offshore wind. Floating wind technology, as well as Power-to-X solutions, will further unlock offshore wind's potential in supporting the global energy transition.
- Growth in emerging markets from Southeast and Central Asia to MENA countries is expected to gain momentum from the middle of this decade.

Global wind power growth in 2024-2028 will continue to rely on three market support mechanisms: 1) 'grid-parity' scheme (China); 2) tax credit (PTC and ITC) and technology-

neutral credits in the US; and 3) wind-specific, technology-neutral, renewable and hybrid auctions (Europe, Latin America, Africa & Middle East and Southeast Asia). In addition, corporate/private power purchase agreements (PPAs) will drive wind energy growth in the next five years.

Global onshore outlook

- The CAGR for onshore wind in the next five years is 6.6%. Expected average annual installations are 130 GW. In total, 653 GW is likely to be added in 2024–2028.

- Growth in China, Europe and the US will remain the backbone of global onshore wind development in the next five years. Together, they are expected to make up more than 80% of the total capacity to be built in 2024-2028.

- China will continue to be the growth engine in the near term, making up more than 60% of total installations in 2024. But installations will accelerate in Europe and the US from 2025, as well as in emerging markets in Southeast Asia, Central Asia and MENA from 2026. Global onshore wind markets will become more diversified by the end of the forecast period with nearly half of the annual growth coming from markets outside of China.

Global offshore outlook

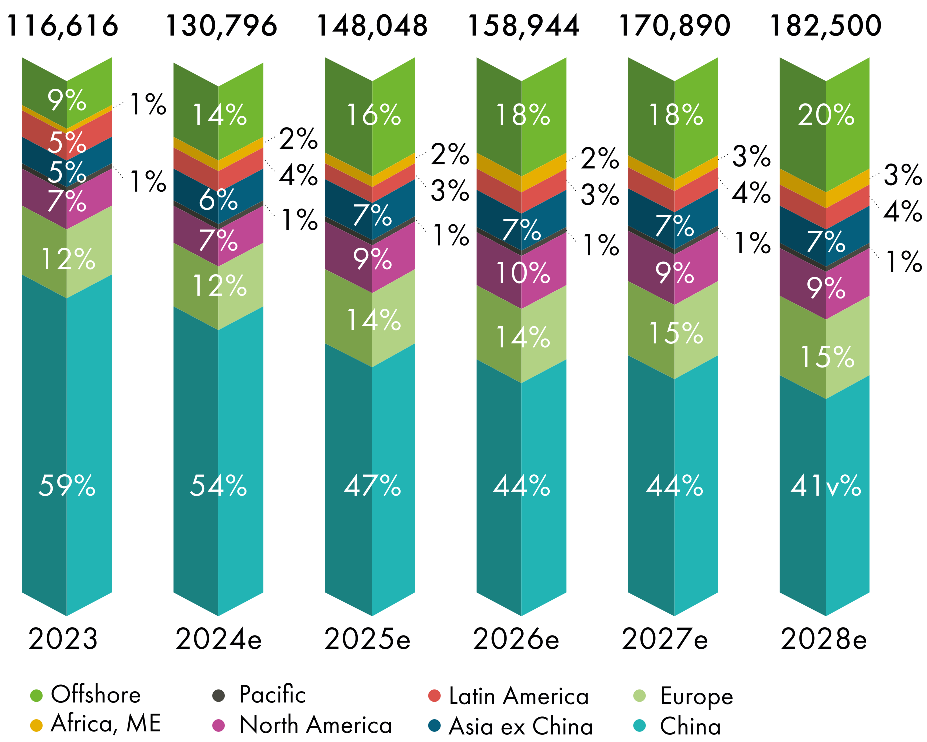
- The CAGR for offshore wind in the next five years is 28%. With such an exciting growth rate, annual offshore wind additions are likely to triple by 2028 from 2023 levels.

- China and Europe will continue dominating growth in the near term with more than 85% global market share in 2024-2025. However, the US and emerging markets in APAC will start gaining sizable market share from 2026 with 5-8 GW of new offshore wind expected to be added over the rest of the projection period. By the end of the forecast period, annual installations outside China and Europe are likely to make up more than 20% of total additions.

- In total, 138 GW of offshore wind capacity is expected to be added worldwide in 2024–2028, with annual installations expected to average 27.6 GW.

Onshore wind in Asia, Europe and the US will be the growth engine while offshore wind gains momentum

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



A detailed data is sheet available in GWEC's member only area

Offshore wind

The global offshore market is expected to grow from 10.8 GW in 2023 to 37.1 GW in 2028, bringing its share of new global installations from today's 9% to 20% by 2028. In Europe, more than 42 GW of offshore wind capacity is expected to be built in 2024-2028, of which 44% is likely to be installed in the UK, primarily driven by the expected commissioning of CfD Allocation Round 3, 4 and 6 projects, 15% in Germany, 11% in Poland, 8% in the Netherlands, 6% in France, and 5% in Denmark.

In Asia, Chinese offshore wind deployment is expected to enter a fast-track once regulations for guiding and supporting project development in the deep sea are in place. The country will retain its leading position in this region with 72 GW to be added in the next five years, followed by Taiwan (China) (6.9 GW), South Korea (3.1 GW) and Japan (1.7 GW). As a route-to-market strategy for offshore wind development is still to materialise, no real offshore wind projects are likely to be built in Vietnam until the end of this forecast period.

Considering recent project cancellations and PPA renegotiations, GWEC Market Intelligence has downgraded its US offshore wind growth projection and believes that the Biden's Administration's 30GW by 2030 federal target is no longer feasible. However, 10 GW of offshore wind capacity is likely to be commissioned in the US in the next five years, making it the largest offshore wind market after China and the UK in terms of new additions.

China

China has committed to further expanding the role of renewables in its energy mix, aiming for renewable energy to contribute more than 50% of new electricity consumption by the end of the 14th Five-Year Period (2021-2025). The explosive growth in renewable energy installations in China in 2023, amounting to 290 GW, has demonstrated that the country is on track to achieving this ambitious target. Given that China has the

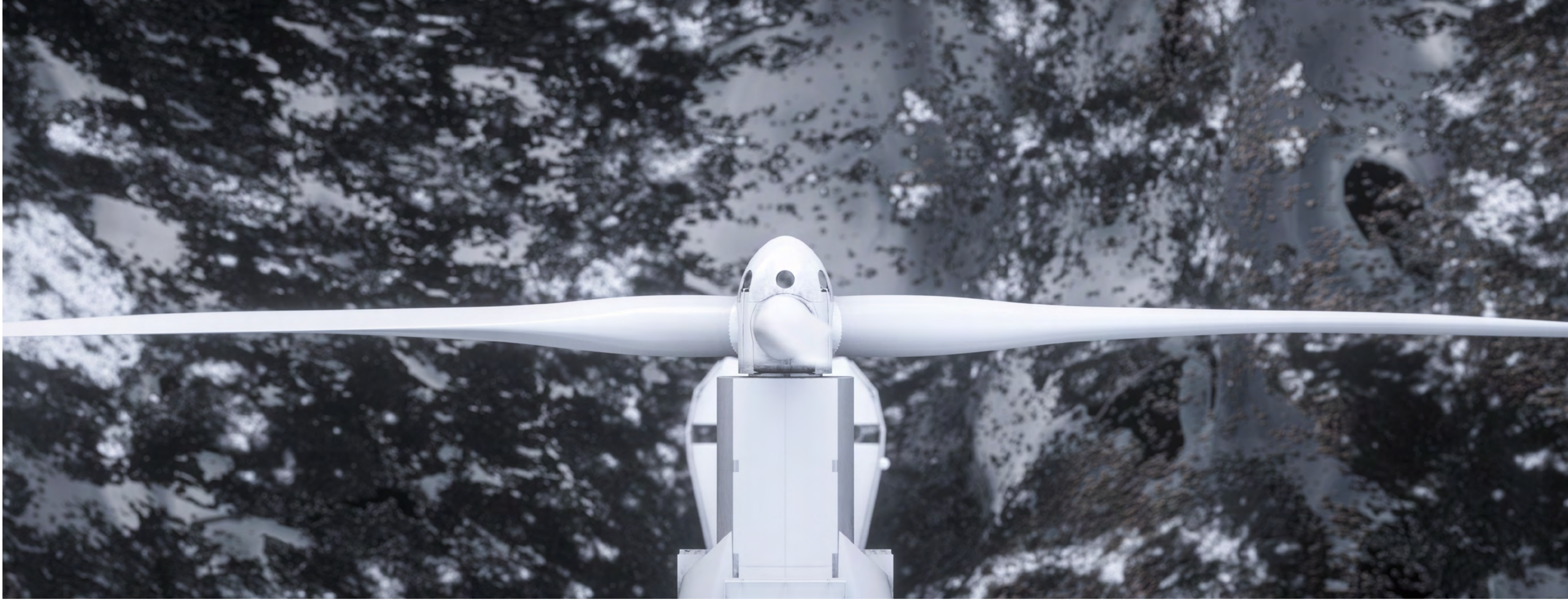
world's largest and most competitive wind energy supply chain – and that clean energy has become one of the growth engines for the Chinese economy – GWEC Market Intelligence has upgraded its onshore wind installations forecast for this market. We now predict that 360 GW of new wind capacity can be added to the grid in the next five years.

Asia excl. China

Although new installations in India in 2023 were less than our forecast, we expect the country's onshore wind market to continue to recover in 2024. We anticipate it to reach 4.8 GW in 2025, driven by the expiry of the 100% interstate transmission charge waiver (ISTS) in June 2025. In 2023, more than 5 GW of onshore wind capacity was awarded, including 1.3 GW of standalone wind auctioned capacity. Winners are expected to be announced this year for another 13 GW of auction capacity launched last year. Considering the 13 GW of standalone wind and hybrid projects that was under construction by the end of 2023, the 10 GW annual onshore wind auctions target for 2023-2027, and the renewable purchase obligations (RPOs) for designated electricity consumers revised last October, we believe that 22.8 GW of onshore wind capacity will be added in India in the next five years, accounting for 45% of the predicted additions for the region.

With the price ceiling set by Vietnam's Ministry of Industry and Trade in January 2023, EVN started negotiating PPAs with investors for installed projects that missed the COD deadline in 2021. Last year saw 823 MW of onshore wind capacity reach agreement with EVN, but another 2 GW of installed wind projects is still waiting for grid connection approval. That capacity is likely to be approved in the next two years. New installations in Vietnam in the rest of the forecast period are expected to be driven by the new market support mechanism, which the government has yet to confirm.

Elsewhere in the region, onshore growth is expected to come from Japan and the emerging markets of southeast and central Asia. GWEC Market Intelligence expects the Philippines, Kazakhstan and Uzbekistan to become the rising stars, together making up 17% of the new capacity expected for this region in 2024-2028.



Pacific
175 MW of onshore wind capacity was commissioned across three projects in New Zealand in 2023, with another 200 MW expected to be connected in 2024. Growth in New Zealand, however, is likely to stop from 2025 unless developers can solve the permitting issues impacting their project pipeline.

2023 was a particularly poor year for new investment in utility-scale generation in Australia. There were no new financial commitments to utility-scale wind projects, compared with six in 2022. The announcement by the Australian government of an expansion of the Capacity Investment Scheme to support the addition of 23 GW of new renewable electricity generation capacity between 2024 and 2027, and a further 9 GW of dispatchable capacity, is expected to get large-scale investment back on track. According to Clean Energy Council (CEC), 15 wind projects worth more than 4 GW were either under construction or committed at the end of 2023. As 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, we believe that the growth momentum is likely to continue for the rest of the decade, and 9.5 GW of onshore wind capacity can potentially be added to the grid in the next five years.

Europe
Our forecast for Europe for the next five years is in line with WindEurope's recently released 2024-2030 Outlook, which takes into account the latest developments in EU regulation, national policies, announcements of signed PPAs, project development timelines and the ability of wind to secure further capacity in upcoming auctions and tenders.

Under this scenario, record onshore wind installations in Europe are expected every year from 2025 to the end of the forecast period. Excluding non-EU-countries, the EU will add

93 GW of onshore wind capacity to the grid in the next five years. This equals 18.6 GW of new installations each year until 2028, which is however much lower than the average rate that EU needs to meet its 2030 energy and climate target. As a champion in European onshore wind installations, Germany will continue to lead the market growth in this region – accounting for 26% of total onshore wind additions in the next five years, followed by Spain (10%), Turkey (8%), France (8%), Finland (6%) and the UK (6%).

North America

Annual onshore wind installations in the US declined for the third year in a row, but this situation is expected to change from 2024. As a tax credit-driven wind market, US onshore wind has been through a series of boom-bust cycles in recent decades. The IRA, which was signed into law by the Biden Administration in August 2022, not only provided much-needed long-term visibility for investors but also stimulated new investment in domestic clean power manufacturing.

According to ACP, 123 new, expanded or reopened manufacturing plants serving wind and other renewable technologies were announced as of February 9, 2024, and onshore wind pipeline capacities grew by 6 GW last year. With developers continuing to refill their pipeline in 2024, we predict that the US onshore wind market will be back in full swing from 2025/2026 and reach 16 GW by the end of the forecast period. In total, 71.5 GW of onshore wind capacity is expected to be added in 2024-2028 in North America, of which 91% will be built in the US and the rest in Canada.

Latin America

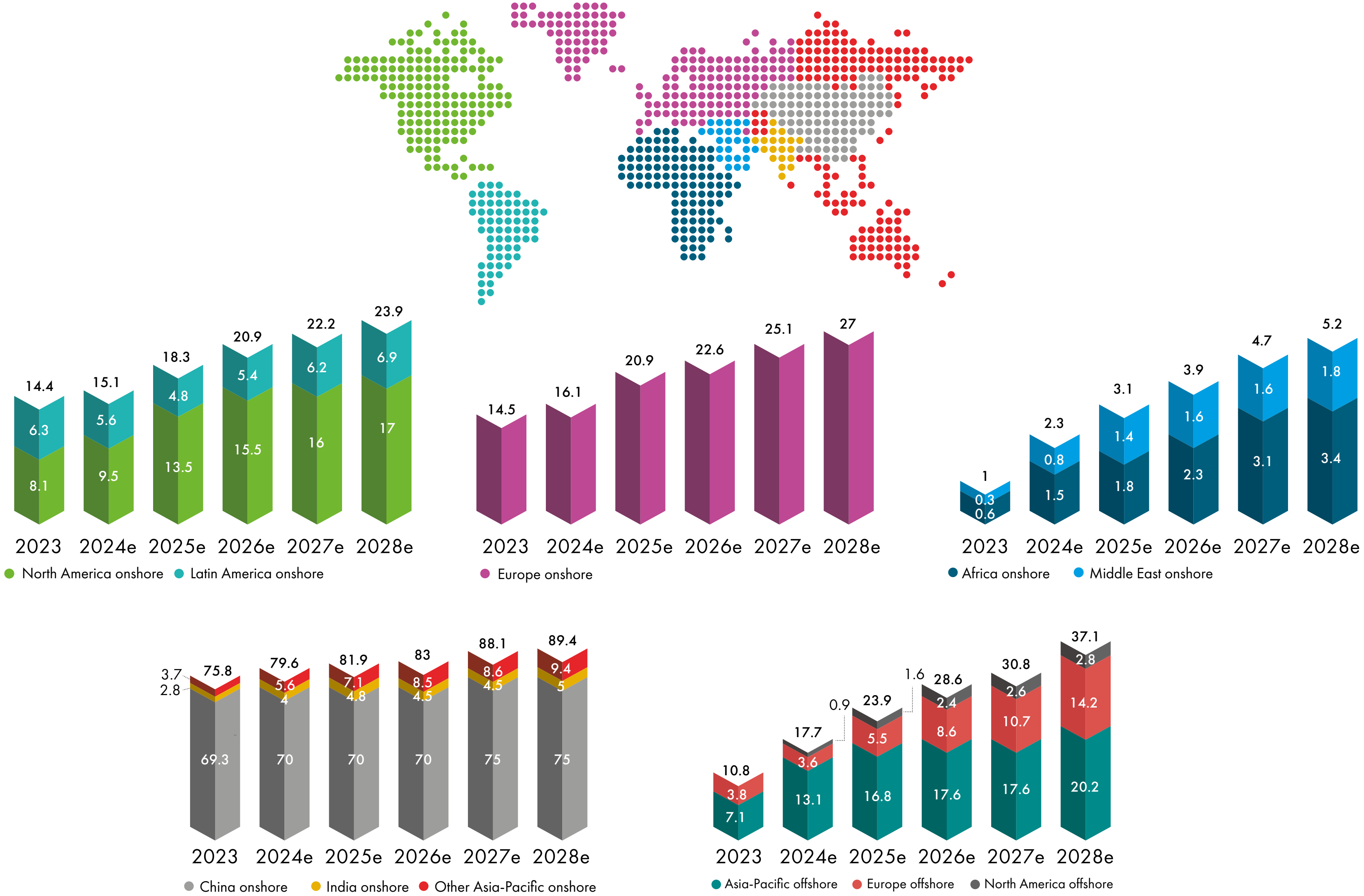
Latin America had a record year in new wind power installations in 2023 with more than three-quarters of the new additions coming from a single market: Brazil. The strong growth momentum in this country has been primarily linked to projects being developed through the free/bilateral market of private PPAs. However, annual growth in LATAM is likely to drop to 4-5 GW in the next two or three years as growth in Brazil slows down as a result of a low power clearing price (PLD) – the reference price in the free/bilateral energy market – as well as relatively slow growth in electricity consumption due to the expansion of distributed generation.

Despite market growth being interrupted by an unconducive energy policy environment in Mexico and economic and political instability in Argentina, GWEC Market Intelligence expects 28.7 GW of onshore wind to be added in this region in the next five years, with Brazil, Chile and Colombia being the top three markets, together contributing 78% of the additions for the region.

Africa/Middle East

Africa & Middle East installed nearly 1 GW of wind power capacity in 2023, almost triple the capacity installed the previous year. With projects awarded through the REIPPP Bid Window 4 auction coming online in South Africa, as well as GW-level onshore wind projects starting to be commissioned in MENA countries – especially Egypt and Saudi Arabia – GWEC Market Intelligence predicts that new onshore wind additions for this region will grow fivefold by 2028 compared with 2023. In total, 19 GW of new capacity is expected to be added in 2024-2028, of which 12 GW (63%) will come from Africa and the rest (37%) from the Middle East.

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



APPENDIX

Global Wind Report 2024 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 2024 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

AI	Artificial Intelligence
APAC	Asia-Pacific
ASEAN	Association of Southeast Asian Nations
CAGR	Compound Annual Growth Rate
CFD	Contracts for Difference
C&I	Commercial and Industrial
COD	Commercial Operation Date
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COP	Conference of the Parties
DEI	Diversity, Equity and Inclusion
DSR	Demand-Side Response
EMDEs	Emerging Markets and Developing Economies
ESG	Environmental, Social, Governance
EU	European Union
FDI	Foreign Direct Investment
FID	Final Investment Decision
FIT	Feed-in-Tariff
FIP	Feed-in Premium
FPIC	Free, Prior and Informed Consent
GDP	Gross Domestic Product
GFANZ	Global Financial Alliance for Net Zero
GHG	Greenhouse Gases
GOWA	Global Offshore Wind Alliance
GST	Global Stocktake
GWEC	Global Wind Energy Council
HSSE	Health, Safety, Security, and Environment
HVDC	High-Voltage Direct Current
IEA	International Energy Agency
IFC	International Finance Corporation
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRA	Inflation Reduction Act
ISO	Independent System Operator
ITC	Investment Tax Credit
JET	Just and Equitable Transition
JETP	Just Energy Transition Partnership
JV	Joint Venture
LCOE	Levelised Cost of Electricity
LCRs	Local Content Requirements
LCCs	Low-Cost Countries
LATAM	Latin America
LNG	Liquefied Natural Gas
MDBs	Multilateral Development Banks
ML	Machine Learning
MOU	Memorandum of Understanding
Mt	Metric Tonnes
MW	Megawatt
MWh	Megawatt Hour
NDCs	Nationally Determined Contributions
O&M	Operations and Maintenance
OEMs	Original Equipment Manufacturers
OPEC	Organization of the Petroleum Exporting Countries
OSW	Offshore Wind
OWSC	Offshore Wind Service Contracts
PSU	Public Sector Undertaking
PV	Photovoltaic
PTC	Production Tax Credit
R&D	Research and Development
RECs	Renewable Energy Certificates
REE	Rare Earth Element
RPS	Renewables Portfolio Standards
STEM	Science, Technology, Engineering and Mathematics
TSO	Transmission System Operator
TW	Terawatt
TWh	Terawatt Hour
UNFCCC	United Nations Framework Convention on Climate Change
UHV	Ultra-High Voltage
VRE	Variable Renewable Energy
VGF	Viability Gap Funding
WACC	Weighted Average Cost of Capital

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?

- Wind energy associations
- Market Intelligence subscription

Contact

membersarea@gwec.net

GWEC Market Intelligence Areas

Market Insights
Market statistics, market outlook, auction updates, project pipeline

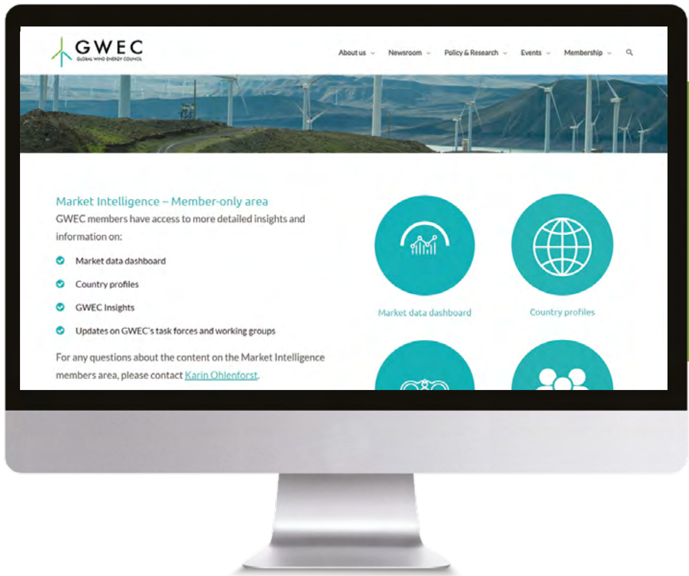
Policy and Regulations
Country profiles, policy updates, offshore updates

Asset Owners
Database of asset owners in key markets, investment trends

Technology/ Supply Chain
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.

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GWEC Market Intelligence Products in 2024

Product	Frequency	Expected Release date
1. Wind Energy Stats/Market Data		
Wind Stats 2023 (historic annual, accumulative, decommission data)	Annual	April 2024
Global Wind Report 2024	Annual	April 2024
Wind Energy Statistics (wind energy generation data, wind energy penetration rate, jobs)	Annual	April 2024
2. Country Profiles/Policy Updates		
Country Profiles Onshores/Country Profiles Offshore	Annual	April 2024 (onshore)
Ad-hoc Policy Updates	Ad-hoc	September 2024 (offshore)
3. Market Outlook		
Global Wind Market Outlook 2024-2028 (Q1 and Q3) Database + Report	Semi-Annual	April 2024 (Q1 Outlook) November 2024 (Q3 Outlook)
India Market Outlook Report 2024-2028	Annual	TBC
4. Supply Side Data		
Global Wind Turbine Supply Side Data Report 2023 (by OEM, by technology, by turbine ratings, models and drive train, etc)	Annual	May 2024
5. Auctions/Tenders		
Global Wind Auction	Quarterly	Q4 2023 results - February 2024
Auction Trends and Learnings	Quarterly	Q1 2024 results - May 2024
		Q2 2024 results - August 2024
		Q3 2024 results - November 2024
6. Offshore Wind Market		
Global Offshore Wind Report 2024	Annual	September 2024
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 2024
7. Components Assessment		
Generator (Q4 2024), Global Wind Supply Chain Deep Dive (Q4 2023), Gearbox (Q4 2022), Blades (Q4 2020)	Special Report	December 2024
8. Wind Asset Owners/Operators		
Asset Owners and Operators Database (Onshore & Offshore Ranking)	Annual	June 2024
Asset Owners and Operators Status Report (including strategical trends)	Annual	
9. O&M		
O&M Service Provider Database (ISP - OEM - Self-perform)	Annual	January 2024
O&M Service Provider Status Report (including regional trends)	Annual	
10. Energy transition, Digitalisation, New Technologies		
Auction design and non-price criteria, community engagement and social acceptance for permitting, supply chain policy analysis, repowering	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 Gamesa
A pioneer from the outset, Siemens Gamesa has been a core player in the wind industry for the last 40 years. By working together with our customers and partners, we have installed 137 gigawatts in 80 countries. And step by step, we're further expanding wind energy: to tackle the pressing challenge of climate change; and to provide sustainable, affordable, and reliable energy to societies across the world – all the while increasing energy security through renewable energy for generations to come.

Shell
Shell is building a global integrated power business spanning electricity generation, trading and supply. Shell entered the offshore wind business in 2000 as part of a consortium that installed the first offshore wind turbine in UK waters. Today, we have deployed, or are developing, over eight gigawatts (GW) of wind across North America, Europe, the UK, and Asia. We see offshore wind as a critical way of generating renewable electricity for our customers and moving Shell towards its target of being a net-zero emissions energy business by 2050 or sooner, in step with 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 Renewable Energy
GE Renewable Energy harnesses the earth's most abundant resources – the strength of the wind, the heat of the sun and the force of water; delivering green electrons to power the world's biggest economies and the most remote communities. With an innovative spirit and an entrepreneurial mindset, we engineer energy products, grid solutions and digital services that create industry-leading value for our customers around 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

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

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.

ReNew

ReNew is the leading decarbonisation solutions company listed on Nasdaq (Nasdaq: RNW, RNWWW). ReNew's clean energy portfolio of ~13.4 GWs on a gross basis as of December 31, 2022, is one of the largest globally. In addition to being a major independent power producer in India, we provide end-to-end solutions in a just and inclusive manner in the areas of clean energy, green hydrogen, value-added energy offerings through digitalization, storage, and carbon markets that increasingly are integral to addressing climate change.

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.

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