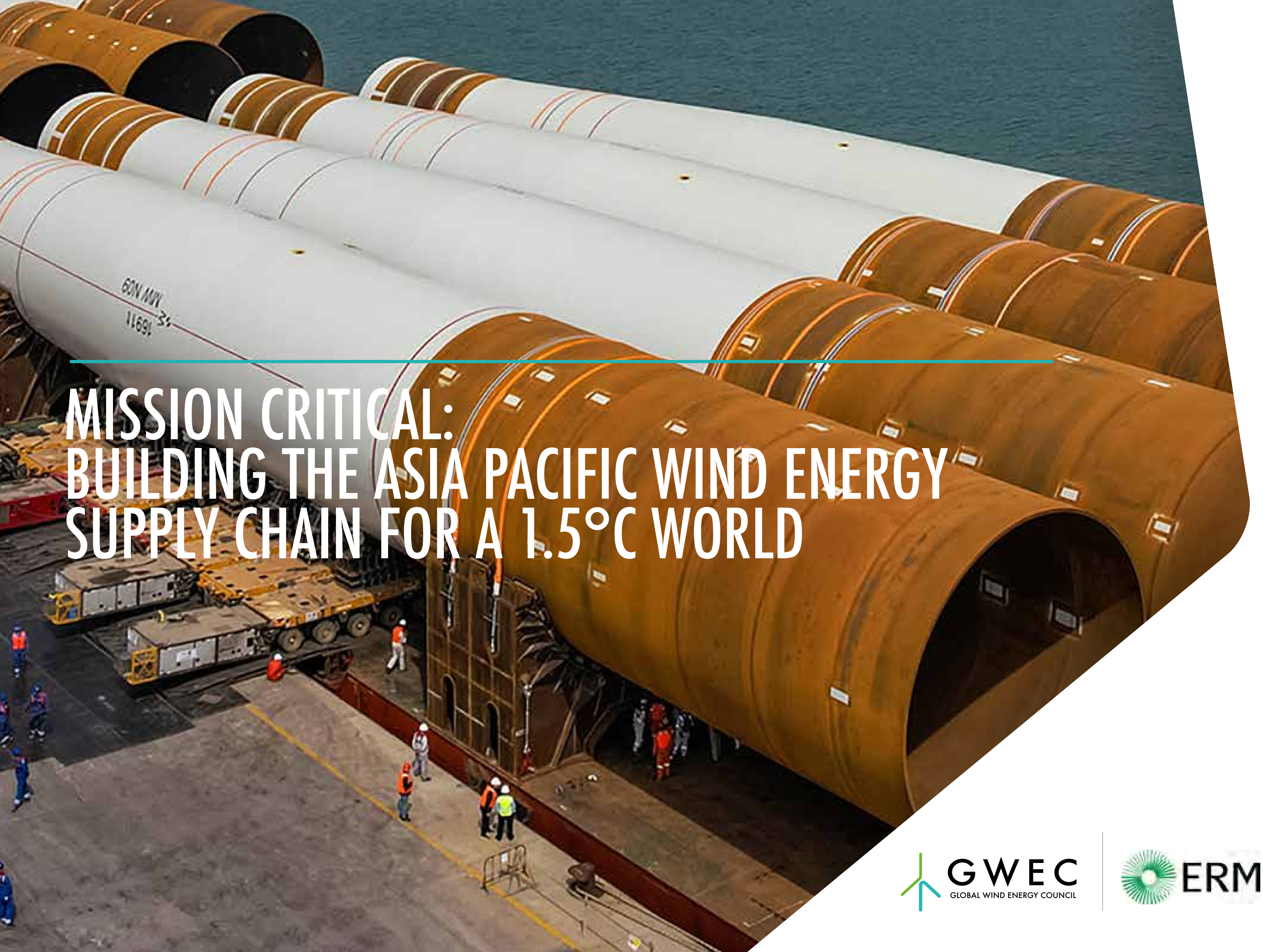

MISSION CRITICAL: BUILDING THE ASIA PACIFIC WIND ENERGY SUPPLY CHAIN FOR A 1.5°C WORLD

GWEC
GLOBAL WIND ENERGY COUNCIL

ERM

Disclaimer

Acknowledgments

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Clarification Notes to Reader

Definition of the region
Asia Pacific Region includes East Asia, Central Asia, South Asia, Southeast Asia, and Oceania.

Definition of the target markets
Although supply chain evaluations and stakeholder consultations were conducted across each APAC market for this study, dedicated case studies were developed for six target countries including Australia, Indonesia, Japan, Philippines, South Korea, and Vietnam.

Foreword

Ben Backwell
CEO, Global Wind Energy Council

The inclusion of a global goal to triple renewable energy by 2030 in the final text at COP28 Dubai was a historic landmark for wind and other renewable technologies. However, despite record-breaking growth the global effort to triple renewable energy by 2030 is falling short. The latest tracking report co-released by IRENA, the COP29 Presidency and the Global Renewable Alliance reveals a significant gap in progress to meet the goals set out in the UAE Consensus and keep the 1.5°C target within reach.

In particular, it is clear that wind is falling behind in its progress relative to other technologies such as solar PV. Given that wind is the most effective technology in replacing carbon per MW due to its robust capacity factors, underperforming wind risks undermining global climate and energy targets and making the energy transition harder to achieve.

For this reason, GWEC is calling for a wide-ranging RE-set of the wind industry, to ensure it is able to fulfil its obligations and seize the enormous business opportunity that lies before us. This means ensuring that the wind sector can invest massively in technology and manufacturing, can scale up the supply chain, and maintain – and enhance – wind's competitiveness versus other technologies, all while building strong political and social support for our mission.

Now it is time for action! We need each region to step up in the world's journey to a clean, secure, fair and equitable energy transition.

The APAC region is the world's largest wind market with more than half (51%) of global total wind power installations by the end of 2023, and is expected to make up 61% of the new additions to be built worldwide in 2024-2030. However, the concentration risk is high in the current APAC wind energy supply chain. Excluding China, the APAC region is unlikely to meet the level of wind power installations required to meet the climate target.

Scaling up the local supply chain is critical to fill in the gap, unlock the growth potential in the APAC region and secure the supply chain security. Despite geopolitics complicating the move to collaboration in the region, political commitment and cooperation is important to accelerate wind growth. Working together helps raise confidence across the region on supply chain investment and allows cooperation on shared challenges including grid systems, ports, vessels and associated skills.

This report, delivered in partnership with ERM, is GWEC's first regional wind energy supply chain report. Not only does it take a deep dive across the wind energy supply chain, from nacelles to components to materials to offshore wind balance of plant, but also identifies key industrial strengths and opportunities across six case study markets which could be scaled up or transitioned to supply the wind industry. Last but not least, this report provides recommendations to policy makers in regard to how to build a reliable, competitive and resilient supply chain in APAC to support the global energy transition.

Action to increase renewable energy generation could not be more urgent, and accelerated wind power installations across APAC countries could play a vital role to achieve the 3x wind power by 2030 target. Working with governments, key partners and key stakeholders in the industry, GWEC and its members will continue to help build the APAC wind supply chain for a 1.5°C world.

EXECUTIVE SUMMARY

Mission Critical: Building the Asia Pacific Wind Energy Supply Chain for a 1.5°C World

Following the historic COP28 pledge to triple global renewable energy capacity by 2030, the drive for wind has continued to gain momentum as reflected in increased installed capacity targets, bespoke policies, and clearer regulations as governments push to meet their climate commitments. International energy agencies agree on the integral role wind energy needs to play under the tripling renewables scenario. IRENA's World Energy Transitions Outlook foresees 3,040 GW of cumulative onshore wind by 2030 and 494 GW of offshore wind by 2030, equating to approximately 3.5 TW of total wind installed by 2030[1] 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.[2] According to GWEC, we need to accelerate annual wind energy installations to more than triple 2023 levels of 117 GW to at least 320 GW over the course of the decade.[3] Though the numbers vary slightly, the message regarding wind energy's importance in tackling climate change over the coming years is clear.

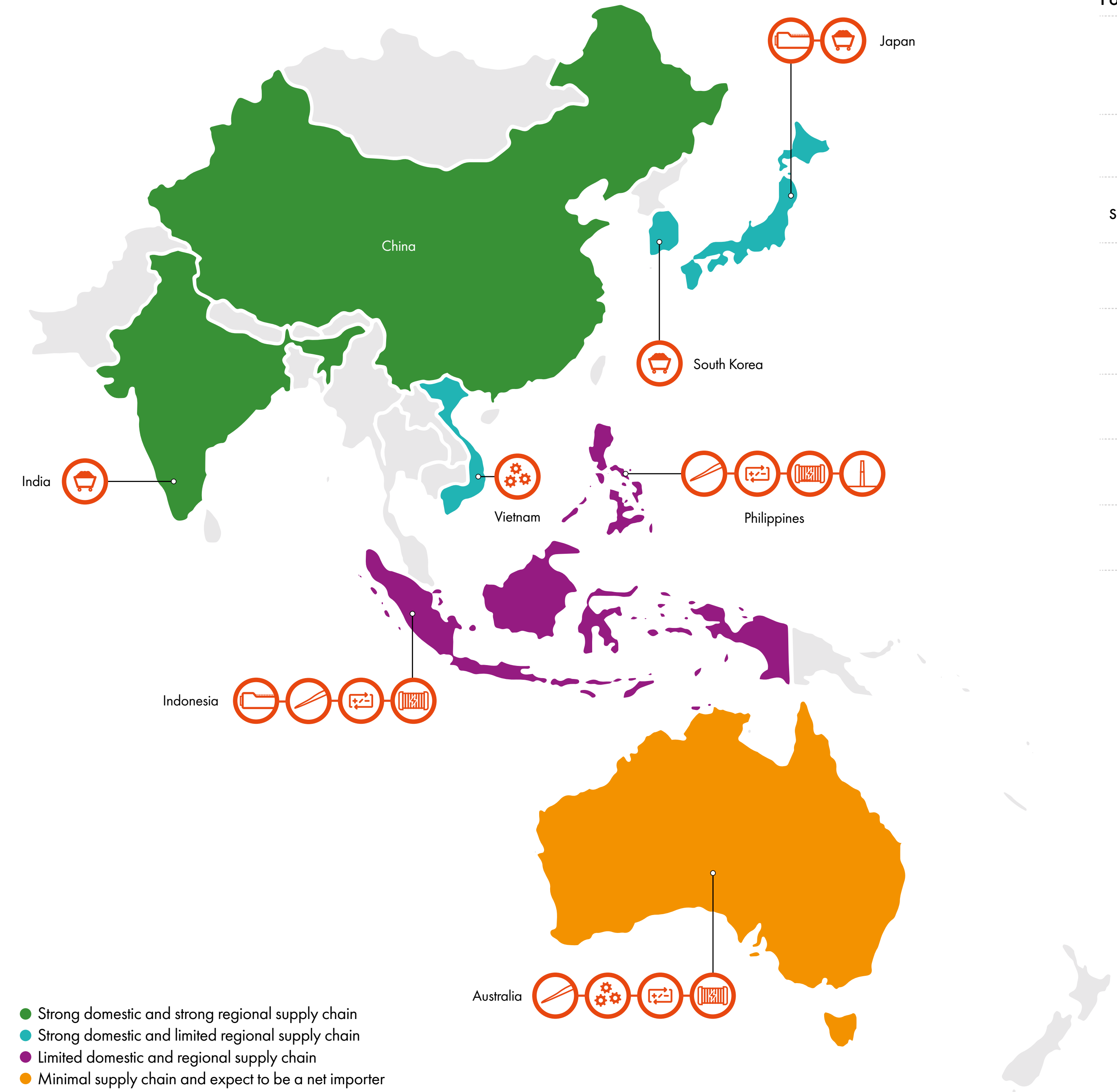
The Asia Pacific (APAC) region possesses some of the most attractive onshore and offshore wind resource globally and could play a pivotal role in the global energy transition. Within the decade, onshore wind capacity could more than double to 1,084 GW. For offshore wind, more than 122 GW of new capacity could come online by 2030, with the cumulative regional total reaching 162 GW by 2030. China is by far the largest onshore and offshore wind market in the region; however, important contributions from other key markets including India, Australia, Vietnam, Chinese Taiwan, Japan, South Korea, Kazakhstan, Uzbekistan, the Philippines, and Indonesia[4] will be critical to meeting net zero targets.

To support the substantial new additions of onshore and offshore wind capacity, urgent scale up of a robust, resilient supply chain is paramount to enabling country and region-wide renewables targets to be met. APAC's current wind energy supply chain is concentrated around China and India (onshore only) and although wind energy supply chain is also identified in other markets in this region and globally, this study shows that APAC's current supply chain setup is not sufficient to build out wind projects to the levels required to meet net zero targets. With a collaborative, cross-border approach to scaling industries in other APAC countries, the APAC supply chain could be grown to meet increased regional and global demands while becoming more competitive, diversified, and resilient. APAC industry, government, civil society, and the financial community could collectively drive the systematic change required to build a supply chain able to meet best practice sustainability requirements. This could take the form of collaboration with China, India, other APAC markets, or more globally.

Through a combination of desktop research, local GWEC and ERM expert knowledge and more than 100 consultations with APAC industry experts, a mapping of the APAC supply chain was undertaken considering both the existing supply

1. IRENA, World Energy Transitions Outlook 2023: 1.5°C Pathway, 2023.
2. IEA, Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach, 2023.
3. GWEC, Global Wind Report, 2024
4. Order based on new additions forecast for both onshore and offshore capacity between 2024 and 2030.

APAC onshore wind supply chain potential by 2030



- Strong domestic and strong regional supply chain
- Strong domestic and limited regional supply chain
- Limited domestic and regional supply chain
- Minimal supply chain and expect to be a net importer

Potential opportunity for transition and cooperation

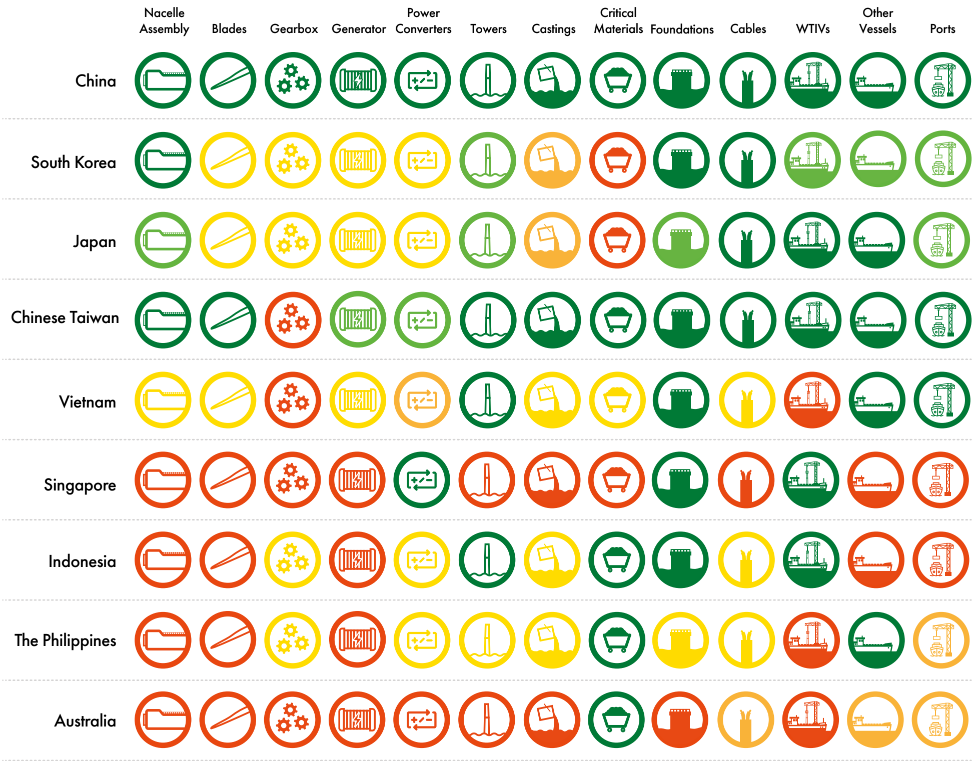
- Existing capability with potential to supply regionwide
- Existing capability with potential to supply countrywide
- Transition capability with potential to supply regionwide
- Transition capability with potential to supply countrywide
- No capability, but can rely on regional cooperation

Current global onshore wind supply chain flow

Imported to APAC	Nacelles, Blades, critical Materials
Exported to other regions	Nacelles, blades, gearboxes, generators, power converter, towers, castings, critical material

APAC offshore wind supply chain potential by 2030

Potential opportunity for transition and cooperation



- Existing capability with potential to supply regionwide
- Existing capability with potential to supply countrywide
- Transition capability with potential to supply regionwide
- Transition capability with potential to supply countrywide
- No capability, but can rely on regional cooperation

Current global onshore wind supply chain flow

↘	Imported to APAC	Nacelles, blades, gearboxes, generators, Critical Materials, cables, WTIVs, Other vessels (cable laying)
↗	Exported to other regions	Nacelles, blades, generators, towers, castings, critical material, foundations, cables, WTIVs, Other vessels

chain capabilities and their expected growth as compared to recent GWEC market forecasts.We conducted a supply chain bottleneck analysis for onshore and offshore wind to consider gaps until 2030 across nacelle assembly, key turbine components (gearboxes, generators, blades, power converters, towers, and castings), critical materials (rare earth elements, carbon fibre, steel, concrete, copper), balance of plant (foundations and cables), as well as offshore wind enablers (wind turbine installation vessels and ports).

Regional demand for nacelle assembly, key components, offshore wind balance of plant and offshore wind enablers[5] can be met by known APAC suppliers until 2030, apart from offshore wind gearboxes and blades where minor bottlenecks[6] are expected in 2029 and 2030, respectively. As many suppliers are based in China and India (onshore wind), this study also looked at the impact of concentration risk, which revealed that without Chinese and Indian supply and demand, the region will start seeing major bottlenecks immediately. Without China, the APAC region could start seeing immediate supply chain bottlenecks for onshore wind castings as well as offshore wind gearboxes, generators, blades, and power converters. Without India and China, there will be immediate onshore wind bottlenecks across all key components apart from towers.

To meet the growing regional demand for wind (with or without China and India), this study has identified key industrial strengths across Australia, Indonesia, Japan, Philippines, Singapore, South Korea, and Vietnam which could be scaled up or transitioned to supply the wind industry. As shown in the onshore and offshore wind maps on pages 5 and 6, the APAC region has a wealth of capabilities within existing companies with the potential to be scaled where they are existing wind suppliers or transitioned where they have operations that could be pivoted to the wind industry.

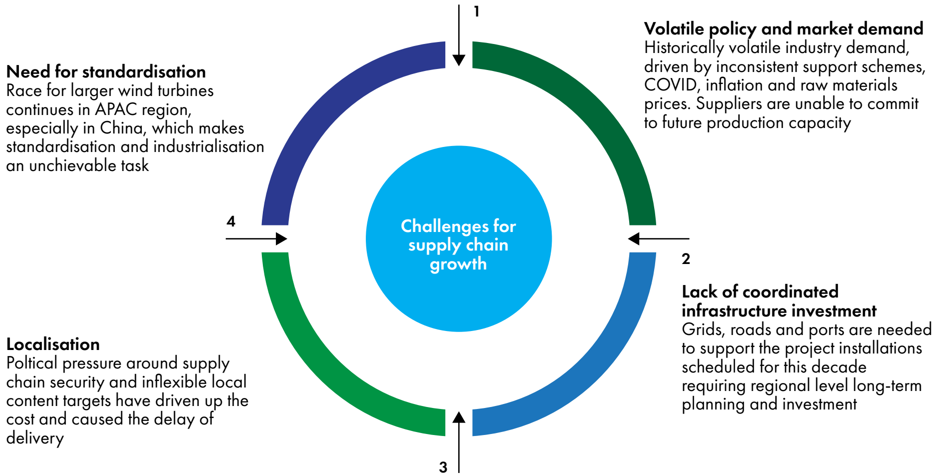
Four key challenges emerged through our industry consultations which should be addressed to scale up the supply chain and prevent the inevitable slowdown of wind installations that will ensue.

1. Volatile policy and market demand are preventing industry from adjusting and scaling production capacity. Parts of the supply chain are now loss-making and unable to commit to future production capacity, largely due to policy and regulatory barriers that lead to heightened uncertainty for project investments. In addition to setting targets and auction schedules, suppliers are looking for government commitments to project awards and the certainty that planned projects will move forward on reasonable timelines. In some cases, Tier 2 and Tier 3 suppliers are lacking the information needed to effectively assess the business case for suppling the wind industry (see recommendations 1, 3, 5 and 6).

2. Lack of coordinated investments in large infrastructure such as grids, ports, and roads as well as major equipment like vessels are impeding regional connectivity and trade. Critical infrastructure is needed to support the project installations scheduled for this decade requiring regional level long-term planning and investment. Large equipment such as vessels are

5. Key components (onshore wind and offshore wind) include gearboxes, generators, blades, power converters, towers, and castings. Balance of Plant (offshore wind) includes foundations and cables. Offshore wind enablers include vessels, ports, and workforce.
6. Minor bottlenecks are when supply is within 10% of demand, major bottlenecks are when supply is more than 10% under demand.
7. Transition industries are those with operations that could be pivoted toward the wind industry e.g., automotive, electronic, shipbuilding, etc.

Challenges for supply chain growth



Executive summary

Category	Assembly	Key Components						Critical Materials					Offshore Wind Balance of Plant		Offshore Wind Enablers		
Subject	Nacelles	Gearboxes	Generators	Blades	Power Converters	Towers	Castings	Rare Earth	Carbon Fibre	Steel Plate	Concrete	Copper	Foundations	Cables	Vessels	Ports	Workforce [8]
APAC onshore level criticality[9]	◔	◔	◕	◑	◕	○	◕	◑	◑	◔	○	◔					
ONW markets with potential to scale up /transition[10]	AUS, PH, SK, VT	IDN, JP, PH, SK	JP, SK, VT	JP, SK, VT	JP, SK, VT		All	AUS, IDN, PH, VT	JP, VT	AUS, IDN, PH, VT		AUS, IDN, PH, VT					
APAC offshore level criticality	◑	●	◕	●	◕	○	◕	◑	◑	◔	○	◔	◔	○	◕	◕	◑
OFW markets with potential to scale up/transition	JP, PH, SK, VT	IDN, JP, PH, SK	JP, SK, VT	JP, SK, VT	JP, SK, VT		IDN JP, PH, SK, VT	AUS, IDN PH, VT	JP, VT	AUS, IDN PH, VT		AUS, IDN PH, VT			All + SG	All + SG	All + SG

Key findings

Assembly and Key Components

- Onshore nacelle assembly is concentrated in China (85%) and to a lesser extent India. Similarly, offshore, assembly is predominantly Chinese (87%) with Korea and Japan expecting to start in 2026. Turbine OEMs prefer to set up nacelle assembly sites where there are significant pipelines.
- Most onshore gearboxes are produced in China (85%) and to a lesser extent India. Offshore gearbox supply is more constrained; technical threshold is high although diversification is possible.
- High concentration risk for generators depending on China who supply 100% OFW and 90% ONW.
- Presently APAC depends almost fully on China and India (onshore only) for blade supply. Japan, South Korea, and Vietnam have potential to increase capacity.
- Most power converters are Chinese (92% onshore and 98% offshore), but there are opportunities for countries with electrical industries to pivot toward wind supply.
- Due to lower entry barriers, towers and foundations have been produced in multiple markets.
- Concentration risk is high for castings, especially offshore; supplied almost exclusively by China.
- Industries with relevant skills e.g., O&G, automotive, electronic could pivot to supply wind components.
- A regional supply chain could enable more resilient access to needed components while ensuring continued trade and regional linkages to enable flexibility and address demand volatility.

Critical Materials

- General availability of needed materials at the regional level with high reliance on China. Australia and Indonesia have the potential to pivot and increase the regional supply of critical materials.
- Lack of geographic diversification, reliability, and affordability of critical minerals are constantly threatened by economic, political, or geopolitical uncertainty as well as high demand from the EU.
- Major centralisation for refining rare earth elements, with close to no capacity outside China and Malaysia. First alternative refineries expected in 2028.
- Sourcing challenge for carbon fibre has been resolved with major capacity expansion made in China. Japan is a global leader in carbon fibre production and potentially Vietnam could be ready to support regional demand.

Offshore Wind Balance of Plant

- Due to low entry barriers, fixed foundations are produced in multiple APAC markets.
- Floating may have supply gaps as technology evolves.
- Cable expertise exists in APAC, primarily SK, JP, and China. Cable supply is expected to exceed the regional demand when new facilities come online.

Offshore Wind Enablers

- More WTIVs with sufficient crane capacity/hook height are needed.
- WTIV bottlenecks are exasperated by cabotage rules. Vessel investments could be accelerated with more access to a regional market.
- Shortages are expected for heavy-lift vessels able to lift XXL monopiles and cable laying vessels as few exist outside China.
- Limited suitable ports outside of China. Some plan to pivot, but significant investment and long lead times are required to support the transition.
- A wide range of workforce skills exist throughout the region.

Recommendations

- Urgently scaling up a regional supply chain is key to reaching APAC's targeted wind installations
- Existing trade agreements can be leveraged to scale up supply chains
- Credible markets and committed pipelines are needed to trigger supply chain investments
- Supply chain capacity building outside auctions could boost resilience and reduce price pressure
- Transition industries could expand or pivot operations to fill wind industry bottlenecks
- International collaboration to scale up the floating wind supply chain could start now
- The wind industry must continue to standardise and industrialise

● = APAC bottleneck risk by 2030
○ = no APAC bottleneck risk by 2030

8. Workforce is addressed in GWEC & GWO: Global Wind Workforce Outlook 2024-2028.
9. Criticality is based on when a bottleneck appears in the region considering both full APAC supply chain availability and accounting for concentration risk (i.e., without China and / or India).
10. Focus is on the six target countries and Singapore where they could offer capabilities to expand or transition into wind by 2030 (this excludes major markets of China, Chinese Taiwan, and India). Countries are listed in alphabetical order AUS = Australia, IDN = Indonesia, JP = Japan, PH = Philippines, SG = Singapore, SK = South Korea, VT= Vietnam. All = the six target countries.

inefficiently used as localisation restrictions prevent a more efficient regional use between markets (see recommendations 2 and 3).

3. Political pressure around supply chain security and inflexible local content targets have driven up the cost and caused the delay of delivery.
The energy crisis of 2021 made energy resilience a core political theme, placing the focus on energy supply. Since then, the resilience agenda has expanded to encompass supply chains and industry. This has prompted varying industrial strategies from new wind markets to countries/regions with a fragmented supply chain footprint and countries with an at-scale supply chain. Thus far, many markets in the APAC region have focused on localisation of the supply chain to maximise the perceived benefits to the local economy. However, restrictive local content requirements in some markets have led to problems such as increased project capital expenditures and delayed delivery of components – and eventually the projects (see recommendations 2 and 4).

4. Race for larger wind turbines continues in APAC region, especially in China, which makes standardisation and industrialisation an unachievable task.
The race for ever larger turbines comes at a cost to suppliers challenged to support new technology with shortened product development time and without sufficient time for thorough testing. The lack of industry standardisation is pushing up costs and adding barriers to regional collaboration (see recommendation 7).

This study shows unequivocally that the development of a domestic supply chain will not be sufficient to support forecasted demand over the coming years but that a regional approach could enable the accelerated growth needed regionally and globally. Individual countries within APAC could leverage existing strengths to service the wider region and learn to lean on each other to cover any shortcoming to develop a symbiotic, mutually beneficial supply chain. Governments, project developers and suppliers throughout the wind energy value chain should engage in purposeful collaboration to prevent bottlenecks and achieve the ambitious wind energy buildout to 2030 and beyond. Seven key recommendations have been presented to achieve the necessary supply chain scale-up to meet the APAC wind energy demand through to 2030.

Recommendations

Recommendation 1: Regional supply chain scale-up is needed urgently if APAC is to meet 2030 targeted wind installations.
Given that the APAC region has a healthy pipeline of onshore and offshore wind projects, urgent action is requested of governments and industry to develop strategies and make necessary investments in time to fill the foreseen onshore and offshore wind supply chain bottlenecks expected to start this decade. This will enable the countries in the region to transform the region's economy while offering the scale of renewables that the world needs to triple renewable energy by 2030.

Supply chain is fundamental to unlocking this untapped renewable energy potential and countries could consider collaboration across borders to leverage the industrial strengths of each market, ensuring new project demands can be met using the best of the regional supply. This type of regional supply chain scaling of existing or pivot industries could bring greater economic returns for the entire region from working together to build out a larger volume of projects.

Recommendation 2: Existing trade agreements can be leveraged to scale up supply chains.
Trade policy should aim to build competitive industries, not push higher costs onto end users. Policy measures which unnecessarily restrict trade and foreign investment could lead to a slowdown in deployment that could put the energy transition in jeopardy. Supply chain capacity utilisation remains key to cost reduction and is only possible if resources can be shared across regions, with competitive cost positions and limited trade barriers.

APAC countries could consider leveraging existing regional trade agreements to build a marketplace that encourages cross-border collaboration, diversification of supply, and provides easier access to the large-scale regional demand needed to justify key investments to strategically grow each market's supply chain capacities and capabilities.

Recommendation 3: Credible markets and committed pipelines are needed to trigger supply chain

investments.
Credible pipelines and committed projects are needed for industry to justify the large investments required to scale up the existing supply chain and transition business toward wind supply. Industry is looking for governments to back up their wind targets with 15-year wind installation schedules supported by straight-forward regulatory policies and accelerated project awards to unlock large supply chain investments. Clear regulatory roadmaps for leasing and offtake processes will increase pipeline certainty driving investor confidence. The inclusion of wind energy targets in national energy plans and nationally determined contributions can provide policy continuity which will build industry confidence.

Recommendation 4: Public support for supply chain capacity building outside of auctions could boost resilience and sustainability while reducing price pressure on developers, especially for near term projects.
Governments could consider taking a longer-term view on supporting supply chain capacity building outside auction evaluation criteria to reduce price pressure during auctions, which is ultimately paid for by households, commercial and industrial consumers, cities, and other consumers of electricity. Although environmental sustainability could be considered among auction criteria, the path to building more sustainable supply chains requires long-term coordination across many stakeholders to drive the systemic change needed to ensure that sustainability targets drive responsible procurement.

Countries will benefit from public investment in supply chain growth, emerging technologies, longer-term industrialisation plans, and workforce training increasing attractiveness for domestic investors and industry (including companies with businesses that could transition to wind) entering the market.

Recommendation 5: Transition industries could be encouraged to expand or pivot operations to fill wind industry supply chain bottlenecks.
APAC industries with the potential to transition (and in many cases also decarbonise) operations include shipbuilding, offshore oil and gas/ EPCs, automotive, composite, and electrical / electronic manufacturing. Companies in these fields are considered to have skills and operations that could potentially be pivoted toward the wind supply chain.

Recommendation 6: International collaboration to scale up the floating wind supply chain could start now.
Floating wind will start to dominate certain APAC markets as it continues its path toward commercialisation, requiring its own supply chain to be ready. Building on the regional supply chain proposed in recommendation 1, a collaborative approach could be used already to build a floating wind supply chain ready to meet the expected growth within and outside the APAC region. This can include early planning with governments and learning from experiences from overseas. Governments could start looking at support schemes which will fit with the market fundamentals in the individual APAC floating markets to unlock the region's huge floating wind potential.

Recommendation 7: The wind industry must continue to standardise and industrialise.
Greater alignment on industry standards (e.g., health and safety, ESG, engineering design codes and environmental sustainability) between APAC countries could improve efficiencies and enhance regional and global collaboration. Governments could explore adopting international best practices on industry standards as financing will have minimum requirements that need to be observed. Adopting industry standards could provide a strategic avenue for APAC wind supply chain manufacturers to access global export markets and opportunities for companies that run responsible sourcing and procurement. Suppliers looking to meet financing requirements to upscale manufacturing or set up new bases should increase transparency and traceability to ensure oversight of the complete process, from raw material procurement to final product delivery.

Turbines are an important example of the need to standardise and industrialise. The race for larger turbines has left insufficient time for thorough testing, resulting in serial defects in the field. Rapid innovation on turbine and component design has not allowed for industrialisation of existing technologies.

CHAPTER 1: APAC MARKET STATUS AND WIND SUPPLY CHAIN OUTLOOK

Introduction and APAC Market Outlook

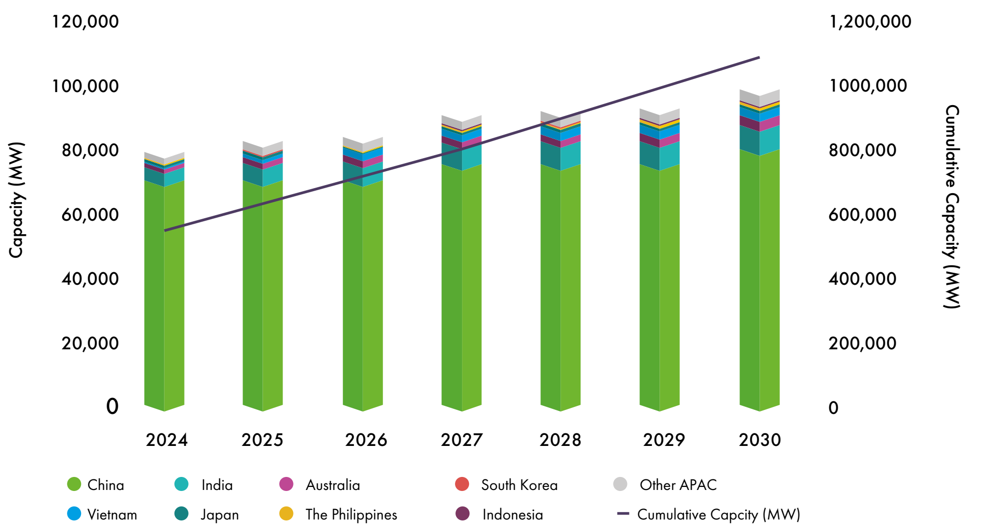
COP28 strengthened the global drive to accelerate renewables, with agreement from 133 countries to double energy efficiency and triple renewables capacity by 2030.[11] Action to increase clean energy generation globally could not be more urgent, and accelerated deployment of wind energy across Asia Pacific (APAC) countries is expected to play a critical role. The Global Wind Energy Council (GWEC) estimates that annual wind installation must increase three-fold this decade to meet net zero benchmarks, and this could be driven by the APAC region which already holds more than half (51%) of the world's total wind power installations by the end of 2023 and is expected to make up 61% of new additions worldwide between 2024 and 2030. Although most new wind installation will be driven by China and India, the rest of APAC may want to consider following suit to meet national wind targets and provide the supply chain with the confidence needed to build capacity and fill the foreseen bottlenecks currently expected to slow the industry.

Despite the potential in the region and ambition of individual countries to accelerate onshore and offshore wind deployment; this report will provide evidence that, without coordinated and strategic investment in a regional supply chain, bottlenecks will further increase hampering the needed acceleration of renewables.

This report provides a comprehensive view of the APAC supply chain capabilities out to 2030, starting with identification of where regional and domestic bottlenecks are most severe, moving to a deep dive into the industrial strengths and opportunities of the six target countries in this report – Australia, Indonesia, Japan, Philippines, South Korea and Vietnam – and substantiating the role of regional collaboration in closing near-future supply chain gaps. Establishment of a symbiotic supply chain ecosystem can allow countries to leverage existing industrial strengths and receive support from surrounding countries where they may fall short. Leveraging regional collaboration for the greater prosperity of all countries will also enable APAC to ramp up to the levels required of the Global Renewables and Energy Efficiency Pledge.

This report presents a bottom-up APAC supply chain assessment and provides recommendations based on more than 100 consultations with industry and government stakeholders across the region conducted in Q3 2024. During the consultations, stakeholders were asked to review the findings and provide opinions and recommendations for solving supply chain bottlenecks where gaps were identified. Although the focus has been on the six target countries, we have also included viewpoints from stakeholders in other APAC markets (e.g., China, India, Chinese Taiwan, and Singapore) to provide a comprehensive view of the region.

Onshore wind installation forecast up to 2030 in the Asia Pacific region (MW)



Source: GWEC, Brinckmann, 2024

Onshore wind APAC market outlook to 2030

APAC's total operational onshore wind (ONW) capacity will more than double to exceed 1 TW by

11. COP28 (2023). https://www.cop28.com/en/global-renewables-and-energy-efficiency-pledge

2030.
Within the APAC region, current GWEC projections show that the cumulative installed onshore wind capacity will more than double to 1,084 GW by 2030, from 466 GW at the end of 2023. This growth is led primarily by China, which is expected to add over 500 GW of onshore wind by 2030 on top of the over 400 GW that is already operational. This forecasted additional capacity in China equates to over 80% of the newbuild onshore wind capacity in this timeframe. India follows with an additional 45 GW by 2030, as the country has grown to be the fourth largest onshore wind market globally with a target to install 140 GW of wind by 2030. Australia and Vietnam are also expected to be significant contributors, installing 15 GW and 12 GW (including intertidal) in the same period, respectively. Annual installed capacity in the APAC region will steadily increase throughout the remainder of this decade from 79 GW in 2024 to 98 GW by 2030.

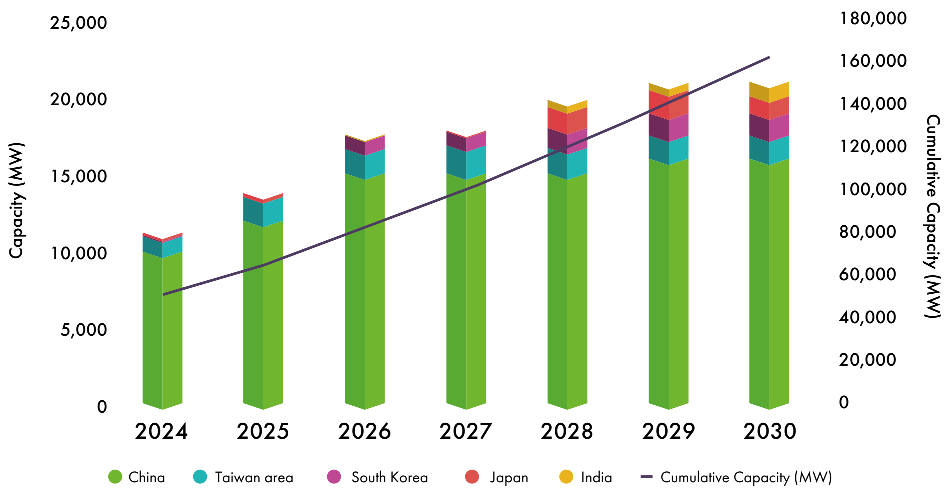
Offshore wind APAC market outlook to 2030

Offshore wind (OFW) development will increase this decade across major APAC markets.

The period leading up to 2030 is an exciting time for the offshore wind industry in APAC, with many markets beyond China and Chinese Taiwan expected to make significant strides. Markets including Japan and South Korea have already held offshore wind auctions with the first awarded projects expected to come online from 2026. Australia has also awarded its first feasibility licences to allow developers to begin site investigations; the Philippines has announced plans to begin the bidding process for its first offtake auction tender for offshore wind by the end of 2024, and Vietnam is developing a process to support its first offshore wind projects, working towards the targets of 6 GW of offshore wind by 2030 and 70 – 91.5 GW by 2050.

From 2024 to 2030, operational offshore wind capacity in APAC is forecasted to increase sixfold.
Over 120 GW of new offshore wind capacity is forecasted to be installed throughout the APAC region between 2024 and 2030, with the cumulative regional total reaching 160 GW by 2030. As with onshore wind, China is the largest offshore wind market with over 130 GW of capacity expected to be operational by the end of the decade. Other key markets include South Korea with 6 GW and Japan with over 4 GW expected to be operational by 2030. The annual installed capacity is projected to increase rapidly over the coming years with the current 11 GW increasing to 21 GW by 2030.

Offshore wind installation forecast up to 2030 in the Asia Pacific region (MW)



Source: GWEC, 2024

APAC Findings on the Wind Supply Chain Through to 2030

APAC wind supply and demand analysis

Onshore and offshore wind construction in APAC is expected to accelerate through 2030 requiring a robust, resilient supply chain to keep up with the forecasted regional demand. This report considers key onshore and offshore wind components, comparing the supply and demand levels for the target countries and the APAC region in isolation. Supply data was calculated from the bottom-up, based on desktop research of existing and planned supplier capacities. Demand data is based on GWEC's future forecasting of onshore and offshore wind installations.[12]

Below are the key assumptions made to conduct the bottleneck analysis.

- The bottleneck analysis assumes a closed market with imports and exports of components between the APAC region only, i.e., APAC supply needs to meet APAC demand with no flow of goods to or from the rest of the world.
- There are no trade restrictions within APAC.
- The demand for onshore and offshore wind components has been assumed to be concentrated entirely within the year of

12. The near-term wind market outlook (2024–2026), built using a bottom-up approach, is based on GWEC Market Intelligence's global wind project database, which covers projects currently under construction, global auction results and announced domestic tenders. For the medium-term market outlook (2027–2030), a top-down approach was used alongside existing project pipelines. This considers existing policies and medium/long-term national offshore wind targets. It assumes status quo on government policy, low to mid-industry interest, and average economic conditions.

Supply and demand analysis of key wind components in the APAC region (including all APAC suppliers)

Component	Unit	2024	2025	2026	2027	2028	2029	2030
ONW Nacelle Assembly	MW	79013	82515	83840	90572	91790	92440	98380
ONW Gearbox	MW	79013	82515	83840	90572	91790	92440	98380
ONW Generator	MW	79013	82515	83840	90572	91790	92440	98380
ONW Blades	MW	79013	82515	83840	90572	91790	92440	98380
ONW Power converters	MW	79013	82515	83840	90572	91790	92440	98380
ONW Towers	units	13326	12588	12707	12994	13089	12272	12790
ONW Castings	tonnes	963959	1006683	1022848	1104978	1119838	1127768	1200236
OFW Nacelle Assembly	MW	11136	13740	17562	17805	19885	20980	21070
OFW Gearbox	MW	11136	13740	17562	17805	19885	20980	21070
OFW Generator	MW	11136	13740	17562	17805	19885	20980	21070
OFW Blades	MW	11136	13740	17562	17805	19885	20980	21070
OFW Power Converters	MW	11136	13740	17562	17805	19885	20980	21070
OFW Towers	units	1137	1343	1439	1391	1410	1404	1347
OFW Castings	tonnes	197107	243198	310844	315149	351965	371346	372939
OFW Cables	km	3959	4885	6243	6330	7069	7458	7490
Fixed Foundations	units	1136	1337	1406	1359	1380	1364	1242
Floating Foundations	units	1	6	33	32	30	40	105
WTIV	MW	11136	13740	17562	17805	19885	20980	21070

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component commercial operation of the respective windfarms.

- Where quantitative data regarding the supply capabilities of a facility was not available, either through publicly available information or consultations with stakeholders, their capacities have been estimated by comparison to similar facilities within the region and/or other markets.

The values included in the tables below reflect the annual demand for each component in the APAC region until 2030. The colour of each cell

Supply and demand analysis of key wind components in the APAC region (excluding Chinese supply and demand)

Component	Unit	2024	2025	2026	2027	2028	2029	2030
ONW Nacelle Assembly	MW	9013	12515	13840	15572	16790	17440	18380
ONW Gearbox	MW	9013	12515	13840	15572	16790	17440	18380
ONW Generator	MW	9013	12515	13840	15572	16790	17440	18380
ONW Blades	MW	9013	12515	13840	15572	16790	17440	18380
ONW Power Converters	MW	9013	12515	13840	15572	16790	17440	18380
ONW Towers	units	2557	3255	3374	3619	3714	3449	3378
ONW Castings	tonnes	109959	152683	168848	189978	204838	212768	224236
OFW Nacelle Assembly	MW	1136	1740	2562	2805	4885	4980	5070
OFW Gearbox	MW	1136	1740	2562	2805	4885	4980	5070
OFW Generator	MW	1136	1740	2562	2805	4885	4980	5070
OFW Blades	MW	1136	1740	2562	2805	4885	4980	5070
OFW Power Converters	MW	1136	1740	2562	2805	4885	4980	5070
OFW Towers	units	137	143	189	237	339	338	347
OFW Castings	tonnes	20107	30798	45344	49649	86465	88146	89739
Fixed Foundations	units	137	143	181	230	315	298	272
Floating Foundations	units	0	0	8	7	24	40	75
Cables	km	404	619	911	997	1737	1770	1802
WTIV	MW	1136	1740	2562	2805	4885	4980	5070

Supply and demand analysis of key onshore wind components in the APAC region (excluding Chinese and Indian supply and demand)

Component	Unit	2024	2025	2026	2027	2028	2029	2030
ONW Nacelle	MW	4813	7015	7740	8472	9290	9940	10880
ONW Gearbox	MW	4813	7015	7740	8472	9290	9940	10880
ONW Generator	MW	4813	7015	7740	8472	9290	9940	10880
ONW Blades	MW	4813	7015	7740	8472	9290	9940	10880
ONW Power Converters	MW	4813	7015	7740	8472	9290	9940	10880
ONW Towers	units	1057	1422	1468	1530	1631	1663	1711
ONW Castings	tonnes	58719	85583	94428	103358	113338	121268	132736

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component reflects the status of the APAC supply chain relative to this demand. Where the current planned supply capacities for the component is greater than the forecasted demand, and thus no bottleneck is expected, this is shown in green. Amber indicates that the demand slightly exceeds the supply levels, by under 10%. Finally, red denotes that the demand exceeds supply by over 10% and therefore there is risk of a significant bottleneck.

Under this study's assumption that APAC demand is met with supply from the region, the earliest bottlenecks are expected in 2029 and 2030 for gearboxes and blades with demand falling to within 10% of the regional demand.

This picture changes quickly when Chinese supply and demand is removed from the analysis, apart from onshore gearboxes, towers, and foundations.

In 2024, China contributed 89% of onshore wind demand and 91% of offshore wind demand. Whilst this share is reduced to 81% for onshore and 69% for offshore by 2030 due to growth in other APAC markets, China will continue to commission and supply the majority of wind energy capacity in APAC, holding a dominant position across nearly the entire supply chain.

Indian supply chain is quite critical to meet onshore wind demand for components, and without China and India the rest of the APAC region would suffer extreme supply shortages across all main components, apart from towers, unless filled by the global market.

China and India will play critical roles in the present and future supply chain; however, even with these two powerhouses, bottlenecks are expected unless our target markets ramp up. With increased regional cooperation, APAC could have a more diversified and efficient supply chain to derisk regional installation rollout as project installations increase.

Overview of existing APAC capabilities

Markets	Nacelle Assembly	Key Components	Critical Materials	Balance of Plant	Offshore Wind Enablers	Other Capabilities	Transition or Pivot Industries
China	Full supply chain						
India	Onshore	Onshore full supply chain	Rare earths, steel, concrete, copper				O&G
Australia		Tower components	Rare earths, steel, copper		Workforce		Ports, mining, cables, shipbuilding (service vessels)
Indonesia		Towers	Rare earths, steel, concrete, copper	Foundations	WTIV, workforce		O&G, mining, automotive (castings), EPC
Japan	Offshore	Onshore gearboxes, towers	Carbon fibre	Foundations, Cables	WTIV, ports	Bearings, switchgear, substations, service vessels	Electrical component manufacturing (generators, power converters), automotive
South Korea	Onshore and offshore	Gearbox, onshore blades, towers	Steel (production not iron ore), concrete	Foundations, cables	WTIV, ports, workforce	Forgings, transformers	Electrical component manufacturing, automotive, shipbuilding
Philippines			Rare earths, steel, concrete, copper	Cables	Workforce (seafarers)	Service vessels	Ports, mining, shipbuilding (floating foundations), EPC, automotive (gearbox, castings)
Vietnam		Towers, power converters, generators	Rare earths, steel, concrete, copper, carbon fibre	Foundations, cables	Workforce	Service vessels, onshore wind EPC	Ports, mining, cables, O&G, shipbuilding, automotive (castings)
Singapore				Foundations	WTIV	Floating platforms, substations, service vessels, project finance, moorings	O&G, shipbuilding
Chinese Taiwan	Offshore	Blades, towers, castings	Carbon fibre, steel, concrete	Foundations, cables	WTIV, ports, workforce	Service vessels. Resins (blades)	Electrical component manufacturing

Looking at a 2030 APAC Wind Supply Chain and Beyond

APAC market capabilities and transition industries

The rapid increase in demand for wind installations offers huge opportunities for suppliers looking to expand existing capacities, develop new capabilities and pivot related industries towards the wind industry. China and India will continue to play a key role in supplying APAC wind projects; however, for the wind industry to thrive, other APAC markets should also invest in their supply chains. The table above summarises the capabilities identified during the consultation phases, as well as non-wind industries that have the potential to transition their businesses to also supply the wind supply chain. Please see the specific country chapters for more details on specific strengths, opportunities and recommendations for each of the target markets.

Key findings

Turbine Nacelle Assembly

Onshore Nacelle Assembly: The impact of removing the supply of onshore nacelle assembly from both China and India indicates a strong regional dependency on these suppliers to meet the demand of APAC, if imports from other regions are not considered. Including supply from China and India, no bottlenecks are expected through to 2030; however, without supply from China and India, the region will face bottlenecks immediately through to 2030.

There are existing onshore nacelle assembly capabilities in South Korea and capabilities in Vietnam that could be transitioned to support the region. However, other countries like Australia and the Philippines have been flagged as having the potential industries to partner with international OEMs to meet domestic needs.

Offshore Nacelle Assembly: Minor bottlenecks[13] for offshore nacelle assembly are expected in 2030 in the APAC region (excluding China). Bottlenecks are expected to become more significant from 2030, as demand increases. When including Chinese nacelle assembly, no bottlenecks are expected across APAC through to 2030.

There are planned offshore nacelle assembly capabilities in Japan and South Korea, and capabilities that could be transitioned in Vietnam.

Key components

Gearboxes: In the APAC region, supply for onshore wind gearboxes is sufficient to meet demand through to 2030. When the supply and demand from China is removed, there are no bottlenecks. However, when the supply and demand from China and India are removed, there is a major bottleneck[14] throughout the whole forecast period.

For offshore wind, the APAC region is expected to face minor shortages of gearboxes towards the end of the decade. However, bottlenecks are significantly increased when supply from China is removed, causing major bottlenecks throughout the whole forecast period.

Gearboxes are currently manufactured predominantly in China, India, Japan, and South Korea. Countries with an automotive industry like Indonesia and the Philippines could consider the potential for a transition to supply of gearboxes, but investors should be aware that the technical threshold and risk for gearbox production is high compared with other build-to-print components.

Generators: The supply of generators in APAC is concentrated in China for both onshore and offshore wind applications. No bottlenecks for offshore wind generators are expected when including Chinese suppliers in the analysis. Excluding China, the APAC region will start seeing gaps in generator supply starting in 2026 for onshore wind and immediately for offshore wind. When removing China and India from the scenario, bottlenecks for onshore generators are expected immediately.

Generators can be provided by Vietnam for onshore applications, but, there is still a large supply chain gap outside China. To improve diversification of supply Japan and Korea could also potentially transition electrical manufacturing toward increased supply of generators.

13. Minor bottleneck means supply is within 10% of the demand in a given year
14. Major bottleneck means supply is greater than 10% of demand in a given year

Blades: Within the APAC region, over 98% of total blade production is in China and India. Starting in 2029 for onshore wind and immediately for offshore wind, the APAC region without China will start seeing gaps in blade supply.

Blades are expected to continue to be supplied by India and China through to 2030; however, a new blade facility has been announced in Vietnam to support the Vietnamese market and growth in this region. Beyond 2030, we expect other countries to build capabilities, especially countries with large pipelines.

Power Converters: When sourcing from within the APAC region, projects are heavily reliant on Chinese power converters to meet on and offshore wind demand. Starting in 2025 for onshore wind and immediately for offshore wind, the APAC region excluding China will start seeing bottlenecks in power converter supply.

Going forward, Vietnam has the potential to expand existing capabilities and increase exports of power converters across APAC. South Korea, Japan, the Philippines and Indonesia could leverage capabilities in electrical component manufacturing to transition towards the supply of power converters.

Towers: For both on and offshore wind, towers are not expected to be a bottleneck when considered regionally.

Castings: China leads casting manufacturing within APAC and is crucial to meeting the region's on and offshore wind demand. Starting immediately for onshore wind and in 2025 for offshore wind, the APAC region without China will start seeing gaps in castings supply.

India has a local casting supply chain, but capacity for the large-casted items used in offshore wind is missing at present. Other markets within APAC (Vietnam, the Philippines and Indonesia) could leverage existing capabilities in their automotive industries and expand capabilities to transition to supply castings for onshore and offshore wind across the region.

Offshore Balance of Plant

Foundations: Foundation supply is healthy across offshore wind; no bottlenecks are expected for fixed foundations through to 2030 in this region even when the Chinese supply chain is excluded. For floating foundations, no bottlenecks are expected across APAC. However, when China is excluded, major bottlenecks are expected in 2026, before additional supply capacity is due to come online, and again in 2030 when demand increases to 75 units.

Cables: When considered regionally, no bottlenecks are expected for cables throughout the forecast period, even when excluding supply from China.

Offshore Enablers

Wind turbine installation vessels (WTIVs): No WTIV shortages are seen across the APAC region when assuming free movement of vessels between APAC countries. However, when excluding China, bottlenecks are seen from 2028. There could be earlier instances of shortages due to cabotage rules in Japan and South Korea, and increasing sizes of turbines making some vessels unsuitable.

With vessels from Europe and Japan available to support, no bottleneck is expected for the Chinese Taiwan offshore wind market, but the situation is likely to change if those foreign WTIVs are required to support the growth in their home markets.

In addition to WTIVs, South Korea, Singapore, the Philippines, Vietnam and Australia could leverage their shipbuilding industries to support the manufacturing of offshore wind service vessels.

Ports: The availability of offshore wind marshalling has been omitted from the supply and demand analysis of key wind components in the APAC region table above as this is best considered at a market-by-market level (see Chapter 2 for a more detailed discussion) in APAC. In certain regions such as Northern Europe, there have been cases where marshalling ports are used to support construction in neighbouring countries, but this is unlikely to be a feasible solution in APAC where the geographical distances involved are much greater.

CHAPTER 2: DEEP DIVE INTO THE APAC WIND SUPPLY CHAIN

APAC wind supply chain status

Over the last decade, China has emerged as not only the world's leading wind turbine manufacturing base but also as the largest production hub for key components and materials. As the second-largest APAC hub for onshore wind turbine assembly and key components production, India has gained an increasingly prominent role in the global onshore wind supply chain.

In addition to the predominantly Chinese and Indian wind suppliers, APAC also relies on regional suppliers from Northeast Asia (South Korea and Japan), Southeast Asia (Vietnam, Philippines, Indonesia, Chinese Taiwan and Singapore) and increasingly central Asia, which has attracted renewable energy investment in recent years (e.g., Kazakhstan).

Onshore wind

Regionally, the onshore wind industry is able to meet its demand across the supplier categories studied through to 2030. However, if China cannot participate in the APAC market (either for supply or demand) supply bottlenecks appear across all categories apart from onshore nacelle assembly, gearboxes and towers. India is a critical regional supplier for nacelle assembly and to a lesser extent gearboxes which Japan and South Korea can also supply. Tower supply is already more diversified across APAC. Even taking both India and China out of the equation, supply from Vietnam, South Korea, Indonesia and Japan is sufficient to meet regional onshore tower demand through to 2030.

Offshore wind

China also dominates the offshore wind supply chain, which it is striving to scale up to meet its high domestic demand. Even with Chinese supply, the study identifies minor bottlenecks for gearboxes and blades starting in 2029 and 2030, respectively. Depending on rigidity around cabotage rules, bottlenecks may appear for vessels before 2030 regardless of the actual supply in the region. Chinese Taiwan expects WTIV bottlenecks due to insufficient domestic supply and may need to rely on foreign vessels. China, South Korea and Japan have ports suitable for offshore wind from 2024 to 2030, but as things stand, only Chinese ports will be able to meet China's domestic demand. Bottlenecks

related to Japanese port availability is dependent on the successful execution of the upgrades of the offshore wind base ports designated by the government.

As with onshore wind, the regional bottlenecks identified without Chinese supply and demand for offshore wind changes considerably. APAC (excluding China) can produce enough offshore wind towers and fixed foundations to meet regional demand, as the supply chains for these two components are the most diversified geographically. Indonesia and Vietnam have the highest export capability potential for offshore towers through to 2030, due to their relatively low domestic demand. Similarly, the Philippines, Vietnam and Indonesia will be the main exporters of foundations for the same reason, while South Korea will also have high exports because of its strong manufacturing capacity. Lastly, assuming fulfillment of the announced investment plans in South Korea and Japan, the regional supply chain for offshore nacelle assembly, even excluding China, will be able to meet demand until 2029, with only a minor bottleneck expected in 2030.

China supplies most critical materials for the wind sector not only regionally, but also globally. The supplier research revealed some mining and refining capacities in other APAC countries, with different protagonists depending on the material.

TURBINE NACELLE ASSEMBLY

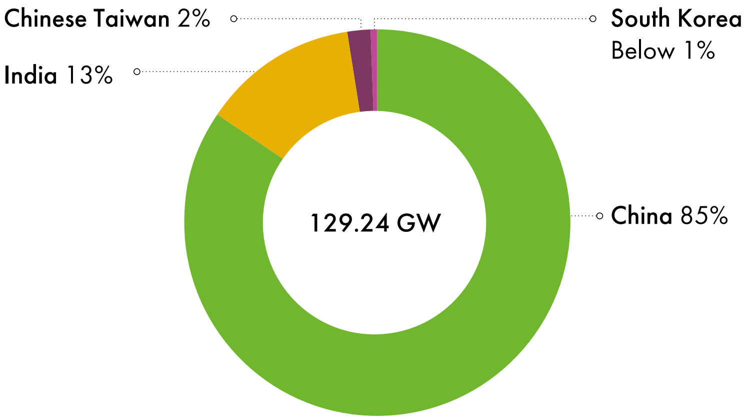
The nacelle of a wind turbine supports the rotor and converts the rotational energy from the rotor into three-phase AC electrical energy. Turbine OEMs assemble nacelles using components generally sourced from a range of external suppliers.

In APAC region, most of the nacelle assembly plants are in China and India. Looking at the overall market for onshore and offshore wind nacelle assembly, the Chinese market accounts for 85% of the whole APAC nacelle assembly capacity. India is the next largest producer of nacelles and driven exclusively by onshore wind, followed by Chinese Taiwan and South Korea to a much lesser extent.

Challenges in the supply chain for onshore wind nacelles

As per the assembly of nacelles for onshore wind turbines, China is still the dominant supplier in APAC, with an 85% share. India and South Korea's nacelle capacity is solely onshore, driven by India's Suzlon, Inox, Adani and Senvion India and South Korea's Doosan and Unison. Record investment commitments were made at RE Invest 2024, including an additional 11 GW of turbine manufacturing capacity expected to be added between 2025 and 2030.

Onshore and offshore turbine nacelle assembly capacity APAC, 2024 (MW)



Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Assessing each market's capacity to supply its own demand for onshore nacelle assembly, only the three APAC countries (China, India, and South Korea) can meet their respective demand. Meanwhile, markets that have no assembling facilities for onshore wind turbines will depend on imports from China or India if they want to avoid bottlenecks in nacelle assembly supply. When excluding supply from China and India, APAC faces major bottleneck risks immediately through to 2030.

In Japan, there were three wind turbine OEMs (Mitsubishi Heavy Industries, Hitachi[15] and Japan Steel Works) with turbines exceeding 2 MW. However, by 2019, all three companies had withdrawn from the market, struggling to grow their capabilities in a stagnant domestic onshore wind market and unable to compete with international OEMs in overseas markets. Though smaller companies such as Komai Haltec are producing 300 kW turbines, Japan currently has no active nacelle assembly capacity for MW-scale onshore wind turbines.

In South Korea, there are two active domestic turbine OEMs, Doosan Enerbility and Unison. Doosan's current onshore wind offerings include 3 MW and 3.3 MW models,[16] with approximately 150 MW of onshore capacity installed in Korea.[17] Meanwhile Unison produces 2 MW and 4 MW sized turbines[18] for onshore wind projects and has contributed over 240 WTGs domestically, equivalent to 480 MW of installed capacity.[19]

Challenges in the supply chain for offshore wind nacelles

In terms of supply for offshore wind nacelle assembly, China accounted for most of the APAC capacity, holding an 87% share. Other production capacity is in Chinese Taiwan, which increased from 1.2 GW in 2023 to 3 GW in 2024. This increase is due to the start of production from Siemens Gamesa at its expanded nacelle assembly facility in Taichung. Furthermore, Japan and South Korea could begin assembling offshore turbine nacelles in 2026, through partnerships between local companies and international OEMs.

Considering the upcoming demand for offshore nacelles, only China and Chinese Taiwan can avoid bottlenecks within their respective

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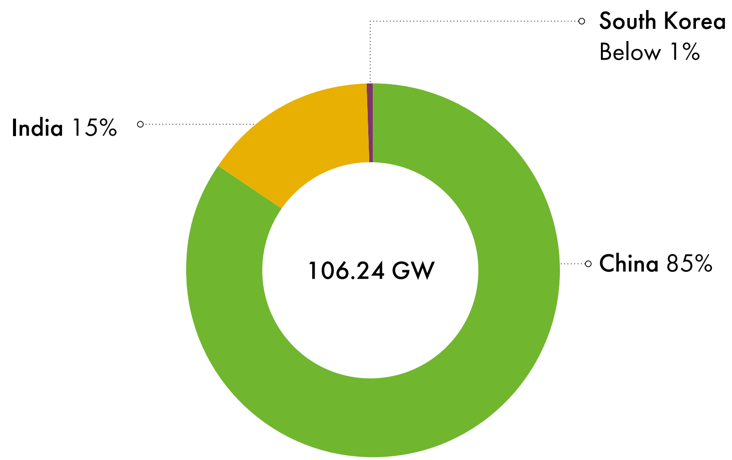
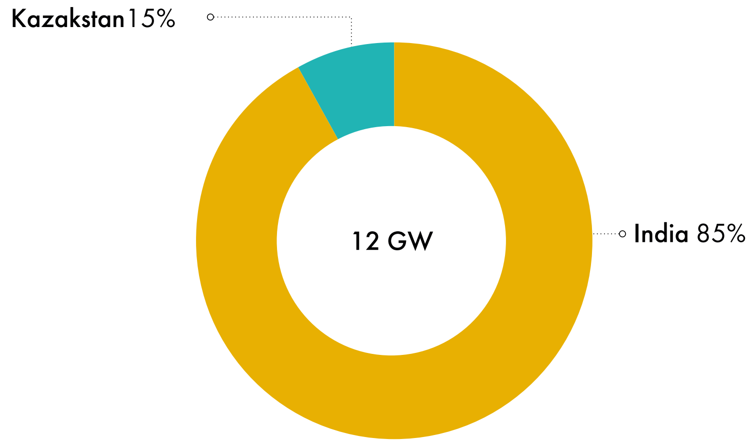
16. Doosan Enerbility. https://www.doosanenerbility.com/en/business/wind_energy_lineup
17. Doosan Enerbility. https://www.doosanenerbility.com/en/business/wind_energy_results
18. Unison. https://www.unison.co.kr/product
19. Unison. https://www.unison.co.kr/unison/performance

APAC onshore wind demand and supply benchmark - 2024-2030

Onshore turbine nacelle assembly capacity APAC, 2024 (MW)



Planned new onshore turbine nacelle assembly capacity up to 2030



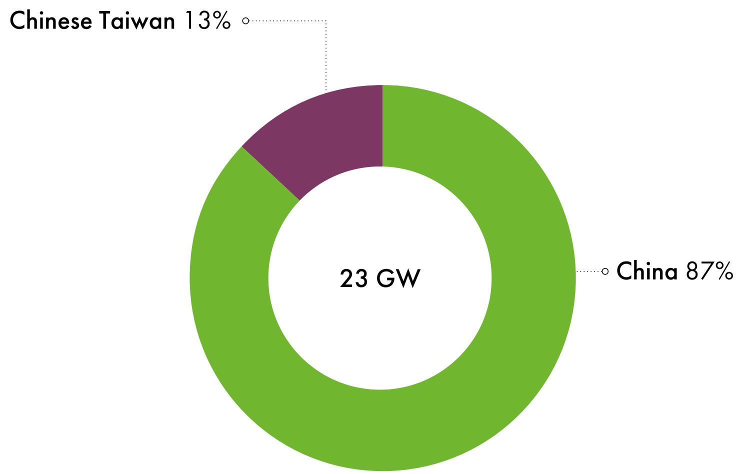
Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	1500	2000	2000	2000	2000	2500	3000
Indonesia	0	180	200	220	240	240	280
Japan	800	800	800	800	800	800	800
Philippines	200	245	750	600	600	600	600
South Korea	200	200	200	200	200	200	200
Vietnam	500	1000	1000	2000	2500	2500	2500
China	70000	70000	70000	75000	75000	75000	80000
India	4200	5500	6100	7100	7500	7500	7500
Chinese Taiwan	50	50	50	50	50	50	50
Other APAC	1563	2540	2740	2602	2900	3050	3450
TOTAL	79013	82515	83840	90572	91790	92440	98380
TOTAL (excl. China)	9013	12515	13840	15572	16790	17440	18380
TOTAL (excl. China and India)	4813	7015	7740	8472	9290	9940	10880

● Supply exceeds demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

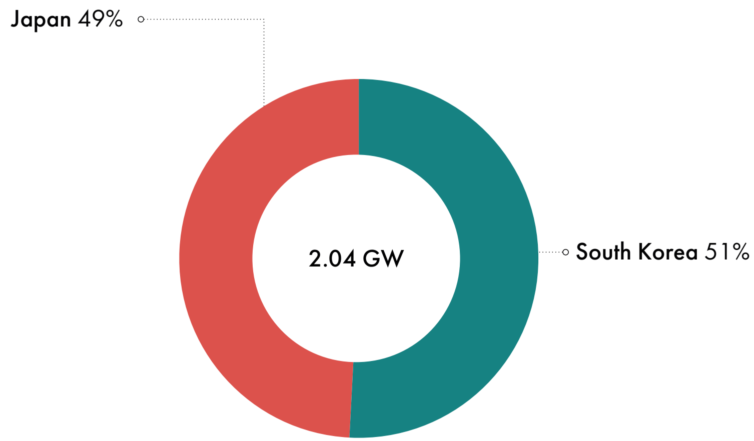
Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

APAC offshore wind demand and supply benchmark – 2024-2030

Offshore turbine nacelle assembly capacity APAC, 2024 (MW)



Planned new offshore turbine nacelle assembly capacity up to 2030



Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	112	220	17	60	1405	1480	1070
Philippines	0	0	0	0	0	0	0
South Korea	100	0	880	895	1230	1500	1500
Vietnam	0	0	0	0	0	0	0
China	10000	12000	15000	15000	15000	16000	16000
India	0	0	20	0	500	500	1000
Chinese Taiwan	924	1520	1645	1850	1750	1500	1500
TOTAL	11136	13740	17562	17805	19885	20980	21070
TOTAL (excl. China)	1136	1740	2562	2805	4885	4980	5070

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

markets, as they serve as primary suppliers for the region. Even without Chinese supply, Chinese Taiwan can support regional demand through to 2029.

At present, there is no offshore wind nacelle assembly plant in Japan. The country will start assembling offshore nacelles in 2026, although current announced capabilities (1040 MW) would not be sufficient to avoid bottlenecks from 2028 to 2030. In 2021, Toshiba Energy Systems announced a partnership with GE for the domestic assembly of the Haliade-X offshore wind turbines in Japan.[20] Assembly of 80 nacelle units per annum[21] is expected to commence in 2026 to supply the Round 1 and Round 2 offshore wind projects, which have announced CODs of 2028 to 2030. Last year, Toshiba announced that it had produced a shortlist of five companies in Akita Prefecture to supply nacelle components, with final decisions expected in 2025.

South Korea's Doosan Enerbility has developed a 5.5 MW offshore model which has been selected for the 100 MW Jeju Hallim Offshore Wind Farm,[22] currently under construction and set to be the largest operational offshore wind project in the country upon completion. The company built its second wind turbine location in 2021 for its 5.5 MW offshore turbine, with an annual production capacity of 30 turbines.[23] It has obtained type certification for its 8 MW model and is developing a 10 MW turbine for commercialisation. Doosan Enerbility is also signing a strategic framework agreement with Siemens Gamesa to assemble their offshore wind nacelles.[24] In October 2024 the two companies signed a MoU with Equinor to supply Siemens Gamesa's 15 MW class turbines, for which the nacelles will be assembled at Doosan Enerbility's Changwon facility, destined for the 750 MW Bandibuli floating offshore windfarm[25] Additionally, GE Vernova revealed in 2022 that it had signed a strategic partnership agreement with Hyundai Electric for the Korean company to support the local nacelle assembly and manufacturing of generators for the Haliade-X wind turbines.[26] Vestas and Danish logistics company Maersk signed a MOU with Jeonnam Province and Mokpo City to build a nacelle factory and logistics base at the Mokpo New Port Hinterland Complex in 2024.[27]

Unison has been developing an offshore wind 10 MW direct-drive turbine which is currently undergoing testing and is expected to be ready for commercialisation by 2026.[28] The company has also established a joint venture with Chinese turbine OEM Mingyang Smart Energy to establish a wind turbine nacelle assembly plant, as well as blade manufacturing facilities in South Korea.[29] Furthermore, Chinese Shanghai Electric co-established a legal entity called HSE Wind with HYOSUNG in South Korea in 2021 and plans to produce 50 units of 10 MW offshore wind turbine per annum in South Korea.

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29. Offshore Wind Biz (2024). https://www.offshorewind.biz/2024/09/05/mingyang-to-manufacture-wind-turbines-in-south-korea/

KEY COMPONENTS

Gearboxes

The gearbox is the part of the wind turbine that increases the rotational rotor speed before feeding it to the generator. The conventional high-speed gear drive converts rotor torque at a speed of 5-15 rpm to a speed of up to about 1500 rpm for conversion to electrical energy by the generator, while a medium-speed gearbox (or hybrid drive) converts it to a speed of 600 rpm. However, not all wind turbines use a gearbox; instead, some utilise direct drive technology as an alternative. Despite the higher costs, direct drive turbines are becoming widely used in offshore wind, as they have better reliability and lower maintenance costs. The most used type of drivetrain technology is still the high-speed gearbox, followed by medium-speed gearbox and direct drive (DD).

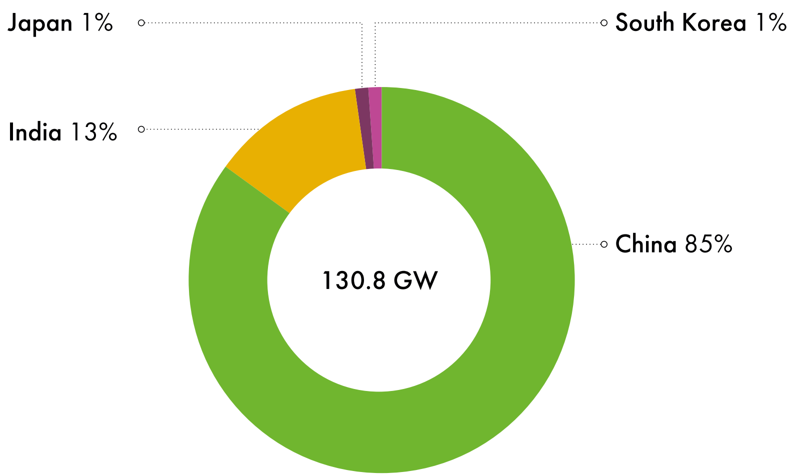
Challenges in the supply chain for onshore wind gearboxes

Onshore gearboxes in the APAC region are mainly produced in China (85%). Outside of China, India is the main producer, followed by Japan and South Korea, whose capacity is rather limited in comparison. China and India are expected to remain as the regional main suppliers, with increases of production capacity in both markets in 2026 and 2025, respectively.

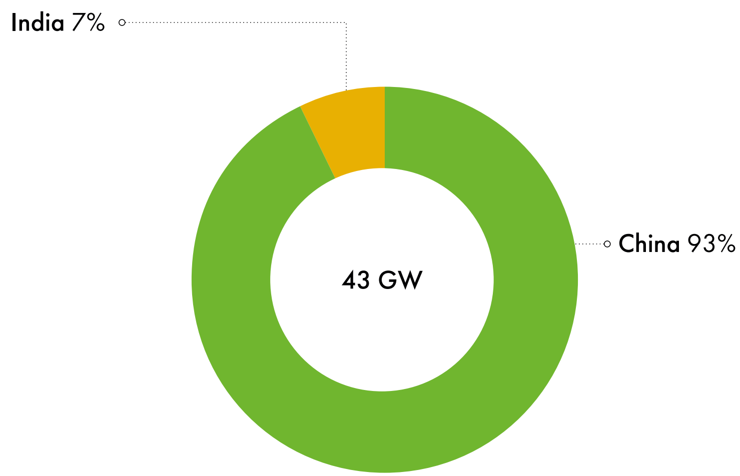
At the national level, the four APAC markets (China, India, Japan, and South Korea) that produce

Onshore wind gearboxes demand and supply benchmark- 2024-2030

Onshore turbine gearbox production capacity APAC, 2024 (MW)



Planned new onshore turbine gearbox production capacity up to 2030



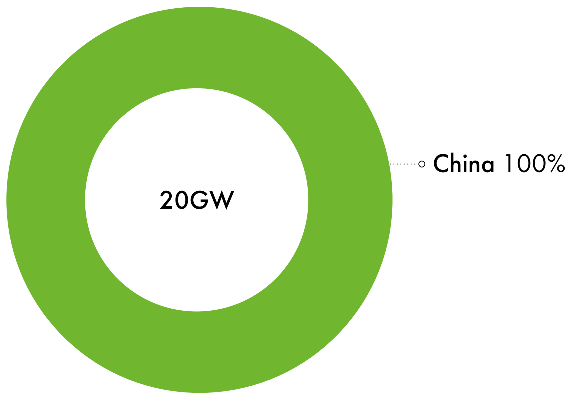
Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	1500	2000	2000	2000	2000	2500	3000
Indonesia	0	180	200	220	240	240	280
Japan	800	800	800	800	800	800	800
Philippines	200	245	750	600	600	600	600
South Korea	200	200	200	200	200	200	200
Vietnam	500	1000	1000	2000	2500	2500	2500
China	70000	70000	70000	75000	75000	75000	80000
India	4200	5500	6100	7100	7500	7500	7500
Chinese Taiwan	50	50	50	50	50	50	50
Other APAC	1563	2540	2740	2602	2900	3050	3450
TOTAL	79013	82515	83840	90572	91790	92440	98380
TOTAL (excl. China)	9013	12515	13840	15572	16790	17440	18380
TOTAL (excl. China & India)	4813	7015	7740	8472	9290	9940	10880

● Supply exceeds demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Offshore wind gearboxes demand and supply benchmark - 2024-2030

Offshore turbine gearbox production capacity APAC, 2024 (MW)



gearboxes for onshore wind turbines will be able to meet their respective demand, with Australia, Indonesia, Philippines, Vietnam, and other APAC countries depending on gearbox imports. Both including and excluding China in the analysis, the APAC region would be self-sufficient, with no dependency on imports from other regions.

Challenges in the supply chain for offshore wind gearboxes

For offshore wind, China is the only gearbox producer in the APAC region. Chinese offshore gearbox capacity accounts for approximately one sixth of its total production of gearboxes, combining both onshore and offshore technologies.

When it comes to offshore turbine gearboxes, Chinese Taiwan's lack of production capacity makes it reliant on imports, like Japan, South Korea and India. Regionally, APAC will be able to meet growing demand with Chinese manufacturers up to 2030, although the demand and supply benchmark analysis shows that the supply of offshore gearboxes could suffer a bottleneck from 2029. This is because at least 15% of the forecasted installations in APAC region in 2024-2030 will use the direct drive technology, in turn reducing demand for gearboxes.

Demand vs supply analysis, 2024-2030 (MW)

Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	112	220	162	60	1405	1480	1070
Philippines	0	0	0	0	0	0	0
South Korea	100	0	880	895	1230	1500	1500
Vietnam	0	0	0	0	0	0	0
China	10000	12000	15000	15000	15000	16000	16000
India	0	0	20	0	500	500	1000
Chinese Taiwan	924	1520	1645	1850	1750	1500	1500
TOTAL	11136	13740	17562	17805	19885	20980	21070
TOTAL (excl. China)	1136	1740	2562	2805	4885	4980	5070

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Generators

Generators are crucial to producing electricity from wind, as they convert mechanical energy to electrical energy. According to GWEC's Global Wind Supply Side Data 2023[30] report, 60% of the new installations in 2023 use doubly fed induction generators (DFIGs), followed by medium speed permanent magnets generators (MS PMGs, 21%), direct drive PMGs (DD PMGs, 7%), squirrel-cage induction generators (SCIGs, 10%) and electrically excited synchronous generators (EESG, 2%). Of the generator technologies, DD PMGs and MS PMGs require rare-earth elements (REE) to support production.

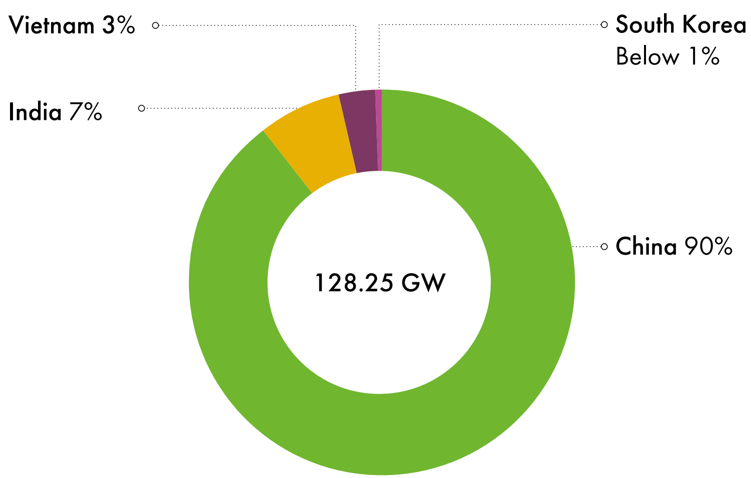
Challenges in the supply chain for onshore wind generators

China holds 90% of the onshore generator production in APAC, with India and Vietnam having capabilities – and South Korea to a lesser extent.

Most APAC countries are dependent on Chinese generators to meet onshore wind energy demand, if imports from other regions are not considered – except for India, Vietnam and South Korea, the other three producers in the region. When assessing the supply and demand of key components under a closed markets scenario, India, Vietnam and South Korea will have sufficient capacity to meet their domestic demand for generators as well as additional capacity that could be exported across the APAC region to help manage the expected

Onshore wind generators demand and supply benchmark- 2024-2030

Onshore turbine generator production capacity APAC, 2024 (MW)



bottlenecks. GE has been operating in Vietnam for over 15 years producing and exporting onshore generator systems at the GE Hai Phong facility. Since 2008, the GE Hai Phong facility has been generating export revenues worth $2 billion.[31] The Haiphong factory is strategically positioned to export primarily wind turbine generators and electrical-control-system components around the world.

Challenges in the supply chain for offshore wind generators

China is the only supplier of generators for offshore wind turbines in the region. Moreover, it has plans to expand its offshore generator capacity by 5 GW in 2025.

Compared with the onshore wind generator supply chain, the situation is different for offshore wind, with higher risks of supply chain bottlenecks. Without China, the APAC markets will rely on imports from other regions to meet the demand, given that China is the only producer of offshore generators. Therefore, markets with growing offshore wind demand like Japan, South Korea, Chinese Taiwan and India will depend on imports either from China or from Europe.

Demand vs supply analysis, 2024-2030 (MW)

Market	2024	2025	2026	2027	2028	2029	2030
Australia	1500	2000	2000	2000	2000	2500	3000
Indonesia	0	180	200	220	240	240	280
Japan	800	800	800	800	800	800	800
Philippines	200	245	750	600	600	600	600
South Korea	200	200	200	200	200	200	200
Vietnam	500	1000	1000	2000	2500	2500	2500
China	70000	70000	70000	75000	75000	75000	80000
India	4200	5500	6100	7100	7500	7500	7500
Chinese Taiwan	50	50	50	50	50	50	50
Other APAC	1563	2540	2740	2602	2900	3050	3450
TOTAL	79013	82515	83840	90572	91790	92440	98380
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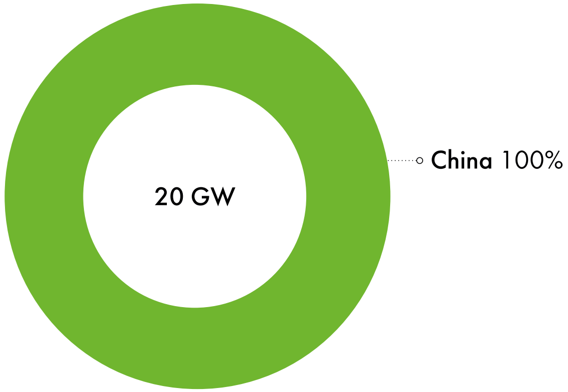
● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

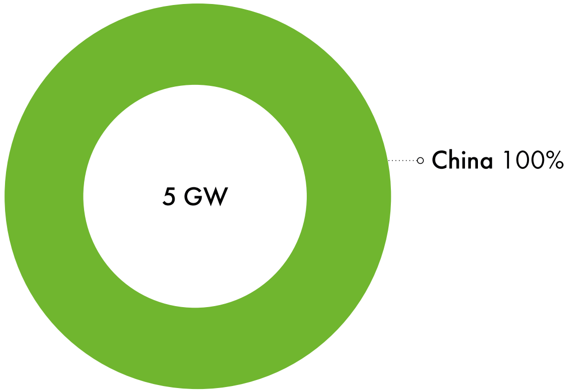
Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Offshore wind generators demand and supply benchmark- 2024-2030

Offshore turbine generator production capacity APAC, 2024 (MW)



Planned new offshore turbine generator production capacity up to 2030



Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	112	220	17	60	1405	1480	1070
Philippines	0	0	0	0	0	0	0
South Korea	100	0	880	895	1230	1500	1500
Vietnam	0	0	0	0	0	0	0
China	10000	12000	15000	15000	15000	16000	16000
India	0	0	20	0	500	500	1000
Chinese Taiwan	924	1520	1645	1850	1750	1500	1500
TOTAL	11136	13740	17562	17805	19885	20980	21070
TOTAL (excl. China)	1136	1740	2562	2805	4885	4980	5070

● Supply exceeds demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Blades

A wind turbine blade captures the energy in the wind and transfers torque and unwanted loads to the drive train and the rest of the turbine. Blades can be made of various materials, with fibreglass and epoxy resin being the most used in the wind industry. However, as manufacturers look to scale up blade and wind turbine sizes, designs incorporating carbon fibre are emerging as an alternative due to its stiffness and lightweight properties. Additionally, certain designs opt for polyester resin instead of epoxy resin. Going forward, more emphasis is expected on decommissioning and circularity requirements.

Challenges in the supply chain for onshore wind blades

Chinese manufacturers overwhelmingly dominate the supply of wind turbine blades in the APAC region, with the capacity to produce blades annually for 100 GW of onshore wind. Excluding China, India has the biggest onshore blades production capacity, followed by South Korea, whose capacities are rather limited in comparison. In 2024, it was announced that a new established subsidiary of Zhuzhou Times New Materials Technology Co Ltd, called Vietnam Wind Blade Engineering Co Ltd, is investing in a new facility for wind turbine blade production in Vietnam.[32] If realised, Vietnam could become the third largest supplier of onshore blades in the APAC region.

At the national level, only China and India are expected to manufacture enough onshore wind turbine blades to meet their domestic demand. Turbine blades however present a bottleneck in all other APAC markets. Though there is limited blade manufacturing capacity in South Korea, it is not considered sufficient to cover its onshore wind pipeline. Even when including capacity from the new blade facility expected in Vietnam, Vietnam is expected to see major bottlenecks through the whole forecasted period.

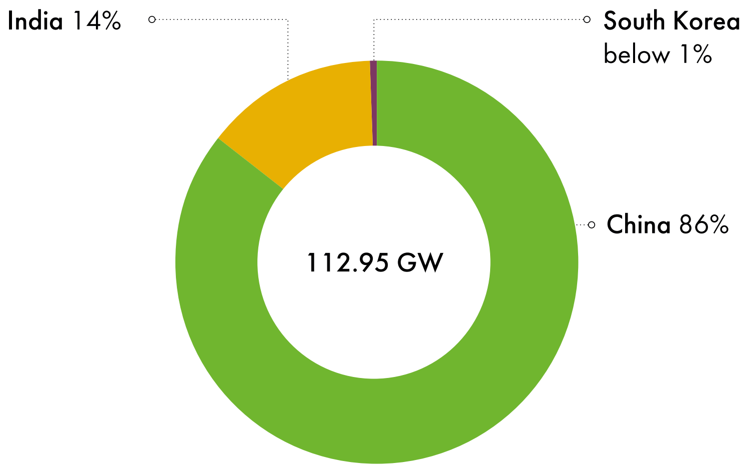
From a regional perspective, blade supply is strong enough to meet the region's total demand through to 2030. However, if China and India are excluded from the analysis, bottlenecks are expected for the entire APAC region. Thus, collaboration is crucial to support growth in this region.

Challenges in the supply chain for offshore wind blades

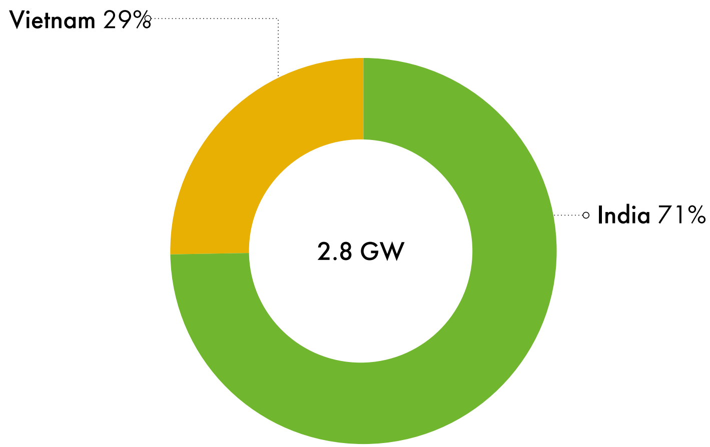
Chinese manufacturers also

Onshore wind blades demand and supply benchmark- 2024-2030

Onshore blades production capacity APAC, 2024 (MW)



Planned new onshore blades production capacity up to 2030



Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	1500	2000	2000	2000	2000	2500	3000
Indonesia	0	200	280	280	220	250	150
Japan	800	800	800	800	800	800	800
Philippines	200	245	750	600	600	600	600
South Korea	200	200	200	200	200	200	200
Vietnam	500	1000	1300	2300	3000	3300	3500
China	70000	70000	70000	75000	75000	75000	80000
India	4200	5500	6100	7100	7500	7500	7500
Chinese Taiwan	50	50	50	50	50	50	50
Other APAC	1563	2540	2740	2602	2900	3050	3450
TOTAL	79013	82515	83840	90572	91790	92440	98380
TOTAL (excl. China)	9013	12515	13840	15572	16790	17440	18380
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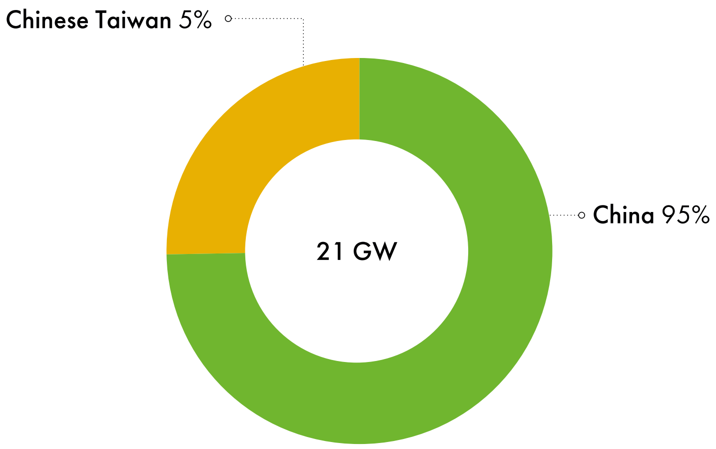
● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Offshore wind blades demand and supply benchmark- 2024-2030

Offshore blades production capacity APAC, 2024 (MW)



dominate the supply of offshore wind turbine blades in the APAC region, with the capacity to produce blades annually for 20 GW of offshore wind. Other commercial offshore blade production capacity present in the region is seen in Chinese Taiwan, which can supply 1 GW of offshore wind annually.

In the case of offshore wind blades, China is the only market that will be able to meet its demand. The production capacity from Chinese Taiwan is not sufficient to meet the supply for local projects due to strong offshore wind forecast demand. Other markets that currently do not have any offshore blade manufacturing facilities like Japan, South Korea and India will also depend on imports to meet their respective demand. Imports may come solely from China within the APAC region, with supply chain pressures building by 2029. This scenario could be seen as an opportunity for South Korea and potentially Vietnam to adapt onshore blades production facilities to make them suitable for offshore wind.

30. GWEC (2023), https://gwec.net/wind-turbine-manufacturers-see-record-year-driven-by-growth-in-home-markets/
31. https://www.ge.com/news/reports/ges-journey-to-improve-vietnamese-suppliers-capacity

Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	112	220	17	60	1405	1480	1070
Philippines	0	0	0	0	0	0	0
South Korea	100	0	880	895	1230	1500	1500
Vietnam	0	0	0	0	0	0	0
China	10000	12000	15000	15000	15000	16000	16000
India	0	0	20	0	500	500	1000
Chinese Taiwan	924	1520	1645	1850	1750	1500	1500
TOTAL	11136	13740	17562	17805	19885	20980	21070
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Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Power converters

Most wind turbines have variable speed generators connected to the grid via AC-DC-AC power converters. There is a range of different generator/converter architectures used. Critical to consider in the design of power converters are requirements imposed by grid operators for wind turbines to support and stabilise the grid during grid faults and to provide or consume reactive power on demand.

Challenges in the supply chain for onshore wind power converters

The manufacturing of most onshore wind power converters is in China, which accounts for 92% of the region's production capacity. India also has strong capabilities, with a production capacity of 10.6 GW, which is set to increase to 11.8 GW in 2027. Manufacturing of power converters also takes place in Vietnam within the APAC region.

The onshore wind power converter supply chain is expected to suffer a bottleneck in APAC as early as 2025, if imports from China are not considered. The shortage worsens as onshore wind demand continues to grow in the region over the years. At a national level, India's production capacity exceeds its demand, leading to potential exports. If local produced power converters in Vietnam are used locally, all onshore wind farms in the country will be able to use locally produced products up until 2027, when imports will be required to meet its onshore wind demand.

Challenges in the supply chain for offshore wind power converters

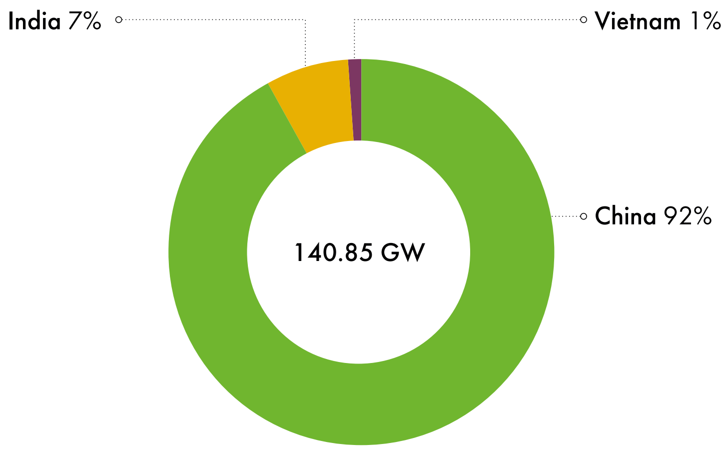
Regarding offshore wind, almost the entirety of the power converters in APAC are manufactured in China, which accounts for 98% of the region's production capacity. In Chinese Taiwan, power converters are also manufactured for offshore wind turbines, where the supply chain is expected to expand from 1 GW to 1.75 GW in 2027.

Similar to onshore wind, the production of power converters for offshore wind in the APAC region lags significantly behind current and future demand if China is excluded. However, when including China, no shortage is anticipated through to 2030. In the case of Chinese Taiwan, its production capacity for offshore wind is projected to fall short of meeting demand between 2025 and 2027, driven by a sharp increase in offshore wind demand starting in 2025. No bottleneck is expected in this market after 2027, given a potential increase in production capacity. Other markets that are developing offshore wind like Japan, South Korea and India will depend on imports as they lack power converter manufacturers in-country for offshore wind at present.

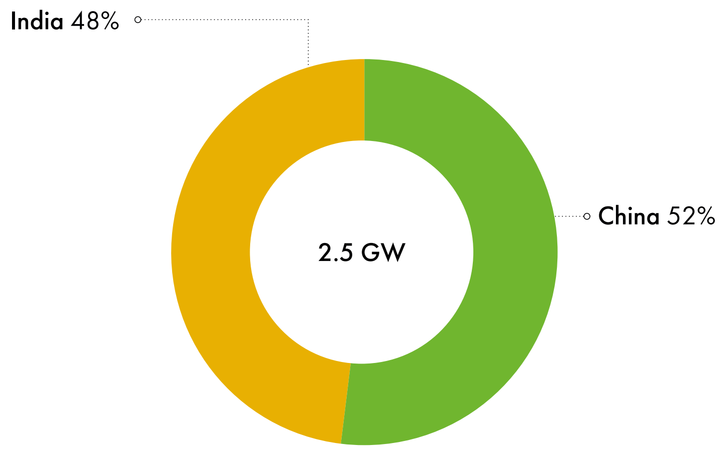
32. https://q.stock.sohu.com/cn/gg/2024/600458/57217766.shtml

Onshore wind power converter demand and supply benchmark - 2024-2030

Onshore power converter production capacity APAC, 2024 (MW)



Planned new onshore power converter production capacity up to 2030



Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	1500	2000	2000	2000	2000	2500	3000
Indonesia	0	180	200	220	240	240	280
Japan	800	800	800	800	800	800	800
Philippines	200	245	750	600	600	600	600
South Korea	200	200	200	200	200	200	200
Vietnam	500	1000	1000	2000	2500	2500	2500
China	70000	70000	70000	75000	75000	75000	80000
India	4200	5500	6100	7100	7500	7500	7500
Chinese Taiwan	50	50	50	50	50	50	50
Other APAC	1563	2540	2740	2602	2900	3050	3450
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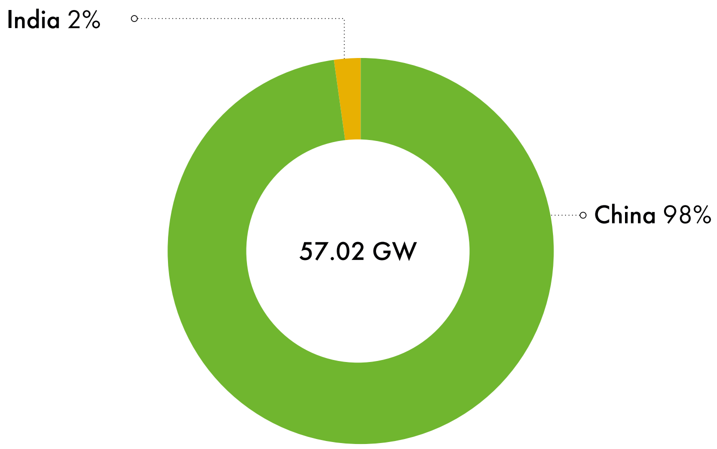
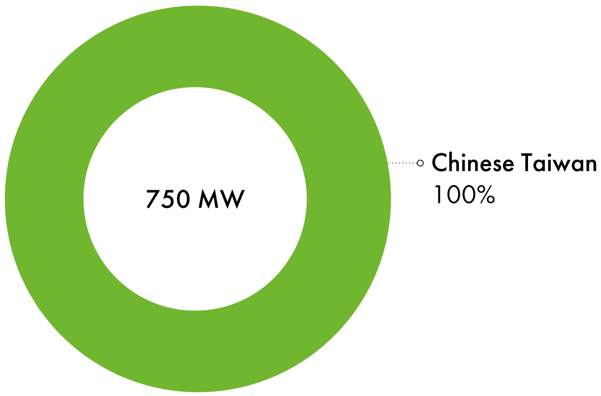
Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Offshore wind power converter demand and supply benchmark- 2024-2030

Offshore wind power converter production capacity APAC, 2024 (MW)



Planned new offshore wind converter production capacity up to 2030



Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	112	220	17	60	1405	1480	1070
Philippines	0	0	0	0	0	0	0
South Korea	100	0	880	895	1230	1500	1500
Vietnam	0	0	0	0	0	0	0
China	10000	12000	15000	15000	15000	16000	16000
India	0	0	20	0	500	500	1000
Chinese Taiwan	924	1520	1645	1850	1750	1500	1500
TOTAL	11136	13740	17562	17805	19885	20980	21070
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Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Towers

As a primary structure of a wind turbine, the tower is an independent component that accounts for approximately 20% of the turbine cost, making it one of the most expensive components. The tower is typically a tubular steel structure that supports the nacelle, although it can also be made of concrete or wood. Towers are also used to house electrical and control equipment, as well as to provide shelter and storage for safety equipment. They do not need to be assembled with other turbine components until installation.

There is a considerable level of diversification in the supply chain for towers, compared to other components. Towers are usually one of the first components to be considered when looking to address local content, as entry barriers are low and companies with steel rolling capabilities can participate easily.

Challenges in the supply chain for onshore wind towers

In the APAC region, onshore wind tower manufacturing facilities are in China, India, Vietnam, South Korea, Indonesia, and Japan. Despite the diversification, China still leads the total regional production of onshore towers. In fact, its onshore tower production capacity will increase even more in the following years, as it is the case for India.

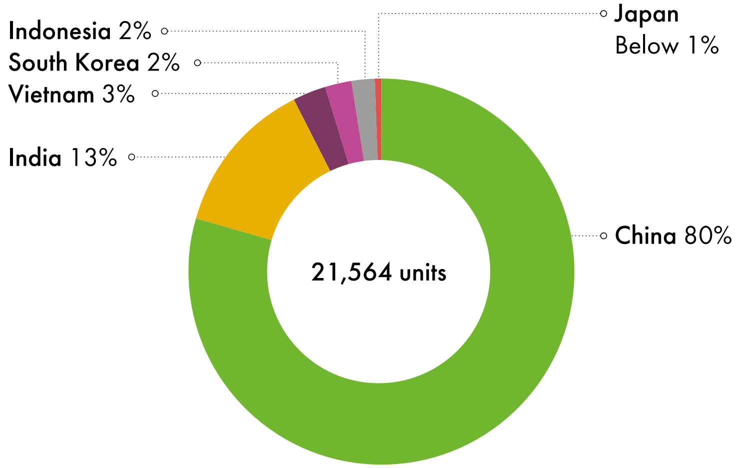
For onshore wind towers, the markets that can meet their expected demand using local supply chains are Indonesia, South Korea, Vietnam, China, and India. CS Wind is a global leader in wind turbine tower manufacturing and has been producing towers in Vietnam since 2003. In 2024, CS Wind announced it will build a factory and storage yard for onshore and offshore towers, as well as foundations, in the Southeast Asia Industrial Park in Long An, Vietnam.[33] CS Wind has sufficient capabilities to serve the Vietnam onshore wind market as well as the demands of the wider APAC market. Regionally, the APAC (excluding China) supply chain is not expected to face any bottlenecks related to onshore wind towers, even when excluding supply from China and India.

Challenges in the supply chain for offshore wind towers

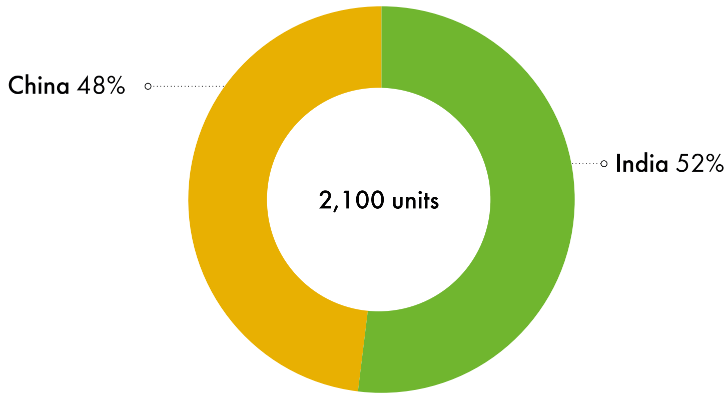
Regarding offshore wind, China dominates the supply chain for towerswith Indonesia, South Korea, Chinese Taiwan, and Vietnam

Onshore wind towers demand and supply benchmark- 2024-2030

Onshore tower production capacity APAC, 2024 (MW)



Planned new onshore towers production capacity up to 2030



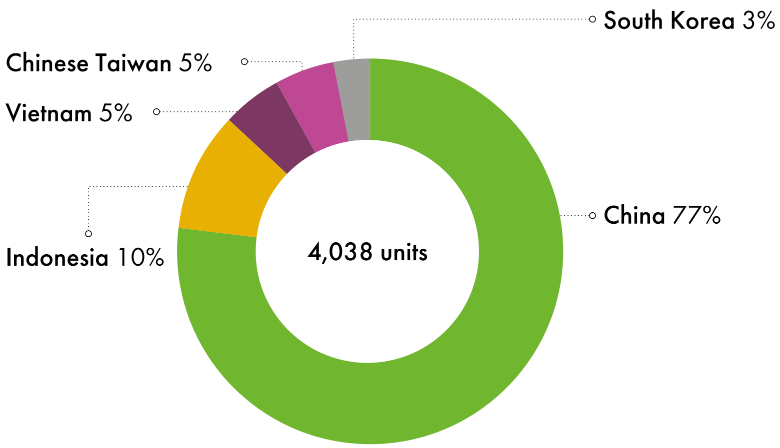
Demand vs supply analysis, 2024-2030 (Units)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	300	364	364	333	333	385	462
Indonesia	0	40	44	44	48	40	47
Japan	178	160	160	145	145	133	133
Philippines	40	49	136	109	109	100	100
South Korea	44	40	40	36	36	33	33
Vietnam	125	250	200	400	455	455	417
China	10769	9333	9333	9375	9375	8824	9412
India	1500	1833	1906	2088	2083	1786	1667
Chinese Taiwan	10	10	10	10	10	8	8
Other APAC	359	509	513	452	494	509	511
TOTAL	13326	12588	12707	12994	13089	12272	12790
TOTAL (excl. China)	2557	3255	3374	3619	3714	3449	3378
TOTAL (excl. China & India)	1057	1422	1468	1530	1631	1663	1711

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

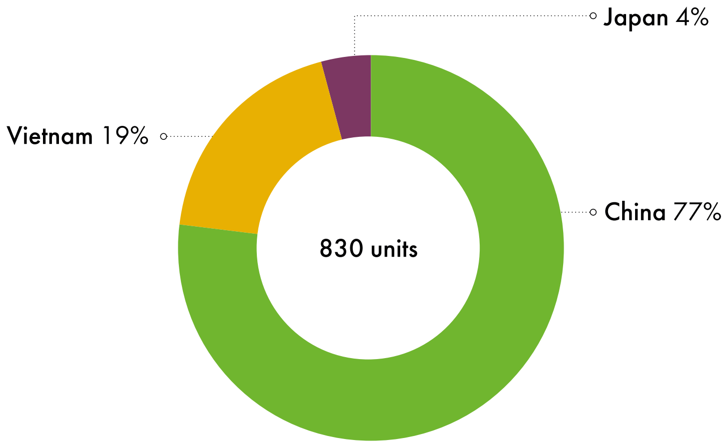
Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Offshore wind tower demand and supply benchmark - 2024-2030

Offshore tower production capacity APAC, 2024 (MW)



Planned new offshore towers production capacity up to 2030



Demand vs supply analysis, 2024-2030 (Units)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	14	25	8	4	100	100	80
Philippines	0	0	0	0	0	0	0
South Korea	10	0	66	106	84	100	100
Vietnam	0	0	0	0	0	0	0
China	1000	1200	1250	1154	1071	1066	1000
India	0	0	2	0	35	35	67
Chinese Taiwan	113	118	113	127	120	103	100
TOTAL	1337	1343	1439	1391	1410	1404	1347
TOTAL (excl. China)	137	143	189	237	339	338	347

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

completing the region's production capacity for offshore wind towers. As for future capacity, expansion in the supply chain of offshore towers is expected in China, Vietnam and Japan.

As for offshore wind, APAC's supply chain is expected to meet the regional demand for towers, both with and without Chinese manufacturers. Production in China, Indonesia and Vietnam amply exceeds their respective offshore wind demand, leaving room for exports to other APAC markets. On the contrary, Chinese Taiwan's high demand causes a bottleneck in its domestic supply chain immediately, until 2030 when demand in units is expected to reduce as larger turbines are expected to be installed. In Japan, Komai Haltec is currently developing an offshore wind tower manufacturing facility in Futtsu City, Japan, with government support through the Green Innovation Fund of the New Energy and Industrial Technology Development Organization (NEDO). Komai's facility is expected to achieve a manufacturing capacity of 20 to 30 units per annum from 2026. However, this facility alone is not expected to be able to meet the increase in domestic offshore wind demand from 2028. Similarly, South Korean manufacturers have capacity to meet the country's demand up until 2029, when it reaches 1.5 GW. However, given the pace at which new turbine platforms are being introduced in China, it is possible that not all manufacturers will be able to meet the base diameter requirements for future turbines. In Portland, Australia, Keppel Prince established a facility to construct and fabricate onshore wind towers; however, the facility struggled to compete with cheaper components sourced from overseas companies.[34]

33. https://www.offshorewind.biz/2024/09/11/cs-wind-to-pour-usd-200-million-into-new-factory-in-vietnam/
34. Australia's wind tower producers call for local supply agreements during renewable energy transition - ABC News

Castings

Castings play a key role in assembling and operating a wind turbine. As the wind turns the rotor blades, they transmit significant fatigue loads to the cast components, which are then passed on to the wind tower. A wind turbine requires various castings, such as the rotor hub, main frame, gearbox housing, main shafts, and bearing housings, extending from the rotor hub to the drivetrain and the nacelle bed frame.

As a traditional industry with non-automated technology and low annual production volumes, the casting industry would benefit from heavy CAPEX investments in the future. However, this is limited by price pressures. Traditionally, foundries have acted as tier 2 or tier 3 suppliers, letting the machining supply base be the OEM interface. Several large wind turbine OEMs typically owned their own in-house foundries and machine shops in the past, but this is now limited to a few OEMs such as Dongfang and Suzlon. Currently the inflow is handled through known independent suppliers globally.

Challenges in the supply chain for onshore wind castings

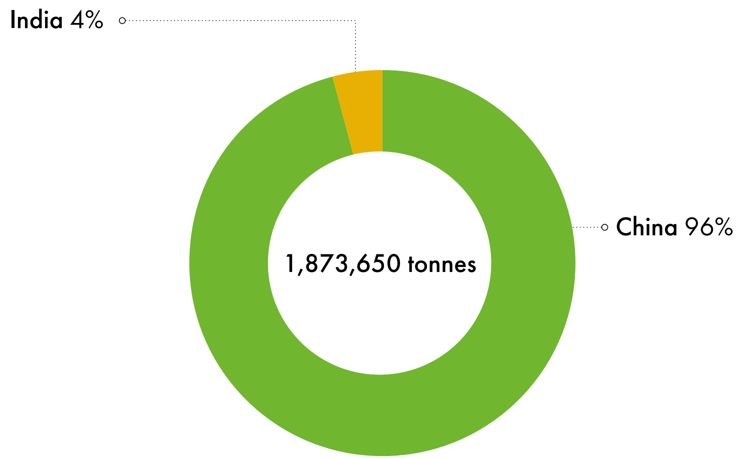
Asia Pacific has the world's largest

manufacturing base for wind castings in terms of annual output and total number of suppliers, as well as the lowest cost. This dominance is mainly driven by China's strength, with more than 40 foundries in operation. Other supply chain capabilities for onshore wind are only found in India.

The significant dominance of China in the APAC region's onshore wind casting supply chain translates into a regional dependency on its surplus. All other APAC markets may need China's capacity to meet their respective demands. As an exception, India's local supply

Onshore wind castings demand and supply benchmark- 2024-2030

Onshore castings capacity APAC, 2024 (MW)



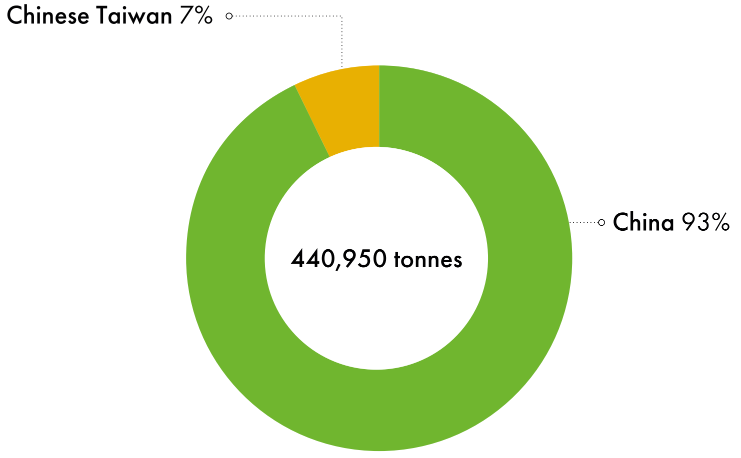
Demand vs supply analysis, 2024-2030 (tonnes)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	18300	24400	24400	24400	24400	30500	36600
Indonesia	0	2196	2440	2684	2928	2928	3416
Japan	9760	9760	9760	9760	9760	9760	9760
Philippines	2440	2989	9150	7320	7320	7320	7320
South Korea	2440	2440	2440	2440	2440	2440	2440
Vietnam	6100	12200	12200	24400	30500	30500	30500
China	854000	854000	854000	915000	915000	915000	976000
India	51240	67100	74420	86620	91500	91500	91500
Chinese Taiwan	610	610	610	610	610	610	610
Other APAC	19069	30988	33428	31744	35380	37210	42090
TOTAL	963959	1006683	1022848	1104978	1119838	1127768	1200236
TOTAL (excl. China)	109959	152683	168848	189978	204838	212768	224236
TOTAL (excl. China & India)	58719	85583	94428	103358	113338	121268	132736

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Offshore wind castings demand and supply benchmark- 2024-2030

Offshore castings capacity APAC, 2024 (MW)



chain will be able to meet the market's demand until 2027, when onshore wind demand will exceed 7 GW.

Challenges in the supply chain for offshore wind castings

Castings capacity mainly resides in China within the APAC region for offshore wind, accounting for 93%. For its part, Chinese Taiwan completes the regional castings capacity with the remaining 7% of supply.

As in onshore wind, the supply chain for offshore wind castings in APAC will suffer bottlenecks starting in 2025 if China is excluded from the analysis. In this scenario, production capacity will be sufficient to meet the needs of APAC (excluding China) in 2024, including the demands of Japan, South Korea, and Chinese Taiwan. However, from 2025 onwards, a gap between supply and demand begins to emerge as demand continues to grow. At a market level, the local supply chain for castings in Chinese Taiwan will meet its demand across the following years, except for 2027 and 2028, when the demand will be slightly higher than the supply.

Demand vs supply analysis, 2024-2030 (tonnes)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	1982	3894	297	1062	24869	26196	18939
Philippines	0	0	0	0	0	0	0
South Korea	1770	0	15576	15842	21771	26550	26550
Vietnam	0	0	0	0	0	0	0
China	177000	212400	265500	265500	265500	283200	283200
India	0	0	354	0	8850	8850	17700
Chinese Taiwan	16355	26904	29117	32745	30975	26550	26550
TOTAL	232507	296298	310844	315149	351965	371346	372939
TOTAL (excl. China)	20107	30798	45344	49649	86465	88146	89739

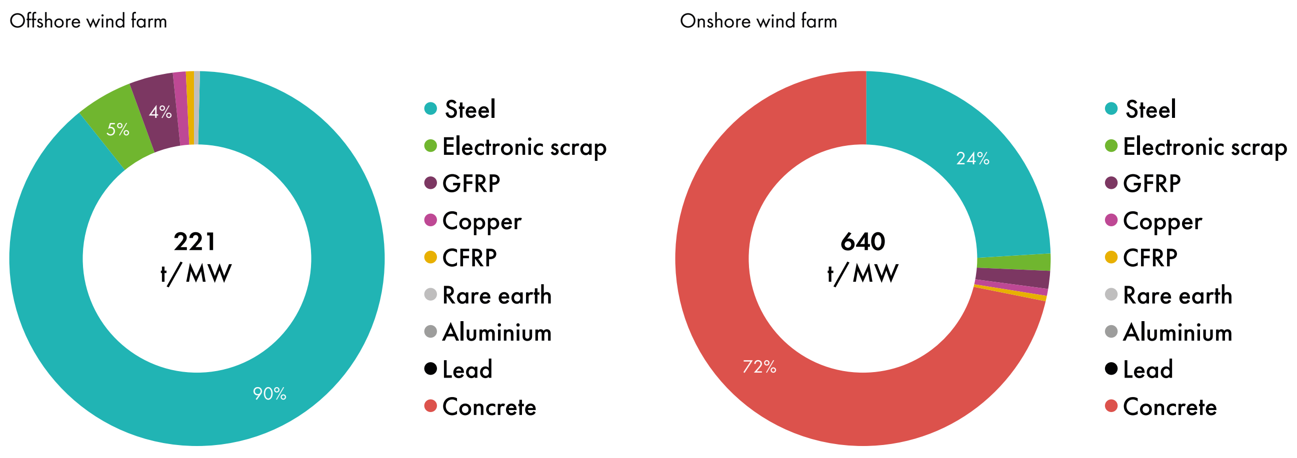
● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

CRITICAL MATERIALS

The global wind industry is expected to continue its rapid growth over the coming decades. The recovery after the COVID-19 pandemic has led to competition among different industries for raw materials and ongoing bottlenecks in manufacturing capacity. This has significantly affected on the wind industry as procurement of raw materials has an immense impact on the capital cost. Around 90% of offshore windfarm components comprise of steel and 72% of onshore windfarm components are concrete.

Materials breakdown for onshore and offshore winfarms

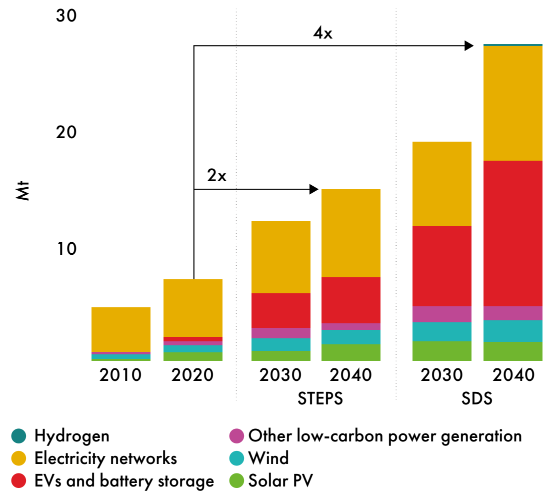


Source: BloombergNEF Note: GFRP - Carbon fibre and reinforced plastic

The expansion of wind energy, together with other types of renewable energy sources, focuses minds on the importance of clean energy supply chains, and the adequate supply of critical materials. According to the International Energy Agency (IEA), total mineral demand from clean energy technologies is set to double in the Stated Policies Scenario[35] and quadruple in the Sustainable Development Scenario[36] by 2040 compared to 2020 levels (see figure to the right). Under the conditions outlined in the IEA's net zero emissions by 2050 scenario, critical minerals supply will need to grow three and a half times by 2030 to meet energy demands. Ensuring that wind energy can continue to draw on sufficient mineral supplies could present some challenges, given that the timescale for new mining projects can be nearly 20 years, with a strong potential for delays caused by a range of environmental, social and permitting issues.[37]

In this report, the critical materials assessed include rare earth elements, carbon fibre, steel, concrete, and copper. The APAC region is well positioned to supply these materials and even without China (the global market leader) there are capabilities across other APAC countries.

Total mineral demand for clean energy techonologies by scenario



Source: IEA, October 2024

35. Outlook based on the latest announced policies
36. Pathway for the global energy sector (through to 2040) that keeps the world on track to meet the long-term mitigation goals of the Paris Agreement
37. ERM, 2023. Critical minerals: How the mining sector can accelerate the energy transition.

Rare Earth Elements

The challenge that a growing wind energy sector presents from a supply chain perspective is particularly true for rare earth elements (REEs). Rare Earth Permanent Magnets (REPMs) play a key role in the energy transition to renewable sources, including wind. Additionally, direct-drive turbines have become one of the reliable technologies for offshore wind, as they are more reliable, cheaper to maintain, and provide better yield. These types of WTGs typically use 0.5-0.6 t of REPMs per MW of generation capacity.

Mining

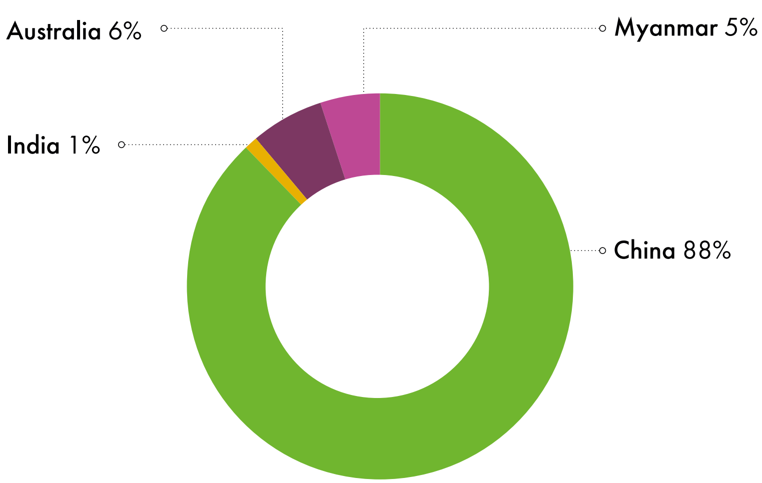
In terms of estimated REE mine production, China leads the industry with approximately 75% of annual global output (in the APAC market this equates to 88%). Most of the other countries that produce REEs are also located in APAC: Australia, India and Myanmar. The latter has emerged as a key supplier of heavy REE ion-adsorption concentrates to separation facilities in China.

The gap between mine production capacity in China and the other markets is substantial, as with the production of other materials. However, estimated global REE reserves are not as unevenly distributed. While China still leads the ranking with 31% of reserves, the rest of the APAC region accounts for 24% of global reserves. This includes Australia, India, and Vietnam, which has the second largest reserves after China with a 16% share.

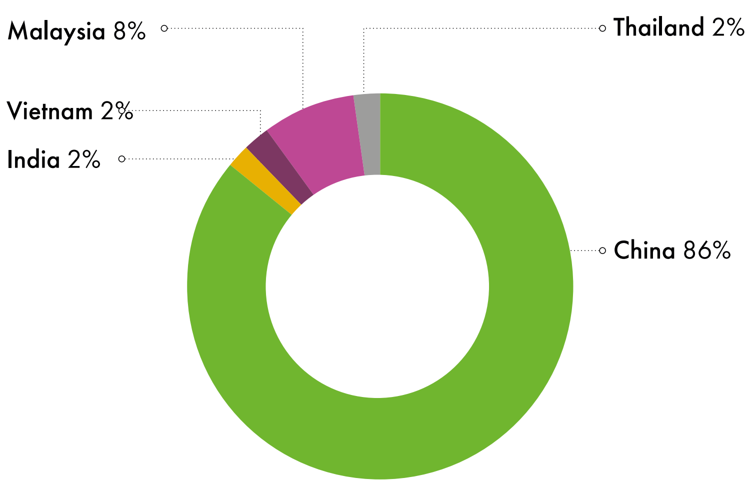
Processing

Regarding processing capabilities, China also dominates the market globally with approximately 90% of the global estimated rare-earth separation capacity, which represents an even larger gap compared to other countries. The Chinese dominance is

Supply of rare earth elements (mined) by market in the APAC region, 2022 (%)



Supply of rare earth elements (refined) by market in the APAC region, 2022 (%)



Source: Rare Earth Industry Association, 2024

due to its authorities' decision to increase the REE production quota by 20% in 2021, 25% in 2022, and a further 14% in 2023, all to supply burgeoning demand in the EV and offshore wind sectors.

Malaysia is the second largest country for separation capacity country for separation capacity, receiving REEs from Australia, amongst others. India, like China, has both mine production capacity and separation capacity. Additionally, Thailand and Vietnam also have processing capabilities, although these are limited considering China's dominance.

Conclusion

In terms of demand, REPM demand for wind energy in China is expected to drop substantially because of the cost-driven shift from direct drive to medium-speed and high-speed drive. From 2023 to 2030, Chinese wind energy REPM demand may fall by 14% CAGR for onshore installations and grow by only 4% for offshore installations. By 2030, China is forecast to account for only 19% of wind energy REPM demand, compared to 64% in 2023. Other APAC REPM demand for wind energy is expected to slightly increase throughout the following years, but it will still be lower than China's alone by 2030.

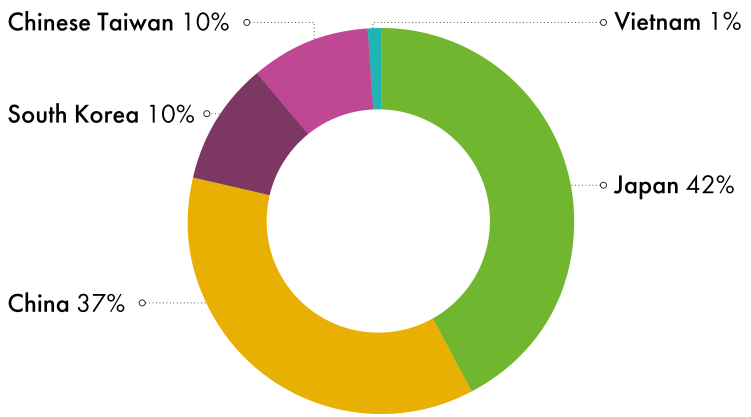
However, APAC cannot be considered as a closed market and China is the main actor in the global supply chain. Therefore, the demand in other regions may be considered, with European REPM demand for wind energy rapidly increasing from 2027 to 2030, largely due to offshore installations. Moreover, REPM for wind energy consumption was estimated to account for no more than 7% of total REPM demand in 2023, growing at the average rate of other demand applications to retain the same market share by 2026.

Carbon Fibre

As wind turbines continue to scale in size to boost energy production, the two key factors of stiffness and weight have become more critical for blade design. The most critical area for material choice in this regard is the spar cap, often referred to as the "spine" or backbone of the blade. Due to its superior strength and stiffness, carbon fibre is the preferred material for this component by western OEMs, especially in larger blades, particularly for offshore applications. However, for cost reasons, glass fibre is still being used in blades, as it is a cheaper option, although it has much less stiffness per kilogram of weight compared to carbon fibre.

Chinese OEMs tend to use more glass fibre than carbon fibre in their spar cap designs, typically reserving carbon fibre for blades over 100 meters in length. In contrast, Western OEMs often incorporate carbon fibre in blades starting at around 70 meters. However, as the industry continues to push blade lengths further, particularly among Chinese OEMs in the offshore sector, the use of carbon fibre in spar caps for blades is seeing a substantial increase. In the next 2-3 years, the demand for large tow carbon fibre in wind energy applications is expected to dominate the market.

Supply of carbon fibre by market in the APAC region, 2024 (%)



Source: Brinckmann, 2024

Conclusion

In China and globally, the wind turbine sector—especially turbine blades—drives a sizeable portion of carbon fibre demand. The wind turbine market's share of total global carbon fibre demand rose from approximately 25% in 2021 to 30% in 2023, with further growth anticipated. Consequently, the rising demand from wind applications necessitates substantial additions to carbon fibre production capacity

In terms of supply, Japan holds the largest share of APAC's carbon fibre production capacity at 42%, followed by China with 37%. South Korea and Taiwan each contribute a similar 10% portion, while Vietnam currently accounts for 2% of the region's supply. However, Hyosung Advanced Materials is constructing a larger carbon fibre facility in Vietnam, projected to increase the country's share to 7% upon completion. These supply estimates are based on nameplate capacities and include both large and small tow carbon fibre.

Chinese Taiwan also has a robust carbon fibre industry focused on providing the requirements for electronics, aerospace, automotive, and sporting goods. Some of the companies in Chinese Taiwan that provide carbon fibres solutions include the Formosa Plastics Corporation, Taiwan Carbon, AWISE, which have been supplying both the domestic market and exports. The carbon fibre industry is also active in research & development initiatives, with support from the Chinese Taiwan area's administration to drive further innovation into the industry.

As offshore wind projects ramp up, companies in China and Japan are likely to increase their large tow carbon fibre production capacities to meet demand.

Steel

The wind energy sector is a key source of demand growth for steel plates. On the face of it, there seem to be plenty of steel plates in the world that could potentially serve the wind energy industry. However, this does not alleviate industry concerns about potential bottlenecks and supply constraints as the wind energy sector expands rapidly. Part of the concern arises because of the critical importance of steel to the sector. For onshore wind, steel is about one-quarter of the total materials required per MW, though as an individual item it is the second largest behind concrete. But for offshore wind, steel represents 90% of all the materials consumed per MW.

In terms of supply, APAC is the leading producer of steel in the world, accounting for three quarters of the world's total production of crude steel. This is mainly due to the strength of the Chinese market, which is responsible for more than half of the world's production, and 72% of the APAC region's production. Two other APAC markets (India and Japan) follow China as top producers, although there is a very substantial gap between the leading market and all the rest. Within the APAC region, South Korea also stands out as the sixth top producer globally, right after the United States and Russia. Thus, even in a scenario where China is excluded, other APAC markets are responsible for over 20% of the global total production of crude steel. The chart below shows the share of crude steel production in APAC markets.

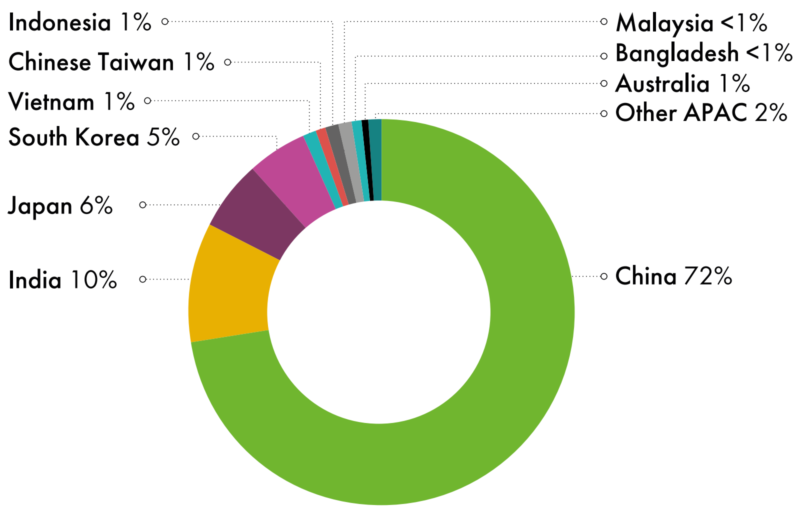
Conclusion

Theoretically, there is no shortage of steel in the world. However, the rapid growth of the wind energy sector could lead to potential bottlenecks. Besides, there are other factors that influence the wind energy supply chain.

Firstly, the wind energy sector places significant demands on suppliers due to the large dimensions required, with plate thicknesses of up to 150 mm in extreme cases. This narrows the pool of steel suppliers able to meet such specifications, as most standard plate demand ranges between 10-60 mm. However, China's plate mills, being relatively modern, can produce high-quality plates that are both wide and thick, meeting these stringent requirements.

Additionally, while renewable energy aims to promote decarbonisation, which fosters interest in the low-emission steel supply chain, most steel in the world is still produced via unabated blast furnaces, i.e. with no emission reduction. Due to the time required to achieve large-scale production, accessing low-emission steel may remain out of reach in the short term. This is due to the costly and technologically complex processes involved, which are still in the developmental stages and require substantial scaling efforts.

Total production of crude steel in the APAC region, 2023 (%)



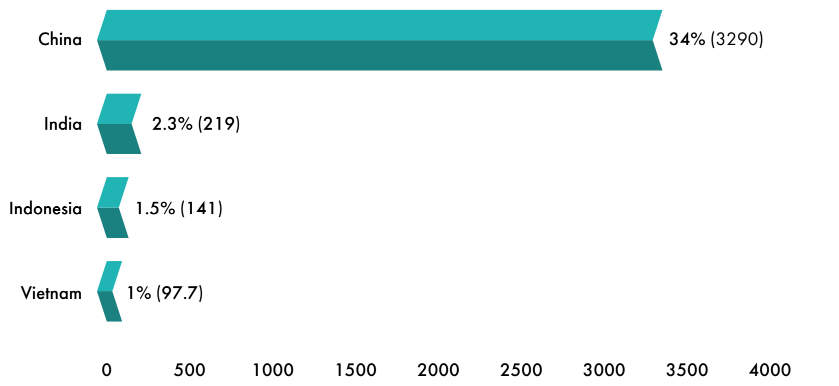
Source: World Steel Association, 2023

Concrete

Concrete can be used for onshore wind foundations, floating substructures, and fixed foundations, as well as for WTG towers, which can be seen typically for onshore in India, Japan and South Korea. This material offers design and construction flexibility, material flexibility, strong environmental credentials, reduced noise emissions, and requires minimal maintenance.

According to Global Concrete, this material is among the few commodities to have been produced in every country in 2022. However, concrete production is not equally distributed between countries, with China producing one third of the world's concrete in 2021. China's concrete production has been growing in recent years, with 16% year-on-year growth in 2021, the highest within the top ten producers. India, Indonesia and Vietnam are the other APAC markets that rank in tthe top ten concrete producers globally. Concrete consumption increased considerably in Indonesia in August 2022 with the launch of construction of its upcoming 10 million-population new capital Nusantara, and it is expected to keep growing during the 20-year period the city will be under construction. In the case of Vietnam, concrete production saw a 5.1% year-on-year decline in 2021.

Concrete production in the top four markets in the APAC region, 2021 (% of global production quantity in Mm3)



Source: Global Concrete Report, 2021

Conclusion

Regarding potential bottlenecks, the risk is minimal in the concrete supply chain, as its production is widely diversified. The simplicity of the production process makes its supply easily flex to demand, which explains why the global top producers have large populations and high construction activity.

Copper

Copper is set to play a key role in the energy transition, as renewable energy has a higher demand for this mineral compared to fossil fuels, besides the growing demand for copper due to electrification. Furthermore, wind energy is the most copper-intensive renewable energy technology, and it is expected to keep driving demand as offshore wind technology expands. In fact, offshore wind consumes more than twice as much copper as onshore wind, due to multiple factors including the use of direct-drive technology, larger components, and marine cables.

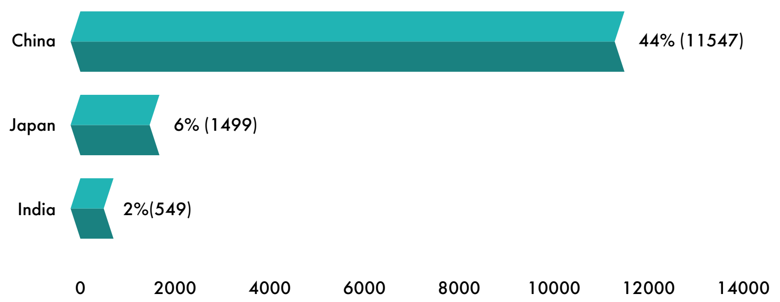
In a wind farm, copper will mainly be used for cables and wiring, but it is also used for the turbine/power generation, for the turbine transformer, and to ground wind turbines from lightning strikes. On the one hand, the expected significant growth in copper demand over the coming decades presents uncertainty on the supply side and its ability to meet demand. However, copper can be recycled repeatedly without deterioration of its properties.

Within APAC, China is the fourth largest producer of copper globally with a share of 8%. Additionally, there is some mining capacity in the Philippines, Indonesia, Australia, Mongolia and Laos, amongst others, but it is limited on a global scale. In terms of copper refining capacity, China clearly leads the global ranking with a 44% share, followed by Chile with an 8% share. Japan and India have the third and fifth highest copper refining capacity globally, respectively. The copper refining industry is also present in South Korea and other Southeast Asian countries, such as Indonesia and the Philippines.

Conclusion

The growth of electrification in APAC over the coming years will increase the demand for copper in electricity networks. According to IEA, China provides the largest share of global electricity demand growth in terms of volume, but India posts the fastest growth rate through 2026 among major economies. For its part, Southeast Asia is also expected to experience robust annual increases in electricity demand of 5% on average through 2026. This, together with the growth of wind energy demand in APAC, will increase the demand for copper. Nevertheless, there is general availability of copper production for all major regions. As different processes and regions participate in the copper supply chain, APAC cannot be treated as a closed market. For example, Japan relies on copper imports and copper scrap to make up its copper stock, the production capacity of which is strong in the country.

Supply of copper (refined) in the top three markets in the APAC region in 2023 (% of global supply, quantity in thousand tonnes)



Source: International Energy Agency, 2024

OFFSHORE WIND BALANCE OF PLANT

Foundations

Several types of foundations are used in offshore wind projects, as there is no universal solution that fits all scenarios. The design, structure, and material selection for these foundations largely depend on specific project conditions, including seabed characteristics, water depth, and the size of the wind turbines.

Currently, two primary types of foundations dominate the industry: steel structures (such as monopiles and jackets) and concrete structures (gravity-based foundations). According to GWEC Market Intelligence's global offshore wind project database, as of the end of 2023, steel monopile foundations hold a 68% market share, followed by jacket foundations (20%). However, jackets are increasingly being adopted in deeper waters alongside innovative XXL monopile designs.

Gravity-based foundations are typically favoured for projects on rocky seabed where piling or suction methods are restricted due to noise regulations, particularly for Vietnam and potentially in the Philippines. As offshore wind projects expand into deeper and more remote areas, floating foundations are also beginning to gain traction.

Fixed-bottom foundations

Regarding the supply of fixed foundations in 2024 in APAC, China accounted for 81% of the region's total production. Without China, the fixed foundation supply chain in APAC is spread across different markets such as South Korea, Chinese Taiwan, Indonesia, Philippines, Japan, and Vietnam. As for future growth, Vietnam, South Korea and Japan will increase its fixed foundation annual capacity. Overall, the APAC supply chain has strong capabilities in the production of offshore wind foundations.

Challenges in the supply chain for fixed-bottom foundations

Previously, Europe was the largest production base, with key suppliers in Germany, the Netherlands, Denmark, and Belgium. However, as offshore wind projects have gained momentum in the Asia Pacific region, new manufacturers have emerged in China, South Korea, Chinese Taiwan, and Vietnam. South Korea's established steel industry, along with its robust heavy industrial fabrication and shipbuilding facilities, would require only minimal modifications or expansions to meet the additional demands of offshore wind production.

Although the APAC region (excluding China) has operational foundation facilities, the current annual production capacity has thus far primarily focused on jacket foundations and suction buckets. New manufacturing facilities for monopile foundations have been developed in recent years in Japan and South Korea.

In Japan, JFE Engineering opened a new monopile manufacturing facility in Okayama Prefecture this year. The plant can produce monopiles with a maximum diameter of 12 metres, plate thickness of 130 millimetres, length of 100 metres and mass of approximately 2,500 tonnes. The annual production capability of the facility is roughly 100,000 tonnes of monopiles. Meanwhile, Nippon Steel Engineering owns Japan's only jacket fabrication facility in Kitakyushu City. Nippon Steel Engineering has already supplied 14 jackets to the operational Ishikari Bay New Port offshore wind project and is currently supporting the Hibikinada offshore wind project with 25 units. The company is currently looking to double its facility's capacity to 20,000 tonnes in FY2025. Sumitomo Heavy Industries has also announced plans to install a large bending roller to begin operation in May 2025 to strengthen its steel plate processing capabilities for foundation manufacturing.

In South Korea, SK Oceanplant delivered the first shipment of jacket foundations to the Hai Long project in April 2024, and also received an order for the 500 MW Fengmiao 1 in June.[38] HSG Sungdong Shipbuilding has signed the contract for foundation supply for the 920 MW Greater Changhua 2b & 4[39] whilst Hyundai Steel Engineering has experience in supplying 27 jackets to Changhua 1 and 2a.[40] For its part, GS Entec has signed a 10-year mutually exclusive agreement with Dutch company Sif Group for the use of its technology to manufacture monopile foundations and transition pieces within Asia.[41] Korean companies such as SeAH Steel[42] and EEW KHPC[t] also manufacture steel pipes for jacket foundations and pin piles.

38. OffshoreWind.Biz (2024) https://www.offshorewind.biz/2024/06/04/cip-orders-jacket-foundations-for-taiwanese-offshore-wind-project-in-south-korea/
39. OffshoreWind.Biz (2024) https://www.offshorewind.biz/2023/05/17/orsted-hsg-sungdong-sign-foundations-contract-for-wind-farms-offshore-taiwan/
40. OffshoreWind.Biz (2019). https://www.offshorewind.biz/2019/06/11/orsted-orders-changhua-jackets-in-south-korea/
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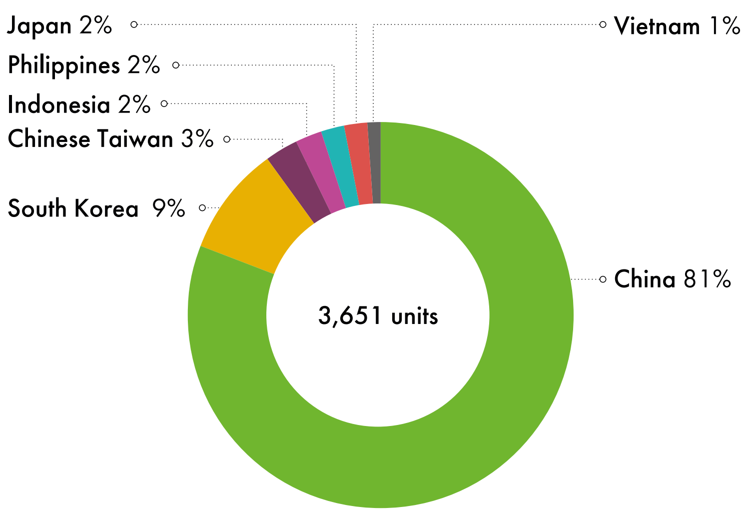
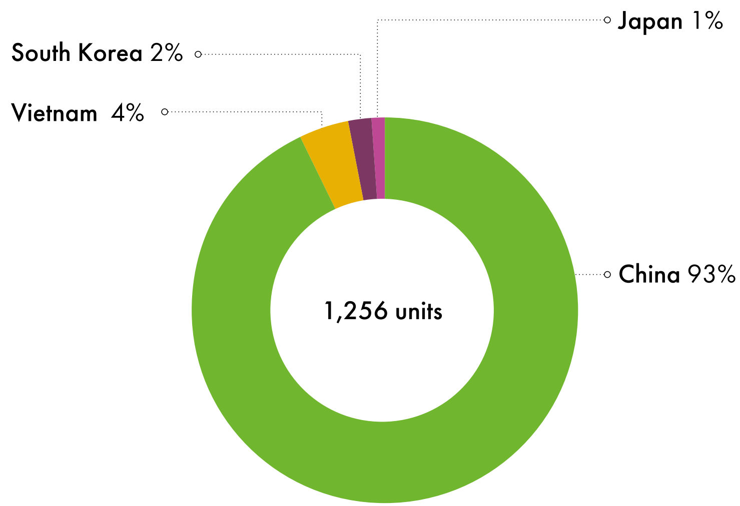
43. EEW Group. https://eew-group.com/company/our-facilities/eew-khpc/

Fixed-bottom foundations demand and supply benchmark, 2024–2030

Fixed foundation production capacity APAC, 2024 (units)



Planned new fixed foundation production capacity up to 2030



Demand vs supply analysis, 2024-2030 (Units)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	14	25	0	0	96	100	62
Philippines	0	0	0	0	0	0	0
South Korea	10	0	66	106	67	60	50
Vietnam	0	0	0	0	0	0	0
China	999	1194	1225	1129	1065	1066	970
India	0	0	2	0	35	35	67
Chinese Taiwan	113	118	113	124	117	103	93
TOTAL	1336	1337	1406	1359	1380	1364	1242
TOTAL (excl. China)	137	143	181	230	315	298	272

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

PTSC is manages and operates a nationwide network of ports across Vietnam, with a total area of over 320 hectares. PTSC has a strong track record of supplying foundations for offshore wind farms, including 33 jackets for the Greater Changhua project in Chinese Taiwan. Supply of foundations in Vietnam is expected to increase in the future with the addition of CS Wind's new factory and storage facility in Long An, which is expected to supply tens of thousands of units a year, including monopiles and transition pieces. As offshore wind is not expected to come online before 2030 in Vietnam, existing and future supply of foundations can serve the demand of the wider APAC region.

When assessing supply and demand at the national level within APAC markets, China demonstrates strong supply capabilities for fixed foundations. South Korea is also positioned to meet demand through its local supply chains. In contrast, Japan and India are expected to face challenges in meeting the rising demand. While the China Taiwanese offshore wind manufacturers have been supplying local projects and are taking steps to develop the local supply chain, it remains limited, and shortages are anticipated in Chinese Taiwan starting from 2024. However, the bottlenecks are expected to reduce from 2029 onwards due to a decrease in demand.

Floating Foundations

Floating foundations are expected to commercialise at scale towards the end of this decade and the demand for floating foundations will be limited before 2030. Currently, there are only a few small-scale operational floating offshore wind farms in China, Japan and South Korea. Typically, the most common types of floating structures are tension-leg platform, semi-submersible, and spar-buoy, although they can take different forms and can be made from varied materials, mainly steel and concrete. For example, Mingyang Smart Energy launched in July 2024 OceanX, a floating platform that holds two 8.3 MW hybrid drive turbines.[44]

Challenges in the supply chain for floating foundations

In terms of supply of floating foundations, the supply chain is only present in China; however, both South Korea and the Philippines plan to start production by 2030.

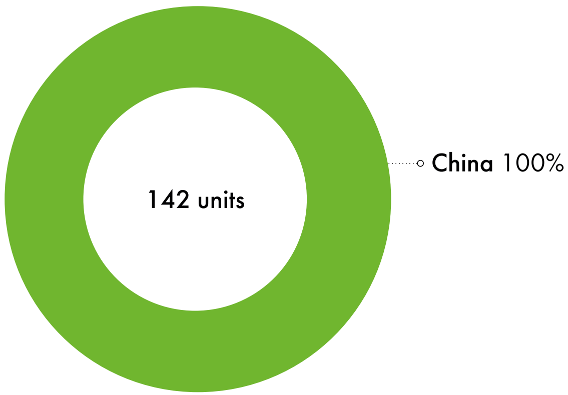
The supply of floating foundations is expected to meet demand in South Korea and China. While there is no existing supply in South Korea, planned capacity is expected to come online later in the decade, meeting demand from 2028. Most companies in Japan have shown interest in the designing and manufacturing of floating substructures, such as Toda Corporation, Kanadevia and Japan Marine United. In July 2024, Sumitomo Corporation and JGC Japan Corporation announced an agreement to cooperate on the design, manufacturing and delivery of floating substructures. Though no bespoke facilities exist yet, Japan is expected to supply floating foundations for the various demonstration and small-scale floating offshore wind projects planned between 2026 to 2028. However, as floating demand increases after 2030 and throughout the next decade, significant bottlenecks are expected based on current manufacturing capabilities. Chinese Taiwan has also indicated an interest to fabricate floating foundations; however, until port infrastructure is in place this market may need to rely on imports.

Looking at the APAC market, no bottlenecks are expected. Major bottlenecks are expected in 2026 in APAC (excluding China) before additional supply capacity is due to come online, and again in 2030 when demand increases to 75 units.

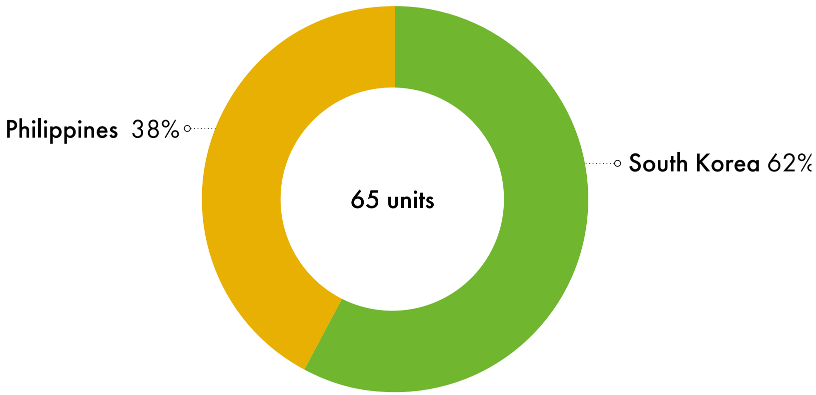
44. OffshoreWind.biz: Mingyang Launches Twin-Rotor V-Shaped Floating Wind Turbine Platform | Offshore Wind

Floating foundations demand and supply benchmark, 2024–2030

Floating foundation production capacity APAC, 2024 (units)



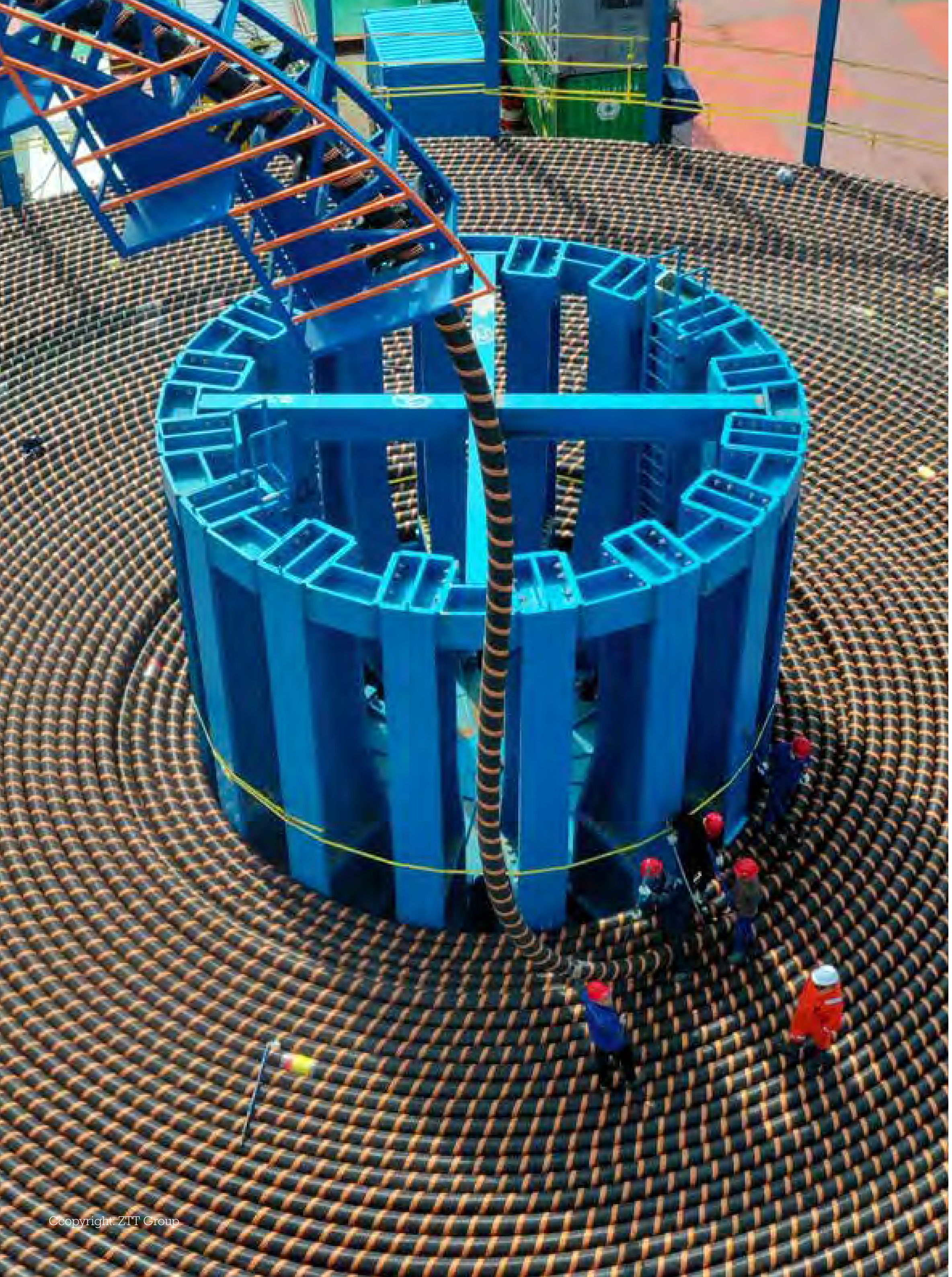
Planned new floating foundation production capacity up to 2030



Demand vs supply analysis, 2024-2030 (Units)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	0	0	8	4	4	0	18
Philippines	0	0	0	0	0	0	0
South Korea	0	0	0	0	17	40	50
Vietnam	0	0	0	0	0	0	0
China	1	6	25	25	6	0	30
India	0	0	0	0	0	0	0
Chinese Taiwan	0	0	0	3	3	0	7
TOTAL	1	6	33	32	30	40	105
TOTAL (excl. China)	0	0	8	7	24	40	75

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024



Cables

The demand for offshore wind cables comprises two main types: array cables, which link individual turbines, and export cables, which connect offshore substations to the onshore grid. Much of the current installed array and export cables use AC technology. From 2023 to 2030, demand for these cables, measured in core-kilometres, is projected to grow at an average rate of 18% per year globally.[45] Demand for cables in APAC excluding China is expected to grow by 18% annually through the end of the decade in line with the global trend. High-voltage direct current (HVDC) technology also enables the connection of far from shore windfarms to the grid (i.e. >100 km from shore).

APAC submarine cables supply chain

China supplies most of the region's medium-voltage (MV) and high-voltage (HV) cables with some supply coming from South Korea and Japan. Manufacturing capacity is expected to come online also in Chinese Taiwan (from the NKT and Walsin Lihwa joint venture) and Vietnam starting in 2027.

China and South Korea also have plans to grow their supply chain up to 2030. South Korea's increases are in part driven by the expansion of LS Cable & System's factory in Donghae City and the opening of a new plant at Pyeongtaek's Dangjin Port by Taihan Cable & Solutions. In China, companies including Baosheng YOFC, Futong Sumitomo JV, Far East, Qingdao Hanhe and Qifan have entered submarine cable production with new plants over the past couple of years. Incumbent players like Hengtong, ZTT and Orient Cable are building new facilities in other Chinese provinces in preparation for local offshore wind projects.

In terms of extra high voltage (EHV) submarine cables, less capability is present in the region, again with China, South Korea and Japan as the supplying markets. Plans to keep growing the EHV submarine cables capacity are in place for China and South Korea.

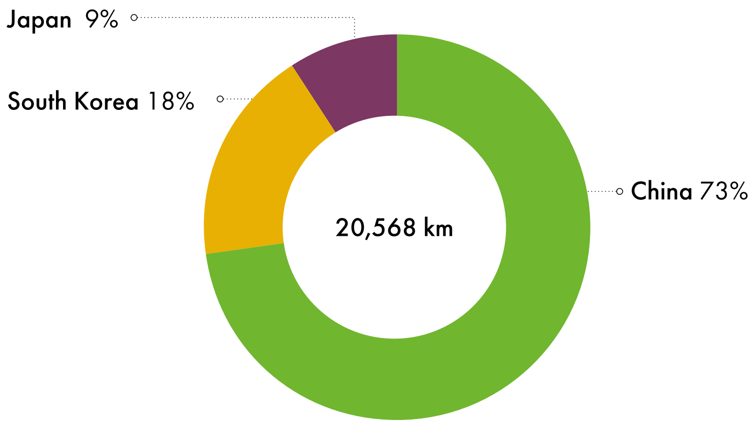
Challenges in the supply chain for cables

When taking China's supply and demand into account, no bottlenecks are expected for cables throughout the forecast period. China boasts robust capacity and a proven track record in supplying submarine power

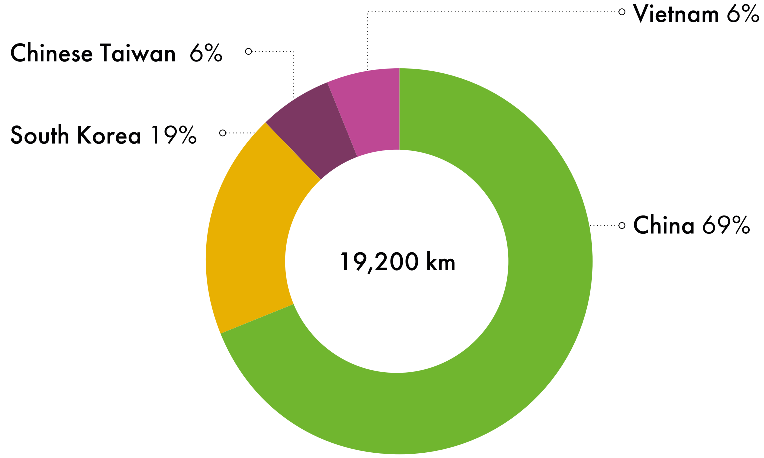
45. GWEC (2023). MISSION-CRITICAL-BUILDING-THE-GLOBAL-WIND-ENERGY-SUPPLY-CHAIN-FOR-A-1.5°C-WORLD.pdf

Submarine cables demand and supply benchmark, 2024–2030

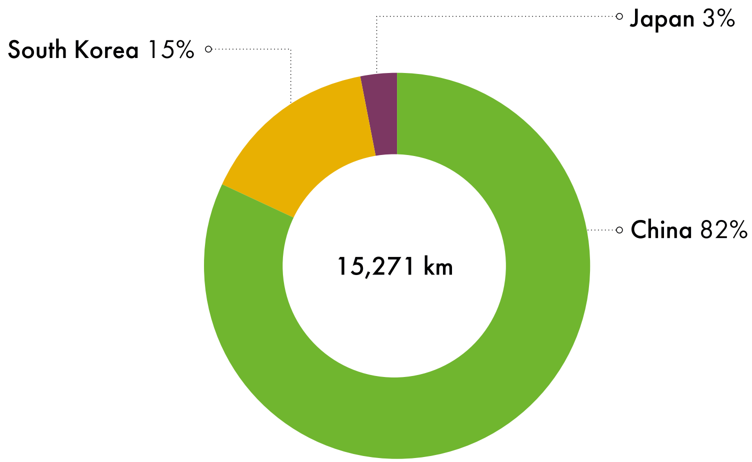
MV+HV submarine cables production capacity APAC, 2024 (km)



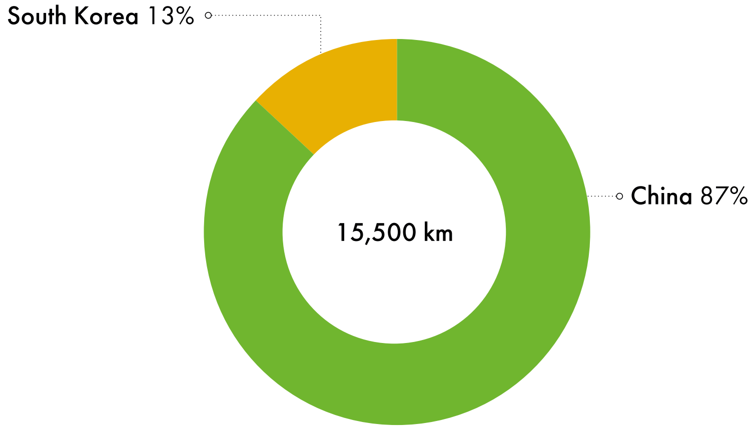
Planned new MV+HV submarine cables production capacity up to 2030



EHV submarinne cables production capacity APAC, 2024 (km)



Planned new EHV submarine cables production capacity up to 2030



Note: To convert capacity of cables from MW into km, ERM analysed existing offshore wind project data to calculate an assumption of average cable length in km per MW of project.
Source: CRU, GWEC Market Intelligence, ERM, November 2024

Demand vs supply analysis, 2024-2030 (km)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	40	78	6	21	499	526	380
Philippines	0	0	0	0	0	0	0
South Korea	36	0	313	318	437	533	533
Vietnam	0	0	0	0	0	0	0
China	4266	5333	5333	5333	5333	5688	5688
India	0	0	7	0	178	178	356
Chinese Taiwan	328	540	585	658	622	533	533
TOTAL	4670	5951	6243	6330	7069	7458	7490
TOTAL (excl. China)	404	619	911	997	1737	1770	1802

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Note: To convert capacity of cables from MW into km, ERM analysed existing offshore wind project data to calculate an assumption of average cable length in km per MW of project.
Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

cables for offshore wind projects. Established companies like Hengtong, ZTT and Orient Cable are expanding their operations by constructing new facilities across various provinces to support both local and global offshore wind initiatives. A total of 20 submarine cable manufacturing plants are currently under construction in China, more than the rest of the world combined. This could lead to overcapacity in China from 2025. On the other hand, China could represent a solution for supply shortages elsewhere in the world.

Similarly, when looking at the APAC region excluding China, no major bottlenecks are expected up to 2030. At the market level, under the same scenario, however, bottlenecks are anticipated in Chinese Taiwan from 2024 to 2026 and India from 2026. But with the NKT-Walsin Lihwa cable manufacturing facility commissioning in 2027, Chinese Taiwan's offshore wind cable demand is likely to be met locally.

As in China, the supply of cables in South Korea is expected to outweigh demand through to 2030. LS Cable & System signed an investment agreement with Donghae City, South Korea, in 2024 to expand its submarine cable factory. The company had already decided in 2023 to invest KRW 155.5 billion in its fourth submarine cable factory and is investing KRW 100 billion for the fifth one, with a total floor area of 19,451 m^2. Once factory number 5 is completed in 2025, the HVDC cable production capacity will quadruple. Also in South Korea, Taihan Cable & Solutions aims at establishing itself as a company specialised in offshore wind, with the opening of a submarine cable plant in Dangjin. The plant is being constructed in two phases, the first one of which focuses on producing inter-array cables and was finalised in May 2024. The second phase is currently under construction and expected to be completed in the first half of 2025. While the first phase focused on inter-array cables, the second one will focus on the production of export cables and HVDC cables.

In short, with additional capacity coming online in China, South Korea, Chinese Taiwan and Vietnam between 2024 and 2027, there is expected to be large overcapacity for both MV&HV and EVH subsea cables in APAC towards the end of the decade (with overcapacity likely to peak around 2027).[46]

46. CRU. (2024). Will new HV and EHV subsea capacities meet global demand? Retrieved from, https://www.crugroup.com/en/communities/thought-leadership/2024/will-new-hv-and-ehv-subsea-cable-capacities-meet-global-demand/

OFFSHORE WIND ENABLERS

Installation Vessels

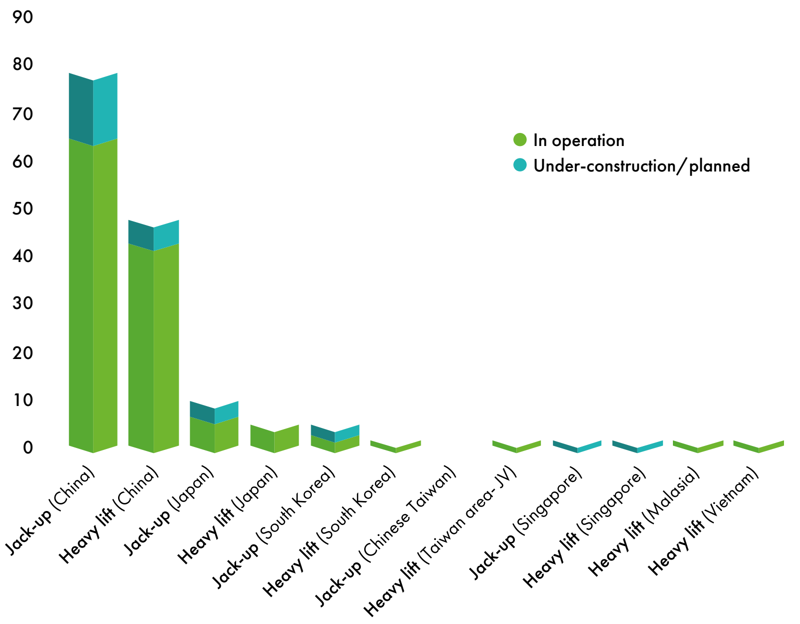
Offshore wind installation vessels can be categorised into three main types based on their functions. Installation vessels include jack-up vessels, monohull vessels and floating installation vessels, all designed for the installation of wind turbines. Heavy lift vessels, such as heavy lift ships and installation barges, are specialised for transporting and installing large components such as turbine foundations. Certain heavy lift vessels can support offshore wind turbine installation. Lastly, cable installation vessels, including cable lay vessels and cable installation barges, focus on the installation of subsea cables that connect turbines to each other and to the onshore grid. Each vessel type plays a crucial role in the efficient and safe development of offshore wind projects.

Offshore wind turbine installation vessels (WTIVs)

A key trend in the offshore wind industry that has enabled the reduction in levelised cost of energy (LCOE) over the years is the growth in turbine sizes. The industry's installation journey began in the 1990s with 450kW turbines. In September 2024, the world's first 20 MW turbine was installed in Hainan,

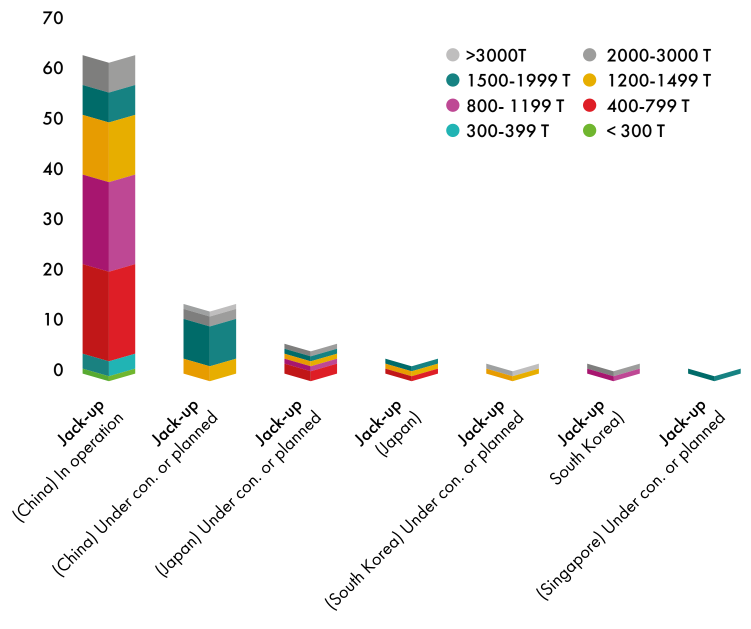
47. ReNEWS. Mingyang installs 20MW turbine - ReNews - Renewable Energy News

Overview of offshore wind turbine installation vessels in 2024



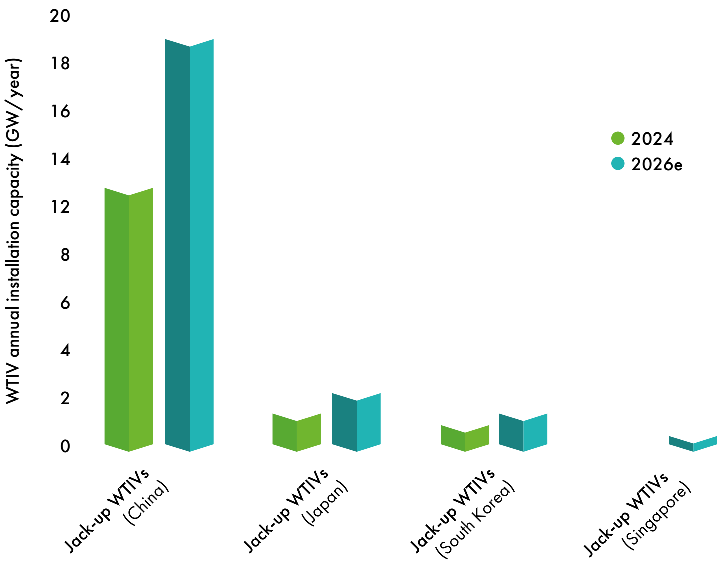
Source: GWEC Market Intelligence, November 2024

Number of jack-up offshore wind turbine installation vessels by main crane (operational in 2024)



Source: GWEC Market Intelligence, November 2024

WTIVs demand and supply benchmark, 2024-2030



China at a coastal test site.[47] By the end of the decade, 15-18 MW turbines are expected to become the standard. The trend of increasing turbine sizes significantly impacts vessel availability and capability, affecting various site and project parameters. The vessels that cannot install 15 MW (and greater) turbines could run the risk of becoming inadequate to serve a substantial proportion of project installation by the end of the decade. Although new installation vessels may be required for the over-26MW turbines of the future, current vessels may be repurposed in future to support the decommissioning and repowering of turbines installed before 2030.

As offshore turbine power ratings continue to grow, two major factors have impacted the availability of WTIVs: the weight of nacelle, tower and foundation; and turbine hub height.

The weight of nacelles for 10-15 MW wind turbines ranges between 500 tonnes and 800 tonnes, but the weight of a pre-assembled tower for a 14 MW turbine can be greater than 2000 tonnes and for an XXL foundation more than 1000 tonnes.

The hub height of a MHI Vestas 9.5–10 MW turbine is in the 110–115m range; for an SGRE 8 MW turbine it is 109–120 m, for an SGRE 10–11 MW it is 125–128m, for an

Demand vs supply analysis, 2024-2030 (MW)

Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	112	220	17	60	1405	1480	1070
Philippines	0	0	0	0	0	0	0
South Korea	100	0	880	895	1230	1500	1500
Vietnam	0	0	0	0	0	0	0
China	10000	12000	15000	15000	15000	16000	16000
India	0	0	20	0	500	500	1000
Chinese Taiwan	924	1520	1645	1850	1750	1500	1500
TOTAL	11136	13740	17562	17805	19885	20980	21070
TOTAL (excl. China)	1136	1740	2562	2805	4885	4980	5070

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, November 2024. Supply includes jack-up vessels and heavy-lift vessels used for offshore wind turbine installation.

SGRE 14 MW it is greater than 150m, and for the GE Haliade X 12-14MW turbine it is more than 150m.

Due to the specialised technical requirements in the lift capacity of the main crane – as well as the hook heights – the availability of vessels capable of installing the new generation of offshore wind turbines in the 12-18 MW size range is significantly reduced.

China has the majority of WTIVs in the APAC region, comprising 106 operational WTIVs and 19 WTIVs under construction. Capacity is concentrated in a few countries, with only Japan, South Korea, Chinese Taiwan, Singapore and Malaysia having a pool of WTIVs outside of China. Sigma Engineering JSC has a heavy lift vessel operational in Vietnam, however this has only supported the installation phases of inter-tidal projects.[48] Japan has strong capabilities and is expected to expand its WTIV pool to 13 vessels by 2030.

According to the offshore wind vessel availability report, which was prepared by H-BLIX for Wind Europe

48. Sigma Engineering. (2021). Soc trang 7 offshore wind farm in early August. https://sigma.net.vn/en/renewable-energy/soc-trang-7-offshore-wind-farm-in-the-early-august.html

and PWEA in 2022, the average WTIV wind turbine installation efficiency is 0.5 GW/vessel/year in 2021 and is likely to increase to 1.31 GW/vessel/year in 2030.

GWEC Market Intelligence has used the lower end of WITV installation efficiency as a reference to convert the numbers of jack-up WTIVs into annual installation capacity in GWs, as buffer room is needed for project coordination and main crane upgrades for some existing WTIVs. Based on this methodology, we calculated the estimated annual WTIVs installation capacity in APAC.

Challenges in the supply chain for WTIVs

When looking at the APAC scenario, no bottlenecks are expected through to 2030. China has shown capabilities to quickly build and mobilise vessels to support staggering growth and is not expected to see any bottlenecks through the next decade. Annual installation capacity of WTIVs in China is estimated to be around 12 GW currently, increasing to 19 GW by 2026. In addition, with new vessels in the pipeline expected to be delivered, supply in Japan and South Korea is also expected to be sufficient to meet their own demand through to 2030. However, when looking at supply and demand in APAC excluding China, bottlenecks are expected from 2028. At the market level, bottlenecks are expected in India and Chinese Taiwan.

In the APAC region, cabotage rules may restrict foreign vessels from conducting projects in local waters depending on the country. For example, Japan's Article 3 of the 1899 Ship Act prohibits foreign-flagged vessels from transporting cargo or passengers between Japanese ports. This regulation presents a significant barrier to using foreign vessels for offshore wind projects in Japan, leading domestic construction companies to seek localised WTIVs to fulfil their needs. Additionally, there are restrictions on foreign crews, including a mandate for these vessels to visit an overseas port every 60 days. Similarly, South Korean law prohibits non-Korean vessels from transporting cargo between domestic ports. For Japan's first offshore wind project in Akita and Noshiro Port, Seajacks' (now Cadeler) Zaratan WTIV was converted to a Japanese-flagged vessel and operated with a non-Japanese crew.

There have been significant efforts within the Japanese offshore wind sector to prepare the WTIVs required through a combination of newbuild, acquisitions and JVs. There are currently six jack-up vessels in Japan that are in operation and an additional three in construction. The largest WTIV is Shimizu Corporation's BLUE WIND, a 28,000-tonne vessel completed in 2022 with a crane lifting capacity of 2,500 tonnes. Penta-Ocean Construction currently owns two vessels with the completion of CP-16001 (1,600 t crane, owned in partnership with Kajima Corporation and Yorigami Marine Construction) in 2023 to join CP-8001 (800 t crane). A third jack-up will join Penta-Ocean's fleet by 2025 through the JV with Belgian contractor DEME Offshore. DEME's Sea Challenger WTIV is to be converted to a Japanese-flagged vessel and upgraded with a 1,600-tonne crane. Similarly, NYK Line has partnered with Dutch company Van Oord to operate a 1,000+ tonne crane jack-up vessel in Japan. Obayashi Corporation and TOA Corporation completed in 2023 a new jack-up with a 1,250-tonne crane, whilst a consortium led by Toda Corporation purchased Teras Sunrise which is currently undergoing upgrades to increase the crane capacity to 1,300 tonnes and will be operational by the end of 2025.

In 2023, Chinese Taiwan and South Korea welcomed their first tailor-made offshore installation vessels, Green Jade and Hyundai Frontier, respectively. However, Chinese Taiwan is anticipated to face local vessel shortages due to its offshore wind market relying on European WTIVs and most recently Japanese WITV to support installations. With foreign WTIVs currently still available to support, no bottleneck is expected for Chinese Taiwan's offshore wind market, but the situation could change from 2027 when foreign WTIVs are required to support the growth in their home markets.

India is likely to face a turbine installation vessel shortage from the second half of this decade as the country currently does not have any WTIVs available. To avoid the bottleneck, the country needs to either rely on European or Chinese vessels, or make the investment now to meet future demand.

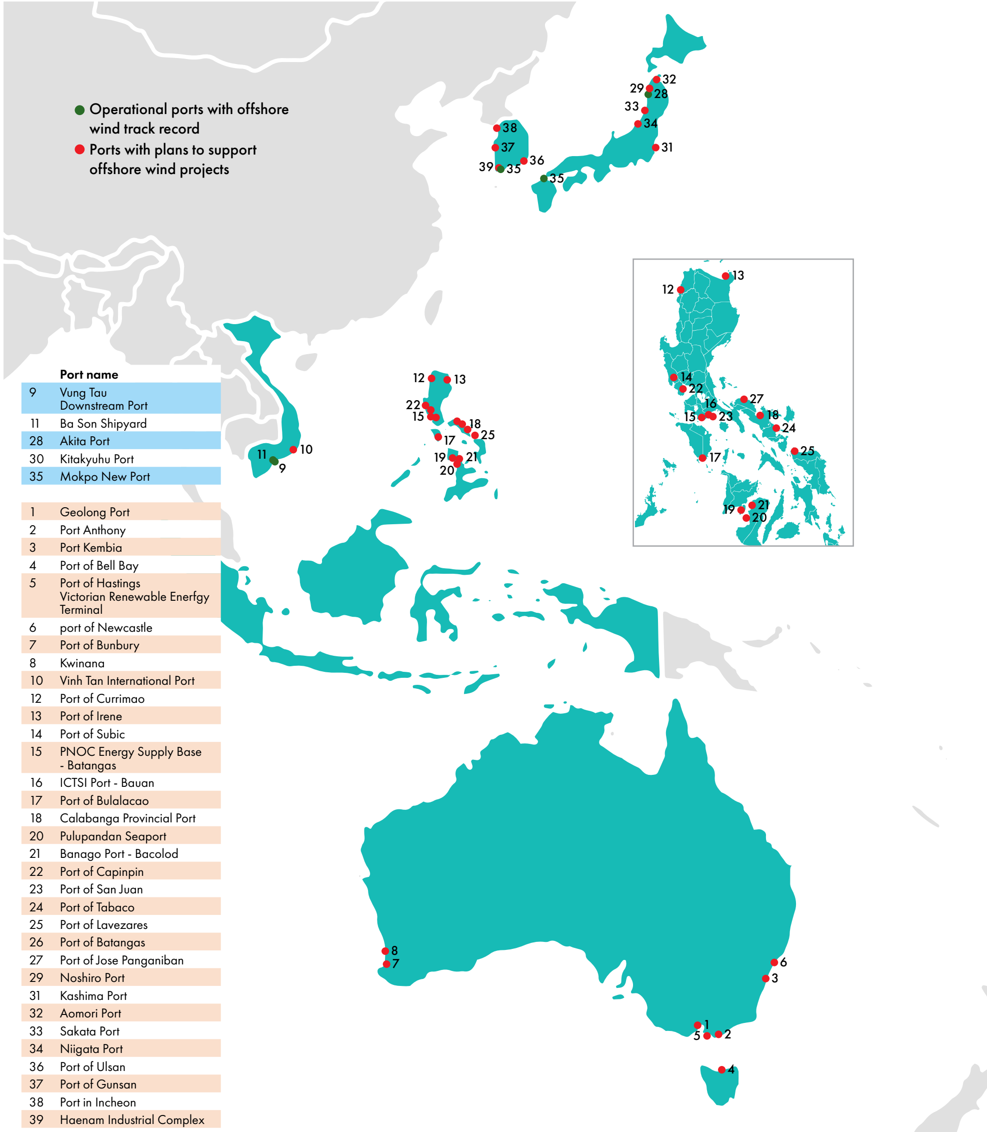
Large offshore WTIVs are extremely expensive and require a skilled workforce and specific knowhow. This means that regional cooperation for vessels in APAC is vital to ensure offshore wind deployment is not delayed.

Ports

Ports can play various roles within the offshore wind supply chain. First, manufacturing ports support the production of wind turbine components such as foundations, towers and blades. These ports demand ample space to accommodate these activities. Second, construction ports accommodate the delivery, handling and assembly of components received in batches that are temporarily stored before loadout to installation and offshore construction support vessels. These ports must be capable of storing and staging foundations, transition pieces, towers, nacelles, blades, and other BoP items.

For floating wind, marshalling and integration (M&I) ports store / marshal foundations in an afloat condition. A heavy lift crane will be used to integrate the wind turbine generator, assemble the tower sections and the rotor nacelle. Certain systems on the foundation can also be commissioned, saving time and eliminating risk offshore. Ideally, M&I ports would be as close to the project site as possible to reduce towing costs, as predictable weather windows are required. M&I

Operational and planned ports for offshore wind in APAC



	Port name
9	Vung Tau Downstream Port
11	Ba Son Shipyard
28	Akita Port
30	Kitakyuhu Port
35	Mokpo New Port
1	Geolong Port
2	Port Anthony
3	Port Kembia
4	Port of Bell Bay
5	Port of Hastings Victorian Renewable Enerfgy Terminal
6	port of Newcastle
7	Port of Bunbury
8	Kwinana
10	Vinh Tan International Port
12	Port of Currimao
13	Port of Irene
14	Port of Subic
15	PNOC Energy Supply Base - Batangas
16	ICTSI Port - Bauan
17	Port of Bulalacao
18	Calabanga Provincial Port
20	Pulupandan Seaport
21	Banago Port - Bacolod
22	Port of Capinpin
23	Port of San Juan
24	Port of Tabaco
25	Port of Lavezares
26	Port of Batangas
27	Port of Jose Panganiban
29	Noshiro Port
31	Kashima Port
32	Aomori Port
33	Sakata Port
34	Niigata Port
36	Port of Ulsan
37	Port of Gunsan
38	Port in Incheon
39	Haenam Industrial Complex

ports require significant wet storage area, which is likely to be a limiting factor considering the heavy traffic within ports.

Ports also perform operations & maintenance (O&M) activities. Port requirements are less intensive for O&M, with distance to the project site playing the largest role in determining its viability. In this case, distance will influence the cost and selection of a maintenance strategy.

Currently, only a limited number of ports are suitable for offshore wind in APAC excluding China, namely seen in Chinese Taiwan, Japan, South Korea and Vietnam. China has 87% of APAC's suitable ports for offshore wind development. Considering planned developments, port capacity is expected to increase in China, Australia, Japan, South Korea and Chinese Taiwan by 2030. The ports that already have a history in offshore wind, as well as those that plan to support offshore wind projects, are mapped on the previous page.

Challenges associated with offshore wind ports

Although the bottleneck assessment shows no regional bottlenecks though to 2030, this assumes that projects can leverage ports across the region (i.e., North Sea offshore wind projects where marshalling ports can support construction in neighbouring countries). At the country level, China is the only market in APAC that will have enough port capacity to deploy its own offshore wind demand. Due to the geographical distances between other APAC markets bottlenecks may still occur.

Apart from 2028 and 2029, Japanese ports (including planned upgrades) should be sufficient to meet domestic project demand. Japan is a maritime nation with five strategic international hub ports, 18 international hub ports and 102 major ports designated under the Port and Harbour Act. However, certain ports require significant upgrades to function as marshalling ports for offshore wind projects. The Ministry of Land Infrastructure Transport and Tourism (MLIT) is responsible for identifying and designating offshore wind "base ports" which developers can lease for up to 30-year periods.

To meet the increasing demand for offshore wind this decade, the Japanese government expects to need seven to nine base ports which could increase to 13 to 19 ports by 2040. So far, there have been seven base ports designated to support the offshore wind projects in Rounds 1 to 3.

In South Korea, domestic ports can meet the offshore wind demand expected for 2024 and 2027, but port capacity will fall behind in 2026 and from 2028 to 2030 due to the growth in demand. Ports in the country will require upgrades to serve as construction bases for projects under development. Mokpo New Port is the only port with a completed official expansion plan for offshore wind. Plans to update Ulsan, Gunsan, Incheon, and Haenam are still at a preliminary stage.

Similarly, Chinese Taiwan's high offshore wind demand in the coming years will exceed the market's port capacity. This will also be the case for India, which currently has no ports suitable for offshore wind.

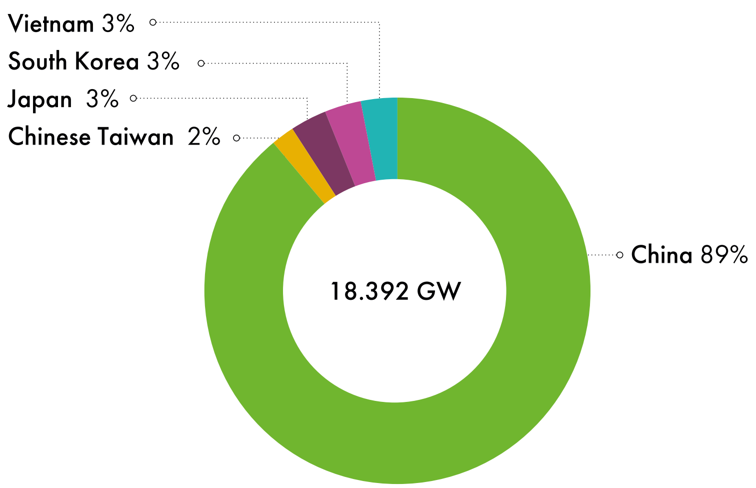
Vietnam is home to around 50 ports and 30 shipyards that operate as major import and logistics bases. With investment, ports in Vietnam could have high potential to support the offshore wind industry through fabrication, marshalling and operations and maintenance. The Vung Tau Downstream Port in Vietnam has already supported the

construction of offshore foundations for the Greater Changhua offshore wind farm.[49] Additionally, Ba Son Shipyard has worked with PTSC to assist with some workload and has plans to develop its fabrication capability to supply monopile foundations for 15 MW+ wind turbines.[50]

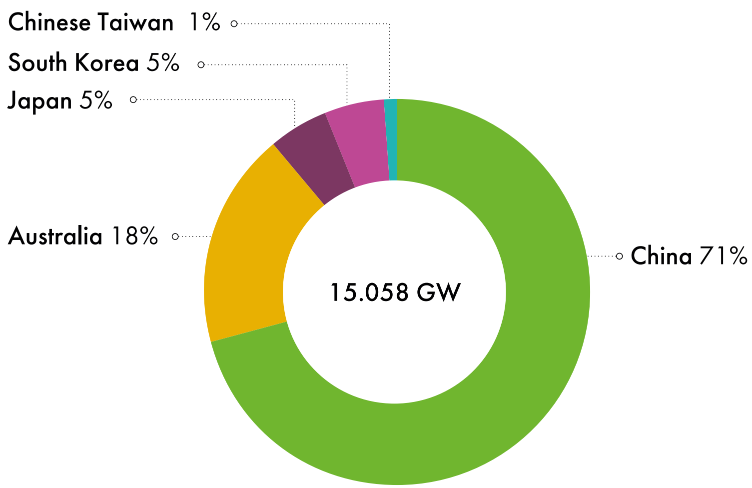
49. https://www.ptsc.com.vn/en-US/ptsc-completed-the-final-integration-for-the-first-foundation-of-offshore-windfarm-greater-changhua-2b-04-1
50. https://ens.dk/sites/ens.dk/files/Analyser/depp_vietnam_port_study_for_offshore_wind_final_report.pdf

Offshore wind ports demand and supply benchmark, 2024-2030

Estmated operational port capacity available for offshore wind in APAC, 2024 (MW)



Estmated planned new port capacity for offshore wind in APAC up to 2030 (MW)



Demand vs supply analysis, 2024-2030 (MW)							
Market	2024	2025	2026	2027	2028	2029	2030
Australia	0	0	0	0	0	0	0
Indonesia	0	0	0	0	0	0	0
Japan	112	220	17	60	1405	1480	1070
Philippines	0	0	0	0	0	0	0
South Korea	100	0	880	895	1230	1500	1500
Vietnam	0	0	0	0	0	0	0
China	10000	12000	15000	15000	15000	16000	16000
India	0	0	20	0	500	500	1000
Chinese Taiwan	924	1520	1645	1850	1750	1500	1500
TOTAL	11136	13740	17562	17805	19885	20980	21070
TOTAL (excl. China)	1136	1740	2562	2805	4885	4980	5070

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

CHAPTER 3: COUNTRY CASE STUDIES

Australia

Overview of Australia's wind market

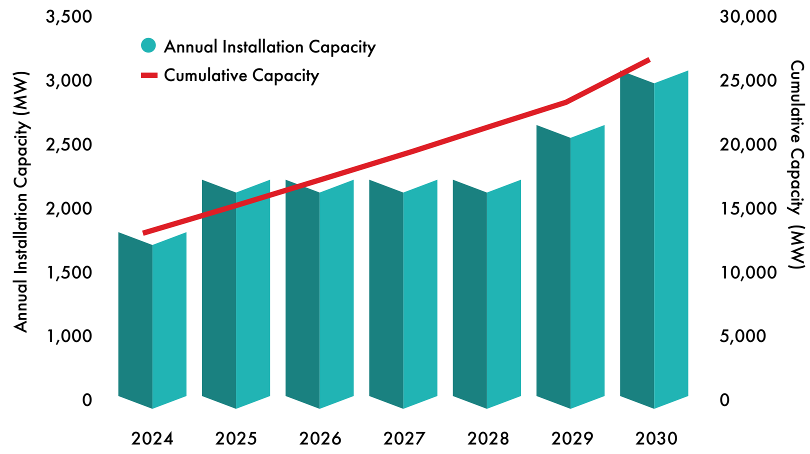
Australia has made huge strides toward increasing renewables in its traditionally fossil fuel driven energy mix, with onshore and offshore wind expected to be paramount to reaching the country's targeted 82% renewables by 2030.[51] It's estimated that an additional 27 GW of wind capacity would be required between 2026 and 2030 to reach this target, alongside solar and storage.[52] Australia's coal-fired generators are reaching the end of their service life, which opens a momentous role for onshore and offshore wind to both fill domestic energy demands and drive an Australian supply chain to meet the needs of the growing wind industries.

Onshore Wind

Australia boasts over 13.5 GW of onshore wind installations, or 13% of the country's current energy supply.[53] The growing trend toward renewable energy will continue as Australia moves away from fossil fuels taking advantage of its vast land area and favourable wind conditions for onshore wind. Although there were no announced financial commitments for utility-scale wind projects in 2023, the Capacity Investment Scheme expanded to help underwrite new wind (and storage) development resulting in new investments for 1.2 GW of wind development reaching financial close in the first 6 months of 2024.[54]

The onshore wind forecast scenario estimates just over 26 GW of onshore wind capacity will be commissioned by 2030. The near-term onshore wind market outlook (2024–2026), built using a bottom-up approach, is based on GWEC Market Intelligence's global onshore wind project database, which covers projects currently under construction, global auction results and announced domestic onshore wind tenders. For the medium-term market outlook (2027–2030), a top-down approach was used alongside existing project pipelines. This considers existing policies and medium/long-term national offshore wind targets. There is currently an implementation gap

Onshore wind installation forecast up to 2030 (MW) Australia



Source: GWEC, 2024

51. DCCEEW. (2022). Annual Climate Change Statement 2022. Retrieved from, https://www.dcceew.gov.au/sites/default/files/documents/annual-climate-change-statement-2022.pdf
52. Clean Energy Council. (2023). Bridging the gap to 82% renewable electricity generation by 2030. Retrieved from, https://assets.cleanenergycouncil.org.au/documents/Bridging-the-gap-to-82-per-cent-renewables-by-2030_Final_August-2023.pdf
53. GWEC. (2024). Global Wind Report 2024. Retrieved from, https://gwec.net/wp-content/uploads/2024/04/GWR-2024_digital-version_final-1.pdf
54. Clean Energy Council. (2024). Renewable projects quarterly report. Retrieved from, https://stg-live.cleanenergycouncil.org.au/getmedia/fe32c5ef-48be-462e-91aa-a39a33f467b6/cec_renewable-projects-quarterly-report_q2-2024.pdf

between declared targets and the rate of annual installations as the forecasted capacity is lower than the expected capacity needed to meet the targeted 82% of renewables by 2030 (i.e., an additional 5.4 GW of wind capacity each year from 2026).[55]

Offshore Wind

Although no offshore wind is currently in operation, the World Bank Group-ESMAP estimates more than 4,900 GW of technical potential (including 1,572 GW fixed and 3,391 GW floating).[57] GWEC forecasts 1 GW of installed offshore wind capacity by 2031, 2 GW by 2032 and 4 GW by 2033, subject to supply chain, market and policy conditions.

Australia has yet to publish national offshore wind targets; however, the State of Victoria is spearheading offshore wind development by targeting 2 GW by 2032, 4 GW by 2035, and 9 GW by 2040. With 12 feasibility licences awarded in Victoria representing as much as 25GW of potential development capacity, there is more than sufficient capacity currently under development to reach the State's targets. Future offshore wind development is expected off the Hunter and Illawarra areas of New South Wales, the Bass Strait off Northern Tasmania, and in the Indian Ocean off Bunbury in Western Australia.

Australia is yet to develop a national route-to-market framework; however, the Offshore Wind Energy Victoria Implementation Statement 3 outlines the country's plans for the first offtake auction in 2026 in that State. The Victorian Government has committed to developing a support package for the first tranche of offshore wind to inform the cadence and volume going forward, ensuring developer and supply chain confidence to invest. This is expected to require financial support from the Commonwealth Government.

Australia's wind supply chain capability

When looking at the Australian supply chain in isolation, the country currently has limited domestic manufacturing capabilities for onshore wind and unsurprisingly no established supply chain for offshore wind key components. This has resulted in a reliance on imports of key components from Europe, China and Vietnam. India could also be a growing source of supply. Wind turbine manufacturer Suzlon, for example, has delivered more than 250 wind turbines since 2004.[58] Considering the ambitious onshore and offshore wind project pipelines, this gap in domestic supply chain coverage presents an opportunity to build an Australian supply chain around wind industries which could start with onshore wind capability establishment prior to 2030 and offshore wind expansion post-2030 as Australia's offshore wind projects move to operation.[59]

Australia has struggled to establish a domestic wind supply chain due to the bust and boom nature of the industry and cheap competing imports. Keppel Prince established a facility in Portland, Victoria, to supply the onshore wind tower industry, but struggled to compete due to the inconsistency of orders, lack of local supply agreements and strong price competition overseas. Through the Wind Turbine Manufacturing Initiative (WTMI), which was established in 2021, the government is working to enhance the participation of Western Australian businesses in wind turbine manufacturing.

Australian companies have demonstrated they can produce anchor cages for onshore wind turbine foundations using steel from one of the over 300 Australian companies in the steel supply chain. For example, steel plate from Bluescope Steel, steel rod from Infrabuild, and fabrication of the anchor cages by Allthread Industries and Precision Oxycut in New South Wales. With a strong and stable demand, Australia could further expand local component manufacture to include onshore turbine towers and post-2030 potentially offshore wind towers – an investment worth hundreds of millions of dollars.[60]

In terms of critical materials, Australia is the second largest producer of rare earth elements in

55. Clean Energy Council. (2024). Renewable projects quarterly report. Retrieved from, https://stg-live.cleanenergycouncil.org.au/getmedia/fe32c5ef-48be-462e-91aa-a39a33f467b6/cec_renewable-projects-quarterly-report_q2-2024.pdf
56. Victoria State Government. (2023). Offshore Wind Energy Victoria Implementation Statement 3. Retrieved from, https://www.energy.vic.gov.au/__data/assets/pdf_file/0026/691181/Offshore-Wind-Energy-Implementation-Statement-3.pdf
58. Australian Trade and Investment Commission. (2024). Australia delivers a windfall for Indian wind turbine maker Suzlon. https://international.austrade.gov.au/en/news-and-analysis/success-stories/australia-delivers-windfall-for-indian-wind-turbine-maker-Suzlon#:~:text=Indian%20wind%20turbine%20maker%20Suzlon%20is%20bringing% 20the%20winds%20of,capacity%20of%20approximately%20764%20MW.
59. Government of Western Australia. (2024). Wind Turbine Manufacturing Initiative. Retrieved from, https://www.wa.gov.au/organisation/department-of-jobs-tourism-science-and-innovation/wind-turbine-manufacturing-initiative
60. Bell, J. (2023). Australia's wind tower producers call for local supply agreements during renewable energy transition. ABC News. Retrieved from, https://www.abc.net.au/news/2023-09-11/wind-tower-companies-and-unions-want-local-procurement-guarantee/102837748

Australia's supply chain coverage (Data represents demand)								
Component	**Unit**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Onshore Nacelle	MW	1500	2000	2000	2000	2000	2500	3000
Onshore Gearbox	MW	1500	2000	2000	2000	2000	2500	3000
Onshore Generator	MW	1500	2000	2000	2000	2000	2500	3000
Onshore Blades	MW	1500	2000	2000	2000	2000	2500	3000
Onshore Power Converters	MW	1500	2000	2000	2000	2000	2500	3000
Onshore Towers	units	125	250	200	400	455	455	417
Onshore Castings	tonnes	18300	24400	24400	24400	24400	30500	36600
Offshore Nacelle	MW	0	0	0	0	0	0	0
Offshore Gearbox	MW	0	0	0	0	0	0	0
Offshore Generator	MW	0	0	0	0	0	0	0
Offshore Blades	MW	0	0	0	0	0	0	0
Offshore Power Converter	MW	0	0	0	0	0	0	0
Offshore Towers	units	0	0	0	0	0	0	0
Offshore Castings	tonnes	0	0	0	0	0	0	0
Fixed Foundations	units	0	0	0	0	0	0	0
Floating Foundations	units	0	0	0	0	0	0	0
Cables	km	0	0	0	0	0	0	0
Ports	MW	0	0	0	0	0	0	0
WTIV	MW	0	0	0	0	0	0	0

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

APAC, after China. It includes world class mines and developments such as Lynas Rare Earth's Mount Weld mine, Iluka's Monazite development and Northern Minerals Limited in Western Australia.[61] In 2024, the Federal Government provided $840 million for Arafura to build what could become the largest rare earth mine and integrated refinery in Australia in the Northern Territory.[62] In 2022, the Government's Critical Mineral Facility granted a $1.25bn non-recourse loan to Iluka Resources for the development of the Eneabba Rare Earths Refinery.

Australia also holds a substantial portion of the world's copper with large reserves in South Australia and Queensland. Last year, Australia produced around 997,000 tonnes of mined copper and 448,000 tonnes of refined copper.[64]

Australia has no existing subsea cable manufacturing capabilities, Suncable is exploring a high voltage cable manufacturing and testing facility in Bell Bay, Tasmania[65] which could supply the HVDC transmission to the Australia-Asia Power Link

61. Rare Earth Industry Association, 2024
62. Ministers for the Department of Industry, Science and Resources. (2024). Joint press conference on Arafura funding, Northern Territory. Retrieved from, https://www.minister.industry.gov.au/ministers/king/transcripts/joint-press-conference-arafura-funding-northern-territory#:~:text=The%20Federal%20Government%20have%20put,of%20%2430%20million%20from%20the
63. Buckley, T., Pollard, M. (2022). State and federal support key to Australia becoming a critical mineral superpower. RENEW Economy. Retrieved from, https://reneweconomy.com.au/state-and-federal-support-key-to-australia-becoming-a-critical-minerals-super-power/
64. Department of Industry, Science and Resources. (2022). Copper | Resources and Energy Quarterly. Retrieved from, https://www.industry.gov.au/sites/default/files/minisite/static/b3caf4fd-b837-4cc5-b443-38782298963a/resources-and-energy-quarterly-june-2022/documents/Resources-and-Energy-Quarterly-June-2022-Copper.pdf
65. Suncable. (2023). SunCable Manufacturing. Retrieved from, https://www.suncable.energy/manufacturing

(AAPowerLink) project and manufacture 1,200 – 1,600 km of cable a year as early as 2029.

Australia has strong vessel capabilities including companies like Teekay, JtK Marine Services, Far Out Charters, BMT, and Bhagwan Marine which offer logistics, shipping, operations support, crew transfer, vessel design, crewing, and operations management.[66, 67]

Australian companies have a history of regional collaboration and knowledge sharing. For example, in July 2024, Singapore's Seatrium was awarded a contract for upgrades and repairs from Teekay for the Australian Defence Maritime Support Services Program (DMSSP). In October 2024, Australia's Macquarie Asset Management agreed to acquire ZITON, a leading provider of offshore wind O&M services in Europe and owner of five jack-up vessels.[68]

There are ports in Australia with capabilities suitable to support offshore wind O&M and some of them areprogressing plans to pivot to support the construction of the growing industry. The Port of Hastings has applied for the rights to develop the Victorian Renewable Energy Terminal, transforming an area of the existing port into a dedicated assembly point to support the construction of Victoria's first offshore wind farms in the Bass Strait including being earmarked as Star of the South's construction port.[69] After rejection for environmental reasons, the application is being revised.

The Port of Newcastle launched a Clean Energy Precinct project to position the Hunter region as a global, diversified energy gateway and a catalyst for economic growth.[70] The plans include an offshore wind staging port which would provide fabrication and storage of offshore wind components set to be in New South Wales, and onshore wind planned in the New England and Central West Orana Renewable Energy Zones.[71] In October 2024, the Port of Newcastle secured a $100 million budget commitment from the Commonwealth Government to support the Clean Energy Precinct and its facilitation of storage and domestic distribution of clean energy.

Additionally, there are existing fabrication companies with oil and gas experience that could be leveraged to support fabrication of key offshore wind components, such as GVP in Victoria, Civmec in New South Wales, and Fremantle Steel in Western Australia.

Strengths and opportunities of Australia's wind supply chain

The main strengths of the Australian supply chain include critical materials (i.e., rare earth elements, steel, and copper), skilled workforce and vessel services (excluding WTIV), with opportunities to transition existing industries to supply towers, subsea cables and ports. Considering the domestic bottlenecks identified in the table above and regional bottlenecks identified in this wider report, this presents opportunities for both wind suppliers and potential transition companies to grow their capabilities to meet the increasing domestic and regional demand.

Additionally, with a strong economy, good ease of doing business score (14/190) and low sovereign risk,[73] with support policy settings, Australia is well placed to receive international investment into the local supply chain industry.

Policy

The Climate Change Act commits Australia to cut emissions to 43% below 2005 levels by 2030 and net zero by 2050.[74] In line with this, the Minister for Climate Change and Energy set a national target of 82% renewable electricity by 2030.[75] Coal-fired power generation in Australia will mostly be retired before 2040; replacing it with high-availability wind power is a major driver of the current and forecast growth in wind power production. The Powering Australia plan includes offtake support for renewable capacity via the Capacity Investment Scheme and funding for new transmission via the $20 billion Rewiring the Nation programme.[76] Additionally, the $4 billion

66. Star of the South. (2024). Offshore Wind Supplier Showcase.
67. Teekay. Retrieved from, https://www.teekay.com/australia/
68. Macquarie. (2024). Macquarie Asset Management agrees to acquire ZITON, a specialist in offshore wind O&M services, from Permira Credit. Retrieved from, https://www.macquarie.com/au/en/about/news/2024/macquarie-asset-management-agrees-to-acquire-ziton-a-specialist-in-offshore-wind-o-and-m-services.html
69. Victorian Renewable Energy Terminal. (2024). Progress update. Retrieved from, https://renewableenergyterminal.com.au/
70. Port of Newcastle. Clean Energy Precinct. Retrieved from, https://www.portofnewcastle.com.au/landside/major-projects/clean-energy-precinct/
71. Port of Newcastle. Clean Energy Precinct. Retrieved from, https://www.portofnewcastle.com.au/landside/major-projects/clean-energy-precinct/
73. World Bank Group. (2019). Ease of doing business rank. Retrieved from, https://data.worldbank.org/indicator/IC.BUS.EASE.XQ?locations=AU&most_recent_value_desc=true
74. Australian Government. (2022). Climate Change Act. Retrieved from, https://faolex.fao.org/docs/pdf/aus213481.pdf
75. DCCEEW. (2022). Annual Climate Change Statement 2022. Retrieved from, https://www.dcceew.gov.au/sites/default/files/documents/annual-climate-change-statement-2022.pdf
76. DCCEEW. Powering Australia. Retrieved from, https://www.dcceew.gov.au/energy/strategies-and-frameworks/powering-australia#:~:text=The%20Australian%20Government's%20Powering%20Australia,and%20net%20zero%20by%202050.

investment into the Hydrogen Headstart programme aims to accelerate the development of Australia's hydrogen industry.[77] If successful, this will drive further uptake in wind energy deployment for green H2 production.

The table below provides a non-exhaustive summary of federal and state-level initiatives to support onshore and offshore wind supply chain development.[78] There is currently no specific policy focus on developing a domestic wind energy supply chain.

Industry

- **Steel (Tower Component Manufacturing)** - Australia has two large steel producers that could be leveraged to support the production and manufacturing of steel for onshore towers and offshore tower components including platforms, ladders and rails. Australia also has existing domestic capabilities to produce anchor cages for onshore wind foundations. Investment into rolling mills to roll the large plate would unlock the potential to manufacture towers for onshore wind. Due to the increase in scale of steel needed, growing manufacturing capabilities for offshore towers and fixed and floating foundations would require significant additional ccapabilities. Investment in new facilities should start now to support the 2030 buildout of projects.

- **Copper (Subsea Cables) –** Copper is indispensable in the wind energy supply chain and necessary for the construction of subsea cables. Australia has large copper reserves and production and refining capabilities. It already exports a sizeable portion of its copper production to international markets including China, Japan, South Korea, India and Vietnam. Australia is well placed to supply copper to the APAC wind supply chain.

- **Rare earth materials –** Australia is a world leader in rare earth production, contributing over 5% globally. Australia currently exports rare earths to Malaysia and South Korea for processing, and, establishing domestic processing capabilities could bolster Australia's role as a rare earth supplier for wind turbine generators within the APAC wind supply chain.

- **Vessel capabilities –** Australia has existing O&M and survey vessel capabilities used in other offshore industries which could transition to offshore wind.

- **Blades –** Capabilities exist within the fibreglass moulding industry such as Composite Materials Engineering and the Advanced Fibre Cluster in Victoria and Quickstep in Victoria and NSW. There are opportunities for Australia to pivot towards blade manufacturing for onshore wind

Summary of supply chain and workforce initiatives in Australia

Direct Supply Chain Related Policy	Description
National Renewable Energy Supply Chain Action Plan (NRESCAP)[79]	The NRESCAP identifies eight action areas to inform policy progress to secure the renewable energy infrastructure required for the energy transition, with onshore wind as one of the focus technologies.
Future Made in Australia Act (FMIA)[80]	FMIA encompasses $7.1 billion over 11 years in tax incentives for critical minerals processing including $68 million to attract investment into domestic projects consistent with the FMIA National Interest Framework.
Circular Economy Market Development Grants (South Australia)[82]	Supporting new suppliers setting up wind turbine manufacturing capabilities by applying and scaling up innovative circular economy business models in SA.
Renewable Energy Supply Chain Hub (RESCH) (Victoria)[83]	RESCH will create a cluster of manufacturing businesses that produce renewable energy components and provide services, including to offshore wind.

77. DCCEEW. Hydrogen Headstart program. Retrieved from, https://www.dcceew.gov.au/energy/hydrogen/hydrogen-headstart-program
78. Australian Government. (2024). National Renewable Energy Supply Chain Action Plan. Retrieved from, https://www.energy.gov.au/sites/default/files/2024-09/nrescap-summary-government-initiatives.pdf
79. DCCEEW. (2024). National Renewable Energy Supply Chain Action Plan: Summary of Government Initiatives.
80. Australian Critical Minerals Research and Development Hub. Retrieved from, https://research.csiro.au/critical-minerals-hub/
81. IEA. (2024). Future Made in Australia. Retrieved from, https://www.iea.org/policies/20158-future-made-in-australia-attracting-investment-in-key-industries
82. Government of South Australia. Circular Economy Market Development Grants. Retrieved from, https://www.greenindustries.sa.gov.au/funding/ce-market-development-funding
83. Victoria State Government. (2023). Offshore Wind Energy Victoria Implementation Statement 3. Retrieved from, https://www.energy.vic.gov.au/__data/assets/pdf_file/0026/691181/Offshore-Wind-Energy-Implementation-Statement-3.pdf

by 2030 and potentially offshore wind post-2030 as a further transition from onshore blade manufacturing.

- **Nacelles -** Local manufacturing company Marand Precision Engineering (Marand) is a supplier of precision engineering parts to the defence, rail and energy industries and previously announced a partnership with Vestas on a wind turbine assembly facility in Geelong. Onshore nacelle assembly facilities could be developed in Australia to meet the domestic demand.

- **Fabrication and port storage –** Due to its strong oil and gas history, Australia is well placed to repurpose the capabilities of existing oil and gas fabricators and transition to support the fabrication of key offshore components including foundations, floating platforms, and offshore substations. Transition fabrication companies identified include GVP in Victoria, Civmec in New South Wales, and Fremantle Steel in Western Australia.

- **Skilled workforce –** There are significant onshore wind engineering capabilities in Australia, including GE, Goldwind, Vestas and Siemens Gamesa Renewable Energy. Engineering companies have a large presence across Australia and provide expertise for energy engineering including onshore and offshore wind design, feasibility, and project management services. As Australia transitions away from coal fired power generation, a workforce will be unlocked to support the growing wind industry, providing opportunities to gain domestic capabilities in construction and assembly, O&M, project management and logistics.

Recommendations for wind supply chain scale-up in Australia

1. To help industry confidently forecast Australia's market size, the government could consider committing to an onshore and offshore 2040 wind target and clarify an auction schedule for offshore wind supported by straightforward regulatory policies.

- The Federal Government could consider setting long-term national onshore and offshore wind targets, with the latter supported by an auction schedule, and providing clarity on the route to market and financial support mechanisms such as the Capacity Investment Scheme and the National Reconstruction Fund. Long-term installation certainty will encourage local supply chain investment. These targets could be written into the Nationally Determined Contributions submitted to the UNFCCC under the Paris Agreement so that they are legally binding and transparent.

- Modernising the electricity grid, through frameworks such as Rewiring the Nation,[84] is crucial to supporting future electricity generation, increasing investment and confidence in the realisation of wind projects.

- Encourage public-private partnerships, to attract local private capital, encourage risk sharing, facilitate permitting, joint research and development and workforce training programmes.

2. The Federal Government could consider developing a National Wind Supply Chain Strategy tailored around Australia's strengths.

- A National Wind Supply Chain Strategy could align state-level strategies, improve investment and inter-state coordination during project construction, supply chain priorities and working groups. The current state focus could shift to promote suppliers around wind clusters.

- An approach to manage procurement contracts at a federal level could be considered e.g., a coordinating body focused on leveraging synergies with economies of scale between states and projects, and increasing investor confidence.

- The strategy could identify key manufacturing and fabrication hubs, inland transport logistics and flagship ports to solve logistical challenges to transporting large components to place of installation for both onshore and offshore projects.

- The federal government could look to develop a Port Development Plan to identify ports with existing or transitioning potential for offshore wind services, leveraging the existing plans, such as those at the Port of Hastings and the Port of Newcastle, and assessing a multi-port approach. Backing for

84. DCCEEW. Rewiring the Nation. Retrieved from, https://www.dcceew.gov.au/energy/renewable/rewiring-the-nation

port development at the federal level is crucial to ensure ports can scale up to provide for offshore wind construction, operations and maintenance.

3. The Federal Government could target investment in the large lead time infrastructure needed to construct offshore wind projects and plan to reduce reliance on imports.

- Australia could focus on building capabilities where it most benefits society and decarbonisation. In the near term, Australia can leverage its existing capabilities in anchor cages for onshore wind and engineering services to support the domestic onshore wind industry. Australia could also leverage its existing vessel capabilities to support survey work and development services.

- Australia could look to develop new manufacturing capabilities, leveraging existing expertise, facilities, and critical material industries. Opportunities include onshore wind tower and tower component fabrication, onshore wind component assembly and cable manufacturing.

- Beyond 2030, as the offshore wind operational portfolio and project pipeline grow, Australia could work to further expand its domestic wind supply chain in line with demand to become more self-sufficient. Notably in areas where regional demand is expected to outweigh supply; offshore nacelle assembly, offshore towers, foundations (fixed and floating).

- For existing and developing capabilities, encourage use of materials sourced from within Australia through sector growth strategies and large industrial policy packages and offer financial incentives to fund strategic investment into the local wind supply chain.[85]

4. Upskill the country's workers to support the domestic wind supply chain.

- Consultations with industry indicate anywhere from 3 to 10 years are needed to upscale a workforce. By 2030, Australia will need an additional 85,000 workers to support the construction, operation and maintenance of renewable energy infrastructure.[86] Given the lengthy training periods, it is crucial to take immediate action to ensure Australia can grow its workforce without delay.

- Australia could promote the development of skills through a national skills and workforce strategy and ensure coordination of skills at a federal level leveraging the National Energy Workforce Strategy[88] and bringing together state-level strategies such as Victoria's Clean Economy Workforce Development Strategy[89] and the Local Jobs First Act 2003.

- Industry could leverage the investment opportunities through Future Made in Australia (which sees investment in skills, training and education and builds programmes to transition workers from the oil and gas industry) and funding available via bodies such as the Australian Renewable Energy Agency[90] and the National Reconstruction Facility.

5. Promote collaboration between domestic firms and leading international wind companies to facilitate knowledge sharing, upskilling, and technology transfer.

- To facilitate knowledge sharing, domestic firms interested in supporting the wind supply chain could establish working groups with APAC suppliers to encourage relationship building and knowledge transfers to support Australia in developing a national supply chain.

- Australia can benefit from collaboration with well-established international wind OEMs who can inject experience into the market via partnerships and joint ventures with local suppliers, as recently proposed in Australia's solar industry. Companies could leverage the existing international partnerships under Australia's international climate and clean energy partnerships.

85. GWEC. (2024). Global Wind Report.
86. Australian Energy Council. (2024). Australia's workforce shortage. Retrieved from, https://www.energycouncil.com.au/analysis/australia-s-workforce-shortage-a-potential-obstacle-on-the-road-to-net-zero/#:~:text=By%202030%2C%20Australia%20is%20expected,of%20the%20renewable%20energy%20infrastructure.
87. DCCEEW. National Energy Workforce Strategy. Retrieved from, https://www.dcceew.gov.au/energy/workforce
88. State of Victoria. (2023). Clean Economy Workforce Development Strategy 2023 – 2033. Retrieved from, https://djsir.vic.gov.au/__data/assets/pdf_file/0012/2179677/Clean-Economy-Workforce-Development-Strategy-2023-2033.pdf
89. State Government of Victoria. Local jobs first policy compliance. Retrieved from, https://www.vic.gov.au/tafe-toolkit-local-jobs-first-policy-compliance
90. The Government is investing $3.2 billion over the next decade through the Australian Renewable Energy Agency to support the commercialisation of technologies that are critical to the net zero transformation. Retrieved from, https://budget.gov.au/content/factsheets/download/factsheet-fmia.pdf

- Australia can also provide expertise and services to support the growth of the APAC wind industry, despite having limited component fabrication capability to date. There are opportunities for UK-based organisations with skilled (visa eligible) workers to seek to develop Australia-based support to the market through migration and transfer of skills. Australia could become the APAC region leader for offshore wind development services.

6. Federal and State Governments to encourage the continued extraction in compliance with ESG standards and the added value of the critical minerals, (and specifically rare earths and copper) required in the wind industry, where Australia has local resource.

Build on the recent plans to expand critical material production in Australia to position Australia as a key provider of crucial components in the APAC wind energy supply chain, such as rare earths for wind turbine generators and copper for subsea cables. State and federal support is critical to position Australia as a key supplier of critical materials.

- **Production –** Provide use of production tax credits to incentivise mining of rare earths, steel and copper to help meet the demand of the APAC wind supply chain.

- **Infrastructure development –** Target investments into Australia's domestic processing and refining industries that will expand its production of rare earths, as seen through the Future Made in Australia Act, to grow Australia's rare earth industry and increase the supply needed for wind turbine generators across the APAC region.

- **R&D support –** Leverage ongoing research through the Australian Critical Minerals Research and Development Hub to promote the development of efficient, cost-effective and environmentally friendly methods of extraction and processing.

- **Exportation facilitation –** Support the development of export facilities to manage the increased export of critical materials to support the demands of the wider APAC region, such as the export of copper from the Port of Newcastle Energy Centre Precinct development.

Indonesia

Overview of Indonesia's wind market

As a coal and natural gas-rich nation, Indonesia's economy and domestic energy supply is tied to fossil fuels which are expected to peak through 2030 while the government transitions its energy industry towards renewables. Considering onshore and offshore wind only, the country has an impressive technical potential of nearly 155 GW.

Indonesia aims to achieve net zero by 2060, in alignment with President Prabowo Subianto's plan to be the fourth largest economy in the world by 2045. Although renewables are expected to contribute to these goals, the government has reduced its previous 2025 ambitions from 23% to 17%-19%.

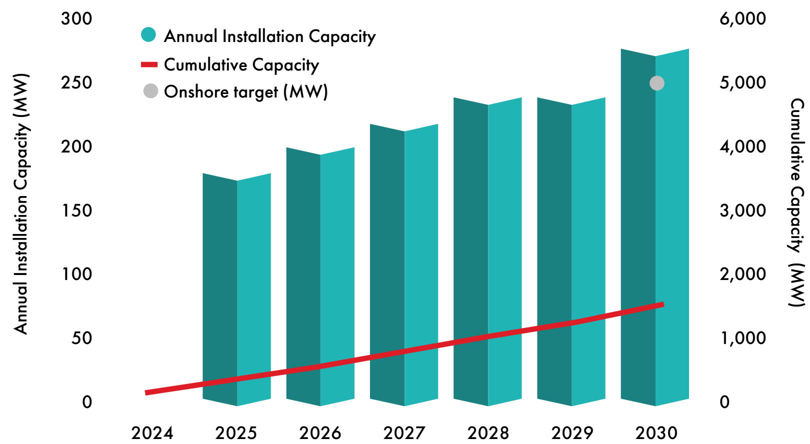
Indonesia's push to increase its renewables capacity is incentivised by international initiatives including the Just Energy Transition Partnership (JETP) and robust government support. The enactment of the Ministry of Energy and Mineral Resources (ESDM) Regulation 11 of 2024 emphasises the importance of utilising locally sourced materials, strengthening national industry, stimulating job creation, and reducing reliance on imported technologies, ensuring that investments directly benefit the local economy.

Onshore Wind

The Southeast Asia Energy Transition Partnership released a roadmap ("Wind Energy Development in Indonesia: Investment Plan") to increase onshore wind development in Indonesia. The roadmap identified policy areas that will streamline regulatory frameworks and address barriers to wind energy development. ESDM sees that through enhanced policy support and leveraging its warm relations with its allies, Indonesia can unlock its onshore wind potential and contribute to the country's renewable energy targets.

Currently, Indonesia only has two onshore wind farms – Sidrap and Tolo Onshore – both located in Sulawesi, with a combined capacity of 152.3 MW accounting for less than 0.1% of the country's total wind energy potential. ESDM aims to increase its wind energy capacity to 5 GW by 2030, and up to 37 GW by 2060,[93] albeit a reduction compared

Onshore wind installation forecast up to 2030 (MW) Indonesia



Source: GWEC, 2024

93. Jakarta Globe. (2024, September 27). Indonesia aims to add 5 GW of wind power capacity by 2030. Retrieved from, https://jakartaglobe.id/business/indonesia-aims-to-add-5-gw-of-wind-power-capacity-by-2030

to the 8.5 GW proposed under the Comprehensive Investment and Policy Plan of JETP Indonesia.[94]

Under its current route-to-market programme, onshore wind projects are awarded according to price-based auctions, with a fixed rate between years 1 to 10 which drops between years 11 to 20 making profit margins uncertain as they do not account for future market conditions.[95] Moreover, during the auction process, projects are selected based on their lowest proposed tariffs. Furthermore, there is a requirement for developers to be in a joint venture with state-owned PT Perusahaan Listrik Negara (PLN) whereby it retains a 51% majority ownership. These requirements have hindered foreign investments in wind projects.

The onshore wind technical potential in Indonesia exceeds 60 GW, with the eastern provinces of East and West Nusa Tenggara and South Sulawesi having the most attractive wind resource.[96] These regions are also home to coal mining methane and coal-fired power plants with huge workforces that will be unemployed when these mines are closed. Tapping into the wind energy potential could help these regions reduce emissions, upskill workers and attract investment to drive the clean energy transition.

The forecast scenario estimates 1.53 GW of onshore wind capacity will be commissioned within the decade. This represents a conservative outlook from the 5 GW onshore wind target that ESDM set and assumes status quo on government policy, low to mid-industry interest, and average economic conditions. Delays in passing the New and Renewable Energy Law currently pending before the Indonesian People's Representative Council (DPR) could lead to challenges in obtaining site approvals and leases, potentially slowing down the project pipeline beyond this forecast scenario.

Offshore Wind

Indonesia has substantial offshore wind technical potential, estimated at

94. Just Energy Transition Partnership Indonesia. (2023). Comprehensive Investment and Policy Plan 2023. Retrieved from, https://jetp-id.org/storage/official-jetp-cipp-2023-vshare_f_en-1700532655.pdf
95. Yustika, M. (2024, July 23). Fact Sheet: Unlocking Indonesia's renewable energy potential through policy reforms. Institute for Energy Economics and Financial Analysis. Retrieved from, https://ieefa.org/resources/fact-sheet-unlocking-indonesias-renewable-energy-potential-through-policy-reforms. Note feed in tariffs are only for hydro, biogas and solar.
96. Southeast Asia Energy Transition Partnership. (2024). Onshore wind energy development in Indonesia: handover ceremony for assessment report. Retrieved from, https://www.energytransitionpartnership.org/2024/06/26/onshore-wind-energy-development-in-indonesia-handover-ceremony-for-assessment-report/

94.2 GW, and mostly concentrated in the areas of Aceh, Southern Java, and Southern Papua. So far developers (both local and international) have had low appetite in pursuing development opportunities in the country, as there is no clear leasing, or a general offshore wind policy in place.

However, this could change with credible targets backed by strong policy and incentives, especially as offshore wind could accelerate progress towards Indonesia's renewables targets while transitioning parts of the workforce currently employed in mining and fossil fuels.

Indonesia's wind supply chain capability

When looking at the Indonesian wind supply chain in isolation, the country has limited or no domestic manufacturing capabilities for onshore and offshore wind key components, as historically there has been no domestic demand to drive supply chain investments. Kenertec Power Systems (KPS) has been Indonesia's sole tower manufacturing facility since 2007, supplying 3,800 towers to wind markets across Asia, Europe and North America up to the end of 2023.[97]

It is expected that, apart from towers, most of Indonesia's onshore wind requirements will need to be met with imports unless the supply chain capabilities expand. Although KPS provided towers, SGRE provided turbines for Indonesia's two operating onshore wind projects.[98, 99, 100]

ESDM recently reduced local content requirements (LCR) for renewable energy projects in Indonesia to spur investments from foreign-sourced funding. Wind energy projects will now have a minimum LCR of 15% which can be waived under two scenarios:[101]

1. **International financing:** projects with at least 50% financing from multilateral or bilateral creditors (including development financing institutions).

2. **Imported components:** subject to an independent audit, when domestic components are not available, do not meet the technical requirements of the developer, or cannot meet the demand.

Indonesia has one of the largest critical minerals reserves in the world including nickel (1.5 billion tonnes), tin (1.2 billion tonnes), bauxite (927 million tonnes), and copper (640 million tonnes). Because the government is positioning the country to be a world leader in the nickel value chain, it banned the exports of raw nickel in 2020 to incentivise investments in Indonesia's downstream nickel industries.[102] The country's vast nickel and copper reserves can be capitalised to support the needs of the regional wind energy supply chain, particularly in supplying refined nickel and copper products to feed into the production of towers, nacelles, gearboxes, generators and power converters.

In addition to its critical minerals reserves, Indonesia has reserves of rare earths such as monazite, zircon, and xenotime, which can be found in various locations in Indonesia, such as Bangka Island in eastern Sumatra and Kalimantan.[103] Monazite is a key source of lanthanides used in high-strength magnets for wind turbine generators, enhancing efficiency. Zircon, while not a primary REE source, contains zirconium for durable turbine components. Xenotime provides yttrium, which is essential for superconductors and electronics that improve wind energy systems. These minerals can further support the development of more efficient wind energy technologies.

The Geological Agency of ESDM is actively investigating Indonesia's REE resources and carried out two exploration activities in Mamuju, West Sulawesi, and Parmonangan in North Sumatra to identify deposits in areas adjacent to current mining sites.[104]

97. PT. Kenertec Power System. (2023). 17 Years of Korindo Wind Tower (PT. Kenertec Power System). LinkedIn. Retrieved from, https://www.linkedin.com/posts/kenertec-power-system_17-years-of-korindo-wind-tower-pt-kenertec-activity-7066959082301116417-ZoNW?utm_source=share&utm_medium=member_desktop
98. PT. Kenertec Power System. (2023). 17 Years of Korindo Wind Tower (PT. Kenertec Power System). LinkedIn. Retrieved from, https://www.linkedin.com/posts/kenertec-power-system_17-years-of-korindo-wind-tower-pt-kenertec-activity-7066959082301116417-ZoNW?utm_source=share&utm_medium=member_desktop
99. RENews.biz. (2018, January 25). Siemens Gamesa rises in SE Asia. Retrieved from, https://renews.biz/33550/siemens-gamesa-rises-in-se-asia/
100. Siemens Gamesa Renewable Energy. (2017, July 21). Siemens Gamesa receives 20-turbine order from Indonesia for Equis Energy's 'Tolo 1' onshore wind power plant. Retrieved from, www.siemensgamesa.com/global/en/home/press-releases/siemens-gamesa-receives-20-turbine-order-from-indonesia-for-equis-energys-tolo-1.html
101. Ashurst. New local content regime for electricity infrastructure development in Indonesia. Retrieved from, https://www.ashurst.com/en/insights/new-local-content-regime-for-electricity-infrastructure-development-in-indonesia/
102. Palaon, H. & Walker, H. (2024). A glimpse into Indonesia's nickel policy. The Interpreter. Retrieved from, https://www.lowyinstitute.org/the-interpreter/glimpse-indonesia-s-nickel-policy
103. Ministry of Energy and Mineral Resources. (2019). Characteristics and genesis of rare earth elements in Western Indonesia. Retrieved from, http://geologi.esdm.go.id/perpustakaan/?p=show_detail&id=203
104. Da Costa, G. (2023, February 8). Energy ministry prepares exploitation of rare earth minerals. Indonesia Business Post. Retrieved from, https://indonesiabusinesspost.com/insider/energy-ministry-prepares-exploitation-of-rare-earth-minerals/

Supply chain strengths and opportunities

The main strengths of the Indonesian supply chain include nickel and copper supplies, relevant transition industries across mining, oil and gas, steel fabrication, shipbuilding and EPC. Considering the domestic bottlenecks identified in the table above and regional bottlenecks identified in this wider report, this presents opportunities for both wind suppliers and potential transition companies to grow their capabilities to meet increasing domestic and regional demand.

1) Indonesia's potential key role in providing nickel and copper for wind energy

As the world's leading raw nickel producer, Indonesia produced 1.8 million metric tonnes of nickel in 2023.[105] Despite its raw nickel export ban being questioned by the EU before the World Trade Organisation (WTO), the new administration of President Prabowo Subianto will continue this policy position introduced by former President Joko Widodo to ensure that the country will achieve its goal of developing its nickel downstream industry.[106]

Indonesia is employing the same strategy of banning raw copper exports as it did for raw nickel to increase the country's copper smelting facilities. The focus on

105 Statista. (2024, August 7). Mine production of nickel in Indonesia from 2010 to 2023. Retrieved from, https://www.statista.com/statistics/260757/indonesian-mine-production-of-nickel-since-2006

106. Asia Sentinel. (2024, October 9). Indonesia defies WTO in EU nickel dispute. Retrieved from, https://www.asiasentinel.com/p/indonesia-defies-wto-eu-nickel-dispute

Indonesia's supply chain coverage (numbers in chart represent expected demand)								
Component	Unit	2024	2025	2026	2027	2028	2029	2030
Onshore Nacelle	MW	0	180	200	220	240	240	280
Onshore Gearbox	MW	0	180	200	220	240	240	280
Onshore Generator	MW	0	180	200	220	240	240	280
Onshore Blades	MW	0	180	200	220	240	240	280
Onshore Power Converter	MW	0	180	200	220	240	240	280
Onshore Towers	units	0	44	62	56	44	42	25
Onshore Castings	tonnes	0	2196	2440	2684	2928	2928	3416
Offshore Nacelle	MW	0	0	0	0	0	0	0
Offshore Gearbox	MW	0	0	0	0	0	0	0
Offshore Generator	MW	0	0	0	0	0	0	0
Offshore Blades	MW	0	0	0	0	0	0	0
Offshore Power Converter	MW	0	0	0	0	0	0	0
Offshore Towers	units	0	0	0	0	0	0	0
Offshore Castings	tonnes	0	0	0	0	0	0	0
Fixed Foundations	units	0	0	0	0	0	0	0
Floating Foundations	units	0	0	0	0	0	0	0
Cables	km	0	0	0	0	0	0	0
Ports	MW	0	0	0	0	0	0	0
WTIV	MW	0	0	0	0	0	0	0

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

promoting domestic processing of nickel and copper to increase the local value added is part of Jakarta's push for the country to achieve high-income status by 2045.

By leveraging its critical minerals reserves and investing into minerals processing facilities, Indonesia can cement its role in the entire energy transition process while supporting domestic employment and economic growth and contributing to net-zero targets. By positioning itself as a nickel and copper hub for the APAC region, Indonesia will be a key player that supports the overarching goal of establishing a regional wind energy supply chain.

However, Indonesia could also consider strengthening ESG principles in its minerals production to ensure that it will benefit the host communities and will not cause further environmental damage. Appropriate safeguards should be in place, including best practices in land use, environmental & social impact assessments (ESIAs), and free, prior, & informed consents (FPICs)[107] especially in mining reserve areas overlapping with indigenous communities.

2) Indonesian transition industries can be well-placed to support wind energy

Offshore oil & gas, offshore steel fabrication, shipbuilding, EPC contractors and automotive can potentially support the uptake of wind energy development in Indonesia.

a) Offshore oil and gas: Indonesia has a robust offshore oil & gas sector including PT Pertamina, the largest state-owned oil & gas company, which has most of its offshore operating blocks in West Java and Kutai Basin in Kalimantan.[108] As the company operates the greatest number of offshore platforms in-country, Pertamina's workforce can provide the transferrable skills that will be needed in a future offshore wind industry in Indonesia.

b) **Offshore steel fabrication:** Indonesia possesses a mature offshore steel fabrication capability specifically tailored to offshore oil & gas. This established expertise is not only valuable for oil & gas applications but has significant potential for transferability to the construction of structures required for both onshore and offshore wind projects. The skills, techniques and technologies developed in offshore steel fabrication can be effectively adapted to meet the structural demands of wind energy installations, such as towers and foundations.

Furthermore, this capability can position Indonesia to provide towers and foundations, particularly for offshore wind. This transition not only supports local economic growth but also fosters job creation in the manufacturing and construction sectors. As the country continues to diversify its energy portfolio, harnessing its steel fabrication capabilities will be crucial in meeting both domestic and international wind energy needs.

c) Shipbuilding: The country hosts a robust shipbuilding industry, mostly located in Batam Island (near Singapore) and the western half of Java Island. The types of vessels that the Indonesian shipbuilding industry provides include offshore oil & gas, container vessels, cruise ships, and oil tankers. Capitalising on the existing shipbuilding industry in Indonesia coupled with experience in the oil & gas industry, makes the learning curve needed for the industry to service offshore wind less steep. In 2023, a WTIV finished construction in PaxOcean Group's Batam shipyard.[t] The vessel has the capacity to install 15-MW offshore wind turbines, monopiles and jackets. Indonesia has the capability to expand its WTIV manufacturing capabilities even further.

d) EPC firms: Indonesia's wind energy sector benefits from a growing network of experienced EPC firms that strengthen the supply chain and present significant opportunities for development. These firms bring extensive expertise in oil & gas and other renewable energy projects, enabling them to effectively manage the complexities of wind farm construction. The collaboration between domestic and international firms fosters innovation, cost efficiency, and a deeper understanding of local regulatory landscapes, positioning Indonesia as a promising market for wind energy expansion. As the country aims to diversify its energy portfolio, these contractors play a pivotal role in driving the transition towards

107. Buxon, A. (2022, February). People and nature first: safeguards needed in mining exploration. IIED Briefing. Retrieved from, https://www.iied.org/sites/default/files/pdfs/2022-02/20736iied.pdf
108. Hurtado, A. (2023, November 30). Bulk of Pertamina's emissions coming from its offshore operations. Offshore Magazine. https://www.offshore-mag.com/energy-transition/article/14302075/bulk-of-pertaminas-emissions-coming-from-its-offshore-operations
109. Offshore Magazine. (2023, October 6). PaxOcean delivers WTIV to Penta-Ocean. Retrieved from, https://www.offshore-mag.com/vessels/article/14299911/paxocean-delivers-wtiv-to-penta-ocean

sustainable energy solutions. The identified EPC contractors engaged in the oil & gas industry in Indonesia include Tripatra, Meindo Elang Indah, Saipem, JGC, IKPT, and Timas. These companies possess experience in complex engineering projects, which positions them well to transition into supporting wind energy development in the country. Their established expertise in project management, construction and logistics can be effectively leveraged to facilitate the construction and implementation of wind energy infrastructure, thereby contributing to the country's wind energy goals. This synergy between oil & gas contractors and the emerging wind energy sector can drive innovation and efficiency, further enhancing Indonesia's energy transition.

e) Automotive: Indonesia's robust automotive industry can serve as groundwork to develop the country's manufacturing capabilities on gearboxes and castings for offshore and onshore wind turbines. Large Japanese car brands dominate the Indonesian automotive industry and use Indonesia (and Thailand) as its ASEAN manufacturing hub. As the country pushes to become the Southeast Asian leader in EVs to leverage its rich nickel deposits, the existing workforce specialising in automotive gearboxes and castings can be upskilled to service the wind energy industry.

Recommendations for wind supply chain scale-up in Indonesia

1. Expand both nickel and copper processing capabilities to consider the needs of wind suppliers that use those products for towers, nacelles, gearboxes, generators, and power converters.

- Leverage Indonesia's vast nickel and copper reserves and push to produce high-value processed nickel products focused on the wind industry. Use a 'market-pull' approach to the type of processed nickel and copper that the wind industry will be looking to purchase.

- Government could target investors with an interest in the wind supply chain. For nickel buyers along the supply chain, this could include towers, nacelles, gearboxes, generators and power converters. Meanwhile, for copper buyers, the government could target cable manufacturers.

2. As the country is expanding its minerals processing capabilities, Indonesia could also provide additional support to strengthen the critical minerals sector's ability to supply minerals for the wind sector.

- **Infrastructure development:** the government could enhance critical infrastructure, such as ports and transportation networks, to support the logistics of minerals exports and to lead to increased efficiency of the minerals value chain.

- **R&D support:** ESDM can incentivise research & development, with a particular focus on more mining and refining processes and innovations in mineral utilisation for wind energy applications.

- **Export facilitation:** Indonesia could ensure stable and predictable export policies on minerals, such as lifting the export restrictions for processed minerals. This will incentivise critical minerals companies to further scale up their production and processing operations.

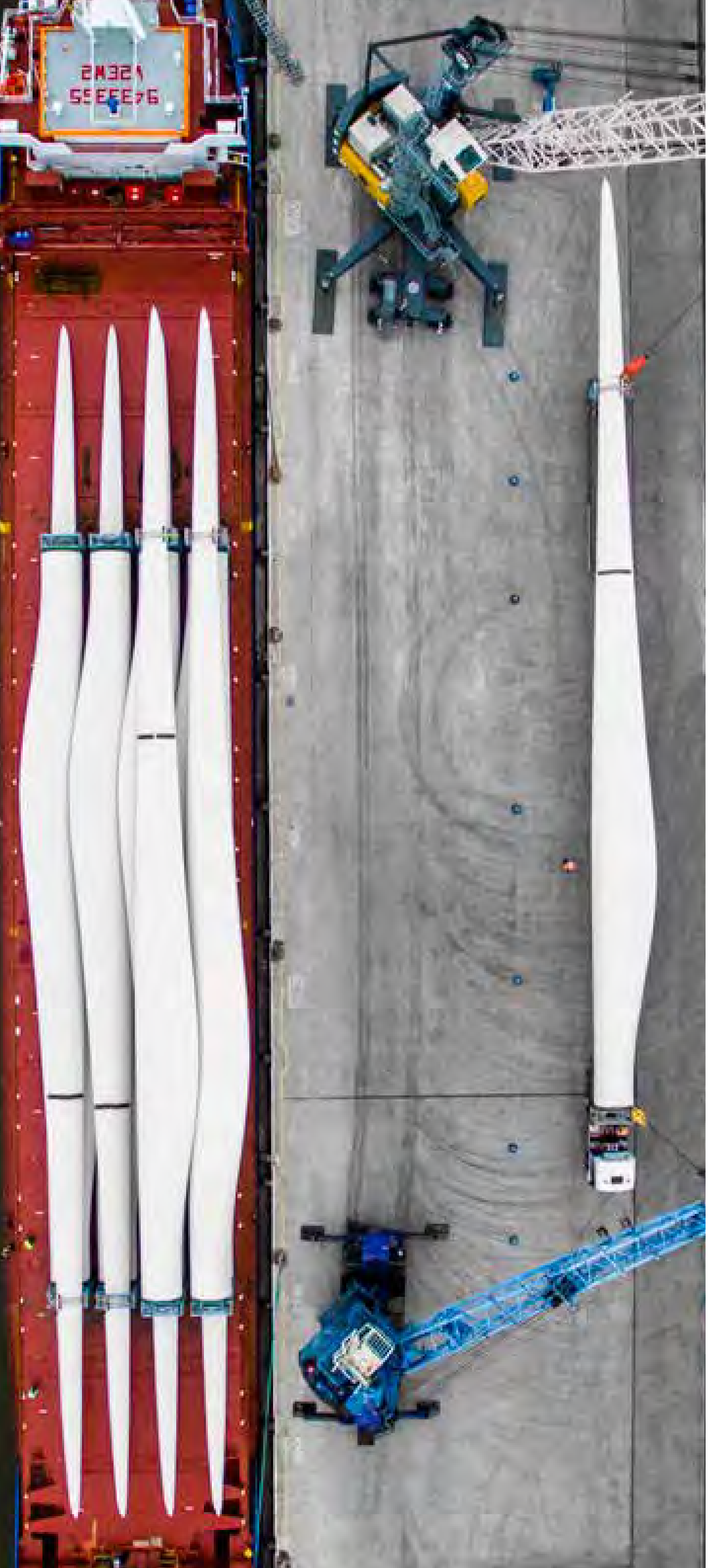
3. Support both manufacturing and critical minerals industries in achieving the global HSE and ESG requirements to sell to the wider wind industry and access both potential multilateral financing and EU markets.

- Jakarta could support the industry to move towards global best practices in HSE and ESG. This could include a roadmap with interim goals backed by government support to move industries towards compliance with global industry standards.

- By ensuring global standards are in place, Indonesia will be well placed to export materials and services to the wind supply chain. This will also set the country for success as it starts to grow a domestic wind portfolio and attract foreign developers. This is critical as wind energy developers have strict HSE and ESG protocols and typically require their prospective suppliers and sub-suppliers to have the same standards.

- Indonesia will be better placed to receive multilateral / development financing for capacity building with HSE and ESG standards meeting those of the wind industry's global best practices.

- Adopting strict HSE and ESG guidelines in its wider manufacturing and critical minerals industries will enable Indonesian companies to benefit from carbon tax exclusions when exporting wind energy products.



4. Indonesia could easily capitalise the export of gearboxes and castings leveraging its automotive industry and relevant copper and nickel reserves.

- Wind turbine gearboxes require higher nickel alloy steels which Indonesia could easily manufacture by upskilling its automotive industry while also capitalising on its rich nickel reserves.

- Similarly, the automotive industry could pivot to supply wind turbine castings which are not so different to those used in automotive.

- The investments needed for upscaling automotive to supply the wind industry gearboxes and castings could come from the Indonesia Investment Authority, its sovereign wealth fund. This could be supported by joint ventures or consortiums with other Indonesian state-owned companies until the country is able to build its domestic capabilities.

5. Indonesia to set ambitious onshore and offshore wind targets, supported by strong policies and a robust project pipeline, to attract supply chain investments that can serve both the export and domestic markets.

- Accelerate the passing of the New and Renewable Energy Law. DPR is deliberating on the New and Renewable Energy Law which will further hasten Indonesia's renewables push. Provisions proposed include the creation of a RE-specific fund to achieve renewables targets and allocating PLN and other state-owned companies to acquire renewable energy projects.

- Indonesia could investigate how wind energy development is being implemented in neighbouring countries such as the Philippines and Vietnam and adopt the best practices in both markets that can be applied to its domestic market.

- As the FIT policy is already in-place for hydro, biogas and solar energies, Jakarta may consider expanding FIT to include wind energy projects. Most markets, including Southeast Asian economies, adopted an FIT regime to build their initial pipelines of wind projects.

- Indonesia can benchmark with its ASEAN neighbours, particularly Philippines and Vietnam, on how they implemented FIT in their respective markets when they were still in their nascent stages.

6. Empower PT Pertamina to explore and spearhead offshore wind viability and commerciality in Indonesia.

- PT Pertamina can investigate how other emerging offshore wind markets such as Vietnam (PetroVietnam) and Brazil (Petrobras) or China (CNOOC and CNPC) used their state-owned O&G companies to explore the viability of piloting offshore wind in their countries.

- Given PT Pertamina's experience in exploring and developing offshore O&G blocks across the vast Indonesian archipelago, the state-owned company is well-placed to explore the viability of piloting offshore wind in Indonesia – anchoring on the technical potential of 94.2 GW.

Japan

Overview of Japan's wind market

Japan has declared its ambition to be carbon neutral by 2050[110] and, as part of the 6th Strategic Energy Plan,[111] outlined its aim to achieve a 36-38% renewable energy share within the country's energy mix compared with the FY2022 renewable energy share of 21.7%.[112] Renewables, including onshore and offshore wind, are expected to play a particularly significant role in Japan's decarbonisation amid the uncertainty that remains regarding the restarting of nuclear power plants. Many reactors are still undergoing safety tests following the 2011 Tohoku earthquake, tsunami and subsequent meltdown at the Fukushima nuclear power plant.[113] Following the nuclear incident, a feed-in tariff (FIT) scheme was introduced to promote the implementation of renewable energy projects in 2012 which has since been replaced by the feed-in premium (FIP) model in 2022.[114]

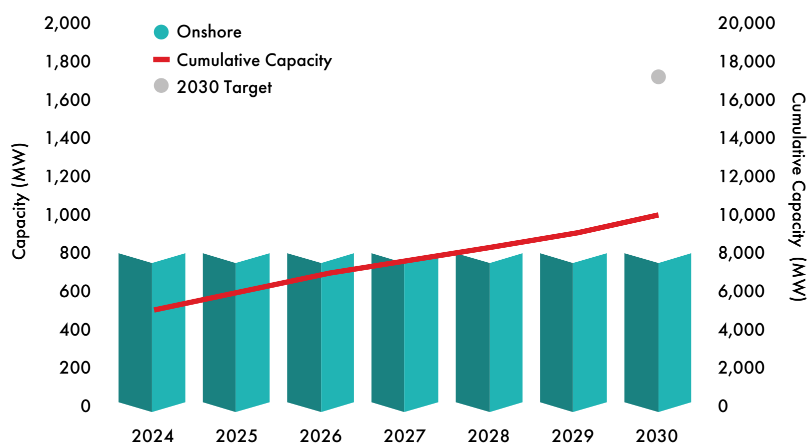
Onshore Wind

Japan's 6th Strategic Energy Plan includes an onshore wind installation target of 17.3 gigawatts (GW) by 2030. As of December 2023, the installed onshore wind capacity was just under 5 GW, including approximately 450 MW of new capacity added that year.[115] Starting in 2021, annual price-based offtake auctions with volumes of approximately 1 GW have been held, now under Japan's mechanism.[116]

Recently, onshore wind projects in development have faced significant difficulties such as delays or cancellations due to strong local opposition from residents with concerns over visual impacts. This has reduced the already limited geographical area available for onshore wind development. Projects have also been challenged with increased expected capital expenditure (CAPEX) driven by inflation and the depreciation of the yen. Due to these headwinds, it will be difficult for the onshore wind industry to reach its 17.3 GW target by 2030.

110. Prime Minister's Office of Japan. (2020). Retrieved from, https://www.kantei.go.jp/jp/99_suga/statement/2020/1026shoshinhyomei.html
111. METI. (2021). Retrieved from, https://www.meti.go.jp/press/2021/10/20211022005/20211022005-1.pdf
112. METI. (2024). Retrieved from, https://www.enecho.meti.go.jp/statistics/total_energy/pdf/honbun2022fykaku.pdf
113. FEPC. Retrieved from, https://www.fepc.or.jp/sp/re-operation/
114. METI (2021). Retrieved from, https://www.enecho.meti.go.jp/about/special/johoteikyo/fip.html
115. Japan Wind Power Association. (2024). Retrieved from, https://jwpa.jp/information/9782/
116. METI. (2024). Retrieved from, https://www.meti.go.jp/shingikai/santeii/pdf/092_01_00.pdf

Annual onshore wind installation forecast up to 2030 (MW) in Japan



Source: GWEC, 2024

The forecast scenario below estimates just under 10 GW of onshore wind capacity will be commissioned by 2030. This forecast assumes status quo on government policy, low to mid-industry interest, and average economic conditions. Delays in the commissioning of consented projects could further potentially slow down the project pipeline beyond this forecast scenario.

Offshore Wind

Japan is particularly rich in offshore wind resource and ideally placed to lead the floating offshore wind industry, reducing dependency on imported fossil fuels. Japan is an island nation with a coastline of over 35,000 kilometres (km) and the 6th largest exclusive economic zone (EEZ) in the world at approximately 4.5 million km^2.[117] Offshore wind has therefore been identified as a key part of the nation's decarbonisation strategy, with a mid-term target to auction 10 GW (of which 5.7 GW is to be operational) by 2030 and 30-45 GW to be auctioned by 2040.[118]

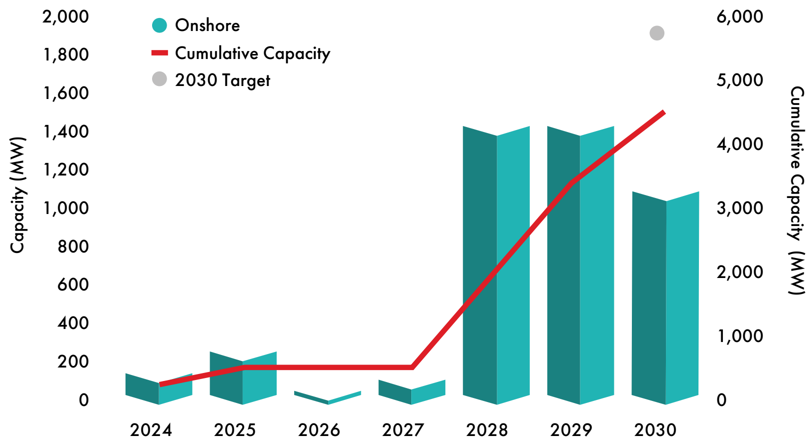
There is approximately 300 MW of operational offshore wind in Japan (as of October 2024), with the largest projects being the 112 MW Ishikari Bay New Port,[119] 84 MW Noshiro Port and 55 MW Akita Port projects.[120] The next project expected to come online is the 220 MW Hibikinada wind farm with an expected commercial operations date (COD) in FY2025.[121]

To reach the 10 GW target, the Japanese government plans to auction an average of 1 GW of offshore wind capacity each year until 2030.[122] So far, roughly 3.5 GW of projects have been awarded a seabed lease and offtake between Rounds 1[123] and 2,[124] with bid submissions currently under review for a further 1 GW in the Round 3 tender.[125] In the coming years, auctions will shift to an increasingly centralised method whereby the government will coordinate and publish pre-auction site surveys which are currently managed by individual developers, in an attempt to minimise the burden on the companies.[126]

Thus far, all offshore wind projects awarded in the Round 1 to 3 auctions are within territorial waters (12 nm from shore). In March 2024, the Japanese government approved an amendment to the Renewable Energy Sea Area Utilisation Act which allows for installation of offshore wind turbines within Japan's full EEZ.[127] This significantly expands the potential area for offshore wind deployment, particularly using floating technologies in the deeper waters further from shore. This new proposed framework involves a two-stage process where a developer will be provisionally awarded a project site, and then expected to complete stakeholder consultations before beginning construction.

Due to the rapidly increasing water depths off the Japanese coast, floating offshore wind is expected to be the dominant technology in the long term. As part of the industry's attempt to commercialise floating offshore wind, an eight-turbine 16.8

Annual offshore wind installation forecast up to 2030 (MW) in Japan



Source: GWEC, 2024

117. Cabinet Office. Retrieved from, https://www8.cao.go.jp/ocean/info/youth_plan/pdf/uminomirai_3.pdf
118. METI. (2020). Retrieved from, https://www.meti.go.jp/shingikai/energy_environment/yojo_furyoku/pdf/002_02_01_01.pdf
119. Green Power Investment. (2024). Retrieved from, https://greenpower.co.jp/2024/01/04/ishikari_offshore_cod/
120. Akita Offshore Wind Corporation. (2023). Retrieved from, https://aow.co.jp/jp/eventa/item.cgi?pro&80
121 Hibiki Wind Energy. (2023). https://hibikiwindenergy.co.jp/news/230313.html
122 METI. (2024). Retrieved from, https://www.meti.go.jp/shingikai/santeii/pdf/092_01_00.pdf
123. METI. (2021). Retrieved from, https://www.meti.go.jp/press/2021/12/20211224006/20211224006.html
124. METI. (2024). Retrieved from, https://www.meti.go.jp/press/2023/03/20240322002/20240322002.html
125 METI. (2024). Retrieved from, https://www.meti.go.jp/press/2023/01/20240119001/20240119001.html
126 METI. (2023). Retrieved from, https://www.meti.go.jp/press/2022/01/20230113005/20230113005.html
127. METI. (2024). Retrieved from, https://www.meti.go.jp/press/2023/03/20240312006/20240312006.html
128. METI. (2021). Retrieved from, https://www.meti.go.jp/press/2021/06/20210611004/20210611004.html
129. METI. (2024). Retrieved from, https://www.meti.go.jp/press/2024/06/20240611007/20240611007.html

MW project off the coast of Goto City, Nagasaki Prefecture was awarded in the Round 1 auctions.[128] Further, demonstration projects are planned under NEDO's Green Investment Fund with two 15+ MW turbines to be installed off the coast of Akita Prefecture and one 15+ MW turbine to be installed off Aichi Prefecture.[129]

As seen on page 88, based on current development plans, annual offshore wind project deployment is expected to increase from 2028 as the larger-scale Round 1 and 2 auction projects begin to come online. However, the forecasted offshore wind capacity assumes that the projects will proceed according to schedule. Supply chain restrictions, particularly due to the concentration of projects within the 2028-2030 period, could lead to projects being delayed by several years.

130. Nihon Keizai Shimbun. (2020). Retrieved from, https://www.nikkei.com/article/DGXMZO66153040S0A111C2X-13000/#:~:text=%E4%B8%89%E8%8F%B1%E9%87%8D%E5%B7%A5%E6%A5%AD%E3%81%8C%E6%B4%8B%E4%B8%8A%E9%A2%A8%E5%8A%9B,%E8%B2%A9%E5%A3%B2%E4%BC%9A%E7%A4%BE%E3%82%92%E8%A8%AD%E7%AB%8B%E3%81%99%E3%82%8B%E3%80%82
131. Nihon Keizai Shimbun. (2019). Retrieved from, https://www.nikkei.com/article/DGXMZO44145250U9A420C1TJ2000/
132. Nihon Keizai Shimbun. (2019). Retrieved from, https://www.nikkei.com/article/DGXMZO40475910V20C19A1TJ1000/
133. Ishibashi Manufacturing. Retrieved from, https://www.ishibashi-mfg.com/business/renewableenergy/
134. METI. (2020). Retrieved from, https://www.meti.go.jp/shingikai/energy_environment/yojo_furyoku/pdf/002_02_01_01.pdf

Japan's wind supply chain coverage (numbers in chart represent expected demand)

Component	Unit	2024	2025	2026	2027	2028	2029	2030
Onshore Nacelle	MW	800	800	800	800	800	800	800
Onshore Gearbox	MW	800	800	800	800	800	800	800
Onshore Generator	MW	800	800	800	800	800	800	800
Onshore Blades	MW	800	800	800	800	800	800	800
Onshore Power Converter	MW	800	800	800	800	800	800	800
Onshore Towers	units	178	160	160	145	145	133	133
Onshore Castings	tonnes	9760	9760	9760	9760	9760	9760	9760
Offshore Nacelle	MW	112	220	17	60	1405	1480	1070
Offshore Gearbox	MW	112	220	17	60	1405	1480	1070
Offshore Generator	MW	112	220	17	60	1405	1480	1070
Offshore Blades	MW	112	220	17	60	1405	1480	1070
Offshore Power Converter	MW	112	220	17	60	1405	1480	1070
Offshore Towers	units	14	25	8	4	100	100	80
Offshore Castings	tonnes	1982	3894	297	1062	24869	26196	18939
Fixed Foundations	units	14	25	0	0	96	100	62
Floating Foundations	units	0	0	8	4	4	0	18
Cables	km	40	78	6	21	499	526	380
Ports	MW	112	220	17	60	14051)	1480 1)	1070 1)
WTIV	MW	112	220	17	60	14052)	1480 2)	1070 2)

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Note: 1) Whilst offshore wind base ports have been designated by MLIT to support the planned offshore wind projects up to 2030, many require significant upgrades which will take 2-3 years. Delays in planned upgrades, deficiencies in port specifications, as well as potential construction delays leading to overlap in usage with the next project, may lead to further bottlenecks from 2028 onwards. 2) Although bottlenecks are not expected for WTIVs, the industry consultations indicated that vessel shortages for foundation installation vessels and cable laying vessels are to be expected.
Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

Japan's wind supply chain capability

When looking at the Japanese supply chain in isolation, the country has limited domestic manufacturing capabilities for onshore wind and offshore wind key components, and it currently relies on imported components to build its onshore wind pipeline.

Historically, Japan had three major domestic onshore wind turbine OEMs (Mitsubishi Heavy Industries, Japan Steel Works, and Hitachi). However, by 2019 they had all withdrawn[130, 131, 132] from turbine manufacturing due to slow growth of the domestic onshore and offshore wind energy markets and their lack of competitiveness internationally. Japanese projects primarily rely on Western OEMs, with certain Tier 2 suppliers (e.g., gearbox manufacturers)[133] remaining active.

For offshore wind, METI has set a non-binding target to achieve 60% local content by 2040,[134] with developers incentivised to select domestic suppliers through inclusion of regional and domestic economic input into the auction scoring.[135] The Japanese government have also supported the development of the local supply chain through the Green Innovation Fund.[136] There has been a particular focus on R&D for floating offshore wind, which is thought to be crucial for Japan to achieve its 2040 offshore wind target, considering the rapid increase in water depth off the coast. METI is expected to announce the results of the GX (Green Transformation) Supply Chain Development Support Program in December 2024, within which the government will provide subsidies to cover equipment, building and system acquisition costs for the manufacturing of components related to floating offshore wind.[137] Currently the Japanese offshore wind supply chain is still maturing and may struggle to be cost-competitive against Chinese and South Korean components manufactured abroad.

Despite a historically strong steelmaking industry, Japan relies heavily on imports for critical minerals such as iron ore. Suppliers have been adversely affected by increased prices related to inflation and the weakened yen.

When it comes to construction, current plans for WTIVs could suffice to meet the planned offshore wind pipeline. Meanwhile, ports are expected to present bottlenecks in 2028 and 2029. Currently there are seven offshore wind base ports designated to support the construction of the nine projects auctioned in Rounds 1 to 3, but only Akita Port has completed upgrade works.[138] There are restrictions such as land availability and severe metocean conditions which make the development of new, purpose-built offshore wind marshalling port infrastructure challenging and costly. Further, shortages of foundation installation and cable laying vessels pose a significant challenge for the sector, considering the strict cabotage rules in Japan. There is also currently a "60-day rule" under which Japanese-flagged vessels must call at an overseas port every 60 days if carrying foreign crew. This adds time and cost to offshore wind construction. In the Financial Services Agency's (FSA) "Policy Package to Achieve Special Zones for Financial and Asset Management Businesses",[139] released in June 2024, the Japanese government has disclosed a plan to make amendments to relevant ordinances in FY2024 to allow use of foreign vessels for offshore wind, should it be deemed that there is insufficient availability of Japanese vessels.

Strengths and opportunities of Japan's wind supply chain

The main strengths of the Japanese supply chain include electrical components, automotive industry, shipbuilding, carbon fibre, and cables. This, considering the domestic bottlenecks identified in the table above and regional bottlenecks identified in this wider report, presents opportunities for both wind suppliers and potential transition companies to grow their capabilities to meet the increasing domestic and regional demand.

1. Electrical Components - Japan historically has had strong electronic component manufacturing capabilities and, according to JEITA, 33% of the global share of the market was held by Japanese companies in 2023.[140] With a strong reputation for high-performance and high-quality components, Japanese companies such as Mitsubishi

135. METI. (2022). Retrieved from, https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/yojo_furyoku/pdf/017_01_00.pdf
136. NEDO. (2022). Retrieved from, https://www.nedo.go.jp/news/press/AA5_101505.html
137. METI. (2024). Retrieved from, https://gx-supplychain.jp/
138. MLIT. (2024). Retrieved from, https://www.mlit.go.jp/kowan/content/001459708.pdf
139. FSA. (2024). Retrieved from, https://www.fsa.go.jp/news/r5/sonota/package.pdf
140. JEITA. (2023). Retrieved from, https://www.jeita.or.jp/japanese/topics/2023/1221.pdfS
141. Vestas. (2024). Retrieved from, https://www.vestas.co.jp/ja-jp/news/2024/20240704_Vestas-Supplier-Day-in-Japan
142. Asahi Shimbun (2022). Retrieved from, https://www.asahi.com/articles/ASQ216W4DQ21ULUC019.html
143. JAMA. (2024). Retrieved from, https://www.jama.or.jp/english/reports/docs/MIoJ2024_e.pdf
144. MLIT. Retrieved from, https://www.mlit.go.jp/maritime/maritime_tk5_000014.html

Electric have been selected as global suppliers of components such as generators and switchgears by Western turbine manufacturers.[141] Further, permanent magnets for generators in the GE turbines for the Round 1 projects will be supplied domestically by TDK[142].

2. Automobile Industry – In 2022, automotive shipments (domestic and exports, including automotive parts) reached 62.8 trillion yen in value equating to 17.4% of Japan's manufacturing shipments.[143] The serial manufacturing capabilities of mechanical components held by Japanese companies can be leveraged for wind turbine parts. Thus far, companies such as NTN, NSK and JETKT have used their experience with automotive parts to supply wind turbine bearings.

3. Shipbuilding – Japan's shipbuilding sector overtook Europe's in 1956 to hold the number one spot in global market share and covered approximately 50% of the market until the early 1990s.[144] Though overtaken by China and South Korea, Japan's shipbuilding

145. Shimizu Corporation. (2022). Retrieved from, https://www.shimz.co.jp/company/about/news-release/2022/2022046.html
146. Obayashi Corporation. (2023). Retrieved from, https://www.obayashi.co.jp/news/detail/news20230512_1.html

remains third in the world, with companies such as Imabari Shipbuilding and Japan Marine United (JMU). This shipbuilding expertise has been leveraged in the domestic manufacturing of SEP vessels,[145, 146] and companies such as JMU and Kanadevia Corporation (previously Hitachi Zosen) are using their background to manufacture floating substructures for NEDO's GI Fund demonstration projects.[147]

4. Carbon Fibre - Japan is also a global leader in the carbon fibre industry, with major producers such as Toray Industries, Teijin Group and Mitsubishi Chemical. Such companies are well placed to supply carbon fibre composites to blade manufacturers and wind turbine OEMs as the transition away from fibreglass materials continues in the coming years, particularly in the offshore wind industry.

5. Cables – Sumitomo Electric and Furukawa Electric are established cable manufacturers in Japan and have gained experience in offshore wind through supporting projects, both domestically and in Europe. The former has also extended its manufacturing capabilities overseas, with the construction of a subsea cable factory at the Port of Nigg, Scotland.[148] However, there may still be supply shortages for the Japanese offshore wind market based on current domestic manufacturing capacity and potential overseas demand, and demand from other uses of subsea cables. Further, in terms of preparations for floating offshore wind, R&D for dynamic cables is being conducted under NEDO's GI Funding.[149]

Although there are bottlenecks across the onshore and offshore wind supply chains, the perception from the industry consultations is that domestic manufacturing and serial production capabilities, particularly in sectors such as the automobile industry, have the potential to transition into supplying key turbine components. This is likely to be a medium to long-term process, requiring significant growth in market volume to present a sustainable and attractive business case for investment in manufacturing capabilities. In the shorter term, existing suppliers such as in cable manufacturing could look to expand their production capabilities to meet domestic and regional demand.

147. METI. (2024). Retrieved from, https://www.meti.go.jp/press/2024/06/20240611007/20240611007.html
148. Sumitomo Electric (2024). https://sumitomoelectric.com/press/2024/05/prs018
149 NEDO (2022). https://green-innovation.nedo.go.jp/pdf/offshore-wind-power-generation/item-001-3/vision-tepco-rp-002.pdf

Recommendations for wind supply chain scale-up in Japan

1. Increase and stabilise the volume of offshore wind projects auctioned through to 2030.

- For offshore wind, though Japan has announced 2030 and 2040 targets, certain stakeholders believe that greater ambition from the government is still possible, particularly in the short to medium term, which prevents suppliers from being able to make large-scale investments.
- The Japanese government could consider increasing auction round volumes, both in terms of individual project size and number of projects, to enable the scaling up of the supply chain.
- Flexibility could be offered in target commercial operation date (COD) to reflect existing supply chain capabilities, preventing avoidable bottlenecks from overlapping projects as is currently expected for the Round 1, 2 and 3 projects.
- Greater transparency and information sharing on the preparation of auction sites is required. Though METI's Promising and Preparatory Areas are being readied for tender, some projects on the list have seen minimal progress for several years and the lack of predictability can impact the industry's confidence in the auction pipeline.

2. Revision of auction framework to minimise downward pressure on offtake price to allow organic growth of domestic supply chain.

- Despite the 50:50 weighting of price and non-price criteria in the Japanese auction framework, in Round 1 the feed-in tariff offtake price was driven significantly below expectations through fierce competition. Further, Round 2 most developers submitted bids at the minimum feed-in premium price. The current auction system has led to a 'race to the bottom' by aiming for wind generation at the lowest possible cost.
- This has amplified cost pressure on suppliers in a still emerging offshore wind industry, and risks making the entry of domestic manufacturers into the market less attractive.
- The government could implement an even more consultative process with industry, including a wide range of suppliers, to adopt an auction design that reflects government ambitions, sector capabilities and wider market conditions.
- The non-price auction criteria should allow for a clear differentiation of bids to allow the reliable selection of projects plans of greatest merit, allowing for healthy returns for developers. This will in turn allow for a healthy offshore wind market environment which will reward supply chain companies for investments made to improve their capabilities.
- Further, ambition to stimulate domestic supply chain could be approached separately to the auction criteria, focusing on the development of robust sector growth strategies and large industrial policy packages such as the Inflation Reduction Act in the United States.

3. Accelerate preparations to auction offshore wind projects in the wider Japanese EEZ.

- Projects in the wider EEZ are larger-scale, and more attractive to investors. Accelerating these projects will attract investment into the supply chain sooner, which will be needed to build out this scale of projects and increase investor confidence.
- Further, the two-step process is also expected to separate the seabed leasing and offtake auctions, allowing projects to secure more realistic prices once the sites have been through a thorough risk reduction process.
- However, there is still no clear indication regarding when this process will commence, and it is highly recommended that policymakers in Japan accelerate preparations and provide greater visibility of progress.
- Studies and surveys of the Japanese EEZ could be commenced as soon as possible to identify suitable areas for offshore wind deployment, and to begin the identification and engagement of relevant stakeholders.
- The auctions for seabed leases within the EEZ will significantly expand the deployment area for floating offshore wind, encouraging suppliers to make the necessary investments required to establish serial production for key components which leverage existing strengths in the domestic industry, such as substructures and dynamic cabling.

4. Introduce exemptions to cabotage restrictions for offshore wind (particularly foundation installation and cable laying) vessels to allow developers to smoothly address potential vessel bottlenecks.

- The existing cabotage restrictions mean that foreign vessels must be reflagged to the Japanese flag, increasing the difficulty of using ships from other APAC markets.

- Cabotage restrictions effectively restricts the pool of vessels that developers can select from, which can prove to be a significant bottleneck when there is a pile-up of projects as seen from Rounds 1 and 2. Though Japanese EPC contractors have worked to secure WTIVs (through newbuilds,[150, 151, 152] acquisitions and JVs with European vessel owners[154,155]) to support the construction of the auctioned offshore wind projects, there is still a shortage with regard to Japanese foundation installation and cable laying vessels.

- There is also limited availability of skilled personnel in Japan and hence it is expected that foreign crew will be required. This means that the 60-day rule should be relaxed for offshore wind vessels, to allow use of foreign crew when required and ensure projects can be delivered efficiently.

- Though the Japanese government plans to review cabotage restrictions for offshore wind, the conditions for granting special permission on a project-by-project basis should be made clear and simplified.

- Access to vessels within the wider APAC region would provide greater flexibility to developers, allowing projects to begin operation in line with their target COD and avoid penalties for delayed start - and further knock-on delays to other projects due to vessel availability restrictions.

5. Develop a long-term port plan to establish purpose-built offshore wind marshalling ports.

- MLIT has designated offshore wind "base ports" based on the specific projects auctioned. There are currently seven base ports[156] to support the nine offshore wind project sites tendered in Rounds 1-3.

- These base ports will undergo upgrade works but are not purpose built for offshore wind. Thus, the port facilities (such as available laydown area) may not be suitable in the construction phase.

- A long-term port infrastructure plan is required to ensure the base ports remain suitable as construction bases and can accommodate larger projects, as well as the requirements for floating offshore wind once commercial-scale projects begin construction.

- The Japanese government could map out key ports that will receive significant investments to support offshore wind projects in the surrounding area, which will also promote the formation of offshore wind supply chain hubs.

- Further, with potential barriers such as land constraints, improved planning and coordination between multiple ports could also be considered to share the demand.

6. Streamline the wind farm certification process for offshore projects to shorten project lead times and minimise unnecessary burdens on suppliers.

- Suppliers in the wind energy industry currently must support developers through the windfarm certification process[157] to receive the construction permit under the Electricity Business Act.

- The criteria that must be met to receive the wind farm certificate are ambiguous and the lengthy process increases the burden placed on the developers, as well as turbine OEMs and foundation manufacturers.

- Streamlining and clarifying such processes will allow for smoother project development to boost investor confidence, leading to greater competition in the supply chain.

150. Shimizu Corporation (2022). https://www.shimz.co.jp/company/about/news-release/2022/2022046.html
151. Penta-Ocean Construction (2023). https://cppenta-ocean.co.jp/news/2023/230927.html
152. Obayashi Corporation (2023). https://www.obayashi.co.jp/news/detail/news20230512_1.html
153. Toda Corporation (2023) https://www.toda.co.jp/news/2023/20231003_003263.html
154. Penta-Ocean Construction (2023). https://www.penta-ocean.co.jp/news/2021/211102.html
155. NYK Line (2020). https://www.nyk.com/news/2020/20200116_01.html
156. MLIT (2024). https://www.mlit.go.jp/kowan/content/001459708.pdf
157. ClassNK (2023). https://www.classnk.or.jp/hp/ja/hp_news.aspx?id=9562&type=press_release&layout=1

Philippines

Overview of the Philippines wind market

The Philippines are Southeast Asia's wind energy pioneers. Already in June 2005[158] the 25 MW Bangui Wind Farm in Bangui, Ilocos Norte, started commercial operations and since then, through the Philippine Energy Plan (PEP) 2023-2050, the government has ambitiously increased the country's target share of renewables from 22% by 2023 to 35% by 2030, 50% by 2040, and over 50% by 2050.[159] Within the PEP 2023-2050[160] are the following two clean energy scenarios (CES).

1) CES 1: 19 GW of operational offshore wind and 26 GW of onshore wind by 2050; and,

2) CES 2: 50 GW of operational offshore wind and 15 GW of onshore wind by 2050.

These scenarios are further supported by the Department of Energy (DOE)'s approval in August 2024 of 85.6 GW of wind energy service contracts,[161] 65.12 GW of which are for offshore wind and the remaining 20.48 GW for onshore wind. The Philippines is considered by EY's Renewable Energy Country Attractiveness Index to be the most attractive renewables market of the ASEAN-6[162] and has the potential to be a major contributor to tripling renewables targets for 2030.

The current administration of President Ferdinand Marcos Jr. is prioritising renewables, particularly offshore wind, in the government's agenda. In 2022, the Marcos Jr. administration removed foreign ownership restrictions, enabling 100% foreign-owned companies to invest in renewable energy

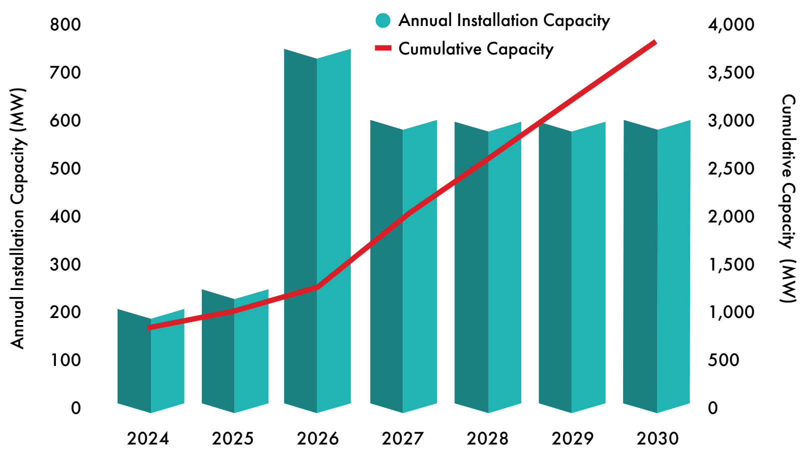
Key Milestones for the Philippine Wind Industry

2018	Start of the Philippine Energy Virtual One-Stop-Shop System. Permitting framework for the onshore wind is integrated into the EVOSS System
2022	The government relaxed the 60% Filipino ownership criteria in renewables. Foreign companies can now own up to 100% equity of renewables projects
2023	Executive Order 21 establishes a specific Offshore Wind Policy and Administrative Framework in the Philippines. It requires permitting agencies to integrate all the necessary permits for offshore wind into the EVOSS System
2024	DOE released the Revised Omnibus Guidelines Governing the Award and Administration of Renewable Energy Contracts and the Registration of Renewable Energy Developers
2024 (planned)	Full integration of EVOSS for offshore wind including ability for companies to make permitting payments through the EVOSS
2024 (planned)	Marine spatial planning tool

Source: ERM

158. https://w3.windfair.net/wind-energy/news/1351-philippines-first-wind-farm-in-southeast-asia-starts-operations-next-month
159. Department of Energy. (2024). Philippine energy plan 2023-2050. https://doe.gov.ph/pep/philippine-energy-plan-2023-2050
160. Ibid.
161. Wind Energy Service Contract is the primary leasing permit in the Philippines that grants the developer a specific lease area where they can conduct exploration, development, and utilisation activities within an initial 25-year lease period, and renewable for another 25 years. The leasing regime is unique in the Philippines in the way that upon the award of a service contract, site exclusivity is guaranteed during the duration of the contract. This is explained in more detail in the GWEC Philippines Offshore Wind Supply Chain Study.
162. Ernst & Young. (2024). Renewable energy country attractiveness index (63rd ed.). https://www.ey.com/content/dam/ey-unified-site/ey-com/en-gl/insights/energy resources/documents/ey-gl-recai-63-report-06-2024.pdf

Onshore wind installation forecast up to 2030 (MW) in the Philippines



Source: GWEC, 2024

development. Subsequently, Executive Order 21 was issued, streamlining the offshore wind permitting process through the whole-of-government approach that is currently in place for onshore wind. 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 offshore wind development stages and permitting requirements. In June 2024, the DOE published the Revised Omnibus Guidelines detailing governance and administration procedures for renewable energy service contract awards (including offshore and onshore wind), including a provision for a maximum three-year Certificate of Authority period for developers to secure permits and conduct surveys needed for pre-feasibility studies. An overview of the key milestones is summarised on page 95, bringing confidence to both investors and the supply chain in the credibility of the pipeline and government targets.

The Philippines has three main route-to-market programmes currently in place to accelerate renewables development – Green Energy Auction Program (GEAP), Green Energy Option Program and Retail Competition and Open Access. This is on top of the Renewable Portfolio Standards legally mandating distribution utilities to contract a portion of their power requirements from renewable energy sources. The route-to-market programmes for renewables are explained in more detail in the GWEC Philippines Offshore Wind Supply Chain Study.

Onshore wind

As of October 2024, renewables capacity in the Philippines is driven by geothermal and hydro[163] with only 427 MW of installed onshore wind capacity. That said, circa 1.7 GW of onshore wind projects were awarded in the first two GEAP auctions, with expected commissioning by 2026. The Renewable Energy Law of 2008 was the first of a kind for Southeast Asia, allowing the government to award lease areas to companies intending to industrialise the country's vast indigenous sources of energy.

The forecast scenario estimates commissioning of 3.78 GW of onshore wind by 2030, assuming status quo on government policy, low to mid-industry interest, and average economic conditions. Certain winners of the recent GEAP Rounds 1 and 2 are observing some setbacks to their committed dates primarily due to grid constraints. Delays in the commissioning of wind projects that won auction allocations can potentially slow down the project pipeline beyond this forecast scenario.

Offshore wind

The Philippines has been studying its offshore wind potential since 2020, although progress in this area has been slower compared to other renewable energy sources. The Philippine Offshore Wind Roadmap estimates circa 178 GW of technical potential, of which 90% is suitable for floating offshore wind (i.e., deeper than 60 meters below sea level)[164].

Given the large offshore wind potential and high political appetite, the Philippines has garnered interest from both established international developers and reputable local developers to jumpstart the country's offshore wind industry.

The offshore wind forecast scenario estimates that 4.3 GW of offshore wind capacity will be commissioned from 2031, based on the Base Case

163. Department of Energy. (2024). 2023 power statistics. https://doe.gov.ph/sites/default/files/pdf/energy_statistics/01_Summar_2023.pdf
164. World Bank. (2022). Offshore wind roadmap for the Philippines. https://documents1.worldbank.org/curated/en/099225004192234223/pdf/P1750040b777da0c30935a0e2aa346f4e26.pdf

Scenario published in the GWEC Philippines Offshore Wind Supply Chain Study. This scenario assumes limited government policy improvements, low to mid-industry interest, and challenging economic conditions, including persistent inflation, low economic growth, and high interest rates. Under this scenario, construction is expected to begin by 2029, with the first projects reaching commercial operation by 2031. Delays in marine spatial planning implementation could lead to challenges in obtaining site approvals and leases, potentially slowing down the project pipeline beyond this Base Case scenario.

The Philippines wind supply chain capability

When looking at the Philippine supply chain in isolation, the country has limited domestic manufacturing capabilities for onshore wind and no established supply chain for offshore wind key components. Historically, the Philippines has relied heavily on imported components to build its onshore wind pipeline, with key components being manufactured across Europe, China and Vietnam. That said, recently domestic onshore wind supply chain capability has been growing around onshore cables, EPC contractors and workforce.

Although offshore wind commissioning will start in 2031 (after this report's forecast period), it is critical for the Philippines to build up its offshore wind supply chain capabilities to meet domestic

Philippines' supply chain coverage (numbers in chart represent expected demand)								
Component	Unit	2024	2025	2026	2027	2028	2029	2030
Onshore Nacelle	MW	200	245	750	600	600	600	600
Onshore Gearbox	MW	200	245	750	600	600	600	600
Onshore Generator	MW	200	245	750	600	600	600	600
Onshore Blades	MW	200	245	750	600	600	600	600
Onshore Power Converter	MW	200	245	750	600	600	600	600
Onshore Towers	units	40	49	136	109	109	100	100
Onshore Castings	tonnes	2440	2989	9150	7320	7320	7320	7320
Offshore Nacelle	MW	0	0	0	0	0	0	0
Offshore Gearbox	MW	0	0	0	0	0	0	0
Offshore Generator	MW	0	0	0	0	0	0	0
Offshore Blades	MW	0	0	0	0	0	0	0
Offshore Power Converter	MW	0	0	0	0	0	0	0
Offshore Towers	units	0	0	0	0	0	0	0
Offshore Castings	tonnes	0	0	0	0	0	0	0
Fixed Foundations	units	0	0	0	0	0	0	0
Floating Foundations	units	0	0	0	0	0	0	0
Offshore Cables	km	0	0	0	0	0	0	0
Ports	MW	0	0	0	0	0	0	0
WTIV	MW	0	0	0	0	0	0	0

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

needs and fill some of the regional supply chain gaps. The Philippines is already attracting interest to establish manufacturing facilities in the country, for example to build towers and floating wind turbine foundations. For example, the Chinese tower and foundation manufacturer Dajin Offshore has expressed an interest in setting up a manufacturing base in the Philippines thanks to its confidence in the market, as the company has exported around $25 million of wind energy products and services to the Philippines in 2022 alone.[t] Similarly, HD Korea Shipbuilding & Offshore Engineering (HD KSOE) is already constructing a facility in the Philippines to manufacture offshore wind floating platforms and shipbuilding modules. It is expected to be operational by 2026.[166]

In addition to existing wind industry suppliers, the Philippines has also attracted transition companies from the oil & gas and shipbuilding industries, and seafarers from the logistics sector. Companies working in these industries will have transferable skills to support the wind energy supply chain in-country, especially as offshore wind development is ramping up in the Philippines. We are seeing already seafarers from offshore oil and gas move easily into offshore wind.

Strengths and opportunities of the Philippines wind supply chain

The main strengths of the Philippine supply chain include offshore and technically skilled workers; vessel manufacturing; copper and cable manufacturing; nickel, chromite / chromium, manganese and rare earth deposits; and transitioning EPC contractors from other construction industries. Considering the domestic bottlenecks identified in the table above and the regional bottlenecks identified in this wider report, this presents opportunities for both wind suppliers and potential transition companies to growth their capabilities to meet the increasing domestic and regional demand.

1. Offshore Skilled Workers – Filipino seafarers are already employed by companies installing offshore wind across Taiwan, the North Sea, and the Scottish Highlands. UK-based firm ERSG is a crewing agent known to hire Filipino seafarers for offshore wind projects across Europe,[167] with certain seafarers working directly for offshore wind developers or Tier 1 suppliers. Further upscaling is underway – for example, the Norwegian Training Centre in Manila is training Filipino students for offshore wind deployment in collaboration with Fred. Olsen Windcarrier. However, there is a need for further upskilling, particularly on the installation of blades offshore and the associated health & safety training.

Filipino seafarers alone can fill up to 9,800 of the workforce demand in offshore wind projects in the Philippines by 2040,[168] with the potential to export this group of skilled workers to support regional and global projects.

2. Technically Skilled Workers – In addition to seafarers, the Philippine workforce includes technically qualified engineers, technical & project development consultants, technicians, nurses, doctors, who are sought after by global organisations

165. Dajin Offshore. (2023). Renewable roundtable meeting with Philippine President Ferdinand R. Marcos Jr. Retrieved from, https://www.dajin.cn/html/news/2023/0112/42.html
166. Kim, W. (2024, May 15). HD KSOE picks Philippines as offshore wind power base camp. The Korean Economic Daily. Retrieved from, https://www.kedglobal.com/shipping shipbuilding/newsView/ked202405150002
167. UK Parliament. (2022). Immigration policy and seafarer jobs. https://edm.parliament.uk/early-day-motion/60420/immigration-policy-and-seafarer-jobs
168. Crismundo, K. (2023, October 6). PH seafarers can fill 9.8K workforce demand in offshore wind projects. Philippine News Agency. https://www.pna.gov.ph/articles/1211272

due to their dedication, artisanry, and English language capabilities. Two highly relevant labour groups that could transition into wind include:

- Engineers: specialising in mechanical, civil and electrical engineering, which are critical for the design, construction and operations & maintenance of onshore and offshore wind infrastructure, including transmission.
- Project managers and support staff: the skills required for project managers and their support staff are complex and wide-ranging from finance & accounting to engineering, technical, environmental, and are critical to the delivery of large-scale wind energy projects.

Industry consultations have reinforced the need for more Filipino skilled workers to serve the domestic demand for wind. Developers are struggling to attract talent from a limited workforce and the competition for human resources in the country is fierce, with developers and others competing for a limited pool of qualified workers. There is a huge opportunity for upscaling the workforce to support local and regional supply chain gaps.

3. Vessel Manufacturing –The Philippines has a strong vessel manufacturing industry which currently serves oil & gas and logistics industries. This existing shipbuilding industry could transition to offer services specific to offshore wind with appropriate investment, workforce training and strategic partnerships. There is an opportunity for Philippine companies to partner with offshore wind vessel players to facilitate technology transfer and access new markets and opportunities for growth.

Opportunities with existing players include HD KSOE's future manufacturing facility in the Philippines to further enhance the country's capability to supply critical components for offshore wind. Austal Philippines, an Australian shipbuilding company based in Balamban, Cebu, is already capable of manufacturing Crew Transfer Vessels (CTVs) for export to European offshore wind markets.

4. Copper and Cable Manufacturing – The Philippines has around four billion mega tonnes of copper reserves, the fourth largest in the world, which is used to domestically produce copper wire for domestic transmission and distribution networks. Building on this strength, local companies could partner with leading wind cable manufacturers like Nexans, Prysmian and NKT cables who want to grow in the Philippines or wider APAC market leveraging the existing Philippine strengths around copper supply and cable capabilities (albeit needing to be upscaled to wind). Establishing these partnerships could provide international firms with critical access to local manufacturing facilities, a skilled workforce, and market insights.

5. Nickel, Chromite / Chromium, Manganese and REE – In addition to its significant copper reserves, Philippine deposits also include nickel, chromite/chromium, manganese, and REE which are critical for wind turbine manufacturing. The country's vast untapped reserves offer a huge opportunity to further develop its critical minerals sector and its downstream value chain, including the production of components such as cables, generators, gearboxes, power converters and towers to support the requirements of the wind industry and the wider renewables sector.

For nickel processing, the Department of Trade and Industry (DTI) is in advanced conversations with local supplies from nickel production, processing and refinement to steel manufacturing for the production of offshore wind towers in the Philippines. DTI expects this could be an "assembly line" where different investors from the wider steel value chain in the manufacturing of towers in the Philippines.

Moreover, the Philippines could strengthen ESG principles in mineral exploration and production ensuring that future mining projects will benefit host communities and will not cause further environmental destruction. To ensure that safeguards are in place, particularly for mining areas inside Indigenous communities, the government can implement best practices on conducting ESIAs and securing FPICs.[169]

6. Transitioning EPC Contractors – The Philippines has a robust construction industry, evidenced by the involvement of major local

169. Buxon, A. (2022, February). People and nature first: safeguards needed in mining exploration. IIED Briefing. Retrieved from, https://www.iied.org/sites/default/files/pdfs/2022-02/20736iied.pdf

construction companies in various government infrastructure projects under the national development program. Certain EPC firms specialising in the construction of transmission and distribution assets are accredited by the country's transmission network provider, the National Grid Corporation of the Philippines (NGCP), as well as major distribution utilities such as Meralco and the Visayan Electric Company.

Major EPC contractors in the Philippines are local, except for the Philippine subsidiary of Japanese EPC firm JGC Group. In the early days of the onshore wind industry in-country, local EPC contractors partnered with western turbine suppliers and/or foreign EPC contractors to gain the skillset needed for onshore wind construction. But some of the newer onshore wind farms in the Philippines (from 2010) were awarded to local EPC contractors.

7. Automotive industry – The Philippines is one of the largest automotive manufacturers in Southeast Asia, after Thailand, Indonesia and Malaysia. As in other Southeast Asian markets, large Japanese car brands also dominate the Philippine automotive industry. The country's established automotive industry can serve as a transition industry to develop Philippine capabilities on gearboxes and castings for onshore and offshore wind turbines.

Recommendations for wind supply chain scale-up in the Philippines

1. Attract foreign investment to develop a cable supply chain that is fed by domestic copper reserves.

- To exploit its copper reserves, the Philippines can expand its copper processing facilities and encourage existing cable manufacturers (both local and foreign firms) to expand electrical cable production capabilities by providing a range of fiscal and non-fiscal incentives and responding to their "needs" to ensure that the investment materialises. The Philippines can target other cable manufacturers to take advantage of copper reserves and existing incentives to set up shop in-country.

2.Position the Philippines as a critical minerals production and processing hub for domestic and regional supply.

- As raw nickel ore is still the primary export of the Philippines, the government can investigate investments that will set up nickel processing facilities in-country to provide higher-value nickel products to feed into other critical components in the wider wind energy supply chain. A more proactive approach can create a business-friendly environment through targeted investments from overseas or additional government incentives to encourage nickel processing companies to set up facilities in the Philippines.

- The government can consider opening new mining areas to explore and develop the country's chromite / chromium, manganese and REE reserves. The government can target investments prioritising production and processing facilities of identified critical minerals within the Philippines. As it would take time to explore and develop the country's production and processing capabilities of its identified reserves, the Philippines could immediately open competitive bidding rounds while ensuring that ESG principles and the safeguarding of human rights of local communities, particularly Indigenous groups, are pursued throughout the process.

- The government could also ensure that internationally accepted ESG principles are practiced in the entire critical minerals value chain by only allowing concessions that have integrated ESG practices into their operations. By enshrining ESG principles in the value chain, this can allow the Philippines to access existing and future multilateral financing that supports the wider push for energy transition in the APAC region.

3. Building on its critical minerals reserves and transitioning its automotive industry, the Philippines can further capitalise the incoming investments from major offshore wind supply chain players to enhance the country's manufacturing capabilities.

- Taking advantage of the country's nickel supply, the government can consider building into more towers and floating foundations manufacturing, capitalising on Dajin and HD KSOE's investments into the country.

- The Philippines can capitalise on its vast nickel reserves and transition its automotive industry to build wind turbine gearboxes.

- Moreover, the country's automotive industry could pivot to supply wind turbine castings which are not so different to those used in automotive applications.

- Investments to enhance the country's wind energy manufacturing capabilities can be achieved by encouraging the Philippine sovereign wealth fund to secure investments from other established wind energy manufacturers through joint venture agreements or consortiums in a potential Philippine subsidiary until the country is able to build its domestic capabilities.

4. Upscale the country's offshore and technically skilled workers to fill domestic and regional supply chain gaps.

- The government could enhance existing programmes to attract Filipino worker e.g., the Balik Scientist Program (Returning Scientist Program) to incentivise Filipino skilled workers based overseas to move back to the Philippines to support the accelerated buildout of the wind industries in the immediate term. Philippine-based companies in other industries, such as chemicals, have already leveraged similar incentives to attract technically skilled Filipino workers abroad to move back to promising careers in a booming industry.

In the long term,, the government could consider enacting a law that attracts overseas Filipino professionals to move back home to build a world-class workforce to support the wind energy industry and the wider Philippine economy. This programme should be able to offer attractive living and financial incentives such as a lower tax bracket or a fixed tax bracket for a set number of years, tax exemption on the import of personal items from abroad and easier immigration requirements for foreign spouses and children.

- Upskilling the local talent to wind energy requirements – The government, industry stakeholders, and the education sector can work together to identify the skillset needs for the wider wind energy industry and its supply chain. The government can spearhead the creation and marketing of technical programmes and courses that will attract Filipino students keen to enter the wind energy industry. Moreover, the government can explore collaborations with other APAC wind energy markets to complement and supplement the needs of the wider APAC region. Academia and universities in the Philippines can partner with the government to work on specialised courses and/or degrees to offer university students a future career in wind energy development. These programmes will ensure a steady stream of quality workforce to service the requirements of both the Philippines and the wider APAC region.

As a transition industry, EPC firms can work with the government and wind energy industry stakeholders to upskill their existing talent to the identified requirements of the industry to further support onshore and offshore wind development in the country.

5. Provide a credible and dependable pipeline for the market to attract investment by ensuring policy continuity of wind energy development (particularly offshore wind) in the Philippines by setting a realistic and long-term wind energy target and ensuring future auction prices are grounded on market movements.

- Realistic and long-term wind energy target – DOE and the Energy Regulatory Commission (ERC) can work together to establish a long-term installation target for both onshore and offshore wind (between 10 to 15 years) that will allow developers and suppliers to forecast the country's supply chain needs. The pipeline can be incorporated into the PEP to send strong signals to attract foreign investments in the local supply chain and technology development. The requirements for expanding offshore wind ports can be incorporated into the PEP as well.

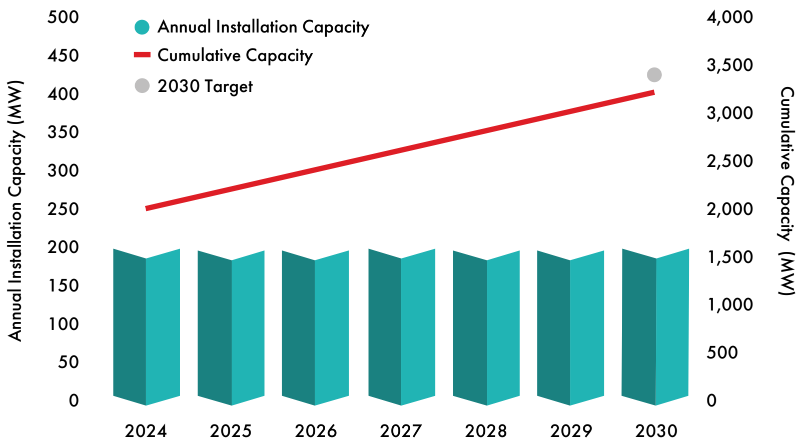
- GEAR prices should be realistically aligned with regional and global market movements while balancing consumer protection – ERC can explore benchmarking auction prices in comparable markets to feed into the future Green Energy Auction Reserve (GEAR) prices. This will allow ERC to be agile in reacting to regional and global market trends that will feed into how each GEAR pricing will look for subsequent GEAP rounds. Moreover, the regulator can explore the possibility of establishing benchmark rates for new and emerging technologies for future GEAP rounds or power supply contracts, as GEAR prices will be one of the major determinants of supply chain movements. Our consultations with developers showed that in their talks/negotiations with suppliers, the main consideration for suppliers will be what the GEAR prices for offshore wind will look like.

South Korea

Overview of South Korea's wind market

South Korea's updated NDC under the Paris Agreement outlined the country's intention to be carbon neutral by 2050, with a 2030 target to reduce national greenhouse gas emissions by 40% compared to 2018 levels.[170] The national government has set a target of 20% for renewables in the electricity generation mix by 2030 under the Korea 3020 Renewable Energy Plan,[171] equivalent to approximately 63.8 GW in capacity.

Annual onshore wind installation forecast up to 2030 (MW) in South Korea



Source: GWEC, 2024

The Renewable Energy Portfolio Standard (RPS) has been the main policy incentivising the deployment of renewable energy in South Korea. Under the RPS programme, power generators must produce a certain portion of their energy mix through renewable sources and address any shortfalls through the purchase of renewable energy certificates (REC) according to the mandated quota.[172]

Onshore wind

By the end of 2023, South Korea's operational onshore wind capacity was just over 1.8 GW.[173] The Korea 3020 Plan includes a combined onshore and offshore wind target of 17.7 GW for 2030, equivalent to approximately 28% of all renewables. Though there is no defined value specific to onshore wind, the installation target capacity for 2030 is 3.4 GW, considering the 14.3 GW target announced by the Ministry of Trade, Industry and Energy (MOTIE) for offshore wind. The discrepancy between the onshore and offshore wind targets reflects the general perception in the country that the long-term potential for onshore wind is limited, considering factors such as land constraints.

Under the RPS scheme, multipliers are used to incentivise the generation of certain renewable energy sources and a factor of 1.2 is applied for onshore wind. However, the current RPS scheme may be reformed to a competitive bidding framework.[174] A tender for 300 MW of onshore wind capacity was launched in October 2024.[175]

The chart to the left shows the forecasted annual onshore wind installation capacity in South Korea. The operational wind energy capacity is expected to reach approximately 3.2 GW by 2030, falling just short of the presumed 3.4 GW target. The near-term onshore wind market outlook (2024–2026), built using a bottom-up approach, is based on GWEC Market Intelligence's global onshore wind project database, which covers projects currently under construction, global auction results and announced

170. UNFCCC. (2021). Retrieved from, https://unfccc.int/sites/default/files/NDC/2022-06/211223_The%20Republic%20of%20Korea%27s%20Enhanced%20Update%20of%20its%20First%20Nationally%20Determined%20Contribution_211227_editorial%20change.pdf
171. MOTIE. (2017). Retrieved from, https://www.motie.go.kr/kor/article/ATCL3f49a5a8c/159996/view
172. IEA. (2020). Retrieved from, https://www.iea.org/policies/4837-renewable-portfolio-standard-rps
173. KWEIA. (2024). Retrieved from, http://www.kweia.or.kr/bbs/board.php?bo_table=en_status&ckattempt=1
174. Invest KOREA. (2024). Retrieved from, https://www.investkorea.org/ik-en/bbs/i-308/detail.do?ntt_sn=490796
175. renews.BIZ. (2024). Retrieved from, https://renews.biz/96647/south-korea-launches-18gw-wind-tender/

domestic onshore wind tenders. For the medium-term market outlook (2027–2030), a top-down approach was used alongside existing project pipelines. This considers existing policies and medium/long-term national offshore wind targets. It assumes status quo on government policy, low to mid-industry interest, and average economic conditions.

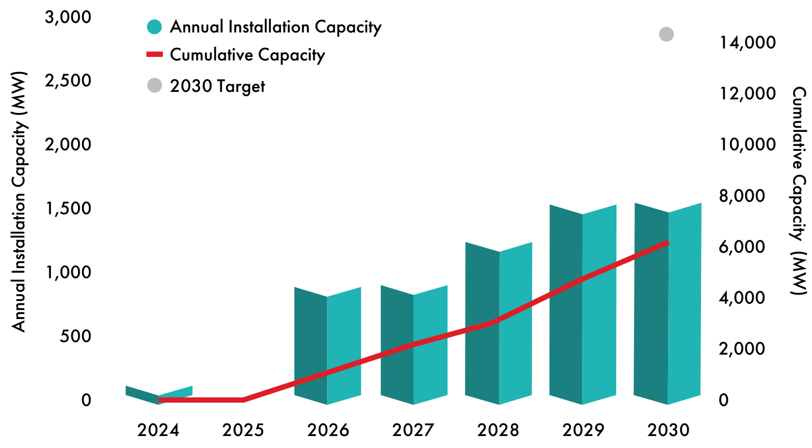
Offshore wind

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.[176] Under the 10th Basic Plan for Power Distribution published in 2023, the MOTIE announced a target of 14.3 GW of installed offshore wind capacity by 2030. South Korea employs a developer-led, open-door system and as of December 2023, 22.6 GW of projects have been granted Electricity Business Licences to begin preliminary site surveys. The first offshore wind offtake auction was held in 2022, with SK E&S and Copenhagen Infrastructure Partners' 99 MW Jeonnam 1 Offshore Windfarm awarded a 20-year fixed price power purchase agreement with Korea Hydro & Nuclear Power.[177] In the following year, a further 1.4 GW of offshore wind capacity was allocated across four projects (Wando Geumil OWF, Sinan Ui OWF, Nakwol OWF and Gochang OWF).

In August 2024, the South Korean government announced an accelerated auction timeline expected to tender 7-8 GW of offshore wind capacity between the second half of 2024 and the first half of 2026. The auction will be organized as a two-stage process: first assessing non-price criteria and then evaluating price attributes. The non-price criteria include aspects such as maintenance, security and local economy contributions, and will be used to select 120-150% of the available auction capacity ahead of the price evaluation. The first tender under this roadmap was launched by MOTIE in October 2024, with allocations of 1 GW for fixed-bottom and 500 MW for floating offshore wind projects announced.[178] The ceiling price was set at 176,565 KRW / MWh for both fixed-bottom and floating windfarms.

176. GWEC. (2021). Retrieved from, https://gwec.net/wp-content/uploads/2021/06/South-Korea_Offshore-Wind-Technical-Potential_GWEC-OREAC.pdf
177. COP. (2023). Retrieved from, https://cop.dk/jeonnam-1-offshore-wind-project-in-korea-reaches-financial-close-and-begins-onshore-and-offshore-construction/
178. KNREC. (2024). Retrieved from, https://www.knrec.or.kr/biz/pds/businoti/view.do?no=4864

Annual offshore wind installation forecast up to 2030 (MW) in South Korea



Source: GWEC, 2024

Current operational capacity stands at 150 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 currently hindering the efficient deployment of offshore wind. Under the RPS policy, the multiplying factor is 2.0 to 2.5 for offshore wind, outlining the government's ambition for this technology.

The figure above shows that the annual offshore wind installation in South Korea is expected to significantly ramp up from 2026. However, based on current development plans, it is unlikely for the 2030 target of 14.3 GW to be achieved. Delays in the commissioning of projects that won auction allocations will further potentially slow down the project pipeline beyond this forecast scenario.

South Korea's wind supply chain capability

Considering its own supply chain, South Korea has the domestic capabilities to cover a sizeable portion of its onshore wind demand through to 2030. However, for offshore wind there are significant bottlenecks expected throughout a substantial portion of the supply chain.

South Korea has two dominant onshore wind turbine OEMs: Doosan Enerbility and Unison. Their presence, considering also the related Tier 2 suppliers, means that the required supply capabilities for many of the wind turbine components are available in-country. However, our analysis shows that there are currently insufficient manufacturing capabilities in blades, power converters and castings for onshore wind domestically to meet the demand through to 2030.

Both domestic OEMs have looked to extend their capabilities to offshore wind in recent years. Doosan Enerbility's 5.5 MW turbine has been selected for the 100 MW Jeju Hallim Offshore Wind Farm.[179] The company obtained type certification for its 8 MW model in 2022 and is currently developing a 10 MW model through the KETEP's (Korea Institute of Energy Technology Evaluation and Planning) Renewable Energy R&D Project Grant Award scheme, in collaboration with local developers and supply chain companies.[180, 181] Unison has also recently unveiled a 10 MW direct-drive turbine for offshore wind which is being prepared for testing.[182]

Further, international turbine OEMs

179. Doosan Enerbility. (2021). Retrieved from, https://www.doosan.com/en/media-center/press-release_view/?id=20172309&page=2&param1=4&param2=jeju

South Korea's wind supply chain coverage (numbers in chart represent expected demand)								
Component	Unit	2024	2025	2026	2027	2028	2029	2030
Onshore Nacelle	MW	200	200	200	200	200	200	200
Onshore Gearbox	MW	200	200	200	200	200	200	200
Onshore Generator	MW	200	200	200	200	200	200	200
Onshore Blades	MW	200	200	200	200	200	200	200
Onshore Power Converter	MW	200	200	200	200	200	200	200
Onshore Towers	units	44	40	40	36	36	33	33
Onshore Castings	tonnes	2440	2440	2440	2440	2440	2440	2440
Offshore Nacelle	MW	100	0	880	895	1230	1500	1500
Offshore Gearbox	MW	100	0	880	895	1230	1500	1500
Offshore Generator	MW	100	0	880	895	1230	1500	1500
Offshore Blades	MW	100	0	880	895	1230	1500	1500
Offshore Power Converter	MW	100	0	880	895	1230	1500	1500
Offshore Towers	MW	10	0	66	106	84	100	100
Offshore Castings	tonnes	1770	0	15576	15842	21771	26550	26550
Fixed Foundations	units	10	0	66	106	67	60	50
Floating Foundations	units	0	0	0	0	17	40	50
Cables	km	36	0	313	318	437	533	533
Ports	MW	100	0	880	895	1230	1500	1500
WTIV	MW	100	0	880	895	1230	1500	1500

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

have announced early plans to establish manufacturing facilities for offshore wind in South Korea through partnerships with existing local companies. GE Vernova revealed in 2022 that it had signed a strategic partnership agreement with Hyundai Electric for the Korean company to support the local nacelle assembly and manufacturing of generators for the Haliade-X wind turbines.[183] In the same year, Chinese Shanghai Electric co-established a legal entity called HSE Wind with HYOSUNG in South Korea and plans to produce 50 units of 10 MW offshore wind turbines per annum in South Korea. The two partners have started certification for their 10 MW offshore wind turbine with TÜV SÜD and have met Korean Industrial Standards since 2023.[184] Siemens Gamesa signed a framework agreement with Doosan Enerbility in 2023 for Siemens Gamesa's offshore wind nacelles to be assembled in Doosan's facility, for installation from 2026.[185] In October 2024 the two companies signed a MoU with Equinor to supply 15 MW class turbines to the 750 MW Bandibuli floating offshore windfarm.[186] Vestas and Danish logistics company Maersk signed a MOU with Jeonnam Province and Mokpo City to build a nacelle factory and logistics base at the Mokpo New Port Hinterland Complex in 2024.[187] More recently, at the Invest KOREA Summit in November 2024, Vestas announced it will set up its regional headquarters in South Korea and construct its main factory for wind power generation equipment[188]. Additionally, Chinese turbine OEM Mingyang Smart Energy also announced its intention to enter the Korean offshore wind market through signing an agreement with Unison for the establishment of a nacelle assembly and blade manufacturing facility.[189] Though offshore wind nacelle bottlenecks are expected from 2028 based on current plans, if several of the OEMs above can successfully begin manufacturing in South Korea, there should be sufficient supply to meet domestic demand. The presence of international suppliers would also be expected to drive the transition of existing Tier 2 suppliers for onshore wind components towards manufacturing offshore wind components.

In terms of offshore wind balance of plant, South Korea is expected to be able to meet its own demand for fixed foundations and cables through to 2030. Foundation manufacturing leverages Korean expertise in steelmaking and steel processing. However, South Korea is poor in natural resources and its steel industry relies heavily on imports. The country is the third largest importer of iron ore in the world with 7.58 billion USD imported in 2022, of which nearly 70% originated from Australia.[190]

Finally, no bottlenecks are currently expected for WTIVs in South Korea when analysing vessel capacity in MW. However, upgrades will need to be made to ensure the capabilities of current WTIVs increase in line with turbine size throughout the decade. Hyundai Challenger 1 is a jack-up barge that was used for the construction of the 30 MW Tamra Offshore wind project and 60 MW South-West Offshore wind projects. However, it is limited to the installation of up to approximately 5 MW rated turbines and thus, due to the continued increase in turbine sizes, is not expected to serve as the main installation vessel for upcoming offshore wind projects. Subsequently, Hyundai completed construction of the Hyundai Frontier in 2023, which features a 1,200-tonne crane to install up to approximately 10 MW turbines.[191] Though considerations to construct larger WTIVs are ongoing, as things stand this vessel alone will not be able to meet the demand for turbine installation, and there are further supply shortages regarding foundation installation vessels. Taihan Cable & Solutions has procured the country's only cable-laying vessel specialising in offshore wind but again, a larger fleet of vessels is expected to be required to support the offshore windfarm buildout to 2030.[192] Other jack-up vessels for offshore wind have been built in Korean shipyards recently but they are expected to predominantly serve the European offshore wind market.[193]

In terms of port infrastructure,

180. Doosan Enerbility. (2022). Retrieved from, https://www.doosan.com/en/media-center/press-release_view?id=20172456
181. Renews.Biz. (2024). Retrieved from, https://renews.biz/95659/doosan-enerbility-eyes-10mw-korean-turbine/
182. Pulse. (2024). Retrieved from, https://pulse.mk.co.kr/news/english/11126747
183. GE Vernova. (2022). Retrieved from, https://www.gevernova.com/news/press-releases/ge-renewable-energy-signs-strategic-partnership-agreement-with-hyundai-electric-support-growth-offshore-wind-south-korea
184. Siemens Gamesa. (2023). Retrieved from, https://www.siemensgamesa.com/global/en/home/press-releases/020623-siemens-gamesa-press-release-offshore-doosan-enerbility-south-korea.html
185. Equinor. (2024). Retrieved from, https://www.equinor.co.kr/en/news/equinor-signs-mou-with-siemens-gamesa-and-doosan-enerbility-on-ulsan-bandibuli-floating-offshore-wind-project
186. OffshoreWind.Biz. (2024). Retrieved from, https://www.offshorewind.biz/2024/04/22/vestas-and-maersk-to-build-offshore-wind-hub-in-south-korea/
187. The Korea Times. (2024). Retrieved from, HP, Vestas to set up regional headquarters in Korea - The Korea Times
188. OffshoreWind.Biz. (2024). Retrieved from, https://www.offshorewind.biz/2024/09/05/mingyang-to-manufacture-wind-turbines-in-south-korea/
189. OffshoreWind.Biz. (2024). Retrieved from, https://www.offshorewind.biz/2024/09/05/mingyang-to-manufacture-wind-turbines-in-south-korea/
190. OEC. (2022). Retrieved from, https://oec.world/en/profile/bilateral-product/iron-ore/reporter/kor OEC. (2022). Retrieved from, https://oec.world/en/profile/bilateral-product/iron-ore/reporter/kor
191. Hyundai E&C. (2023). Retrieved from, https://www.hdec.kr/en/newsroom/news_view.aspx?NewsSeq=847&NewsType=LATEST&NewsListType=news_clist

Mokpo New Port is the only port with an official expansion plan for offshore wind to have been completed. This is expected to be insufficient to support the project pipelines expected to come online from 2026, and the preparation of further ports will be required. Alternative ports such as Ulsan, Gunsan, Incheon and Haenam have been identified but concrete plans to upgrade the facilities for offshore wind have not been finalised.[194]

Strengths and opportunities of South Korea's wind supply chain

Policy

- **Ambitious short-term offshore wind auction schedule –** With its 14.3 GW of installed offshore wind by 2030 target in mind, as outlined in the 10th Basic Plan of Power Distribution, MOTIE recently announced plans to auction 7-8 GW by 2026 Q2, including up to 3 GW for floating projects. This emphasises the government's strong commitment to offshore wind, helping to provide suppliers with the necessary confidence to consider investments in manufacturing capacity.

Industry

The main strengths of the Korean supply chain include shipbuilding, foundations, submarine cables, offshore wind turbine production, the automobile industry, and electrical / electronic components. Considering the domestic bottlenecks identified in the table above and regional bottlenecks identified in this wider report, this presents opportunities for both wind suppliers and potential transition companies to grow their capabilities to meet the increasing domestic and regional demand.

- **Shipbuilding capabilities –** In 2021 South Korean shipbuilding held a market share of 37.1%, second only to China,[195] with the country's sector led by the "big three" shipbuilders HD Hyundai Heavy Industries, Samsung Heavy Industries and Hanwha Ocean. The shipyards have constructed WTIVs for leading European vessel owners. Two jack-up vessels ordered by Eneti (now Cadeler) are currently under construction at Hanwha Ocean's shipyard. This experience could now be leveraged to build the wide variety of vessels required for the domestic and wider APAC offshore wind sector.
- **Existing domestic turbine OEMs –** Active South Korean turbine and component manufacturers such as Doosan Enerbility, Unison, Hyundai Electric and Hyosung Heavy Industries provide a base for future growth of the onshore and offshore wind turbine supply chain. The existing Tier 2 and Tier 3 suppliers that collaborate with the companies also offer opportunities to scale up parts production across the wider supplier landscape if international OEMs are able to successfully establish manufacturing bases in the country.
- **Submarine cables –** South Korea has strong cable manufacturing capabilities which have already been applied to inter-array and export cables for the offshore wind sector. LS Cables & Systems and Taihan Cable & Solutions have supplied submarine cables domestically, as well as throughout the APAC region and Europe. LS C&S is investing nearly USD 700 million in a submarine HVDC manufacturing facility in Virginia, United States, which will be completed in 2027.[196]
- **Strong steel industry –** South Korean steel processing capabilities related to the shipbuilding sector have thus far been leveraged to supply wind towers and bottom-fixed foundations for domestic and international offshore wind projects. CS Wind and SeAH are leading Korean tower suppliers to the wind industry. Companies such as SK oceanplant, Hyundai Steel Engineering and HSG Sungdong Shipbuilding have experience in supplying jackets for projects in Taiwan.
- **Industry leader in forging technology-** Korean suppliers including Taewoong, Mysco, Hyundai IFC and Seohan have been supplying world-class forging products such as main shafts, tower flanges, pitch and yaw bearing rings to the global wind industry for more than a decade.
- **Automotive industry –** South Korea is the fifth largest producer of automobiles globally[197] and has established a strong automotive industry, particularly centred around the Ulsan area.[198] Shilla Corporation[199] has expanded its initial expertise in manufacturing forged components for the automotive industry to supply

192. Taihan. (2023). Retrieved from, https://www.taihan.com/en/news/pr/taihanNewsDetail?idx=603
193. offshoreWIND.biz. (2024). Retrieved from, https://www.offshorewind.biz/2024/06/05/cadelers-first-m-class-mega-jack-up-launched/
194. NEXT Group. (2023). Retrieved from, https://eng.nextgroup.or.kr/
195. JSMEA. (2022). Retrieved from, https://www.jstra.jp/PDF/kaigaijouhou9.pdf
196. offshoreWIND.biz (2024). Retrieved from, https://www.offshorewind.biz/2024/07/10/ls-cable-system-to-build-largest-us-subsea-cable-factory-in-virginia/#:~:text=The%20factory%20will%20be%20built,according%20to%20LS%20Cable%20%26%20System.

slewing ring bearings to global turbine makers. SHIN IL and ILJIN are also two well-known Korean slewing bearing suppliers to the wind industry.

- **Electrical / electronic manufacturing –** South Korea is one of the global leaders in manufacturing of electrical machinery and electronics, with over 200 billion USD in exports in 2022.[200] Korean companies have provided ultra-high voltage power equipment such as transformers and reactors for offshore wind projects in Europe too.[201] This offers a strong base for companies to potentially transition into manufacturing of components such as generators and power converters that are currently seen as a bottleneck in South Korea and many key wind power markets in APAC.

Recommendations for wind supply chain scale-up in South Korea

1. Streamline regulatory issues such as permitting and grid connection to ensure a steady and credible realisation of offshore wind projects giving suppliers the confidence to make the necessary investments in expanding their capabilities.

Under a developer-led approach in the South Korean offshore wind market, the individual consortia are responsible for obtaining permits and community acceptance. However, South Korean offshore wind projects have thus far faced delays due to factors such as opposition from local communities and fisheries, as well as insufficient capacity within the transmission network.

- The accelerated implementation of the "one stop shop" permitting process, currently under consideration, may be prioritised to reduce development timeframes and get closer to achieving 2030 targets.
- Government-led marine spatial planning could help to proactively address stakeholder engagement issues and may significantly reduce development risk to deliver the ambitious offshore wind project pipeline.
- Grid development and expansion plans must be matured in accordance with offshore wind deployment schedule, particularly where projects are clustered in specific sea areas.

2. Capitalise on existing appetite from international turbine OEMs to establish manufacturing facilities to make South Korea an offshore wind turbine supply chain hub for the APAC region.

- GE Vernova, Shanghai Electric, Siemens Gamesa, Vestas, and Mingyang Smart Energy have recently announced their intention to produce offshore wind turbine nacelles and other components together with local partners in South Korea.
- South Korea provides an attractive market for these turbine OEMs, owing to a combination of government ambition to support the growth of the offshore wind industry and the existing manufacturing base to build a supply chain.
- The South Korean government could seek to provide incentives such as tax credits for these companies to enter the market and look to support the success of their partnerships and joint ventures with local companies.
- The South Korean government could provide a longer-term plan beyond the current auction plan of 7-8 GW by 2026 2Q to provide the volume of projects required for turbine OEMs to successfully establish themselves in the market. However, those OEMs should also include the wider APAC market outside of South Korea in their considerations to accurately assess the total accessible pipeline capacity.
- The presence of these turbine OEMs will also contribute to the increased capabilities of the wider supply chain as the companies will look to local industry to source key components.

3. Leverage Korean shipbuilding expertise to address vessel shortages and achieve serial production of floating substructures to meet offshore wind demand domestically, throughout APAC and globally.

- Currently, there is only one tailor-made WTIV active in South Korea which is insufficient to support the annual 1+ GW installations expected from 2028 onwards. Further, shortages of specialist

197. OICA (2022). Retrieved from, https://www.oica.net/category/production-statistics/2022-statistics/
198. InvestKOREA. Retrieved from, https://www.investkorea.org/us-en/cntnts/i-1443/web.do
199. Shilla Corporation. Retrieved from, https://shillacorp.en.ec21.com/company_info.html
200. OEC (2022). Retrieved from, https://oec.world/en/profile/bilateral-product/electrical-machinery-and-electronics/reporter/kor
201 offshoreWIND.biz (2024). Retrieved from, https://www.offshorewind.biz/2024/11/04/south-korean-firm-to-supply-power-equipment-for-orsteds-hornsea-4-offshore-wind-farm/

vessels such as foundation installation and cable-laying vessels are also expected once offshore construction ramps up in the coming years. Similar situations are being seen in other offshore wind markets in APAC.

- Korean shipyards have the potential to build world-class offshore wind vessels to address the current shortage and are capable of accessing the significant export opportunities both in APAC and globally. Governments could collaborate to provide predictability to the shipbuilding industry, as industry consultations have indicated that there is not enough confidence in the APAC market to justify investment in WTIVs.

- Further, South Korean conglomerates such as Hyundai, Samsung and Daewoo E&C have been actively exploring commercialisation of floating substructure technology. Hyundai and Samsung have recently signed agreements with local and international developers to deliver foundations for floating wind projects.

- Regional collaboration such as partnerships between suppliers throughout APAC could be explored to ensure mutually beneficial technology and knowledge sharing for the growth of the floating offshore wind supply chain.

4. Introduction of a transparent and streamlined application process for cabotage restriction exemptions for offshore wind vessels.

- Under Article 6 of the Ship Act, the transport of cargo between domestic ports by a non-Korean flagged vessel is prohibited. However, to address the shortage of offshore wind vessels, not just for turbine installation but also foundations and cable laying, some reliance on overseas vessels is expected to be required in the short to medium term.

- Whilst reflagging or applications for an exemption to the Korean cabotage rules are an option, this remains a significant entry barrier for foreign vessel owners.

- The introduction of a clear and streamlined process to grant exemptions for offshore wind vessels will reduce the supply constraints expected from 2026, as well as increase flexibility and options for vessel selection in the long term.

5. Accelerate training and upskilling of personnel to support the growing offshore wind industry.

- Due to the historical lack of offshore O&G activity off the coast of South Korea, there is a shortage of technical personnel to serve the offshore wind industry. GWEC research shows that if South Korea were to achieve its 2030 target of 14.3 GW, 770,000 new jobs would be generated to support the buildout of these projects. Most of these jobs will be located in coastal cities and will contribute to the revitalisation of the local economy.

- The local and municipal governments, in collaboration with the national government, developers, suppliers and universities, could lead the development of a plan to ensure necessary training for the offshore wind workforce.

- With regards to the lack of offshore O&G experience, industry-wide HSE standards for offshore wind could be developed as a high priority through collaboration between active developers and organisations such as KOSHA (Korea Occupational Safety and Health Agency).

6. Creation of an offshore wind port development plan to support both fixed-bottom and floating offshore wind deployment.

- South Korea has existing port infrastructure from related industries such as shipbuilding which have the potential to support offshore wind construction. However, major ports such as Busan and Incheon with the best specifications are currently occupied for other uses and hence there is limited availability for offshore wind. Upgrades and expansions will still be required to allow the ports to function as effective marshalling bases for planned offshore wind projects.

- The importance of port upgrades is amplified once the future prevalence of floating offshore wind projects is considered, as this would require greater port depths.

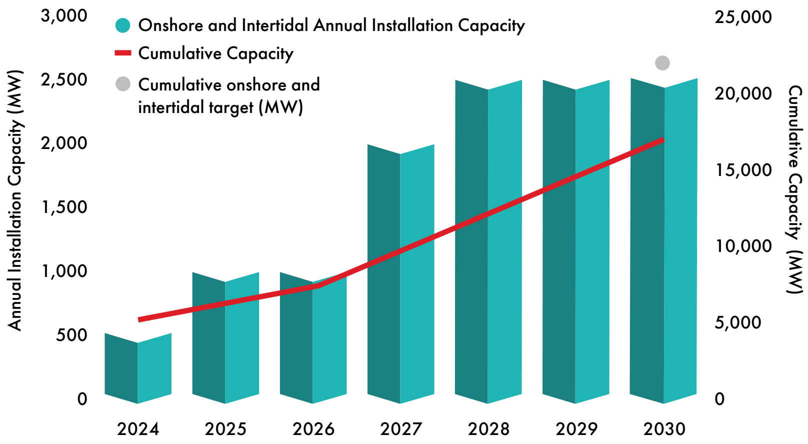
- The South Korean government could consider developing a long-term, offshore wind specific port investment plan to meet demand in the coming years to allow for the successful delivery of the planned offshore wind projects.

Vietnam

Overview of Vietnam's wind market

Vietnam is the fourth largest wind market in the APAC region with nearly 5 GW of wind energy installed by the end of 2023. However, the country does not yet have any real offshore wind projects in operation and all capacity installed so far is from onshore and intertidal wind projects.[202] As one of the fastest-growing economies in Southeast Asia, coupled with rising electricity demand, Vietnam is already facing power shortages with a forecasted deficit in generation capacity in coming years. As wind is a dependable, affordable and secure alternative to fossil fuels, the development of a domestic wind industry presents an opportunity for Vietnam to bridge power demand and supply challenges in the short term, while positioning the country well towards achieving its net zero by 2050 target.

Onshore and inter-tidal wind installation forecast up to 2030 (MW) in Vietnam



Source: GWEC, 2024

Onshore Wind

In Vietnam, 82% of its total wind installation capacity is onshore. In addition, the country has 3 GW of projects negotiating power purchase agreements (PPA) with Vietnam Electricity (EVN). In May 2024, the government issued a long-awaited Power Development Plan 8 (PDP8) which sets the energy strategy for the country from 2021-2030 with a vision to 2050. The PDP8 includes a target for 21.8 GW of installed onshore and near-shore wind by 2030. Despite that, GWEC estimates just under 16 GW of onshore wind capacity (including inter-tidal) to be commissioned by 2030. The near-term onshore wind market outlook (2024–2026), built using a bottom-up approach, is based on GWEC Market Intelligence's global onshore and inter-tidal wind project database, which covers projects currently under construction, global auction results and announced domestic onshore wind tenders. For the medium-term market outlook (2027–2030), a top-down approach was used alongside existing project pipelines. This considers existing policies and medium/long-term national offshore wind targets.

Offshore Wind

According to the World Bank Group, Vietnam has 599 GW of offshore wind technical potential, including 261 GW fixed and 338 GW floating, yet there are no operational offshore wind projects in Vietnam to date,

202. Inter-tidal or nearshore projects are located in shallow waters close to shore. Inter-tidal projects have been grouped as onshore wind in this report, which is in line with government targets for onshore wind.

and all projects in the development pipeline are in the very early stages of devtelopment.[203] The Ministry of Industry and Trade (MOIT) released a draft amendment to the Electricity Law in March 2024 which included high-level provisions regulating offshore wind power projects for the first time. The Draft Electricity Law reflects a two-step competition model. It also laid out the framework for private companies to develop offshore wind projects.

PDP8 targets 6 GW of offshore wind by 2030 rapidly increasing to 70 – 91.5 GW by 2050. The plan sets out regional 2030 targets, including 2.5 GW in the Northern Region, 500 MW in the Central Region, 2 GW in the Central South Region and 1 GW in the Southern Region. A seabed leasing process specific to offshore wind has not yet been established in Vietnam and no offshore wind projects to date have secured site exclusivity. A joint venture between PTSC and Sembcorp Utilities is the only project to have been given the green light by the Ministry of Natural Resources and Environment to execute marine resource investigation for offshore wind development.[204] Recently, the MOIT proposed a development process for the first offshore wind projects owned companies EVN and PetroVietnam (PVN)) might take the lead in developing those first projects, laying the foundation for legal framework development.

The pending regulatory framework combined with expected development times of 6-8 years from the start of surveys will make it challenging for any offshore wind capacity to come online before 2030. Despite certain international developers announcing they were exiting the Vietnamese offshore wind market, interest in the market remains, with reputable local and international developers continuing to sign various cooperation deals regarding collaboration in offshore wind.

Vietnam's wind supply chain capability

Supply for onshore and offshore wind towers, onshore generators and onshore power converters exists in Vietnam through investment and collaboration with foreign companies, such as Korean's CS Wind and GE. However, when looking at the wider supply chain coverage, Vietnam does not yet have the domestic manufacturing capabilities for most onshore and offshore wind turbine components.

Sufficient supply of onshore generators and towers is expected to meet the domestic onshore wind demand up to 2030, and supply of power converters should meet onshore wind demand up until and including 2026. Offshore wind in Vietnam is not expected to come online until after 2030, but there are capabilities to provide offshore wind foundations and towers at present. It should be noted that the table on page 111 is based on a closed market approach, which assumes all domestic supply will serve the domestic market. However, while GE has capabilities to make generators in Vietnam, these are currently not serving the Vietnamese market.

CS Wind, a subsidiary of South Korea's CS Wind Corporation, supplies a considerable proportion of key wind components in which produces onshore and offshore towers at its Phy My facility in the province of Ba Ria-Vung Tau in southeastern Vietnam. The facility opened in 2023 produced, the first offshore tower in 2024 for the 99 MW Jeonnam I in South Korea.[205] In September 2024, CS Wind signed a cooperation agreement with Dong Tam Group to lease land for a wind power manufacturing facility in the Southeast Asia Industrial Park, Vietnam. The manufacturing facility is set to provide onshore and offshore towers, foundations, and other materials.[206]

GE has been operating in Vietnam for over 15 years producing and exporting generator systems and power converters at the GE Hai Phong facility in northern Vietnam. Since 2008, the GE Hai Phong facility has been generating export revenues worth $2 billion.[207] In addition, JABIL produces power converters at its dedicated wind manufacturing site at the Saigon Hi-Tech Park (SHTP) in Ho Chi Minh City, Vietnam.[208] The site at SHTP was expanded in 2017 to provide additional storage space and

203. 261 GW is suitable for fixed offshore wind and 338 GW is suited for floating offshore wind projects - World Bank Group. (2021). Offshore wind technical potential in Vietnam. Retrieved from, https://documents1.worldbank.org/curated/en/340451572465613444/pdf/Technical-Potential-for-Offshore-Wind-in-Vietnam-Map.pdf
204. Duong, T. (2023, August 30). Retrieved from, https://vir.com.vn/ptsc-and-sembcorp-secure-clean-energy-export-licence-104815.html
205. Lagan Wind. Made-in-Vietnam wind turbine towers set sail for CIP's project site in Korea. Retrieved from, https://www.laganoffshorewind.vn/made-in-vietnam-wind-turbine-towers-set-sail-for-cips-project-site-in-korea/
206. Memija, A. (2021). CS Wind to Pour USD 200 Million Into New Factory in Vietnam. OffshoreWind.biz. Retrieved from, https://www.offshorewind.biz/2024/09/11/cs-wind-to-pour-usd-200-million-into-new-factory-in-vietnam/
207. GE. (2021). GE's journey to improve Vietnamese suppliers' capacity. Retrieved from, https://www.ge.com/news/reports/ges-journey-to-improve-vietnamese-suppliers-capacity
208. Jabil. (2019). Retrieved from, https://www.jabil.com/dam/jcr:991e4082-2023-40aa-9399-f2eb1b4204d7/infographic-wind-solutions.pdf

accommodate higher volumes of production.[209]

There is currently no domestic supply of blades in Vietnam. However, in 2024 it was announced that a newly established subsidiary of Zhuzhou Times New Materials Technology Co Ltd, called Vietnam Wind Blade Engineering Co Ltd, is investing in a new facility for wind turbine blade production.[210] If realised, the facility would help meet a large proportion of Vietnam's onshore blade supply, though bottlenecks would still be expected through to 2030.

Regarding critical materials, Vietnam has a well-established copper industry, large steel production capabilities and large rare-earth reserves. Carbon fibre manufacturing facilities are also present, such as Teijin Carbon Vietnam Co, which produces carbon fibre products.[211] Additionally, in July 2023, Hyosung Vietnam announced plans to invest approximately $1 billion in a carbon fibre manufacturing facility.[212]

In terms of offshore wind balance of plant, PTSC has a strong track record

209. Jabil. (2017). Jabil Expands Facility Footprint in Saigon Hi-Tech Park. Retrieved from, https://www.jabil.com/news/jabil-expands-facility-in-saigon.html
210. Sohu. (2024). Times New Materials: Announcement on the establishment of a wholly owned subsidiary in Vietnam. Retrieved from, https://q.stock.sohu.com/cn/gg/2024/600458/57217766.shtml
211. Teijin. Teijin Carbon Business Unit. Retrieved from, https://www.teijincarbon.com/about-us/global-network/
212. Vietnam Investment Review (2023). Hyosung Vietnam to invest nearly $1 billion in a carbon fibre manufacturing facility, solidifying its strategic position in Vietnam's industrial landscape. Retrieved from, https://vir.com.vn/hyosung-vietnam-to-invest-nearly-1-billion-in-carbon-fiber-plant-103747.html

Vietnam's supply chain coverage								
Component	Unit	2024	2025	2026	2027	2028	2029	2030
Onshore Nacelle	MW	500	1000	1000	2000	2500	2500	2500
Onshore Gearbox	MW	500	1000	1000	2000	2500	2500	2500
Onshore Generator	MW	500	1000	1000	2000	2500	2500	2500
Onshore Blades	MW	500	1000	1000	2000	2500	2500	2500
Onshore Power Converter	MW	500	1000	1000	2000	2500	2500	2500
Onshore Towers	units	125	250	200	400	455	455	417
Onshore Castings	tonnes	6100	12200	12200	24400	30500	30500	30500
Offshore Nacelle	MW	0	0	0	0	0	0	0
Offshore Gearbox	MW	0	0	0	0	0	0	0
Offshore Generator	MW	0	0	0	0	0	0	0
Offshore Blades	MW	0	0	0	0	0	0	0
Offshore Power Converter	MW	0	0	0	0	0	0	0
Offshore Towers	MW	0	0	0	0	0	0	0
Offshore Castings	tonnes	0	0	0	0	0	0	0
Fixed Foundations	units	0	0	0	0	0	0	0
Floating Foundations	units	0	0	0	0	0	0	0
Cables	km	0	0	0	0	0	0	0
Ports	MW	0	0	0	0	0	0	0
WTIV	MW	0	0	0	0	0	0	0

● Supply exceeds demand ● Minor Bottleneck - Supply is < 10% below demand ● Major Bottleneck - Supply is > 10% below demand ● Values in the cells indicate that year's demand for a component

Source: GWEC Market Intelligence, ERM, Brinckmann, October 2024

of supply foundations for offshore wind farms and substations in Taiwan and Europe, including 33 jackets for the Greater Changhua project in Taiwan and structures for three offshore substations.[213] Additional suppliers have expressed an interest in manufacturing capabilities for foundations.[214]

There are currently no subsea cable manufacturing facilities in Vietnam, but Korean LS Cable & Systems operate in Vietnam through LS Vina Cable & Systems. At its facility in Hai Phong, LS Vina produces extra-high, medium, and low voltage power cables.[215] PTSC and LS Cable & Systems are exploring a joint subsea cable business partnership to support projects in Vietnam and ASEAN countries.[216] Subsea cable manufacturing capacity is expected to be established in Vietnam by 2026.

Vietnam is home to around 50 ports and 30 shipyards which operate as major import and logistics bases and have the potential to support the offshore wind industry through fabrication, marshalling and operations and maintenance.

Ports to the south are well-established due to the oil and gas industry in the region. PTSC has already supported the construction of offshore foundations for the Greater Changhua offshore wind farm at the Vung Tau Downstream Port.[217] Ba Son Shipyard has worked with PTSC to assist with some of the workload and the Shipyard has plans to develop their fabrication capability to supply monopile foundations for 15 MW+ wind turbines.[218] Additionally, Vinh Tan International Port is a deep-water port located close to sites most suitable for fixed-bottom offshore wind zones in Vietnam.[219] The Vinh Tan Port Master Plan is currently in development and looks to construct a dedicated offshore wind terminal within the port to meet its ambitions of becoming a construction port for offshore wind as well as supporting the fabrication of foundations. Additional ports in the south would require minimal investment to make them suitable for offshore wind fabrication, marshalling and O&M.[220] Examples include PTSC Phu My port, SREC port, PV shipyard, PTSC supply base and Alpha EEC port.[221]

In the north, the Hai Phong cluster represents an opportunity for fabrication services, in particular PTSC Dinh Vu port, Nam Dinh Vu port and Tan Vu port.[222] The Nghi Son International Port (NSIP) has the potential to become the dedicated offshore wind construction port in the north if the necessary investments are made to increase storage.[223]

Extensive shipbuilding capabilities in Vietnam means shipyards are also able to support the offshore wind vessel industry. Significant investment into Vietnam's shipbuilding sector since the early 2000s has enabled Vietnam to become one of the world's leading shipbuilders with established universities and colleges supporting a skilled workforce. It is estimated that Vietnam's shipbuilding sector could reach a CAGR of 6% from 2023 to 2032, with the value of ships built to reach US$680 million in 2032.[234]

Vietnam's shipbuilding industry has attracted large foreign direct investment, with a network of global corporations active in the industry. Hyundai Vietnam Shipbuilding (HVS), established in 1996, is a joint venture between Hyundai Mipo Shipyard in Korea and Shipbuilding Industry Corporation (SBIC) in Vietnam with around 5,000 skilled employees. The company has grown

213. PTSC. (2024). Retrieved from, https://www.ptsc.com.vn/Data/Sites/1/media/brochure/TA_Brochure2024.pdf
214. Innovation Norway., Norwegian Embassy in Hanoi. (2023). Offshore wind supply chain for fast-track scenario in Vietnam. Retrieved from, https://www.norway.no/globalassets/2-world/vietnam/documents/034625-vietnam-supply-chain-study_eng.pdf
215. LS Eco Energy. Retrieved from. https://lsecoenergy.com/en/about/subsidiaries?ckattempt=1
216. Vietnam Investment Review. (2023). South Korean cable maker expands into Vietnamese market. Retrieved from, https://vir.com.vn/south-korean-cable-maker-expands-into-vietnamese-market-106012.html
217. PTSC. (2024). PTSC completed the final integration for the first foundation of offshore windfarm Greater Changhua 2B&04. Retrieved from, https://www.ptsc.com.vn/en-US/ptsc-completed-the-final-integration-for-the-first-foundation-of-offshore-windfarm-greater-changhua-2b-04-1
218. Danish Energy Agency., Royal Danish Embassy in Viet Nam., Electricity and Renewable Energy Authority. (2024). Mapping port infrastructure for the offshore wind industry and job creation in Viet Nam. Retrieved from, https://ens.dk/sites/ens.dk/files/Analyser/depp_vietnam_port_study_for_offshore_wind_final_report.pdf
219. Innovation Norway., Norwegian Embassy in Hanoi. (2023). Offshore wind supply chain for fast-track scenario in Vietnam. Retrieved from, https://www.norway.no/globalassets/2-world/vietnam/documents/034625-vietnam-supply-chain-study_eng.pdf
220. Danish Energy Agency., Royal Danish Embassy in Viet Nam., Electricity and Renewable Energy Authority. (2024). Mapping port infrastructure for the offshore wind industry and job creation in Viet Nam. Retrieved from, https://ens.dk/sites/ens.dk/files/Analyser/depp_vietnam_port_study_for_offshore_wind_final_report.pdf
221. Innovation Norway., Norwegian Embassy in Hanoi. (2023). Offshore wind supply chain for fast-track scenario in Vietnam. Retrieved from, https://www.norway.no/globalassets/2-world/vietnam/documents/034625-vietnam-supply-chain-study_eng.pdf
222. Damen. (2024). Damen Song Cam Shipyard. Retrieved from, https://www.damen.com/companies/damen-song-cam-shipyard
223. Danish Energy Agency., Royal Danish Embassy in Viet Nam., Electricity and Renewable Energy Authority. (2024). Mapping port infrastructure for the offshore wind industry and job creation in Viet Nam. Retrieved from, https://ens.dk/sites/ens.dk/files/Analyser/depp_vietnam_port_study_for_offshore_wind_final_report.pdf
224. Research and Markets. (2023). Vietnam Shipbuilding Industry Research Report 2023-2032. Retrieved from, https://www.researchandmarkets.com/reports/5806830/vietnam-shipbuilding-industry-research-report?gclid=Cj0KCQjw2qKmBhCfARIsAFy8buJizsE-EQObCdE2Yyp_HcpTuw6AwE906ERmBzJXTw6tOkm5ItlrWdgaAks9EALw_wcB

to be the largest shipyard in southeast Asia, exporting to Japan, Korea, Singapore and more.

Existing shipyards in Vietnam are strategically positioned to supply to the wider APAC market and support the increasing demand for offshore wind vessels. In the north, ports in the Hai Phong cluster could become a hub for vessels fabrication, considering that major steel resources are in or imported from the north of Vietnam.[225] Some Vietnamese shipyards are already engaged with their European partners to support global offshore wind development.

- **Ha Long Shipyard –** Damen Shipyards, Windcat and CMB. TECH are constructing six Commissioning Service Operation Vessels (CSOVs) at the Ha Long shipyard in the north of Vietnam. The first CSOV was launched in October 2024.[226]
- **Damen Song Cam Shipyard –** is a joint venture between Damen Shipyards Group and Song Cam, part of SBIC. The shipyard is located near Hai Phong and will be the preferred production location for Damen tug and workboats up to 60 metres long.[227]
- **Nam Trieu Shipyard –** Royal IHC and Vietnamese shipyard Nam Trieu signed an agreement to collaborate on vessel manufacturing, including the construction of a trailing suction hopper dredger. According to Royal IHC, shipbuilding in Vietnam offers the same quality level as seen in the Netherlands and the far east but offers lower labour and energy costs. The joint venture plans to build cable laying vessel for offshore wind.
- **Vard Vung Tàu Shipyard –** Norwegian Edda Wind placed orders for four CSOVs.[228]
- **Austal Vietnam Vung Tàu –** Austal Vietnam has capabilities to deliver commercial vessel solutions at its shipbuilding facility in the south of Vietnam, including design and fabrication of high-speed passenger and vehicle passenger ferries, work boats, offshore crew transfer vessels, windfarm vessels and other commercial and utility vessels.[229]

Vietnam has no tailormade heavy lift crane vessels and jack-up vessels for offshore wind. However, Sigma Engineering JSC owns a heavy lift vessel which has supported inter-tidal projects in Vietnam[230]. With partnerships between experienced international companies, and significant investment, these suppliers could expand capabilities to supply larger vessels for the offshore wind industry, such as WTIVs.

Strengths and opportunities of Vietnam's wind supply chain

Policy

- Ambitious climate commitments and onshore & offshore wind targets – Vietnam's core climate commitments are articulated in the National Climate Change Strategy to 2050 (NCCS) which sets a goal of reaching net zero by 2050.[231] The PDP8 targets 47% of renewable power generation by 2030 and 68-72% by 2050.[232] Under the PDP8, a total of 28 GW worth of wind capacity is targeted to be connected to the national grid, including 21.8 GW for onshore and nearshore and 6 GW for offshore wind.

Industry

Foreign private sector investment has supported the growth of Vietnam's manufacturing and steel industries, positioning Vietnam well to support offshore wind services to meet its domestic wind supply chain and support the wider APAC wind supply chain.

- **Existing supply chain for wind turbine key components and other industrial products that can be used in the wind industry –** Vietnam has existing wind supply chain capabilities, with ongoing manufacturing of onshore and offshore towers,

225. Innovation Norway., Norwegian Embassy in Hanoi. (2023). Offshore wind supply chain for fast-track scenario in Vietnam. Retrieved from, https://www.norway.no/globalassets/2-world/vietnam/documents/034625-vietnam-supply-chain-study_eng.pdf
226. Damen. (2024). Windcat's first CSOV launched by Damen. Retrieved from, https://www.damen.com/insights-center/news/windcat-s-first-csov-launched-by-damen
227. Damen Song Cam. Damen Song Cam Shipyard. Retrieved from, https://media.damen.com/image/upload/v1719560449/companies/damen-song-cam-shipyard/damen-song-cam-shipyard-brochure-en.pdf
228. VARD. (2023). VARD has signed contracts for four Commissioning Service Operation Vessels for Edda Wind. Retrieved from, https://www.vard.com/articles/vard-has-signed-contracts-for-four-commissioning-service-operation-vessels-csovs-for-edda-wind
229. Austal Vietnam. Austal Vietnam Corporate Profile. Retrieved from, https://vietnam.austal.com/sites/default/files/00-images-philippines/AV%20Corporate%20Profile%20July%202019%20FINAL.pdf
230. Sigma Engineering. (2021). Soc Trang 7 Offshore Wind Farm in the early August. Retrieved from, https://sigma.net.vn/en/renewable-energy/soc-trang-7-offshore-wind-farm-in-the-early-august.html
231. Socialist Republic of Vietnam. (2023). Approving the National Strategy for Climate Change Until 2050. Retrieved from, https://thuvienphapluat.vn/van-ban/EN/Tai-nguyen-Moi-truong/Decision-896-QD-TTg-2022-approving-the-National-strategy-for-climate-change-until-2050/525126/tieng-anh.aspx#google_vignette
232. 47% in the case of a "full and substantial implementation" of the JETP – Socialist Republic of Viet Nam. (2023). Resource Mobilisation Plan. Retrieved from, https://climate.ec.europa.eu/system/files/2023-12/RMP_Viet%20Nam_Eng_%28Final%20to%20publication%29.pdf

onshore generators, and power converters. The existing supply chain has been built by international suppliers like Hitachi, Schaeffler, Bosch and Bonfiglioli for products such as transformers, industrial bearings, and powertrain solutions for automobile and electric motors (respectively), which can be expanded to support the wind industry when necessary.

- **BOP - Strong local oil and gas industry with track record to support regional offshore wind development in APAC.** PTSC has a strong track record of supplying foundations for offshore wind farms and substations in Taiwan and Europe, including 33 jackets for the Greater Changhua project in Taiwan and structures for three offshore substations.[233] Vietnam can leverage its experience with jacket foundations, growing steel industry and skilled workforce to develop manufacturing capabilities for monopile foundations.

- **Shipbuilding (Offshore wind vessels) –** Vietnam has existing shipbuilding capabilities for offshore wind vessels, including heavy lift vessels for inter-tidal projects, CSOVs, tugboats, crew transfer vessels and potential cable laying vessels. These existing capabilities provide significant opportunities for Vietnam to become a key provider of offshore wind service vessels across the APAC region.

- **Ports –** With investment, Vietnam could build the capability of its ports to support the construction, fabrication, pre-assembly, installation, commissioning and ongoing operation and maintenance of foundations and towers. According to a report by Innovation Norway and the Norwegian Embassy in Hanoi, there are 13 ports in Vietnam which could support inter-regional socio-economic development, in addition to 21 ports which could support regional and local socio-economic development.[234] Existing studies provide the Vietnamese government and international companies with investment opportunities to develop Vietnam's ports to be suitable for offshore wind services. [2t35, 236] Industry consultations also indicated that Hyundai Vietnam Shipbuilding (HVS) is well-positioned to support floating offshore wind foundations for projects in the APAC region.

- **Copper (Subsea Cables) –** Vietnam's copper industry is well established and driven by consistent growth in the automotive and manufacturing sectors. However, Vietnam has limited domestic refining capacity for copper and most of the copper produced in Vietnam is exported to countries with larger refining capacities. By investing into refining facilities for copper, Vietnam could leverage the existing support of skilled subsea engineers from the oil and gas industry and existing cable manufacturing companies to transition to develop capabilities to supply subsea cables.

- **Steel –** Vietnam is the fifth largest producer of steel in the APAC region, following a period of significant growth. In recent years, Vietnam has focused on increasing its domestic production to reduce reliance on imports and meet its growing domestic demand. Foreign direct investments have supported the growth of Vietnam's steel producing capabilities.[237] As Vietnam's domestic steel production grows, it can service the demand of Vietnam's wind industry, supplying steel for towers and foundations.

- **Rare Earth Materials –** Vietnam has one of the largest rare-earth reserves, second only to China globally, but relatively low production capabilities. Vietnam is positioning itself well to play a key role in supplying rare earths to the APAC wind supply chain. According to a government plan, Vietnam aims to raise its rare earth extracting and processing capacity to two million tonnes per year by 2030 and 2.11 million

233. PTSC. (2024). Retrieved from, https://www.ptsc.com.vn/Data/Sites/1/media/brochure/TA_Brochure2024.pdf
234. Innovation Norway., Norwegian Embassy in Hanoi. (2023). Offshore wind supply chain for fast-track scenario in Vietnam. Retrieved from, https://www.norway.no/globalassets/2-world/vietnam/documents/034625-vietnam-supply-chain-study_eng.pdf
235. Danish Energy Agency., Royal Danish Embassy in Viet Nam., Electricity and Renewable Energy Authority. (2024). Mapping port infrastructure for the offshore wind industry and job creation in Viet Nam. Retrieved from, https://ens.dk/sites/ens.dk/files/Analyser/depp_vietnam_port_study_for_offshore_wind_final_report.pdf
236. Innovation Norway., Norwegian Embassy in Hanoi. (2023). Offshore wind supply chain for fast-track scenario in Vietnam. Retrieved from, https://www.norway.no/globalassets/2-world/vietnam/documents/034625-vietnam-supply-chain-study_eng.pdf
237. The Formosa Ha Tinh Steel Complex was primarily funded by Formosa Plastic Group of Taiwan and produces around 7 million tonnes of crude steel annually. In the draft Vietnam Steel Industry Development Strategy to 2030, the Ministry of Industry and Trade have set plans to develop green and energy saving steel products and increase the market share of domestically produced steel to gradually replace imported products – Vietnamplus. (2024). Vietnam targets developing green steel products. Retrieved from, https://en.vietnamplus.vn/vietnam-targets-developing-green-steel-products-post295941.vnp

tonnes by 2050[238] through extracting higher output from existing mines and developing three to four new mines after 2030. Additionally, Vietnam's trade minister signed an agreement with his South Korean counterpart to cooperate on the exploration and development of rare earths in Vietnam, promote investment, stabilise supply and manage the global supply chain.[239]

- **Casting –** Vietnam's casting industry features a growing number of factories, the majority of which are located the northern region. Vietnam has capabilities to produce a wide range of castings to support the automotive and aerospace industries and exports to key markets across Asia, Europe, and North America. The casting industry in Vietnam provides an opportunity for the region to diversify its supply chain for castings, in turn reducing the current concentration risk.

- **Technically skilled workers –** Vietnam has strong experience and engineering skills in onshore wind project development gained during the installation rush. Together with installation equipment such as cranes, it can use its knowhow to support wind turbine installations in southeast Asia markets. IPC Group is a leading EPC contractor for Vietnam's renewable energy projects and has recently won an EPC contract to construct and install wind turbines in the Philippines.[240] Additionally, Vietnam has a strong foundation of expertise, skilled engineering and technical training through its oil and gas industry.[241] These skills have already been leveraged to support the EPC of key wind components. There is an opportunity to further capitalise on the existing skilled workforce to support transition opportunities to the wind industry for engineers, installation support services, maintenance and inspection. Vietnam's has universities that support careers in the offshore wind industry, including Hanoi University of Science and Technology and Ho Chi Minh City University of Technology.[242] Vietnam's shipbuilding industry is backed by a high-level maritime education system, with four universities offering maritime related degrees and four maritime vocational colleges.[243]

Recommendations for wind supply chain scale-up in Vietnam

1. To provide long-term visibility to the wind industry and help investors to justify the upfront investment into the supply chain, the government could consider committing to a 10–15-year electricity procurement schedule aligned with its PDP8 wind targets supported by straightforward regulatory policies.

- The wind targets outlined in the PDP8 would be more attractive to industry if supported by a 10-15-year electricity procurement schedule as well as clarification on the seabed leasing processes, and implementation of a Marine Spatial Plan (MSP) .

- The legal and regulatory frameworks for offshore wind are still missing at present, so investors are reluctant to commit to investing in and expanding the domestic supply chain and infrastructure. The establishment of such legal frameworks could help accelerate the development of the domestic supply chain and attract new investments.

- To further boost investor confidence and to maximise supply chain development, the State Energy Steering Committee, established in 2023 could consider expanding its scope to include supply chain capacity building focusing on the key strengths outlined in the section above.

2. Vietnam already has a wide range of capabilities that could be expanded to meet the increasing demand from the wind industry, especially offshore wind. The government could consider focusing supply chain capacity building on companies with ability or potential to pivot their businesses toward increased supply of the wind components that are expected to be insufficient by 2030.

- Vietnamese businesses with established manufacturing,

238. Chinhphu. (2023). Home Decision No. 866/QD-TTg of the Prime Minister: Approving the Planning for exploration, exploitation, processing, and use of minerals for the period 2021 - 2030, with a vision to 2050. Retrieved from, https://vanban.chinhphu.vn/?pageid=27160&docid=208313
239. Willing, N. (2023). Vietnam becomes focus for new rare earths supply. Argus Media. Retrieved from, https://www.argusmedia.com/en/news-and-insights/latest-market-news/2406483-vietnam-becomes-focus-for-new-rare-earths-supply
240. Vietnam Investment Review. (2024). IPC E&C agrees deal to install wind-farm turbines in Philippines. Retrieved from, https://vir.com.vn/ipc-ec-agrees-deal-to-install-wind-farm-turbines-in-philippines-114356.html
241. VietNam News. (2024). Unprecedented opportunity for oil giants in offshore wind power. Retrieved from, https://vietnamnews.vn/economy/1663928/unprecedented- opportunity-for-oil-giants-in-offshore-wind-power.html
242. CIP (2023). Opportunities for an offshore wind career to support Vietnam's green energy transition. Retrieved from, https://offshorewindvietnam.com/wp-content/uploads/2023/11/01-110_11012023.pdf
243. SBIC. (2018). Vietnam Maritime Industry. Retrieved from, https://www.asef2015.com/asef-forum/pdf/NO18.%20SBIC%20Presentation%20on%20VIETNAM%20MARITIME%20INDUSTRY.pdf

shipbuilding and port operations in the north (i.e. around Hai Phong) and south of the country (i.e., the Ba Ria – Vung Tau region) could consider expanding capabilities.

- Vietnamese business and government could consider prioritising growth around existing capacity and capabilities related to onshore generators and power converters, onshore and offshore towers, jacket foundations, offshore substation foundations, offshore wind vessels such as CSOV, CTV and cable laying vessels.

- Vietnamese business and government could consider prioritising growth around new capacity and capabilities where existing businesses may have relevant skills related to monopile foundations, subsea cables, offshore generators, offshore power converter, onshore and offshore castings.

- Considering future bottlenecks across the APAC region (excluding China), Vietnam could take a larger role in blade manufacturing and onshore nacelle assembly. Offshore nacelle assembly could be a possibility post 2030 as our consultations indicate that an offshore wind pipeline will be required to justify the investment in a nacelle assembly facility.

- To support businesses that want to pivot into the supply of wind components, the government could encourage foreign collaborations that accelerate knowledge transfer, training and upscaling.

- Government could try to support businesses in reaching the international industry standards around HSE, ESG, engineering design codes and regulations such as the carbon border adjustment mechanism (CBAM) to unlock foreign investment and attract concession financing.

3. Government and industry could consider long-term planning on infrastructure upgrades, such as grid and ports, to support and enhance industry growth.

- Support grid infrastructure upgrades in line with the grid investment noted in PDP8 and ensure facilities in the north of Vietnam have reliable access to electricity.[244]

- Ports will serve as critical hubs for logistical support and transport facilitation, and it is anticipated that some ports in Vietnam require minimal investment to make them suitable for offshore wind storage, fabrication and construction. Investment into port improvements will provide a role for the local supply chain, unlock further capabilities to support offshore wind, increasing investment and confidence in the realisation of offshore wind projects, and reduce development costs.

- The government and industry could consider a national Port Upgrade Plan to identify ports with existing or transition potential to offshore wind services which could be financed with grant or multilateral financing (e.g., like the Philippines ADB financing of its offshore wind port feasibility study)[245], [246]

- Analysis of the cost of port upgrades could be necessary to provide the government with a business case to support decision making and targeted investment.

244. To support energy transmission, the Power Development Plan VIII (PDP8) estimates costs of $15 billion by 2030 and $38.6 billion by 2050. Foreign investment and private sector involvement will be necessary to support the development of transmission grids – Seungho, K. (2023). Vietnam embarks on green energy revolution with PDP8 blueprint. Retrieved from, https://vir.com.vn/vietnam-embarks-on-green-energy-revolution-with-pdp8-blueprint-104362.html#:~:text=PDP8%20estimates%20costs%20of%20%2415.0,by%202050%2C%20for%20this%20transmission

4. Government could support industry in accelerating export of critical materials to support regional demand for rare earths and enhance the growing capabilities of Vietnam's wind supply chain.

- To support domestic and regional demand for rare earths in the domestic and regional supply chain, government and industry could start planning sustainable expansion of the Dong Pao mine as well as the mines in the northern provinces of Lai Chau, Lao Cai and Yen Baiat which have been outlined as large rare earth reserves.[247] Government and industry could promote special economic zones for exporting the increased supply of rare earths across the APAC region to help meet regional demand.

- To support the development of subsea cable manufacturing critical for Vietnam's offshore wind supply chain, government and

245. Energy OMNI (2024). ADB Approves OSW Fund for Philippines to Conduct Feasibility Studies on Port. Retrieved from, https://www.energy-omni.com/en/news/article/947zy41SnBMnAGj6?page=23
246. Northern ports that could be prioritized include Hai Phong, Nam Dinh Vu, Nghi Son International Port, PTSC Dinh Vu, and Tan Vu. Southern ports that could be prioritized include Alpha EEC, Ba Son Shipyard, PTSC Phy My, PTSC Supply Base, PTSC Vung Tau Downstream Port, and PV Shipyard, SREC, Vinh Tan International.

industry could consider developing processing facilities for copper to meet the domestic demand for subsea cables in offshore wind, advancing the business case for a subsea cable manufacturer in the country, and export additional supply to support regional growth.

- To support the production of steel components necessary to meet the demand of Vietnam's wind industry, government and industry could leverage plans to develop Vietnam's domestic steel capabilities further production so that Vietnam can become self-sufficient in meeting the demand for steel in its developing renewable energy hubs. Government and industry could consider developing plate mills to produce steel plates with the optimal physical properties and product dimensions to support the domestic wind supply chain, as well as plate rolling technologies to manufacture towers and foundations for onshore wind and offshore wind.

247. Prime Minister of Vietnam. (2023). Decision No. 866/QD-TTg: Approval of the planning for exploration, mining, processing, and utilization of minerals for the period 2021 – 2030, with a vision to 2050

Seatrium's flagship Tuas Boulevard Yard in Singapore. Copyright: Seatrium Limited

Snapshot on Singapore

Even without a domestic wind market, Singaporean companies are already leveraging existing capabilities in marine and offshore energy to support offshore wind projects globally. Companies that traditionally served offshore oil and gas are pivoting towards offshore wind where they can use their long-standing experience in offshore infrastructure and operations under severe conditions that mirror those of offshore wind. Enterprise Singapore, the Singapore government agency championing offshore wind, estimates that more than 30 Singapore companies are supporting offshore wind projects in the US, UK and Taiwan through the fabrication or leasing of vessels, offshore structures such as offshore substations, WTIVs, construction support vessels and service vessels.

The vessel bottlenecks highlighted in the earlier chapters are on the radar of Singaporean firms Seatrium and Cyan Renewables. Seatrium has supplied 3 WTIV projects so far,[248] a Jones Act-compliant WTIV constructed at Seatrium's Texas Shipyard,[249] and multiple fixed offshore substations including the HVDC converter station for RWE's Sofia Offshore Wind Farm[250] and HVAC substation for Orsted's Hornsea 2 Offshore Wind Farm.

Cyan Renewables, Asia's first pure-play offshore wind vessel owner-operator, offers a fleet of more than 30 vessels that can support the end-to-end vessel needs of wind farm developers and turbine OEMs across the value chain. Cyan also formulated a model of raising private equity financing rounds to finance the construction of offshore wind vessels in an approach similar to project financing. This innovative business model is a prime example of how Singapore companies are blending their marine and offshore engineering skills with financing capabilities to address global supply chain and financing gaps for offshore wind vessels. Besides vessels, Cyan is raising financing for key offshore wind infrastructure such as offshore substations.

Looking forward, as APAC moves towards floating offshore wind installation in the late 2030s, Singapore companies such as Seatrium and Mooreast are positioning themselves to provide floating foundations and other services in floating offshore wind. Singapore's strengths in offshore wind vessels, platforms and foundations suggest that Singapore companies are serious in playing an active role in the regional offshore wind industry.

248. Seatrium. (2024). Retrieved from, https://www.seatrium.com/investor-day-2024/presentations/Seatrium-Investor-Day-2024-Presentation_Offshore.Wind_Samuel.Wong.pdf
249. Buljan, A. (2024). Dominian Energy Launches First US Offshore Wind Turbine Installation Vessel. OffshoreWind.biz. Retrieved from, https://www.offshorewind.biz/2024/04/16/watch-dominion-energy-launches-first-us-offshore-wind-turbine-installation-vessel/
250. Seatrium. (2024). Retrieved from, https://www.linkedin.com/posts/seatrium_offshorewind-hvdc-ocp-activity-7235161791486443520-hDMw/

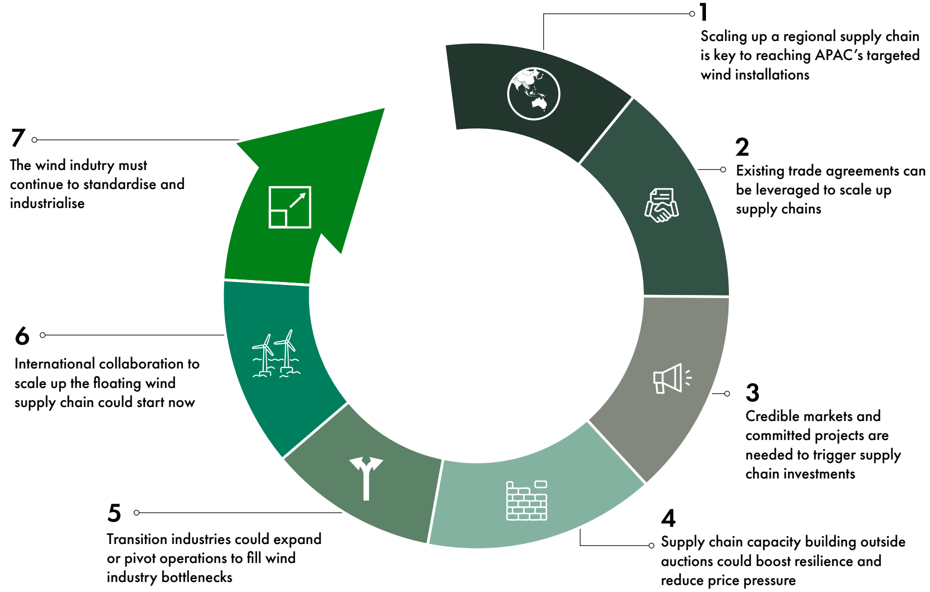
CHAPTER 4: RECOMMENDATIONS TO SECURE APAC'S WIND SUPPLY CHAIN

To achieve COP 28's goal of tripling renewables by 2030, the pace and deployment of wind energy must accelerate. Global wind growth must rapidly accelerate to meet 2030 targets and GWEC expects 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.[251] The APAC region has the potential to play a significant role in the energy transition both for new wind capability and by filling supply chain gaps that threaten to slow down the industry.

APAC does not only have the greatest new and total installed wind potential but is also the world's largest wind manufacturing hub. As the clarion call for tripling renewables capacity across the world is getting louder, this is an opportune time for businesses and governments to consider scaling up their wind energy capacities and upskilling the capabilities identified in each of the country case studies, including pivoting transition industries towards the wind supply chain.

This report has demonstrated the depth and breadth of existing capabilities held by APAC businesses across most supply categories – from wind turbine components to offshore wind vessels, foundations, and even critical minerals. The analysis revealed that APAC companies hold a wealth of expertise with the potential to transition certain operations to the wind supply chain and often decarbonise their businesses in parallel e.g., offshore O&G, shipbuilding, mining, and automotive. To meet the growing demand, APAC governments and industry across wind markets could consider targeted regional collaboration, building on the strengths of each market to build a secure regional supply chain with healthy, managed competition. Seven key recommendations for action are explored below.

Seven recommended actions for building a resilient regional supply chain



Recommendation 1: Regional supply chain scale-up is needed urgently if APAC is to meet 2030 targeted wind installations.

The APAC region possesses some of the most attractive wind resources globally. Harnessing this potential could transform the region's economy while offering the scale the world needs to triple renewable energy by 2030. To realise these projects, APAC needs urgent action from government and industry to develop strategies and make necessary investments in a regional onshore and offshore wind supply chain that is resilient, competitive, and able to meet this decade's increasing demand for new wind capacity.

Supply chain is fundamental to unlocking this untapped renewable energy potential and countries could consider collaboration across borders to leverage the industrial strengths of each market, ensuring regional wind installations can be met using the best of the regional supply. This type of regional supply chain scaling of existing or pivot industries could bring greater economic return for the entire region from working together to build out a larger volume of projects.

To facilitate a regional approach, APAC markets could consider relaxing local content requirements and trade barriers to encourage competition in the supply chain

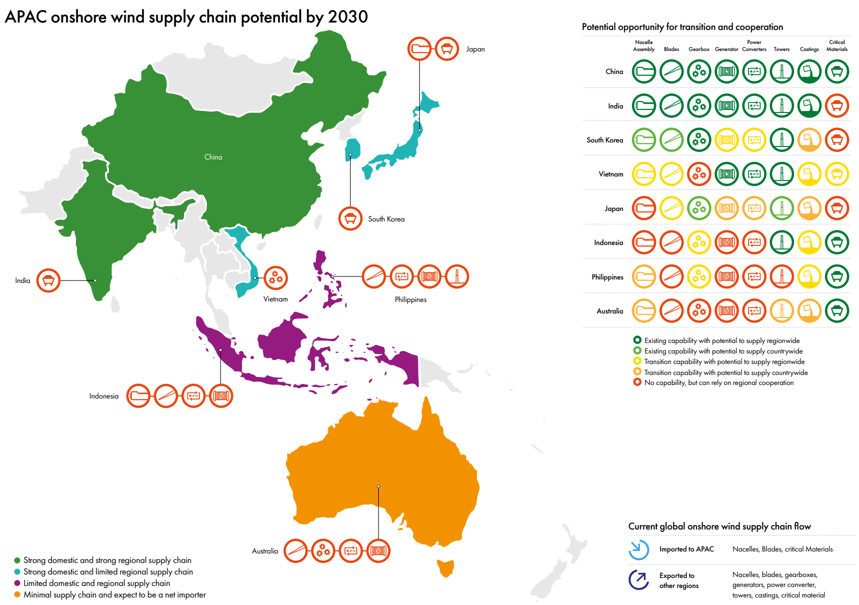
251. GWEC, Global Wind Report, 2024.

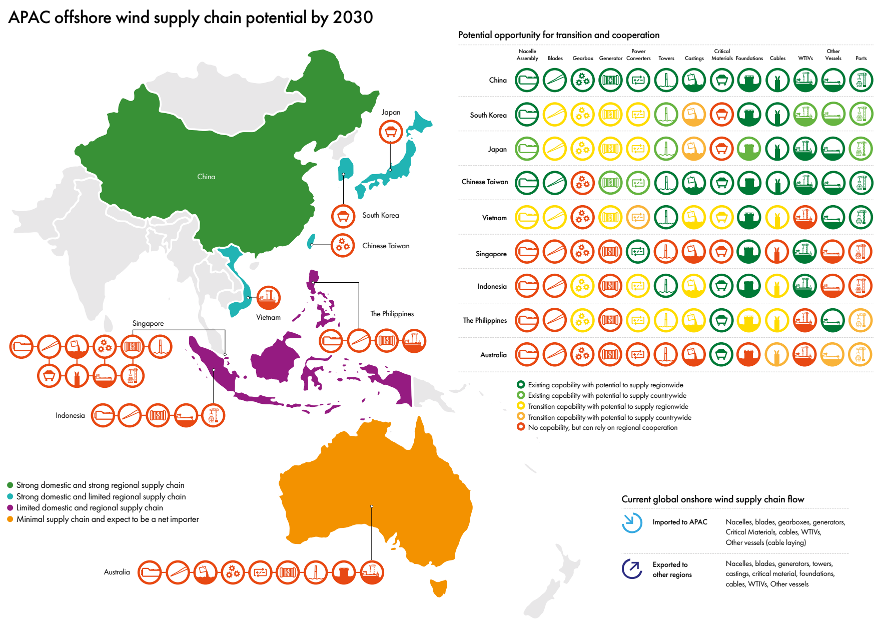
which will lower costs and diversify the regional supply chain in a way that strategically builds on each market's industrial strengths. Localisation policies could instead focus on the strengths of the local industries within the broader region, aiming to achieve a balance between local job creation, supply chain, and cost efficiencies.

There is a concentration of key component supply in China and India; however, there are opportunities to diversify the supplier base using existing and transition capabilities as flagged in the maps below. A coordinated, regional approach to wind turbine installation vessels with relaxed cabotage rules could improve resource utilisation (also coordinating between northern and southern hemisphere projects) and justify investments in APAC-designed vessels (e.g., designs that consider geographic conditions such as seismic activity). Regional workforce strategies could include knowledge transfer through collaboration between universities, overseas job exchanges, and training centres. Offering a regional demand for critical materials could justify opening new mining licenses and a more diversified supply. Regional demand could also trigger investment in large infrastructure projects such as ports which could supply cross-border clusters and be designed to offer multi-port and co-location arrangements to optimise the offshore wind supply chain.

Recommendation 2: Existing trade agreements can be leveraged to scale up supply chains.

Trade policy should aim to build competitive industries, not push higher costs onto end-users. Policy measures which unnecessarily restrict trade and foreign investment could lead to a slowdown in deployment that will put the energy transition in jeopardy. Supply chain capacity utilisation remains key to cost reduction and is only possible if resources can be shared across





regions, with competitive cost positions and limited trade barriers.

To ensure supply chain security and mitigate the risk of concentration, countries will need to pursue supply diversification strategies, reshore / onshore some segments and grow their own local industries and personnel to create social economic benefits. But this should not manifest in measures that outright block current trade flows and interrupt or delay deployment.

Select APAC Multilateral Agreements

Agreement[252]	Australia	China	India	Indonesia	Japan	Philippines	Singapore	South Korea	Vietnam
ASEAN				●		●	●		●
ASEAN – Australia & New Zealand FTA	●			●	●	●	●		●
ASEAN – Japan Comprehensive Economic Partnership				●	●	●	●		●
ASEAN – Korea FTA		●		●		●	●	●	●
ASEAN – China FTA			●	●		●	●		●
ASEAN – India FTA	●	●		●	●	●	●	●	●
Regional Comprehensive Economic Partnership	●				●		●		●
Indo-Pacific Economic Framework	●		●	●	●	●	●	●	●

There are at least six existing regional or free trade agreements (FTA) which APAC governments could leverage to build a trade environment that encourages regional collaboration and supply chain investment while increasing economic benefits for individual markets. The Association of Southeast Asian Nations (ASEAN) is a leading organisation in the region and its FTAs allow members to access larger markets where they can contribute to wider regional supply chains and generate trade, investments and jobs for their domestic markets.

252. Note that this is not a comprehensive list of member-countries participating in the listed regional arrangements but rather is only focused on the six target countries of this report plus China, India, and Singapore.

Apart from India, the Regional Comprehensive Economic Partnership (RCEP) integrates various FTAs that ASEAN has with most APAC wind markets. RCEP could serve as the framework for a regional wind energy supply chain as the simplified rules of origin allow for cross-sharing of resources within the RCEP trading bloc, reducing barriers to cross-border collaborations.

By supporting each APAC wind market in enhancing its capacity to deliver at scale; ensuring flexible access to needed materials, components, and services; and complementing the supply chain strengths of each country will benefit a dependable and scaled up regional supply chain able to serve the full APAC region.

Recommendation 3: Credible markets and committed pipelines are needed to trigger supply chain investments.

Industry needs market certainty to invest. This comes from increased project awards and project volume predictability (i.e., continuous auction schedules with 15-year timelines). Clear regulatory roadmaps for leasing and offtake processes will drive investor confidence in the realisation of projects – as will governments addressing basic barriers to wind industry growth in terms of land, grids and permitting which also serve to increase volume and predictability.

Although governments will change, policy continuity will be critical in unlocking supply chain investments that look out to 15 years for returns. Governments could consider tying their wind energy targets to national energy plans and nationally determined contributions (NDCs) under the UN Framework Convention on Climate Change (UNFCCC). As countries are legally obligated to submit their NDCs, this will provide additional investor certainty and market confidence.

To justify supply chain investments, credible markets and committed projects will help make business cases work, attracting Tier 1, 2 and 3 suppliers to enter the wind supply chain.

Recommendation 4: Public support for supply chain capacity

building outside of auctions could boost resilience and sustainability while reducing price pressure on developers, especially for near term projects.
Governments may want to consider taking a longer-term view on supporting supply chain capacity building outside auction evaluation criteria to reduce price pressure during auctions. This could also increase initiatives aimed at building more sustainable supply chains which is becoming more salient to responsible procurement. Longer-term coordination across stakeholders and markets that drives systemic change is needed to achieve sustainability targets across the supply chain. Governments could consider non-price criteria for auctions that are transparent, viable, practical and reflective of existing capabilities without specific supply chain requirements. This will encourage growth and scale-up before adding price pressures that minimise return on investment, discouragingtransition and foreign companies from entering the market. Alternative criteria could focus on the environmental sustainability requirements to be integrated into the wider supply chain.

APAC markets could explore a joint regional pathway that will help optimise investment needs across countries. Indonesia, the Philippines and Vietnam may consider securing concessional financing from multilateral development banks to mobilise capital and investments into the supply chain, given that these three countries are eligible.

Recommendation 5: Transition industries could be encouraged to expand or pivot operations to fill wind industry supply chain bottlenecks.

The APAC region already has a vast skillset which can be scaled or pivoted to meet the increased regional demand for wind installations. For related industries that are scaling down, this may offer an opportunity to repurpose workforces, facilities, and assets to upskill for the wind supply chain. Key transition industries identified in this study include shipbuilding (installation vessels and floating foundations), offshore oil and gas/ EPCs, electronics (generators, power converters, transformers, and control panel), composite (blades), automotive (gearboxes and castings), as well as manufacturing workforces (nacelle assembly). Further transition industries are expected as projects move towards operations (service vessels) and as floating wind projects are built (moorings).

Markets should make their wind project pipelines and market dynamics appealing to both transition and foreign suppliers and OEMs to ensure steady inflow of components – as there is a race for market attractiveness. APAC markets could create an environment that encourages mutually beneficial knowledge sharing between existing APAC companies and foreign companies where experience and expertise can be shared (e.g. experiences by CS Wind in Vietnam or Seatrium in Indonesia).

Recommendation 6: International collaboration to scale up the floating wind supply chain could start now.

Floating wind will start to dominate certain APAC markets as it continues its path towards commercialisation, requiring its own supply chain to be ready. Building on the regional supply chain proposed in recommendation 1, a collaborative approach could be used now to build a floating wind supply chain ready to meet the expected growth within and outside the APAC region.

This can include early planning with governments and learning from experiences from overseas. Governments could start looking at support schemes which will fit with the market fundamentals in the individual APAC floating markets to unlock the region's huge floating wind potential. This can include support schemes and early planning with governments to leverage learnings from experiences from overseas such as the UK and alignment between countries like Japan and Korea which are currently running parallel tracks to grow their floating industries. These specialised support schemes could include relatively higher PPA prices (compared with fixed-bottom offshore wind) set to derisk floating wind investments and ensure commercial returns while including qualitative criteria in the auction to encourage investment in this emerging technology.

All the six target markets studied in this report have technical potential for floating wind and many APAC businesses have the potential to transition to support the floating wind supply chain – with the right support and market demand in place.

Recommendation 7: The wind industry must continue to standardise and industrialise.

Greater alignment on industry standards (e.g., health and safety, ESG, engineering design codes and environmental sustainability) between APAC countries could improve efficiencies and enhance regional and global collaborations.

Governments could explore adopting international best practices on industry standards as financing will have minimum requirements that need to be observed. Consideration for environmental sustainability may be worked into auction criteria, as

needed. APAC may want to ensure regional supply chains meet those requirements so that eligible companies can access this financing. Suppliers looking to meet financing requirements to upscale manufacturing or set up new bases will need to increase transparency and traceability to ensure oversight of the complete process, from raw material procurement to final product delivery. Moreover, international developers require subcontractors to work to globally recognised standards to attract financing.

Countries, particularly those with critical materials, could consider strengthening ESG principles to ensure that operations benefit host communities without undue environmental damage. For example, implementation of safeguards around land use, environmental and social impact assessments, and free, prior and informed consent.

Once the region is better connected with increased imports/exports, there may be a need to consider establishing green corridors (e.g. shipping fuelled by ammonia) to transport critical elements and manufactured goods achieving improved sustainability of steel production, mining of critical elements, etc. This can also provide a strategic avenue for APAC wind supply chain manufacturers to access global export markets and benefit from regulations such as carbon tax exclusions under the carbon border adjustment mechanism (CBAM).

The wind sector must industrialise with designs becoming standardised, global and modular, based on a massified and highly specialised global industry producing necessary components. The industry is already capable of supporting different wind turbine base models, optimised for market needs, but going forward these models could be designed in a more modular and scalable manner. This will allow the industry to achieve economies of scale and make the supply chain financially sustainable.

The race for larger turbines has left insufficient time for thorough testing, resulting in serial defects in the field. Development costs have not been recuperated due to shortened product life cycles. Rapid innovation at the component and system level has not allowed for industrialisation of existing technologies.

APPENDIX

Definitions and Terminology

Definitions
Asia Pacific Region includes East Asia, Central Asia, South Asia, Southeast Asia, and Oceania

Target markets - The target markets or target countries in this report include Australia, Indonesia, Japan, Philippines, South Korea, and Vietnam.

Transition industries – These include companies not currently supporting the wind industry that run operations with the potential to be pivoted toward a part of the wind supply chain.

Acronyms

AAPowerLink	Australia-Asia Power Link
ADB	Asian Development Bank
APAC	East Asia, Central Asia, South Asia, Southeast Asia, and Oceania
ASEAN	Association of Southeast Asian Nations
BOP	Balance of plant
CAPEX	Capital Expenditure
CBAM	Carbon border adjustment mechanism
CfD	Contract for Difference
COD	Commercial operations date
COP	Conference of the Parties
CLV	Cable Laying Vessel
CTV	Crew Transfer Vessel
DD	Direct drive
DEVEX	Development Expenditure
DFIG	Doubly fed induction generators
DMSSP	Defence Maritime Support Services Program
DOE	Department of Energy (Philippines)
DPR	People's Representative Council (Indonesia)
DTI	Department of Trade and Industry (Philippines)
EESG	Electrically excited synchronous generator
EEZ	Exclusive economic zone
EPC	Engineering, Procurement, Construction
ERC	Energy Regulatory Commission (Philippines)
ESDM	Ministry of Energy and Mineral Resources (Indonesia)
ESG	Environmental, Social, and Corporate Governance
ESMAP	Energy Sector Management Assistance Program
EV	Electric vehicle
EVN	Vietnam Electricity
EU	European Union
EVOSS	Energy Virtual One-Stop Shop
FID	Financial Investment Decision
FIP	Feed-in-premium
FIT	Feed-in-tariff
FMIA	Future Made in Australia Act
FSA	Financial Services Agency (Japan)
FTA	Free trade agreement
GEAP	Green Energy Auction Program
GEAR	Green Energy Auction Reserve
GW	Gigawatt
GWEC	Global Wind Energy Council
HD KSOE	HD Korea Shipbuilding & Offshore Engineering
HSSE	Health, Safety, Security, and Environment
HVDC	High-voltage direct current
IEA	International Energy Agency
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency
JETP	Just Energy Transition Partnership
JPY	Japanese Yen
JV	Joint venture
KPS	Kenertec Power Systems
KRW	South Korean Won
kWh	Kilowatt Hour
LCOE	Levelized Cost of Energy
LCR	Local content requirements
M&I	Marshalling & integration
METI	Ministry of Economy, Trade, and Industry (Japan)
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)
MOIT	Ministry of Industry and Trade (Vietnam)
MOTIE	Ministry of Trade, Industry, and Energy (South Korea)
MSP	Marine Spatial Planning
MSPMG	Medium speed permanent magnets generators
MW	Megawatt
MWh	Megawatt Hour
NCCS	National Climate Change Strategy
NDCs	Nationally Determined Contributions
NEDO	New Energy and Industrial Technology Development Organization (Japan)
NPC	Non-price criteria
NRESCAP	National Renewable Energy Supply Chain Action Plan
O&G	Oil and Gas
O&M	Operations and Maintenance
OFW	Offshore Wind
OEMs	Original Equipment Manufacturers
ONW	Onshore Wind
OPEX	Operational Expenditure
OWF	Offshore wind farm
PEP	Philippine Energy Plan
PDP8	Power Development Plan 8
PLN	PT Perusahaan Listrik Negara (Indonesia)
PPA	Power Purchase Agreement
PTSC	PetroVietnam Technical Services Corporation
PVN	PetroVietnam
R&D	Research and Development
RCEP	Regional Comprehensive Economic Partnership
REC	Renewable energy certificate
REE	Rare earth elements
REPMs	Rare earth permanent magnets
RESCH	Renewable Energy Supply Chain Hub
RNA	Rotor nacelle assembly
ROI	Return on investment
RPS	Renewable energy portfolio standards
SCIG	Squirrel-cage induction generators
WTG	Wind Turbine Generator
WTIVs	Wind Turbine Installation Vessels
WTO	World Trade Organisation
UNFCC	United Nations Framework Convention on Climate Change
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About GWEC
Global Wind Energy Council (GWEC) is the industry association representing the global wind industry sector. GWEC articulates the vision for wind energy to major world bodies, including the International Energy Agency, the International Renewable Energy Agency, the UNFCCC, and other bodies, as well as governments which are responsible for strategies, targets, and implementation thereof in electricity generation and supply. GWEC works together with the leading representative industry associations as well as the global wind energy industry to build a platform which communicates a common vision to all leading global decision-makers, policymakers, and key opinion leaders.
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