OFFSHORE WIND ROADMAP FOR THE M&OE SECTOR IN SINGAPORE

ASMI
ASSOCIATION OF SINGAPORE MARINE INDUSTRIES

GWEC
GLOBAL WIND ENERGY COUNCIL

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About GWEC

GWEC is a member-based organisation that represents the entire wind energy sector. The members of GWEC represent over 1,500 companies, organisations and institutions in more than 80 countries, including manufacturers, developers, component suppliers, research institutes, national wind and renewables associations, electricity providers, finance and insurance companies.

Our members are also all of the national wind industry trade associations, from both established and emerging markets, including the world largest markets of the United States, all the European markets, India and China and the South East Asia and East Asia region.

GWEC works at the highest international political level to create a better policy environment for wind power. GWEC and its members are active all over the world, educating local and national governments and international agencies about the benefits of wind power.

Working with the UNFCCC, REN21, the IEA, international financial institutions, the IPCC and the International Renewable Energy Agency (IRENA), GWEC represents the global wind industry to show how far we've come, but also to advocate new policies to help wind power reach its full potential in as wide a variety of markets as possible.

@GlobalWindEnergyCouncil

@GWECGlobalWind

About ASMI

The Association of Singapore Marine Industries (ASMI) is a non-profit trade organisation formed in 1968 to promote the interests and advancement of the marine and offshore engineering industry in Singapore.

ASMI represents companies in the business of ship repair, ship conversion, shipbuilding, rig building and offshore engineering. Its membership comprises shipyards, manufacturers and suppliers of marine & offshore equipment and components. ASMI members also include marine & offshore engineering companies, marine consultants, and contractors as well as classification societies.

The Association has a membership strength of over 250 corporate members. ASMI key roles include enhancing the knowledge and skills of the industry's workforce, promoting the collective interests of the marine and offshore engineering industry, and linking up and integrating the marine and offshore engineering industry.

@AssociationofSingapore MarineIndustries

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Foreword

As early as 1991, offshore wind took its first steps and has been growing in scale ever since, and especially in the recent years, we saw its accelerated growth. The global offshore market grew on average by 22% each year in the past decade, bringing total installations to 35.3 GW, which accounted for 5% of total global wind capacity as of the end of 2020. In terms of investment, that figure is much higher, and the current labour market is starting to reflect this.

Offshore wind has matured and is now gaining traction all around the world, with significant opportunities in Asia Pacific (APAC). Given the enormous technical potential of up to 1,500 GW across APAC, and with ambitious targets such as those China, Japan and South Korea have announced, the fundamentals provide a glimpse at how the entire region will move towards a lower carbon future with offshore wind. By the end of 2020, the cumulative installation in Asia passed the milestone of 10 GW, making it the second largest regional offshore wind market.

In 2018, Singapore launched the Marine and Offshore Engineering (M&OE) Industry Transformation Roadmap, with offshore wind identified as a pillar of growth where supply chain development and diversification are now being looked into.

As the supply chain develops and businesses get awarded more offshore wind projects, the variety of career opportunities in the sector for Singapore also widens.

To support the expanding sector, it is useful to consider the roles that are of high interest for Singapore's M&OE companies and where their unique value proposition sits in the offshore wind supply chain.

The Global Wind Energy Council (GWEC) has a deep understanding of the global wind industry and we are therefore pleased to be working with the Association of Singapore Marine Industries (ASMI), Enterprise Singapore (ESG) and Singapore Economic Development Board (EDB) to provide an insight into the potential future landscape of Singapore's jobs market within offshore wind.

The global offshore market grew on average by 22% each year in the past decade, bringing total installations to 35.3 GW, which accounted for 5% of total global wind capacity as of the end of 2020.

HIGH-LEVEL OVERVIEW OF OFFSHORE WIND INDUSTRY

Views on the Global Situation, Market Sizes, Key Technology Trends

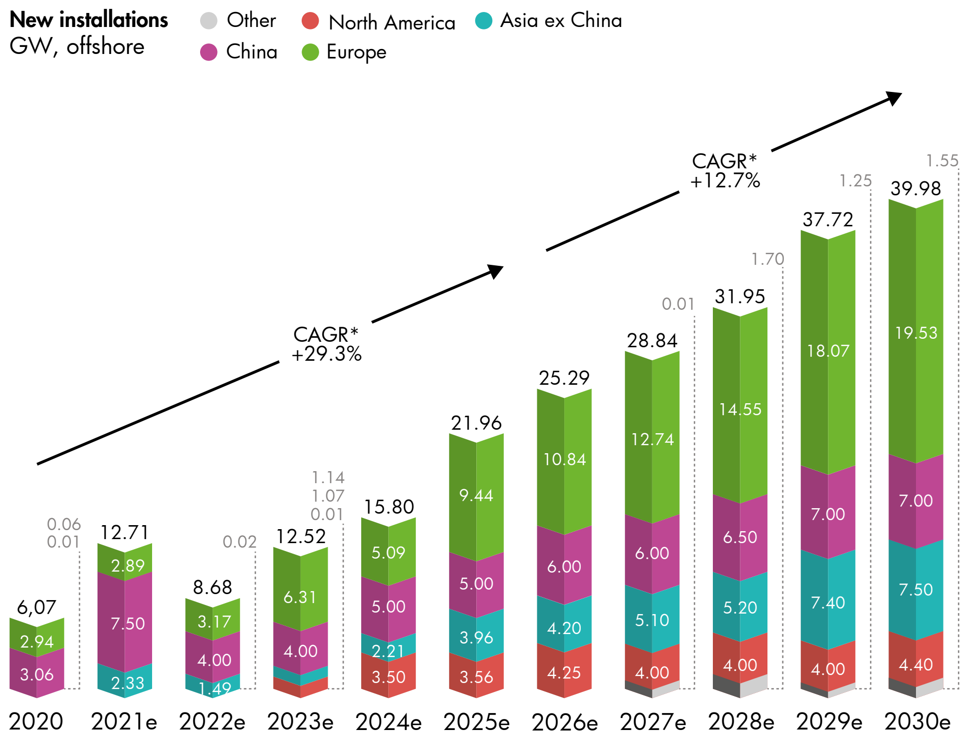
Global Situation
Almost thirty years have passed since the world's first offshore wind farm, Vindeby (5MW), was built in Denmark. Since then, offshore wind has made its name as one of the fastest-growing industries. Originally spurred by policy support and financial incentives, today, the levelized cost of energy (LCOE) of offshore wind is on track to further drop by 2030 allowing head-to-head competition with fossil fuel-based energy.

Despite the impact of COVID-19, the global offshore wind industry had its second-best year ever in 2020 with an average growth of 22% - from 2.2 GW in 2016 to 6.1 GW in 2020 - bringing total installations to 35.3 GW, accounting for 5% of total global wind capacity.

The market outlook to 2030 has become even more promising with an average annual growth rate of nearly 30% until 2025 and 12.7% up to 2030, the global new installations are expected to sail past the milestones of 20 GW in 2025 and potentially 40GW by the end of the decade. GWEC Market Intelligence expects that over 235 GW of new offshore wind capacity will be added between 2020-2030, bringing total offshore wind capacity to 270 GW by 2030. The annual offshore wind installation volume is expected to more than triple, from 6.1 GW in 2020 to 23.1 GW in 2025, bringing its share of global new installations from today's 6.55 to 20% by 2025.

Europe continues to retain its status as the largest regional offshore wind market as of the end of 2020, but new installations outside Europe, predominantly in Asia, already surpassed Europe in 2020 for the first time - with a cumulative installation of 10 GW by the end of 2020, making it the second largest regional offshore market.

Figure 1: New offshore wind installation: Global offshore wind growth to 2030



* CAGR = Compound Annual Growth Rate

Source: GWEC Market Intelligence, July 2021

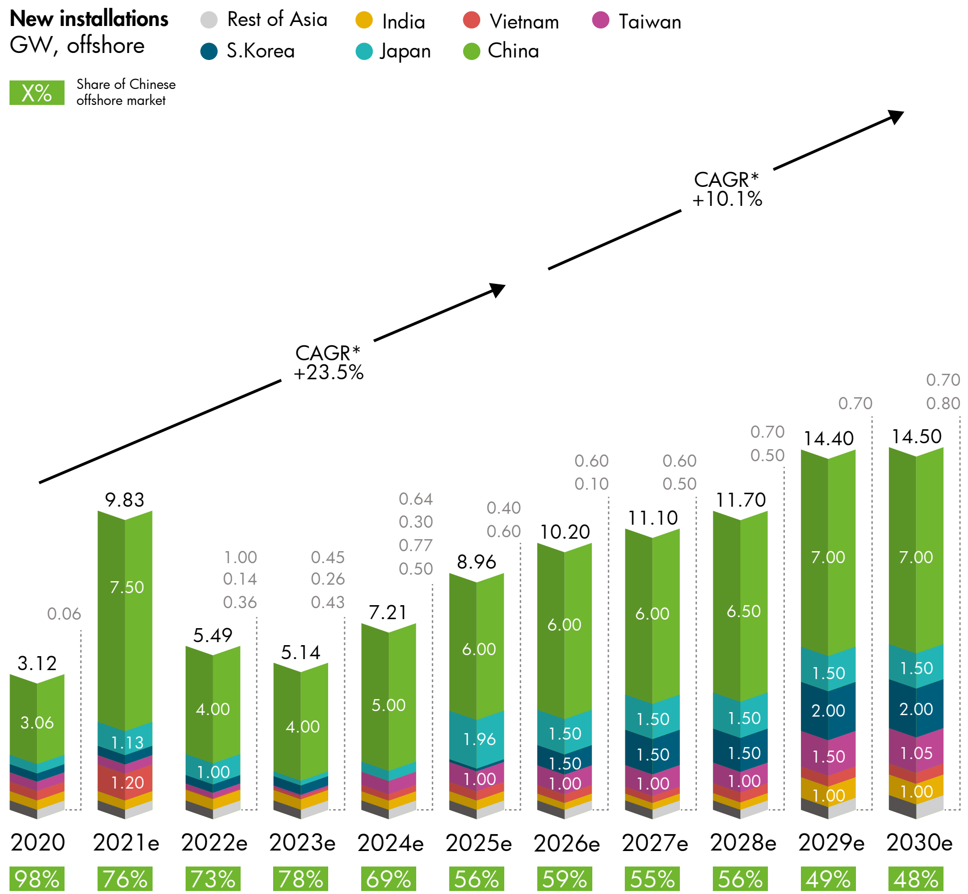
Asia Pacific Market Size
Power demand is set to grow by 50% through 2050, and APAC will contribute nearly 2/3 of the growth. This region will become the next frontier for offshore wind developments, reaching over 150 GW installed capacity and a nearly US$210 billion investment opportunity through 2030.[1]

China is expected to continue its domination of the Asian offshore wind market in the first half of this decade, with more than 70% market share (52GW). Taiwan is expected to be after China in the new installation in the same period (10.5GW) followed by South Korea (7.9GW), Japan (7.4GW) and Vietnam (5.2GW).

However, the market will become more diversified from 2025 onward, when large-scale offshore wind projects are set to be commissioned in Japan, South Korea and Vietnam. GWEC Market Intelligence forecasts that China's market share in this region is likely to drop from 76% in 2021 to 56% in 2026. This decline is expected to continue, to reach 48% by the end of this decade with new installations from emerging markets like India and the Philippines.

> China is expected to continue its domination of the Asian offshore wind market in the first half of this decade, with more than 70% market share (52GW)

Figure 2: Global offshore wind growth to 2030 in Asia



* CAGR = Compound Annual Growth Rate

Source: GWEC Market Intelligence, July 2021

1. Wood Mackenzie Asia Pacific power & renewables market outlook: H1 2020

Key Technology Enhancements

As offshore wind project size and numbers continue to expand, technology innovation in the coming decades shall bring the highest overall potential impact for the uptake of offshore wind.

1. Future generation turbines

As development in the blade, drivetrain and control technologies continue, the larger, more reliable turbines with higher capacity ratings would drive a lower LCOE.

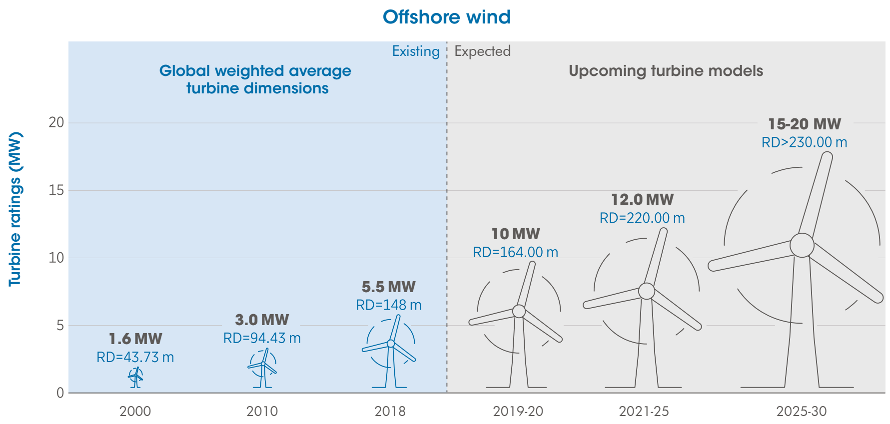
2. Floating Offshore

Over 80% of all offshore resources are located in deep waters that require floating foundations, making this technology development critical for access to better wind resources.

3. Power-to-X

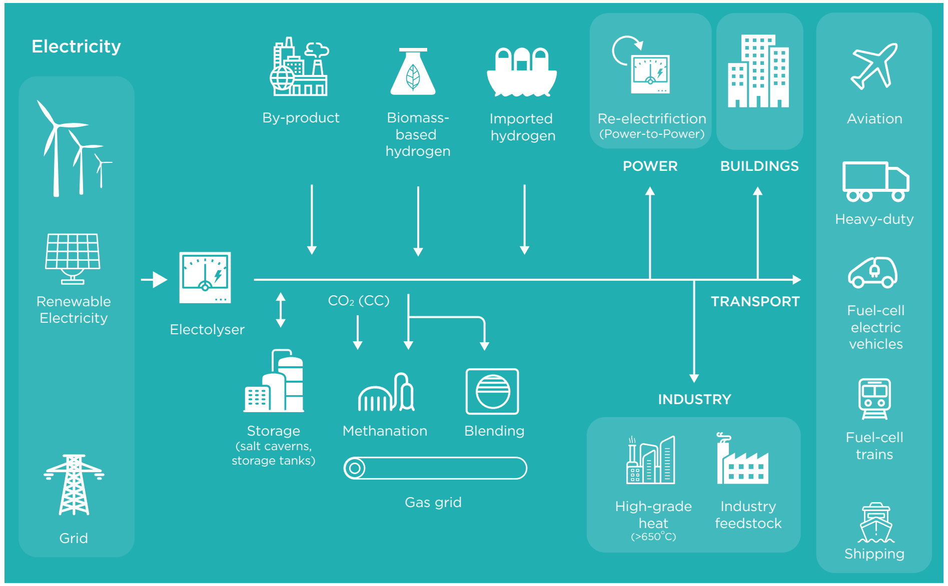
Increases the level of flexibility of offshore wind resources that minimises curtailment and widens the applicability to support decarbonisation of other sectors like industry, buildings and transport.

Figure 3: The average size of offshore wind turbine grew by a factor of 3.4 in less than two decades and is expected to grow to output capacity of 15-20 MW by 2030



Source: GE Renewable Energy, 2018; IRENA, 2019c, 2016b; MHI Vestas, 2018.

Figure 4: Power-to-X: Integration of renewable energy into end-uses



Power-to-X and Renewable Hydrogen

Power-to-X allows the conversion of surplus renewable energy into liquid or gaseous chemical energy sources through electrolysis and further synthesis processes. One such example is offshore wind-to-hydrogen whereby stored electricity can be used for water splitting into hydrogen to be used as chemical feedstocks for other industrial processes. This will increase the level of flexibility of offshore wind resources, minimise curtailment and widen its application to support decarbonisation of other sectors.

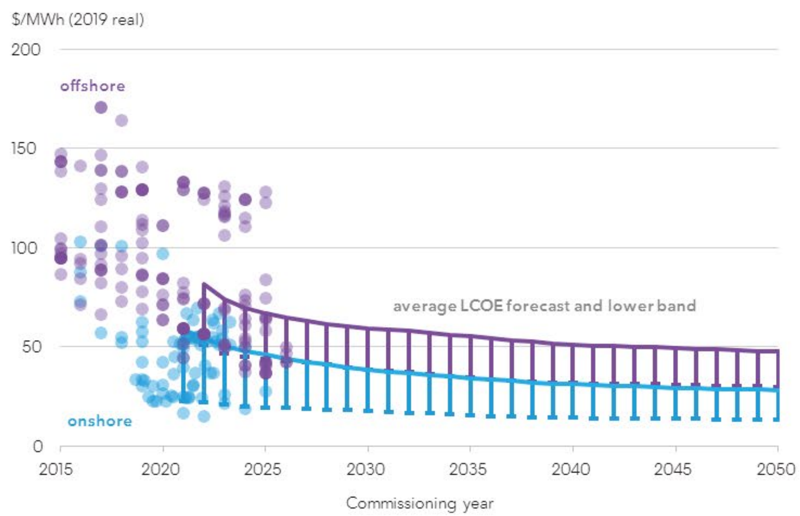
Increase the level of flexibility of offshore wind resources, minimise curtailment and widen its application to support decarbonisation of other sectors.

Technology advancement has the highest potential impact on the reduction of LCOE across the entire offshore wind supply chain of project planning; fabrication; installation; operations and maintenance (O&M) to decommissioning, which is also highly dependent on other successes in the expansion of offshore wind into emerging markets, higher climate ambitions, and more.

According to the BNEF Q2 Global Wind Market Outlook, offshore wind prices have fallen rapidly and are closing in on the onshore prices. According to BNEF, the levelised cost of electricity from various energy sources, both onshore and offshore wind average mid-case LCOE will continue to decrease from US$37-$103/MWh in 2021 to US$16-$49/MWh in 2050 while the average mid-case LCOE of coal is expected to increase from US$93/MWh to $112/MWh. Offshore wind prices have fallen rapidly and are closing in on the onshore prices.

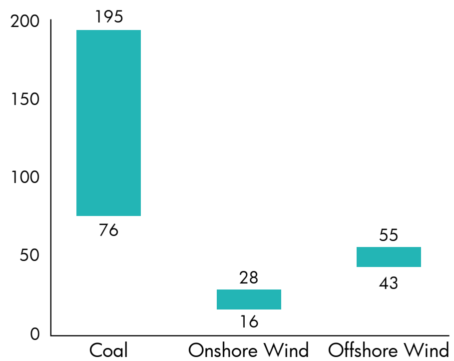
For the past 20 years, the offshore wind industry has grown significantly, and it is expected to continue. Given the developments and the vast potential of offshore wind in APAC, the existing marine and offshore capabilities of Singapore has a lot to offer the burgeoning offshore wind industry in Southeast and North Asia.

Figure 5: Comparing levelized prices and LCOE forecasts



Source: BloombergNEF. Note: Levelized prices taken from 2Q Global Wind Market Outlook (https://www.bnef.com/insights/23353 | https://blinks.bloomberg.com/news/stories/QBSY61T0AFB7) where each dot is a project or auction-level price. Average LCOE is of mid-cases, lower limit is the lowest country LCOE in a given year.

Figure 6: Levelised cost of electricity for different technology by 2050 (USD)



Source: BNEF (2020)

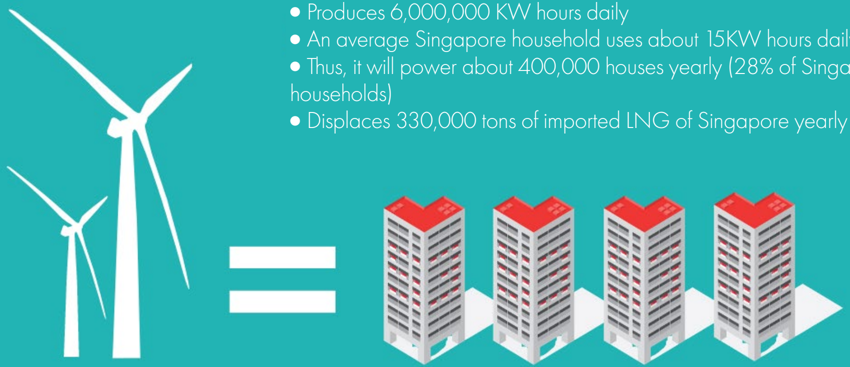
Offshore Wind Scale vs Singapore

To provide an analogy, a Taiwanese offshore wind farm with an installed capacity of 500 MW will produce 219 GWh/year, enough to power nearly 400,000 Singapore homes and meet 28% of the country's total residential electricity demand. It would displace 330,000 metric tonnes of Liquified Natural Gas (LNG) annually.

Figure 7: 500 MW offshore wind farm can produce 219 GWh/year to power 400,000 Singapore households yearly.

For a 500 MW offshore wind farm:

- Produces 6,000,000 KW hours daily
- An average Singapore household uses about 15KW hours daily
- Thus, it will power about 400,000 houses yearly (28% of Singapore households)
- Displaces 330,000 tons of imported LNG of Singapore yearly



Assuming a 5MW turbine, powers roughly 4 blocks of HDB flats (that has an average of 108 units)

Source: GWEC Market Intelligence

Status of Key Offshore Wind Markets in Asia

China

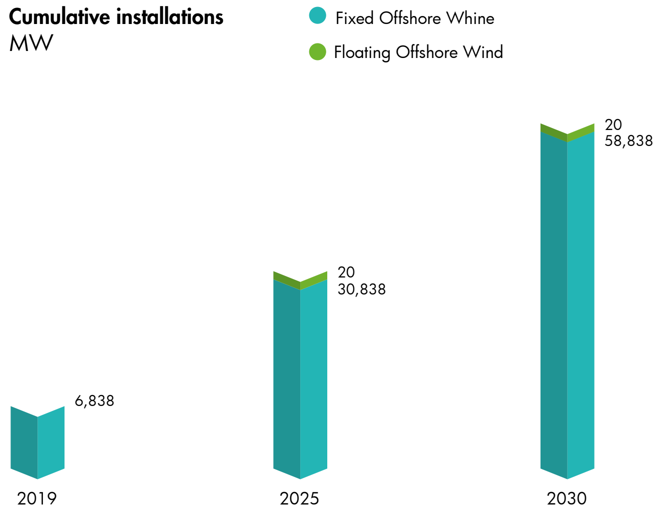
As one of the world-leading offshore wind markets today, China is set to continue driving growth of the global offshore wind industry. It has nearly 9.85 GW of current installed capacity as of the end of 2020, and this volume is expected to swell to nearly 60 GW by the end of the decade. Since the first offshore project, Donghai Bridge, was commissioned in 2010, growth in the Chinese market has been driven by a National Offshore Wind Development Plan (2014-2016), ocean management measures published in 2016 and a feed-in tariff (FIT) from the central government which expires for projects grid-connected after 2021 - prompting an installation rush last year.

With more than 500 GW of fixed offshore wind technical potential, according to the China Meteorological Administration, provincial authorities have set their sights high for offshore wind to deliver clean energy and meet emissions reduction targets. Around 60 GW is being targeted across provinces like Guangdong, Jiangsu, Zhejiang, Fujian and Shandong, while other provinces like Liaoning and Hebei also have offshore wind development plans. This is providing long-term visibility and scale for local industry investment. In order to sustain the pace of installations, provincial authorities may introduce their own financial support schemes now that the offshore FIT expired in 2021.

A robust onshore wind supply chain in China has supported the rapid expansion of the sector, and a number of offshore wind industrial clusters have emerged in coastal provinces. Guangdong, for instance, is developing strategic clusters for offshore wind research and development (R&D) and aiming for offshore wind to reach grid parity by 2025. Six Chinese turbine manufacturers have introduced offshore turbines with ratings greater than 8 MW in the past two years, raising the prospects for advanced domestic manufacturing of components.

The 14th Five Year Plan (released 2021) gave an insight into a higher and longer-term target for wind and renewable energy, building on China's recent commitment to carbon neutrality in 2060. With sufficiently ambitious targets, the Chinese and global wind industry has pledged that it can deliver at least 50 GW of annual installations of onshore and offshore wind through 2025, and then 60 GW annually from 2026 onwards. This would further propel the offshore sector to new heights, but a stable support scheme and international cooperation will be critical to scaling up the supply chain and delivering this volume in a least-cost approach.

Figure 8: Cumulative fixed and floating offshore wind installation projection in China from 2019-2030



Source: GWEC Market Intelligence, Global Offshore Wind Report 2020

Taiwan

After Mainland China, Taiwan is shaping up to be the second-largest market for offshore wind in the APAC region in the 2020s. A green pledge from the government, ambitious capacity targets and strong resource potential have attracted interest from leading developers and technology providers to Taiwan. It will have installed over 5.7 GW of offshore wind on the west coast by the end of 2025. This is the result of the government's Thousand Wind Turbines Project presented in 2012[2], in which the government announced 3 phases to achieve Taiwan's renewable energy targets - the Round 3 tenders are the last phase of this initiative.

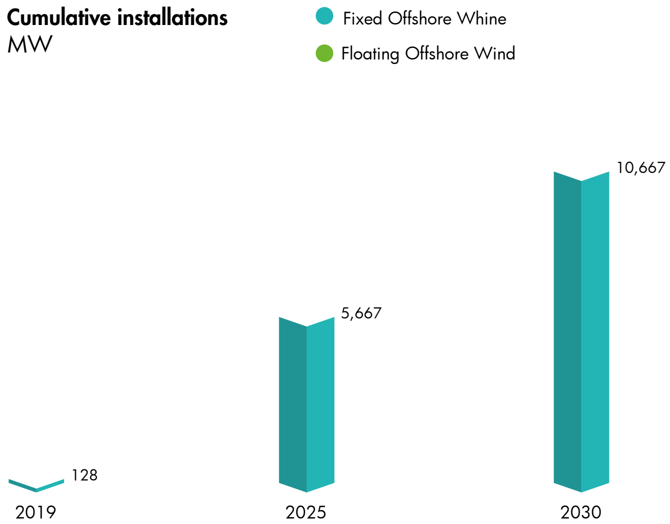
In August 2021, Taiwan's Ministry of Economic Affairs (MOEA) announced the offshore wind allocation plan for 2026-2035, during which 15 GW of new offshore wind capacity will be added at 1.5 GW per year. Following the announcement of the 10-year plan, the localisation policy for the Round 3 offshore wind tender was finally released in December, which will be procuring the projects for the period stated has been set at 60% for the optional list. The lower limit of the bid price is set at NTD 0/kWh and the upper limit is set at NTD 2.49/kWh (EUR 0.076/kWh)[3], for subsequent rounds the average bids received in the previous round will be used as the new price ceiling. The first Round 3 tender for projects with commercial operation dates in 2026/2027 will be held in August 2022 where 3 GW will be released for bidding.

Building on a promise to limit nuclear generation and facing limited terrain, offshore wind is a clear pathway to achieve high-level policy aims of generating 20% of electricity with renewable energy by 2025. Having embraced an open investment environment, the government foresees nearly US$30 billion in inward investment by 2025 from the offshore wind sector, and by 2035 investment is expected to reach US$90 billion and generate nearly 60,000 jobs.

Milestone investments in building local capacity have been announced in the last year, including a blade manufacturing facility and nacelle production in Taichung, as well as the building of Taiwan's first offshore wind installation vessel. With a 60% local content requirement for Round 3, with some on an optional list that earns more points, it remains a challenge in this fast-growing market. Many developers have raised their concerns over the flexibility of the localisation components as the local supply chain is not fully mature. Furthermore, the Round 3 mandatory list is also more comprehensive than that of Round 2 which will further challenge the supply chain and industry moving forward.

Home to several large manufacturing and industrial firms, Taiwan's support for offshore wind is also being driven by the bilateral market - corporates seeking to procure renewable energy to power their own operations. In 2020, the world's largest corporate Power Purchasing Agreement (PPA) to date was signed between Ørsted and Taiwan Semiconductor Manufacturing Company for a 20-year fixed-price contract to offtake the full production of the 920 MW Greater Changhua 2b & 4 offshore wind project.

Figure 9: Cumulative fixed and floating offshore wind installation projection in Taiwan from 2019-2030



Source: GWEC Market Intelligence, Global Offshore Wind Report 2020

2. https://www.twtpo.org.tw/eng/Home/
3. https://www.moea.gov.tw/MNS/populace/news/News.aspx?kind=1&menu_id=40&news_id=96475

Japan

2020 marked an inflexion point for Japan's offshore wind sector. Since the first small-scale pilot projects were installed in 2003, the government has recently taken strong measures towards a viable market structure. Towards the end of the year, the first Offshore Wind Industry Vision outlines a plan to allocate 1 GW of offshore wind capacity annually through 2030, as well as a supply chain development and cost reduction pathway to reach JPY 8-9/kWh of LCOE by 2035 and 30-45 GW of cumulative capacity by 2040, cementing Japan as one of Asia's offshore wind leaders. In September 2021, 12 areas were newly designated by the government, making a total of 23 candidate areas. The total number of promotion areas and promising areas has reached 5.6 GW, 70% of which are off the coast of Akita Prefecture. The government also plans to designate two or three sea areas per year from 2022 to achieve the target of 10GW by 2030. GWEC Market Intelligence forecasts nearly 8.5 GW of offshore wind to be installed over the next decade, including more than 1 GW of floating offshore wind.

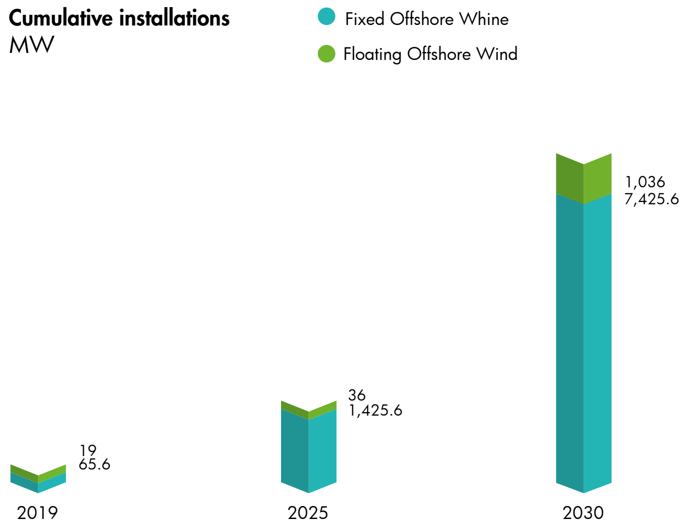
An attractive FiT for offshore wind has been in place since 2014, although uptake has been slow to date due to complex environmental assessment and permitting procedures.

The mandated environmental assessment alone can take up to 4-5 years to complete and the long lead time has been cited as one bottleneck for developing offshore wind farms in Japan. By January 2020, nearly 15 GW of offshore wind projects remained in the Environmental Impact Assessment (EIA) pipeline, with less than 100 MW of installed capacity. But government efforts to streamline regulation and promote offshore wind development are beginning to bear fruit, a 16.8 MW of floating projects in Goto, Nagasaki Prefecture and three offshore wind projects of 1.689 GW were awarded through Round 1 auction at a winning price of JPY 16.49/kWh (EUR 0.127/ kWh) in June and December of 2021 respectively.[4]

The momentum is reflected in a growing number of joint ventures and partnerships formed between foreign wind companies and Japanese developers, utilities, engineering, procurement & construction (EPCs) and manufacturers. The industry is primed to deliver large volumes at competitive prices, following a series of public-private dialogues with METI and MLIT initiated in 2020 and a forthcoming cost reduction study by the Japan Wind Power Association and GWEC on investment and industrialisation opportunities.

Japan's recent commitment to carbon neutrality by 2050 may accelerate the phase out of coal, which currently provides one-third of its electricity. As there are already social acceptance barriers around nuclear generation, these factors may translate to more ambitious long-term targets for offshore wind. Officials have expressed support for 10 GW of total capacity by 2030 and then at least 30 GW by 2040, but decarbonisation commitments combined with the economics of the clean energy transition may lead to a greener energy vision.

Figure 10: Cumulative fixed and floating offshore wind installation projection in Japan from 2019-2030



Source: GWEC Market Intelligence, Global Offshore Wind Report 2020

4. https://jwpa.jp/en/information/6227/

South Korea

South Korea rounds out North East Asia as an emerging hub for large-scale offshore wind growth, with GWEC Market Intelligence forecasting more than 9 GW of installations over the next decade. This includes 1.2 GW of floating offshore wind installed closer to 2030, as a regional supply chain is established and floating platform technology reaches commercialisation. While this falls short of the government's 12 GW target for offshore wind by 2030, an increase in R&D spending, regulatory reform and favourable pricing mechanisms could increase the volume of offshore wind in the pipeline.

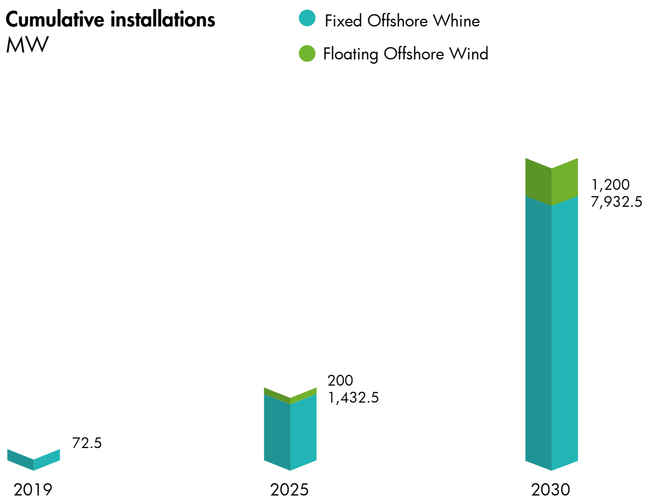
Early last year, South Korea unveiled a US 43.2 billion plan to build the world's largest wind power plant by 2030, in the western coast area of South Jeolla, taking shape as a focal point for offshore wind developments in this decade to come.

Nearly 10 years ago, South Korea adopted its ambitious Green Growth Strategy to reduce greenhouse gas emissions by 30% by 2020. This was followed by a pledge to source 20% of its electricity from renewable energy by 2030, and then the milestone announcement of a Green New Deal in 2020, committing nearly US$95 billion to decarbonisation and transformation of the energy, housing, transport and industry sectors. In October 2020, the government reaffirmed its commitment to reaching net-zero by 2050. While South Korea currently generates about 6% of its power from renewable energy and 40% from coal, these policy commitments are converging to light the way for offshore wind growth.

Progress in South Korea has been slower than its neighbours (Taiwan and Japan), due to stakeholder management issues and overly complex permitting procedures. But growing consortia of local and international wind energy developers - as well as Korean companies active across the supply chain, from support structures to submarine cables - are investing in offshore wind development. South Korea is set to install the greatest volume of floating wind across the entire APAC region by 2030. Early last year, South Korea unveiled a US 43.2 billion plan to build the world's largest wind power plant by 2030, in the western coast area of South Jeolla, taking shape as a focal point for offshore wind developments in this decade to come.

Growth is driven by preferential terms for renewable energy credits (RECs) for offshore wind projects, which are at least double the compensation level for solar PV, as well as an advanced manufacturing and shipbuilding industry already present in the market. But some supply chain inefficiencies need to be addressed, particularly around turbine manufacturing, installation and vessels, in order to enable long-term, cost-competitive growth.

Figure 11: Cumulative fixed and floating offshore wind installation projection in South Korea from 2019-2030



Source: GWEC Market Intelligence, Global Offshore Wind Report 2020

South East Asia

Although projects in Indonesia and the Philippines will begin coming online from 2028 onwards, the growth story for offshore wind in South East Asia has largely concentrated around Vietnam. Vietnam has emerged as the regional leader for the offshore wind industry's growth in South East Asia with a target in the March 2022 draft Power Develop Plan VIII (PDP8) of 7 GW of offshore wind by 2030, this to help them achieve their net zero commitment by 2050.

From roughly 2028 onwards large-scale fixed offshore projects will get connected in Vietnam and total capacity will reach 5.3 GW by 2030. In the interim, the industry still faces some critical challenges around permitting procedures, grid access and project bankability. While offshore wind is viewed as a necessary means to bridge the gap between Vietnam's energy demand and its phaseout of coal-fired generation, more concrete policy frameworks for large-scale

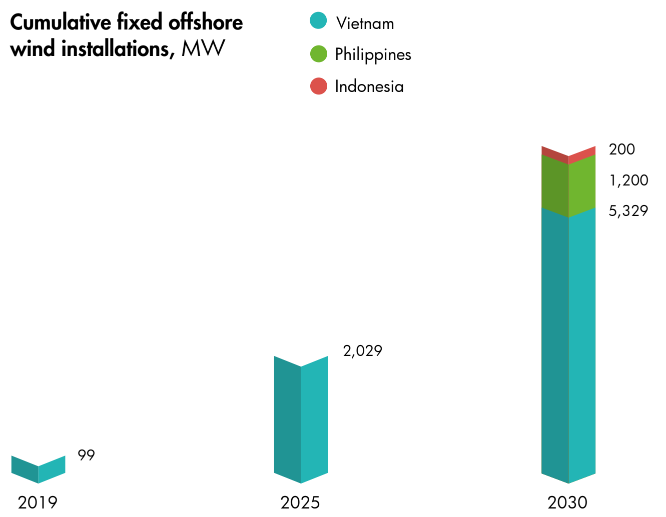
Vietnam has emerged as the regional leader for the offshore wind industry's growth in South East Asia with a target in the March 2022 draft Power Develop Plan VIII (PDP8) of 7 GW of offshore wind by 2030, this to help them achieve their net zero commitment by 2050.

offshore wind will be needed to really unlock potential, including policies for zoning, marine spatial planning, port infrastructure planning, grid upgrades and streamlined permitting Philippines is not far behind for offshore wind, with 1.2 GW forecast to be installed this decade and nearly 180 GW in technical potential. Likewise, Indonesia will begin installing offshore wind projects by 2029 and will benefit from the supply chain synergies developed in Vietnam, the Philippines and Taiwan.

Investors and developers have piled into Vietnam, which holds an estimated 475 GW of technical resource potential across both fixed and floating projects. Strong growth fundamentals, such as expanding industrialisation and power supply which struggles to keep up with the rise in demand, are supporting the prospects for offshore wind.

While floating technology is set to reach commercialisation in the next decade, floating projects may not be deployed in the South East Asia region until the post-2030 period. At that time, the Philippines may be particularly attractive for development, with strong resource potential in deep waters to the north of Mindoro, near the large demand centre of Manila.

Figure 12: Cumulative fixed and floating offshore wind installation projection in South East Asia from 2019-2030



Source: GWEC Market Intelligence, Global Offshore Wind Report 2020

POINT OF DEPARTURE - OFFSHORE WIND SUPPLY CHAIN AND ITS IMPLICATION ON SINGAPORE M&OE COMPANIES

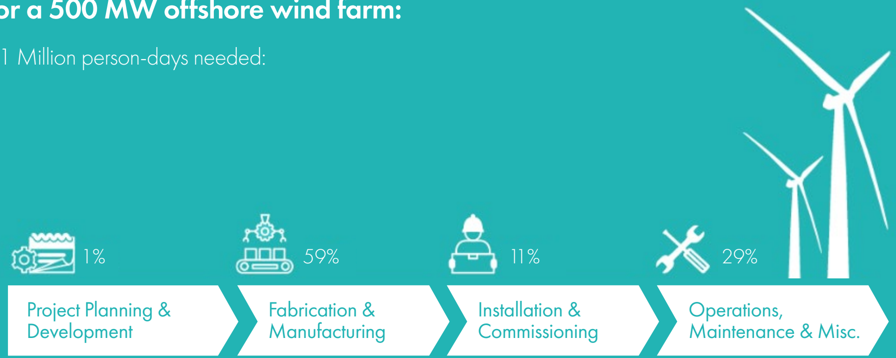
The offshore wind industry has a major role in contributing to climate change mitigation and renewable energy transition. Supply chain challenges abound for this nascent yet massive scale industry that seeks experience in taking shape while achieving high-quality assurance standards, to fully realise the potential of offshore wind development.

According to the International Renewable Energy Agency (IRENA), the majority of the labour requirements (totalling 2.1 million person-days for a 500 MW offshore wind farm) are found in the **Fabrication and Manufacturing** segment (59% of the total), and that includes procurement and transportation as well. Followed by **Operations, Maintenance and Misc.** (29%) which is an ongoing 25-30 years activity before it ends off with decommissioning included. **Installation and Commissioning** amount to 11% and that covers grid connection too and last but not least, 1% on **Project Planning and Development.**

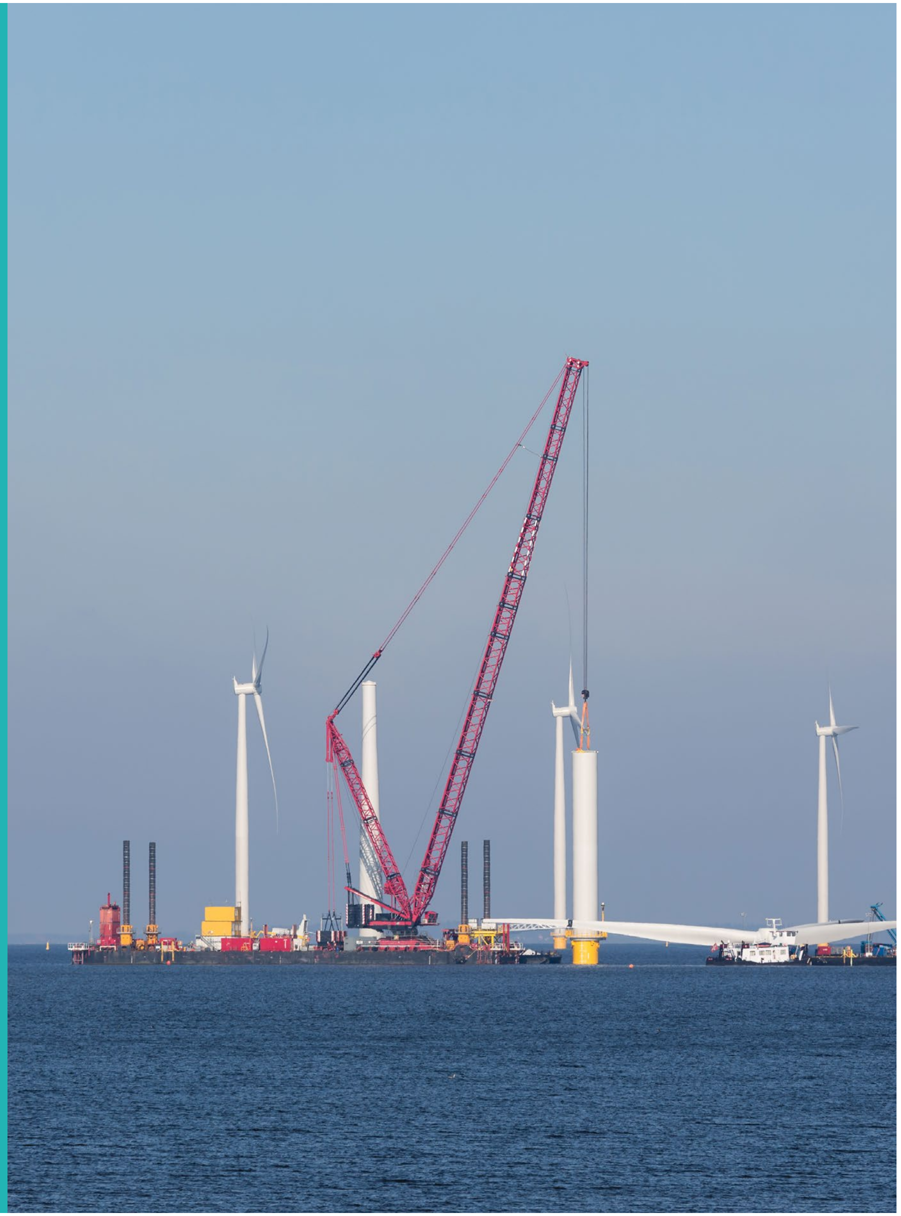
Figure 13: Distribution of human resources along the offshore wind supply chain

For a 500 MW offshore wind farm:

2.1 Million person-days needed:



Source: IRENA (2019), Future of wind: Deployment, investment, technology, grid integration and socio-economic aspects (A Global Energy Transformation paper), International Renewable Energy Agency, Abu Dhabi.



Risk management in offshore wind

Given the cost, scale and risks involved, there is great focus given at the beginning of an offshore wind farm's life to "interface risk" – the interaction between those responsible for constructing different parts of the wind farm – see figure below that details key parts of an offshore wind farm.

When trying to reduce risk, experience matters

As noted above, offshore wind farms are extremely complex and often constructed in challenging environments. In addition, and unlike many other large infrastructure projects, most offshore wind farms are not undertaken through an EPC "wrap" wherein a single contractor is responsible for the entire project through completion. This means that there are usually multiple contracts, and managing their interface is critical for success.

Different developers approach interface risk and the number of contracts differently. Some wish to push as much of the risk management as possible onto the Original Equipment Manufacturers (OEMs) and the balance of plant (BOP) contractors (e.g. developers A & B in the figure below). Some developers are comfortable managing the interface risk and subcontract multiple packages (Developer C below who would subcontract towers, foundations, cabling, etc.).

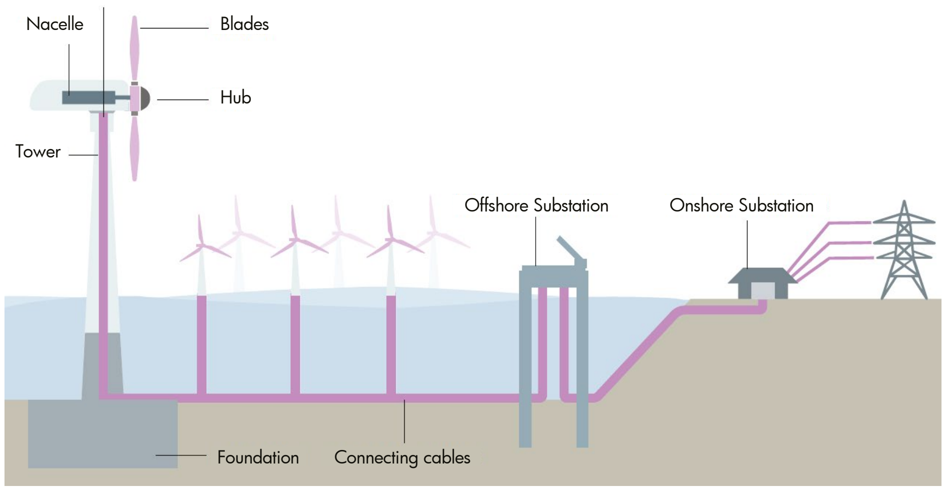
There is no "right" way to do this and it depends on the capabilities and risk appetite of the developer. Larger developers are more likely to be able to/want to manage their own risks with multiple contracts – it also depends on their confidence in the subcontractors.

As offshore wind grows in Asia and subcontractors become more capable, it is likely that more developers will choose to manage their own risks and work with their trusted subcontractors.

The implications for Singapore's M&OE companies are varied:

- Regardless of which entity takes responsibility for different parts of the supply chain, they will likely be tendering out various contracts for vessel chartering, construction, engineering services, fabrication, etc.
- Suppliers will have to understand the preferences and modes of operation of the various OEMs, developers, contractors for balance of plant, etc. and their philosophies for subcontracting vs ownership of their own capabilities, vessels, etc.

Figure 14: Key parts of an offshore wind farm



Source: Siemens, IRENA

	WTG	Towers	Foundation	Balance of Plant	Cabling	Offshore Substation	Onshore Substation	O&M
Developer A	OEM			Balance of Plant Packgage				OEM
Developer B	OEM	Balance of Plant Package						3rd Party
Developer C	OEM	Developer C						Developer

Operations, Maintenance and Misc. (O&M)

Post-warranty period, there are three typical ways that O&M services are provided to an offshore wind farm. See Table 1 below. Regardless of who provides O&M services, there will be opportunities for Singapore M&OE sector, but it will change depending upon who contracts for them. As such it is critical that suppliers understand which developers prefer to undertake their own O&M, and which ones subcontract O&M and to whom.

Other key trends to consider in offshore wind O&M are distance to shore and weather complexity. As more of the close-to-shore sites are developed, wind farms will have to move further and further offshore. In places like Japan, water depths quickly move beyond the depths where fixed bottom projects are feasible. In addition, wind speeds are often higher further from land thus leading to greater weather complexity and potentially shorter periods where projects can be safely serviced (and constructed).

The solutions to provide O&M services will have to adapt to projects being both further from shore and facing greater weather complexity. See Figure 15 below for a schematic diagram of the types of vessels required given increased weather complexity and distance to shore.

The implications for Singapore's M&OE industry are many and range from the types of vessels to build to the need to innovate given learnings in the Oil and gas (O&G) sector. Companies will have to monitor how the sector evolves to understand the requirements of the different players in the sector.

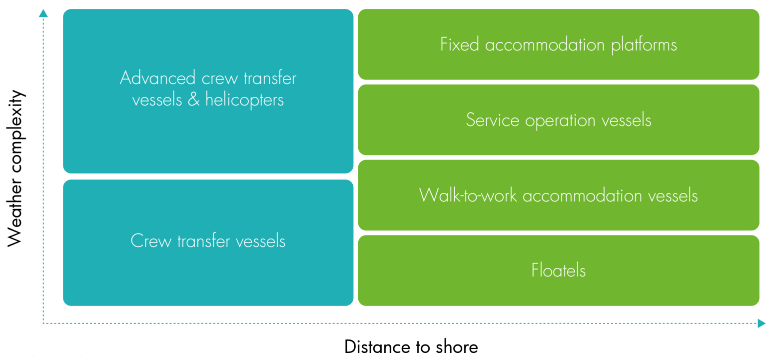
Besides, suppliers to the O&G sector can offer a track record of experience in maintaining assets in challenging offshore marine environments, as well as deploying well-trained personnel to sites with strong health and safety requirements. Requirements for marine or underwater inspection and repair could be highly transferable. Capabilities in the digitalisation of O&M services, such as remote monitoring and predictive analytics, could also be applied to the offshore wind sector.

BVG Associates provides many examples of successful transitions of Scottish oil and gas companies transitioning to offshore wind in their report: "Oil and Gas 'Seize the Opportunity' Guides - Offshore Wind".

Table 1: Deployment of O&M for various parties

Who Provides O&M?	Comments
OEMs	• The OEMs dominate post-warranty. • However, high OEM profitability in O&M markets has attracted the attention of 3rd party providers and encourages developers to build their own capabilities. • Many OEMs expect developers to provide vessels while the OEMs provide the crew. • The developers may own the vessels or charter them.
3rd Party (Highest Opportunity for Singapore's M&OE)	• It is difficult for 3rd party providers to build the capabilities and track record needed to be successful in offshore O&M markets. • High developer expectations for innovation, high levels of up-time, etc. make this segment challenging. • It is likely that 3rd party providers will charter vessels and not own them.
Developer	• To reduce costs and take more control over risks, larger developers are bringing as much O&M inside their organizations as is possible. • As their fleets and capabilities grow, they can gain economies of scale and leverage knowledge across multiple projects. • Some developers will own their vessels, others will charter.

Figure 15: The type of vessels needed for various distances to shore and weather complexity wind projects.



Source: Wood Mackenzie

Background information on turbine operation, maintenance and service (OMS) by the Crown Estate:

£75 million per annum is needed to maintain a 1GW wind farm, including insurance and internal asset owner costs.

For wind turbine planned maintenance and service in response to faults, wind turbines are typically under warranty for the first five to ten years of operations and the wind turbine suppliers offer a service level agreement during this period to provide turbine maintenance and service.

The performance of offshore turbines often have availability in a similar range to onshore in the range of 95%-98%.

Turbine availability is the percentage of time the wind turbine is ready to produce power if the wind speed is within the operational range of the turbine. The performance of offshore turbines often have availability in a similar range to onshore in the range of 95%-98%.

If required, specialist staff from the wind turbine supplier (more commonly) or 3rd party providers (less common) will carry out major repairs and replacement of main components. The wind turbine supplier and other third parties will carry out repairs of turbine blades.

Find out more: here

Floating vs Fixed Bottom – How the Opportunities Differ?

As noted above, the industry is moving into deeper waters, further from shore and facing increased weather complexities. In addition, many argue that waters deeper than 50-60 meters will require floating wind solutions. 2009 saw the world's first MW-scale floating offshore wind turbine grid connected by Equinor in Norway, but as the end of 2020 only 73 MW of net floating wind capacity was in operation worldwide. According to GWEC Market Intelligence's global offshore floating wind project database, floating wind installations are likely to take off from the second half of this decade, expecting to reach the 1 GW of floating wind annual installations milestone in 2026 and 16.5 GW in the next 10 years.[5]

Differentiating factors between floating and fixed bottom offshore wind are affected by water depth, weather complexity and distance to shore, which needs to be put forward as considerations for Singapore's M&OE companies. All of the foundation types that are being used or being considered by offshore wind developers have been deployed at scale in the O&G industry, albeit under different loading patterns.

floating wind installations are likely to take off from the second half of this decade, expecting to reach the 1 GW of floating wind annual installations milestone in 2026 and 16.5 GW in the next 10 years.

Table 2: Cost driver for fixed and floating wind

Cost Driver	Fixed (Jacket)	Floating
Water depth	Jacket size increases with water depth, increasing fabrication and steel base costs.	Length of mooring lines increases with water depth. Platform size is unaffected.
(Harsh) Met-ocean conditions	Harsh met-ocean conditions (bad weather, high waves, etc.) increase required jacket weight.	Similarly, it increases the required floating platform weight. However, floating installation is less affected by the need to wait for operational weather than fixed.
Distance to shore & installation vessel rates	Longer transit times equate to higher vessel costs. Fixed installation vessels are more expensive than those required for floating.	Longer transit times equate to higher vessel costs, however floating installation vessels are less expensive than those for fixed.

Source: https://www.xodusgroup.com/wp-content/uploads/2021/05/Fixed-vs-Floating-Wind.pdf

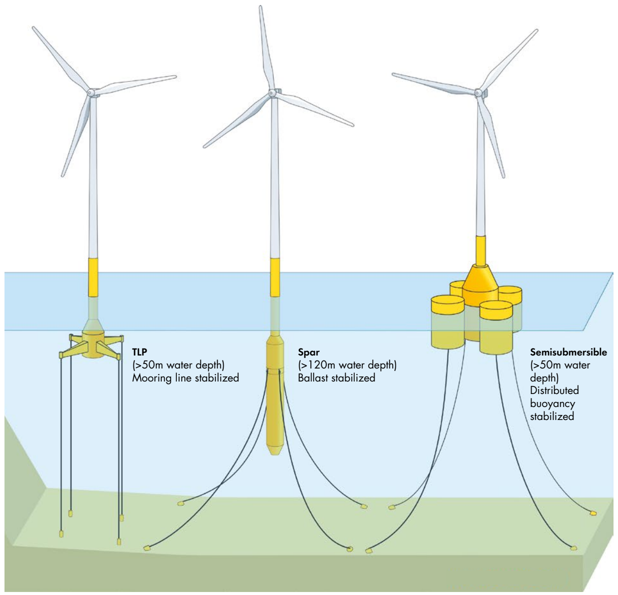
5. GWEC, Global Offshore Wind Report 2021

There are three main types of floating wind, and it is not yet clear which will be the most successful as each has pros and cons. The three are (see Figure 16):

1. **Tension leg platform**
2. **Spar**
3. **Semi-submersible**

The pros and cons of each type that are relevant to Singapore's M&OE industry are detailed indetailed in Table 3 (next page). As can be seen, there are large differences in the types of vessels required, where the structures can be assembled (onshore, nearshore or at the wind farm), how they are transported, the types and costs of the mooring systems and so forth.

Figure 16: Floating offshore wind platform types



Source: https://www.xodusgroup.com/wp-content/uploads/2021/05/Fixed-vs-Floating-Wind.pdf

Table 3: The benefit and challenges associated with three basic floater concepts

Spar	Semisubmersible	TLP
Overview: • Simplest concept and attractive dynamics • Minimum depth 80m during whole installation process • Achieves stability through ballast installed below its main buoyancy tank • Complex manufacturing and Weight for 6 MW: ~3.500 t	**Overview:** • Most popular concept and less attractive dynamics • Typically requires moveable water ballast to limit tilt • Requires dry dock for fabrication • Achieves static stability by distributing buoyancy widely at the water plane • Weight for 6 MW: ~3.000 t	**Overview:** • Attractive dynamics but not widely deployed • Achieves static stability through mooring line tension with a submerged buoyancy tank • Typically requires purpose-built installation vessel • Weight for 6 MW: ~2.000 t
Benefits: • Inherent stability • Suitable for even higher sea states • Soil condition insensitivity • Cheap & simple mooring & anchoring system • Simple fabrication process • Low operational risk • Little susceptible to corrosion	**Benefits:** • Heave plates for reducing heave response • Broad weather window for installation • Depth independence • Soil condition insensitivity • Cheap & simple mooring & anchoring system; Overall lower risk • Simple installation & decommissioning as specialized vessel required	**Benefits:** • High stability, low motions • Having a good water-depth flexibility • Small seabed footprint and Short mooring lines • Simple & light structure, easy for O&M • Lower material costs due to structural weight of the substructure • Onshore or dry dock assembly possible
Challenges: • High cost, 5-8 mEUR/MW (based on the 30 MW demo); • Heavy weight, with long mooring lines and long & heavy structure • Deep drafts limit port access and Large seabed footprint • Relatively large motions • Assembly in sheltered deep water challenging and time-consuming • High fatigue loads in tower base • Specialised installation vessels needed	**Challenges:** • Non-industrialized fabrication • Higher exposure to waves leads to lower stability and impacts on turbine • Labour intensive and long lead time • Large and complex structure, so complicated in fabrication • Foundation always built in one piece, requiring dry dock or special fabrication yard with skid facilities • Lateral movement presents potential problems for the export cable	**Challenges:** • Unstable during assembly, requiring the use of special vessel • High vertical load moorings • Complex & costly mooring & anchoring system making it the most expensive floater design type • Mooring tendons presenting higher operational risk in case of mooring failure and add requirements on site seabed conditions

Source: Stiesdal A/S, NREL, DNV.GL , Carbon Trust, IRENA

CHALLENGES & OPPORTUNITIES - LOCAL CAPABILITIES MAPPING OF M&OE COMPANIES

Job Opportunities in Offshore Wind

In addition to providing affordable, clean and reliable electricity, offshore wind has the capacity to bring enormous socioeconomic benefits to local communities. At large operating scales and with longer project development and construction timelines (typically 8-10 years) than other forms of energy, offshore wind projects can generate sustainable jobs across the full value chain of the sector. And these jobs can continue over the entire lifetime of the project, roughly 25 years with current technology, creating a variety of permanent and localised jobs.

Jobs generated from offshore wind projects encompass a variety of technical and professional skills. Key segments include: project planning and development; procurement and manufacturing of components and systems; transport; installation, grid connection and commissioning; O&M; and decommissioning at the end of the project lifetime.

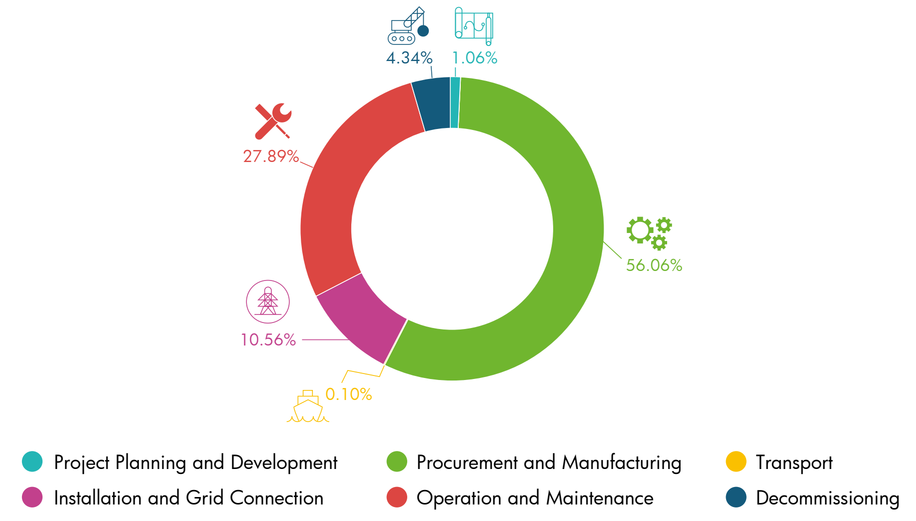
Altogether these segments would require: civil, naval, electrical and computer engineers; geotechnical, environmental and marine scientists; construction workers; truck drivers, crane operators and ship crew; legal, regulatory, taxation and financial analysts; logistics and weather experts; and a number of other job disciplines. A study from the US-based Workforce Development Institute found that offshore wind projects require an estimated 74 distinct occupations, ranging from white-collar engineers and legal/financial professionals to blue-collar jobs in construction, manufacturing and transportation.

A 2018 report by IRENA drew on a global survey to calculate jobs generated by a fixed-foundation offshore wind farm, from inception to decommissioning. This study found that around 8,650 full-time equivalent (FTE) jobs (defined as one calendar year, or 260 working days, of full-time employment for one person) are created for a typical 500 MW offshore wind farm over its lifetime, with most labour concentrated in the manufacturing and O&M segments (see Figure 17).

Using a unit-basis calculation, this would mean more than 17 FTE jobs are required per MW of generation capacity for an offshore wind project over its lifetime. While there are undoubtedly limitations to this calculation, barring a more comprehensive in-market study this figure can be instructive in estimating direct job creation potential from forecast wind capacity growth.

In Asia, including China, the new fixed-foundation offshore wind volume installed from 2020 to 2030 is estimated at 89 GW. Drawing on the unit-basis for job creation, this volume would require more than 1.5 million FTE jobs to deliver - many of which would be permanent jobs spanning the 25-year lifetime of projects. In South East Asia, where offshore wind is forecast to grow by more than 6.6 GW in Vietnam, the Philippines and Indonesia by the end of 2030, the sector could deliver 115,000 direct FTE jobs through this decade and over project lifetimes.

Figure 17: Total distribution of jobs across a 500MW fixed-foundation offshore wind farm



Notes: 1FTE Job = 1 year of full-time employment for 1 person, as defined by 260 working days in 1 calendar year. Estimates draw on a global survey of onshore and offshore wind stakeholders, conducted by IRENA and published in 2018. Considerations which might impact actual job creation include technology evolution, varying health and safety requirements, domestic labour productivity and economies of scale.

Source: IRENA (2018), Renewable Energy Benefits: Leveraging Local Capacity for Offshore Wind, IRENA, Abu Dhabi.

Transitioning Employment from the Conventional Sector to Renewables

As socioeconomic principles, cost dynamics and the climate emergency convene to transform energy markets and accelerate the global energy transition, shifts in local and regional labour markets are already underway. Job disruptions may be further pronounced under the recessionary impact of the COVID-19 pandemic. The offshore oil and gas and marine engineering sectors are undergoing a period of compression, and analysts are predicting "peak oil" at some point between now and the 2030s.

In the context of these market transformations, it is critical that policymakers and industry unite to ensure that the energy transition is just and inclusive. This includes ensuring equal opportunities for minority groups, as well as applying proactive measures to address workers in the conventional sector who may face mass displacement.

Policymakers, of those offshore wind nations, can leverage existing skill and knowledge-transfer opportunities in areas such as marine surveying, offshore lifting/construction, subsea cabling and manufacturing for strategic advantages. Where possible, preparing and reskilling workers from the conventional sector for the growing offshore wind sector should be a priority to invest in domestic value creation in an economically competitive and growing industry.

For instance, the most labour-heavy segment of an offshore wind farm, manufacturing, requires more than 1.25 million days of labour for completion of a 500 MW wind farm with foundation fabrication taking a major share of these high-paying jobs (See Table 4 on next page).

This segment can absorb workers with offshore oil rig experience for construction of offshore wind farm foundations and substations. In South East Asia, government investment in training and facilities for the production of technologically advanced sub-components, such as gearboxes and generators, can also take advantage of the nascent supply chain for these parts.

Targeted industrial policy and workforce education and development programmes will be required to build supply chain capabilities and re-designate labour to the expanding offshore wind sector. In Asia, these frameworks should be considered by policymakers without delay, given that evolving and strengthening local content requirements in various regional markets are already firming up domestic promotion schemes for industrial development and workforce training. Governments must also consider the proximity of their workforce to forecast project locations and emerging supply chain logistical hubs and routes.

For those markets with existing competitive advantages in the conventional sector, governments should align, as far as possible, occupational profiles with the offshore wind sector to leverage overlapping skills and requirements. A successful transition will require a combination of such profile-matching, proactive education/training programmes and targeted investments in capability-building.

The socioeconomic benefits of offshore wind extend far beyond creating sustainable jobs at home. Additional wind power deployment also mitigates energy-related carbon emissions, which can in turn generate tremendous cost savings in healthcare, infrastructure, social welfare and system resilience across markets, as carbon reductions work to limit the most harmful impacts of climate change, including pollution-linked illness and frequency/intensity of natural disasters - both high concerns for the South East Asia region.

Table 4: Number of days required per person to complete the manufacturing segment of a 500 MW offshore wind farm

	Nacelle	Rotor	Tower	Cabling	Foundation	Substation	Total by Occupation
Factory Workers	170,291	92,886	68,942	17,359	267,926	57,194	674,598
Marketing and sales personnel	34,058	15,481	10,606	2,671	41,219	11,493	115,474
Administrative and accounting personnel	34,058	15,481	10,606	2,671	41,219	11,493	115,474
Quality, health and safety experts	34,058	15,480	10,606	2,670	41,220	11,438	115,472
Industrial engineers	17,029	7,750	5,303	2,670	20,610	11,438	64,790
Logistic experts	17,029	7,750	5,303	1,335	20,610	5,719	57,736
Taxation experts	17,029	7,750	5,303	1,335	20,610	5,719	57,736
Regulation and standardisation experts	17,029	7,750	5,303	1,335	20,610	5,719	37,126
Electric engineers	-	-	-	1,335	-	5,719	7,054
Design and R&D engineers	-	-	-	1,335	-	5,719	7,054
Total (as%)	340,581 (27%)	170,288 (14%)	121,972 (10%)	34,716 (3%)	453,414 (35%)	131,543 (10%)	1,252,514

Considerations which might impact actual job creation include technology evolution, varying health and safety requirements, domestic labour productivity and economies of scale.

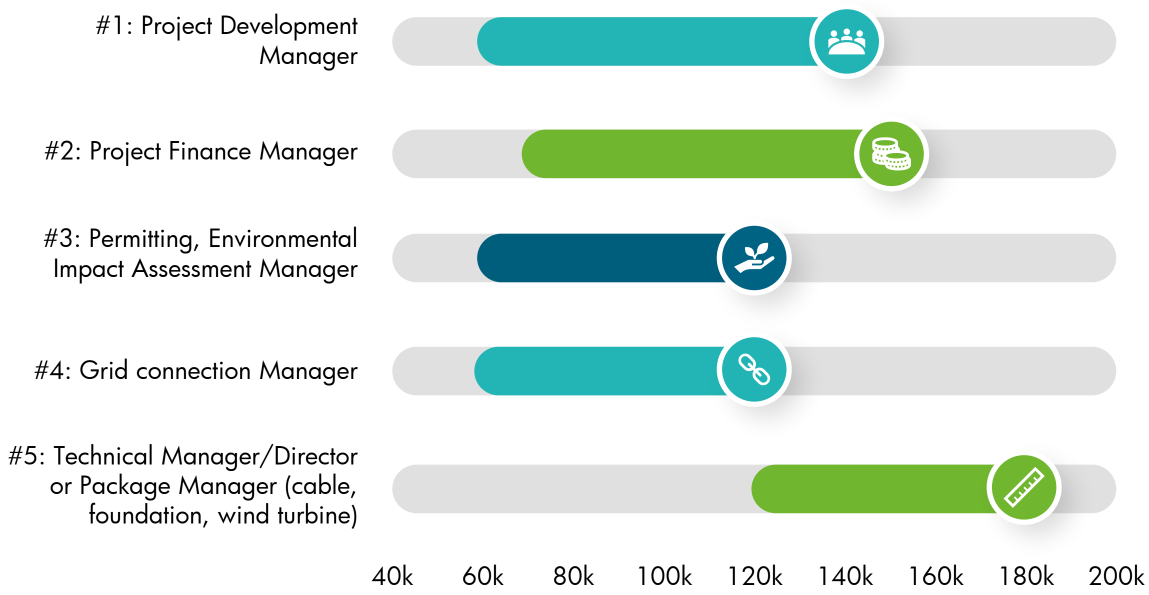
Source: IRENA (2018), Renewable Energy Benefits: Leveraging Local Capacity for Offshore Wind, IRENA, Abu Dhabi

Types of Jobs Available in the APAC Offshore Wind Industry

According to the human resource data of the offshore wind industry provided by the Nextwave Partners, an established leading recruitment brand of the renewables sector, the types of jobs available in the APAC region within its client base at the moment is reflective of the project phase, with the **development stages ending and early construction phases beginning.**

The majority of their clients have successfully developed offshore wind projects in Europe and the United Kingdom and have engineering capabilities in-house. However, those companies require **an increasing number of local professionals aware of the regulations of the host country** to implement the project on the ground (permitting, stakeholder management, government relations, grid connections).

Figure 18: Salary range of the top 5 jobs in the APAC offshore wind industry (USD)



Source: Nextwave Partners, illustrated by GWEC

LOOKING AHEAD - IDENTIFY UPSKILLING NEEDS FOR SG M&OE COMPANIES

Looking Ahead - Identify Upskilling Needs for SG M&OE Companies

Amid the increasing momentum of the clean energy transition in the region, policymakers and investors are hardening their positions on new fossil fuel investments, especially given the imperative of decarbonisation commitments and the risk of stranded assets. Singapore's marine and offshore engineering (M&OE) companies are now set on future-proofing their business models, including upskilling workers to develop either new or relevant competencies for the clean energy industries of the future.

Overview of Types of Singapore's M&OE Employment Opportunities

According to the Ministry of Manpower of Singapore, the M&OE sector employs close to 77,000 workers. It is anchored by Keppel Offshore & Marine, Sembcorp Marine and ST Engineering Marine, supported by a network of small and medium-sized enterprises (SMEs).[6] As at mid-October 2020, there are more than 800 available opportunities in the M&OE sub-sector, including 700 jobs and 84 % of which are in Professionals, Managers, Executives and Technicians (PMET) roles.

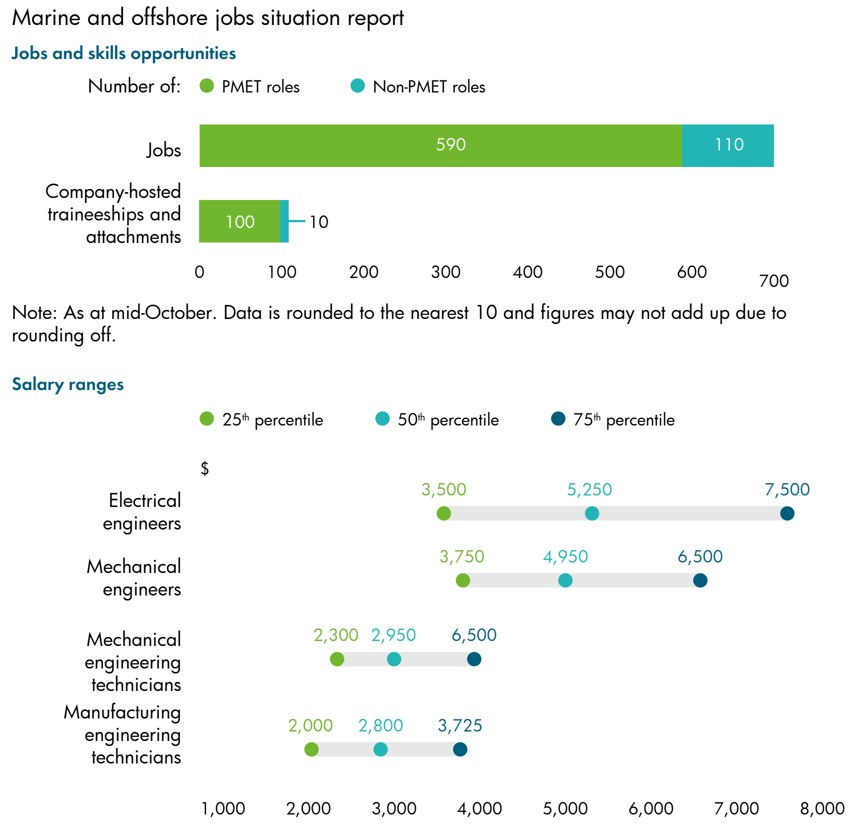
Although the recent oil & gas price increases have temporarily changed the situation, the industry has been hard hit in recent years due largely to weakened rig demand leading to shedding of workers, mostly from firms in oil and gas equipment manufacturing, said MOM. However, hiring continued among those in marine activities such as ship repair, conversion, and refurbishment during this period.

This indicates that the sector is not seeking an abundance of workers but rather specialised, and skilled and high-earning workers who demand ones that need to be better paid. At the same time, companies in the sector are considering the prospects for business transformation and pivoting to the growth area of offshore wind.

As at mid-October 2020, there are more than 800 available opportunities in the M&OE sub-sector, including 700 jobs and 84 % of which are in Professionals, Managers, Executives and Technicians (PMET) roles.

6. https://www.straitstimes.com/business/economy/marine-and-offshore-sector-can-pivot-to-new-areas-chan

Figure 19: Number of jobs and skills opportunities and salary range in M&OE sectors in Singapore



Source: Ministry of Manpower, Straits Times graphics

Transition into the Offshore Wind Is of Utmost Importance

Since Singapore published its M&OE Industry Transformation Roadmap in 2018, identifying offshore renewables as a new growth area, the M&OE sector has shifted attention to offshore wind. For instance, SembMarine and GE Renewable Energy recently partnered on services for a UK wind farm project, while Keppel announced that it will build a S$600 million offshore wind turbine installation vessel in the US. Over the past few years, M&OE companies have been applying their O&G experience to serve the offshore wind market, due to the alignment of established assets and knowledge required for both industries.

This report considers four main offshore wind supply chain segments and seeks to identify the opportunities for upskilling from Singapore's M&OE sector to serve the regional offshore wind sector. The four segments are:

1. Offshore Wind Project Planning & Development: the development and project management of the offshore wind farm from the point of signing a lease exclusivity agreement to the construction works completion date.

2. Fabrication & Manufacturing: the supply of cables, turbine foundations and towers and offshore and onshore substations.

3. Installation & Commissioning: the commissioning work on all balance of plant and turbine sub-elements.

4. Operation, Maintenance and Misc.: operational services, inspection and maintenance services for the lifetime of the asset, along with health and safety and certification training.

In order to identify specific opportunities, the four main elements of the offshore wind supply chain have been broken down into a further 17 sub-elements. Table 5 shows the results of a survey conducted with 42 Singapore M&OE companies. Each company ranked their current capabilities and interests into one of the following: high, medium, low or none. GWEC then tabulated the results (Table 1).[7] Through this exercise, Singaporean companies involved in M&OE identified the most relevant sub-elements for future development.

> Over the past few years, M&OE companies have been applying their O&G experience to serve the offshore wind market, due to the alignment of established assets and knowledge required for both industries.

7. GWEC took the individual capabilities and interest rankings provided by the Singaporean M&OE companies and applied the following formula: High X 3 + Medium X 2 + Low X 1 + None X 0. The highest weighted number received the rank of 1 and so on until the lowest weighted number received the lowest rank.

Table 5: Offshore wind supply chain sub-element opportunity score

Element	Sub-Element	Current Capabilities	Interest in Increasing Capabilities
Offshore Wind Project Planning & Development	Environmental, Health and Safety Assessment	2	6
	Wind Resources and Metocean Assessment (e.g. wind speed, seabed)	11	10
	Engineering & Consultancy	1	1
Fabrication & Manufacturing	Towers	6	3
	Cables	13	14
	Foundation (inclusive of corrosion/scour protection)	5	5
	Substations	9	4
	Floating Foundation	3	2
Installation & Commissioning	Heavy lift / Jack up vessels	10	11
	Cable dredging & Layers	12	13
	Support vessels (e.g. Crew Transfer, Barge, Remotely Operated)	8	8
	Offshore logistics (e.g. Marine Work Coordination, Warranty Surveyor)	8	7
Operation, Maintenance and Misc.	Site/Environmental Monitoring	10	12
	Marine Supervision	4	8
	Vessels and Quayside Infrastructure	7	7
	Substations Operations and Maintenance	10	10
	Health and Safety Training and Inspection	5	9

Highest capability (1) — Lowest capability (10)

Highest interest (1) — Lowest interest (10)

High Potential Opportunities for Transferable Skills

This survey shows the opportunities where Singapore's M&OE companies can leverage their current capabilities and pivot to the offshore wind sector. The screening process identified the following top 5 areas of opportunities:

1. Offshore Wind Project Planning & Development - Engineering and Consultancy.

2. Fabrication/ Manufacturing Services - Floating Foundation.

3. Fabrication/ Manufacturing Services - Towers.

4. Fabrication/ Manufacturing Services - Substations Supply and Installation.

5. Operations and Maintenance - Vessels and Quayside Infrastructure

#1: Offshore Wind Project Planning & Development - Engineering and Consultancy

Engineering has been a key enabler of Singapore's economic, infrastructural and societal progress. For the strong engineering foundation that has been built over the decades, opportunities do exist for Singapore's M&OE companies in this Engineering and Consultancy sub-element of the offshore wind supply chain.

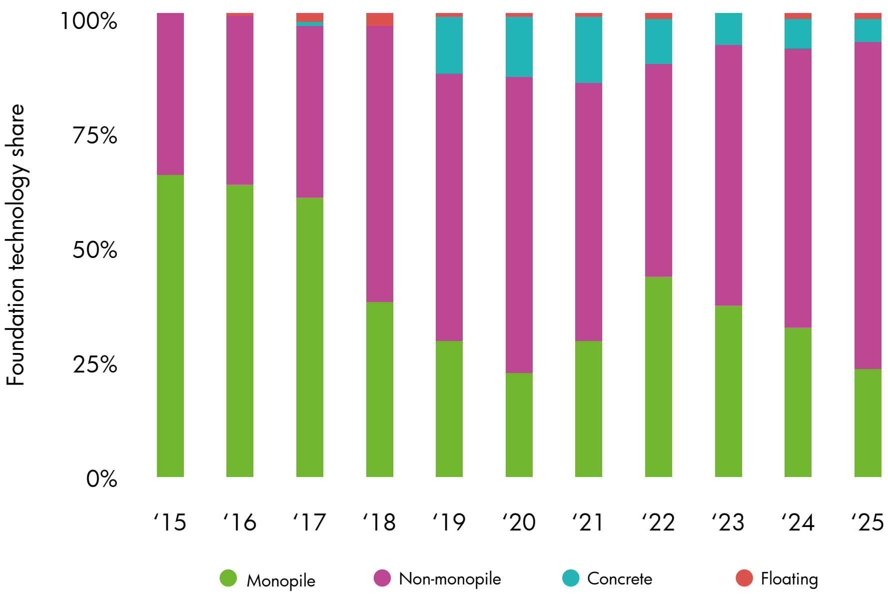
This covers engineering design, including the mechanical and electrical design of the turbines and substations, geological engineering to understand the considerations of the site (wind, seabed, marine and coastal characteristics) and the civil engineering and structural design work required for the infrastructure.

For the strong engineering foundation that has been built over the decades, opportunities do exist for Singapore's M&OE companies in this Engineering and Consultancy sub-element of the offshore wind supply chain.

*Top jobs of Engineering and Consultancy within APAC:	
Structural/civil engineer	• Minimum requirement: Bachelor's degree / sometimes PE registration • Salary bandwidth: 60k to 90k USD yearly
Electrical engineer	• Minimum requirement: Bachelor's degree / sometimes PE registration • Salary bandwidth: 60k to 90k USD yearly
Environmental Impact Assessment	• Minimum requirement: Bachelor's degree • Salary bandwidth: 60k to 120k USD yearly
Geotechnical engineer	• Minimum requirement: Bachelor's degree / sometimes PE registration • Salary bandwidth: 60k to 90k USD yearly
Wind resource analysis & modelling	• Minimum requirement: Engineering /Computer Science Degree • WASP Wind Pro proficiency • Salary bandwidth: 60k to 90k USD yearly

#2: Fabrication/ Manufacturing Services - Floating Foundation Supply and Installation

Figure 20: Percentage share of various foundation technology



Source: BVG Associates

Floating wind technology is set to open new opportunities for offshore developments, especially in the APAC region in countries with great floating potential such as Japan, Korea, the Philippines, as constructing offshore wind farms at deep-sea sites gains traction.

Although turbine foundations only represent 8.2% of the total capital expenditure (CAPEX) of an offshore wind project[8], with only demonstration-scale floating wind projects built to date, developers are targeting improvements in manufacturing and installation of floating foundations to deliver significant LCOE reduction, and standardisation of technical design to generate economies of scale.

Singapore's M&OE companies would reap more advantage with a focus on the design and engineering fundamentals, eventually providing the experienced know-hows on the synergies in terms of design requirements and functionality between offshore O&G floating foundation to that of floating offshore wind foundation. For instance, tension leg and semi-submersible platforms have been widely used in the oil and gas sector, but the underlying physics differences in terms of the thrust force, side force and aerodynamic torque will need to be studied, adjusted before implementation.

In addition, Singapore's M&OE companies are well recognised for expertise in building and chartering offshore supply vessels, where tug and anchoring vessels will be needed to install turbines on floating foundations. On this note, the strategic move of Sembcorp Marine that acquired LMG Marin AS - a naval architecture as well as ship design and engineering house, exemplifies the direction of Singapore's M&OE companies on strengthening its intellectual property and knowledge to execute leading-edge design and engineering solutions for the global offshore and marine sector which extends into offshore wind.

***Top jobs of Floating Foundation Supply and Installation within APAC:**

Fabrication Manager/Inspector - Contract based role	• Minimum requirement: Bachelor's degree • Salary bandwidth: 60k to 90k USD yearly
Site Inspector - Contract based role	• Minimum requirement: Bachelor's degree • Salary bandwidth: 60k to 90k USD yearly
QA/QC Inspector - Contract based role	• Minimum requirement: Bachelor's degree / ISO901 proficiency • Salary bandwidth: 60k - 90k USD yearly

8. https://guidetoanoffshorewindfarm.com/wind-farm-costs

* The salary bandwidths are inclusive of the labour markets of all APAC countries, with a general trend of the lower benchmarks from Taiwan and Vietnam, China is around the medium mark, and the higher ones are for Japan and South Korea.

#3: Fabrication/ Manufacturing Services - Towers Supply and Installation
The tower component of a wind turbine includes, but is not limited to, steel plate, personnel access and survival equipment, electrical system, tower internal lighting and fasteners. As it is a bulky component that tends to be localised in manufacturing, local turbine tower supply chains, including portside manufacturing capability and load-out facilities, grow very quickly in offshore wind markets. High volume, low IP components such as towers already have well-established manufacturers experienced in working in this area of supply. Opportunities for Singapore's M&OE companies to support turbine tower supply are therefore likely to be limited to sub-contracting partnerships with existing suppliers.

That said, Singapore's M&OE companies do have an opportunity to support the secondary steelwork sector which mainly includes the fabrication of small components within the turbine tower. The areas that require secondary steel include cable entry systems, boat landing systems, platforms and rails, sacrificial anodes, air conditioning systems and jacket pile sleeves. Supply of these components is often sub-contracted via competitive tenders on a project-by-project basis. There is no real requirement for manufacturers to have coastal facilities as in many cases the components can travel by road.

#4: Fabrication/ Manufacturing Services - Substations Supply and Installation
Offshore substations house electrical medium and high-voltage components for transforming current in order to reduce energy losses during transmission and all new offshore wind projects with a capacity larger than 100MW will require one.

Substations are made up of a number of sub-elements including the platform, secondary steel, architectural items and the foundation with electrical components such as the backup generator, reactive compensation system, switchgear, transformer.

These are typically one-off designs with significant synergy with O&G platforms and accommodation modules, with developers often awarding EPCI with the contract that shows a strong marine construction track record, for instance, Sembmarine SLP was awarded the Dudgeon substation contract in 2014.

Singapore's M&OE companies will need to build up their track record for working with developers that are aiming to simplify and standardise topside designs; in-house design and value engineering excellence is therefore a real advantage.

Opportunities for Singapore's M&OE companies to support turbine tower supply are therefore likely to be limited to sub-contracting partnerships with existing suppliers.

*Top jobs of Towers Supply and Installation within APAC:	
Yard Manager - Contract based role	• Minimum requirements: Degree in engineering • Salary: 12k to 15k SGD monthly (1-2years contract)
Package Manager - Contract based role	• Minimum requirement: Degree in engineering • Salary: 12k to 15k SGD monthly (1-2 years contract)

*Top jobs of Substations Supply and Installation within APAC:	
Electrical and Instrumentation (E&I) Designer	• Minimum requirements: Degree in Engineering, electrical of mechanical • Salary: 40k to 50k USD yearly
Structural Engineer	• Minimum requirements: Degree in Engineering, structural or civil • Salary: Limited to conclude

#5: Operation, Maintenance and Misc. - Vessels and Quayside infrastructure

O&M services present a great opportunity for Singapore's M&OE companies seeking a secure long-tenor services contract, with 20-year agreements common to cover the minimum lifetime of an offshore wind project. In the sub-sector of vessels and quayside infrastructure, Singapore's M&OE companies can leverage experience from the O&G sector in facilitating the movement of resources across the onshore base to the offshore wind farm.

The most common offshore wind farm vessels include crew transfer vessels (CTVs) and service operations vessels (SOVs). CTVs typically provide transport for technicians and spares on high-speed crafts from port to site. SOVs, on the other hand, are larger and more capable CTVs, which are typically used for wind farms much further away from the port. They are effectively a floating Order Management System (OMS) base that accommodates between 60 to 90 passengers and contains workshops and storage for equipment, consumables and spares.

O&M services present a great opportunity for Singapore's M&OE companies seeking a secure long-tenor services contract, with 20-year agreements common to cover the minimum lifetime of an offshore wind project.

*Top jobs of Vessels and Quayside Infrastructure within APAC:	
Vessel Supervisor	• Minimum requirements: Degree in marine or mechanical engineering • Salary: 1200 USD daily for 6 months contract

Barriers and Recommendations of High Impact M&OE Upskill Support

While the 42 companies surveyed identified several areas for upskilling, and some have undertaken some training and secondment activities, they also highlighted current perceived barriers to business transformation which would support a transition to supporting offshore wind:

1. Convincing company management to give offshore wind serious consideration as a growth area for the company.

2. Upskilling the workforce in order to increase technical knowledge on offshore wind.

3. Develop synergies among sectors with significant similarities in their needs to promote skills transferability between them (e.g. oil and gas, offshore wind energy, ocean energy).

4. Need for specialisation and expertise in skills that are not yet standardised and are still under development (e.g. decommissioning).

5. Research and development of legislation, guidelines and policies associated with offshore wind.

Various initiatives can support Singapore's M&OE companies to identify, develop and exploit the business opportunities within offshore wind, and accelerate their transition to services that are supportive of renewable energy and a low-carbon economy. Industry associations and academic institutions can organise **general knowledge-sharing sessions on offshore wind project development,** as well as **B2B networking opportunities between the M&OE and offshore wind sectors.** These associations can furthermore organise overseas delegation trips, which can include technical visits to offshore wind sites in the region, or alternatively virtual study tours which convene developers and supply chain services providers in offshore wind markets in the region.

While some of these initiatives can and have been funded by industry, there is a strong need for **public-sector funding to create and promote the training opportunities** for workers dislocated by the energy transition. Public transition funding can **subsidise the costs of upskilling and training courses, incentivise certification of offshore wind-relevant health and safety standards and support job identification services.** Within the Workforce Singapore's (WSG) redeployment professional conversion programme (PCP), to equip workers with new skill sets, courses provided to the M&OE sector should have a dedicated pillar into the offshore wind to steer and accelerate the creation of a higher-value Singapore's M&OE workforce to serve the rapidly growing market. It can further be harnessed to provide preferential credit for the creation of an industry incubator in Singapore, such as a centre of excellence for offshore wind R&D and training. The Government of Singapore can also work with local institutions of higher learning to **develop tailored professional training courses for O&G/M&OE workers to shift their skillsets to offshore wind.**

Potential Recommendation for Both Private and Public Sectors	
Industry Associations & Academic Institutions	Governmental Agencies
• **Knowledge sharing & networking opportunities** • Organise knowledge-sharing session on wind project development • Organise overseas delegation trips to offshore wind project sites • Organise virtual study tours to connect developers and supply chain service providers • Provide B2B networking sessions between M&OE and OFW sector	• **Training, certification & financing support** • Collaborate with institutions and higher learnings to develop professional training courses • Create industry incubator to accelerate OFW R&D • Subsidize the costs of upskilling and training courses and incentivise certification of OFW related health and safety standards • Support OFW job identification services

SUMMARY

Summary

The offshore wind sector presents Singapore's M&OE companies with an exciting new opportunity and access to a growing business stream. Key recommendations for Singapore's M&OE companies seeking to diversify into offshore wind are:

- Offshore wind presents a considerable diversification opportunity for Singapore's M&OE engineering companies, provided they act now and accelerate their workforce transition into offshore wind.

- Stemming from the challenges in the oil & gas industry, M&OE winners are those who accept the challenges for what they are: a chance to form their own views of the future and to lead to capture new opportunities, based on the fundamental core of strong hard skills and the lessons learnt from past O&G experience.

- Singapore's M&OE companies should look into offering prospective customers cost-competitive and/or innovative solutions to value add on top of their existing suppliers such as that of a one-stop consulting, design and/or engineering solution house. As offshore wind projects move farther offshore to deeper waters with higher wind speeds, the industry will be challenged to deliver larger, reliable and secure assets while reducing costs and maintaining a strong health and safety record in which M&OE companies can utilise its best practice and skills from the past experience of working in the offshore O&G sector.

- The main areas where synergies could be achieved between offshore wind and oil and gas project installations are in the fabrication and installation of towers and foundations utilising the vessels know-hows and overall project management, but with the share of O&M now left out of the scope of Singapore's M&OE companies.

- O&M spend on offshore wind farms offer suppliers certainty of long-term demand. M&OE companies have a vast amount of experience in maintaining assets in harsh offshore environments especially when safety standards and maintenance practices are highly transferable, hence, more attention can be placed in this sub-sector.

- Emerging offshore wind technologies such as floating turbines offer opportunities for Singapore's M&OE companies, based on strong synergies of offshore structures within both sectors. Given the early stage of the floating market and the lack of standardisation across foundation designs, proactive M&OE companies should identify a specialised niche within the floating foundation supply chain. Their contributions can help shape offshore wind practices that contribute towards the delivery of cost reduction across the next decade.

- Localisation content requirement across the APAC offshore wind sector poses an identified challenge to Singapore M&OE which can be well addressed utilising strategies such as JVs, or specialisation in highly skilled engineering tasks that are hard to be substituted.

- As the offshore wind industry expands to new and early-stage markets in Asia, the labour requirements call for technical and specialised roles across the entire offshore wind supply chain. Often, these roles are not being fulfilled locally and require the transfer of knowledge or experience from foreign developers and service providers with experience in mature offshore wind markets in Europe. Singapore M&OE's workforce who are well trained, and relatively competitive in salary as compared to Europe's workforce, have an opportunity to fulfil these technical roles to a high standard of technical specificity. In addition to the burgeoning of projects, when all executed at the same time or within a 12 to 24 months period, as we've seen in the O&G sector, this will put a strain on the talent pool which exemplified a strong need to get the workforce ready for that as soon as possible.

- Various initiatives can support Singapore's M&OE companies to identify, develop and exploit the business opportunities within offshore wind, and accelerate their transition to services that are supportive of renewable energy and a low-carbon economy.

Table of Abbreviations

APAC	Asia-Pacific
ASMI	Association of Singapore Marine Industries
BOP	Balance of Plant
CAPEX	Capital Expenditure
EDB	Economic Development Board
EPCs	Engineering, Procurement & Constructions
ESG	Enterprise Singapore
EIA	Environmental Impact Assessment
FiT	Feed-in-Tariff
FTE	Full-time Equivalent
GWEC	Global Wind Energy Council
IRENA	International Renewable Energy Agency
LCOE	Levelized Cost of Energy
LNG	Liquified Natural Gas
METI	Ministry of Economy, Trade & Industry
M&OE	Marine and Offshore Engineering
MLIT	Ministry of Land, Infrastructure, Transport & Tourism
MOM	Ministry of Manpower
O&G	Oil and Gas
O&M	Operations and Maintenance
OMS	Order Management System
OEMs	Original Equipment Manufacturers
PDP8	Power Development Plan VIII
PPA	Power Purchasing Agreement
PCP	Professional Conversion Programme
PMET	Professionals, Managers, Executives and Technicians
RECs	Renewable Energy Credits
R&D	Research and Development
WSG	Workforce Singapore

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