

Logistics' Role in Scaling Offshore Wind Energy to Climate Targets

A scenario study on installation vessel
requirements

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**CLIMATE
CENTER**

by Kühne Foundation

In collaboration with :

Panticon®

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The Kuehne Climate Center KCC is a subsidiary of the charitable Kühne Stiftung (Foundation), established in 1976 by the Kühne family in Switzerland. KCC develops and implements logistics-focused solutions to accelerate the transition to a just, low-carbon society by reducing emissions, removing carbon, and strengthening resilience.

In its program “Logistics for the Transformation of Energy and Industry”, KCC supports the development of logistics systems with the right capacities for the energy sector to master its transition faster and more efficiently.

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Executive summary

Offshore wind energy is expected to play a central role in the future net-zero renewable energy system. The International Renewable Energy Agency (IRENA) estimates that wind energy will need to provide 10,320 GW of installed capacity by 2050, with offshore wind contributing approximately 2,500 GW. At COP28 in 2023, 133 parties signed up to the ‘Double Down, Triple Up’ pledge, which calls for doubling energy efficiency and tripling global renewables capacity by 2030. For wind energy, the suggested installed capacity by 2030 amounts to 3,540 GW, with a share of 500 GW offshore. By the end of 2023, global offshore wind capacity had reached 75 GW. Achieving 500 GW by 2030 would thus have required more than a sixfold increase, followed by continued, though less steep growth through 2050. Reaching such a scale not only demands a supportive market environment for offshore wind deployment but also a substantial expansion of the supply chain.

While neither the 2030 ambition nor the 2050 net-zero requirements represent a binding political target, this study uses these steep growth pathways to illustrate the effect of delayed action and the implications for the supply chain, here with the example of the installation vessel fleets. After an introductory overview of offshore wind installation logistics, it examines the logistics for installing bottom-fixed offshore wind turbines, focusing on two key vessel types: Wind Turbine Installation Vessels (WTIVs) and Heavy Lift Vessels (HLVs). Using scenario modelling and accounting for future turbine growth, it estimates the capacity that the existing and ordered vessel fleets could install by 2030 as well as the additional vessels needed under different wind capacity growth scenarios. It also examines how the demand for the installation of different turbine sizes impacts their installation performance. Since offshore wind is not a uniform global market, fleet capacity and performance are modelled separately for PR China and the Rest of World.

Overall, three key findings and their implications seem to merit further discussion:

- As a result of overall market realities together with the vessel fleets’ existing and forthcoming installation capacities, achieving 500 GW offshore wind in 2030 does not seem to have been a realistic ambition, not even back in 2023. Such scaling would have required earlier action. While setting output targets is vital to guide the market, the findings suggest that formulating future targets should be informed by full supply chain capacity assessments and backed with supply chain development targets.
- From the vessel fleets’ perspective, reaching 400 GW globally by 2030 remains technically feasible. The Rest of World alone could achieve 175 GW—with an annual USD 3 to 4 billion in vessel investments over the next three years. While this study cannot speak to the broader supply chain’s ability to keep pace, a strong collective effort and immediate political action is needed to support offshore wind in delivering renewable generation capacity and preventing further setbacks on the path to meeting climate targets.
- A qualitative mismatch between market demand for turbine installation and vessel fleet capabilities would bear the risk of slowing down capacity additions and increasing costs. Greater transparency, forecasting, and coordination, not only within but across projects and regions, could increase the collective output and cost efficiency by enhancing project sequencing and vessel allocation. Sharing aggregated information on planned installations and mapping it against the capacity and availability of the vessel fleet—e.g., *inter alia* a multi-regional, cross-project coordination platform—would be a pragmatic first step toward a more coordinated system. Such coordination would benefit from increased efforts to standardize equipment interfaces in favor of interoperability as well as supportive regulation.

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List of abbreviations

APAC	Asia Pacific
CCS	China Classification Society
CIS	Commonwealth of Independent States
CLV	Cable Laying Vessel
COP	Conference of the Parties (to the United Nations Framework on Climate Change)
CTV	Crew Transfer Vessel
GRA	Global Renewables Alliance
GW	Gigawatt
GWEC	Global Wind Energy Council
HLV	Heavy Lift Vessel
IRENA	International Renewable Energy Agency
MW	Megawatt
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
RoW	Rest of World
SOV	Service Operation Vessel
UAE	United Arab Emirates
WFO	World Forum Offshore Wind
WTIV	Wind Turbine Installation Vessel

1. Wind energy: status vs. 2030 ambition and 2050 climate targets

Renewable energy is the main driver of the global energy transition. By 2050, nearly 90% of all electricity is expected to come from renewables (IEA, 2021). Wind power, together with solar, stands out as a key pillar of this transformation.

Wind energy will have to grow tenfold by 2050.

Globally, wind energy capacity stood at 1,136 GW in 2024, with 1,053 GW onshore and 83 GW offshore wind (GWEC, 2025a, 2025b). In its World Energy Transition Outlook 2023 (IRENA, 2023), IRENA estimates that, in 2030, 3,540 GW of installed wind capacity will be required, with 3,040 GW

from onshore and 500 GW from offshore wind (see Figure 1). The ‘Double Down, Triple Up’ energy efficiency and renewable campaign 2030 launched in 2023 by the Global Renewables Alliance GRA and IRENA (GRA & IRENA, 2023) helped turn these estimates into ambition: at COP28, 133 parties signed up to the campaign, thereby “commit[ting] to work together to triple the world’s installed renewable energy generation capacity to at least 11,000 GW by 2030, taking into consideration different starting points and national circumstances.” (UAE COP Presidency, 2023). To align with a 1.5°C climate scenario, IRENA estimates that 10,320 GW of installed wind capacity will be required by 2050; 7,820 GW from onshore and 2,500 GW from offshore wind (IRENA, 2023).

Fig. 1: Global wind capacity in GW, historic values, 2030 ambition and 2050 climate targets



1. Wind energy: status vs. 2030 ambition and 2050 climate targets

Scenario vs. Market Projection

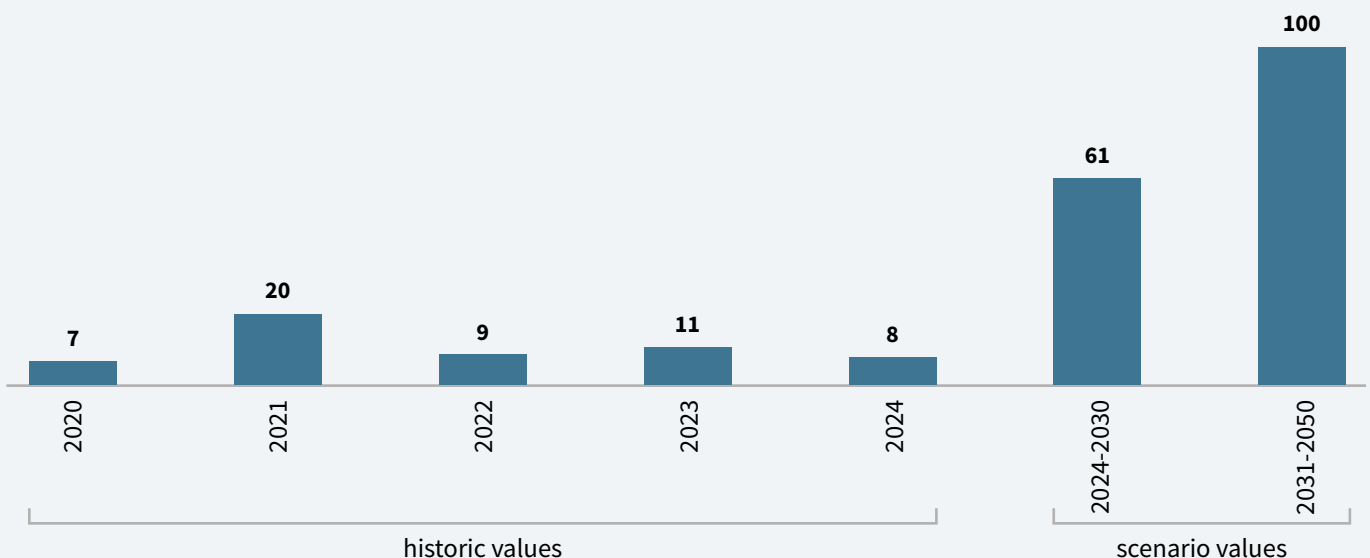
Scenarios, such as in IRENA's 'World Energy Transition Outlook-1.5°C Pathway' which we used as a framework for this study, use a back-casting approach that starts with a desired future goal, in this case, limiting global warming to 1.5°C by the end of the century. This normative scenario is constrained by the remaining carbon budget and maps out the amount of renewable energy needed to meet the goal; it therefore anticipates future energy needs based on likely economic, social and technological developments, and considers the deployment potential of a given technology, in this case, wind energy. A normative scenario is therefore different from a market projection, which typically uses a forecasting approach that starts in the present to derive a likely, near-term development based on data from the past, current trends, and market assumptions.

In a linear growth scenario, yearly average additions of 61 GW offshore wind capacity would be required each year for the period 2024-2030 to reach 500 GW in 2030. For the period 2031-2050, the yearly average additions would have to increase further to 100 GW to reach 2,500 GW (see Figure 2).

Considering that yearly offshore wind additions have hovered around 10 GW per year over the last three years (GWEC, 2025), scaling the value chain to meet the 2030 ambition within just seven years presents a considerable challenge.

Also, this growth ambition contrasts starkly with actual wind farm planning and market projections: for example, based on Clarksons Renewables Intelligence Network (Clarksons Research, 2025), a total of 274 GW offshore wind are currently scheduled to be operational by the end of 2030, representing a little over half of the ambition; the Global Wind Energy Council GWEC projects an offshore wind capacity of 441 GW to be reached by the end of 2034 (GWEC, 2025).

Fig. 2: Yearly offshore wind additions in GW, historic and scenario to meet the 2030 ambition and the 2050 climate targets



1. Wind energy: status vs. 2030 ambition and 2050 climate targets

After an introductory overview of offshore wind installation logistics, this study examines the logistics for installing bottom-fixed offshore wind turbines, focusing on two key vessel types: Wind Turbine Installation Vessels (WTIVs) and Heavy Lift Vessels (HLVs). The following scenario modelling explores whether the installation vessel fleet—one critical element of the offshore wind value chain—

would have been able to support the steep growth towards 2030, the offshore wind additions it can actually deliver, and what the way from 2030 to 2050 could potentially look like. Particular interest is given to the interactions between market demand for the installation of different turbine sizes and the capabilities and performance of the vessel fleets.



SOURCE: LANCE BELLERS/SHUTTERSTOCK.COM

2. Logistics' role in offshore wind

2.1. Vessels' tasks and challenges in offshore wind installations

Logistics plays a key role in all the life cycle stages, from manufacturing to decommissioning (also see Poulsen & Lema, 2017). With still relatively short experience—offshore wind accounted for 7% of global installed wind capacity in 2023—the sector and its logistics are still developing.

Wind components—nacelles, generators and hubs, blades, foundations, towers, and substations—are large and heavy, with physical challenges for transport, particularly on land. Manufacturers of wind equipment therefore increasingly choose plant locations where they have direct access to a port, not only but especially those who serve offshore wind farms.

Particularly, site preparation and installation of an offshore wind farm requires a team of specialized vessels, crews, and ports; depending on the project, a fleet of 10 to 50 vessels may be involved (BCG, 2022). Heavy-Lift Vessel (HLVs), Wind Turbine Installation Vessels (WTIVs), and Cable Laying Vessels (CLVs) play the leading roles in installing and connecting offshore wind farms; survey vessels examine the site before construction starts; rock installation vessels provide scour protection for foundations; multi-purpose vessels, tug vessels, barges, and crew transfer and service operation vessels support the transport, installation, and maintenance work. With the still young fleet of bottom-fixed offshore wind farms, decommissioning has little experience. Much of the installation process at sea is reversed, and the equipment for disassembling and transporting offshore turbines' components back to shore is largely the same as used in the installation process.

Over the last years, offshore wind turbines have grown significantly, and industry outlooks suggest that they will continue to do so (also see 3.1). While larger, more powerful turbines offer greater energy production and maintenance efficiency, the complexity for transporting and handling them increases with size. Bigger turbines consist of

heavier components, with longer blades and higher towers of larger diameters. Infrastructure, transport and handling equipment must grow along.

Of the vessels required for offshore wind farm construction, Heavy Lift Vessels (HLVs) and Wind Turbine Installation Vessels (WTIVs) are particularly affected by increasing turbine sizes: their cranes must have greater lifting capacities and working heights; their decks need more space and load-bearing strength. Whereas HLVs are more versatile across a range of offshore construction activities, the purpose-built WTIVs are more specialized and hence highly sensitive to changes in demand from the wind sector.

Particularly Heavy-Lift Vessels and Wind Turbine Installation Vessels are critical to accelerating offshore wind development.

Vessels that are outgrown by increasing turbine sizes must seek new opportunities—of varying attractiveness: some of these vessels may transition to emerging offshore wind markets that start with using smaller wind turbines. Others might shift to supporting larger installation vessels or move to maintenance and repair activities on existing offshore wind farms. Where technically feasible and economically justified, certain vessels may undergo upgrades to extend their installation capabilities and service life. Vessels that can no longer compete in wind markets may seek redeployment in other offshore sectors. Finally, if no viable options can be found, some vessels will eventually be decommissioned and scrapped.

In addition to their sensitivity to changes in wind equipment size, several other factors contribute to making HLVs and even more so the purpose-built WTIVs a critical element in the offshore wind

2. Logistics' role in offshore wind

value chain: First, these vessels are built by a limited number of shipyards with a strong regional concentration in Asia, particularly in PR China: Over 75% of the existing WTIV fleet originates from a Chinese shipyard; yet only eight of these shipyards have demonstrated experience in building WTIVs for the international market, as our analysis based on Clarksons Renewables Intelligence Network (Clarksons Research, 2025) reveals. Since orders for wind installation vessel compete with orders for other vessel types, lead times from order to delivery can reach four to five years in a tight shipbuilding market, as the recent years have shown. Second, these vessels represent a large investment, typically in the range of USD 200 to 600 million, with HLVs in the lower and WTIVs in the middle to higher range; eventually, their specific features and the shipbuilding market determine the price. Vessel owners naturally strive to mitigate their financial risk in an uncertain and fast-changing market through contract-based investments; they tend to place their orders only once a first contract for the new vessel's deployment has been secured. Vessel delivery times thus constitute a significant determinant to the offshore wind value chain's growth pace. Lastly, due to the combination of still limited experience in wind vessel construction and the constantly evolving technical requirements, most WTIVs have unique, one-off designs, limiting opportunities to achieve economies of scale through design replication and accumulated experience. With standardized designs slowly emerging and shipyards gaining experience, vessel delivery times and cost may be reduced—provided that broader conditions in the shipbuilding market remain favorable.

To increase the deployment efficiency of critical offshore wind installation vessels, new logistics strategies are being explored. Traditionally, these costly vessels also handle the transport of components from port to site—a lower-value task

that does not require their specialized capabilities. The use of dedicated feeder vessels to shuttle components to the wind farm while the installation vessel remains stationed is expected to reduce costs and accelerate operations. However, safe vessel-to-vessel lifting operations at sea require advanced onboard equipment, tightly synchronized logistics managed by specialized crews, and calm sea conditions.

While feeder models are attracting growing interest—for efficiency reasons but also driven by national cabotage rules that restrict foreign-flagged installation vessel from executing transport tasks (also see 2.3)—their feasibility remains constrained, notably by weather and sea states, which vary significantly by season and region.

The logistics of floating wind—as the technology itself—are still developing.

Compared to bottom-fixed offshore wind, which has a track record of over 30 years, the floating wind technology is still in its early stages—and so are its logistics. At the end of 2024, 36 floating turbines were installed globally, with a total capacity of 246 MW (based on Clarksons Research, 2025). In floating wind installation, high-capacity anchor-handling and tug vessels pull the floaters with the mounted turbines to the wind farm site for installation. While the requirements in specialized vessels for the last steps in the installation process are lower than those for bottom-fixed wind, much of the logistical challenges lie with the handling of the very large floating foundations already before installation, mounting of turbines to their floaters, and with the maintenance over wind turbines' entire service life.

2. Logistics' role in offshore wind

Summary overview of logistics key tasks and equipment in bottom-fixed offshore wind :

Manufacturing	Moving of components between manufacturing, storage, and loading areas.
Site preparation and balance of plant	Seabed preparations by various types of survey and offshore construction vessels; heavy-lift vessels and tug vessels for transport and installation of substations and their foundations; cable laying vessels; multi-purpose vessels for support activities.
Transport and installation of turbines	Depending on location of equipment manufacturers, shipping from fabrication yard to wind farm site or marshaling port as midway spot. Heavy-lift and wind turbine installation vessels for transport and installation of foundations and turbines; multi-purpose vessels to support specialized vessels.
Operation and maintenance	Heavy-lift or wind turbine installation vessels for major component replacements. Crew transfer vessels or service operation vessels for planned maintenance, helicopters for urgent access, remote-controlled unmanned vehicles for certain maintenance activities.
Decommissioning	Similar equipment to reverse activities from installation.

Note: Simplified overview; phases blend into each other.



SOURCE: IWETA0077/SUTTERSTOCK.COM

2. Logistics' role in offshore wind

2.2. Ports' multiple roles in offshore wind logistics

Ports play an essential role for the trade, manufacturing, installation and servicing of wind energy. In offshore wind, components such as nacelles, towers, and foundations are manufactured at specialized wind manufacturing ports. Marshaling ports then serve as logistics hubs, receiving components from manufacturers, storing them, and conducting pre-assembly activities before transport to the installation site. Installation ports, typically located close to the wind farm area, handle the final loading of components onto installation vessels. In some cases, a single port may combine the functions of manufacturing, marshaling, and installation, depending on its capacity and infrastructure.

For handling and shipping of large components, ports need to meet several requirements, like a deep draft for the specialized vessels, sufficient air draft for loaded components to pass, long quays with a high load capacity, and wide access channels. Particularly manufacturing and marshaling ports require large amounts of space for fabrication workshops, storage, and on-quay storage.

Operations and maintenance (O&M) ports play a critical role throughout the entire lifetime of an offshore wind farm. Their infrastructure requirements are generally lower than those of manufacturing, marshaling, or installation ports; particularly O&M ports that primarily serve Crew Transfer Vessels (CTVs) and Service Operation Vessels (SOVs) are less demanding in port infrastructure. For these ports, as for installation ports, proximity to the wind farm site is essential to minimize transit time and increase operational efficiency. O&M ports that handle major component repairs (e.g., blades, gearboxes, or export cables) must meet additional

requirements for heavy-lift handling, storage, and sometimes quayside assembly. These ports may serve as centralized maintenance hubs for multiple wind farms in a region.

Also, multi-purpose seaports with suitable terminals play a role in the offshore wind sector, particularly for imports, exports, coastal shipping to offshore wind ports, and potentially for marshaling wind turbine components.

In addition to these central roles in offshore wind development, ports are also expected to support new energy activities, like offshore wind-based hydrogen production. This will require them to integrate infrastructure and services for both energy technologies.

Ports have been identified as a critical bottleneck to the fast built-out of offshore wind across regions (see e.g., Royal HaskoningDHV, 2023; Poulsen & Lema, 2017; Sabina, 2023; Parkinson & Kempton, 2022; Danish Energy Agency & COWI, 2024). A lack of coordination between energy and infrastructure strategies, lengthy planning and capital-intensive investment for port upgrades, competition from other port users, conflicting priorities within complex port governance structures, and the absence of a continuous offshore wind project pipeline—all contribute to slowing down the development of offshore wind port infrastructure.

While an analysis or the modeling of port requirements are beyond the scope of this scenario study, the importance of developing ports to support the required offshore wind development cannot be overstated.

2. Logistics' role in offshore wind

2.3. Regional differences in offshore wind logistics readiness

Regions face distinct challenges and opportunities when developing logistics systems to support the wind energy sector. In offshore wind, these are mainly influenced by four factors: the maturity of the maritime industry, including ports, operational expertise, and hinterland infrastructure; experience in offshore construction, such as in the oil and gas sector; the level of policy and regulatory support; and the overall development stage of the regional wind value chain. Expertise in bottom-fixed offshore wind installation has so far been concentrated mainly in Europe; there, the established offshore wind value chain can leverage advanced port

facilities and experienced offshore service providers. Over the last decade, PR China has made significant strides in developing a largely autonomous national offshore wind value chain—including offshore wind installation logistics (also see Poulsen & Hasager, 2017). The country has invested in its ports and developed a substantial offshore wind vessel fleet and installation expertise.

Logistics readiness varies considerably across regions.



SOURCE: OBATALA-PHOTOGRAPHY/SUTTERSTOCK

2. Logistics' role in offshore wind

In the APAC region, especially Taiwan has gained significant experience in offshore wind and its logistics; Japan and the Republic of Korea are developing ports and skills, including for the floating wind sector. The southern Pacific region still faces a substantial need to expand and modernize ports and installation fleets, as well as to train the workforce to support ongoing offshore wind efforts. The United States and Canada do not yet have a fully established offshore wind sector but are working to develop it and upgrade selected ports. The United States, where the Jones Act prohibits the use of vessels that are not U.S.-built, owned, and operated for moving goods between two points within its territory, aims to develop a specialized vessel fleet.

The offshore wind logistics and installation market is largely split into two major regions: PR China and the Rest of World, led by Europe.

In Latin America, several countries have announced offshore wind projects, but have no practical experience yet. Brazil, with its national value chain in onshore wind and expertise in the offshore oil and gas sector, appears to have good prerequisites for developing the necessary offshore wind logistics capacities—if market signals remain stable. While the Middle East has a track record in manufacturing foundations and other components for export, offshore wind development in the region is still nascent, with only a few projects announced for the middle of the next decade. In Africa, interest in offshore wind is starting to grow, but the sector is still very early in its development. In both regions, countries with offshore oil and gas activities may

be able to leverage this experience in developing offshore wind logistics.

In line with the historical division of the global offshore wind energy market between Europe and PR China, the associated demand for offshore wind transport and installation logistics has also developed as two separate systems. PR China has catered to its domestic needs largely independently, while European vessel operators have served the European market.

With their internationally classed vessel fleets, European operators are well positioned to offer installation services in emerging offshore wind markets outside Europe, where national fleets are still nonexistent or insufficient. In contrast, most Chinese installation vessels have been classified only by the China Classification Society (CCS) rather than by internationally recognized classification societies, limiting their ability to operate globally. As new regions develop their offshore markets, the emergence of a more decentralized vessel fleet could not only increase regional independence and share investment needs but also help allocate vessels more efficiently, with shorter transit times.

However, differences in national market regulations still create entry barriers for foreign vessel operators. For example, cabotage laws—such as the U.S. Jones Act mentioned above—exist in many countries and prohibit the use of foreign-flagged vessels. While such regulations can be designed intentionally to protect national interests, their restrictive effects on offshore wind installation services can also be an unintended consequence of broader maritime and offshore legislation. To accelerate offshore wind deployment globally and cost-effectively, these regulations may need to be revisited.

3. Evolutions in the wind sector with implications for logistics

3.1. Growth in turbine size

Turbine size, capacity targets, logistics requirements and activity levels are all interdependent factors shaping offshore wind deployment.

Turbine size determines logistics requirements and activity level.

Turbine size and the targeted installed capacity result in the number of turbines required: higher turbine power ratings mean fewer turbines are needed to achieve a certain amount of installed GW. Consequently, fewer logistics equipment but of greater capacity is required to handle the increased weight and dimensions of the components. Delivering the same amount of installed GW with turbines of lower power ratings means more logistics equipment yet with a lower handling capacity is needed.

Since the early days of the offshore wind, turbines' power ratings and with it, their size, has grown tremendously. Starting at around 4 MW in the early years 2000, offshore turbines have reached 15 MW in 2025, and development continues: a Western OEM is currently testing a 21.5 MW turbine (Proctor, 2025);

Chinese OEMs are working on 22 MW (Tisheva, 2023) and 26 MW turbines (Dong Fang Electric Windpower, 2024).

Larger turbines have advantages in energy efficiency, space use, installation, and operations and maintenance work per GW installed; yet they also come with trade-offs in various areas: more powerful turbines require larger blades and higher hub heights; structural loads and material requirements increase. Also, component manufacturing and ultimately, handling equipment and infrastructure need to adapt; larger turbines require more space for storage and maneuvering, more quay and deck strength, and larger cranes with higher lift capacity on land, in ports, and on vessels (also see 2.1).

While larger turbines offer greater resource efficiency, they also come with trade-offs, among them, increased handling complexity.

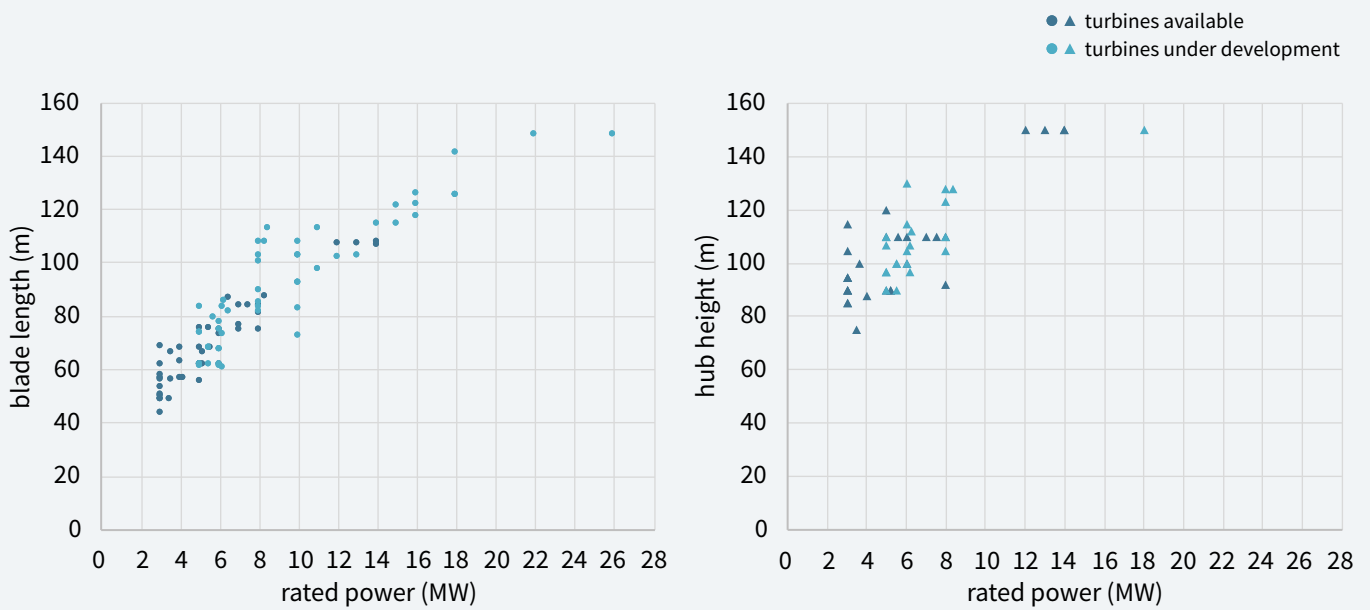


SOURCE: VESTAS

Figure 3 illustrates how blade length and hub height has grown and will grow further with continuing growth in turbine size. While turbines below 8 MW have blades under 100 m long, the 12 to 16 MW turbine segment achieves lengths around 115 m; the 20+ MW turbines currently under development reach blade lengths of 130 m and more.

While hub height varies depending on site-specific conditions, 6 to 8 MW offshore turbines typically reach 100 to 120 m; larger turbines in the 12 to 15 MW segment can reach hub heights of up to 150 m, driven by their larger rotor diameters and design optimizations for higher energy capture (own analysis based on The Wind Power EI, 2025).

Fig. 3: Blade length and hub height as a function of turbine power rating



Note: Own analysis based on The Wind Power database as of January 2025; 98 data points for blade length, 50 data points for hub height; for hub height, the average of the minimum and maximum value is used.

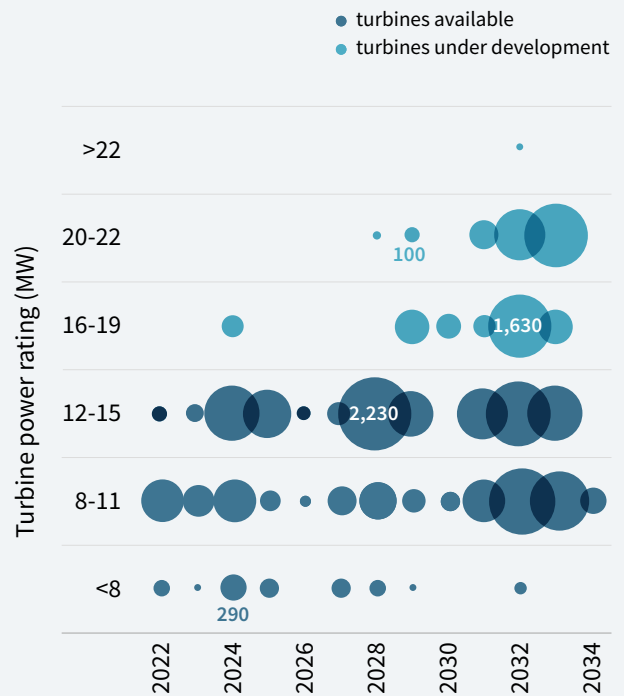
3. Evolutions in the wind sector with implications for logistics

Not all increases in turbine power ratings come with significant growth in physical size. Technological advances have enabled OEMs to boost the power output of existing turbine models; for example, models initially rated at 6, 8, or 12 MW have been upgraded to 11, 10, and 14 MW, respectively.

Our analysis of turbine choices for offshore wind farms under construction and in the planning stage, based on data from the Clarksons Renewables Intelligence Network (Clarksons Research, 2025), shows a continued shift toward larger turbines (see Figure 4). Projects scheduled for the upcoming years already feature turbines exceeding 15 MW, with some reaching up to 21 MW.

While smaller turbines may still be used—particularly in emerging offshore wind markets—their overall share is expected to decline. According to wind farm data from Clarksons Renewables Intelligence Network (Clarksons Research, 2025), turbines below 8 MW still accounted for over 60% of all bottom-fixed turbines in wind farms that began construction from 2020 to 2023 in PR China, and about 20% in the Rest of World. For wind farms starting construction between 2024 and 2030, data for PR China shows that turbines under 8 MW will comprise less than 4% of installations by unit count and less than 2% by capacity. In the Rest of World, these turbines still make up approximately 11%—mainly driven by emerging offshore wind markets like Vietnam. Overall, this size segment contributes less than 4% of the planned GW installations. It is important to note that the dataset may not be fully representative: data on Chinese wind farms seems under-represented given the country’s large share of global offshore capacity additions; data for later years is likely incomplete across regions. Nonetheless, the available information reflects the industry’s general direction.

Fig. 4: Wind turbine sizes in ongoing and planned offshore wind farm construction



Note: Number of wind turbines per size segment in offshore wind farms under construction and planned over the year of construction start.¹ Own analysis based on data from Clarksons for 76 offshore wind farms under construction and in pre-construction phase with start-up date up to 2033, in North America (8), Latin America (7) Europe (43), APAC & CIS excl PR China (15), PR China (1).

¹ Construction start per wind farm is not indicated for all wind farms in Clarksons. As a proxy, we use the scheduled commissioning year and reduce it by the median duration from construction start to commissioning derived from available datasets for the two regions and with construction start in 2015 at the earliest and commissioning in 2025 at the latest.

3. Evolutions in the wind sector with implications for logistics

3.2. Technical and procedural innovations beyond turbine size

Ongoing improvements in procedures and technologies are expected to increase the efficiency of both wind turbine components and the related logistics for transport, installation, operation, and maintenance. Regarding component innovations that may also influence logistics, modular nacelle designs and bolted blade connections stand out as notable examples. Modular nacelle designs are gaining ground for larger turbines and provide benefits in transportation, assembly, maintenance, and upgradability. Simultaneously, research in blade design is progressing in several areas. One particularly promising—though still early-stage—innovation involves new bolted connections, which could allow for longer blades without increasing the diameter of the blade root. While this technology has significant potential for onshore wind, where blade transport limitations are more critical, it could also benefit offshore applications by reducing component weight and easing assembly at sea. Regarding equipment for installation, maintenance, and

decommissioning, the growing use of turbine-mounted or self-erecting cranes can help reduce dependence on large conventional cranes. While the deployment of these cranes has been successfully demonstrated in onshore wind, their use in offshore wind with larger turbine sizes and more complex working conditions is still under development. There, these cranes promise to reduce reliance on installation vessels, weather conditions, and, in the case of floating wind, costly tow-to-port maintenance activities.

Innovations can drive efficiency— with logistics on board.

In operations and maintenance, robotics, artificial intelligence, and the Internet of Things all help increase efficiency, including in logistics. Using human on-site intervention only as a last resort helps protect workers' health and safety and limits



SOURCE: CORLAFFRA/SHUTTERSTOCK.COM

3. Evolutions in the wind sector with implications for logistics

vessel use, thereby lowering maintenance costs. Among robotic solutions, visual inspection drones and climbing robots for inspection, repair, and data collection are increasingly employed; unmanned and autonomous underwater vehicles, which can stay at the wind farm site with minimal shuttling, can examine substructures, mooring lines, and power cables.

Finally, digital modeling and digital twins of wind farms support decision-making for interventions and improve operational efficiency throughout the wind farm's lifespan. Early detection of potential failures and better inspection coordination also positively impact the planning and logistics of maintenance.

3.3. Standardization and harmonization of wind equipment

Greater standardization and harmonization in offshore wind can greatly improve the efficiency of transport and installation logistics. In the highly specialized maritime offshore wind supply chain, standardizing and harmonizing wind turbine components can help optimize vessel use and decrease port-side handling times.

Greater standardization and harmonization can make the value chain and its logistics faster and cheaper.

Wind turbine components often differ significantly in size, weight, and interface design, even within similar power rating categories. This variation

requires vessel operators and port terminals to adjust sea-fastenings, lifting gear, and deck arrangements from one project to another, leading to inefficiencies such as reduced fleet flexibility, increased idle time, more complex logistics, and ultimately higher costs. Standardization and harmonization could improve compatibility between OEMs and logistics providers, enabling better predictability and faster turnarounds. Some efforts to harmonize handling equipment are underway, but more comprehensive initiatives are still needed; progress varies across regions and turbine manufacturers. Coordination among OEMs, vessel designers, port operators, and regulatory agencies promotes effective standardization. However, offshore wind must also consider regional differences, and balancing global standards with site-specific adjustments is essential.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

The following analysis examines whether the installation vessel fleet, as one critical element of the offshore wind supply chain, would have been capable of delivering the announced offshore wind additions; the performance levels it can actually achieve in response to different installation demands; and the required fleet expansion under different capacity growth scenarios. It concludes with a high-level outlook on potential evolutions beyond 2030.

4.1. Approach and assumptions

4.1.1. Offshore wind energy growth scenario and market split

The wind energy ambition of 3,540 GW of installed capacity in 2030 includes a 500 GW share of offshore wind; this represents an increase of over 420 GW, more than six times the 74 GW installed in 2023. In the 2050 climate scenario, offshore wind should reach 2,500 GW, necessitating an additional 2,000 GW of capacity additions from 2031 to 2050.

To reflect the current split of the offshore wind installation market and the installation vessel fleets (also see 2.3), the analyses divide the global market into two large offshore wind energy markets: the PR China market on one side, and the Rest of World market on the other.

Over the last decade, PR China has taken significant steps to build its national wind energy value chain and has installed wind capacity at record levels. Accounting for onshore and offshore wind together, the country is home to 40% of global wind installations; in offshore wind, it represents 50% of global installations. Within the APAC region alone, PR China accounted for over 90% of offshore installations at the end of 2023. In 2021, over 17 GW of the global 20 GW of offshore additions were installed in PR China; this is four times the typical yearly average capacity addition in the Rest of World. In projections for 2030, the IEA estimates that 60% of renewable capacity will be installed in PR China (IEA, 2024). For this scenario, we therefore assume

that PR China will own 55% of globally installed offshore wind capacity, and that 45% fall to the Rest of World.

This scenario assumes that, by 2030, PR China and the Rest of World will share global offshore wind capacity at 55% and 45%, respectively.

To focus on vessels for bottom-fixed installations, assumptions about the distribution between bottom-fixed and floating installations are necessary. For 2030, in line with GWEC's estimates (GWEC, 2024), the analysis assumes that 8 GW could come from floating wind. It remains unclear whether the floating wind technology can mature and expand from 246 MW in 2024 to this scale. Yet, and despite persisting technological challenges, 14 GW floating wind are announced to go online by the end of 2030 (Clarksons Research, 2025).

Based on the assumed regional split, the Rest of World would then have to reach about 219 GW of bottom-fixed offshore wind in 2030, and PR China would have to reach 272 GW, the remaining 55%. Both regions start at about 37 GW of installed bottom-fixed offshore wind in 2023. The Rest of World would thus require total additions of 183 GW, resulting in yearly average additions of about 26 GW over the period 2024 to 2030; this compares to

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

yearly average additions in the preceding years of about 3 to 4 GW. PR China would need total additions of 235 GW, with annual average additions of close to 34 GW. Even though the country delivered installations of 17 GW in 2021 alone and has seen annual average additions of 8 GW over the period 2020 to 2023, the stretch is significant.

This market split also reflects the market structure in installation services: while only the PR China vessel fleet serves its home market, the fleet has limitations regarding its ability to operate internationally. Thanks to its classification, the Rest of World vessel fleet is better positioned to access international markets. However, the analyses do not account for the fact that national regulations can restrict the deployment of foreign-flagged vessels (see 2.3), and that, therefore, the Rest of World market is not a truly single market.



SOURCE: CORLAFFRA/SHUTTERSTOCK.COM

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

It seems reasonable to assume that this dual-market structure in offshore wind installation logistics will continue, at least in the near term. Although the medium- to long-term developments beyond 2030 remain uncertain, we also use this market division for the period 2031 to 2050 for consistency. However, this assumption is not meant to predict that separate markets will always exist.

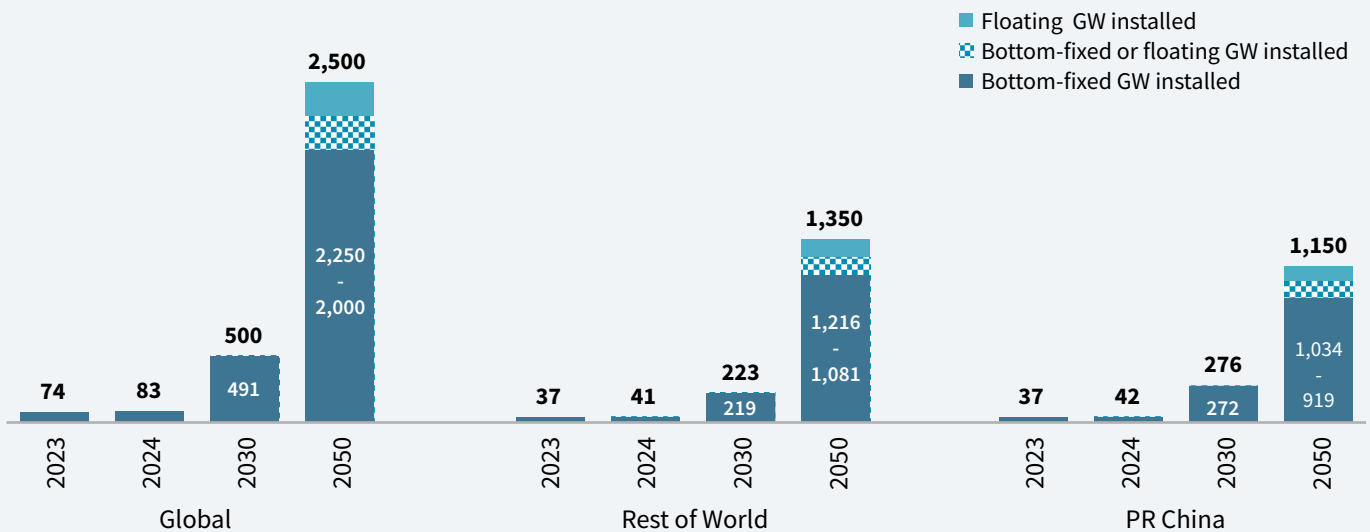
By 2050, the scenario assumes that the Rest of World will have a 55% share of installed offshore wind capacity.

For 2050, we assume that the Rest of World accelerates offshore wind deployment and therefore allocate about 55% of the global offshore capacity to the Rest of World and 45% to PR China; this results in around 1,350 GW and 1,150 GW, respectively.

Estimating the contribution from floating wind is difficult, and we therefore use ranges for both technologies. Building on DNV's estimates (DNV, 2022) that floating wind could account for 15% of offshore wind by 2050, we allocate about 10% to 20% of the total installed capacity to the technology, that is, 250 to 500 GW. Bottom-fixed offshore wind would then contribute between 2,000 GW to 2,250 GW.

Figure 5 shows the 2030 ambition of 500 GW offshore wind and the 2050 climate targets as distributed in this scenario modelling.

Fig. 5: Assumed regional distribution of global offshore wind capacity in bottom-fixed and floating installations towards the 2030 ambition and 2050 climate targets



Note: Historic data from IRENA (2025)

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

4.1.2. Wind turbine size

Wind turbine size is an essential factor in determining the number and technical specifications of logistics equipment and vessels required for the to-be-installed offshore wind capacity (see 2.1 and 3.1). For this analysis, assumptions about future turbine sizes are made, and turbines are grouped into four

size segments based on their power ratings; these are labeled as lower-, medium-, upper-, and super-size segments (see Figure 6). For each segment, an average turbine power rating across the turbine fleet, by size segment and period, is assumed. To reflect anticipated near-term developments, we use a more incremental increase in turbine size from 2024 to 2030.

Fig. 6: Defined offshore turbine size segments per installation period

turbine size segment	turbine MW range	2024-2030			2031-2050	
		turbine fleet average MW			turbine MW range	average MW
		2024-2025	2026-2027	2028-2030		
super	NA	NA	NA	NA	32-48	40
upper	21.5-24	NA	NA	22	21.5-28	26
medium	12-19	13.5	15	15	14-19	17
lower	8-11	9	10	10	8-11	10

The assumptions about turbine sizes of the lower- and medium-segment are grounded in real-world trends. Turbines in the upper-size segment are still in testing and, as of 2025, are not yet commercially available. The super-size turbine segment is a forward-looking assumption based on expected technological advances; it becomes relevant only in the 2031 to 2050 period of our scenario. Technological progress in this later period is also reflected in the phase-out of the lower-size turbine segment and a shift toward higher average power ratings within

each segment. With the declining role of turbines below 8 MW (see 3.1), the analysis excludes this turbine size segment.

Particularly for the period 2031 to 2050, it is difficult to make assumptions about technological evolution and turbine size choices. The analysis of this period can therefore only be indicative and is primarily intended to raise awareness of the need to use forward-looking planning tools and update their assumptions regularly.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

4.1.3. Technical vessel requirements and deployment strategies

The analysis focuses on HLVs and WTIVs in the context of foundation and turbine installation for the above-mentioned turbine size segments. Vessels listed in the Clarkson's Renewable Intelligence Network (Clarkson's Research, 2025) in the categories "WTIV" and "Heavy-Lift / Crane Unit", existing and on order, served as the basis for the analysis. In line with the assumptions regarding future turbine sizes, vessels suitable only for the installation of turbines and their foundations below 8 MW are excluded from the analysis.

Vessel requirements

The vessel fleets are assessed for their technical capability to install the defined turbine size segments based on two key factors: crane lift capacity and crane hook height (see Figure 7); other factors,

such as leg length, deck strength, space, and layout, were not considered. The fleets were assessed based on information available in Clarkson's Renewable Intelligence Network (Clarkson's Research, 2025). Even though the requirements for installing wind turbines in the lower- and medium-size segment are based on experience, they remain subject to many factors and can vary from case to case. The upper-size turbine segment has no practical installation experience yet, but the first turbines and vessel designs exist and provide the basis for our assumptions. Given the significant uncertainties that remain for the super-size segment, we refrain from making assumptions about vessel requirements and assume that none of the existing or ordered vessels are suitable.

Lastly, our scenario assumes that all turbines use monopile foundations, the dominant foundation type, which is reflected in the vessel requirements for foundation installation.

Fig. 7: Assumptions on vessel requirements to install the defined turbine size segments

turbine size segment	turbine MW range	turbine installation (only WTIVs)		foundation installation (HLVs and WTIVs)	
		hook height above deck (m)	lift capacity (t)	hook height above deck (m)	lift capacity (t)
super	32-48	NA	NA	NA	NA
upper	21.5-28	≥ 150	≥ 1,900	≥ 110	≥ 3,500
medium	12-19	≥ 130	≥ 1,200	≥ 100	≥ 2,500
lower	8-11	≥ 100	≥ 900	≥ 90	≥ 1,500

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Vessel utilization rates

For the analysis of vessel installation capacity, three vessel utilization rates were established: a high rate of 80% (292 productive vessel days per year), an average rate of 72.5% (265 productive vessel days per year), and a low rate of 65% (237 productive vessel days per year). In practice, vessel utilization rates are influenced by various factors, some less controllable, such as extended downtime due to repairs, adverse weather, or delays caused elsewhere in the supply chain that result in vessel idle time; other factors affecting vessel utilization relate to coordination within the project and the overall market, including project sequencing, vessel allocation to projects, and time lost during inter-regional transit.

Vessel days for installation

For the duration of the installation work, we assume that foundation installation requires, on average, three active vessel days and turbine installation requires four active vessel days; both include vessel mobilization and a minimum delay for various reasons. The assumptions are based on industry experience collected for this analysis.

Vessel deployment strategies

The modelling of the vessel fleets' installation capacity uses a combination of three assumed vessel deployment strategies: First, turbine installation is carried out exclusively by WTIVs; HLVs are used only for foundation installation. Second, WTIVs with suitable specifications are deployed for foundation installation only once HLVs' capacity is fully utilized. Third, vessels prioritize installing turbines in the largest size segment they can support and shift to

smaller segments only when no further installations are possible in their primary segment. For example, a high-capacity HLV will cease installing foundations in its highest segment if no WTIVs are available to complete turbine installation in that segment. In line with the second deployment strategy, the HLV will then support foundation installation in a lower turbine size segment—as long as turbines there can be completed by respective WTIVs. Similarly, WTIVs work in their highest possible turbine segment until no vessels (WTIVs or HLVs) are available to provide the required foundation installation or, if that happens earlier, until all market demand for the installation of this turbine segment has been served. The WTIV may then shift to installing smaller turbines or foundations in a size segment for which it has sufficient capabilities.

Together, these deployment strategies result in installing the largest number of turbines in the largest possible turbine size segment and enable vessels to deliver the largest possible number of GW additions—within the limits of market demand (also see 4.1.4).

The second and third vessel deployment strategies are rather optimistic, as it would require both full market transparency and coordinated collective action aimed at maximizing overall GW installations across markets. In contrast, in a real market with competing market actors and national interests, a certain degree of intransparency, and a lack of mechanisms and incentives to optimize installation activities toward the highest collective result in terms of GW installed, stakeholders are likely to pursue strategies that optimize their own outcomes.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

4.1.4. Wind turbine installation scenarios

In our scenario analysis for 2024 to 2030, we model and test the fleets of HLVs and WTIVs, existing and all vessels on order, regarding their installation capacity under several scenarios:

The **Theoretical Supply-Driven Scenario** starts from the vessel fleet; its results express the fleet's installation capacity when free to build an unconstrained number of turbines across all size segments—always in line with the vessel deployment strategies laid out above.

This scenario is bound to result in the maximum amount of GW the vessel fleets could theoretically install. It remains theoretical in three respects: First, it ignores market preferences for specific turbine sizes by assuming that vessels install turbines in the largest possible size segment. Second, the total GW capacity the fleets could install includes, in retrospect, the amount that could have been installed since 2023 (when the 2030 ambition was announced), accounting for time that has already passed. Third, the offshore wind turbine installations planned for the next few years are already committed: Project development—from planning to construction—has historically taken anywhere from about three to eight years, with PR China on the shorter end and other markets in the middle to upper range. This means that, in the near term, vessels' installation capacity can only limit planned installations if vessel capacity is below these projections. Still, excess vessel capacity beyond planned installations cannot increase these. Therefore, this scenario illustrates the GW installations that vessels could achieve in the near term if past planning had been aligned accordingly.

The **Best-Case Supply-Driven Scenario** accounts for these timing constraints, which were ignored in the Theoretical Supply-Driven Scenario. Like the latter, the Best-Case Supply-Driven Scenario starts from the vessel fleets' capabilities but caps the market in the near term at the number of GW actually scheduled;

values are based on commissioning dates as listed in Clarksons Renewables Intelligence Network (Clarksons Research, 2025). To acknowledge that data, especially for PR China, may be incomplete, our scenario adds an extra 20% to the country's scheduled capacity additions for the constrained period; for the Rest of World, where information tends to be more easily accessible, we still factor in an extra 5% of the announced commissioning to account for potentially missing data.

The supply-driven scenarios start from the capabilities of the vessel fleets and thus result in the highest possible GW installations the fleets can deliver.

With the optimistic assumptions that wind farm project preparations can be accelerated, this 'real-world cap' is removed from the start of 2028 for the Rest of World and from the start of 2027 for PR China, due to the country's demonstrated ability to fast-track projects. This means that wind farms currently not yet in a visible planning stage could begin construction in 2028 or 2027, respectively. From those years forward, vessel availability is the only constraint considered in the scenario to model potential capacity additions. While we purposefully use the above supply-driven scenarios to identify the vessel fleets' maximum installation capacity, the market typically begins by selecting turbines and only then seeks suitable vessels. This market behavior is modeled in the **Demand-Driven Scenario** and its different variations. This scenario aims to capture the impact of pre-selecting turbines on the vessel fleets' maximum installation capacity. To simulate demand for turbine installation, we use the maximum amount of GW the vessel fleets could technically install (as results from the Supply-Driven Scenario) as the target value for capacity additions in a given year and then break down the overall GW target into different turbine fleet compositions (details are provided

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

along with the results under 4.2.2). By setting the overall demand in terms of GW to be installed at the fleets' theoretical maximum, the scenario avoids artificially constraining vessel activity due to weak demand on the one hand; on the other hand, it sets a limit to an otherwise too large or infinite market where vessels could, again, choose projects based on their preferences and with no limiting impact on their aggregate performance. The vessel deployment strategies remain unchanged, meaning that, within the constraints of the demand-driven scenario, vessels operate to produce the best possible result.

The demand-driven scenarios start from the wind turbine fleet composition that vessels are expected to install, thereby capturing the effect of misalignments between demand and supply.

All scenarios are modeled for two possible near-term developments in wind technology: one, where turbines in the 20 to 24 MW range—currently still in development—begin construction in 2028; and two, where this turbine size segment remains unavailable for construction throughout the entire period from 2024 to 2030.

In all scenarios, we simplify the actual sequence of wind farm construction and assume that foundation installation, wind turbine installation, and commissioning can occur in the same year. Given that, for example, wind farms in the range of 40 to 60 turbines take on average 680 days or 1.8 years from construction start to commissioning in Europe and 560 days or 1.5 years in PR China (Clarksons Research, 2025), this assumption brings forward a certain amount of GW additions and hence slightly overestimates the amount of turbines and GW installed by the end of 2030.

4.1.5. Vessel and investment needs

To estimate the number of additional vessels that would be required under different capacity addition scenarios, we assume all extra vessels will be able to install turbines in the specified upper-size segment (see 4.1.2), and that delivery takes two to two and a half years. This means that, with immediate orders, vessels could be delivered by early 2028. Since delivery times for vessels have been longer in the past, these estimates are optimistic but still possible (see 2.1).

Newbuild prices for WTIVs and HLVs are barely available in the public space; plus, only a few vessels of the latest generation of WTIVs have so far been built. Also, prices vary considerably between vessels built in PR China for the Chinese market, vessels built in PR China for the Rest of World, and according to international standards, and the very low number of vessels built outside PR China for the Rest of World (see 2.1 and 2.3). This further diminishes the already scarce basis for pricing information across the different markets. Some publicized newbuild prices, like the escalated cost of over USD 700 million of the US-compliant WTIV Charybdis (Offshore Energy, 2024), significantly exceed the reported newbuild prices of USD 325 to 400 million for WTIVs with a similar turbine installation capacity and built in Asia for the European market (Cadeler, 2024; Marinelog, 2021). WTIVs built for the Chinese market can be cheaper than those for the international market, among others, due to lower classification requirements. Overall, price differences reflect differences in vessel specifications and compliance requirements, local shipbuilding costs, and shipyard experience. As with delivery time, the emergence of more standardized designs and greater shipyard experience can positively affect vessel prices. At the same time, higher specifications that anticipate further turbine size growth can drive up vessel prices.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

For HLVs suitable for the offshore wind sector, the publicly available pricing data is even more limited, and our estimates rely on information received from shipbuilding experts.

Based on the preceding, we use newbuild prices for WTIVs capable of installing the upper-size turbine segment of USD 480 million for the Rest of World fleet and USD 400 million for the PR China fleet. High-capacity HLVs for foundation installation in the upper-size turbine segment are here priced at USD 280 million for the Rest of World fleet and at USD 220 million for the PR China fleet.

It should be noted that these price estimates are subject to significant uncertainties, which are further influenced by broader market factors such as overall demand for shipbuilding, fluctuations in steel prices, and choices regarding fuel systems and compliance technologies.

An overview table of the assumptions and input data with their sources can be found in the annex.



SOURCE: I AM FROM MYKOLAYIV/SHUTTERSTOCK.COM

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

4.2. Vessels fleets' installation capacities

4.2.1. Available WTIVs and HLVs

At the beginning of 2024, just after the 'Triple Up, Double Down' pledge was announced and suggestions for a share of 500 GW offshore wind energy were made, the global vessel fleet for the installation of offshore wind turbines and their foundations in the defined turbine size segments (see 4.1.2) comprises 86 vessels: 47 WTIVs and 39 HLVs (Clarksons Research, 2025).

As shown in Figure 8, the Rest of World fleet then counts 26 vessels; it comprises more WTIVs than HLVs, and over 70% of the fleet can install turbines of the medium- and upper-size segment. In comparison, the more than twice as large PR China fleet of 60 vessels comprises an almost equal number of WTIVs and HLVs; more than half of the fleet is suitable only for installations in the lower-size turbine segment.

The PR China fleet of wind installation vessels, WTIVs and HLVs, is more than twice as big as the Rest of World fleet.

The orderbook for WTIVs and HLVs (Clarksons Research, 2025) indicates, as of March 2025, that all vessels at that time on order will be delivered by the end of 2027, and thus be available to the market by the beginning of 2028 at the latest. From 2028 onwards, when the entire orderbook will have been delivered, further growth of the vessel fleet would require new vessel orders in the near term.

Between the beginning of 2024 and 2028, 42 vessels on order are scheduled for delivery, bringing the total fleet to 128 WTIVs and HLVs. This equals a

global fleet growth of almost 50%. 15 vessels will be added to the Rest of World fleet, a plus of close to 60% compared to the fleet's size beginning of 2024; 27 vessels will be added to the PR China fleet, a plus of 45%.

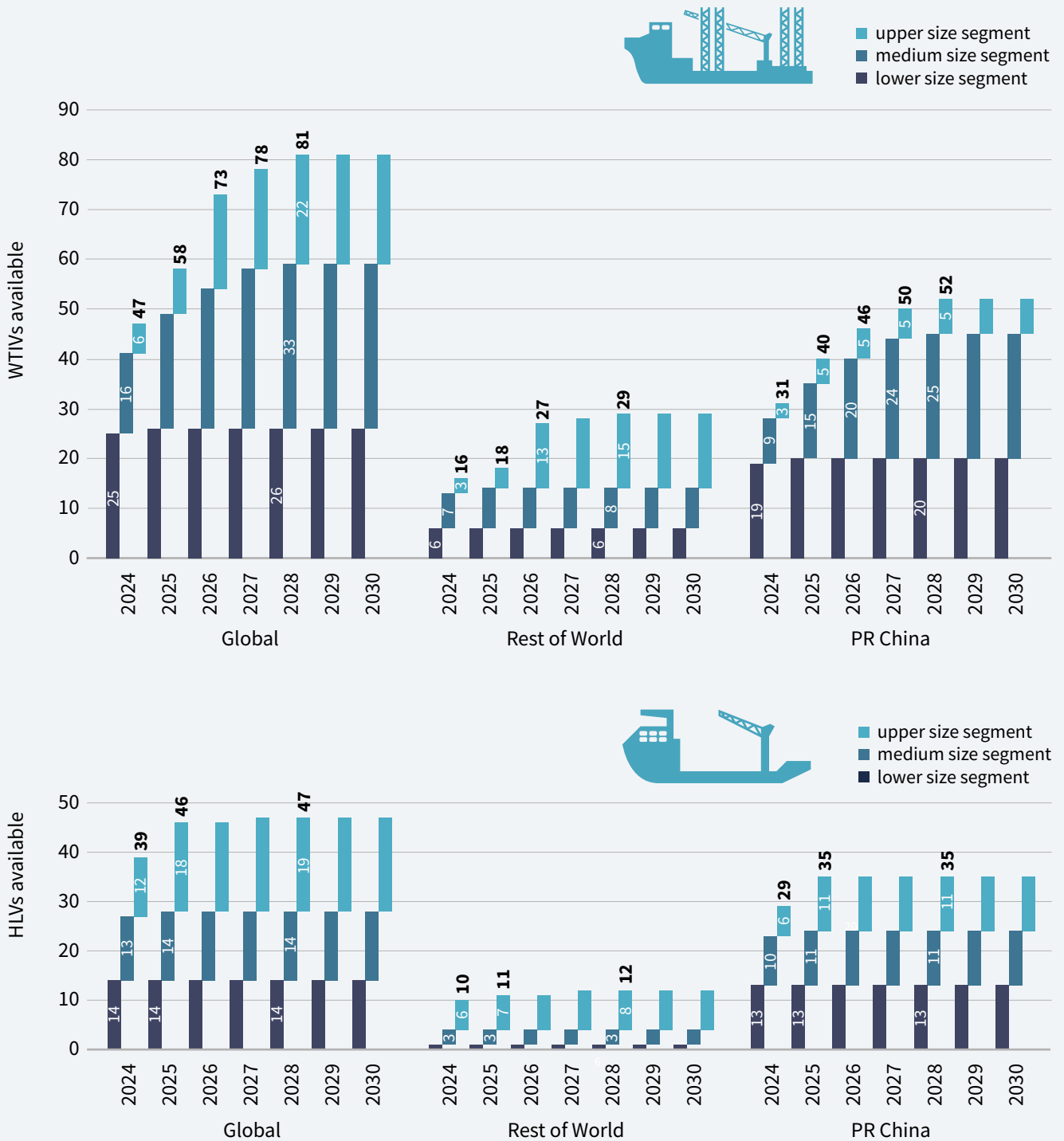
Between 2024 and 2028, the global wind vessel fleet is expected to grow by 50%.

Most growth in the Rest of World fleet occurs in the segment suitable for installing larger turbines; in 2025 alone, nine high-capacity WTIVs are scheduled for delivery. PR China gradually expanded its WTIV fleet during this period, focusing on WTIVs for the medium-size segment. Unlike in the Rest of World fleet, where numbers of HLVs stagnate, PR China adds six new HLVs to its fleet in 2025, five of which are suitable for supporting foundation installation for turbines in the larger-size segment. Globally, WTIV deliveries are set to peak in 2025 with 15 vessels. The highest annual addition of HLVs during this analysis occurred in 2024, with 7 vessels. In total, 35 shipyards build the WTIVs covered in this analysis, and 33 shipyards build the HLVs. Accounting for shipyards that build both types of vessels, we find 56 shipyards with offshore wind vessel experience.

The PR China fleet comprises a larger share of vessels that can only install turbines in the lower-size segment. The Rest of World fleet is more aligned for the installation of upper-size turbines.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Fig. 8: Availability of WTIVs and HLVs with the required specifications per region



Note: Own analysis based on vessel data from Clarksons Renewables Intelligence Network (Clarksons Research, 2025) as of March, 2025. Vessels are labeled only once and according to their priority task (foundation installation for HLVs, turbine installation for WTIVs).

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

4.2.2. Vessel fleets' installation capacity in the period 2024 to 2030

Supply-Driven Scenarios (for details, see 4.1.4)

In the **Theoretical Supply-Driven Scenario A** with turbines of the upper-size segment coming to the market in 2028 and ignoring real-world constraints in the near term (also see 4.1.4), the accumulated installed capacity at the average vessel utilization rate reaches 492 GW of bottom-fixed offshore wind globally—coincidentally, the same amount of GW as expected under the 2030 ambition (also see 4.1.1). With a high vessel utilization rate of 80%, the ambition could even have been surpassed by 43 GW, almost 10% (see Figure 9, upper graph).

The global vessel fleet could have delivered 492 GW bottom-fixed wind energy installations by 2030—if more wind farms had started preparations earlier and if turbines of the upper-size segment become available at scale by 2028.

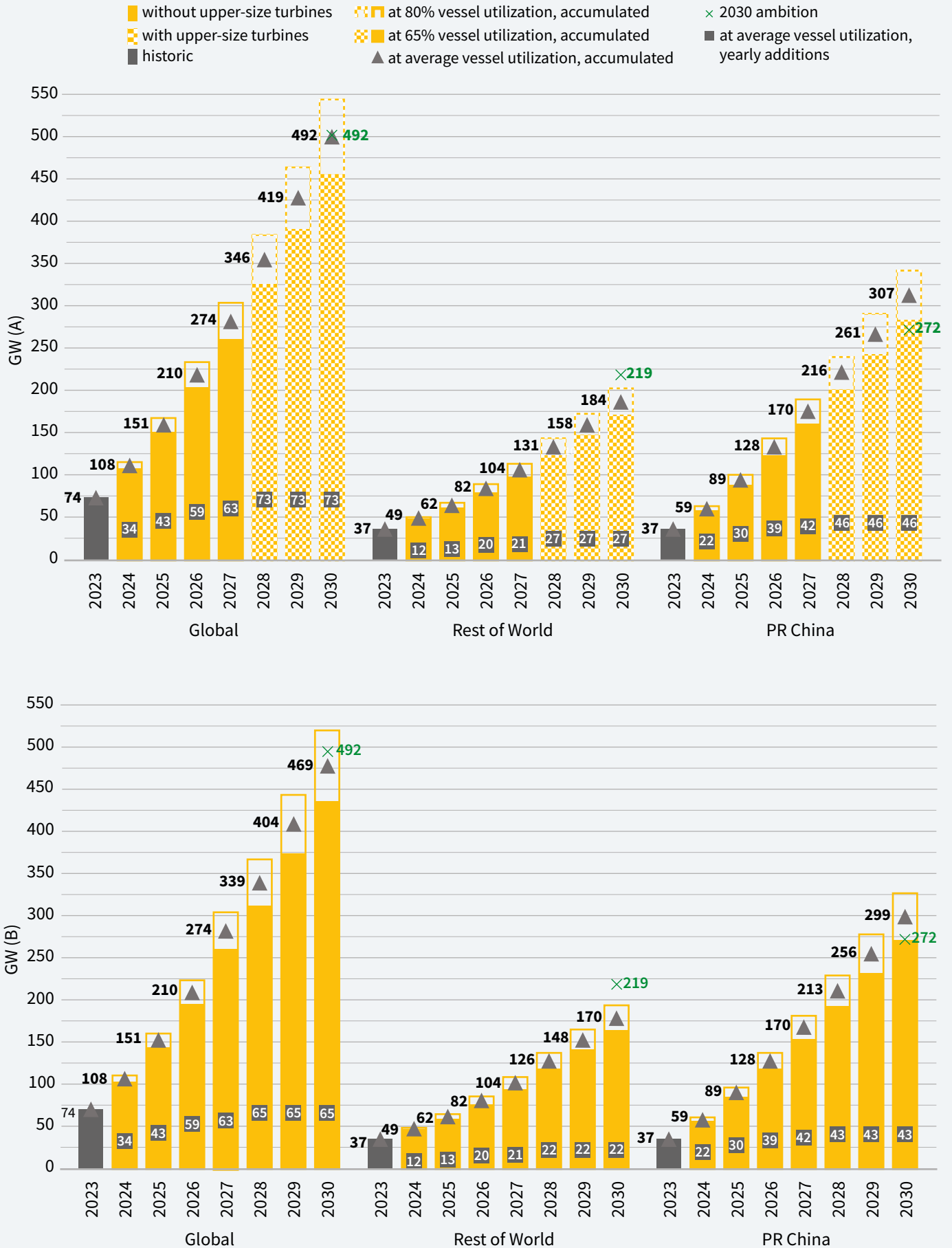
The Rest of World vessel fleet falls slightly short of its assumed share in this scenario and reaches, with average vessel utilization, 184 GW, 16% less than the

required 219 GW. The PR China fleet overperforms, delivering 307 GW at average utilization, 35 GW or 13% more than its assumed share of 272 GW in the 2030 ambition. Ignoring all other market factors, the PR China fleet has about 67% more theoretical installation capacity than the Rest of World fleet.

In the **Theoretical Supply-Driven Scenario B** without the upper-size turbine segment coming to the market in 2028 (see Figure 9, lower graph), the accumulated capacity the vessel fleet can at best deliver, at average utilization rate, reaches 469 GW globally, 23 GW or about 5% less than in scenario A with upper-size turbines. However, the differences vary significantly between the two regions: for the Rest of World fleet, the yearly possible additions for 2028 to 2030 fall from 27 GW to 22 GW, a minus of 19%. For PR China, yearly possible additions fall from 46 GW to 43 GW, a minus of only 6%. In this scenario, without upper-size turbine segments coming to the market, the theoretical installation capacity of the PR China fleet is 76% larger than that of the Rest of World fleet.

The unavailability of turbines in the upper-size segment throughout 2030 limits the Rest of World fleet's installation potential significantly more than that of the PR China fleet.

Fig. 9: Vessel fleets' installation capacity in the Theoretical Supply-Driven Scenarios A (upper) and B (lower)



Note: 2023 values are historic, values for 2024-2030 result from our modelling.

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The GW additions that the vessel fleets can deliver result from the number of turbines they can install, overall, and per size segment. At an average vessel utilization rate, the two regional vessel fleets could install around 3,000 turbines in 2024; the Rest of World fleet could install close to 1,000 turbines, about half the amount of the PR China vessel fleet's installation capacity of over 2,000 turbines. As the vessel fleets grow toward 2028, they achieve a combined installation capacity of 5,000 turbines, an increase of 60% (see Figure 10). In the case of PR China, growth in turbine installation capacity reaches 60% and exceeds the growth of the vessel fleet by about 45% (see 4.2.1); this is due to the over time improving complementarity of the WTIV and HLV fleets.

From 2024 to 2028, the global turbine installation capacity expands by around 60%.

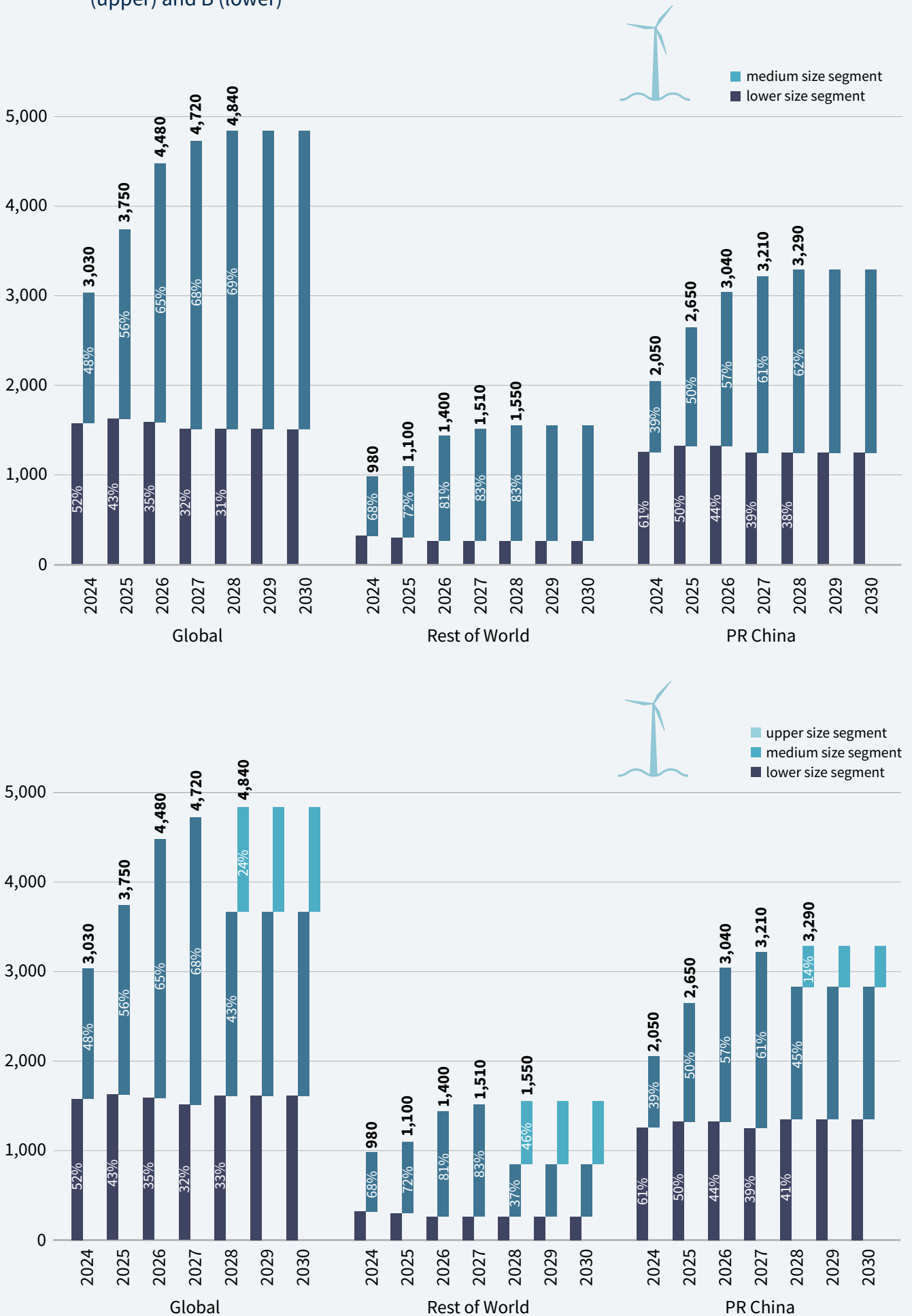
If the upper-size turbine segment comes to the market in 2028, as in scenario variation A, high-capacity vessels that until then work in the medium-size turbine segment would switch to installing

larger turbines. The Rest of World fleet, whose technical specifications are much more aligned to the installation of larger turbines, could then install over 700 turbines in the upper-size segment, representing 46% of its total turbine installation capacity. The PR China fleet could only install around 460 turbines in this segment, representing only 14% of its installation capacity.

If the upper-size turbine segment does not come to the market, as in scenario variation B, and the vessel fleets cannot make use of their full capabilities, the share of turbines installed in the medium-size segment remains high with 83% in the Rest of World; in PR China, the medium-size segment remains moderate at 62% as more vessels are suitable for the lower-size turbine segment.

If the upper-size turbine segment comes to the market in 2028, the Rest of World fleet could dedicate almost half of its installation capacity to this segment; the PR China fleet only 14%.

Fig. 10: Turbine fleet composition resulting from the Theoretical Supply-Driven Scenarios A (upper) and B (lower)



Note: Numbers of turbines installed by the two regional vessel fleets if turbines are selected based on vessel fleet capabilities (Supply-Driven Scenario). Total numbers are rounded to 10. Numbers indicated per size segment is the percentage of all turbines installed per year.

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In the **Best-Case Supply-Driven Scenarios**, wind farm construction in the near term is constrained based on actual wind farm data from Clarksons Renewable Intelligence Network (Clarksons Research, 2025), and as described under 4.1.4. For the years 2024 to 2027, offshore wind additions in the Rest of World are then expected to reach 40 GW, 27 GW, or 40% below the vessel fleet's theoretical installation capacity for this period. Based on available wind farm data and with a top-up of an additional 20%, PR China remains 64 GW below its vessel fleet installation capacity over the years 2024 to 2026 and uses less than a third of its theoretical potential.

The gap between the constrained results and the theoretical vessel potential can partly be explained with the lower average power rating of turbines: real-world data from Clarksons indicates an 11 MW average per turbine installed over the constrained period in the Rest of World, whereas the vessel fleet in the Theoretical Supply-Driven Scenario would install turbines with an average of 13.3 MW. For PR China, the average turbine size for wind farms with a start-up date in the constrained period 2024 to 2026 is 10.8 MW, whereas the scenario vessel fleet would install turbines of 11.7 MW on average. The remaining difference is due to the lower overall number of turbines that is expected to be installed compared to the vessel fleets' here identified theoretical capacity. While this suggests that a certain number of vessels face idle times, especially the more versatile HLVs may take on work outside the wind sector. Also, inefficiencies in allocating vessels to projects and project delays may camouflage the full extent of the vessel fleets' unused installation capacity. Despite this, developers may still struggle to find the right vessels for installing a specific turbine size segment at the designated location and time.

In the **Best-Case Supply-Driven Scenario A** with the upper-size turbine segment coming to the market in 2028 (see Figure 11, upper graph), the Rest of World achieves 155 GW in 2030 at average vessel

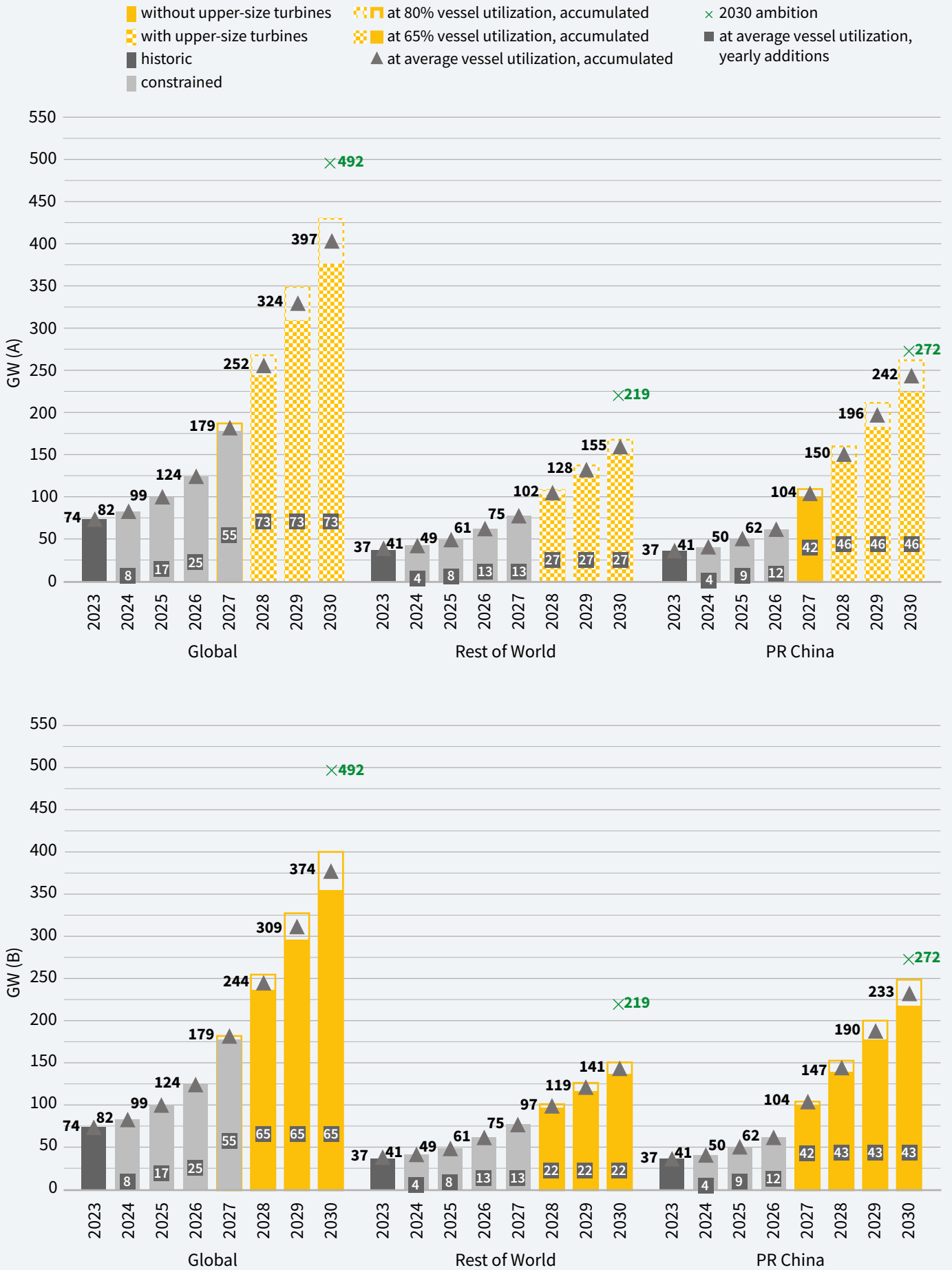
utilization, 15% less than in the unconstrained Theoretical Supply-Side Scenario A and 64 GW or 30% below the 2030 ambition. PR China reaches 242 GW, about 20% less than in the unconstrained Theoretical Scenario, and about 10% below the 2030 ambition. As a result, both markets remain below their assumed contributions. Global installed bottom-fixed capacity reaches 397 GW, 95 GW, or 20% below the 2030 ambition.

The vessel fleets' theoretical installation capacity lies beyond the offshore wind capacity that will be added in the near term.

These numbers fall further in the Best-Case Supply-Driven Scenario B without the upper-size turbine segment (see Figure 11, lower graph); installations now reach 374 GW globally, 24% less than the 2030 ambition of 492 GW. In the Rest of World, the accumulated installation capacity reaches 141 GW, 14 GW or 10% less than with the upper-size turbine segment becoming available in 2028 and 35% below the 2030 ambition; the gap toward the 2030 ambition then reaches 78 GW. In PR China, where the vessel fleet is less aligned to the requirements of the upper-size turbine segment, the difference between the two scenarios is less significant: the country still achieves an accumulated 233 GW in 2030, only 9 GW or 4% less than in the scenario with the upper-size turbine segment, and 39 GW or 15% below the 2030 ambition.

The Rest of World fleet can at best achieve 140 to 155 GW, about 65% to 70% of its assumed contribution to the 2030 ambition. The PR China fleet can deliver 230 to 240 GW, 85% to 90% of its assumed share.

Fig. 11: Vessel fleets' installation capacity in the Best-Case Supply-Driven Scenarios A (upper) and B (lower)



4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Lastly, the findings show the impact of vessel utilization rates on achievable GW installations. For example, in the Best-Case Supply-Driven Scenario B years 2028 to 2030, an average vessel utilization rate results in yearly global additions of 65 GW. At a high vessel utilization rate of 80%, installation could achieve 72 GW; this is about 10% more than with the average utilization rate and a plus of 23% compared to the installations at a low vessel utilization rate.

Different vessel utilization rates impact the overall GW additions that can be installed.

With the scenario assumption that turbine installation takes a total of four days and foundation installation takes three days, a WTIV that installs 15 MW turbines would achieve 1.10 GW per year at a high utilization rate, and 0.99 GW or 0.89 GW, respectively, at average and low utilization rates. Vessels that install foundations for 15 MW turbines would achieve 1.46 GW, 1.32 GW, or 1.18 GW.



SOURCE: IMAGESOURCECURRED/ELEMENTS.ENAVATO.COM

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target







Demand-Driven Scenarios (for details, see 4.1.4)

Other than the above Supply-Driven Scenarios, which start with the vessel fleets' capacities to determine the maximum amount of GW they can install, the Demand-Driven Scenario starts with a defined wind turbine fleet that the market requests be installed. This scenario thus reflects a more realistic market in which turbines are selected first, and suitable vessels are identified afterwards.

The Demand-Driven Scenario and its variations illustrate the interaction between the total market demand for installing a given set of wind turbines and the vessel fleets' technical capacities.

The following analysis compares the vessel fleets' theoretical capacity as identified in the Theoretical Supply-Side Scenarios A and B (there, the vessel fleet could 'choose' the set of turbines that allow it to install the highest number of GW) with its installation capacity if tasked with the installation of a pre-defined set of turbines. These pre-defined sets of turbines differ in their shares of the defined turbine size segments (also see 4.1.4 for assumptions). As shown in Figure 12, six different turbine fleet compositions are tested, three with and three without the upper-size turbine segment coming to the market in 2028. For simplicity, the analysis uses only the average vessel utilization rate.

Fig. 12: Turbine fleet compositions tested in the Demand-Driven Scenario variations

Demand-Driven Scenario - Variations	color legend	% of turbines in fleet composition		
		lower-size segment	medium-size segment	upper-size segment
Demand 1A: 40-50-10 (as of 2028)		40	50	10
Demand 1B: 40-60-0		40	60	0
Demand 2A: 30-60-10 (as of 2028)		30	60	10
Demand 2B: 30-70-0		30	70	0
Demand 3A: 20-60-20 (as of 2028)		20	60	20
Demand 3B: 20-80-0		20	80	0

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Figure 13 shows the GW additions the two regional fleets can install at an average vessel utilization rate when tasked with installing the six different turbine fleet compositions per year, and the accumulated total by 2030.

Overall, as observed in the preceding analyses, the Rest of World vessel fleet has greater capacity to install turbines in the upper-size segment (also see Figure 10 in the above section) and can serve the simulated market demand for this turbine size segment across all scenario variations. However,

in variations without turbines in the upper-size segment and in those with a high share of lower-size turbines, the Rest of World vessel fleet remains well below its theoretical installation capacity; supply and demand are misaligned, and a considerable number of turbines simply do not get installed.

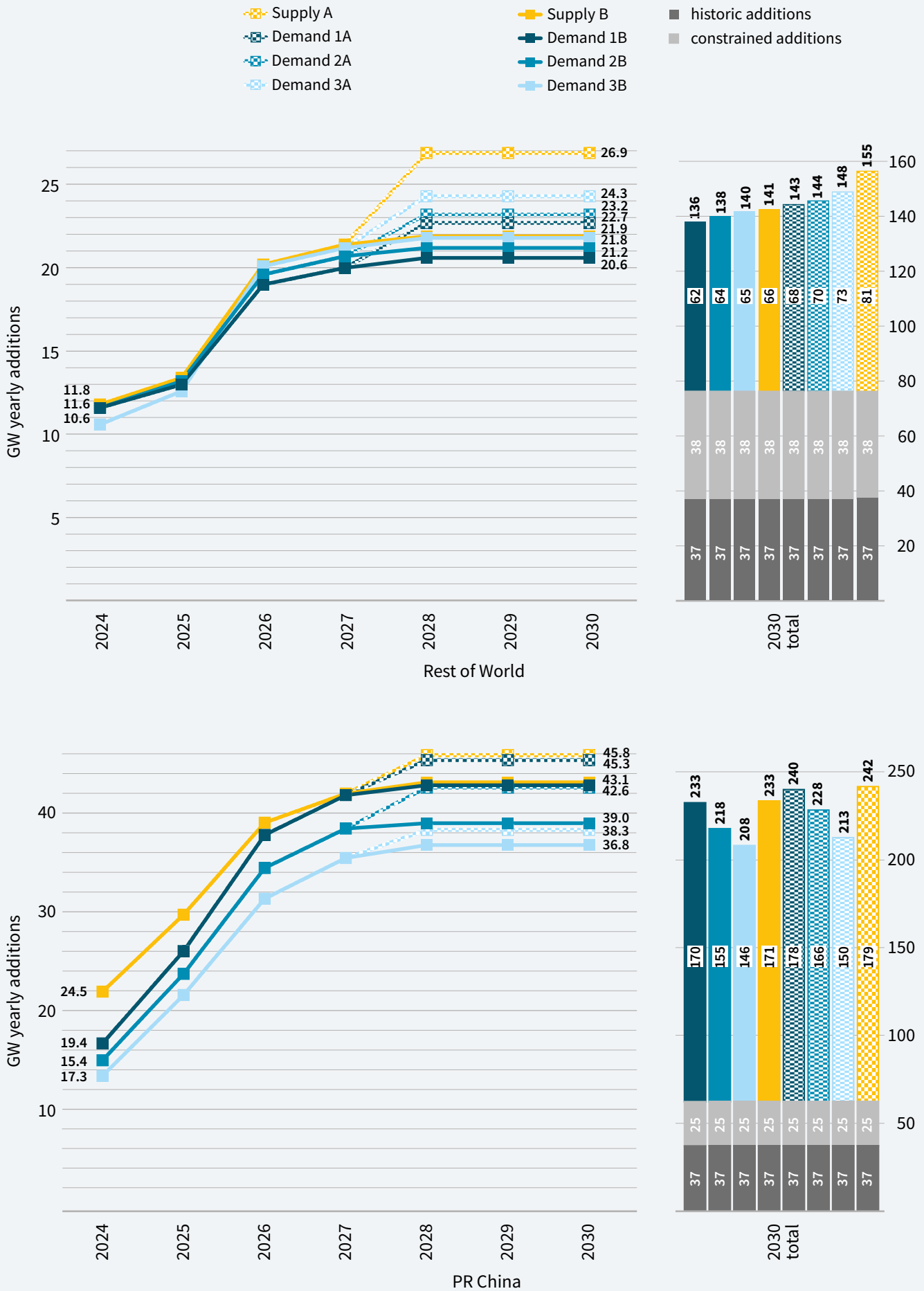
In contrast, the PR China fleet has limited capacity for installing turbines, particularly in the upper-size segment. It cannot fully meet the high market demand for their installation under the respective scenario variations. This not only leaves a certain number of turbines in these segments uninstalled; it also underutilizes the vessel fleet's large installation

capacity in the lower-size turbine segment, for which supply is considerably higher than market demand.

The analysis over time shows how changes in the vessel fleet's capabilities interact with market demand for turbine installation: as the vessel fleet's composition evolves throughout 2028, so does its optimal turbine fleet composition. For example, while Demand 3B with a large share of medium-size turbines was still unfavorable for the Rest of World vessel fleet in 2024, it becomes the most suitable turbine fleet composition in 2026, getting close to the vessel fleet's ideal turbine fleet composition as identified in the Supply-Side Driven Scenario.

The availability of turbines in the upper-size segment starting in 2028 improves the Rest of World's fleet performance considerably. As shown earlier, the fleet would perform best if it could install 47% of turbines in this segment. If the demand for the installation of these turbines remains at only 10% or 20%—as in Demand 2A and Demand 3A, and probably a more likely market share in the early days after their eventual introduction—the fleet's installation capacity drops from a possible 27 GW to 24 and 23 GW, respectively.

Fig. 13: Regional vessel fleets' possible yearly additions and accumulated GW in the different Demand-Driven Scenarios



4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

In the case of the PR China fleet, the Demand 3B variation, which scored best with the Rest of World fleet, yields the lowest yearly GW additions among the tested scenario variations; with 13.9 GW in 2024, it lies 37% below the vessel fleet's maximum capacity of 22 GW. In comparison, Demand 1B, which starts out with 17.5 GW in 2024, 21% below the vessel fleet's maximum installation capacity, gets very close to the vessel fleet's most favorable turbine fleet composition in 2027.

The introduction of the upper-size turbines improves the PR China fleet's performance only marginally, as few vessels can install them. But also here, the actual share that these turbines represent in the overall installation demand and the mix of the remaining turbines to be installed determine how close the fleet can get to its best possible performance of 46 GW: whereas Demand1A almost aligns with what the vessel fleet can achieve, Demand 2A and 3A remain, in 2028, at yearly possible additions of 42.5 GW and 38.3 GW, 7% to 16% below the fleet's theoretical installation capacity.

A mismatch between the overall market demand for installation of a certain turbine fleet composition and the capabilities of the vessel fleets results in lower GW additions, uninstalled turbines, and idle vessels.

The analysis also shows that relatively small changes in the turbine fleet composition lead to a different result for the vessel fleets' achievable performance: for example, in Demand1B and Demand2B, the shift of 10% between the lower and the medium size turbine segments does not have a noticeable impact for the Rest of World fleet in 2024; as of 2028, it results in 0.6 GW more or less that can be installed. Looking at the same two scenarios for the PR China

fleet, results show that already with the vessel fleet composition of 2024, there is a difference of 1.7 GW, over 10% of vessels' total installation capacity; this difference widens to 4 GW in 2028. Similarly, Demand2A and Demand3A, where the share of the lower- and upper-size turbine segments differ by 10% of total installation demand, the Rest of World fleet can install 0.9 GW more than under 3A, whereas the PR China fleet installs 4.3 GW less.

In summary, the overall additions that the vessel fleets could deliver vary significantly depending on the turbine fleet composition presented to them. Over the years 2028 to 2030, for example, the tested scenario variations that align the least with the Rest of World vessel fleet's installation capacities lie 6% (without upper-size turbines) to 15% (with upper-size turbines) below its possible performance. For the PR China fleet, the least-aligned scenarios remain 15% to 16% below its potential performance.

In the Demand-Side Driven Scenario and its variations, certain turbines do not get installed because no suitable vessels are available; at the same time, a certain amount of vessels remain idle, because there is either no demand for their services in a turbine size segment they could technically handle, or because there is no vessels available to provide the complementary part of the installation, the foundation or the wind turbine. Over time, such coordination failure of the market leads to a widening gap between the wind energy capacity that could technically have been installed and the capacity that will actually be installed.

Aligning wind turbine installation plans as closely as possible with the vessel fleets' evolving capabilities allows for wind energy capacity to be built faster and more efficiently.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

4.2.3. Additional vessel requirements under the 2030 ambition

If bottom-fixed offshore wind should have delivered its assumed share of 492 GW to reach the 2030 ambition of 500 GW (see 4.1.1), more installation vessels would be required to close the gap. The gap has its origins, in large parts, in the years 2024 to 2027, when the planned wind farm installations remain below the vessel fleets' capacities. As shown in the above, the gap between the installations that the vessel fleets can deliver and the 2030 ambition is further determined by three factors: the alignment of the chosen turbine fleet composition and the vessel fleets' capabilities, vessel utilization rates, and the availability of turbines in the upper-size segment.

To identify the number of vessels that would be required to close the gap, the scenario optimistically assumes that new vessels can have a delivery time of two to two and a half years, and hence enter the

market at the beginning of 2028 if orders are placed immediately (also see 4.1.5). This leaves three years of installation work to achieve the 2030 ambition. The scenario also assumes that vessel operators would anticipate further turbine growth and only order high-capacity vessels capable of installing at least turbines of the upper-size segment.

Furthermore, the analysis needs to make assumptions about turbine installation scenarios until 2028 and thereafter: Up to 2028, the Demand3 scenario variation is used for the Rest of World, where the vessel fleet approaches its best possible performance with the upper-size turbines (A) and without them (B). For PR China, the Demand1 scenario variation is used, where the vessel fleet performs best in A and B (see 4.2.2). For the years 2028 to 2030, the analysis assumes that both regions will install the additional turbines as in scenario Demand3 and its variations A and B. Figure 14 provides an overview of the remaining gaps in the two regions across the different scenarios.

Fig. 14: Gap toward the 2030 ambition

	Scenario A with upper-size turbines as of 2028		Scenario B without upper-size turbines	
	Total gap	Yearly av. gap	Total gap	Yearly av. gap
Rest of World	71 GW	23.7 GW	79 GW	26.3 GW
	achieves 148 out of 219 GW in Demand3A: 20-60-20		achieves 140 out of 219 GW in Demand3B: 20-80-0	
PR China	32 GW	10.7 GW	39 GW	13.2 GW
	achieves 240 out of 272 GW in Demand1A: 40-50-10		achieves 233 out of 272 GW in Demand1B: 40-60-0	
Global	104 GW	34.4 GW	119 GW	39.5 GW
	achieves 388 out of 492 GW		achieves 373 out of 492 GW	



SOURCE: IMAGESOURCECURATED/ELEMENTS.ENVATO.COM

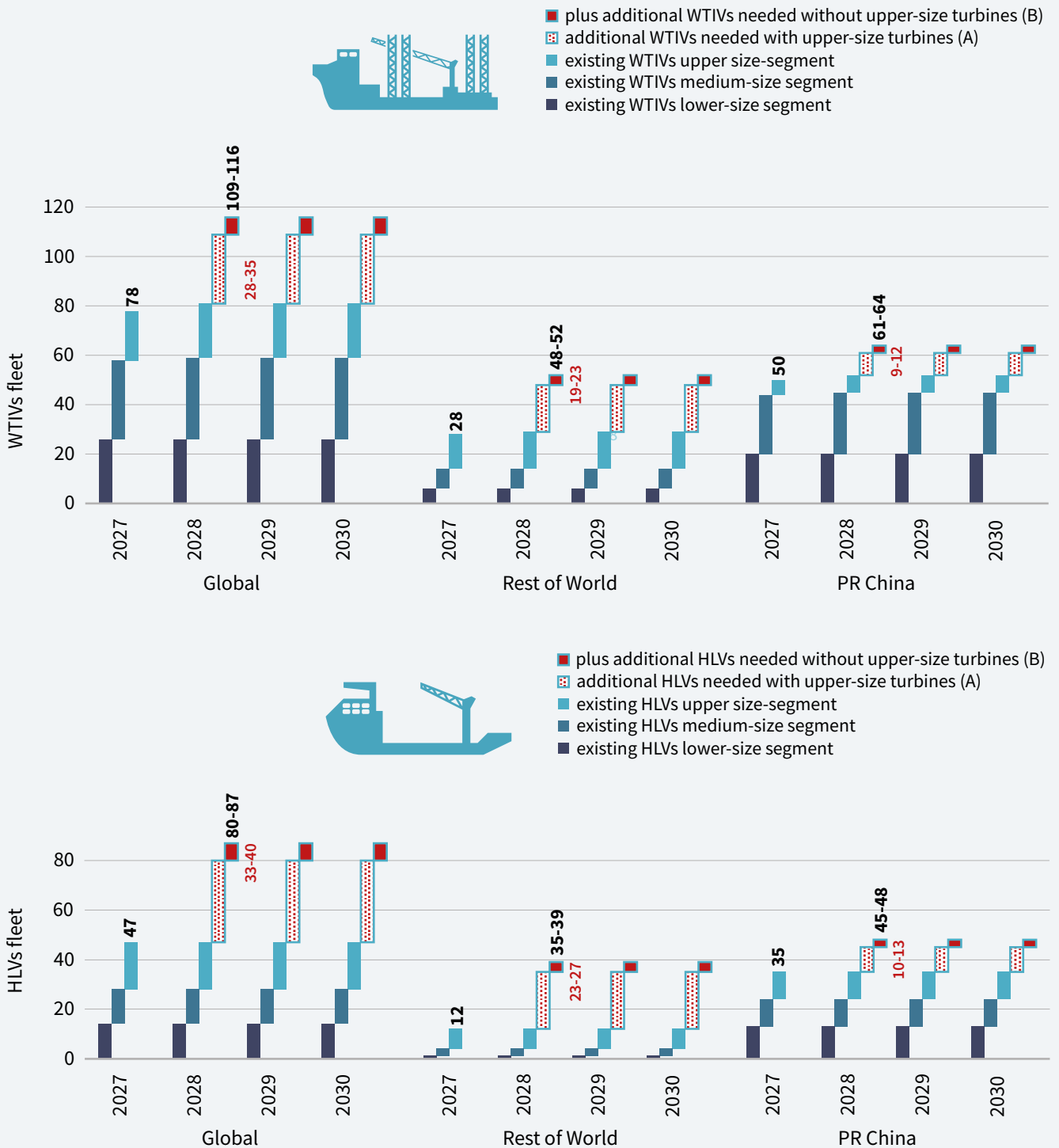
Distributing the gap toward the 2030 ambition equally over the remaining three years leads to yearly extra additions of 24 to 26 GW for the Rest of World, about 100% of the installations that the vessel fleet of 2028 can deliver. PR China would need to fill an annual gap of 11 GW to 13 GW; this would equal an addition of about a quarter to a third of the existing vessel fleet's installation capacity.

Figure 15 shows the required fleet growth: If turbines in the upper-size segment come to market in 2028 (scenario A), the Rest of World fleet would need to grow from 41 to 83 vessels by the beginning of 2028 to provide the additional installation capacity.

With the assumed vessel deployment strategies (see 4.1.3), 19 WTIVs and 23 HLVs need to be ordered immediately. Without the upper-size turbines (scenario B), 50 additional vessels —23 WTIVs and 27 HLVs —will be required. This translates into an expansion of the Rest of World fleet of about 100% to 120% in just one ambitious shipbuilding cycle. For PR China, the required fleet growth is 19 to 25 vessels, a plus of about 20% to 30% compared to the existing fleet in 2028. Globally, this means the existing fleet of 128 vessels in 2028 needs to grow by 61 to 75 vessels, representing about 50% to 60%.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Fig. 15: Required vessel fleets to achieve the 2030 ambition



4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

To meet the 2030 ambition, the global vessel fleet would need to be at least 50% larger than the fleet that exists in 2028. The Rest of World vessel fleet would need to at least double.

A vessel fleet of this size could install around 7,200 to 7,600 wind turbines annually: 3,200 to 3,400 in the case of the Rest of World fleet, and 4,000 to 4,200 in the case of the PR China fleet. With the turbine sizes used in the above scenario, vessels could install around 104 GW of offshore wind capacity annually. With further growth in turbine size and vessels' readiness to handle these, even more GW could be installed. While these results do not yet account for the increasing O&M work and that some vessels may shift from installation to maintenance activities, the fleet's capacity would still be significant.

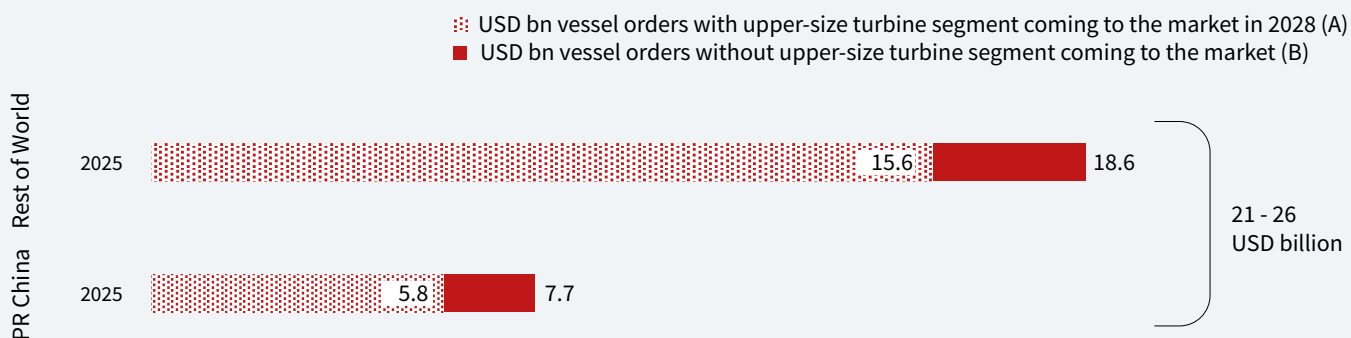
In terms of investments, such an expansion of the global fleet would require ordering vessels worth USD 21 to 26 billion in the immediate (see Figure 16). Expanding the Rest of World fleet alone would require an order volume of USD 15 to 18 billion.

Considering that vessel deliveries for the Rest of World peaked in 2025, with an estimated value in the range of USD 4 billion (for historic vessel prices, see 4.1.5), investments would need to be multiplied by approximately a factor of 4. These investments would increase if operators opted for more of the higher-priced WTIVs, which could also take on the work of HLVs.

USD 21 to 26 billion in additional investments in the vessel fleet would have to be mobilized immediately to deliver the 2030 ambition for bottom-fixed offshore wind.

The investment needed in the PR China fleet—the estimate order volume lies between USD 5 and 8 billion—is much lower, first, since the gap between the country's here assumed contribution to the 2030 offshore wind ambition is lower while the vessel fleet is larger; second, because the estimates assume lower prices for vessels built in PR China for the national market and with lower classification requirements (see 4.1.5).

Fig. 16: Global vessel orders needed in USD to deliver the 2030 ambition



4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Expanding the vessel fleet at this scale entails significant uncertainties: First, it remains unclear whether the rest of the offshore wind value chain can expand its capacity. Second, mobilizing these investments at once in the immediate may lead to increased capital costs and, most importantly, require strong investor confidence that demand for these vessels is certain and extends well beyond the 2030 ambition.

Expanding the vessel fleet at this scale entails significant uncertainties and may have led to adverse effects.

Third, it is unclear whether shipyard capacity would be sufficient to deliver this unprecedented number of 28 to 35 WTIVs by the end of 2027. As the fleet register shows (Clarksons Research, 2025), shipyards delivered a record 20 WTIVs in 2023, of which 16 were built by and for PR China. In 2025, 15 WTIVs are expected to enter the market, with nine destined for the Rest of World. HLVs for the wind sector were delivered in significantly lower numbers in the past; yet these figures do not allow for drawing conclusions about general shipyard capacity for HLVs. Finally, in response to such intense demand, shipbuilding prices may rise—potentially creating new obstacles to the rapid scale-up of offshore wind.

Lastly, these vessels need highly specialized crews. It seems unlikely that crews capable of operating 61 to 74 additional vessels are currently available; recruiting and training them within just two and a half years is another significant task.

A phased fleet expansion, where vessels are added incrementally rather than all at once, could mitigate the challenges mentioned above. However, deferring vessel deliveries obviously postpones available



SOURCE: DJ MATTAAR/SHUTTERSTOCK.COM

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

installation capacity and shifts part of the gap into later years. As a result, the fleet by 2030 would be even larger than the one in the one-off investment scenario discussed above.

4.2.4. Additional vessel requirements under alternative capacity growth scenarios

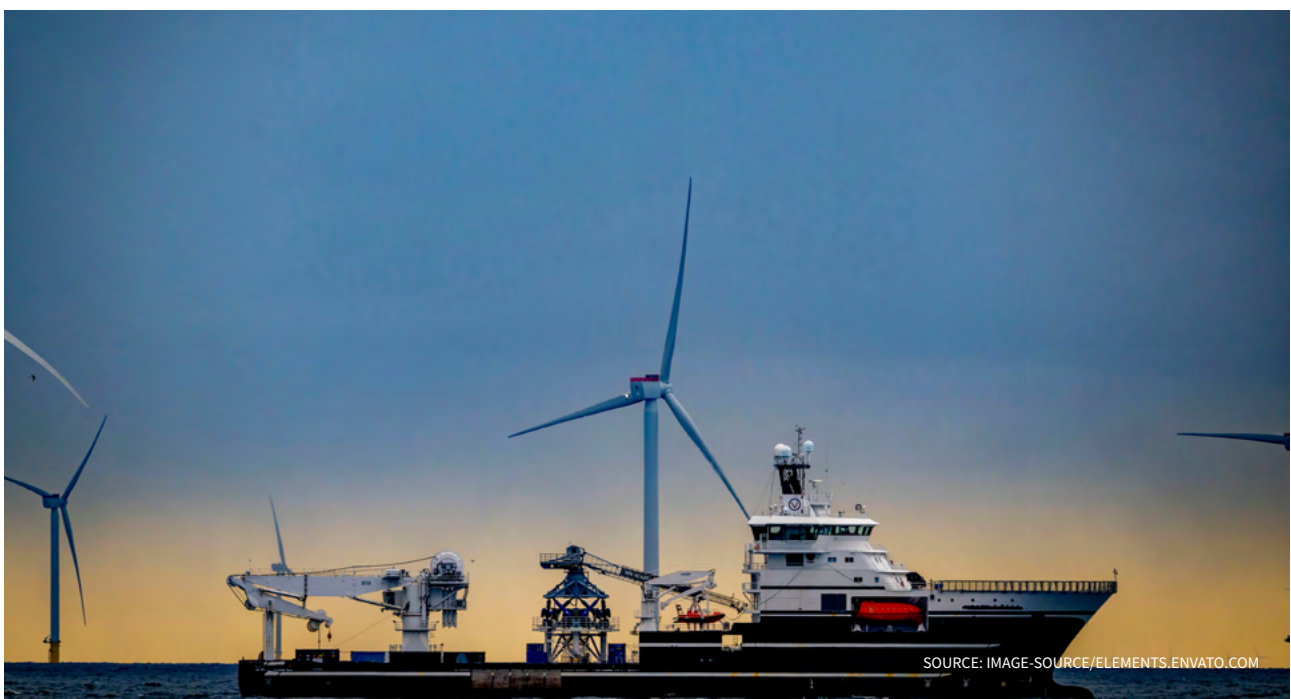
From the vessel fleets' perspective—ignoring all other factors that determine the build-out of offshore wind—meeting the 2030 ambition of 500 GW offshore wind is out of reach.

In the following, we test two scenarios in which regions could still achieve 80% to 85% of the 2030 ambition individually; globally, this results in around 400 GW of installed bottom-fixed offshore wind capacity. The assumptions regarding turbine fleet composition, as outlined in 4.2.3 are maintained.

Achieving 85% of the 2030 ambition, equal to 418 GW installed globally, translates into 186 GW

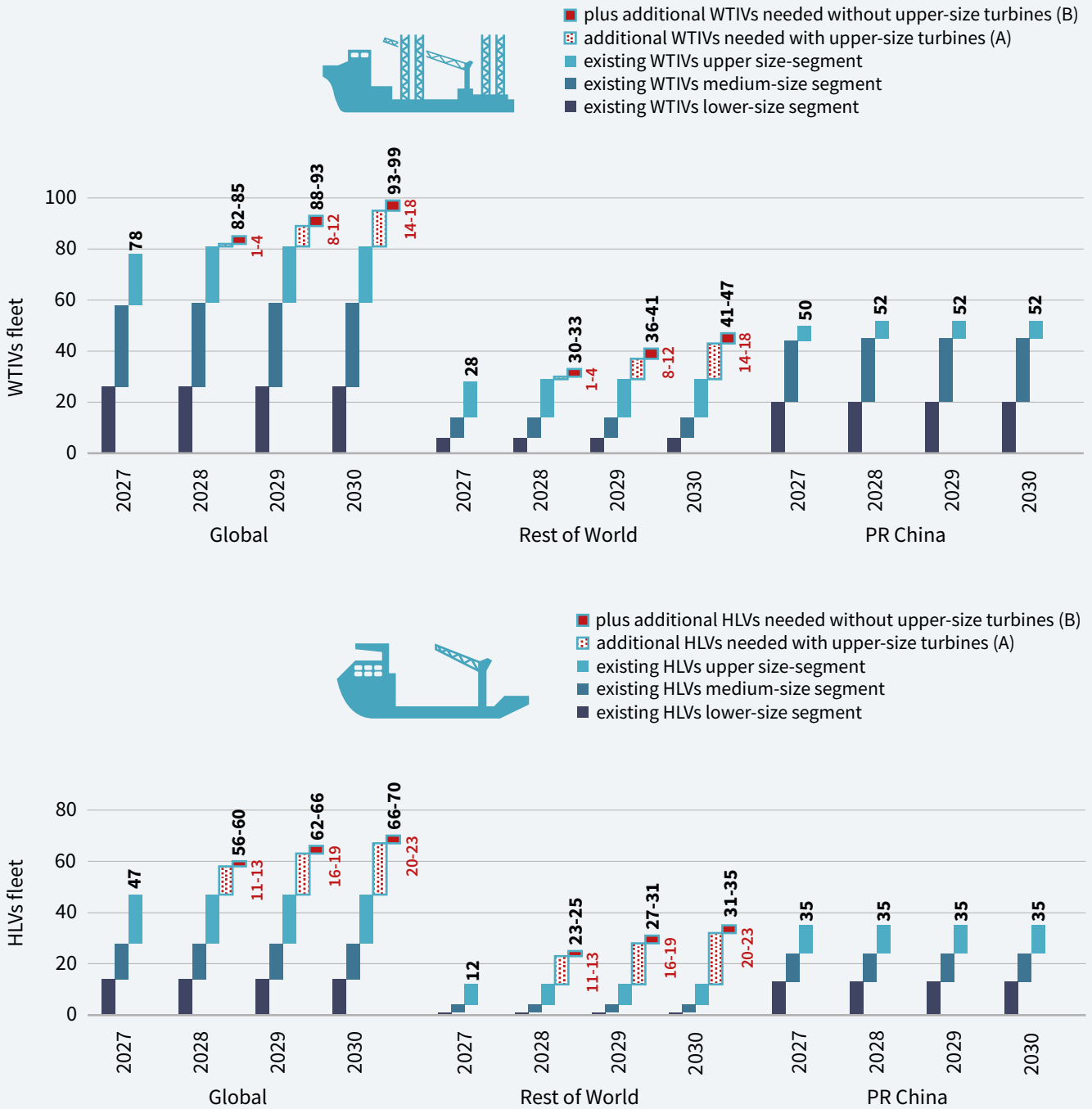
installed capacity (out of 219 GW) for the Rest of World fleet. The phased expansion of the vessel fleet to support this growth will result in a fleet of 75 to 82 vessels by 2030. As in all estimates, the market introduction of the upper-size turbine segment in 2028 is the decisive factor for this range (see Figure 17). Over three years, the fleet would thus have to grow by 80% to 100%, up from 41 vessels in 2028. In this period, the vessel fleet could install a total of 111 GW. In 2030, the fleet is expected to reach an annual installation capacity of 2,800 to 3,100 turbines, assuming the specified turbine sizes, resulting in approximately 43 GW of potential yearly additions. Vessels that may shift to operations in the increasing maintenance activities have not been accounted for.

Achieving 186 GW requires the Rest of World to expand the vessel fleet by 80% to 100% over three years, with a total investment of USD 12 to 15 billion.



4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Fig. 17: Required vessel fleets to deliver about 420 GW installed capacity



4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

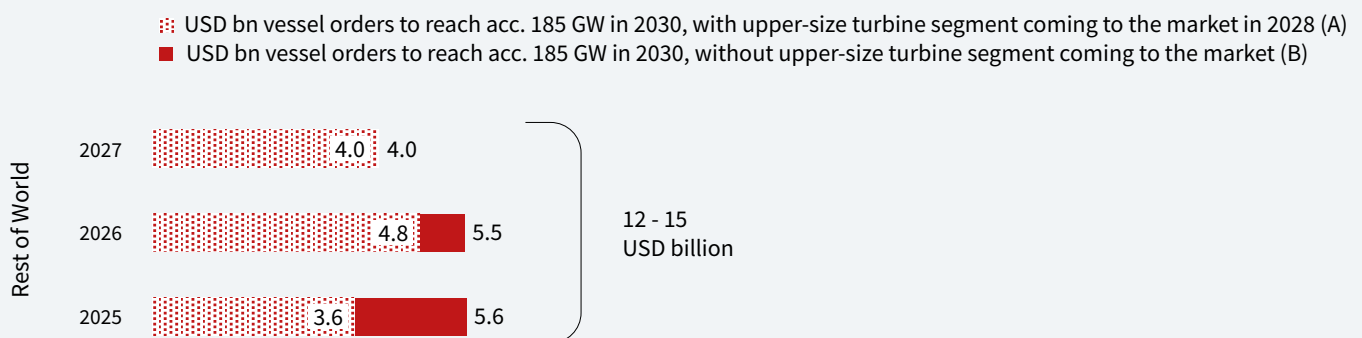
Yearly vessel deliveries would lie in the range of 10 to 17 vessels, thus within the historically proven wind vessel shipyard capacity. The investments to be committed for the Rest of World fleet’s expansion amount to USD 4 to 5.6 billion annually, totaling USD 12 to 15 billion over the three years (see Figure 18). While the annual investments on the lower end align with the estimated value of vessels added to the Rest of World fleet in 2025, the consecutive mobilization of these amounts year after year would be a first in the wind vessel market. If the upper-size turbine segment does not come to the market and the required investments reach the higher end, the financial challenge increases. Whether the relatively small group of wind vessel operators has the capacity to mobilize these investments lies beyond the scope

of this analysis. It would require, first and foremost, a reliable and robust market outlook well beyond 2030; the ability of other value chain partners to keep pace; and access to qualified vessel crews.

PR China could deliver about 230 GW by 2030 without further vessel fleet growth.

Meanwhile, PR China could deliver its 85%-share of 231 GW (out of 272 GW) with the vessel fleet already in place in 2028, as shown in 4.2.2; in scenario A, with the larger turbines coming to market, it could even slightly exceed this value.

Fig. 18: Rest of World vessel orders needed in USD to deliver 85% of the 2030 ambition (185 GW)

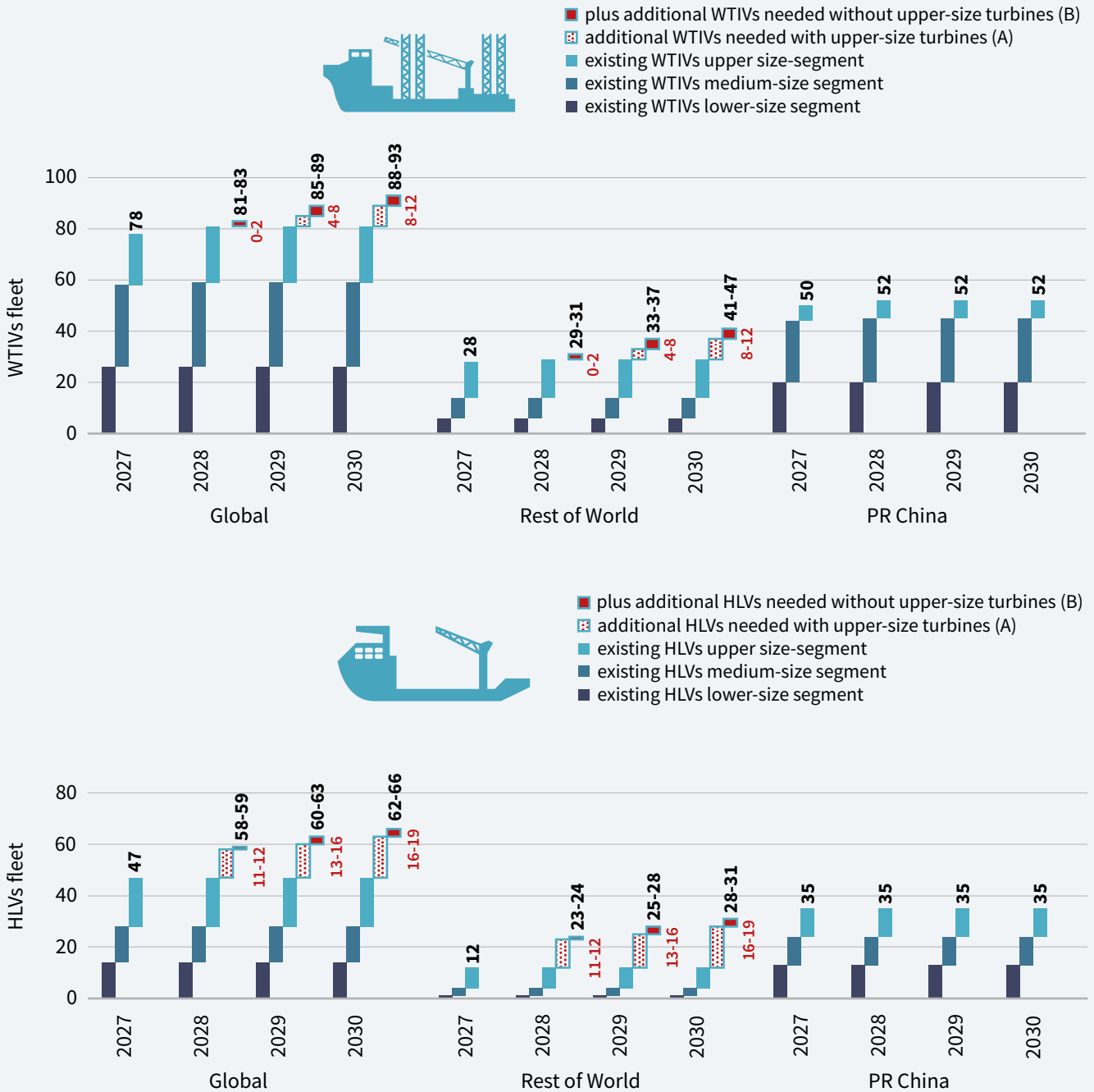


Achieving 80% of the 2030 ambition with 394 GW bottom-fixed offshore wind, and where the Rest of World would contribute 175 GW of accumulated capacity, results in a required fleet of 65 to 72 vessels (see Figure 19). Fleet growth is then around 60% to 75% compared to the fleet’s size in 2028. Over the three years, a total of 100 GW could be installed. By 2030, the fleet would have reached the capacity to install 2,400 to 2,700 turbines annually, equivalent to almost 38 GW.

To achieve 175 GW of installed capacity by 2030, the Rest of World needs to grow its vessel fleet by 60% to 75% over three years, with investments in the range of USD 8 to 11 billion.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Fig. 19: Required vessel fleets to deliver about 400 GW



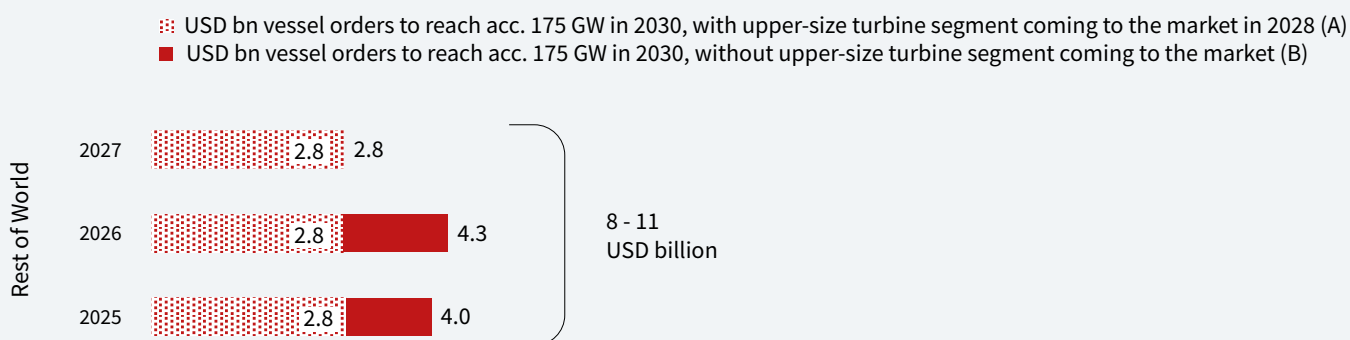
4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

Vessel deliveries would range from 7 to 13 per year. Investments amount to USD 2.8 to 4.3 billion per year, totaling at around USD 8 to 11 billion over the three years (see Figure 20). Here, even the upper end of the range aligns with investments the industry mobilized for vessel deliveries in 2025. Yet again, the challenges may lie with the consecutive mobilization of resources. As mentioned above,

certainly regarding the investments' profitability, the rest of the value chain's ability to keep pace, and vessel crews' performance remain critical factors.

PR China would, in the 80%-case, contribute 218 GW (out of 272 GW) and remain under its vessel fleet's potential.

Fig. 20: Rest of World vessel orders needed in USD to deliver 80% of the 2030 ambition (175 GW)



4.2.5. A high-level outlook beyond 2030

To support the 2050 climate targets, IRENA's renewable energy scenario suggests that 2,500 GW of offshore wind capacity is needed (see 1.). Assuming that floating wind's contribution lies in the range of 10% to 20% of the total installed capacity, bottom-fixed offshore wind would then contribute 2,000 GW to 2,250 GW; regions would contribute with shares in the range of 1,150 GW (55%) in the case of the Rest of World, and 1,000 GW (45%) for PR China (also see 4.1.1).

The additions required over the period depend on the level at which the world and the regions start in 2030. As shown in 4.2.3, it is unlikely that the world could achieve 500 GW of offshore wind by then. From the vessel fleets' perspective, with the above-outlined investment trajectories and deployment strategies, 400 GW seems possible. The following outlook uses the scenario in which 80% of the 2030 ambition is met through bottom-fixed installations as a starting point, i.e., 175 GW for the Rest of World and 218 GW for PR China, for a total of 393 GW. Depending on floating wind's contribution over the period 2031-2050, the Rest of World would have to build on average 45 to 52 GW of bottom-fixed installations annually, and PR China 35 to 41 GW.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

There are several pathways to achieving the required bottom-fixed offshore wind installations by 2050. Figure 21 shows one possible turbine fleet composition and yearly average additions that result in 2,125 GW of bottom-fixed installations, which will be used as a basis for estimating the vessel fleets. The expected advancements in turbine capacity are reflected in the introduction of a super-

size turbine with an average rating of 40 MW, an increase in average power ratings for turbines in the medium- and upper-size segments, and the phase-out of turbines in the lower-size segment between 2041 and 2050. The scenario assumes that contributions from floating wind increase over time, leaving fewer GW additions for bottom-fixed in the later period.

Fig. 21: Examples of future turbine fleet composition

2031-2050 Turbine Fleet Demand Scenarios	2031 to 2040				2041 to 2050			
	lower-size segment	medium- size segment	upper-size segment	super-size segment	lower-size segment	medium- size segment	upper-size segment	super-size segment
Average power rating	10 MW	17 MW	26 MW	40 MW	10 MW	17 MW	26 MW	40 MW
Turbine fleet composition	10%	55%	30%	5%	0%	40%	50%	10%
Yearly bottom- fixed GW installations	93 GW				80 GW			

Acknowledging that there are many uncertainties regarding future innovations in installation processes and vessel design, our estimates of the required vessel fleets, shown in Figure 22 are based on the assumptions described in Section 4.1.3 and an average vessel utilization rate of 72.5%.

The estimates illustrate how the assumed further increase in turbine size and the increasing share of floating wind reduces the number of vessels required for installation: Compared to the period 2024 to 2030, where a global vessel fleet of around 160 vessels (see Figure 19 above) could install about 80 GW per year in the scenario achieving 80% of the ambition, the installation fleet for the 2031 to 2040

period comprises ‘only’ 120 vessels that together deliver about 90 GW annually. The investments in vessels capable of operating in the upper-size turbine segment in the preceding period, as discussed above, would also equip the Rest of World fleet for this future scenario; mainly, vessels for the new super-size segment would need to be added. PR China would still need to enlarge its fleet in the upper-size segment to deliver the here-assumed scenario, as well as in the super-size segment.

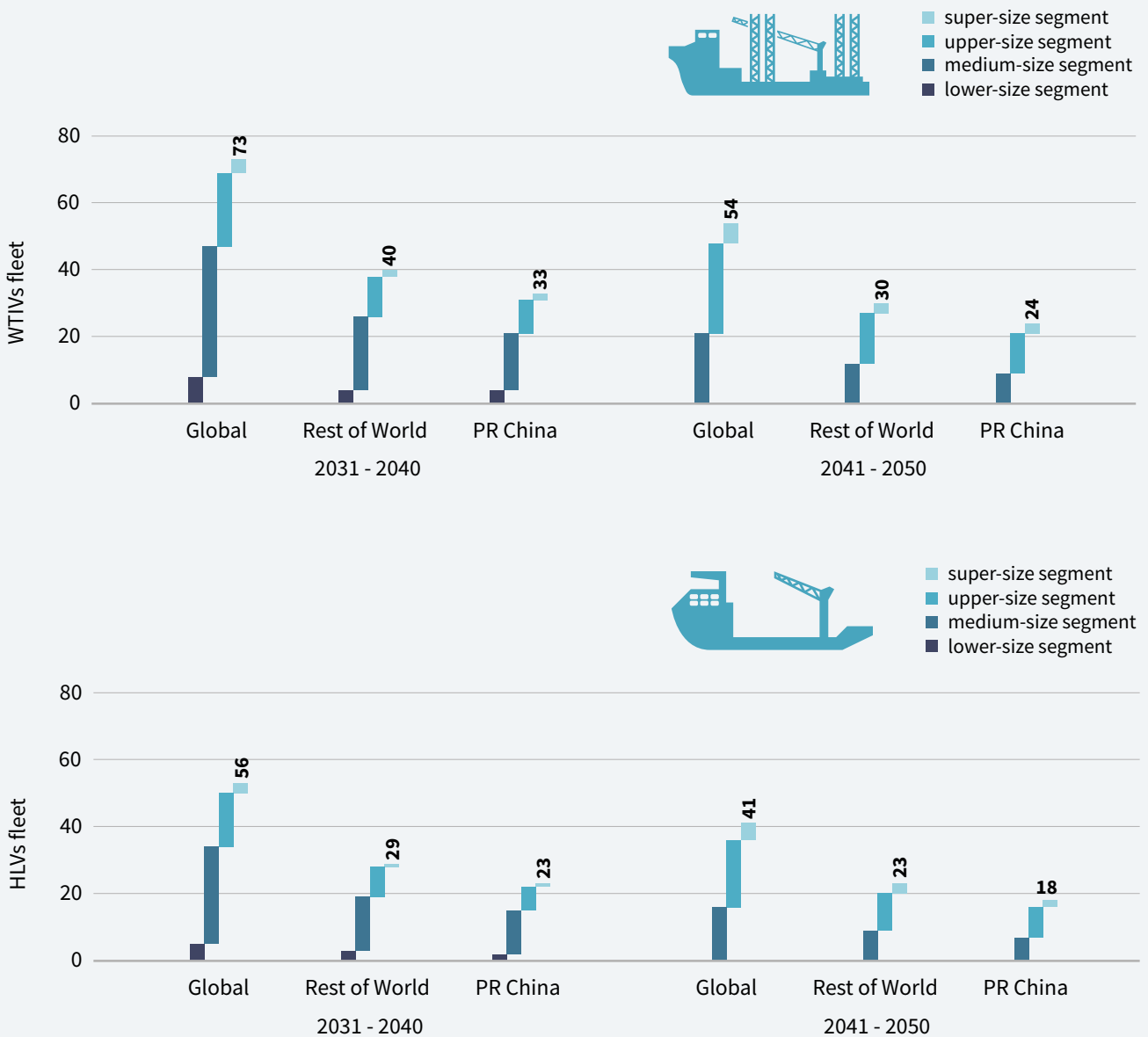
In the period 2041 to 2050, about 90 vessels make up the fleet that could install 80 GW per year—again, with a shifting composition of the fleet.

4. Vessel requirements for offshore wind installations under the 2030 ambition and 2050 climate target

As these estimates do not yet account for vessels required for the significantly increasing maintenance and decommissioning work, the active vessel fleet will be larger and will still include smaller vessels that may no longer be suitable for new installations.

While this high-level outlook cannot—and does not intend to—provide definitive guidance, it serves to illustrate that delivering offshore wind at scale over the next 25 years will require a functional and well-coordinated supply chain, supported by complementary investments across its various segments—including, as discussed here, the vessel fleets.

Fig. 22: Vessel fleets required under the installation scenario towards 2050



5. Implications and recommendations

The analyses in this study assess the offshore wind installation vessel fleets' potential to support a steep growth in capacity additions and outline the fleet expansion and investment pathways needed to deliver 500 GW by 2030, as well as 80% and 85% of this ambition. Simulating different demand patterns for turbine installation in various scenarios illustrates how these interact with the fleets' evolving capabilities. The separate analysis of the two regional fleets reflects, on the one hand, the current situation in which the PR China fleet serves only its domestic market and faces barriers to international deployment. On the other hand, treating the Rest of World fleet as fully deployable across markets remains optimistic but highlights the potential of more integrated installation markets.

Overall, three key findings and their implications merit further consideration:

First, modelling the vessel fleets' potential performance showed that achieving 400 GW by 2030 still technically seems feasible, provided that wind farm planning and shipbuilding can be accelerated, that other parts of the value chain can expand their capacities accordingly, and importantly, that political realities align—an aspect that was deliberately excluded in this study to maintain the focus on the vessel fleet as one critical element of the supply chain. As discussed above, such scaling of long-lived assets requires a robust market outlook, and a strong collective effort would be required in the immediate to deliver the 400 GW offshore wind by 2030.

The vessel fleets could still be scaled to achieve 400 GW installed capacity by 2030—if the broader supply chain and political will can keep pace.

Second, the findings suggest that, without immediate corrective action, achieving the 2030 ambition was already unlikely, at least from the perspective of the vessel fleet, when it was announced in late 2023. Modelling the extreme case of a rapid vessel fleet expansion that would now be required shows how delayed action compounds and amplifies gaps. It not only illustrates the massive and rather unrealistic effort that would be required to catch up; more importantly, it points to the potentially adverse effects of delayed action itself, where a well-intentioned attempt to scale up rapidly may raise capital costs and vessel prices, making offshore-wind deployment more expensive rather than more efficient.

Credible output targets must be supported by value chain development targets.

While setting output targets in the form of installed capacity is essential to guide the market, these targets must remain credible to sustain confidence. They should be complemented by corresponding value chain targets that reflect realistic growth in turbine manufacturing, port and vessel capacity, and grid integration capability. Defining such targets requires coordinated effort, combining policy direction from governments with foresight from industry associations. They need to be informed by full supply chain assessments that can evaluate its delivery capability, and identify investments and support needed early on to turn ambition into reality.

Third, the assessment of existing and ordered fleets under different installation scenarios—the Theoretical Supply-Driven Scenario, where vessels deliver their best possible performance; the Best-Case Supply-Driven Scenario, which factors in near-term constraints from missed wind farm planning in recent years; and the Demand-Driven Scenario, which simulates demand for different turbine fleet

5. Implications and recommendations

compositions—highlights the benefits of aligning the overall turbine fleet composition with the vessel fleet’s installation capabilities. When demand and supply are aligned in qualitative terms, more capacity can be installed. When they diverge, demand for specific vessel categories rises, potentially driving up prices while other vessels remain idle; high versus low vessel utilization rates of active vessels amplify the difference. Overall, fewer turbines get installed at a higher cost; the total yearly possible capacity additions decrease and slow down offshore wind development.

A multi-regional, cross-project coordination platform could accelerate offshore wind installations and improve cost efficiency.

Greater transparency on vessel availability and wind farm planning, combined with stronger coordination among developers, OEMs, vessel operators, and permitting authorities, could increase the collective output through better use of vessels across projects, within and beyond regions. The vast majority of vessels are currently owned and homeported by Chinese and European operators; yet, regional decentralization of an internationally deployable fleet will become increasingly necessary to support the development of offshore wind in emerging regions. Fragmentation into national or too small regional markets would limit the efficient allocation

of vessels and potentially slow down offshore wind capacity additions. Efficient sharing of vessel fleets’ capacities, within and beyond a region, will also rely on countries revising prohibitive national regulations.

While it is unlikely that developers in mature markets would alter turbine choices merely because of vessel availability, greater transparency, forecasting, and coordination could still inform actors on forthcoming market developments, enhance project sequencing and vessel allocation, and align construction schedules to avoid installation peaks. Sharing aggregated information on planned installations and mapping it against the capacity and availability of the vessel fleet would be a pragmatic first step toward a more coordinated system. Such coordination would benefit further from continued standardization of equipment interfaces and component handling procedures, enabling greater interoperability and flexibility in vessel deployment.

Although the need for stronger supply chain coordination is widely acknowledged in the offshore wind sector, existing initiatives have tended to exclude vessel planning, focus on national rather than regional supply chains, or address mainly engineering and design questions—typically with an advisory rather than implementation focus. A regional, cross-project coordination platform linking aggregated turbine deployment forecasts with vessel fleet capabilities would therefore fill a recognized but still unaddressed gap in offshore wind.

6. Limitations

This study uses a normative scenario of wind energy capacity suggested to meet the ‘Double Down, Triple Up’ renewables pledge for 2030 and the net-zero climate targets in 2050. These milestones are derived from modeling energy pathways that keep global warming within 1.5°C; however, they are not formal political commitments. Since the necessity of meeting global climate targets remains unchanged by political shifts in individual countries, the analysis intentionally excludes national policy trends and their potentially obstructive effects.

Since the normative scenario is global but the offshore wind market is not, the study assigns the necessary wind energy capacity to two main regions: PR China and the Rest of World. While the split is guided by energy modeling and market forecasts, especially regarding PR China’s role in the energy transition, this split is just one of many possible ways to meet the global offshore wind capacity target. The division also reflects a basic level of regional separation in the current offshore wind installation market. However, the Rest of World is not a single, unified market, the study does not further subdivide it. This approach aims to avoid a narrow view of the offshore wind installation market, which could underestimate its potential to share vessel capacity across countries and regions. At the same time, it prevents overly detailed allocations of offshore capacity increases to smaller sub-regions or individual countries, which might shift the focus of this study away from vessel fleet capacities and requirements toward national energy policies.

The offshore wind capacity ambition used in this study is an informed global suggestion rather than a global commitment.

The concept of a Rest of World market has limitations: first, it assumes that installation vessels can be deployed freely across this market,

whereas in practice, national regulations create barriers. Moreover, while it can be argued that transit times are, to some extent, reflected in the assumptions on vessel utilization rates, these may be underestimated, particularly if vessel ownership and homeporting remain concentrated in Europe. This could result in an overestimation of the Rest of World fleet’s actual installation capacity identified in this study. Second, viewing the Rest of World as a single market does not provide insights into where vessel demand will occur, nor into how regional sharing could optimize the deployment of the vessel fleet to minimize transit times and improve overall capacity utilization. These aspects warrant further analysis.

Framing the Rest of World as a single market ignores existing barriers and cannot guide the development of regionally shared vessel fleets for optimal capacity utilization.

Further limitations relate to vessel qualification, workload estimates, and deployment strategies. This study uses two main specifications that determine a vessel’s ability to install a specific turbine size: crane lift capacity and hook height. These parameters are based on operational experience with current turbine sizes and on informed assumptions for the still-developing larger turbine segment. However, the assumed values are averages; additionally, factors such as leg length, deck strength, space, and layout can limit a vessel’s suitability for a specific project. This may result in overly optimistic outcomes. But also, the vessel database used may be incomplete, which could lead to too low outcomes. The workload estimates, based on the average number of days required for installation per component, may be somewhat conservative, especially for new high-capacity vessels operating under ideal conditions. It is unclear whether the potential overestimations

6. Limitations

and underestimations across different assumptions in this study cancel each other out, leaving some uncertainty.

In practice, vessel selection and deployment strategies tend to be more complex and less optimal than assumed in this study.

While the deployment strategies were deliberately designed to reflect vessels' optimal performance, actual market behavior may deviate from that. For example, operators may not always find it attractive to mobilize vessels for smaller campaigns that fill short-term gaps, as this study's modeling allows. Also, operators might deploy WTIVs for foundation installation not only when the turbine installation market is fully served, but also before, and for strategic or commercial reasons. In practice, this

would reduce the WTIV fleet's turbine installation capacity identified here. Moreover, mobilizing WTIVs for both scopes can increase capital requirements. While this may be acceptable for the operator who expects to strengthen their competitive position with a dual-use deployment strategy, it raises the total investment needs required to achieve the same market outcome. In this sense, the study's results may underestimate the overall vessel investments needed to fill the gap towards 2030. Further comparative analyses of alternative vessel deployment strategies could help clarify how these choices influence overall fleet efficiency and investment requirements.

The assumptions made here only reflect a few of the many possible future developments in offshore wind turbine choices.



6. Limitations

Additionally, uncertainties persist regarding several underlying assumptions: predicting future development and selecting turbine sizes remains challenging. Average turbine sizes may vary, and the tested configurations of the overall turbine fleet represent only a small subset of the many possible setups. The assumed vessel delivery times of two to two and a half years could turn out to be overly optimistic, just as the expectation that wind farms not yet at a visible planning stage could begin construction in 2026 or 2027—but this is mainly to acknowledge that available data might be incomplete. Furthermore, the role and contributions of floating wind with varying requirements remain uncertain but will also influence the growth of the installation market.

Simplifications, such as equating the start year of construction with the year of wind farm commissioning, may lead to a slight overestimation of operational GW by 2030. Vessel prices could evolve differently from the assumptions underlying this analysis. In the medium term, innovation in installation processes, vessel deployment, interface standardization, and vessel design (all briefly mentioned under 2.1, 3.2, and 3.3) may enhance vessel performance; this could not be accounted for in this study. More detailed forecasting studies could help continuously update and refine these

assumptions and consider potential developments in areas of innovation currently overlooked.

A comprehensive assessment of the offshore wind supply chain as a whole, across regions, is still needed to guide its efficient and complementary development.

Ultimately, and most importantly, this study focuses on two key vessel types essential for the installation of bottom-fixed offshore wind turbines. This scope excludes other vessel types required for installation, vessel crews, port infrastructure, vessel workload for installing substations, wind farm maintenance, and the various components of the supply chain necessary to achieve the projected capacity additions. These include permitting processes, turbine manufacturers' ability to deliver equipment on time and at scale, and the grid's capacity to integrate the additional generation. Therefore, more comprehensive assessments are needed to evaluate the entire supply chain's potential, including across different regions, and the developments necessary to deliver the offshore wind installations required to meet climate targets.

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8. Annex

Overview of sources for input data and assumptions

Input	Value	Application	Source	Comment
Offshore wind capacity 2050 to meet climate targets	2,500 GW	adopted	IRENA (2023): World energy transitions outlook 2023: 1.5°C Pathway	
Offshore wind capacity 2030 to be achieved under 'Double Down, Triple Up' pledge 2023	500 GW	adopted	GRA & IRENA (2023): Tripling Renewable Power and Doubling Energy Efficiency by 2030 – Crucial Steps towards 1.5°C	
Offshore floating capacity installed by 2030	8 GW	adopted	GWEC (2024): Global Offshore Wind Report 2024	
Offshore floating capacity share in 2050	10–20%	based on	DNV (2022): Floating offshore wind: the next five years	Source states 15%; authors opted to reflect uncertainty.
PR China share of global offshore wind capacity 2030	55%	based on	IEA (2024): Renewables 2024: Analysis and forecast to 2030	Source suggests 60% of overall renewable capacity; actual share for offshore wind end of 2024 is 50%.
PR China share of global offshore wind capacity 2050	45%	own assumption		It seems likely that the Rest of World would accelerate deployment as new regions may start developing offshore wind after 2030.
Turbine sizes	See Fig 6.	based on / own assumptions		Up to 2030, optimistic assumptions based on industry trends; beyond 2030, assumptions, based on reported attempts and past experience that turbine sizes have developed faster than had been predicted.
Vessel requirements	See Fig 7.	based on / own assumptions	Partially: Clarksons Renewable Intelligence Network deployment history. Complemented with non-representative industry consultations	Lower and medium size requirements based on documented examples of vessel deployment; upper size requirements informed own assumptions based on first turbine models.

8. Annex

Input	Value	Application	Source	Comment
Vessel fleet qualification		based on / own assumptions	Primarily: Clarksons Renewable Intelligence Network fleet register. Partially complemented with own research on vessel features and deployment history.	
Vessel utilization rates	80% 72.5% 65%	based on / own assumptions	Non-representative industry consultations	
Vessel days turbine installation	4	based on / own assumptions	Documented vessel performance / non-representative industry consultations	Assumed average across active vessel generations.
Vessel days foundation installation	3	based on / own assumptions	Documented vessel performance / non-representative industry consultations	Assumed average across active vessel generations.
Vessel delivery times	2 to 2.5 yrs	own assumptions		Optimistic assumption based on emerging standardized vessel designs and shipyard experience, yet subject to overall ship building market.
Vessel prices HLVs	USD 220 to 280 million	based on / own assumptions	Non-representative industry consultations	
Vessel prices WTIVs	USD 400 to 480 million	based on / own assumptions	e.g., Cadeler (2024), Marinelog (2021)	Reported newbuild prices of the last years plus top-up to reflect further capacity and cost increase for vessels handling upper-size turbine segment and other evolutions that might affect vessel prices.



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