Offshore wind power: despite obstacles to its development, growth prospects remain good

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Confidential

Executive Summary

After a period of strong growth in the 2010s, the development of offshore wind power now seems to be slowing down, despite the ambitious targets adopted by many countries.

In 2024, installed capacity is estimated at 83.2 GW, far from the 1,052.3 GW of onshore wind power, and it remains a very small contributor to global electricity production (0.6%). Several factors explain this relative disappointment. First, the transition to deep-water wind turbines has been slower than expected. Next, after a decade of continuous decline, the average cost of electricity from offshore wind rose again in 2024 (79 USD/MWh).

Finally, since the early 2020s, several shocks have weakened the sector's growth, such as the rise in credit costs following the Covid-19 pandemic and the surge in prices for certain raw materials linked to the war in Ukraine or recent trade tensions. Donald Trump's return to the White House in 2024 is also weighing on the sector's development in the United States. These instability factors add to the long lead times required to develop new projects (6 to 10 years) and the high share of capital in offshore wind (up to 80% of total costs). As a result, many mega projects have recently been postponed or cancelled.

But despite a recent downward revision, international organizations still anticipate strong growth in installed capacity in the coming years (441 GW worldwide in 2034), driven by rising electricity demand and the commercial maturity of floating wind turbines. Offshore wind does indeed have many advantages: when installed in deep waters, farms benefit from stronger and more predictable winds than onshore turbines. These farms reach production capacities that allow them to potentially generate as much electricity as a nuclear power plant.

The global market remains characterized by a Sino-European duopoly, accounting for 95% of installed capacity as well as almost all offshore wind turbine manufacturing.

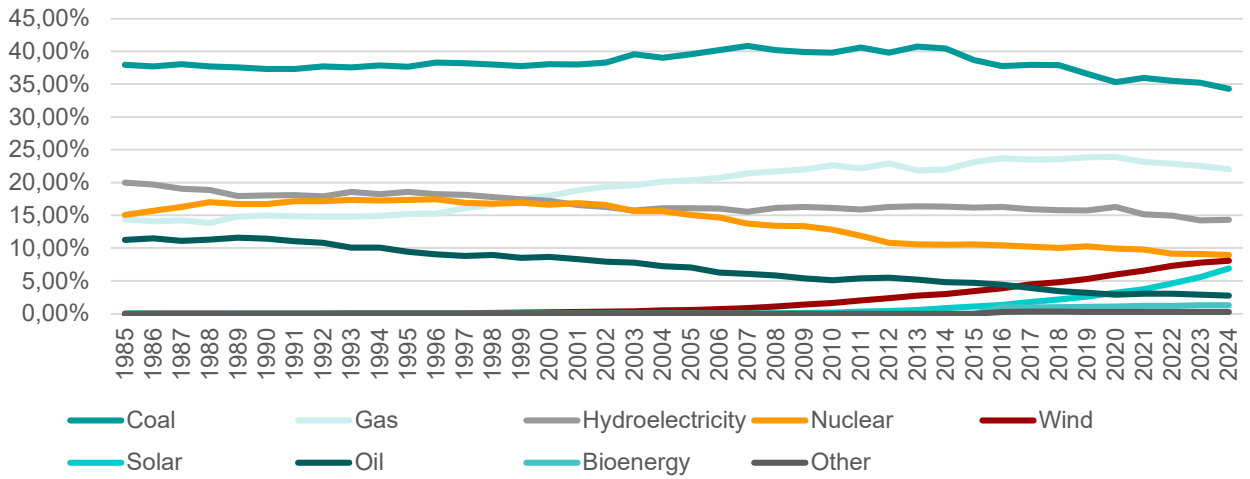
But new markets are expected to emerge: in Latin America, Africa, or Asia, countries (Brazil, Colombia, The Philippines and Morocco, in particular) with strong wind potential are seeking to integrate offshore wind into their electricity mixes. In this context, improving power grids and stronger state support are key factors fostering the development of offshore wind power.

1. Wind power: a rapidly changing market in an uncertain environment

1.1. Despite 20 years of growth, wind power remains a very small part of the global energy mix

Twenty-five years after their widespread integration into energy mixes (excluding hydroelectricity), renewable energies **produced more electricity than coal for the first time in the first half of 2025**[1].

Figure 1 : Share of electricity production methods



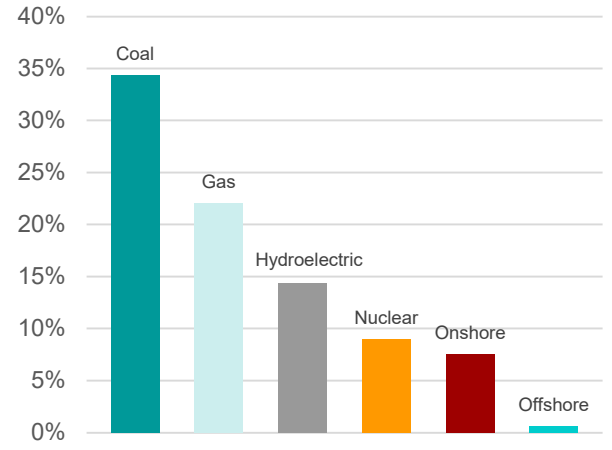
Source: Ember - Statistical review of world Energy, data consolidated by Oxford Martin School

Over the period 2004-2024, wind power's share of the global electricity mix rose from **0.5%** to **8.1%**.

This rise in wind power is explained by **its rapid design and construction timeline**, averaging between **4 and 8 years for an onshore wind farm**[2]**.** Major tech companies are investing in it to meet the needs of artificial intelligence (AI)[3]. **Offshore wind** farms, for their part, require **6** to **10 years**[4] to be built, compared with **5** to **6 years** for **coal** [5] and **11** to **12 years** for a **nuclear plant**[6]. In **2024**, global **installed offshore capacity** was estimated at **83.2 GW**, supplying electricity to **73 million households**[7] (270.5 TWh)[8]. By comparison, onshore wind accounted for **1,052.3 GW** over the same period[9] (2 251.4 TWh) [10].

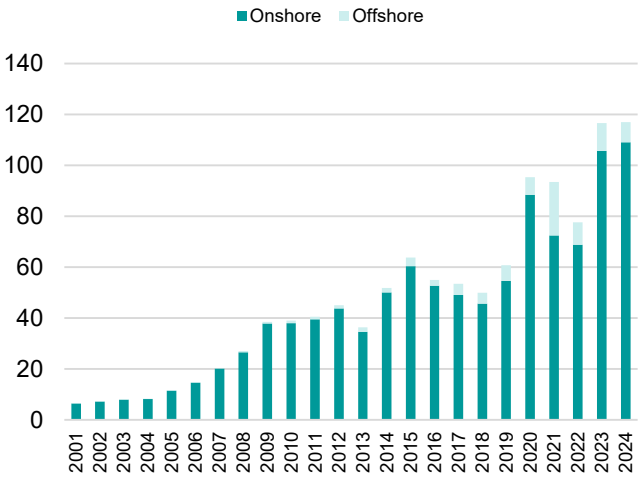
[1] Global Electricity Mid-Year Insights 2025 | Ember, *Ember*, 07/10/2025
[2] Construction of an offshore wind farm - Iberdrola, *Iberdrola*,
[3] Plus rien ne semble freiner l'appétit gargantuesque en électricité des géants de l'intelligence artificielle - Le Temps, *www.letemps.ch*, 03/07/2025
[4] Overview — Star of the South, *Star of the South*,
[5] (PDF) Schedule Modeling to Estimate Typical Construction Durations and Areas of Risk for 1000 MW Ultra-Critical Coal-Fired Power Plants, *ResearchGate*, 22/10/2018
[6] Typical timeline of a nuclear plant construction and start-up project... | Download Scientific Diagram, *ResearchGate*,
[7] Le parc éolien en mer mondial dépasse les 83 GW de puissance installée, *Révolution Énergétique*, 19/08/2025
[8] Renewable Energy Progress Tracker – Data Tools - IEA, *IEA*, 07/09/2025
[9] GWEC's Global Wind Report 2025 - The definitive guide to the wind industry, *www.gwec.net*, 23/04/2025
[10] Renewable Energy Progress Tracker – Data Tools - IEA, *IEA*, 07/09/2025

Figure 2 : **Share of onshore and offshore in global electricity production, 2024**



Source: GWEC - Global Offshore Wind report 2025 consolidated by GSA

Figure 3 : New wind power installations in GW



These offshore capacities represent only **0.6%** of **global electricity production,** far from the **8.1% of wind power**. However, the share of offshore continues to **grow** in terms of **new installations**, from **6.9%** in 2020 to **8%** in 2024[11].

Just **1 GW** produced by an offshore wind farm is enough to power up to **1.2 million households**[12]. Despite this strong potential and broad availability, offshore remains marginal compared to onshore and solar. However, as the International Energy Agency (IEA) highlights in its "World Energy Outlook 2025," global electricity demand will increase by 40% by 2035, requiring a diversification of sources to ensure the security of electricity mixes[13].

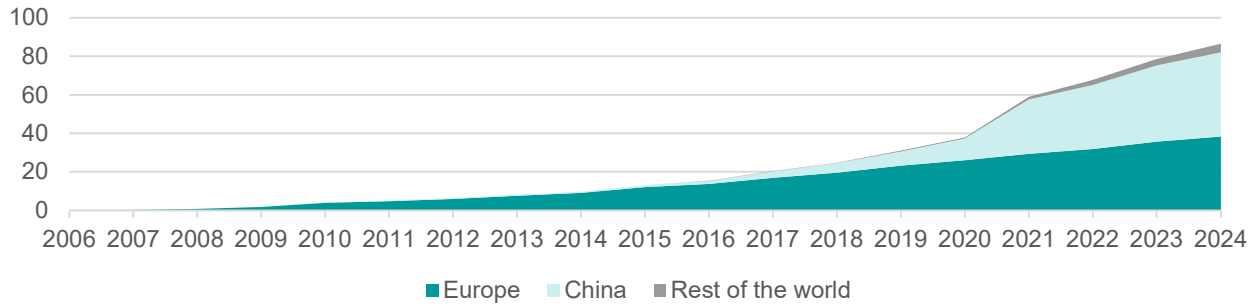
1.2. From a global market dominated by Europe to a Sino-European duopoly

Offshore wind was initially largely dominated by Europe. It first emerged with the **Vindeby wind farm**, installed off the Danish coast in **1991**, with a capacity of 5 MW, before being dismantled in 2017[14].

Until 2021, the **United Kingdom was the largest market** before being caught up with and **then far overtaken by China**[15]. In that single year, **China** installed **16.9 GW** along its coasts, representing **20% of all capacity ever installed in history**.

[11] GWEC's Global Wind Report 2025 - The definitive guide to the wind industry, *www.gwec.net*, 23/04/2025
[12] L'Écosse Approuve Un Projet éolien Flottant Majeur De 1GW Au Large D'Aberdeenshire - Energynews.pro, *energynews.pro*, 20/06/2025
[13] World Energy Outlook 2025 – Analysis - IEA, *IEA*, 12/11/2025
[14] Le tout premier parc éolien en mer a été démantelé, *Le marin*, 06/09/2017
[15] Éolien offshore : le vent souffle en Chine, *Le Monde de l'Energie*, 05/01/2022

Figure 4 : Offshore GW capacity installed worldwide



Source: GWEC - Global Offshore Wind report 2025

The sector is now structured around a **Sino-European duopoly**[16], with the two regions accounting for **95%**[17] of global installed capacity. In early 2025, **China** held **42.7 GW**[18], compared with **15.9 GW** for the **United Kingdom** and **9.06 GW** for **Germany** (**37.6 GW** for **Europe** as a whole)**.**

This Chinese hypergrowth — which significantly supported global expansion — can be explained by the **end of the Feed-in Tariff (FiT) subsidy in 2021**[19] : the densely populated and industrialized coastal provinces of **Guangdong, Jiangsu, and Fujian** mainly sought **to complete their respective project pipelines** before the end of the central government subsidy[20]. Since the **end of the FiT, Chinese growth has slowed sharply, from 16.9 GW installed in 2021 to only 4 GW in 2024.**

The market slowed in 2024, with **new installations falling 26% compared with 2023**, due to difficulties connecting to distribution grids and a slower-than-expected transition to deep-water sites.

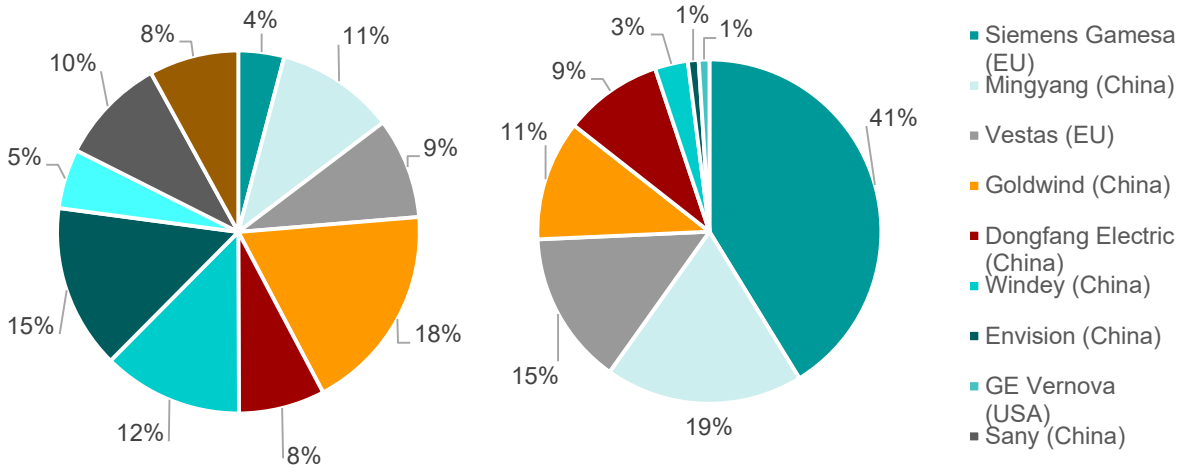
1.3. Main offshore wind turbine manufacturers

For **twenty years**, **Europeans** held an **almost exclusive position** in the **offshore market**, giving them a **technological advantage.**

China's catch-up is due to its late development, allowing it **to leapfrog technologies**[21], especially since the **similarities between offshore and onshore equipment**[22] reduce research costs. These turbines are said to be 40% cheaper than their European alternatives[23] As offshore remains complex and costly, **some manufacturers operate only in onshore wind**.

[16] When referring to Europe, we include the United Kingdom; the distinction will only be made when we use the term European Union
[17] GWEC's Global Offshore Wind Report, *www.gwec.net*, 27/09/2025
[18] La capacité solaire et éolienne terrestre de la Chine atteint de nouveaux sommets, tandis que l'éolien offshore est prometteur - Global Energy Monitor, *Global Energy Monitor*, 08/07/2025
[19] China Ends Wind Feed-In Tariffs and Opts for Auctions, *Mercomindia.com*, 03/07/2018
[20] La capacité solaire et éolienne terrestre de la Chine atteint de nouveaux sommets, tandis que l'éolien offshore est prometteur - Global Energy Monitor, *Global Energy Monitor*, 08/07/2025
[21] West will sacrifice cheap power if it spurns Chinese tech, says turbine maker, *www.ft.com*, 17/10/2025
[22] La construction d'un parc éolien offshore | Vattenfall, *Vattenfall*,
[23] West will sacrifice cheap power if it spurns Chinese tech, says turbine maker, *www.ft.com*, 17/10/2025

Figure 5 : Market share of onshore and offshore manufacturers in 2024



Source: Bloomberg Nef

European manufacturers account for 55.6% of the global offshore market, compared with **19% of the onshore** market.

Spanish company **Siemens Gamesa** is the manufacturer with the highest installed offshore capacity in history (27 GW)[24]. The company has directed its production more strongly toward this segment than other manufacturers: 50% of its installed capacity in 2024 was offshore (4 GW onshore, 4 GW offshore). Danish company **Vestas**, currently the leading European globally, has installed over 11 GW offshore in 30 years [25].
In 2025, Chinese manufacturers were present abroad only in Asia and at the Beleolico wind farm in Italy[26]. **Mingyang,** the world's third-largest offshore manufacturer and China's leading one, has already announced that **Europe will be its priority market**[27]**.**

With the Med Wind and Green Volt projects, Mingyang is firmly entering Europe

The Med Wind project aims to build the first floating wind farm in the Mediterranean, south of Sicily, on an 85 km² site. The project is expected to produce 2.8 GW and could theoretically power 3.4 million households. In 2024, Mingyang won the tender to equip the site. While the initial project planned for 190 turbines, Mingyang's offer includes only 148, made possible by its MySE 18-292 turbines, which generate 18.8 MW per unit [28]. This contract follows a memorandum of understanding signed between the Chinese firm and the Italian Ministry for Enterprises for the installation of a Mingyang factory in Italy to produce the MySE 18-292, which will supply the Med Wind project and is expected to create 1,300 direct jobs[29].

[24] 5000 turbines, *www.siemensgamesa.com*,
[25] Offshore Wind Turbines | Vestas, *www.vestas.com*, 12/11/2025
[26] Renexia called on Mingyang because German manufacturer Senvion had gone bankrupt after winning the tender
[27] Mingyang chair says 'Europe the focus' as he launches 50MW turbine | Recharge, *rechargenews.com*, 21/10/2025
[28] Mingyang Enters Deal with Renexia, Italian Gov't to Set Up Shop in Italy | Offshore Wind, *Offshore Wind*, 08/08/2024
[29] EU launches probe into Chinese wind turbine companies, *www.ft.com*, 09/04/2024

Despite the EU's desire to protect European jobs and companies, an increasing number of European states and/or regions are turning toward Chinese proposals, which create jobs and reduce the budgets required for infrastructure development[30].

Mingyang is applying the same strategy in the United Kingdom, announcing plans to invest GBP 1.5 billion (EUR 1.7 billion) in three phases, including GBP 750 million allocated to building a blade and nacelle factory. According to Mingyang, this factory would create 1,500 jobs and begin operations in 2028.

At the same time, the firm is in discussions with developers Flotation Energy and Vårgrønn to supply the Green Volt project in Scotland from its new plant, with the wind farm expected to produce 560 MW[31].

In addition to these two megaprojects, Mingyang had been selected by the German company Luxcara for a 300 MW wind farm, before the operator changed course and chose Siemens Gamesa instead.

Figure 6 : Wind Energy Index

Source: Trading economics – Wind Energy Index

The index brings together the main offshore wind players present on the markets, and it clearly reflects the sector's recent difficulties.

1.4. A market undergoing a technological shift: floating wind turbines

To adapt to the specificities of the marine environment, manufacturers have **developed two types of offshore wind turbines**:

- **Fixed turbines,** with a **maximum depth of 50 to 60 meters** depending on the seabed[32].
- **Floating turbines**, which can be installed up to **200 km from the coast**, in waters up to **1,000 m deep[33]. hese floating turbines benefit from stronger and more predictable winds, allowing for a higher average electricity output.**

[30] EU launches probe into Chinese wind turbine companies, *www.ft.com*, 09/04/2024
[31] Mingyang Plans to Build 'Britain's First Fully Integrated Offshore Wind Manufacturing Facility' | Offshore Wind, *Offshore Wind*, 13/10/2025
[32] Eolien : Situation, Développement et opportunités, *Magellan Consulting*, 15/04/2022
[33] Home | ESMAP, *www.esmap.org*, 17/07/2025

The Hywind Scotland floating wind farm, in service since 2018, thus has an **average capacity factor[34] of 54%, compared with 38% for conventional wind farms.** The capacity factors expected for **new onshore wind farms built in Europe in 2022 are 30 to 45% and around 50% for offshore wind**[35]. But according to Equinor (Norway), floating farms would only be viable in the long term from 1.2 GW onwards, due to infrastructure costs[36] and the risk of high maintenance expenses[37].

Fixed turbines therefore **remain the majority**, as floating turbines have not yet achieved commercial maturity due to a cost per MWh that is still too high.

Technical innovation aims to **increase unit production capacity**. Ten years ago, unit capacities were only **10 MW**; Mingyang (China) is currently testing a **20 MW floating turbine**[38] and has unveiled plans for a **dual fixed turbine of 50 MW**[39].

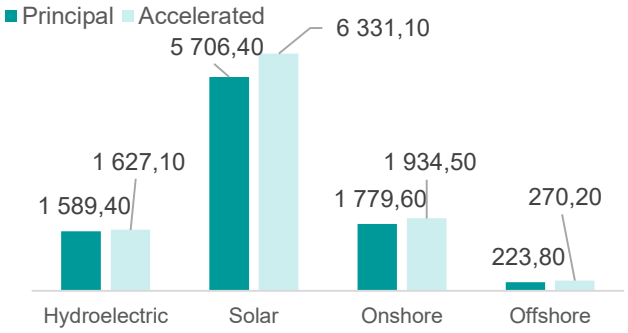
Overall, while **115 countries** are considered to have **technically exploitable offshore wind potential**, totaling just over **71,000 GW[40]** (11 times estimated electricity demand in 2040), only around **20,000 GW are located in shallow waters suitable for fixed turbines**[41].

[34] Power generated compared to installed capacity
[35] Éolien en mer: et si la solution passait par le flottant?, *Bpi France*, 11/12/2025
[36] Equinor: 500MW floating offshore wind is not cost-effective in the long term, *energywatch.com*, 30/09/2025
[37] Fixed: world's first floating wind power array back with lessons learned, says Equinor | Recharge, *rechargenews.com*, 09/10/2024
[38] La plus grande éolienne offshore de la planète a été installée à Hainan, en Chine - Geo.fr, *Geo.fr*, 05/09/2024
[39] China Firm Plans World's Largest Wind Turbine as Rivals Flop - Bloomberg, *Bloomberg.com*, 21/10/2025
[40] GWEC's Offshore Wind Hub, *www.gwec.net*,
[41] ESMAP offshore wind tech potential analysis maps

2. The market remains dynamic and growing thanks to emergence of new players

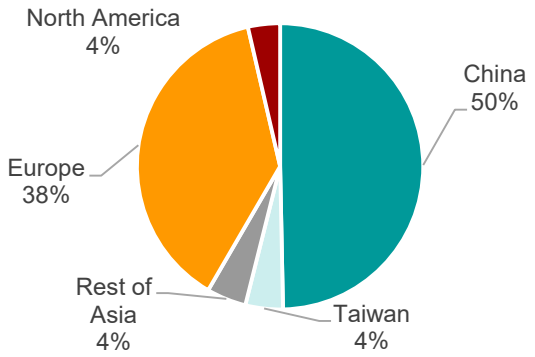
2.1. Despite a downward revision in anticipated growth, production capacity is expected to double in ten years

Figure 7 Estimated total capacity by renewable energy source in 2030 in GW



Source: AIE - Renewables 2025

Figure 8 : Percentage share of GW additions by region 2024–2034



Source: GWEC - Global offshore report 2025

In its "Renewables 2025" report, the IEA revised **downward by 27% its forecast for offshore wind capacity growth for the period 2025–2030**[42], (compared with its 2024 report), partly due to the 50% decrease expected for the U.S. market[43].

Despite this downward revision, the agency still expects **capacity to double by 2030**, with an anticipated increase of **140 GW** (598.5 TWh) in the main scenario and 1**86 GW** (713.7 TWh) in the accelerated scenario[44].

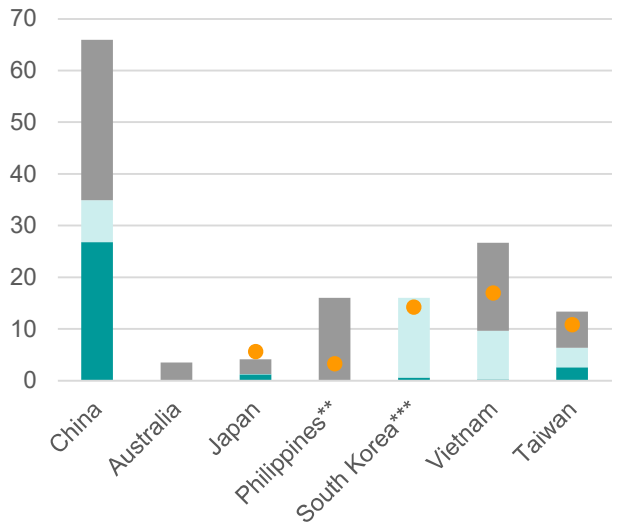
The Global Wind Energy Council (GWEC)[45] has also **revised down** its **growth forecasts by 24%** for the period **2025–2029**, now forecasting **118 GW of new capacity** (compared with 156 GW anticipated in 2024). For the 2029–2034 period, a strong acceleration is expected, doubling the total projected 2029 capacity to reach 441 GW [46] **of installed capacity in 2034.**

In **2034**, the **global offshore wind** market should still be dominated by China (164 GW) and the United Kingdom (60 GW). However, their share in the global market is expected to decline as new players enter[47]**. Between 2025 and 2034, 23% of added capacity in Europe is expected to come from countries that currently have no**

[42] Renewables 2025 – Analysis - IEA, *IEA*, 07/09/2025
[43] Triplement des renouvelables d'ici 2030 : un objectif désormais hors de portée, plombé par les États-Unis - Forbes France, *Forbes France*, 08/10/2025
[44] Renewable Energy Progress Tracker – Data Tools - IEA, *IEA*, 07/09/2025
[45] Industry interest group Representing more than 1,500 companies, organizations, and institutions in over 80 countries
[46] GWEC's Global Offshore Wind Report, *www.gwec.net*, 25/06/2025
[47] GWEC's Global Offshore Wind Report, *www.gwec.net*, 25/06/2025

operational wind farms. Likewise, France and Germany should significantly increase their capacity, with 7.2% and 20% respectively of new capacity[48].

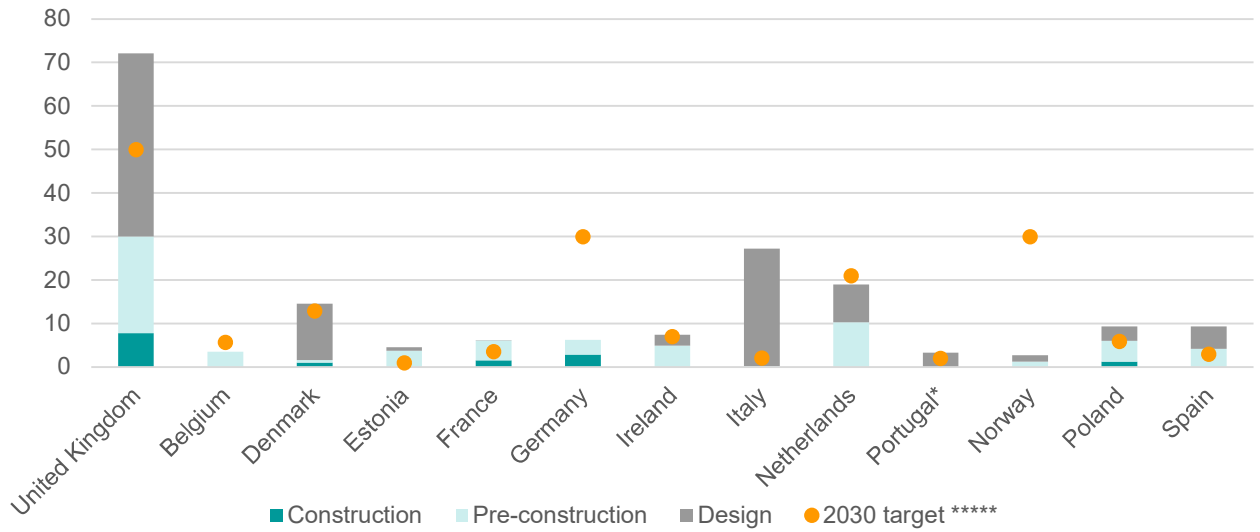
Figure 9 : APAC pipeline as of February 2025



By 2034, Australia and the Philippines will also have their first operational wind farms. Other countries, such as Colombia, will soon announce the results of their first tender.

This downward revision also reflects the delayed commercial maturity of floating wind: of the **18 GW projected to be installed by 2034**, only **1.3 GW** is expected **before 2030**. An average annual growth rate of 72% is then expected for the period 2029–2034[49].

Figure 10 : European pipeline as of February 2025



Source: Global Windpower tracker 02/25 – Global Energy Market; Market Intelligence - TGS 4C; GWEC Global Offshore wind Report, consolidated by GSA

[48] GWEC's Global Offshore Wind Report, *www.gwec.net*, 25/06/2025

[49] GWEC's Global Offshore Wind Report, *www.gwec.net*, 25/06/2025

*Wind energy offers many benefits to Portugal. Its potential is even greater - WindEurope, *WindEurope*, 17/01/2024

** Offshore wind to add 16 GW in new capacity — Energy dep't - BusinessWorld Online, *BusinessWorld Online*, 19/01/2025

*** Asia-Pacific's Offshore Wind Pipeline Grows, But Few Turbines Have Hit Water - OGV Energy, *OGV Energy*, 30/05/2025

**** Pre-construction does not guarantee construction, and includes areas where bidding has not yet taken place

***** Norway's target is 2032, Vietnam's is 2035, China does not yet have a national target but has regional targets, and neither does Australia. The EU's target is 111 GW, 65 GW for the countries of the Esbjerg Declaration and 19.6 GW for the Baltic countries. The United States and Sweden will be treated separately.

2.2. Political decisions affect the development of the sector and its stakeholders

Donald Trump's 2024 campaign, with its "*Drill Baby, Drill*" slogan, followed by the presidential orders "Reinvigorating America's Beautiful Clean Coal Industry and Amending Executive"[50] and the "One Big, Beautiful Act[51]", signaled a strong opposition to renewable energy.

The **U.S.**, although a late entrant to the market (**0.174 GW** installed)[52], had been ambitious under President Biden, setting **a target of 30 GW** installed by **2030**.

This target will not be reached; the country was already behind in 2024[53]. Since Donald Trump's return, **the Bureau of Ocean Energy Management (BOEM)** has announced that it will reject new permits and review those already granted[54], **for solar and wind projects**[55], on federal land or waters.

In addition to removing federal funding[56], the new administration attempted (unsuccessfully) to **block ongoing construction** of Empire Wind 1 (810 MW, developed by Equinor) and Revolution Wind (704 MW, developed by Orsted).

Several other megaprojects will not be built, such as Empire Wind 2 with a capacity of 1.3 GW, as **Equinor considers political changes and inflation are causing profitability issues**[57].

The future of the **30 GW in the U.S. pipeline is therefore uncertain**. Thanks to projects already **under construction**,[58] **5.8 GW** should still be connected by **2030.**

Because of U.S. **strategic reversals and the trade war**, Equinor (also affected by falling oil prices) **reported a net loss of USD 210 million in Q3 2025**[59], due to a **USD 955 million impairment** on its U.S. project[60]. Danish company **Orsted** was also hit, **losing 30% of its market value** and cutting 2,000 jobs[61]. These uncertainties prevented it from selling shares of another U.S. project under construction[62], forcing it to **undertake a massive USD 9.4 billion recapitalization**[63].

The significant losses caused by these developments **make consolidation likely, along with the disappearance of mid-sized operators and a refocusing on traditional markets.** Equinor is

[50] Reinvigorating America's Beautiful Clean Coal Industry and Amending Executive Order 14241 – The White House, *The White House*, 08/04/2025
[51] Text - H.R.1 - 119th Congress (2025-2026): One Big Beautiful Bill Act | Congress.gov | Library of Congress, *www.congress.gov*, 20/05/2025
[52] Offshore Wind farms in The United States | TGS 4C | 4C Offshore, *www.4coffshore.com*, 21/04/2013
[53] US Offshore Wind to Hit 14 GW by 2030, Missing President Biden's 30 GW Target - ACP Report | Offshore Wind, *Offshore Wind*, 10/07/2024
[54] US DOJ moves to quash Atlantic Shores offshore wind approval TGS 4C | 4C Offshore News, *TGS 4C | 4c Offshore*, 02/10/2025
[55] A timeline of Trump's moves to dismantle the US wind and solar energy industries | Reuters, *Reuters*, 26/08/2025
[56] Trump cancels $679 million in federal funding for offshore wind projects | Reuters, *Reuters*, 29/08/2025
[57] Éolien : Equinor déprécie un grand projet au large de New York, déjà ciblé par Trump | Connaissances des énergies, *Connaissance des Énergies*, 23/07/2025
[58] Offshore wind targets underpin acceleration to 2030 and beyond | Ember, *Ember*, 30/10/2025
[59] Le géant norvégien Equinor dans le rouge au 3e trimestre, malgré une hausse de sa production | Connaissances des énergies, *Connaissance des Énergies*, 29/10/2025
[60] Éolien: Equinor déprécie un grand projet au large de New York, déjà ciblé par Trump | Connaissances des énergies, *Connaissance des Énergies*, 23/07/2025
[61] Eolien : en pleine crise, Orsted va supprimer un quart de ses effectifs | Les Echos, *Les Echos*, 09/10/2025
[62] Orsted Raises $9.4 Billion to Counter Hit From US U-Turn on Wind - Bloomberg, *Bloomberg.com*, 06/10/2025
[63] Ørsted Moving Ahead with EUR 8 Billion Rights Issue to Build Sunrise Wind, Shore Up Finances Amid US Market Uncertainty | Offshore Wind, *Offshore Wind*, 25/08/2025

already Orsted's second-largest shareholder and wants to bring its renewables division closer to the Danish company, which Orsted has so far refused[64].

Major oil companies are also revising their plans following Trump's return, such as the UK's Shell, which has abandoned renewable projects it had committed to in order to refocus on oil extraction[65].

To address the crisis, government support measures are possible[66], especially as **unsuccessful tenders are multiplying**, including the most recent one in the Netherlands for a 1 GW project that received no bids**. States therefore need to adapt their tender mechanisms** (particularly risk allocation[67] and permitting timelines[68]).

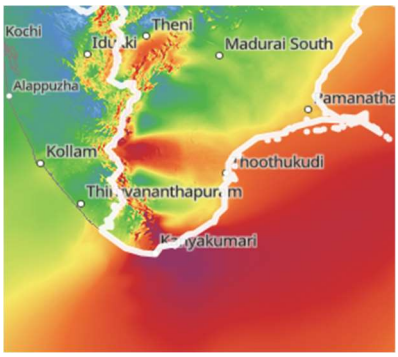
2.3. Emerging countries are partly responsible for the upcoming increase in global capacity

Some emerging markets have shown strong interest in developing offshore wind due to their favorable weather conditions and easier access to capital thanks to relatively low perceived country risk. Based on a study conducted in more than 50 countries by the World Bank and the Energy Sector Management Assistance Program (ESMAP)[69], we can examine the case of four promising emerging countries. The Philippines, already involved in the market and with the construction of some of its farms imminent[70] will not be addressed in the following section.

The following countries face common challenges: an electricity mix relying mainly on hydropower (Brazil, Colombia), fossil fuels and imports (Morocco, India), the development of electric vehicles and electrified industry. All of which will affect future electricity demand.

2.3.1 India

Figure 11 : Wind map of Tamil Nadu



Source: Global Wind Atlas

India's energy needs are immense. To meet this demand, the country increased its total installed energy capacity from **249 GW** in **2014** to **457 GW** in **2023**. Nearly **half** of this increase is due to **renewable energy**[71]. **Coal** still accounts for more than **half of the energy mix**[72]**.**

The country has a **technical offshore wind potential** estimated at **174 GW** (91 GW fixed, 83 GW floating), with the most suitable region being **Tamil Nadu** in the south.

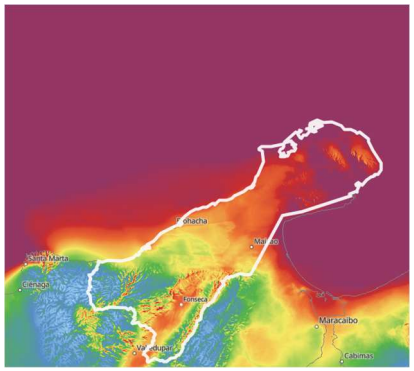
Despite land-related challenges for onshore and solar development, India has still not developed its first offshore wind farm, even though its **2030 target** is **30 GW**[73].

64 Orsted écarte toute fusion avec la division renouvelable d'Equinor | Zonebourse, *Zonebourse*, 05/11/2025
65 Shell abandons floating North Sea wind farm projects, *www.ft.com*, 10/11/2025
66 Offshore wind targets underpin acceleration to 2030 and beyond | Ember, *Ember*, 30/10/2025
67 GWEC's Global Offshore Wind Report, *www.gwec.net*, 25/06/2025
68 European Governments must get their act together on wind energy - WindEurope, *WindEurope*, 03/09/2025
69 World Bank Trust Fund dedicated to solving energy challenges in emerging markets
70 Ming Yang and Buhawind partner on Philippine offshore study - reNews - Renewable Energy News, *reNEWS - Renewable Energy News*, 07/11/2025
71 L'Inde Investit Dans 457 GW Pour Répondre à La Demande énergétique Croissante - Energynews.pro, *energynews.pro*, 03/01/2025
72 Gestion énergétique en Inde : Perspectives, enjeux et évolution de la consommation, *Enerdata*, Date not found
73 Global Offshore Wind to Triple by 2030, India Plans 37 GW Auctions – Outlook Business, *Outlook Business*, 31/10/2025

developed its first offshore wind farm, even though its 2030 target is 30 GW. Companies remain reluctant to commit for now, notably because the Gulf of Mannar is a protected national park home to vulnerable species, and recent tenders have received no bids.

2.3.2 Colombia

Figure 12 : Wind map of La Guajira



Source: Global Wind Atlas

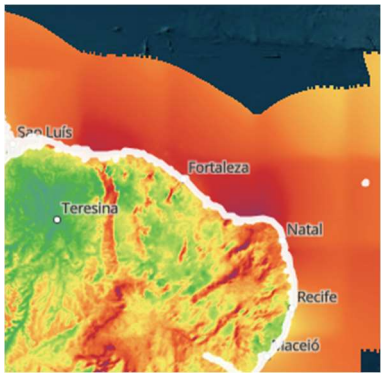
Colombia is among the most dynamic emerging players, as the country seeks to **diversify its economy** and is **experiencing rapid growth in electrified vehicles**[74]. These new needs, combined with recurring hurricanes and thermal anomalies in the Caribbean[75] raise the risk of **energy shortages starting in 2028**.

The country has a **technical potential** estimated at **109 GW** (31 GW fixed, 78 GW floating)[76], and a target of **7 GW** installed by **2040** and **13 GW** by **2050**[77]. In 2025, the country has **total installed capacity of 21.2 GW** (including 12.2 GW of hydropower).

To encourage investment, the government **offers 15-year contracts under the Contract for Differences (CfD) scheme**. These projects are located in the **La Guajira** region, lands inhabited by the **Wayu people who oppose the construction of energy infrastructures**. However, the **expected depletion of the El Cerrejon coal mine in the region by 2034** (50% of Colombia's coal exports) **is pushing the government to facilitate the installation of new infrastructures**[78]. Manufacturer Vestas is already present in the onshore wind sector

2.3.3 Brazil

Figure 13 : Wind map of the Nordeste



Source: Global Wind Atlas

The **first tender was expected to take place in 2022** but has been repeatedly delayed[79].

The country has a technical potential estimated at **1,229 GW** (480 GW fixed, 748 GW floating), mainly across **three regions** (Nordeste, Sudeste and Sul). Due to technical challenges or protected areas, the **Nordeste province is the most favorable**, with strong winds and **356 GW of technical potential**[80].

The country has **210 GW installed, with hydropower accounting for more than 50%** at 110 GW[81]. In 2023, **around 189 GW of**

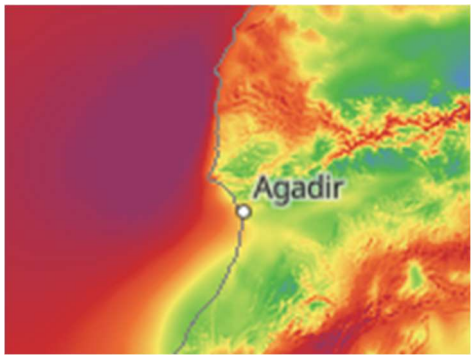
[74] Electrified Vehicle Sales in Colombia Double Diesel in First Half of 2025 - Mobility Portal, *Mobility Portal*, 28/07/2025
[75] Colombia battles to diversify economy away from oil and gas, *www.ft.com*, 11/11/2024
[76] Offshore Wind Technical Potential Colombia – ESMAP & World Bank (2020)
[77] Offshore wind targets underpin acceleration to 2030 and beyond | Ember, *Ember*, 30/10/2025
[78] Renewable energy ambitions in northern Colombia collide with Indigenous worries | AP News, *AP News*, 20/02/2025
[79] Brazil risks postponing the first offshore wind auction in 2026, *brazilenergyinsight.com*, 09/10/2025
[80] Offshore Wind Development Program: Scenarios for Offshore Wind Development in Brazil | ESMAP, *www.esmap.org*, 18/07/2024
[81] Snapshot: Brazil's installed power capacity - BNamericas, *BNamericas.com*, 09/05/2025

offshore projects were under review by the authorities[82]. Although the country has **no quantified GW target** yet, this gap is expected to be addressed soon. **The first pilot project**, in the province of Rio Grande do Norte, with a capacity of 24.5 MW, is **expected to be connected to the grid in 2028**[83].

The **numerous delays have caused some players**, such as Copenhagen Infrastructure Partners, **to leave**[84] and have led to reallocations of TotalEnergies' teams, creating an opportunity for Chinese actors and other non-traditional investors, **as the authorities are seeking substantial financing**[85]**.**

2.3.4 Morocco

Figure 14 : Wind map of Essaouira



Source: Global Wind Atlas

Morocco is benefiting **from its major 2030 plans to transform its energy sector, increasing capacity from 12 GW to 27 GW** (of which 80% renewable)[86]. In **2024**, the country was still **importing** part of its **energy**[87] and remained **largely dependent on coal** (52%).

The country aims to **become an exporter of renewable electricity** to Europe as part of the Power Export: One Shop Export plan. Following the failure of the Xlinks project—estimated at EUR 29.5 billion and intended to enable Morocco to sell renewable electricity to the UK market via a nearly 3,000 km cable—the country is redirecting its attention toward Portugal and Spain[88].

Morocco has a **technical potential estimated at 200 GW** (22 GW fixed, 178 GW floating). The preferred region is **Essaouira**, to benefit from **Atlantic winds and its large settlement area**.

In **June 2025,** the country announced its **intention to build a 1 GW** wind farm starting in **2029**, though the tender has not yet been launched[89].

[82] Global offshore wind: Brazil | Global law firm | Norton Rose Fulbright, *www.nortonrosefulbright.com*, 31/12/2023
[83] Work Starts on Brazil's First Offshore Wind Project, Pilot Expected to Come Online in 3 Years | Offshore Wind, *Offshore Wind*, 26/06/2025
[84] Largest investment firm fund in renewable energy infrastructure
[85] 'Project in Rio Grande do Norte Is No Longer Just an Idea' | Brazilian Institute Invites Partners to Join Offshore Wind Pilot | Offshore Wind, *Offshore Wind*, 30/10/2025
[86] Morocco Aims to Double Electricity Capacity by 2030 World Cup - Bloomberg, *Bloomberg.com*, 21/05/2025
[87] Réduction des importations d'énergie et augmentation continue des importations de matériel et de biens manufacturés en 2024 | Express TV, *Express TV*, 24/07/2025
[88] Le Maroc lance un plan stratégique pour devenir le leader des exportations d'énergie propre vers l'Europe, *Atalayar*, 18/08/2025
[89] Morocco Plans to Start Building 1 GW Offshore Wind Farm by 2029 | Offshore Wind, *Offshore Wind*, 17/06/2025

3. Several obstacles to the growth of the offshore wind market

3.1. Supply chain congestion and volatile material prices are negatively affecting the sector

In **2016**, **offshore** projects were the energy **infrastructures** facing the **fewest delays and cost overruns** during construction, benefiting from a **constantly growing market with limited uncertainty** and unaffected by supply chain issues.[90] That period is now over, in **2025**, an estimated **300 GW** have been **cancelled**, **postponed**, or **delayed**[91], While political decisions have had an impact, they are not the only explanations.

Like many infrastructures**, wind power is capital-intensive**[92], **80% of project costs represent upfront capital** (8% related to development and 72% to financing, studies, turbine construction, foundations and moorings, installation, and grid connection)[93]. The **average total construction** cost is **EUR 3.5 million/MW**[94], and the levelized cost of energy (**LCOE**[95]) ranges from **56** to **125 USD/MWh**[96] in Europe.

As early as **2023**, Vattenfall estimated that **upfront costs had increased by 40% in one year** due to **supply chain problems and rising interest rates**[97]. **Offshore** wind faces more **complex conditions** due to **saltwater and stronger winds**, requiring more resilient infrastructure than onshore[98]. Turbines are mainly produced using **materials with volatile market prices.**

Steel, which accounts for up to **90%** of a turbine, and **fiberglass,** used for **nacelles,** are affected by **chronic overcapacity and significant customs duties.** The use of **permanent** magnets is more widespread offshore than onshore to reduce the weight of the infrastructure[99], the main rare earths used are **neodymium** and **dysprosium**[100]. By 2035, the **wind sector** is expected to represent **6% and 30% respectively of annual demand** for these materials, even though they account for only **0.01%** of the infrastructure's **total weight**[101].

With increased U.S. tariffs, **Beijing strengthened export controls on its rare earths and permanent magnets** as a countermeasure (representing 90% and 94% of global production)[102]. **Europeans** and **Americans**[103] have since reached an agreement with China, but it must be

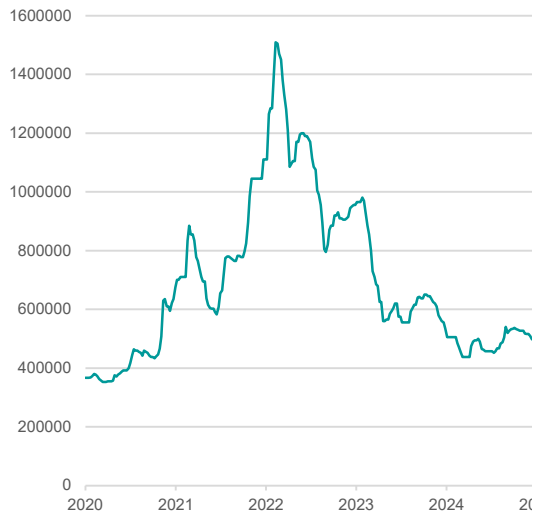
[90] Offshore Wind Projects Have Less Delays and Cost Overruns, Says EY - Offshore Energy, *Offshore Energy*, 02/12/2016
[91] North American Clean Energy - Cancelled Culture: Abandoned and Delayed Offshore Wind Projects Now Account for 300 GW, *www.nacleanenergy.com*, 02/07/2025
[92] Capital Intensive Industries Explained: Definition, Examples, and Impact, *Investopedia*, 18/11/2003
[93] 2021-09_Eolien_mer_Sud_Atlantique_DMO_Fiche13.pdf, *debatpublic.fr*, 09/2021
[94] How Much Does Wind Power Cost in Europe? ROI, Financing & Payback, *www.delfos.energy*, 18/09/2025
[95] LCOE is the price of electricity required for a project to generate revenues equal to its costs, including a return on invested capital equal to the discount rate. A higher electricity price would result in a higher return on capital, while a lower price would result in a lower return or even a loss.
[96] Renewable Power Generation Costs in 2024, *www.irena.org*, 22/07/2025
[97] First six months 2023: A positive development for the customer business and challenges in offshore wind power - Vattenfall, *Vattenfall*, 20/07/2023
[98] Leadvent Group| Wind Blade Material Selection for Offshore vs. Onshore Wind Farms, *www.leadventgrp.com*, 26/10/2023
[99] Les besoins de terres rares en matière d'énergies renouvelables | Connaissances des énergies, *Connaissance des Énergies*, 27/11/2019
[100] The supply chain limitations facing the wind turbine market, *Power Technology*, 24/04/2025
[101] Les terres rares dans l'éolien - Info éolien, *Info éolien*, 11/10/2021
[102] Terres rares : la Chine accorde à l'Europe un sursis d'un an, *Le Point*, 01/11/2025
[103] Terres rares : que change l'accord conclu entre la Chine et les États-Unis ? - Le Parisien, *leparisien.fr*, 30/10/2025

renegotiated annually, leaving the risk of future production chain disruptions, **as few alternatives to Chinese supply exist**. These **disruptions** drive **production costs sharply upward**, and projects that become unprofitable are generally cancelled[104] because penalties are relatively small[105] compared with the cost of an unprofitable project.

Since **most turbines are fixed** and **built at sea**, **vessels play a crucial role** in construction and maintenance. These vessels are subject to the **same market pressures** as the wind sector, leading to contract **cancellations and project delays**[106]. **The rapid increase in turbine capacity**, with increasingly large nacelles, requires new vessels at an accelerating pace[107].

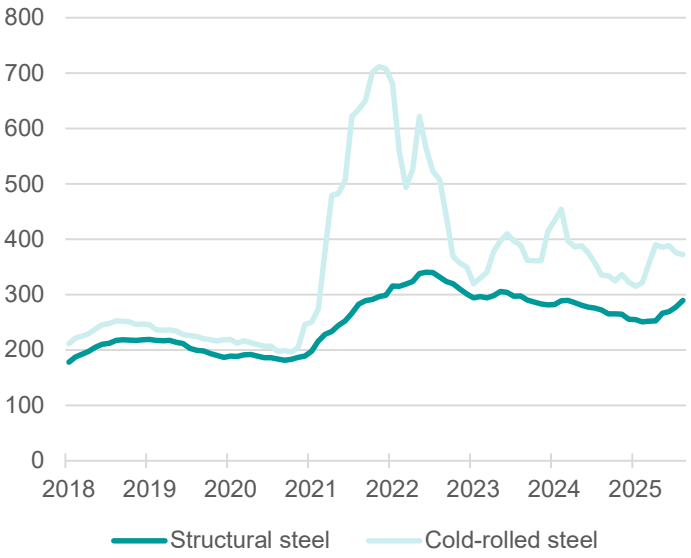
The rise of **floating wind should help reduce uncertainties** thanks to **onshore construction**, lowering upfront costs, if ports receive necessary investment, including larger quays[108] to facilitate construction and maintenance.

Figure 15: Neodymium prices 2020–2025 in CNY/t



Source: Trading zone – Neodymium Index and Federal Reserve Bank of St Louis – Steel index

Figure 16: Steel price index (Base 100 in 1982)



3.2. Grid access, a major obstacle for developers

Access to the electricity grid is now one of the main obstacles to the large-scale deployment of renewable energies. To operate, offshore **the infrastructure** is **connected** to an **offshore substation** that transmits power to the onshore grid[109] . This transmission is carried out via **submarine cables,** which face **manufacturing capacity constraints, leading to a shortage**[110] .

[104] Pourquoi l'extension du plus grand parc éolien en mer du monde est mise en pause, *Révolution Énergétique*, 15/05/2025
[105] BP and Equinor Could Cancel US Offshore Wind Projects | Offshore Wind, *Offshore Wind*, 01/08/2023
[106] Shipping giant cancels £356m offshore wind vessel order TGS 4C | 4C Offshore News, *TGS 4C | 4c Offshore*, 10/10/2025
[107] Larger Wind Turbines: What does this mean for offshore installation vessels? - Offshore Construction Associates, *Offshore Construction Associates*, 09/09/2021
[108] WFO financing offshore wind 2022 - WFO-Global, *WFO-Global*, 09/2022
[109] Offshore substations - Spinergie, *www.spinergie.com,* 09/19/2025
[110] Shortage of submarine power cables poses threat to offshore wind market | Offshore Magazine, *www.offshore-mag.com,* 04/11/2024

As **the turbines** produce **alternating current, HVAC cables** are traditionally **used,** but these cables **lose power as their length increases.** To overcome this, high-voltage direct current (**HVDC)** cables are **increasingly being used,** as wind farms are located farther from the shore. They have **the advantage of losing less electricity** and becoming **more cost-effective at distances of 80 km or more**[111]. However, to feed this electricity into the grid, a **second substation is needed** to **convert the direct current back into alternating current** because the voltage is too high for the grid[112]. **HVDC** is expected to account for **37% of wind farms ordered in 2035**[113], promoting the creation of a manufacturing sector in countries that do not have one.

However, **the completion** of infrastructure **construction does not guarantee access to the electricity grid**: it is estimated that in **2025**, **500 GW** in Europe **will be awaiting assessment for connection**[114], with waiting times of up to **10 years** due[115] to electricity overcapacity and a **lack of grid availability**. This situation, **which is not specific to offshore** wind**,** causes cancellations and delays, as these issues are **beyond the scope of developers' control.** In addition, the rules governing the order of connection of new electricity generation capacity are **specific to each country**[116]**.** For the European interest group Wind Europe, "*the objective must be to reduce the number of projects on hold, eliminate premature and speculative bids, and ensure a balanced distribution of grid capacity among all strategic net-zero emission technologies*." This demonstrates the **need for interconnections between players in order to streamline project costs and duration. The integration of a network access permit from the tender stage** and the grouping of projects into lots encourages a wider range of suppliers to position themselves, **limiting the risk of tenders without competitors**[117].

Once **the infrastructure is connected to the grid, other challenges** arise because this is an intermittent energy source. During **periods of** high **winds**, **production** increases sharply and can **exceed electricity demand**. This **excess** electricity **production** drives **prices down, even to negative levels**[118] , because it cannot be destroyed and is rarely stored. Under a **physical Power Purchase Agreement,** i.e., the purchase of electricity at a fixed price, **production must be maintained** because it is backed by electricity delivery[119] . These overproduction problems may only be temporary, as the electrification of the economy and the increase in the number of electric vehicles on the road are expected to drastically increase the amount of electricity required.

As the network infrastructure was built before the advent of renewables, **the capacity to redistribute renewable production or sell it to other countries is limited**. A **major European cross-border interconnector cable project is under construction** but is being slowed down by congestion in the cable market[120].

[111] Offshore substations - Spinergie, *www.spinergie.com,* 09/19/2025
[112] Wind power costs: Why the industry is facing cost headwinds | World Economic Forum, *World Economic Forum,* 01/11/2024
[113] Offshore substations - Spinergie, *www.spinergie.com,* 09/19/2025
[114]Wind power: difficulties accessing the grid cause massive bottlenecks, *www.latribune.fr*, 01/13/2025
[115] There is no green future for Europe without an upgraded power grid, *www.ft.com,* 09/04/2023
[116] Immediate actions needed to unblock grid capacity for more wind energy - WindEurope, *WindEurope,* 07/05/2024
[117] Case study: A new era in building offshore grid connections | Arthur D. Little, *www.adlittle.com,* 11/2024
[118] French renewable energy is in turmoil after massive Spanish power outage, *Le Monde.fr,* 07/06/2025
[119] Financial Power Purchase Agreement and electricity prices, *cms.law,* 06/18/2020
[120] Will there be enough cables for the clean energy transition?, *www.ft.com,* 07/30/2023

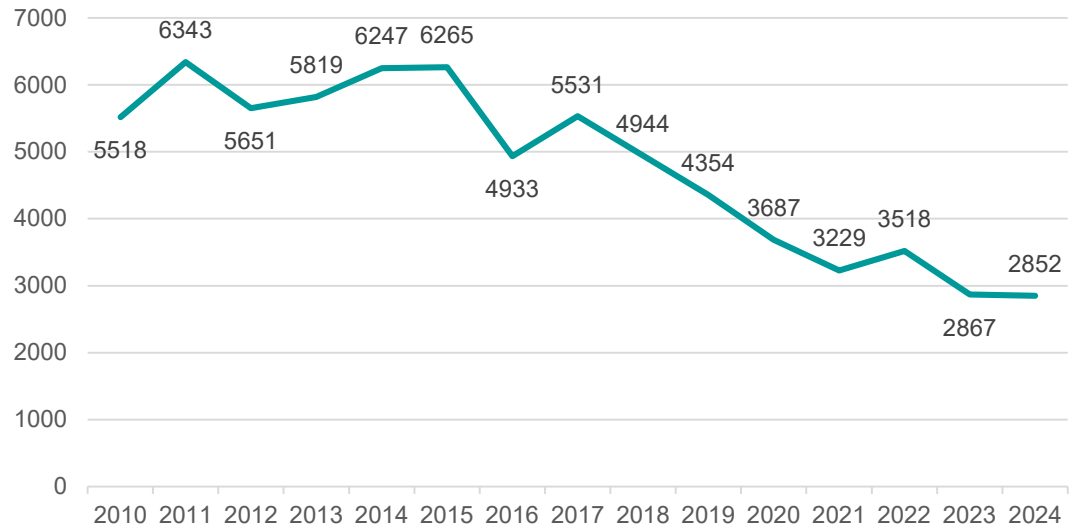
The **development of grid-connected battery storage systems** (BESS), which help to **smooth out the intermittency of renewable energies**, could promote the deployment of offshore wind power: by allowing **surplus electricity produced during peak production periods to be sold during peak demand periods,** they **limit** forced **disconnections** due to excess production, thereby **improving profitability**[121] . Until now, BESS have proven to be **better suited to solar power,** which has regular production peaks, than to wind power, but the **reduction in BESS installation costs could change the situation**.

3.3. Between increased borrowing costs and additional capital costs, project financing is a complex equation that weighs heavily on implementation

In 2025, the construction of **1 MW offshore will cost between USD 3 and 4 million**, meaning that a **1 GW** wind farm could cost **up to USD 3 billion**[122] , (which is double the cost of an onshore wind) farm, and could take up to **11 years to become operational** (3 to 5 years for the development phase, 1 to 3 for the pre-construction phase, and 2 to 4 years for construction)[123] . **Offshore construction** operations **are risky, which contributes to inflating the risk premium and therefore the cost of financing**.

A **large number of players** are involved in the construction of the infrastructure, **making it difficult for inexperienced investors to understand**, especially in immature markets. The **risk perceived** by **inexperienced investors is significant**, which can lead to massive investment withdrawals.

Figure 17 : Total installed costs [124] , global weighted average for offshore wind, in USD/kW[125]



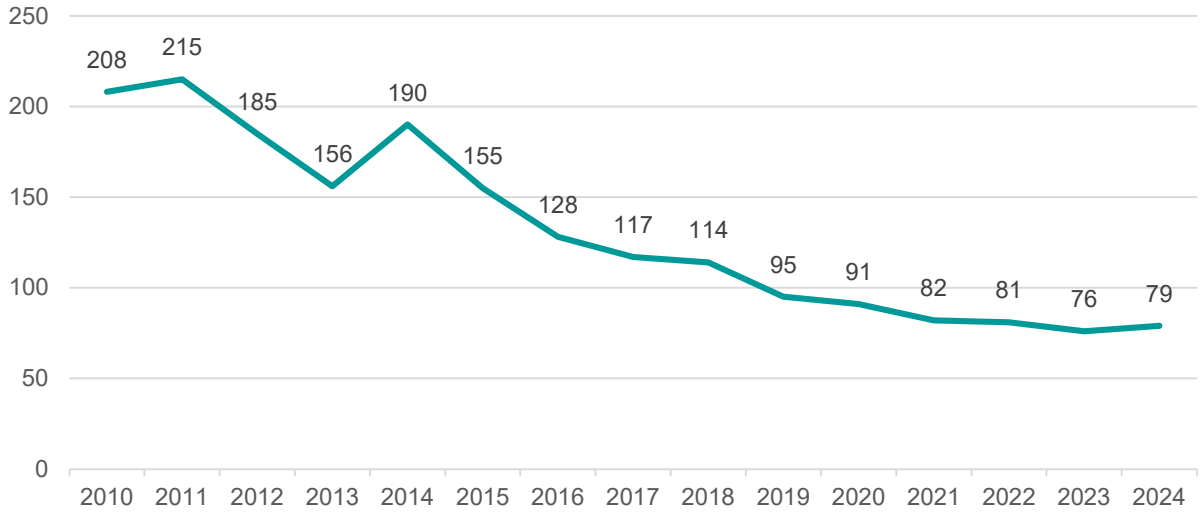
Source: IRENA – Renewable Power Generation in 2024

Renewable energies are vulnerable to interest rate fluctuations due to their high capital intensity during the construction phase. With a **debt ratio** generally around **70%**[126] , **the increase in central**

[121] Electricity storage: on the cusp of an energy revolution, Global Sovereign Advisory, 09/17/2023
[122] How Much Does Wind Power Cost in Europe? ROI, Financing & Payback, *www.delfos.energy,* 09/18/2025
[123] Construction of an offshore wind farm - Iberdrola, *Iberdrola,* Date not found
[124] The total installed cost does not include borrowing costs
[125] Figures 18 and 19 only cover projects that have been commissioned, so the impact of rising interest rates and material costs is lower than for projects currently under consideration or in the early stages of construction.
[126] Higher interest rates pose a challenge to financing renewables, *International Energy Forum,* 08/29/2024

bank key interest rates in 2022 played **a critical role in the wave of project renegotiations and cancellations**. After winning a tender, it **takes an average of two years to sign contracts with all suppliers**[127] . This **delay** affects the **viability of projects,** as **conditions** during the development phase **differ** from those at **the start of construction,** both in terms of material costs and electricity prices. However, once the construction phase has begun, developers generally benefit from protection against price volatility thanks to long-term contracts.

Figure 18: Weighted global average LCOE 2024 USD/MWh offshore wind



Source: IRENA – Renewable Power Generation in 2024

After nearly a decade of continuous decline, the **LCOE for offshore wind power has started to rise again, due to the increase in borrowing costs following the Covid-19 pandemic and the surge in prices of certain raw materials following the start of the war in Ukraine. From USD 231/MWh in 2015**[128] **it fell to USD 76.6/MWh in 2023 before rising again to USD 80/MWh in 2024**[129]**.**

Generally, a 1 percentage point increase in interest rates increases the LCOE by 8%[130]. Between 2022 and 2023, these **rates** jumped from **-0.5%** to almost 4%[131] . Due to the time, it takes for a project to become operational, the increase in costs has a future impact and influences the number of projects in the pipeline that will actually be carried out.

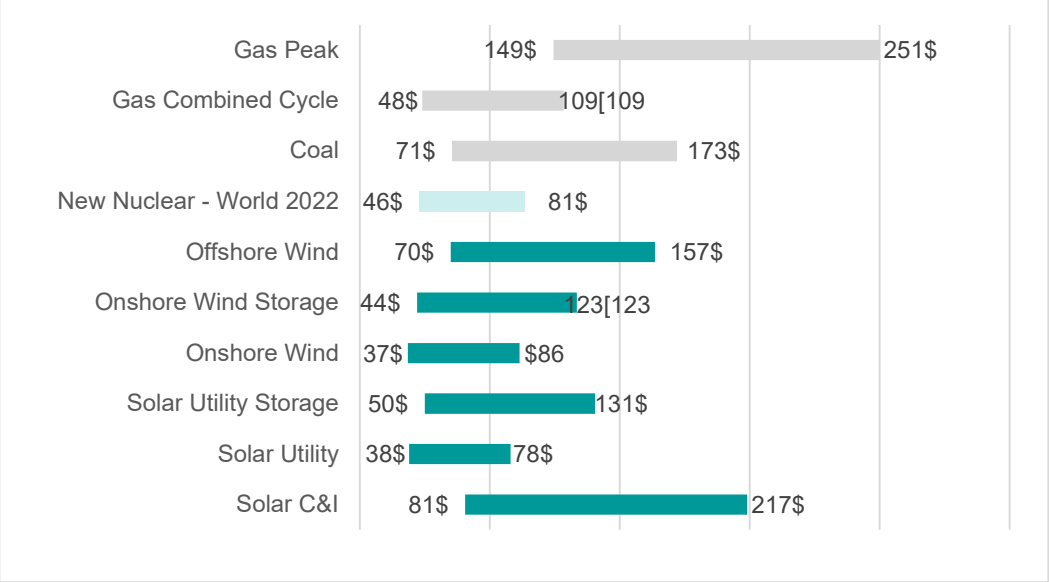
The **LCOE varies from country to country**. In **2024, Denmark** and China had an LCOE **of $53/MWh** and $56/MWh, respectively, while in **France** and Japan it stood at **$123/MWh** and $181/MWh, respectively[132] . In **Europe,** the **LCOE increased** by around **16%** in 2024, from $69/MWh to $80/MWh[133] .

[127] Report: Offshore wind at a crossroads | Ørsted, *orsted.com,* 04/2025
[128] Report: Offshore wind at a crossroads | Ørsted, *orsted.com,* 04/2025
[129] IRENA Report: onshore and offshore wind — the most cost-competitive power generation globally - Baltic Wind, *Baltic Wind,* 07/28/2025
[130] Financing Offshore Wind in APAC - REGlobal - Finance, *REGlobal,* 09/06/2025
[131] Euribor chart - graphs with historical Euribor rates, *euribor-rates.eu*
[132] Renewable Power Generation Costs in 2024, *www.irena.org,* 07/22/2025
[133] Renewable Power Generation Costs in 2024, *www.irena.org,* 07/22/2025

The stabilization of the **ECB's key interest rates** at around **2%**[134] , giving the sector some **relative breathing space,** even though they remain higher than before the Covid crisis. However, this good news is offset by **the volatility of** commodity prices.

Offshore wind power, an already competitive LCOE, the American example

Figure 19: Comparison of LCOE by source in 2025 in the U.S. (Nuclear in 2022)



Source: Lazard LCOE June 2025

In the United States, despite upward pressure from multiple factors and the fact that floating wind power has not yet reached commercial maturity, offshore wind has a lower LCOE than conventional energy sources, ranging from $70 to $157/MWh compared to $71 to $173/MWh for coal.

This volatility has made it more **complex** to develop offshore wind power in **emerging countries** than in mature markets. Emerging countries **suffer from higher capital costs**[135] . The higher weighted average cost of capital (**WACC**) risks **delaying the establishment of a market and supply chain**, which are **necessary conditions** for **lowering production and capital costs**. **Emerging markets account for** a **significant proportion** of the member countries of **the Global Offshore Wind Association**[136] **(**Brazil, Chile, Colombia, Panama, Papua New Guinea, Saint Lucia, Trinidad and Tobago), demonstrating their willingness to change their electricity mix.

The cost of capital consists of a base rate linked to country risk and a rate linked to the sector. According to the IEA, the **base rate accounts for 60 to 90% of the WACC** in **emerging countries,** compared with **30% in China** and **10% in Europe**[137] . **WACC** is intrinsically **linked** to **LCOE,** as **financing costs account for 50% of LCOE**[138] . A **3-4% increase** in **WACC** would lead to a **30% increase** in **LCOE**[139] .

[134] ECB rates, refi rates, *euribor-rates.eu*
[135] Higher interest rates pose a challenge to financing renewables, *International Energy Forum*, 08/29/2024
[136] How a high cost of capital is holding back energy development in Kenya and Senegal – Analysis - IEA, *IEA,* 06/02/2025
[137] How a high cost of capital is holding back energy development in Kenya and Senegal – Analysis - IEA, *IEA,* 06/02/2025
[138] LCOE and WACC (weighted average cost of capital), *BVG Associates*, 06/03/2016
[139] Report: Offshore wind at a crossroads | Ørsted, *orsted.com*, 04/2025

« Contracts for differences »

Contracts for differences (CFDs) are popular with market players and encourage investment in renewable energies. These contracts offer protection against price volatility by guaranteeing predictable revenues for operators[140] .

A reference price is set in advance, and when the market price falls below this price, the operator receives compensation. When the price of electricity rises above this price, the operator reimburses the difference, protecting consumers from cost increases[141] . Operators miss out on opportunities when prices are high, but this allows them to reduce capital costs during the construction phase. The risk is lower since the price and volume are guaranteed over a long period, generally 15-25 years[142].

CfDs, already widely used in the United Kingdom, are becoming increasingly common in the rest of Europe, particularly to revive struggling markets. Germany[143] , the Netherlands[144] , and Denmark[145], three countries that have experienced tenders without bidders, have announced that they will return to CfDs.

4. Political and social risks can also slow the construction of offshore wind farms

4.1. Conflicts of use persist, whether environmental or related to land use

The largest offshore wind farms will cover more than 100 km² and have several hundred turbines[146] . Due to their size, these infrastructures generate conflicts of use.

Indeed, the **fishing** industry **requires geographical conditions that are relatively similar to those for wind power**: shallow seas, loose sediments, and proximity to the coast[147] . There is currently **no common legislation across all countries:** some European countries prohibit fishing throughout the entire wind farm, while others limit the ban to 50 meters around the turbine to avoid damaging the infrastructure[148] . The creation of these **farms can damage marine biodiversity because of the cables** that lie on the seabed and causes fishermen to relocate[149] . This potential **territorial conflict could cause social unrest** when renewable energy projects, which are critical to achieving decarbonization targets, are prioritized over fishing despite its importance to the economies and social fabric of coastal regions. To **resolve conflicts, governments can offer financial compensation to affected fishermen[150] or require developers to compensate the fishing**

[140] Offshore Wind Finance | Global Offshore Wind Alliance (GOWA), *Global Offshore Wind Alliance (GOWA),* 10/29/2025
[141] GWEC's Global Offshore Wind Report, *www.gwec.net,* 06/25/2025
[142] Contracts for Difference: the Instrument of Choice for the Energy Transition - Oxford Institute for Energy Studies, *Oxford Institute for Energy Studies,* 04/24/2024
[143] Germany considering offshore wind CfDs in new 'pragmatic' outlook TGS 4C | 4C Offshore News, *TGS 4C | 4c Offshore,* 06/11/2025
[144] Dutch Gov't Bringing Subsidy Scheme Back to Offshore Wind, But Only Temporarily – Reports | Offshore Wind, *Offshore Wind,* 09/16/2025
[145] Denmark Targets This Autumn for Offshore Wind Tender Reboot with State Support | Offshore Wind, *Offshore Wind,* 05/20/2025
[146] The 10 largest offshore wind farms in the world (2024) - OUCO, *OUCO,* 07/23/2024
[147] Spatial Conflict in Offshore Wind Farms: Challenges and Solutions for the Commercial Fishing Industry | UKERC | The UK Energy Research Centre, *UKERC,* 03/07/2025
[148] Offshore Renewable Energy & Fisheries | The European Maritime Spatial Planning Platform, *The European Maritime Spatial Planning Platform,* Date not found
[149] NAMO_Fiche_41_Peche_eolien_en_mer.pdf, *debatpublic.fr,* 11/2023
[150] Ilocos Norte Offshore Wind Farm threatens livelihood of fisherfolk livelihood and marine ecosystems – group, *Bulatlat,* 04/22/2025

industry through a royalty[151] **.** Developers, for their part, argue that the concrete bases of offshore wind turbines act as artificial reefs, providing spawning and breeding grounds for certain fish species[152].

Furthermore, in the context of **rising tensions in Europe, several European armies have raised concerns about the defensive limitations** that offshore wind farms would represent.

Sweden, **a major player** in the offshore wind market, perfectly illustrates this issue. Its national company, **Vattenfall**, **operates 12 wind farms** and **is** currently **developing 5 GW** in several European countries[153] . However, the country only **has 0.2 GW** of installed capacity, despite **favorable weather and geographical conditions**. The country nevertheless has an **estimated pipeline of 88 GW** in February 2025[154] and an estimated technical potential of 588 GW[155].

However, in November 2024, **13 of the 14 offshore projects under consideration were rejected**[156] . The presence of **wind turbines would limit radar detection capabilities** by creating interference due to radar waves bouncing off the infrastructure's blades, creating a barrier for radars[157] . However, although this decision is supported by some foreign officers, **it has been criticized** by **many stakeholders in the sector, who point out that offshore infrastructure no longer interferes with the latest radar systems**[158].

4.2. Critical infrastructure that could be targeted for sabotage

Energy infrastructure is a prime military target, as illustrated by the sabotage of the Nordstream gas pipeline and the series of cuts to electrical and communications cables in the Baltic Sea, which some coastal states consider to be acts of sabotage committed by Russia[159]. **Offshore infrastructure** is vulnerable, with its size and number **multiplying the nature of the risks**.

There are **three major risks**:

- As electricity production is **connected to the grid via submarine cables,** a ship would only have to drop its anchor to **sever the cables**, causing millions of euros in damage and destabilizing a country's electricity supply network [160] . In the Baltic Sea alone, there is a cable transit capacity of 20 GW[161].
- The **number and distance between wind turbines** already make maintenance complex for operators, ensuring the physical integrity of their infrastructure[162] . In a hybrid warfare context, **it is difficult to prevent "ghost ships" from mapping the infrastructure or sabotaging it**[163] .

[151] Offshore wind tax funds first four fishing-related projects in Pays de la Loire, *Le Journal des Entreprises,* 04/11/2025
[152] Can offshore wind and commercial fishing coexist? Orsted, 12/11/2025
[153] Offshore wind power | Vattenfall, *Vattenfall*
[154] Global Wind Power Tracker - Global Energy Monitor, *Global Energy Monitor,* May 17, 2022
[155] Offshore Wind Technical Potential in Sweden – ESMAP and World Bank
[156] Sweden pours cold water on offshore wind power, *Le Monde.fr,* 11/19/2024
[157] Defense forces: Wind farms reduce Estonia's defense capacity | News | ERR, ERR, 11/28/2024
[158] Offshore wind farms do not interfere with Estonia's radar operations | News | ERR, *ERR,* 07/11/2024
[159] Underwater sabotage: a Baltic Sea Timeline, Marine Technology News, February 23, 2025
[160] Sabotage of cables in the Baltic Sea: three sailors, including the captain of the Eagle-S, charged in Finland, *Le Monde.fr,* 11/08/2025
[161] Russian vessels 'mapping Nordic subsea energy assets' | S&P Global, *S&P Global Commodity Insights,* 04/19/2023
[162] Why Offshore Wind Maintenance Is Risky - and How Smarter Tech Can Help, *DWTEK - Subsea Solution Provider,* June 8, 2025
[163] Ukraine war: The Russian ships accused of North Sea sabotage, *www.bbc.com,* 04/19/2023

- The **turbines are vulnerable to cyberattacks**, as the **blades must constantly adapt to wind speed and direction**; if they are prevented from doing so, the infrastructure could be seriously damaged[164].

To counter these threats, some stakeholders want **to equip wind turbines with military radar**.

[164] How cyberattacks on offshore wind farms could create huge problems, *The Conversation,* 09/05/2024