Cuadernos de Dirección Aseguradora

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Floating Offshore Wind in Spain

A (Re)insurance Perspective

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A (Re)insurance Perspective

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Cuadernos de Dirección Aseguradora es una colección de estudios que comprende las tesis realizadas por los alumnos del Máster en Dirección de Entidades Aseguradoras y Financieras de la Universidad de Barcelona desde su primera edición en el año 2003. La colección de estudios es una idea original del Dr. José Luis Pérez Torres, profesor honorífico de la Universidad de Barcelona y la Dra. Mercedes Ayuso Gutiérrez, catedrática de la misma Universidad, y cuenta con la coordinación del Sr. Ferran Rovira Isanda, profesor del Máster.

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Summary

Floating offshore wind is an emerging, costly technology with the potential to unlock vast deep-water wind resources. Following initial pilot projects, the industry is moving toward commercial-scale deployments to help countries meet their energy transition targets. Spain is among these countries, with its first floating offshore wind tender expected soon.

This thesis provides a global overview of the floating offshore wind industry and its (re)insurance landscape, and examines the specific challenges, opportunities, and expectations for (re)insurers considering the underwriting of these projects in Spain.

Keywords: Floating offshore wind, insurance, reinsurance, Spain, renewable energy, construction all risks, operational all risks, delay in start-up, business interruption, risk.

Resumen

La eólica marina flotante es una tecnología incipiente y costosa, con el potencial de aprovechar los vastos recursos eólicos disponibles en aguas profundas. Tras los primeros proyectos piloto, la industria avanza hacia una fase comercial que ayudará a los países a cumplir con sus objetivos de transición energética. España es uno de esos países, y se espera que convoque próximamente su primera subasta de eólica marina flotante.

Esta tesis ofrece una visión global de la industria eólica flotante y de su panorama (re)asegurador, para acabar explorando los retos, oportunidades y expectativas específicas de las (re)aseguradoras que se plantean participar en estos proyectos en España.

Palabras Clave: Eólica, marina, flotante, offshore, seguro, reaseguro, España, energía renovable, todo riesgo construcción, todo riesgo operación, pérdida de beneficios anticipada, pérdida de beneficios, riesgo.

Resum

L'eòlica marina flotant és una tecnologia incipient i costosa, amb el potencial d'aprofitar els extensos recursos eòlics disponibles en aigües profundes. Després dels primers projectes pilot, la indústria avança cap a una fase comercial que ajudarà els països a assolir els seus objectius de transició energètica. Espanya és un d'aquests països, i es preveu que convoqui properament la seva primera subhasta d'eòlica marina flotant.

Aquesta tesi ofereix una visió global de la indústria eòlica flotant i del seu panorama (re)assegurador, per acabar explorant els reptes, oportunitats i expectatives específiques per a les (re)asseguradores que es plantegin participar en aquests projectes a Espanya.

Paraules Clau: Eòlica, marina, flotant, offshore, assegurança, reassegurança, Espanya, energia renovable, tot risc construcció, tot risc operació, pèrdua anticipada de beneficis, pèrdua de beneficis, risc.

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1. Presentation

According to the World Meteorological Organization, 2024 “was likely the first calendar year to be more than 1.5ºC ± 0.13 ºC above the pre-industrial era”[1].

For reference purposes, 1.5ºC above pre-industrial (1850-1900, according to the Intergovernmental Panel on Climate Change – IPCC – the United Nations’ body for assessing the science related to climate change) levels was precisely the temperature limit aimed by the Paris Agreement back in 2015[2].

The Paris Agreement was signed at the United Nations (UN) in New York by 175 countries (out of 193 UN Member States at the time). Despite its content being non-binding, it remains a policy cornerstone to tackle global climate change.

Similar to global temperatures, carbon dioxide (CO_2) levels were at their highest in 2023 and “real-time data from specific locations”[3] show that levels of CO_2 continued to increase in 2024. Simply put, “the human-caused increase in the concentration of CO_2 in the atmosphere is the largest driver of climate change”[4].

In order to limit and reduce those two factors (rising temperatures and CO_2 levels) the IPCC established in 2018 the so-called Net-Zero Emissions (NZE) target by 2050. It aims to reduce global net human-caused emissions of CO_2 by 45% by 2030 (from 2010 levels)[5].

In line with these targets, more recently, “at the 2023 United Nations Climate Change Conference (COP 28) in Dubai, United Arab Emirates, a historic pledge was made to triple renewable energy capacity and double energy efficiency by 2030”[6].

As such, renewable energy is a key pilar of the Nationally Determined Contributions (NDCs). These are the official climate action plans submitted by each country under the Paris Agreement. For example, Spain, according to its most updated National Energy and Climate Plan (NECP), aims to increase

[1] WORLD METEOROLOGICAL ORGANIZATION. State of the global climate 2024. 2025.
[2] UNITED NATIONS. Paris agreement. 2015
[3] WORLD METEOROLOGICAL ORGANIZATION. State of the global climate 2024. 2025.
[4] WORLD METEOROLOGICAL ORGANIZATION. State of the global climate 2024. 2025.
[5] IPCC. Special Report on Global Warming of 1.5ºC. 2019
[6] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating offshore wind outlook. 2024

renewable energy generation to 81% of the electricity mix by 2030 and achieve 100% by 2050[7].

However, despite these recent developments, global renewable energy capacity has been growing for decades before the Paris Agreement. Indeed, global hydropower capacity experienced a significant growth in the 1950s when "the construction of new hydroelectric plants accelerated after World War II"[8]. More recently, in the early 2000s, global wind capacity (both onshore and offshore, although mainly the former) started to grow rapidly as well. Similarly, in the early 2010s global solar capacity experienced rapid expansion.

Looking specifically at the global offshore wind capacity installed over the years, a notable growth can be identified from 2010 onwards when annual new installations reached the 1,000 MW threshold[9]. Despite offshore wind being a relatively young technology, it has experienced rapid growth and at the end of 2024 global offshore wind installed capacity reached 79,434 MW[10].

However, most of this offshore wind capacity is installed in waters up to 50 meters deep, which requires the so-called bottom-fixed foundation technology. On the other hand, only 236 MW of floating offshore wind was installed globally at the end of 2023[11].

Despite currently representing a very small fraction of the overall global renewable energy capacity installed, floating offshore wind is gearing up to play an increasingly important role in the following decades. According to BloombergNEF[12], global floating offshore wind installed capacity is forecast to reach over 25,000 MW by 2035. This represents a 106-fold increase from its current levels.

Floating offshore wind is particularly suitable for countries and regions with deep coastal waters (deeper than 50 meters) where bottom-fixed offshore wind technology is currently not feasible. Spain is one of these countries.

With this background, in September 2022, the Spanish Government published the "Roadmap for the development of offshore wind and marine energy in

[7] SPANISH GOVERNMENT. Integrated national energy and climate plan 2023-2030 update. 2024
[8] CLEVELAND, C. What countries have the greatest hydropower capacity? 2024
[9] GLOBAL WIND ENERGY COUNCIL. Global offshore wind report 2024. 2024
[10] INTERNATIONAL RENEWABLE ENERGY AGENCY. Renewable capacity statistics 2025. 2025
[11] GLOBAL WIND ENERGY COUNCIL. Global offshore wind report 2024. 2024
[12] BLOOMBERGNEF. The next phase of wind power growth in five charts. 2022

Spain"[13] which included a target of 1,000 – 3,000 MW of floating offshore wind capacity to be installed by 2030.

Recent global geopolitical conflicts, namely Russia's invasion of Ukraine in 2022, have increased even further the role of renewable energy today as a reliable, independent, safe and competitive source of energy, making it top of the agenda for both public and private sectors alike.

This thesis aims to study floating offshore wind in Spain from a (re)insurance perspective. The author will tap into his bottom-fixed offshore wind (re)insurance experience together with the limited floating offshore wind market experience available to date in order to assess the opportunities and challenges faced by (re)insurers willing to consider a potential involvement in these upcoming Spanish floating offshore wind projects. Finally, a set of forecasts, expectations and recommendations will conclude the thesis.

The author has used two main types of methodologies when preparing this thesis. On one hand, information research has been the key methodology when analyzing the floating offshore wind market, both globally and in Spain. Despite the relatively infancy of this technology, abundant relevant documentation was available and reviewed. On the other hand, in order to research the (re)insurance markets' risk appetite for floating offshore wind, both globally and in Spain, an online survey was conducted among key renewable energy (re)insurers worldwide to obtain valuable, tailor-made information about the subject of this thesis. The reason to carry out an online survey was to provide the solid quantitative grounds upon which draw the conclusions of this thesis.

The thesis was written in English as most of the bibliography available to date is written in this language. Similarly, most of the conversations with key stakeholders contacted for the purposes of this study were held in English. Finally, the author hopes that the study can be of interest to a wider audience beyond Spain.

[13] SPANISH MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Roadmap for the development of offshore wind and marine energy in Spain. 2022

2. Floating Offshore Wind Globally

2.1. Background

In essence, floating offshore wind can be described as an evolution of bottom-fixed offshore wind technology, which, in turn, was an evolution from onshore wind. The main advantage of offshore wind technology compared to onshore wind is the ability to harness the stronger and more constant winds available at sea.

Offshore wind turbines can be divided into two main categories, depending on their foundation technology: bottom-fixed (foundations piled into or based on top of the seabed, suitable for waters up to 50 meters) and floating (foundations anchored to the seabed through mooring lines, suitable for waters between 60 and 300 meters)[14].

There are other important differences between floating offshore wind and bottom-fixed, such as the use of dynamic cables, which will be analysed in further detail under Chapter 2.3. Technology.

Floating offshore wind is much more incipient than bottom-fixed. Indeed. The first bottom-fixed offshore wind farm, which hosted 11 wind turbines totaling 5 MW capacity (Vindeby) was installed in Denmark in 1991. Today, global bottom-fixed installed offshore wind capacity is nearly 80,000 MW[15].

On the other hand, the industry had to wait nearly two decades to see the first full-scale floating offshore wind farm to be installed in 2009. The project (Hywind Demo) consisted of a one-off wind turbine (2.3 MW capacity) installed 10 kilometers off the coast of Karmøy (south-west of Norway)[16] in waters 210 meters deep[17]. As of the end of 2023, the installed global floating offshore wind capacity was only 236 MW[18], representing a very small fraction compared to bottom-fixed offshore wind.

Certainly, floating offshore wind is deemed to remain a relatively small share of the cumulative global offshore wind capacity forecasted in the near future (5% by

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[14] IBERDROLA. Floating offshore wind power: A milestone to boost renewables through innovation.
[15] INTERNATIONAL RENEWABLE ENERGY AGENCY. Renewable capacity statistics 2025. 2025
[16] STATOIL HYDRO. The world's first large scale floating wind turbine.
[17] ONSTAD et al. Assessment of the floating wnd turbine Hywind Demo. 2016.
[18] GLOBAL WIND ENERGY COUNCIL. Global offshore wind report 2024. 2024.

2033[19]). But it is projected to increase its share in decades to come (15% by 2050[20]).

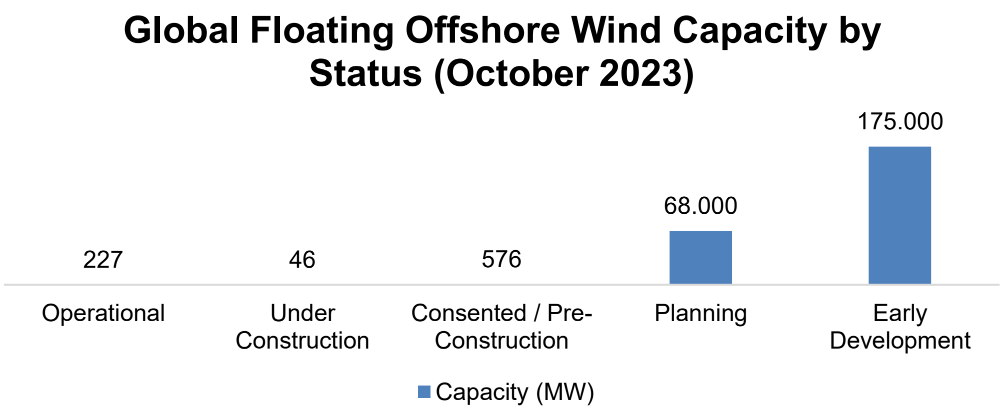
To give a broader perspective compared to other sources of renewable energy, DNV[21] estimates that 82% of the world's grid-connected electricity will be generated from renewable sources by 2050, but just 2% will come from floating offshore wind, compared to 11% from bottom-fixed offshore wind and 20% from onshore wind.

According to the German Federal Association of Offshore Wind Energy (BWO, by its German acronym), "around 80 percent of the sea areas eligible for offshore wind energy are deeper than 60 meters and are therefore not economical for traditional wind turbines anchored to the ground ("bottom-fixed offshore wind").[22]". Therefore, the global potential for floating offshore wind is huge.

Even if just 227 MW of floating offshore wind have been installed as of the end of October 2023[23], several countries have plans and auctions in place to deploy floating offshore wind turbines in their coasts in the coming years. Chapter 2.5. Forecast will dive into the forecasted growth.

Graph 1 below provides an overview of global offshore floating wind capacity at various development stages.

Graph 1. Global floating offshore wind capacity by status (October 2023)[24]



Source: RenewableUK. Own elaboration.

[19] ONSTAD et al. Assessment of the floating wind turbine Hywind Demo. 2016.
[20] DNV. Floating offshore wind: The next five years. 2022.
[21] DNV. Floating offshore wind: The next five years. 2022.
[22] BWO. Expansion into the deep sea with floating wind power.
[23] RENEWABLEUK. Global floating offshore wind project pipeline grows by one-third over 12 months. 2023
[24] RENEWABLEUK. Global floating offshore wind project pipeline grows by one-third over 12 months. 2023

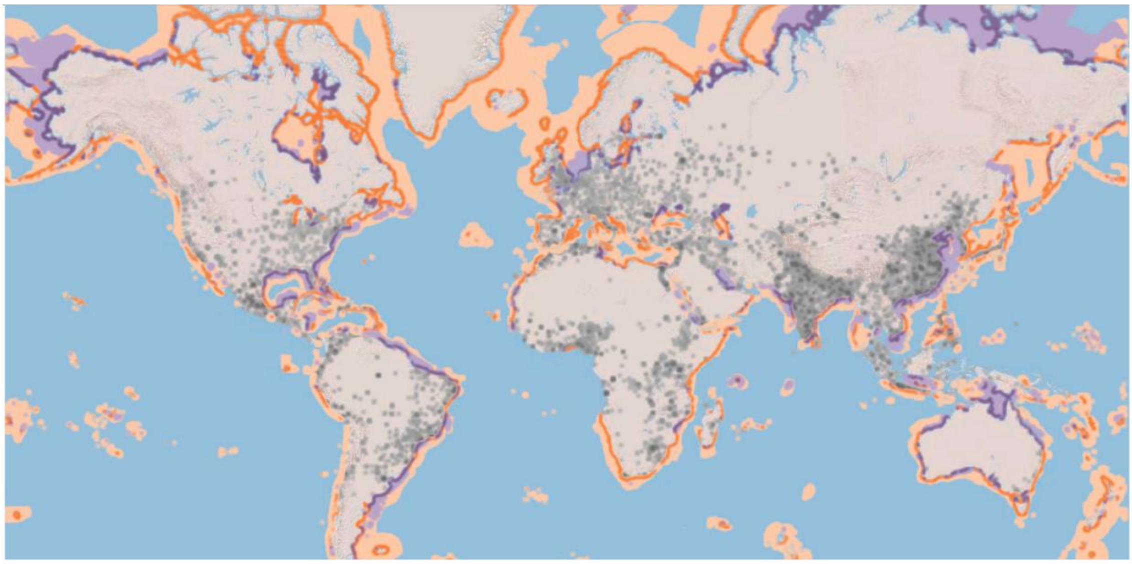
The capacity for floating offshore wind to be deployed in deeper waters has broadened the number of countries and regions suitable for this technology, compared to the limited coastal areas with shallow waters suitable for bottom-fixed offshore wind. The next Chapter 2.2. Geographies reviews such regions and countries in further detail.

2.2. Geographies

As previously presented, floating offshore wind is particularly suitable for countries and regions with deeper coastal waters. In some cases, deeper waters are further away from shore and enjoy stronger and steadier winds. On some other cases, deep waters are the only option available due to the coastal conditions.

The following map highlights the coastal areas suitable for floating offshore wind globally.

Figure 1. Global offshore wind technical potential map[25]



Deeper water	(60 – 2,000m):	Near shore (<60 km)	Far from shore (60 – 300 km)
Shallow water	(10 – 60m):	Near shore (<60 km)	Far from shore (60 – 300 km)

Source: IEA

[25] IEA. Offshore Wind Outlook. 2019

The following table summarises the volumes of floating offshore wind capacity operational across different counties as of October 2023.

Table 1. Operational floating offshore wind farms (October 2023)[26]

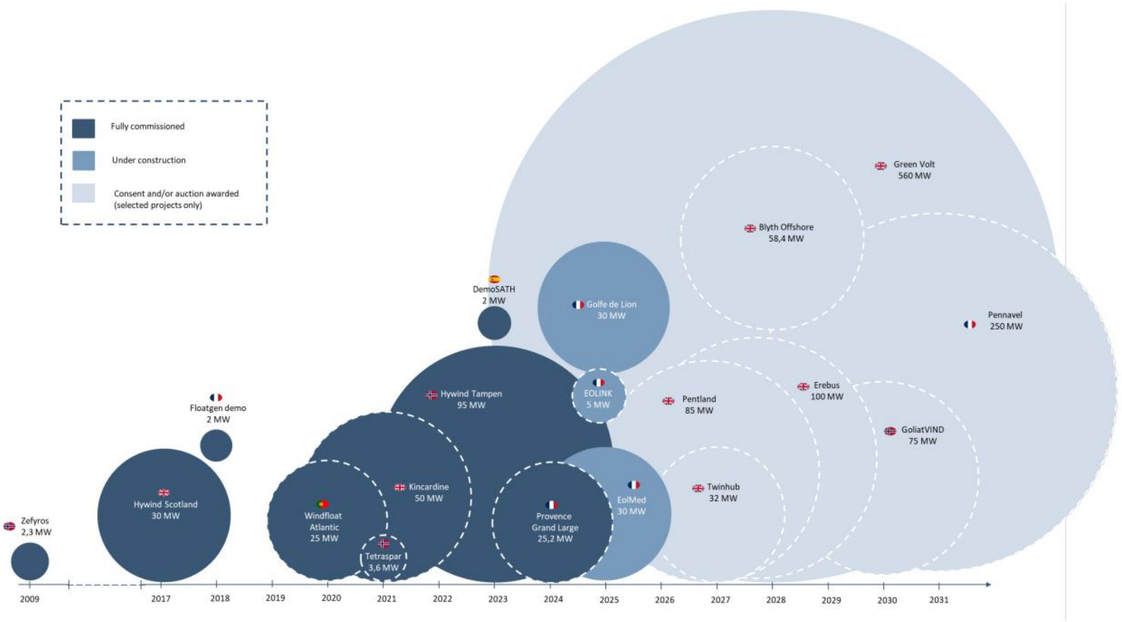
Country	Capacity Installed (MW)	Number of Projects
Norway	94	3
United Kingdom	80	2
Portugal	25	1
China	19	3
Japan	5	2
Spain	2	2
France	2	1
TOTAL	**227**	**14**

Source: RenewableUK

Below is a timeline of the main floating offshore wind farms in Europe by 2024 and their status (fully commissioned, under construction, consent and/or auction awarded – selected projects only):

[26] RENEWABLEUK. Global floating offshore wind project pipeline grows by one-third over 12 months. 2023

Figure 2. Timeline of selected floating offshore wind projects in Europe[27].



Source: TGS 4C Offshore, edited by Menon Economics

Despite the relatively small number of operational floating offshore wind farms to date, their main locations differ from the main regions used for bottom-fixed offshore wind. Indeed, whereas bottom-fixed was initially established mainly in the shallow waters of the North Sea and the Baltic Sea to grow afterwards in other countries such as China, Taiwan, France and United States; floating offshore wind can be seen being developed in different regions with deeper waters such as the Mediterranean Sea, Atlantic Ocean and Japan among others.

According to DNV, “Europe is shaping up to be the leader in the floating offshore wind market, particularly by leveraging developments in the North Sea”[28]. This is backed by the recent European Commission’s Communication on the European Wind Power Package, where floating offshore wind is highlighted as a key measure to meet the new offshore wind targets[29]. These ambitions can be reflected in the early developments of the following countries, all of which benefit from long coastlines, deep waters and strong wind resources:

2.2.1. Norway

If Denmark is deemed the pioneering country for bottom-fixed offshore wind, when it comes to floating offshore wind, the same applies to Norway. Indeed,

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[27] MENON ECONOMICS. Market development for floating and fixed offshore wind. Future outlook for the Norwegian offshore wind industry. 2024
[28] DNV. Energy transition outlook. 2024
[29] EUROPEAN COMMISSION. Delivering on the EU offshore renewable energy ambitions. 2023

Norway currently holds some pioneering milestones. In addition to deploying the very first full-scale floating offshore wind turbine (Hywind Demo) in 2009, Norway is home to the largest floating offshore wind farm worldwide to date: Hywind Tampen. Consisting of 11 floating wind turbines totalling 88 MW of capacity, the project was fully commissioned in 2023 and is also the "the world's first floating wind farm built specifically to power offshore oil and gas installations"[30].

"With sea areas five times the size of its landmass combined with good wind conditions, Norway is well positioned to produce energy from offshore wind"[31].

As such, Norway is currently the largest floating offshore wind market with approximately 41% of the capacity installed worldwide[32].

The country also has ambitious plans for offshore wind going forward: "The Norwegian Government wants to allocate 30 GW of offshore wind capacity by 2040[33]". To provide some wider context on the vast size of such a target, this represents around 75% of the capacity of the whole Norwegian power system in 2025[34].

Even if the exact split between bottom-fixed and floating offshore wind capacity was not disclosed at the time (2022), two years later, in 2024, the Norwegian government proposed approximately EUR 3 billion for a support scheme dedicated towards the first commercial floating offshore wind tender within the Vestavind F and Vestavind B areas[35].

Similarly, in May 2025, Norway launched the first part of its inaugural floating wind tender[36]. The Utsira Nord floating tender is expected to award 1.5 GW of capacity across three project areas in average water depths of 265 meters[37].

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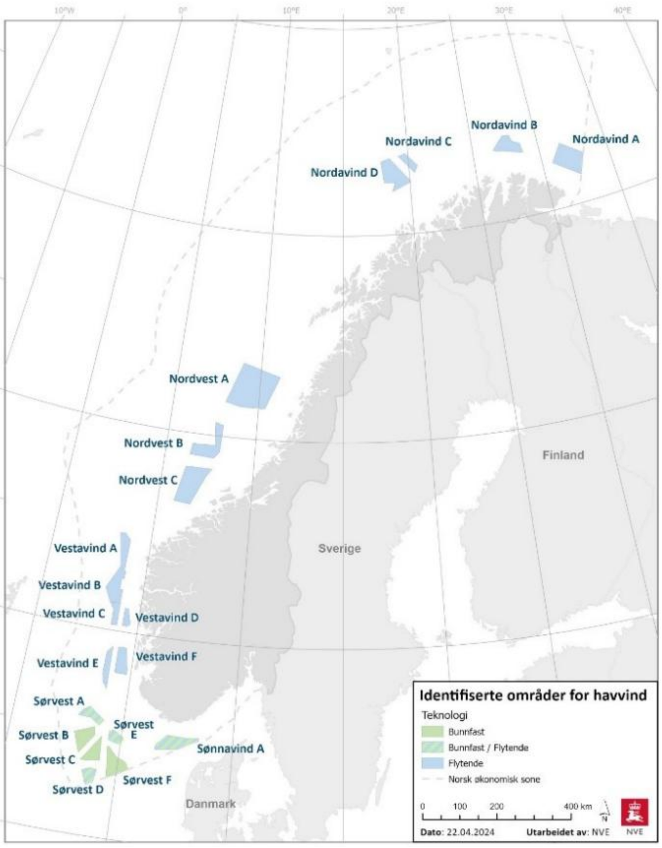
30 HYWIND TAMPEN. Hywind Tampen: the world's first renewable power for offshore oil and gas
31 EFTA Surveillance Authority (ESA). Norwegian scheme for floating offshore wind – Utsira Nord. 2025
32 RENEWABLEUK. Global floating offshore wind project pipeline grows by one-third over 12 months. 2023
33 WINDEUROPE. Norway announces big new offshore wind targets. 2022
34 EFTA Surveillance Authority (ESA). Norwegian scheme for floating offshore wind – Utsira Nord. 2025
35 NORWEGIAN GOVERNMENT. A responsible approach to floating offshore wind. 2024.
36 REUTERS. Norway opens floating offshore wind tender. 2025
37 EFTA Surveillance Authority (ESA). Norwegian scheme for floating offshore wind – Utsira Nord. 2025

Figure 3. Overview of the identified areas for offshore wind and suitable technology (bottom-fixed in green, floating in blue and mixed in stripes)[38].



Source: Norwegian Royal Ministry of Energy

2.2.2. United Kingdom

With more than 15 GW of installed offshore wind capacity at the end of 2024, the United Kingdom is the second largest offshore wind market, only behind China[39]. However, most of its installed capacity to date is bottom-fixed. Indeed, floating offshore wind only represents approximately 0.5% (i.e. 80 MW across 2 projects) of its total offshore wind installed capacity.

However, the country has both early experience and ambitious plans going forward to develop floating offshore wind at a larger scale, particularly in Scotland.

Indeed, as per Table 1 above, the United Kingdom is also the second largest floating offshore wind market, only behind Norway. Its buoyant offshore wind supply chain, long coastline and strong wind resources make the United Kingdom the perfect turf for developing floating offshore wind at a larger scale.

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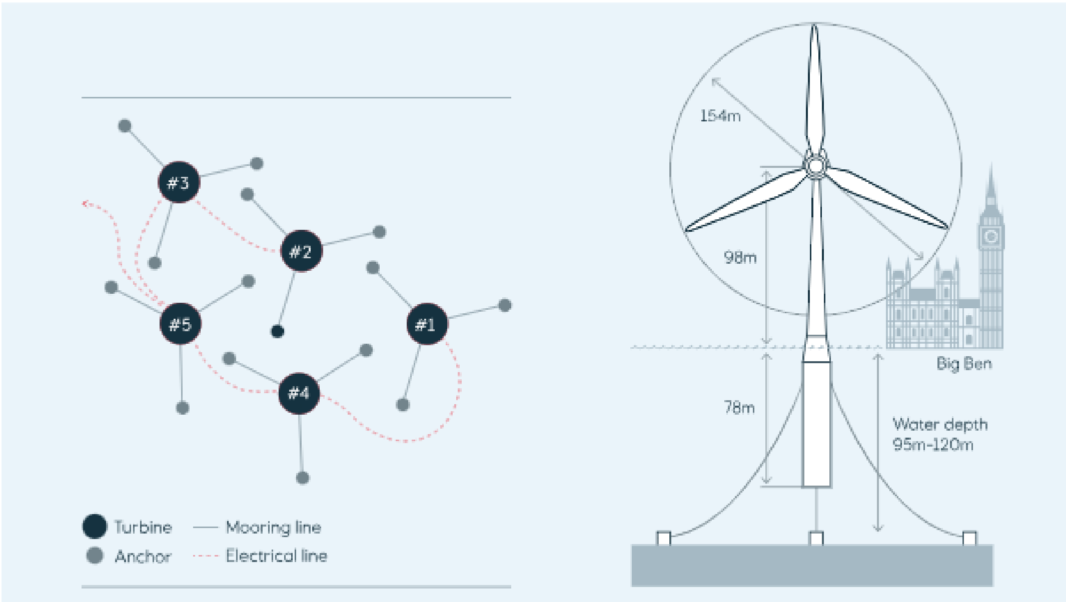
[38]NORWEGIAN ROYAL MINISTRY OF ENERGY. Consultation on support scheme for floating offshore wind in Vestavind B and Vestavind F.
[39] WORLD FORUM OFFSHORE (WFO). Global offshore wind report. 2025

The United Kingdom is home to what is deemed as the world's first floating offshore wind farm (Hywind Scotland), highlighting the fact that previous floating projects (including Hywind Demo in Norway) were single-wind-turbines projects. Hywind Scotland consists of 5 floating wind turbines totalling 30MW capacity (6 MW each) and it was fully commissioned in October 2017. The project is located off the coast of Peterhead, east of Scotland, in water depths ranging from 95 to 120 meters[40].

Figure 4. Hywind Scotland configuration[41].



Source: Equinor

Four years later, in 2021, Kincardine floating offshore wind farm was fully commissioned. In line with the industry trend toward deploying increasingly larger wind turbines, Kincardine hosts five 9.5 MW wind turbines, resulting in a total capacity of 47.5 MW. The project is located 15 km off the coast of Aberdeen (Scotland), in waters ranging from 60 to 80 meters deep[42].

The floaters, a semi-submersible foundation design from floating wind specialist Principle Power branded WindFloat, were manufactured by Navantia in Ferrol, northwest of Spain (all five except one, which was manufactured in Gibraltar). From Ferrol, they were loaded onto a semi-submersible barge and taken one at a time to Rotterdam's port for assembly with the wind turbine. The journey from Ferrol to Rotterdam took about six days. Once assembled in Rotterdam's port, each complete wind turbine was towed to Scotland (image 1 below) at a speed

40 EQUINOR. Hywind Scotland.
41 EQUINOR. Hywind Scotland.
42 PRINCIPLE POWER. Kincardine offshore wind farm.

of three knots (equivalent to 5.5 km/h) to minimize risks in a journey that took about six days for each wind turbine[43].

Image 1: Transport of one of the floating wind turbines from Rotterdam's port to Scotland

Source: Boskalis

In addition to its two operating floating offshore windfarms, the United Kingdom has big plans for floating offshore wind going forward. Remarkably, in January 2022, the Crown Estate Scotland announced the results of the ScotWind leasing round. Out of the 30.3 GW awarded, contrary to most previous tenders anywhere, most of the capacity was awarded to floating offshore wind projects, rather than bottom-fixed projects. A remarkable 19.5 GW of floating wind capacity (64% of the awarded capacity) coming from 13 projects. To provide wider context on the scale of these numbers, they represent over 85 times the floating offshore wind capacity operational in the world at the end of 2023[44].

2.2.3. Portugal

Similar to the United Kingdom, but at a smaller scale, Portugal's involvement in floating offshore wind comprises both an early experience and a considerable

[43] BOSKALIS. A great future. Magazine issue 08
[44] OFFSHORE WIND SCOTLAND. ScotWind leasing round.

pipeline going forward. Its coastline is perfectly suited for floating offshore wind as it is deep (bottom-fixed technology is currently not possible in the country) and enjoys the strong wind capacity factors from the Atlantic Ocean.

To date, Portugal only has one floating offshore wind farm: WindFloat Atlantic. The project has been operational since 2020. It consists of three wind turbines of 8.4 MW capacity each mounted on top of semi-submersible foundations. WindFloat Atlantic was the world's first semi-submersible floating offshore wind farm. It is located 18 kilometres off the coast of Viana do Castelo, north-west of the country, in around 100 meters water depth[45]. "Over its 5 years in operations, WindFloat Atlantic has successfully navigated unprecedented challenges. Notably, in 2023, during Storm Ciaran, the system withstood waves reaching 20 meters in height and wind gusts of up to 139 kilometers per hour, demonstrating its resilience and robustness"[46].

Prior to WindFloat Atlantic being operational, there was a prototype testing phase (WindFloat 1 or WindFloat Demo) off the coast of Aguçadoura (35 kilometres north of Porto) implemented in 2011 for five years in waters 45 meters deep. It consisted of a single 2 MW floating wind turbine. According to one of their project sponsors, Principle Power, the project "endured extreme Atlantic Ocean weather conditions, including waves exceeding 17 meters in height and winds exceeding 40 m/s [144 km/h], proving the robustness of the technology"[47].

Going forward, Portugal intends to grow its floating offshore wind capacity from these early experiences. "The country planned to put 3-4 GW of floating wind capacity up for auction in the summer of 2022. The auction was postponed to 2023 but the planned capacity was upgraded twice to 10 GW"[48]. The 10 GW are now being tendered in three phases of 3.5 GW. The first tender received expressions of interest from 50 developers from ten counties in October 2023, highlighting the global interest in this technology.

2.2.4. France

At 5,500 kilometres long, the French Metropolitan (i.e. excluding overseas territories) coastline is one of the longest in Europe. A country traditionally heavily reliant on nuclear energy (67.4% of the electricity mix in 2024 according to RTE[49]), it has only started its offshore wind journey recently. However, France is leading the way for European countries outside the North Sea and the Baltic Sea, particularly regarding floating offshore wind. And the country's ambitious targets are a clear sign of its energy transition plans.

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[45] WINDFLOAT ATLANTIC. World's first semi-submersible floating offshore wind farm
[46] WINDFLOAT ATLANTIC. Five years generating clean energy.
[47] PRINCIPLE POWER. WindFloat 1
[48] GLOBAL WIND ENERGY COUNCIL. Global offshore wind report 2024. 2024.
[49] ENERDATA. Nuclear and renewables raised France's 2024 power generation to 5-year high. 2025

Indeed, the country is targeting 18 GW of offshore wind capacity installed by 2035 and 45 GW by 2050[50]. This means a huge jump from the mere 842 MW installed at the end of 2023. Even more remarkable is the fact that half of its total offshore wind projects will be floating. This means a total capacity of 20 GW in floating offshore wind[51], making France one of the largest markets worldwide.

France's floating offshore wind journey began, like others, modestly, with a first demonstration project. Floatgen is a 2 MW floating wind turbine commissioned in 2018 off the Atlantic coast of Le Croisic (west of Nantes). Floatgen is also France's first offshore wind turbine. Its foundation, BW Ideol's patented Damping Pool, is the world's first floating barge designed for offshore wind and used innovative pre-stressed reinforced concrete. The project was initially scheduled for 5 years of operations; however, it was recently extended for an additional 5 years, proving a valuable source of floating wind experience, including coping with harsh weather conditions (maximum wave heights of nearly 11 meters in February 2020)[52].

Later, in 2023, the French floating offshore wind journey stepped-up when "EDF successfully installed three floaters of the Provence Grand Large project, which have a combined capacity of 25 MW (8.4 MW per turbine) and are located 40 kilometres west of Marseille in water depths of around 100 m."[53]

Currently, there are two additional 30-MW floating projects under construction in France (both in the deep waters of the Mediterranean Sea). EOLMED and Eoliennes Flottantes du Golfe du Lion (EFGL), consisting of 3 wind turbines each. Another smaller floating project is also currently under construction in France: Eolink, a one-off 5 MW floating offshore wind turbine to be installed at the SEM-REV test site off the coast of Le Crosic (same as Floatgen).

Moving towards commercial-scale size, in May 2024 France held its first large-scale floating offshore wind tender (AO5). Ten candidates were pre-selected by the Commission for Regulation of Energy (CRE) to develop and operate the 250 MW Pennavel floating offshore wind farm, which "will be the first commercial floating offshore wind farm in the world to be awarded a long-term Contract for Difference (CfD)"[54]. A consortium between Elicio and BayWa r.e. was announced as the tender winner with a strike price of EUR 86.45 per MWh (significantly below the EUR 140 per MWh ceiling prince). This represented a record-low for floating offshore wind at the time, prompting concerns across the industry, including from WindEurope, the European wind energy association[55].

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[50] STRATEGIC ENERGY EUROPE. France defines its energy roadmap until 2035: Offshore wind and the transition to a decarbonized mix. 2025
[51] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating offshore wind outlook. 2024
[52] BW IDEOL. Floatgen. France's first offshore wind turbine and BW Ideol's first unit.
[53] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating offshore wind outlook. 2024
[54] BAYWA R.E. Elicio and BayWa r.e. win floating offshore wind tender. 2024.
[55] WINDEUROPE. French auction results are not the new benchmark for floating offshore wind in Europe. 2024

AO5 was just the first of several floating offshore wind tenders scheduled in France. Indeed, in December 2024, A06 tender winners were announced for two 250 MW floating wind projects in the Mediterranean Sea[56]. Going forward, AO9 tender is auctioning 2.5 GW floating offshore wind capacity across four new sites, for which twelve candidates were pre-qualified at the end of 2024[57]. Last but certainly not least, A010 tender, currently in consultation phase, is aiming to award three floating offshore wind projects with a total combined capacity of up to 5.2 GW[58].

2.2.5. Italy

"Italy has the largest project pipeline (40,071 MW)"[59] arising from a huge potential (183,000 MW[60]) for floating offshore wind. This is partly due to the country's long and deep coastal waters.

Today, Italy only has one operational offshore wind farm (30 MW) and it uses bottom-fixed foundation technology. The project may be considered "nearshore" as it is located very close to the Taranto harbour. Installed in 2022, it is deemed as the first offshore wind farm operational in the Mediterranean Sea. Furthermore, to date, it is the only offshore wind farm using Chinese manufactured wind turbines (MingYang) in European waters[61].

With a "long-term strategy of being carbon neutral by 2050, the country's offshore wind capacity will need to reach 20 GW (i.e. 20,000 MW)[62]". In order to do so, the country is expected to "award Contracts for Difference (CfD) for fixed-bottom and floating offshore wind projects through a scheme for which the Italian government"[63] received permission in June 2024.

Several developers have expressed their interest in the auction. Some have formed joint ventures to develop floating offshore wind farms in the country - whilst others are working through the planning and consent stages[64].

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56 OFFSHOREWIND.BIZ. Consortia led by EDF, Ocean Winds win French floating wind tender. 2024
57 OFFSHOREWIND.BIZ. 12 developers in running for four new offshore wind sites in France. 2024
58 OFFSHOREWIND.BIZ. France kicks off consultation for AO10 offshore wind tender. 2025
59 RENEWABLEUK. Global floating offshore wind project pipeline grows by one-third over 12 months. 2023.
60 GLOBAL WIND ENERGY COUNCIL. Offshore wind technical potential in Italy. 2021
61 RECHARGE. First Chinese offshore turbines turning in Europe as Mediterranean joins wind era. 2022
62 RENEWABLEUK. Global floating offshore wind project pipeline grows by one-third over 12 months. 2023
63 OFFSHOREWIND.BIZ. Italy to award contracts for difference for offshore and floating wind projects, EU greenlights EUR 35.5 billion renewables subsidy scheme. 2024
64 ION ANALYTICS. Italy plots floating offshore wind boom. 2024

2.2.6. Other

Other countries with plans and upcoming auctions for floating offshore wind include but are not limited to:

1. Republic of Korea: As part of an Offshore Wind Power Competitive Bidding Roadmap unveiled in August 2024, five developers secured grid connection with Korea Electric Power Corporation (KEPCO) for a total of 6 GW floating offshore wind capacity in October 2024[65]. One of them, Firefly/Bandibuli floating wind farm, was awarded 750 MW capacity by the Ministry of Trade, Industry and Energy two months later[66].

2. United States: According to IRENA, "two-thirds of the offshore wind potential of the United States is in deep waters"[67] including the west coast, Gulf of Mexico, Hawaii and the Great Lakes. The US Federal Government announced in 2023 plans to deploy 15 GW of floating offshore wind by 2035[68]. However, these plans were put on hold straight after the second presidency of Donald Trump started at the end of 2024[69].

3. Japan: Japan was one of the earliest testers of floating offshore wind. Indeed, after the 2011 tsunami and consequent Fukushima nuclear accident, the country decided to shut down all its nuclear reactors (a similar decision was echoed in Germany) which pushed through a number of floating offshore wind demonstration projects, such as Fukushima Forward (the first semi-submergible 2 MW wind turbine was commissioned in 2013, the second phase with two spar turbines – 5 MW and 7MW respectively - was completed in 2015), Haenkaze's 2MW hybrid spar in 2013, Sakiyama's 2 MW floating wind turbine in 2016 and Hibiki's 3 MW barge-type floating wind turbine in 2019. The Japan Wind Power Association (JWPA) is aiming to have 60 GW of floating wind capacity installed by 2050[70]. In 2021, European companies Shell, Equinor, and Ocean Winds, together with Japanese companies Sumitomo Corporation Global Metals, JGC Japan Corporation and Toda Corporation launched a

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[65] OFFSHOREWIND.BIZ. Three more floating offshore wind projects in South Korea secure grid connection. 2024
[66] OFFSHOREWIND.BIZ. South Korea awards nearly 1.9 GW of offshore wind capacity. 2024
[67] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating Offshore Wind Outlook. 2024
[68] WH.GOV. Fact Sheet: Biden-Harris Administration announces actions to expand offshore wind nationally and harness more reliable, affordable clean energy. 2023
[69] THE WHITE HOUSE. Temporary withdrawal of all areas on the outer continental shelf from offshore wind leasing and review of the Federal Government's leasing and permitting practices for wind projects. 2025
[70] REUTERS. Wind industry aims to provide a third of Japan's power by 2050. 2023

group with the aim to achieve a floating wind target of 2-3 GW in Japan by 2030[71].

4. Philippines:“The Philippine offshore wind roadmap released in Abril 2022 by the Department of Energy and the World Bank Group, estimated that the Philippines has the potential to install 21 GW of offshore wind power [floating and bottom-fixed] by 2040”[72]. In December 2024, the “National Grid Corporation of the Philippines (NGCP) has approved the grid connection for BuhaWind Energy Philippines’ 2 GW floating offshore wind farm in Northern Luzon.”[73] International developers are also active in the country. Indeed, Copenhagen Energy and PGEC are developing three floating offshore wind farms in the Philippines totaling 5 GW. Similarly, Corio Generation aims to develop up to five offshore wind projects totaling 3 GW (1 GW of which would be floating)[74].

2.3. Technology

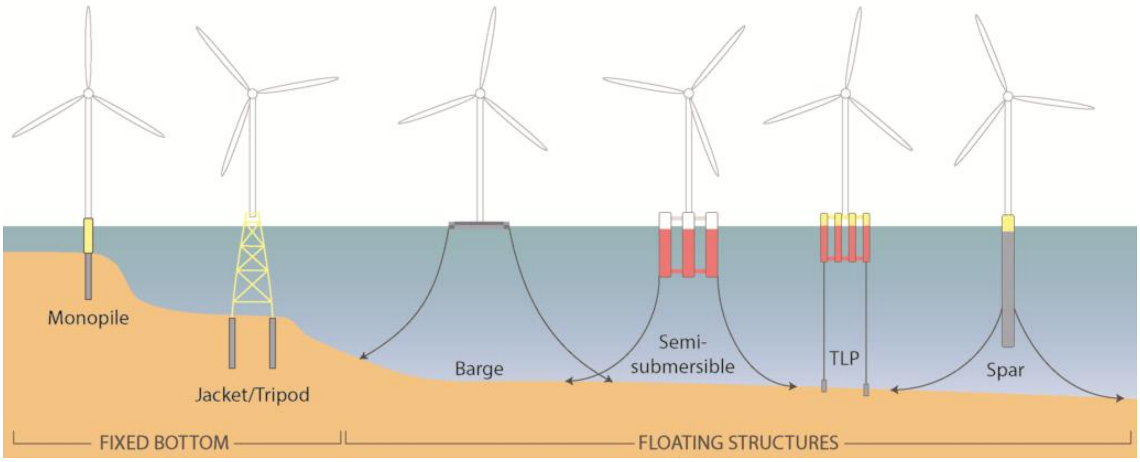
As presented by The Renewables Consulting Group[75], floating offshore wind can be understood as a combination of bottom-fixed offshore wind (itself, an evolution from onshore wind), oil and gas (due to its floating particularities) and marine industries (for its design, facilities and materials’ performance). As such, despite its infancy, floating offshore wind is based on proven technology with decades of commercial experience. It is the combination of these proven technologies (wind turbines on top of floating structures) that makes floating offshore wind a novelty.

Precisely, “offshore wind could mirror the trend seen in the oil and gas industry when it moved from fixed to floating foundations during the 1970s, in order to access oil wells in deeper waters further from shore.”[76]

The following figure provides a visual representation of both bottom-fixed and floating offshore wind technologies for illustrative purposes.

[71] OFFSHOREWIND.BIZ. Shell, Equinor, Ocean Wind and Japanese partners launch Japan’s floating offshore wind group. 2021
[72] BLUEFLOAT. BlueFloat Energy advancing offshore wind energy in the Philippines. 2023
[73] OFFSHOREWIND.BIZ. BuhaWind secures grid connection approval for 2 GW floating wind farm in Philippines. 2024
[74] OFFSHOREWIND.BIZ. Philippines to launch offshore wind auction in Q3 2025. 2024
[75] THE RENEWABLES CONSULTING GROUP. Technical advisor’s floating offshore wind. Overview and key focus points. Paris. 2019
[76] CARBON TRUST. Floating offshore wind: Market and technology review. UK. 2015

Figure 5. Common types of support structure technologies for bottom-fixed and floating offshore wind turbines (Principle Power)[77].



Source: Ocean Focus

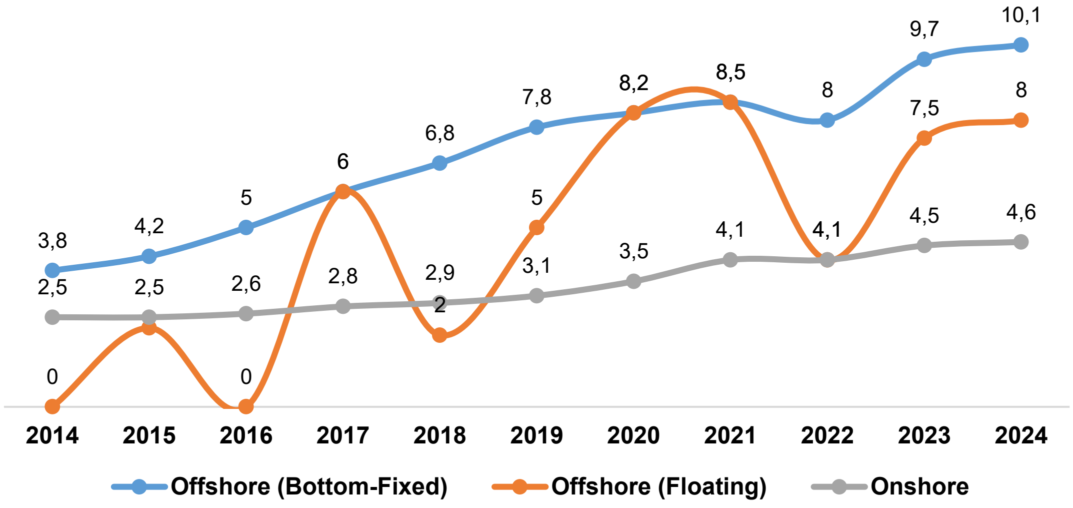
Offshore wind bottom-fixed and floating have several similarities, however, notorious differences too. The following points will provide an overview on the key components of a floating offshore wind farm.

2.3.1. Wind Turbines

One of the main advantages of offshore wind compared to onshore wind is the possibility to harness stronger winds at sea. To do so, larger capacity offshore wind turbines are deployed offshore compared to those onshore. Indeed, the following graph highlights the size (MW capacity) of each technology deployed in recent years in Europe.

[77] OCEAN FOCUS. Blueprint for offshore wind to green Ireland's energy supply. 2020

Graph 2. Average capacity (MW) of wind turbines installed in Europe



Source: WindEurope, GlobalData, own elaboration.

However, when it comes to comparing the size of floating and bottom-fixed offshore wind turbines, the difference is smaller (although more volatile, due to the very small number of floating projects currently installed) than comparing onshore and offshore wind turbines. Indeed, according to Sea Impact[78], the most popular wind turbine model installed offshore (excluding China) in 2024 was Siemens Gamesa's SG 11.0-200 DD (11 MW capacity) followed by Vestas' V174-9.5 (9.5 MW capacity). It is remarkable that similar-sized wind turbines have also been installed on floating foundations. For example, Kincardine floating offshore wind farm hosts 5 Vestas' V164-9.5 wind turbines since 2021. More recently, in the summer of 2025, 10 MW wind turbines are expected to be installed in two French floating offshore wind farms: EFGL and EolMed.

As shown in Graph 2 above, there is a clear trend for larger offshore wind turbines being installed over the years. This is mainly to benefit from economies of scale, reduce installation costs (fewer units per wind farm) and increase the output power delivered by the wind turbines. And the trend is likely to continue in the foreseeable future. For example, the largest bottom-fixed offshore wind turbine installed for a commercial project in 2024 was Goldwind's GWH-252-16 MW turbine[79].

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[78] SEA IMPACT. Siemens Gamesa dominate 2024 WTG installation. 2025
[79] OFFSHOREWIND.BIZ. Offshore wind turbines in 2024: 20+ MW prototypes rolling out in Europe, China; 16 MW remains most powerful turbine installed offshore. 2025

Meanwhile, floating offshore wind, despite being significantly more incipient than bottom-fixed, is trying to keep up with the fast-paced growing scale of wind turbine installations. Indeed, in May 2025, DNV awarded the basic design certificate to floating foundation specialist BW Ideol “for its floating wind platform that can support wind turbines with an output of 15 MW and beyond.”[80] Similarly, “Aikido Technologies is set to deploy its innovative 15 MW floating wind platform, A060, in Norway by 2027”[81].

As such, the difference in the size of the wind turbines being used for floating and bottom-fixed projects is narrowing down as floating offshore wind becomes a more mature and developed technology.

On the other hand, one of the main differences regarding offshore floating and bottom-fixed wind turbines is the transport and installation methodology. Whereas bottom-fixed installation is done offshore at the project site (it involves the use of several vessels, including jack-up vessels for different wind turbine components such as towers, nacelles and blades); floating wind turbines are assembled onshore at the port yard “or in dry dock, then towed out by conventional tugs”[82] to the project site.

2.3.2. Foundations

Floating foundations are a key differential element when comparing bottom-fixed and floating offshore wind technologies. As introduced earlier in Chapter 2.1. Background, bottom-fixed foundations are piled into or based on top of the seabed; whereas floating foundations provide “buoyancy and stability”[83] and are anchored to the seabed.

Floating foundations can also be referred to as floating sub-structures, floating platforms or simply floaters. They are mainly made of steel, concrete or a combination of both.

Despite being based on floating oil and gas technology in use since the 1970s, floating offshore wind is a relatively young configuration. As such, a significant amount of research and development is currently required to gain industry experience and confidence. This has resulted in a rather large number of floating

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[80] OFFSHOREWIND.BIZ. BW Ideol receives DNV certification for 15+ MW floating wind platform. 2025
[81] OFFSHORE CHANNEL. Issue 03/2025. 04/2025. United Kingdom. 2025
[82] DNV GL. Floating wind: the power to commercialize. Høvik. 2020
[83] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023

wind concepts and designs: between 80[84] and 150[85], according to different sources. Which in turn is creating a lack of standardization, a major obstacle for developers, investors, supply chain and other key industry stakeholders according to a 2025 survey[86].

Each floating offshore windfarm will choose the foundation design on a case-by-case basis, considering several criteria including but not limited to geographical conditions (water depth, expected wave heights), logistics (size of the wind turbine, depth of the harbour, available manufacturing facilities) and costs (price of materials and equipment).

The following are the four main types of floating foundation at the time of writing (2025)[87, 88, 89, 90, 91, 92]:

1. Spar buoy:
    - Overview:

      The structure comprises a single vertical cylinder with a low water plane area, ballasted to keep the centre of gravity below the centre of buoyancy (stabilized through gravity) with a ballast at the bottom. The wind turbine is directly connected to the ballast. The foundation is kept in position by catenary or taut spread mooring lines with drag or suction anchors.

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[84] OFFSHOREWIND.BIZ. So many floating wind designs, so few test sites – Norwegian METCentre sold out. 2023
[85] OFFSHOREWIND.BIZ. Supply chain calls for narrowing down floating wind platform designs. 2024
[86] WESTWOOD GLOBAL ENERGY GROUP. Unlocking the potential. Results of the 2025 floating offshore wind survey. London. 2025
[87] ORSTED. Floating offshore wind energy. 2024
[88] CARBON TRUST. Floating offshore wind: Market and technology review. UK. 2015
[89] GREEN GIRAFFE. Financing floating offshore wind projects. EU. 2019
[90] GLOBAL WIND ENERGY COUNCIL. Floating offshore wind – A global opportunity. 2022
[91] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[92] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating offshore wind outlook. 2024

Image 2: Spar buoy figure (IRENA[93]) and Hywind Tampen's computer-animated floating spar wind turbine (Aker Solutions[94]).

Source: IRENA and Aker Solutions

- Benefits:
  - Design and manufacturing simplicity makes it amenable to serial fabrication processes
  - Proven technology
  - Few moving parts (no active ballast required)
  - Good stability
- Challenges:
  - Difficult to tow, as it requires a deep dock or sheltered area, as well as a large offshore crane to install the turbine
  - Heavy and large structure that has a high fatigue load on the base
  - Large draft requirement can create logistical challenges during assembly, transportation and installation
  - Low deck space for maintenance

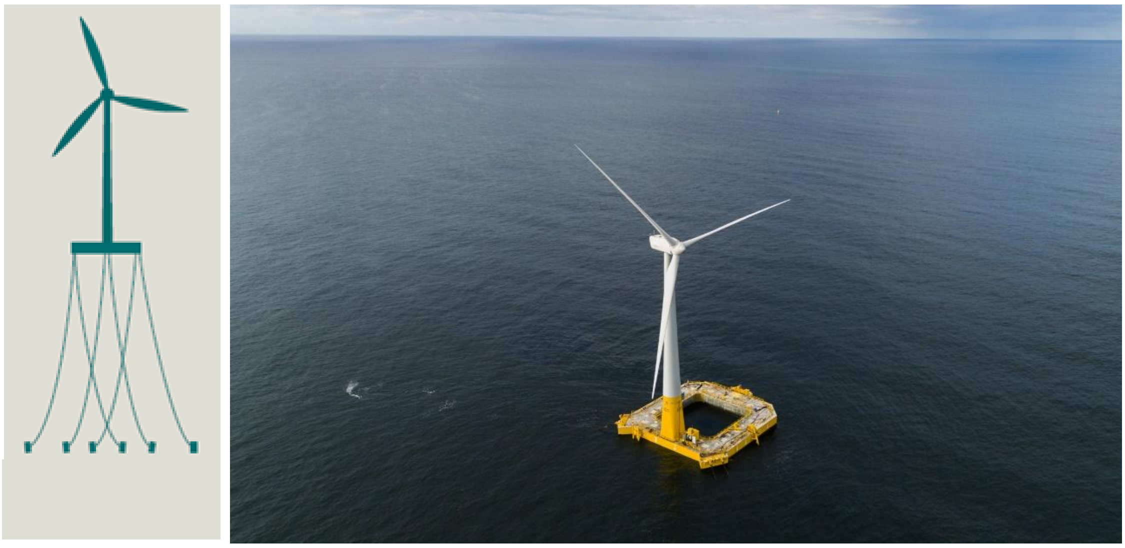
[93] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating offshore wind outlook. 2024
[94] AKER SOLUTIONS. Hywind Tamper – Floating offshore wind. 2024

2. Barge:

   - Overview:

     The most common structure for barges is a shallow and wide floating platform that sits along the water surface. Water stabilization is used. The principle is like that of ship design. Anchored to the seabed with a spread mooring system.

Image 3: Barge figure (IRENA[95]) and BW Ideol's Floatgen barge wind turbine (BW Ideol[96]).



Source: IRENA and BW Ideol

   - Benefits:
     - Manufacturing and installation simplicity
     - Potential to use traditional shipyard building techniques
   - Challenges:
     - Less stable than other designs
     - Particularly exposed to wave
     - Demanding more robust mooring systems, increasing complexity

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[95] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating offshore wind outlook. 2024

[96] BW IDEOL. Floating is the future of offshore wind. Solutions. 2025

3. Semi-submersible:

- Overview:

  Buoyancy stabilized platform which floats semi-submerged on the surface of the ocean whilst anchored to the seabed with catenary mooring lines and drag anchors.

Image 4: Semi-submersible figure (IRENA[97]) and Principle Power's WindFloat semi-submergible wind turbine (Principle Power[98]).

Source: IRENA and Principle Power

- Benefits:
  - Low draft allows for more flexible application and simpler installation
  - Flexible application due to the ability to operate in shallow water depths
  - Low vessel requirement – only basic tug boats required
  - Onshore turbine assembly
  - Amenable to port-side major repairs
- Challenges:

[97] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating offshore wind outlook. 2024
[98] PRINCIPLE POWER. WindFloat 1. 2025

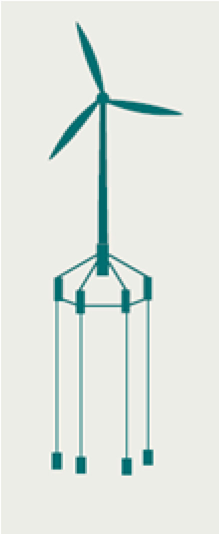
- High structural mass to provide sufficient buoyancy and stability
- Complex steel structures with many welded joints can be difficult to fabricate
- Potentially costly active ballast systems
- Less stable than other designs

4. Tension-Leg Platform (TLP):

   - Overview:

The submerged foundation is connected to mooring lines. A central column is the interface between the foundation and the wind turbine above the surface. The foundation is stabilized through moors and is highly buoyant, with the central column and arms connected to tensioned tendons that secure the foundation to the suction / piled anchors.

Image 5: Tension-leg platform figure (IRENA[99]) and Modec's computer generated conceptual drawing of tension-leg platform (Modec[100]).



Source: IRENA and Modec

[99] IRENA (INTERNATIONAL RENEWABLE ENERGY AGENCY). Floating offshore wind outlook. 2024

[100] OFFSHOREWIND.BIZ. Japanese companies make progress with tension leg floating tech. 2022

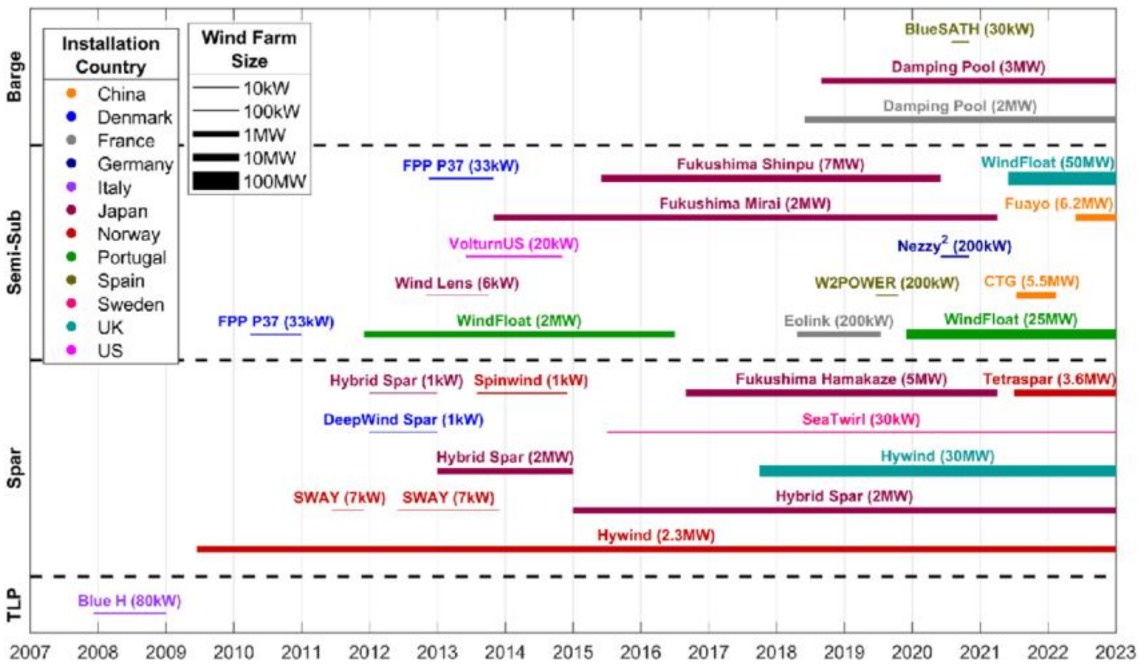
- Benefits:
    - The most stable once installed
    - Low seabed footprint
    - Can be sited at variable water depths
    - Light and small structure, which implies lower material costs
    - Tendency for lower critical wave-induced motions
    - Can be assembled onshore or in a dry dock
    - Taut mooring lines contribute to good stability
    - Few moving parts (no active ballast required)

- Challenges:
    - Requires a special purpose-built installation vessel
    - Expensive mooring lines and anchors with high vertical load
    - A single mooring line failure can result in catastrophic event
    - Has a low technology readiness level compared to other categories
    - Challenging installation process
    - No space for maintenance
    - Not suitable for project sites with large tidal range
    - Design increases stress on the tendon and anchor system

As we can see from Graph 3 below (vertical axis), most industry efforts to date have been concentrated within the spar and semi-submergible type of floating foundations. Indeed, for example, Provence Grand Large, with a capacity of 24 MW, which was only fully commissioned in June 2025[101] in France, is deemed as "world's first deployment of tension leg platforms for floating offshore wind."[102]

[101] EDF RENEOUVELABLES. Provence Grand Large: full commissioning. 2025
[102] CARBON TRUST. Floating wind JIP (joint industry programme). Phase V. Summary report. United Kingdom. 2024

Graph 3. Timeline of floating offshore wind turbines deployments, including prototypes, demonstrators and windfarms (Edwards, et. al.)[103]



Source: Edwards et. al.

Last but not least, it is of particular relevance to (re)insurers the current supply chain constrains affecting the offshore wind industry, including floating foundations. Certainly, as highlighted by RystadEnergy[104], “from the current and announced floating foundation manufacturing levels, capacities must grow five to sixfold towards 2030 to meet the projected demand”. This is no small feature and one that may raise questions and concerns regarding how feasible the 2030 targets are and, more relevant to this research, what are the replacement lead times likely to be in case of damage or loss of floating foundations.

2.3.3. Mooring Lines

Another key differential component between bottom-fixed and floating offshore wind technologies is the use of mooring lines on the later configuration. Mooring lines provide stability to the floating wind turbine by connecting the floating

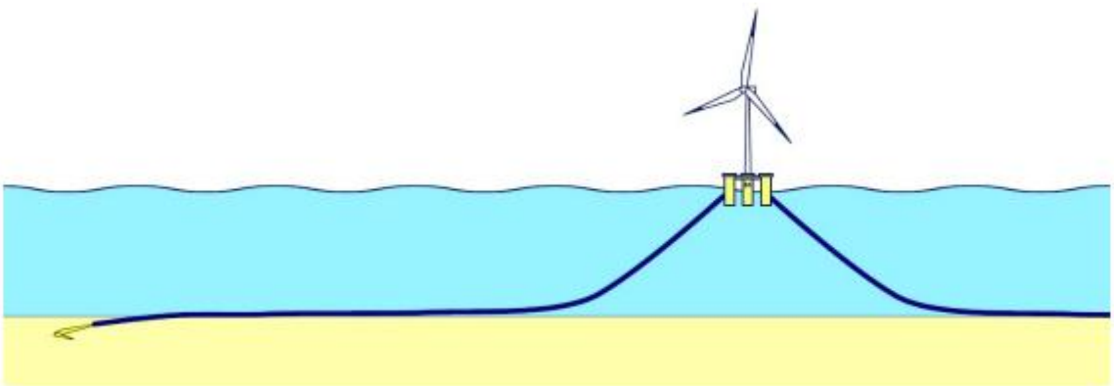
[103] EDWARDS, E.; HOLCOMBE, A.; BROWN, S.; RANSLEY, E.; HANN, M.; GREAVES, D. (2023). Evolution of floating offshore wind platforms: A review of at-sea devices. Renewable and sustainable energy reviews. 10.1016/j.rser.2023.113416.
[104] RYSTAD ENERGY. The state of the European wind energy supply chain. Oslo. 2023

foundation with the anchor installed in the seabed. Indeed, mooring lines keep the floating wind turbine in a fixed position.

As presented by the WFO[105], the main mooring configurations can be listed as follows:

1. Plain catenary: Long steel chains and/or wires linking the anchor point with the floating foundation. The length of the mooring lines, partly resting on the seabed, reduces loads on the anchor points. Its "weight and curved shape holds the floating platform in place"[106]. Typically used at shallow water depths. It has a large footprint due to the section of chain resting on the seabed.

Figure 6. Plain catenary mooring spread (WFO)[107].



Source: WFO

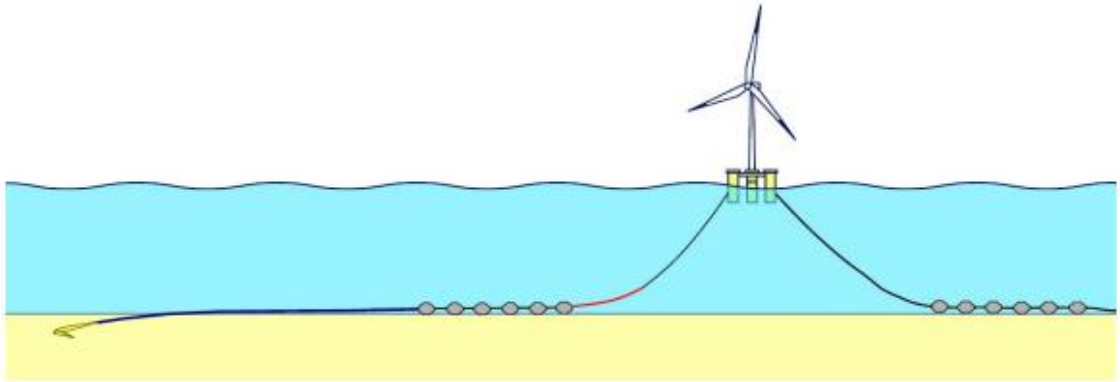
2. Multi-catenary: Long chains that are a hybrid of chain and synthetic ropes, which achieves stationary motion by taking advantage of the weight of ground chain and stiffness characteristic of this hybrid composition.

[105] WORLD FORUM OFFSHORE (WFO). Mooring systems for floating offshore wind: Integrity management concepts, risks and mitigation. 2022

[106] CARBON TRUST. Floating offshore wind: Market and technology review. UK. 2015

[107] WORLD FORUM OFFSHORE (WFO). Mooring systems for floating offshore wind: Integrity management concepts, risks and mitigation. 2022

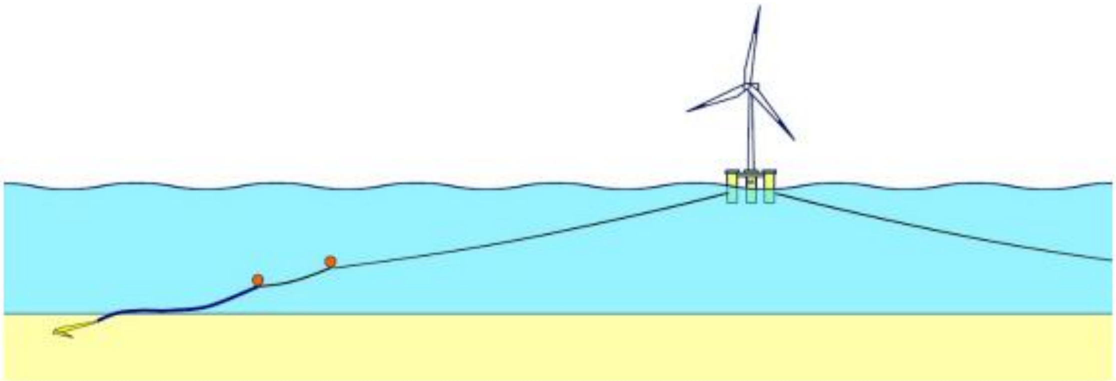
Figure 7. Multi-catenary mooring spread (WFO)[108].



Source: WFO

3. Buoyant semi-taut: Similarly employing a synthetic rope/chain line, but with significantly reduced ground chain and an increased proportion of synthetic rope. Buoyancy modules are attached to the rope to prevent damage through contact with the seabed. Compliance is achieved predominantly by visco-elastic properties of the rope and the single connection anchor points will make the floating platform susceptible to wave induced motion and experience significantly increased vertical uplift loads.

Figure 8. Buoyant semi-taut mooring spread (WFO)[109].



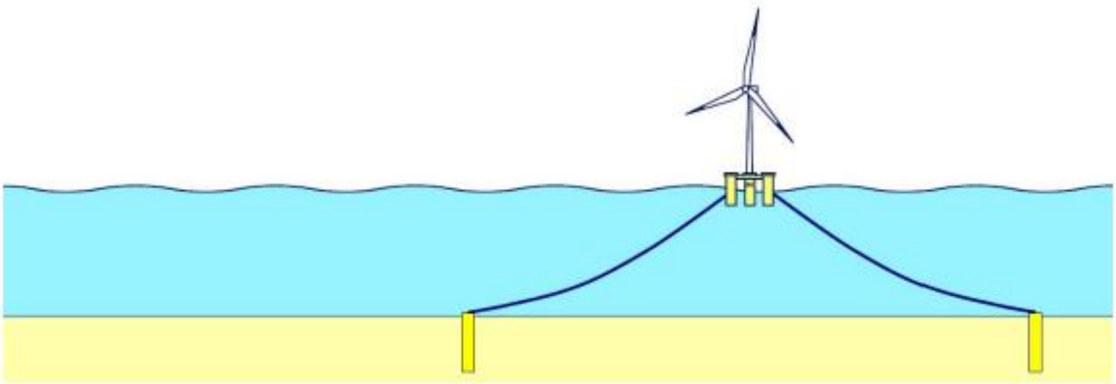
Source: WFO

108 WORLD FORUM OFFSHORE (WFO). Mooring systems for floating offshore wind: Integrity management concepts, risks and mitigation. 2022

109 WORLD FORUM OFFSHORE (WFO). Mooring systems for floating offshore wind: Integrity management concepts, risks and mitigation. 2022

4. Taut: A system comprising rope tendons connected under high tension to the firm anchor point. Lines experience high loads and the anchor must withstand vertical uplift. Short sections of chain and connectors may be employed at the termination points to allow the adjustment of length and overall tension. Typically used for Tension-Leg Platforms foundations, it involves a challenging installation procedure. Experiences small footprint due to minimal disruption to the seabed.

Figure 8. Taut mooring spread[110].



Source: WFO

As suggested by IMIA, it "may be important to consider redundancy in terms of not just station-keeping, but also making sure that the platform does not capsize with the loss of just one mooring cable, especially in a tension leg mooring system"[111].

"Typically, mooring systems are designed to achieve CC1 [Consequence Class 1: where failure is unlikely to lead to unacceptable consequences such as loss of life, collision with an adjacent structure, and environmental impacts] unless they are non-redundant, in which case CC2 [Consequence Class 2: where failure may well lead to unacceptable consequences of these types] applies."[112]

On that note, redundancy can be achieved mainly in two different ways:

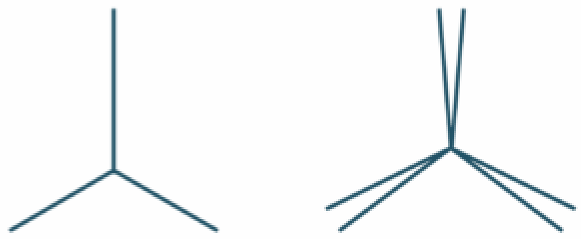
1. Alternative Load Paths:

   The n+1 concept is the preferred method of mitigating risk of single line failure. That is having 3x2 configuration (two lines per anchor) as opposed to 3x1 (one line per anchor) mooring spreads. The 3x2 line configuration

[110] WORLD FORUM OFFSHORE (WFO). Mooring systems for floating offshore wind: Integrity management concepts, risks and mitigation. 2022
[111] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[112] WORLD FORUM OFFSHORE (WFO). Mooring systems for floating offshore wind: Integrity management concepts, risks and mitigation. 2022

“appears to be an attractive compromise between redundancy provision and full-lifecycle levelized cost of energy (LCOE)”[113]. As expected, the ORE Catapult report has demonstrated that “the provision of redundant lines is essential in case line failure occurs.”[114]

Figure 9. Typical 3x1-line (left) and 3x2-line (right) mooring spreads, seen from above[115].



Source: World Forum Offshore Wind (WFO)

Redundancy is therefore critical at this early stage of floating offshore wind developments. However, as the industry matures towards a commercial phase in the following years with larger projects such as Equinor’s Firefly/Bandibuli floating offshore wind farm, expected to include 50 floating wind turbines (15 MW each)[116], redundancy to avoid a total loss of a floating offshore wind turbine could mean such a project has approximately 300 mooring lines, increasing significantly the project costs.

“The key risk associated with the failure of a mooring system is loss of position. This is heightened if FOWFs [floating offshore wind farms] are tethered to adjacent floating structures in a honeycomb mooring concept. Additional risks associated with mooring failures are the sinking or capsizing of the FOWT [floating offshore wind turbine] itself and damage to attached cables and auxiliary components”[117].

2. Strengthening:

   Improving structural integrity of remaining mooring lines when the turbine may be considerably offset from its regular operating position. That is increasing the size and reliability of equipment and components employed.

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[113] FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE. ORE CATAPULT. Failure implications of different mooring spreads and lines. Public summary report. Glasgow. 2024

[114] FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE. ORE CATAPULT. Failure implications of different mooring spreads and lines. Public summary report. United Kingdom. 2024

[115] WORLD FORUM OFFSHORE WIND (WFO). Crash course – Floating offshore wind, a blog series (Part 3) – FOWT moorings & anchoring. 2023

[116] OFFSHOREWIND.BIZ. Equinor’s South Korean floating wind farm to feature Siemens Gamesa 15 MW turbines. 2024

[117] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023

As identified by the WFO[118], innovation is required across the industry on mooring lines to perform a quick connection and disconnection to reduce downtime and loss of revenue in case of repair or maintenance of a key component.

Similarly, from a geotechnical risk perspective, when comparing the mooring systems used for oil and gas (typically applied for much deepwater locations i.e. > 1,000 meters) and floating offshore wind (applied for shallower waters i.e. 60-300 meters), other risk factors such as “seismic hazards of liquefaction, seismic settlement, lateral spreading and earthquake loads”[119] must be taken into consideration, as well as the potential for tsunamis in certain regions.

Other risks related to mooring systems identified by Carbon Trust in 2023[120] were poor design, manufacturing defects, installation damage, corrosion, wear processes and fatigue loading.

Therefore, solid design and manufacturing considerations supported by extensive qualification and certification, as well as robust plans for contingency and operations and maintenance including spares are key to minimizing the potential frequency and severity of insurance claims arising from mooring lines.

2.3.4. Anchor Systems

Anchor systems are another key differentiating element between floating offshore wind farms and bottom-fixed ones. Even though the former technology is based on a floating substructure concept, the mooring system attached to the floating substructure is linked and secured to the bottom of the sea by anchoring systems. These can be different, mainly depending on the geotechnical conditions of the subsea and loading forces arising from the type of floating substructure and mooring system.

The main types of anchoring systems are:

Table 2. Description of major types of anchors expected to be used by floating offshore wind turbines[121]

	Drag embedment	Driven pile	Suction pile
Where used	Best suited to cohesive sediments that are not too stiff to impede embedment. Used where possible as lowest cost.	Can be used in a wide range of conditions, including where there are boulders or hard ground	Requires sea bed conditions that are firm enough to hold suction but not so hard that penetration is impeded

[118] WORLD FORUM OFFSHORE WIND (WFO). Challenges and opportunities of major maintenance for floating offshore wind. 2021
[119] MALHOTRA, S. “Design and construction considerations for offshore wind turbine foundations”, Proceedings of the 26th International Conference on Offshore Mechanics and Arctic Engineering, OMAE07 (2007) page 2.
[120] CARBON TRUST. Floating Wind joint industry programme. Mooring system redundancy, reliability and integrity. London. 2023
[121] BVG ASSOCIATES. Guide to a floating offshore wind farm. 2023

Loading	Uni-directional, horizontal only	Multi-directional, horizontal, and vertical	Multi-directional, horizontal, and vertical
Installation	Simple, requires pre-tensioning	Driving by vibro- or impact-hammer causes noise	Relatively simple process: self-weight starts embedment, followed by suction
Removal	Are designed to be recoverable	Difficult to remove	Removal is the reverse of installation

Source: BVG Associates

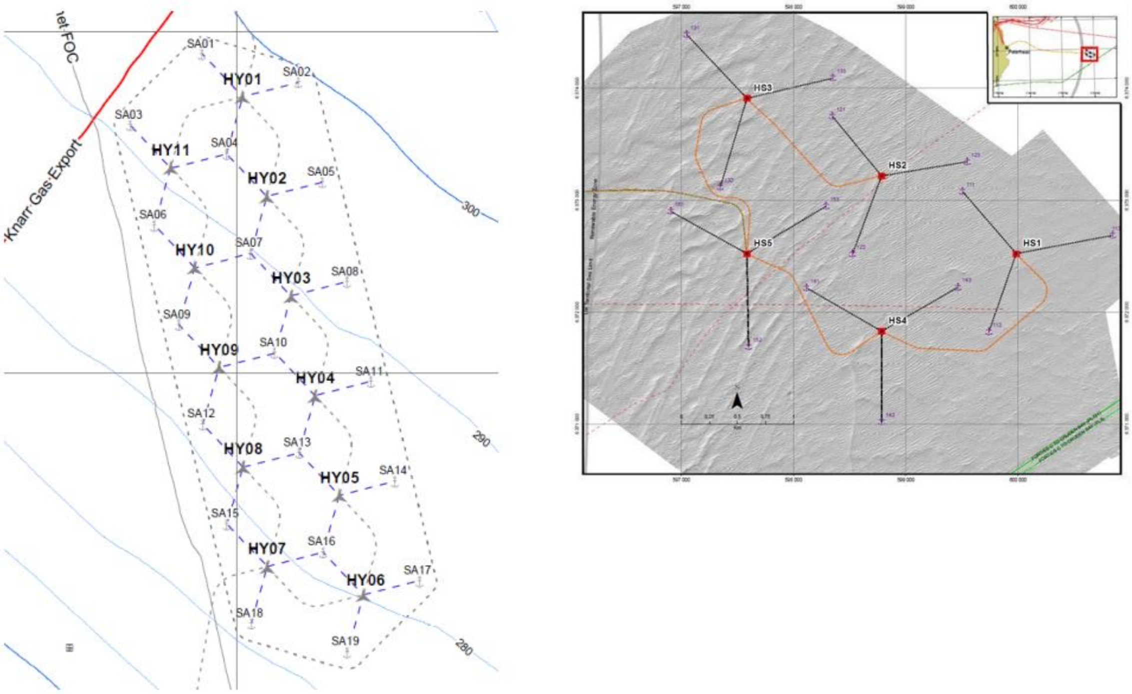
From a (re)insurance perspective, as noted by IMIA, the subsea anchoring configuration "is further complicated by the close proximity of the individual floating turbine structures to each other and the addition of inter-array cables. For this reason, the design phase of the wind farm layout needs to be carefully planned". Furthermore, "it must be noted that floating projects, even though not directly connected to the seabed, face significant geotechnical risks. This is especially where anchor piles or caissons are used which could result in hundreds of repetitive operations per project"[122].

"Hywind Tampen is the world's first floating wind farm to use a shared anchoring system"[123]. The project optimised the use of 19 suction anchors for its 11 spar floating turbines[124], which is dramatically less than the earlier Hywind Scotland project that used 15 suction anchors (each 16 meters tall[125]) on 5 spar floating turbines (figure 10 below).

Indeed, as noted by the WFO[126], "the benefits [of shared anchors] are an associated reduction in equipment cost by a factor of up to 6 for certain geometries, fewer expensive geotechnical site investigations and reduction in peak demand by up to 30%. However, anchors will need to resist multiple-directional loading and the impact on soil capacity. Furthermore, these arrangements may be more suited to deep water environments and the consequence of cascade effects resulting from single/multiple line failures will need to be addressed".

[122] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[123] FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE. ORE CATAPULT. ARUP. Floating offshore wind anchor review. Public summary report. Glasgow. 2024
[124] RENEWS.BIZ. Suction anchors installed at Hywind Tampen. 2022
[125] EQUINOR. Hywind Scotland. The world's first commercial floating windfarm
[126] WORLD FORUM OFFSHORE (WFO). Mooring systems for floating offshore wind: Integrity management concepts, risks and mitigation. 2022

Figure 10. Hywind Tampen[127] (left) and Hywind Scotland[128] (right) anchor and mooring line layout.



Source: DOF SUBSEA and STATOIL

2.3.5. Dynamic Cables

Subsea power cables can be divided as follows within an offshore wind farm:

1. Inter array cables: the network of array cables transfer power from the wind turbines to the offshore substation[129]. Dynamic inter array cables "are currently certified and deployed but they have limited operational experience"[130].

2. Export cables: which transfer electricity from the offshore substation to the onshore substation

Due to the limited size of the existing floating offshore wind farms (i.e. below 100 MW), no offshore substations are required to date in waters deeper than 50m, therefore, the export cables transmit power directly to the landfall. As such, for the purpose of this thesis, the focus will be on inter array cables.

Dynamic cables are another key difference between bottom-fixed offshore wind farms and floating ones. The former uses static strings of inter array cables

[127] DOF SUBSEA. Hywind Tampen: Floating wind farm installation. 2023
[128] STATOIL. Hywind Scotland Pilot Park project plan for construction activities. 2017
[129] BVG ASSOCIATES. Guide to a floating offshore wind farm. 2023
[130] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023

coming out of the bottom-fixed foundations which are usually buried in the seabed. These have a short portion of the cable at the exit of the bottom-fixed foundation which is dynamic and equipped with a cable protection system.

On the other hand, floating offshore wind uses dynamic cables which have a longer dynamic section hanging in the water column from the floating foundation. “The dynamic cable length typically follows a lazy wave configuration to accommodate dynamic movement of the floating substructure, including lateral excursion (the horizontal movement of a floating offshore wind turbine). It must also accommodate the loads resulting from the cable being exposed to the whole water column, as well as withstanding abrasion from the sea bed. At the sea bed, the cable is either buried or sits on the sea bed anchored using rocks or protective matting.”[131]

“In deep water array cables could be suspended across their whole length. This would put greater loading on the cable due to water current-induced movement of the cable but would reduce the length of cable required. Floating projects to date have not used this approach so the water depth at which this becomes attractive is not well understood, but it is likely to be in water depths of around 500 m.”[132]

“Array cables are typically rated at 66 kV. In the next few years, array cable voltages are expected to increase to 132 kV. This is to accommodate more efficiently turbines rated at and above 16 MW and to reduce the number of array cable strings required.”[133]

As highlighted by IMIA, “as the dynamic cable industry develops, continued emphasis needs to be put on certification (type tests and entire projects) as well as best practice exchange”[134]. Similarly, “industry-wide standardisation of connection means (e.g. splicing, dry- or wet-mate connectors) for dynamic cables is needed in order to reduce the cost and risk associated with these”[135].

Another key consideration for (re)insurers is the project’s ability to easily connect and disconnect the cabling system during installation and major repairs. Indeed, as wind turbines are getting bigger, so are the inter array cables (the industry is moving from 66 kV to 132 kV) which may trigger larger losses (both property damage and business interruption) in case of failure. Therefore, cabling connection and disconnection operations must be as fast, safe and easy as possible to reduce downtime. On this note, it is important to highlight that “the

[131] BVG ASSOCIATES. Guide to a floating offshore wind farm. 2023
[132] BVG ASSOCIATES. Guide to a floating offshore wind farm. 2023
[133] BVG ASSOCIATES. Guide to a floating offshore wind farm. 2023
[134] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[135] ORE CATAPULT. An introduction to risk in floating wind. Key risks and how to mitigate them. Glasgow. 2017

electrical connections used for dynamic cables are often bespoke to each floating wind project."[136]

Finally, as reviewed by the World Forum Offshore Wind[137] the following project management methods undertaken with a holistic engineering approach are aimed to achieve lower probability of cable failure as well as lower downtime in case of failure:

- Mooring integrity management
- Monitoring for predictive maintenance
- Spare parts strategy

2.3.6. Installation and Commissioning

Floating offshore windfarms have some substantial differences compared to bottom-fixed offshore windfarms when it comes to installation and commissioning. The installation process starts when major components are shipped to the construction port and end, approximately three years after – depending on the size of the project and potential delays, when commissioned assets are handed over to operational teams.

As noted in the previous sections, floating offshore wind farms include certain components which are not used for bottom-fixed offshore wind farms, such as floating foundations, mooring lines, anchors and dynamic cables. Furthermore, it is important to note that the installation methodology for floating offshore wind farms will depend on the type of floating substructure selected for the project.

One of the main differences between bottom-fixed and floating installation is the wind turbine assembly process. Whereas for bottom-fixed configurations, the wind turbine is assembled at project site (offshore) using different vessels for different components such as tower, nacelle and blades; for floating configurations, the wind turbine is usually assembled with the floating foundation at port, where is pre-commissioned "to the greatest possible extent to reduce offshore commissioning work. This involves mechanical and electrical testing of the various subsystems"[138]. Afterwards, the assembled floating wind turbine is towed out to project site for hook-up to the pre-installed moorings and array cables. "This can be done by way of a heavy-lift vessel, but is more typically achieved by wet towage. Any accident during these operations may cause the

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136 ORE CATAPULT. An introduction to risk in floating wind. Key risks and how to mitigate them. Glasgow. 2017

137 WORLD FORUM OFFSHORE WIND (WFO). Floating offshore wind dynamic cables: overview of design and risks. 2024

138 BVG ASSOCIATES. Guide to a floating offshore wind farm. 2023

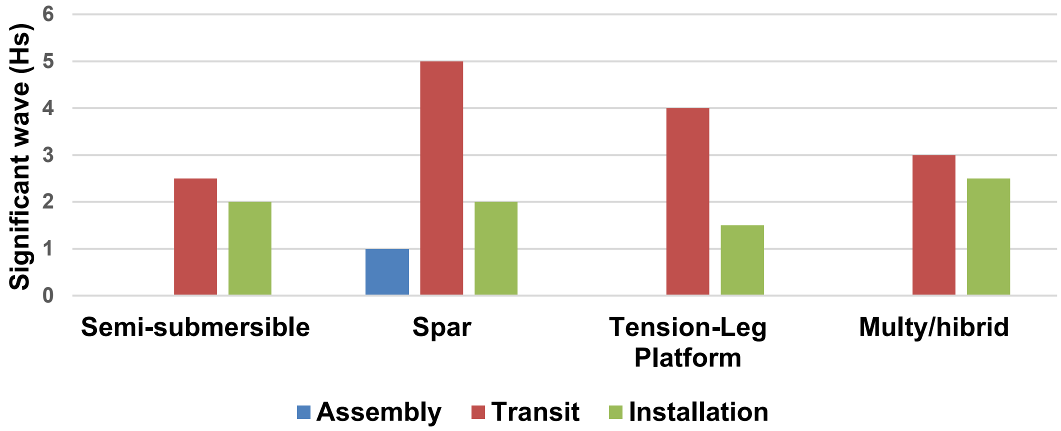
total loss of the entire turbine, plus additional costs relating to sue and labour, removal of wreck and debris."[139]

"Transit distance is a limiting factor in the tow-out of floating offshore wind turbines and this is a key consideration for construction port and wind farm site selection". Furthermore, "the channel depth between the port and the project site is one factor which influences the choice of substructure type and construction material."[140]

There may be projects where the fabrication location is different from the assembly location. In such cases, the installation process includes "transit of the completed foundation to the assembly yard where the tower and turbine is waiting to be installed."[141]

The sequence of activities involved makes floating offshore wind installation less weather-dependent compared to bottom-fixed installation. Indeed, as highlighted by Green Giraffe[142], most of the installation and assembly processes are done onshore, therefore, as only commissioning is done offshore, hook-up to moorings and array cables become the most weather sensitive activities. Graph 3 below summarizes wave limitations depending on the type of floating foundation and activity.

Graph 4. Met-ocean limitations during assembly, transit, and installation[143]



Source: Carbon Trust

[139] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[140] BVG ASSOCIATES. Guide to a floating offshore wind farm. 2023
[141] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[142] GREEN GIRAFFE. Floating wind – Risk analysis towards bankability. 2018
[143] CARBON TRUST. Floating offshore wind: Market and technology review. UK. 2015

Similarly, should adverse weather be encountered, the economic implications (i.e. tug boats' daily rates for towing) are much lower for floating wind compared to bottom-fixed, where wind turbines installation vessels' daily rates are significantly higher.

2.3.7. Operations and Maintenance

As defined by BVG Associates[144], "operations and maintenance (O&M) are the combined functions which, during the lifetime of the wind farm, support the ongoing operation of the wind turbines, balance of plant and associated transmission assets. O&M activities formally start at the wind farm construction works completion date".

The aim of these functions is to keep the wind farm operations safe and maintain asset integrity whilst maximizing electricity output. The focus is to balance costs and power performance, often scheduling maintenance in low-wind summer periods to boost winter availability.

Turbines are generally available 95–98% of the time when wind conditions are appropriate. Offshore wind turbines match onshore performance but at a larger scale as highlighted previously on Graph 2. On the other hand, access limits at sea can lower availability. Round-the-clock support, including fault response and SCADA-based monitoring, helps to achieve high availability levels.

Maintenance, both scheduled (preventive) and unscheduled (corrective), involves transferring crews and tools offshore – which provides access and safety challenges. Floating wind turbines add complexity due to dynamic motions which become even more challenging the higher the component location.

Indeed, as highlighted by IMIA, "the execution of any maintenance or repair operations on a floating installation will always remain a challenge."[145]

To overcome the added complexity of performing maintenance or repair activities on a buoyant platform, the projects must take careful consideration as to whether in-situ functions are safe and tested or if towage to port is a preferred option.

Due to its complexity, there is limited experience with in-situ maintenance and repair on floating offshore wind turbines, particularly regarding major components. This is also restricted since jack-up vessels are not able to perform component exchanges in-situ due to the depth of the floating wind farm sites. However, recent developments and solutions such as the successful completion

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[144] BVG ASSOCIATES. Guide to a floating offshore wind farm. 2023

[145] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023

of “the world’s first in-situ Major Component Exchange (MCE) on a floating wind turbine”[146] at Kincardine, where a generator was replaced by using an up-tower crane, will help to make in-situ maintenance more streamlined going forward, particularly, as floating offshore wind farms are scheduled to grow and the larger number of floating wind turbines per project will add additional complexity to tow-to-port operations particularly when disconnecting and connecting mooring lines and cables.

On the other hand, the tow-to-port option is currently the preferred, albeit lengthier and more expensive, choice when it comes to maintaining and repairing floating offshore wind turbines. This method requires “adequate port capability and capacity”[147]. Which is currently limited, as recently experienced by Hywind Scotland when it towed their 5 floating wind turbines approximately 282 nautical miles (i.e. 523 km) across the North Sea (see Figure 11) from the project site on the east side of Scotland to Wergeland Base in Gulen, Norway for a heavy maintenance campaign. According to Equinor, one of the project owners, “this was the safest, most efficient and proven method, as towing the turbines to shore allowed the operations to take place in a controlled, sheltered environment”[148]. However, according to Carbon Trust the campaign was implemented this way “as no Scottish port has sufficient water depth for the drafts of these spar foundations”[149].

The below Graph 5, illustrates the duration of each operation involved on Hywind Scotland’s heavy maintenance program at the time when the first of the five floating wind turbines had been “successfully repaired, towed back to site, and reconnected.”[150] On site activities included cable and mooring disconnection, lay-down the disconnected cables and moorings on seabed, recovering these from seabed and reconnecting them again.

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146 4C OFFSHORE. World-first major component exchange completed on floating wind turbine. 2024

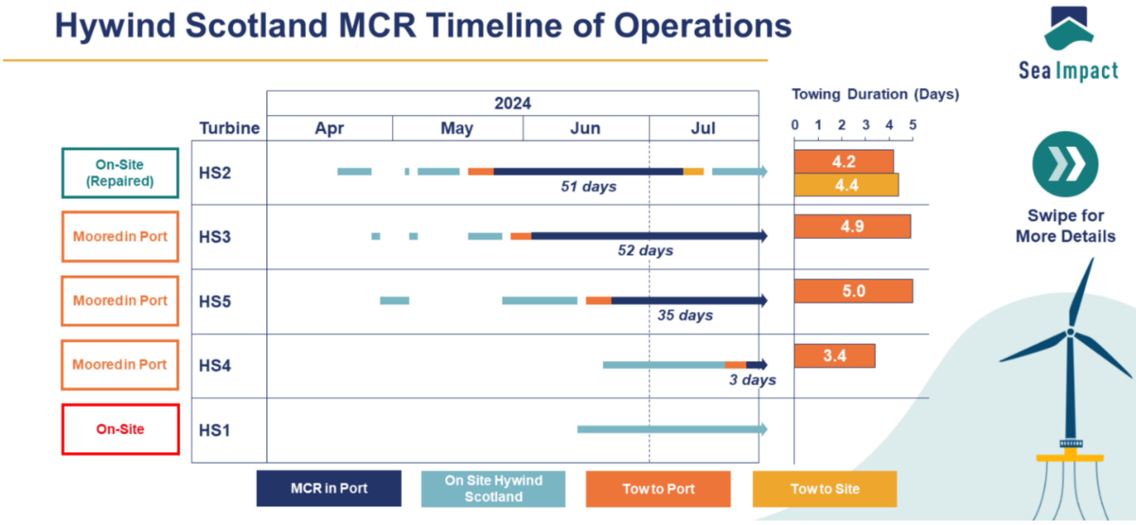
147 IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023

148 EQUINOR. Heavy maintenance campaign completed on Hywind Scotland floating offshore wind farm. 2024

149 CARBON TRUST. Floating wind JIP (joint industry programme). Phase V. Summary report. United Kingdom. 2024

150 SEA IMPACT. Hywind Scotland’s Heavy Maintenance: Tow-to-Port Approach. 2024

Graph 5. Hywind Scotland major component replacement timeline of operations as of 26th July 2024[151]



Source: Sea Impact

Previous and similarly, Kincardine floating offshore windfarm undertook major component replacements on two of their six wind turbines between 2022 and 2023. At the time, both turbines were towed approximately 367 nautical miles (i.e. 680 km) from the project's site on the east coast of Scotland to the quayside at the port of Massvlakte, Rotterdam (The Netherlands) for maintenance. "This marked the first incidence of a floating wind turbine requiring heavy maintenance (i.e. being disconnected and towed for repair) anywhere in the world."[152]

The below Graph 6 summarises the duration of each activity and highlights the reduced time taken on the second turbine, compared to the first one, "despite using a similar four-vessel marine spread."[153]

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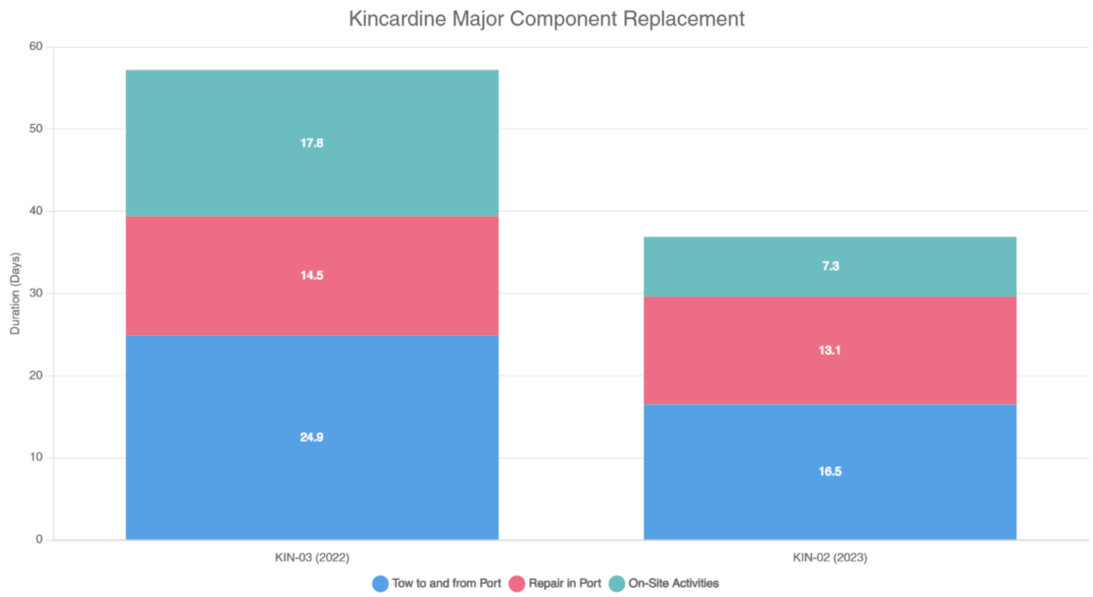
[151] SEA IMPACT. Hywind Scotland's Heavy Maintenance: Tow-to-Port Approach. 2024
[152] SPINERGIE. Lessons learned from heavy maintenance at the world's first commercial floating wind farm. 2023
[153] SEA IMPACT. Kincardine heavy maintenance: tow-to-port approach. 2023

Graph 6. Kincardine major component replacement[154]



Source: Sea Impact

These two recent tow-to-port replacement campaigns (Hywind Scotland and Kincardine) highlight how critical a nearby suitable port is to optimize floating offshore wind maintenance and repair campaigns. Indeed, "a port requires sufficient room and a deep water quay in order to be suitable for O&M in floating offshore wind. It needs to be equipped with a heavy crane with sufficient tip height to accommodate large floaters and reach turbine elevation. Furthermore, the distance to the wind farm is a key element in reducing towing time to minimize transit and non-productive turbine time."[155] As floating windfarms increase the number of turbines per project, faster campaigns supported on close by suitable ports will be key to limit (re)insurers' loss of profit exposure.

154 SEA IMPACT. Kincardine heavy maintenance: tow-to-port approach. 2023
155 SPINERGIE. Lessons learned from heavy maintenance at the world's first commercial floating wind farm. 2023

Figure 11. Hywind Scotland (left) and Kincardine (right) tow-to-port distances

Source: Google maps, own research

Likewise, vessel availability is also key to tackle maintenance and repair costs. As reported by Spinergie[156], “with spot day rates ranging from $63k to $210k contracted for Kincardine’s maintenance, the total cost of the marine spread used in the first repair campaign was more than $4 million”. A thorough provision and planning of frame agreements or long-term charters with AHTS (Anchor Handling Tug Supply) companies are effective ways to reduce the exposure to high spot market day rates.

Last but certainly not least, a proactive role of the Marine Warranty Surveyor (an independent expert ensuring safe marine operations and compliance with insurance requirements) will be of even greater importance to (re)insurers (compared to bottom-fixed offshore wind) given “the large number of units and repetitive operations” disconnecting and reconnecting cables and moorings during “O&M as well as repair scenarios”[157].

2.4. Costs

As with any source of energy, the Levelised Cost of Energy (LCOE) is a key metric to measure the average cost of a project or technology throughout its lifetime. As per Graph 7 below, floating offshore wind is currently significantly more expensive than bottom fixed offshore and, for reference purposes, onshore wind too.

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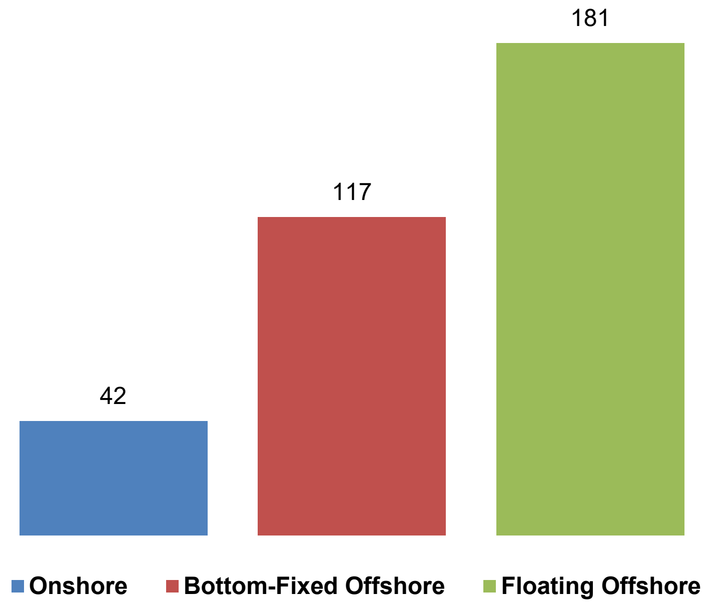
[156] SPINERGIE. Lessons learned from heavy maintenance at the world’s first commercial floating wind farm. 2023

[157] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023

Graph 7. Levelised cost of energy (LCOE) in USD/MWh[158]



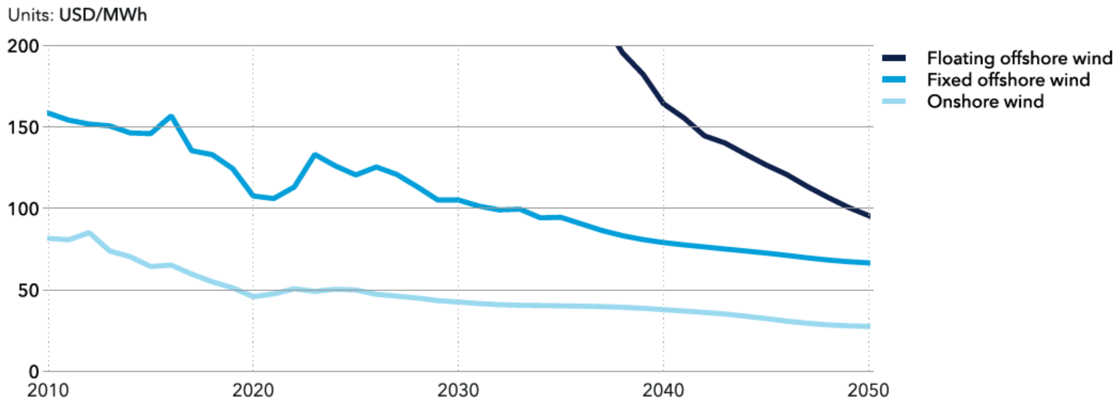
Source: NREL

It is important to note that the above figures are based on utility scale projects which, in the floating offshore wind case, are yet to be installed and are expected to do so towards the end of this decade. Indeed, at the time of writing, the largest operational floating offshore wind farm, Hywind Tampen, only has 88 MW capacity. Therefore, according to DNV[159], currently, the LCOE for floating offshore wind is USD 290/MWh, which is more than twice that of bottom-fixed offshore wind (USD 133/MWh).

However, as presented in Graph 8 below, floating LCOE is expected to decrease rapidly over the next decades due to "mass deployment, once designs have been optimized to reduce structural weight, introduce novel component technologies, improve installation methods, adopt serial fabrication processes, and benefit from scale effects"[160] in the floating offshore wind space.

[158] NREL. Cost of wind energy review: 2024 edition. United States. 2024
[159] DNV. Energy transition outlook 2024. Høvik. 2024
[160] ECN. Cost modelling of floating wind farms. Petten. 2016

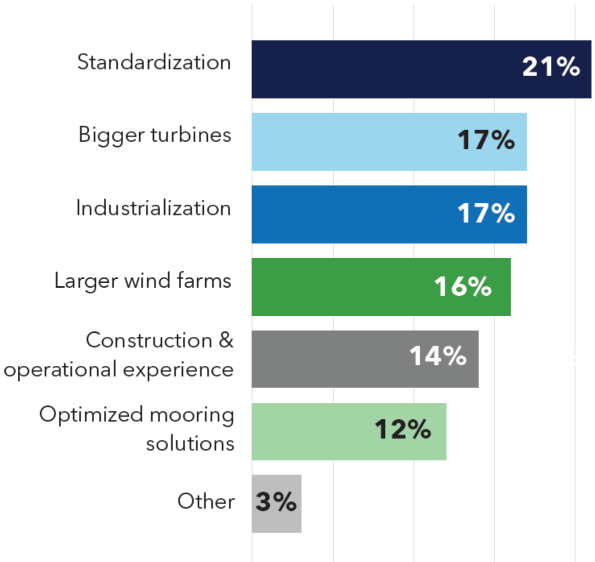
Graph 8. World average levelized cost of wind energy[161]



Source: DNV

A recent survey conducted by DNV among floating offshore wind experts from across the globe highlighted that LCOE reductions are expected to come from several items. The largest one being "standardization, either through reduction in the number of concepts or one preferable structure emerging"[162]. Other cost reductions are expected to come from bigger turbines, industrialization, larger wind farms, construction and operational experience and optimized mooring solutions.

Graph 9. Survey responses on where will LCOE reduction come from[163]

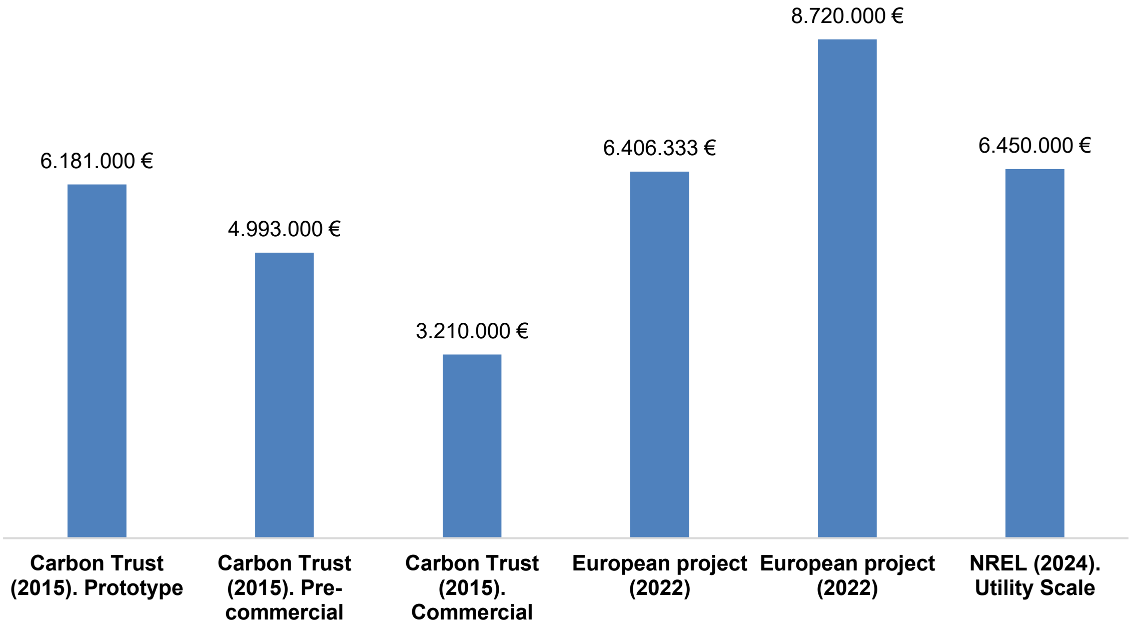


Source: DNV

[161] DNV. Energy Transition Outlook 2024. Høvik. 2024
[162] DNV. Floating wind: Turning ambition into action. Edition 2. Oslo. 2023
[163] DNV. Floating wind: Turning ambition into action. Edition 2. Oslo. 2023

The higher costs of floating offshore wind compared to bottom-fixed offshore wind are also reflected in the capital expenditure (CAPEX) per project. However, the volatility in the costs per MW installed presented on Graph 10 is due to the emerging state of the industry and the very limited number of floating wind farms currently deployed globally.

Graph 10. CAPEX per MW for floating wind (converted to EUR currency for comparative purposes)



Source: Own research, Carbon Trust[164], NREL[165]

As disclosed throughout Chapter 2.3. Technology, floating offshore windfarms have a slightly different configuration when it comes to main components (i.e. moorings, anchors, dynamic cables) and installation methodologies, compared to bottom-fixed. Similarly, as per Graph 11, the breakdown of typical CAPEX differs between these two configurations.

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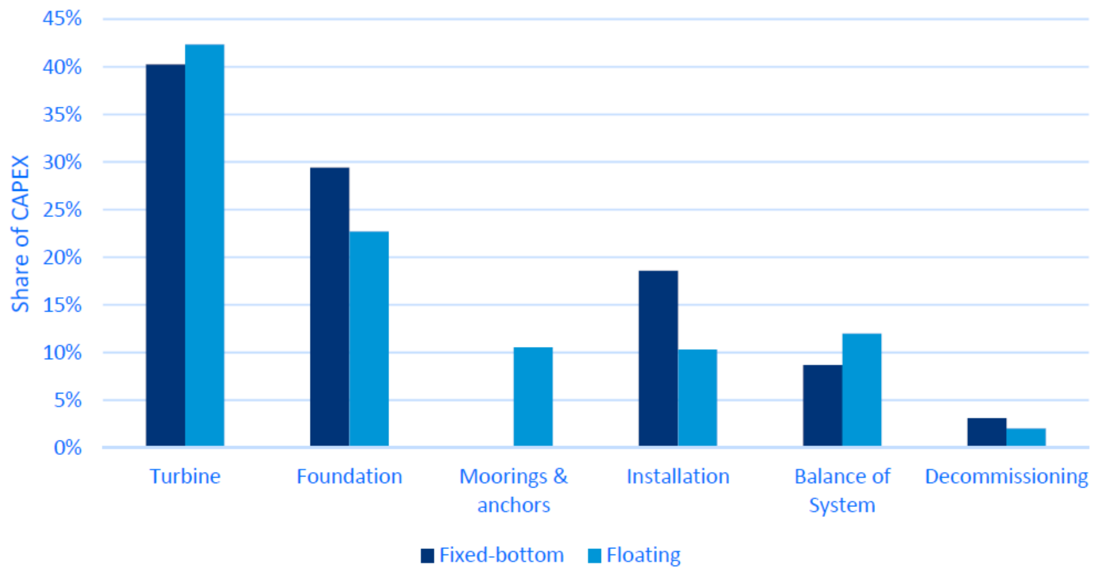
[164] CARBON TRUST. Floating Offshore Wind: Market and Technology Review. United Kingdom. 2015

[165] NREL. Cost of wind energy review: 2024 edition. United States. 2024

Graph 11. Cost breakdown for typical fixed-bottom and floating offshore wind projects[166]



Source: CARBON TRUST

On Graph 11, it is important to note that, once foundation costs are added to moorings and anchors', foundation costs become higher for floating wind projects than for bottom-fixed ones. Therefore, the main expenditure where "floating wind can deliver significant cost savings is in installation. Namely, the ability to assemble the turbine onshore and tow the fully assembled structure to site primarily using simple tug boats removes the need for expensive heavy lift jack-up and dynamic positioning vessels, for both foundation installation and offshore turbine assembly. Charter day rates can be around 4-8 times lower for the vessels required to install floating wind structures, in addition to dramatically lower mobilization costs, resulting in significant CAPEX savings"[167].

As previously reviewed in Chapter 2.3.2, foundations are a critical component for floating wind farms. Cost-wise too. "Today, floating foundation costs are five times higher than bottom fixed."[168] This is because floating requires double the amount of steel than bottom-fixed (when using a 8 MW turbine). As such, steel price fluctuations will have a significant impact on floating wind costs. Furthermore, floating foundation structures "are more complex to design and fabricate, especially compared with monopiles"[169].

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[166] CARBON TRUST. Floating Offshore Wind: Market and Technology Review. United Kingdom. 2015
[167] CARBON TRUST. Floating Offshore Wind: Market and Technology Review. United Kingdom. 2015
[168] DNV. Floating offshore wind: the next five years. 2022.
[169] DNV. Floating offshore wind: the next five years. 2022.

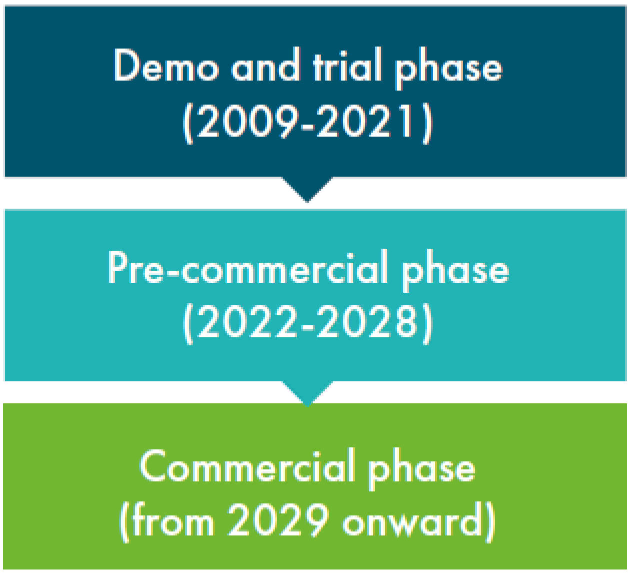
Last but not least, “floating wind O&M costs are projected to be higher than for bottom-fixed due to the maintenance operation and associated downtime.”[170] This is a relevant expense item as O&M costs may represent a significant portion of the overall project lifetime cost.

2.5. Forecast

Forecast figures for global floating wind installations change year on year based on the fast-paced, uncertain and volatile times that we are experiencing globally. They also change significantly from one source to another.

However, most of the industry literature reviewed concurs that floating offshore wind globally is still going through its infancy stage. Currently, each step is a significant milestone towards achieving the commercial stage, where the size of the floating projects and the annual installations will reach volumes high enough to enable the cost reduction necessary to unlock a faster industrialization of the sector.

Figure 12. Roadmap of floating offshore wind commercialisation[171]



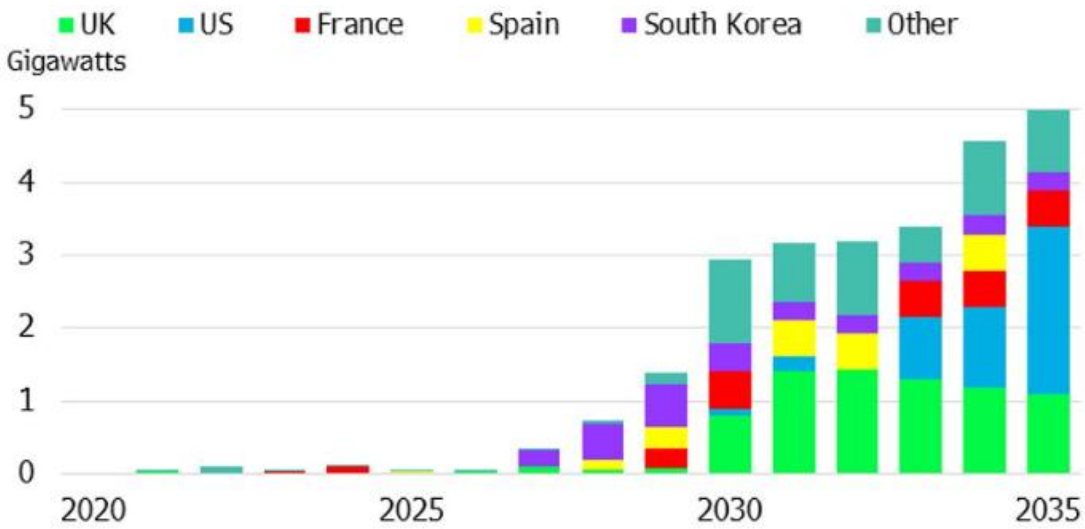
Source: GWEC

[170] WORLD FORUM OFFSHORE WIND (WFO). Onsite major component replacement technologies for floating offshore wind: the status of the industry. 2023
[171] GLOBAL WIND ENERGY COUNCIL. Global offshore wind report 2024. 2024

Given the current geopolitical context, it is extremely difficult to estimate with a decent degree of confidence and precision how much and how fast floating offshore wind will grow in the next decades globally, let alone in the next few years within any given country or region.

As an example, as recently as in June 2022, WindEurope stated that “it is not unreasonable to expect that Europe will have over 10 GW of floating wind in operation by 2030.”[172] With just 203 MW of floating installed in Europe as of October 2023, this means a nearly 50-fold increase in a relatively short amount of time. At the time of writing, the author considers the expectation completely unrealistic. Even reaching 5 GW by 2030 in Europe would be a huge achievement which requires annual installations of 1 GW during the rest of the decade. Again, an extremely ambitious target considering annual installations so far have been well below 100 MW (i.e. 41.8 MW floating wind capacity was installed globally in 2024[173]). On that note, Graph 12 below suggests that floating wind annual installations of 1 GW in Europe will only be reached from 2030 onwards.

Graph 12: Annual floating wind installations globally[174]



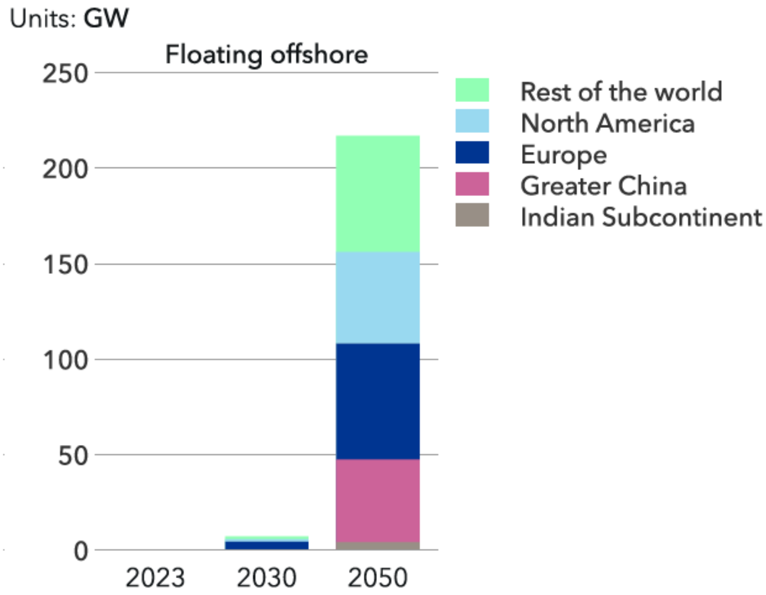
Source: BloombergNEF. Note: “Other” includes Norway, Greece, Italy, Mainland China, Portugal and Japan.

[172] WINDEUROPE. Europe can expect to have 10 GW of floating wind by 2030. 2022
[173] GLOBAL WIND ENERGY COUNCIL (GWEC). Global wind report 2025. Lisbon. 2025
[174] BLOOMBERGNEF. The next phase of wind power growth in five charts. 2022

Nevertheless, the global potential remains huge. Indeed, “around 80 percent of the sea areas eligible for offshore wind energy”[175] are suitable for floating offshore wind.

At the same time, there seems to be political, social, environmental and economic willingness to grow floating wind globally. However, the current challenges faced during the early stages (high costs, lack of standardization and experience) plus future unknown challenges make the journey towards commercialization slower than anticipated and difficult to predict.

Graph 13: World installed floating offshore wind capacity by region[176]



Source: Historical data source: GlobalData, DNV analysis

Another area of broad consensus in the industry is the need to scale up projects to achieve economies of scale and lower costs. The size of the project matters. Even more so currently when wake issues are becoming a growing concern among developers and lenders in the congested waters of the North Sea, “the world’s densest installation of offshore wind turbines”[177]. Indeed, the ability of floating wind to operate in less crowded, deeper waters to harness stronger wind resources remains a key strength for floating wind.

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[175] BWO. Expansion into the deep sea with floating wind power.
[176] DNV. Energy Transition Outlook 2024. Høvik. 2024
[177] OFFSHOREWIND.BIZ. New research project aims to create more accurate wake modelling for offshore wind. 2025

The experience accumulated to date will be vital, as early entrants continue to extract key insights while the industry transitions to the commercial phase and confronts evolving challenges. Floating offshore wind developers and original equipment manufacturers have gained valuable experience in extreme weather conditions too – insight that is particularly relevant to (re)insurers. For example:

Table 3. Reported extreme weather conditions faced by floating wind turbines

Windfarm	Event	Year	Windspeed (km/h)	Wave height (m)
Windfloat Demo	n/a	n/a	144	17
Hywind Scotland	Hurricane Ophelia	2017	125	
Hywind Scotland	Storm Caroline	2017	160	8.2
Haenkaze	Typhoon Prapiroon	2018	187	6.9
Windfloat Atlantic	Storm Dora	2020		9
Floatgen	n/a	2020		11
Kincardine	n/a	2022		8
Floatgen	Storm Ciaran	2023		12.9
Windfloat Atlantic	Storm Ciaran	2023	139	20
Qingzhou IV (OceanX)	Super typhoon Yagi	2024	234	
Yangjiang Shapa III	Super typhoon Yagi	2024	159	
Hywind Tampen	Storm Ingunn	2024	154	11

Source: The Renewables Consulting Group , Windfloat Atlantic , Offshorewind.biz , Equinor , PrinciplePower , , Tanaka et al , BW Ideol , . Note: some of the windspeeds refer to wind gusts instead of sustained windspeeds.

Another key element for floating wind, as for any other nascent industry, is the political will and support. This can be translated into national tenders and subsidy schemes that provide the stability and long-term clarity required to attract developers and lenders' commitment as well. On this note, different regions and countries are expected to grow their floating wind ambitions at different speeds in the upcoming decades to meet their renewable energy targets.

Finally, sustained research and development and multi-stakeholder collaboration will be essential to enhance efficiency in technology and cost reductions. These efforts will be key to establishing floating offshore wind as a reliable and cost-competitive energy source.

3. Global (Re)Insurance Market for Floating Offshore Wind

3.1. Background

As discussed in Chapter 2, the number of floating offshore wind farms currently operational or under construction worldwide remains very limited, reflecting the early-stage development of this technology. Most existing projects are demonstration or pilot-scale with a scarce number of floating wind turbines per project; the largest to date being Hywind Tampen, which has 8 installed wind turbines with a total combined capacity of 88 MW (very small compared to the largest bottom-fixed to date being Hornsea 2 consisting of 165 wind turbines with a total combined capacity of 1,386 MW[178]).

Nevertheless, Chapter 3 will review the existing floating wind projects from a (re)insurance perspective, supported by the longer track record available on its elder sister technology: bottom-fixed offshore wind.

The study will focus on the following types of cover available in the market for the owners and developers of the windfarms:

- Construction All Risks
- Delay in Start Up
- Operational All Risks
- Business Interruption

It is common for construction policies to include the first year of operation in the same policy to avoid any gaps in cover during the construction handover process.

The (re)insurance required to cover physical damage and consequential loss (time element) on an offshore wind farm is critical for project financing. It provides the risk transfer necessary for lenders to extend credit and for investors to commit capital to new developments. Therefore, (re)insurance serves as a fundamental facilitator of the energy transition. This was highlighted in one of the first pieces ever written about offshore wind (re)insurance, which was authored by Gen Re: "Without comprehensive insurance protection, however, investors will usually not make capital available for these projects. Thus, insurers have an opportunity to take on a central role in the expansion of offshore wind energy"[179].

The global offshore wind (re)insurance market has changed considerably since 2010, when annual installations reached 1.0 GW capacity (most of it bottom-fixed)[180]. Back then, offshore wind (re)insurance was a very niche product offered

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[178] ORSTED. Hornsea 2 offshore Wind farm.
[179] STEIN, O. "Offshore wind energy in Europe – Fresh wind for insurers, too?" Gen Re. Topics No. 19. 2012
[180] GLOBAL WIND ENERGY COUNCIL (GWEC). Global wind report 2025. Lisbon. 2025

by a limited number of specialist markets. This was in line with both the smaller scale of projects at the time and the limited number of installations worldwide. These factors allowed for a (re)insurance market where the policy leader used to underwrite large shares of the policy in many instances (around 40% of 100% of the project). The leader was then followed by a relatively small number of co-insurers, some of whom were local domestic insurers from the country where the project was being installed, or from the country where the main policyholder was from. In turn, several of those co-insurers required facultative reinsurance capacity due to several factors, including but not limited to:

- Offshore being an exclusion of their reinsurance treaties
- Limited experience
- New technology
- Relatively large sums insured and limits
- Keeping their portfolios as balanced as possible

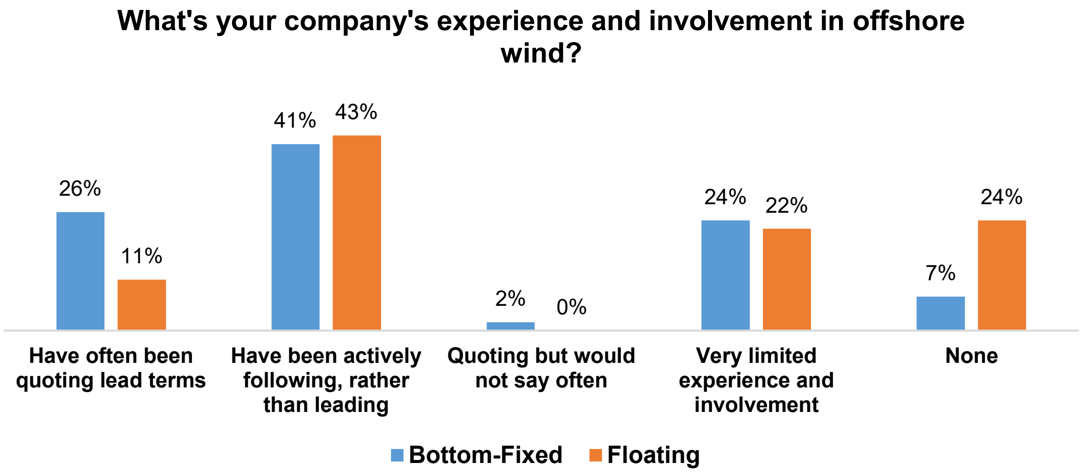
Nowadays, in contrast, a large number of (re)insurers are actively underwriting offshore wind in one way or another (direct insurers, treaty reinsurers, facultative reinsurers, capacity providers to Managing General Agents). The policy leader rarely underwrites more than a 15% share of a new large construction policy (due to much higher values and limits than in the past). The leader is now followed by a relatively large number of international co-insurers. Currently, it is also quite common to see bottom-fixed offshore wind policies end up with significant overcapacity during the placement stage, which results in co-insurers being signed down from their initial offering or being left out of the (re)insurance placement altogether.

The increase in the number of markets offering (re)insurance cover for offshore wind can be explained by several factors, including but not limited to:

- Increasing demand to cover larger projects in number and size
- Support to energy clients transitioning from fossil fuel focused to renewable energy (including offshore wind)
- (Re)insurers' commitment to ESG criteria
- Transfer of knowledge, expertise and (re)insurance capacity from upstream oil and gas to offshore wind

Indeed, the survey prepared for this thesis identified, at least, 36 (re)insurance markets with high involvement and experience in bottom-fixed offshore wind (either often quoting lead terms or actively underwriting as a following company). However, in contrast, when analyzing the same (re)insurers' experience and involvement in floating offshore wind, the number dropped to 29, reflecting the different stages of maturity of each configuration.

Graph 14: (Re)insurers' experience and involvement in offshore wind



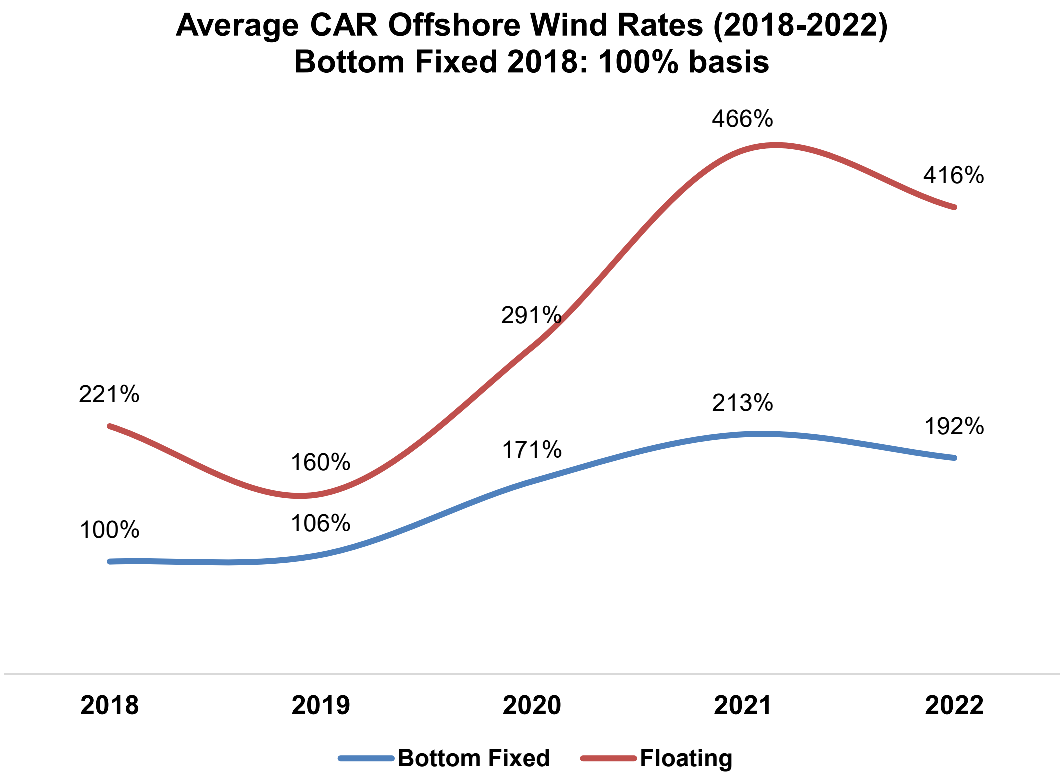
Source: Own elaboration

The survey also confirmed that, whilst there is plenty of (re)insurance capacity and carriers actively involved and experienced in offshore wind, most of these are acting as followers, instead of leaders. This is the case for both bottom-fixed and, particularly, for floating wind, where only 6 (re)insurers “have often been quoting lead terms”.

The global offshore wind (re)insurance market has shifted in the last 15 years from emerging technology underwritten by a few specialists to a mature mainstream line of business underwritten by most industrial (re)insurers globally. Indeed, it is now common nowadays for many (re)insurers to have specialist teams of underwriters, claims and risk engineers fully dedicated to offshore wind business (mainly bottom fixed though). This was not the case in the early days, when very few offshore wind farm projects came to the (re)insurance market looking for cover and were scrutinized by a very limited number of (re)insurers from various different departments (engineering, construction, property, marine, upstream energy) as it was uncommon to have a fully dedicated offshore wind department back then.

The global offshore wind (re)insurance market, like any other market, is affected by the laws of supply and demand. As reflected in Graph 15, (re)insurance offshore wind construction all risk rates have increased considerably from 2018 to 2022. This was fueled by the global hardening (re)insurance trends. Since 2022, the market is seeing a new gentle decrease of rates driven, in part, by the entrance of new (re)insurers willing to tap into the growing offshore wind market.

Graph 15: Construction All Risks (CAR) rates evolution for bottom-fixed offshore wind (2018-2022)



Source: Own research and elaboration

The above Graph 15 clearly states that, as expected, floating wind construction all risks rates are significantly higher than bottom-fixed and both follow similar trend dynamics over the years. It is important to highlight the very small sample of projects available for floating wind though. This provides higher volatility to the average rate figures displayed on Graph 15. Whereas for bottom-fixed rates, the sample is considerably wider, hence the annual changes are softer.

As reflected by the survey prepared for this thesis among 54 respondents, (re)insurance capacity levels remain very high for bottom-fixed projects (EUR 4.5 bn on total insured values) and a bit lower for floating wind (EUR 3.5 bn on total insured values).

Similarly, out of the 14 (re)insurance markets that responded that “have often been quoting lead terms” for bottom-fixed technology, only 6 gave the same response when it came to floating wind.

The survey provides therefore grounds to assert that global floating offshore wind (re)insurance capacity is abundant, although the experience and involvement to date with the technology is rather limited.

3.2. (Re)insurance Considerations

3.2.1. Background

Even though each offshore wind farm, be it bottom-fixed or floating, is a unique project with its own set of features, challenges and risk mitigation measures, the following Chapter 3.2 will provide some considerations seen in the global (re)insurance market since 2010.

Similar to previous chapters, the analysis will be focused on the limited number of floating offshore windfarms to date, however, it will also be supported by factors applied to bottom-fixed projects given the longer track record available.

As stated by Julien Marchal, Development Director at Naval Energies[181] "for floating wind, the new and innovative part is the floater and mooring system, which invariably means a fair few risks compared to fixed-bottom, and of course these risks have to be addressed."

The Insurance Subcommittee of the World Forum Offshore Wind (WFO)[182] identified the following major differences in the risk perception between bottom-fixed and floating offshore wind configurations:

- Moorings
- Dynamic cables
- Repair and Maintenance

Another difference in the risk perception between bottom-fixed and floating wind configurations is the lack of availability guarantees of the Operations and Maintenance contract for the floating foundations and station-keeping systems (mooring lanes and anchors) which increases the risk profile of this technology.

On the same report, WFO also identified the following key parameters with a positive influence on insurability:

- Floating Offshore Wind Turbine integrity – design phase considerations
- Mooring Integrity Management – risk mitigation considerations
- Dynamic cable reliability
- Efficient concept for repair or exchange of major components
- Special Operation & Maintenance concept

Similarly, the Survey and Engineering Subcommittee of the Lloyd's Market Association's Joint Natural Resources Committee (JNRC) provides guidance and

[181] REUTERS EVENTS. Offshore & floating wind Europe 2020. Conference Report. London. 2020
[182] WORLD FORUM OFFSHORE WIND (WFO). Insurability of floating offshore wind. 2021

recommendations “on the key areas of interest to risk engineers working for potential insurers of”[183] floating offshore wind farms.

Indeed, JNRC’s guidelines contain “suggested courses of action to mitigate associated concerns via the adoption of what are considered to be best practice engineering approaches. The guideline highlights the need for project sponsors to provide clear evidence that the design, fabrication, construction and operation of each element of the asset has been carefully considered to ensure the level of risk of damage or loss has been minimised as far as practicable.”[184]

A list of minimum information recommended by JNRC[185] and required from brokers for the construction phase of a floating offshore wind farm is included herein under Annex 1.

3.2.2. Loss Scenarios

Floating offshore wind farms present novel and diverse risk profiles compared to their bottom-fixed counterparts, particularly due to their buoyant nature, mooring systems, and less mature industry. As for any other line of business, loss scenarios are primarily considered in terms of physical damage and business interruption, depending on the project phase (construction or operation).

The Joint Natural Resources Committee (JNRC)[186] identifies several high-impact scenarios, including:

- Failure of export cables or substations, which can lead to the total loss of generation capacity. These incidents often define the Estimated Maximum Loss (EML) for operational coverage.
- Bottleneck component failure, such as inter-array cables or underwater electrical components, potentially disabling multiple turbines.
- Serial defects, which can cause widespread outages and are typically addressed by specific “serial loss clauses” in policy wording.
- Tropical revolving storms (TRS) present catastrophic risks, particularly in locations like the East Coast U.S. or Taiwan.
- Major component exchange (MCE) events, due to their logistical complexity and cost implications, represent another significant insurance exposure.

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[183] JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024
[184] JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024
[185] JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024
[186] JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024

According to Aon (a major global (re)insurance broker), “new risk scenarios for floating wind, and the costs associated with these, require careful consideration in EML and PML studies, as well as good quality discussion with risk engineers”[187].

Loss scenarios influence pricing, coverage conditions, and deductible levels, underlining the need for robust preventive engineering and insurance considerations from the early phases of project design.

Annex 2 (Construction Phase) and 3 (Operational Phase) include JNRC’s loss scenarios for construction and operation phases respectively and their impact, applicability, severity, likelihood, remedial works required, potential cause(s), potential risk mitigants and concerns.

3.2.3. Collision

In recent years, a number of vessels suffering collisions against offshore wind farms’ (bottom-fixed) foundations of either a wind turbine or the offshore substation have been reported. This type of event remains very unusual; however, due consideration is required to mitigate such risk against a floating offshore wind turbine. To that extent, the WFO recommends “installation of warning systems such as visual and sonic warning, including cameras with constant real-time monitoring that allow for immediate action in case of imminent danger.”[188]

3.2.4. Redundancy

To counteract the higher risk-profile arising from the lack of availability guarantees in floating platform Operations and Maintenance contracts, (re)insurers are relying on redundancy of the station-keeping systems to secure “uninterrupted energy production; or a well-thought spare parts concept that secures a prompt replacement of the damaged or lost items, therefore reducing the loss of energy production below the maximum number of days of the Waiting Period of the Business Interruption insurance policy.”[189]

Similarly, the JNRC[190] emphasizes that failure of a single mooring line can compromise structural integrity, position holding, and cable integrity. Therefore, it is recommended to:

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187 AON. Floating offshore Wind unlocks new opportunities and challenges. 2024
188 WORLD FORUM OFFSHORE WIND (WFO). Insurability of floating offshore wind. 2021
189 WORLD FORUM OFFSHORE WIND (WFO). Insurability of floating offshore wind. 2021
190 JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024

- Clear articulation of redundancy strategies, such as (n-1) configurations, where a single line failure does not lead to uncontrolled drift or cable failure.
- Adoption of emergency disconnect systems for cables that can safely disengage if excessive tension arises due to drift.
- Detailed risk assessments outlining the consequences of partial or total mooring failure on turbine stability and power export capabilities.

(Re)insurers considering to participate in a floating offshore windfarm expect redundancy not only as a technical safeguard but as an operational commitment that directly affects underwriting confidence and policy terms and conditions.

3.2.5. Serial Loss Clause

Serial defects pose systemic risk, especially in projects where turbines or cable systems share common design or manufacturing flaws. Indeed, "the potential inability of cables and other equipment such as main components to resist premature fatigue is driving significant serial loss exposure."[191] Such defects can cause failures across multiple assets and are thus a high concern to (re)insurers.

To address this, (re)insurance policies often include serial loss clauses, which:

- Define the extent to which repeated similar failures are treated as one event versus multiple claims.
- Limit coverage in scenarios where design faults or material flaws propagate across the asset base.

According to law firm Kennedys, "previously, SLCs [Serial Loss Clauses] were often quite limited in scope. For instance, they might only apply to property supplied under the turbine supply agreement and be confined to the property damage section of a policy, but not to the business interruption (BI) or delay in start-up (DSU) sections.

More recent LMA wordings (LMA5587 and LMA5588) apply to all property and BI/DSU [Business Interruption / Delay in Start-Up] losses as well as property damage. Notably, the LMA SLCs also apply a deductible per each "loss amount", defined as loss of or damage to each individual item of insured property"[192].

The JNRC[193] notes that (re)insurers rely heavily on design verification, type certification, and operational monitoring to mitigate such exposures. Floating

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[191] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[192] KENNEDYS. Serial defect claims in offshore wind projects will challenge insurers. 2024
[193] JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024

wind platforms, with their limited field experience, elevate these concerns, especially in shared components such as moorings or dynamic cables. A proactive defect management and asset tracking system is therefore recommended to isolate and address defects before widespread propagation.

Similarly, IMIA[194] provides the following checklist to ensure that Serial Loss Clauses contain key safety provisions and limit series loss exposure effectively:

- Does the Serial Loss Clause apply to all insured property or only to specific components?
- How does the deductible apply and is there any deductible aggregation?
- Is the defects language of the Serial Loss Clause aligned with the defects cover of the policy?
- Is the scale reasonable?
- Does the Serial Loss Clause also apply to curtail Delay in Start Up / Business Interruption losses?

3.2.6. Defects Exclusions

The London Engineering Group (LEG)[195] clauses are central to (re)insuring engineering and construction risks. Their applicability in floating offshore wind is under scrutiny due to high innovation levels and limited track record data available.

The following are the main clauses used by (re)insurers to limit or exclude defects:

- LEG 1/96 – An out-right defects exclusion - offers the most limited cover, excluding all defects in design, material, and workmanship.
- LEG 2/96 – A “Consequences” style wording - includes physical damage resulting from defects, excluding the defective part itself.
- LEG 3/06 – A wider or “full defects” style wording - offers the broadest cover, including defective parts if they cause physical loss or damage, excluding the cost incurred to improve the original.

The use of appropriate defects clauses is of paramount importance to (re)insurers involved in floating offshore wind. A recent case in Japan where “Goto Floating Wind Farm Consortium has postponed the commissioning of the Goto City

[194] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[195] LONDON ENGINEERING GROUP. LEG group defects wordings.

Offshore Wind Power Generation Project by two years following the discovery of defects"[196] during construction in the floating structures, highlights the relevance of its consequences.

The usual defect cover provided by bottom-fixed offshore windfarms' construction policies was initially LEG 3/06 for all components, except LEG 2/96 for wind turbine generators. Special attention is still paid to the policy definition of "wind turbine generators" as it may vary from policy to policy. This set up, however, has been restricted in recent years with LEG 2/96 provided as the basis for all components, except certain packages benefiting from sublimited LEG 3/06 coverage.

Regarding floating offshore wind, given the novel configurations and limited testing of certain components, the author's limited experience is to witness LEG 1/96 for critical components such as floating foundation, station keeping system and inter array cables as long as these do not have a relevant type certificate.

The author's experience is backed by WFO's white paper. Indeed, "lowering the probability of failure in dynamic cables (risk mitigation) and the reduction of their repair cost and downtime (loss mitigation) are key for floating offshore wind because it is expected that for a certain qualification period, technologies in floating wind including the dynamic export/inter-array cable and substation are regularly falling under the LEG 1 exclusion of coverage for defective parts."[197]

The criteria are also in line with IMIA recommendations for (re)insurance companies to "give due consideration to the largely unproven components in FOWFs [floating offshore windfarms] and the associated risk level before defining an appropriate design exclusion"[198].

Last but not least, renewable energy insurer GCube stated that "manufacturing defects are already subject to more exclusions on floating offshore wind projects and coverage is quite restricted in comparison to fixed bottom structures. Without a conscious effort to improve project standards, insurance will remain more restricted and offered at a higher price"[199].

3.2.7. Maintenance

Maintenance strategies for floating offshore wind farms must accommodate their remoteness, complexity, and limited port infrastructure. As reviewed on Chapter 2.3.7. Operations and Maintenance, there is ongoing debate between in-situ repair and tow-to-port models. Both have significant (re)insurance implications.

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[196] OFFSHOREWIND.BIZ. Structural defects delay Japan's first floating offshore wind farm. 2023
[197] WORLD FORUM OFFSHORE WIND (WFO). Floating offshore wind dynamic cables: overview of design and risks. 2024
[198] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[199] GCUBE. Opinion: Floating wind will continue to be risky to insure without standardization. 2024

Key recommendations from JNRC[200] and IMIA[201] include:

- Developing specialized O&M vessels and pre-arranged logistics for major component exchange (MCE).
- Holding critical spare parts in proximity to minimize downtime.
- Implementing predictive maintenance systems, such as Condition Monitoring Systems (CMS), especially for mooring lines and cables.
- Using digital twins for real-time fatigue and motion analysis to inform preventive maintenance scheduling.

Lack of clarity or preparedness in O&M strategies often results in exclusions or higher deductibles during the underwriting process.

3.2.8. Standards and Certification

"A lack of standardization will impact the time needed to repair or replace parts, or whole structures, which could impact delay in start-up or business interruption coverage."[202]

Similarly, certification and classification underpin (re)insurers' confidence and degree of comfort, particularly with young technologies. The key frameworks applied include:

- Project certification (e.g., IECRE OD-502) covering design, manufacturing, installation, and operation.
- Type certification (e.g., IECRE OD-501 or DNV-SE-0441) for individual components like wind turbines or cables.
- Classification by societies such as DNV, ABS, or BV for floaters and mooring systems.

According to IMIA, "some developers exclude inter array cables from the project certification which is not recommend[ed] as experience has shown that cables are a leading source of claims"[203].

The JNRC[204] recommends pursuing integrated certification and classification, ensuring comprehensive third-party verification across all phases. This is

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[200] JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024
[201] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[202] ALLIANZ COMMERCIAL. A turning point for offshore wind. Global opportunities and risk trends. Munich 2023
[203] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[204] JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024

especially important for mooring systems and dynamic cables, which often fall outside traditional certification scopes.

Regular in-service inspections and maintaining certification beyond commissioning are advised to preserve insurance coverage throughout the operational lifetime. Floating wind projects omitting certification or fragmenting responsibility across multiple Independent Verification Bodies (IVBs) risk being underinsured or facing premium loading.

Similarly, WFO highlighted the “importance to have the turbine and floating platform design integrity independently reviewed and evaluated”[205].

3.3. Claims

Given the very limited number of floating offshore wind projects currently operating or under construction, claim statistics specific to this technology are scarce and most of them not publicly available. Nevertheless, the limited floating claims record will be supported by certain types of claims seen in bottom-fixed offshore wind farms over the years, which can provide evidence for potential future floating claims and, more importantly, how to prevent them.

3.3.1. Cable Claims

As simply put by ORE Catplut[206], “the next generation of dynamic cables will need to be robust enough to survive with having larger stresses acting on them. These greater stresses will cause the cables to fatigue faster than those in a conventional static cable configuration, resulting in a greater risk of cable failure”. Indeed, “static cables were designed for service in environments wholly different to those experienced by cables for floating offshore wind. The dynamic cables will be exposed to sea currents, action of the waves and the movement of the floating turbine platform itself.”

The fact that subsea cable losses are of big concern to (re)insurers in the offshore wind bottom-fixed field is well documented. According to a Gcube report[207], “subsea cables (inter-array and export) represent 30% of claims incurred and 55% of total claims spend” between 2010 and 2020 in offshore wind. The same report emphasises that “the main root cause of this damage is contractor error during transit and cable laying, with this amounting to 44% of the claims spend on cables”.

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[205] WORLD FORUM OFFSHORE WIND (WFO). Insurability of floating offshore wind. 2021

[206] ORE CATAPULT. Predicting dynamic subsea cable failure for floating offshore wind. United Kingdom. 2018

[207] GCUBE. Uncharted Waters. Navigating emerging risks and rising claims in global offshore wind. Q4 2021 Report. London. 2021

In terms of severity, “in the UK, the average downtime for a bottom-fixed wind farm inter-array cable repair is approximately 40 days and for an export cable approximately 60 days. Inter-array cable damage costs between $1.8M to $12M, and export cable damage costs between $10M to $30M”[208].

In terms of frequency, The Carbon Trust[209] estimated that the average failure rate for static offshore wind subsea cables was between 0.0019 failures/km/year and 0.0213 failures/km/year, with installation and manufacturing as the most common failure modes. This represents that for an offshore windfarm with 100 km of static subsea cables, on average, the windfarm is expected to experience a subsea cable failure between every 5.26 years (best case scenario) and 0.47 years (worst case scenario).

These figures are based on static cable experience (i.e. cables with bottom-fixed foundations). As such, as the industry slowly develops floating offshore wind configurations, the risk profile of dynamic cables increases due to the motion of the floating foundations which the dynamic cables need to withstand, together with greater fatigue loading compared to static cables.

Certainly, (re)insurers “are particularly concerned with the technology readiness of cable systems given the consequence of cable failure as well as a history of issues at various bottom-fixed wind farms”[210].

This is partly due to the fact that “significant platform drift is likely to cause extensive inter-array cable (IAC) damage, incurring additional expense and turbine downtime”[211]. Therefore, “a degree of mooring system redundancy is critical to avoiding (expensive) cable damage and subsequent prolonged turbine downtime.”[212]

Similarly, IMIA identified cable hang-off systems – which may be designed as “weak-link” connectors as an element that may be susceptible to design issues. Indeed, “weak-link cabling systems are designed to disconnect at certain extreme axial loads such as during an allision or during contact with an iceberg to “save” other property. They have been common for flowlines in oil and gas projects but are relatively new for cables in offshore wind projects. Such weak-link connectors might also be used as grid connectors. A question that may arise in circumstances where weak-links are designed to “break” is whether a break at the point at which the weak-link is designed to break is physical damage at all.

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208 WORLD FORUM OFFSHORE WIND (WFO). Floating offshore wind dynamic cables: overview of design and risks. 2024. Based on ORE Catapult. 2021. ELECTRODE project data
209 CARBON TRUST. Floating wind JIP (joint industry programme). Phase V. Summary report. United Kingdom. 2024
210 WORLD FORUM OFFSHORE WIND (WFO). Floating offshore wind dynamic cables: overview of design and risks. 2024
211 FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE. ORE CATAPULT. Failure implications of different mooring spreads and lines. Public summary report. Glasgow. 2024
212 FLOATING OFFSHORE WIND CENTRE OF EXCELLENCE. ORE CATAPULT. Failure implications of different mooring spreads and lines. Public summary report. Glasgow. 2024

Of course, the type of disconnection and what caused it (as well as the law of the policy) will be relevant considerations for any claim of this nature."[213]

3.3.2. Foundation claims

According to the Gcube report[214], approximately 80% of (bottom-fixed) offshore wind farms have monopile foundations. However, 65% of foundation claims are from non-monopile foundations.

These figures highlight the importance of well proven and tested technologies for (re)insurers. Indeed, the statistic becomes of paramount relevance when considering floating offshore wind potential losses. Even if floating foundations' technology has decades of experience in the oil and gas industry, it is a very novel concept for offshore wind. As such, (re)insurers will require designs to be certified by a third party independent body to mitigate design, fabrication or material issues.

As highlighted by IMIA[215], "as the floating design concepts are improved, it may be the case that certain designs become favoured by contractors and operators. This may mean that certain designs being used now may become obsolete, or partially obsolete. This may create challenges at the claims stage if only certain contractors are able to remedy issues arising on particular projects. It may also be the case that the manufacture of certain components may become more restricted for certain designs." Accordingly, an issue that may arise for foundation designs is "a limited manufacture or contractor pool for components"[216].

3.3.3. Major Component Replacements

Major component replacement undertaken at two floating offshore wind farms recently resulted in significant (re)insurance claims, the author understands, mainly due to the long distance between project sites and the relevant repair ports.

These (re)insurance claims brought major questions and concerns to the (re)insurance market, the answers of which are still being addressed as they require a holistic approach from several stakeholders.

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[213] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[214] GCUBE. Uncharted Waters. Navigating emerging risks and rising claims in global offshore wind. Q4 2021 Report. London. 2021
[215] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[216] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023

Both cases were previously mentioned in Chapter 2.3.7. Operations and Maintenance, which can be summarized as follows:

Table 4. Summary of major component replacements at Kincardine and Hywind Scotland

	Kincardine	**Hywind Scotland**
Commercial Operation Date	2021	2017
Repair Date	2022-2023	2024
Number of Wind Turbines Repaired	2	5
Distance Towed to be Repaired	678 km	523 km
Repair Campaign Duration per Wind Turbine*	47 days**	90 days***

Source: Sea Impact[217,218]

Note: *Estimated time including on-site activities, tow to port and tow to site. It does not take into account any gaps between activities. **Average time between wind turbine KN-03 (57.2 days) and wind turbine KN-02 (36.9 days). ***Wind turbine HS2.

Towage under an Operational All Risks policy becomes then of paramount importance. Indeed, as stated by IMIA "where a damaged turbine is being transported to a repair site, this presents a very different risk profile and it is likely that a specific (and additional) marine voyage policy will be required to cover the turbine from the risks of the voyage. Communication at the claims stage will be vital to ensure that any potential liabilities arising from towage or transportation costs can be satisfactorily assessed and apportioned."[219]

After two of Kincardine's six wind turbines were towed to port (from Scotland to The Netherlands) between 2022 and 2023, a third wind turbine replaced a generator in-situ successfully using an up-tower crane in 2024. This was deemed as "the world's first in-situ Major Component Exchange (MCE) on a floating wind turbine."[220]

The benefit of using this alternative maintenance or repair strategy "is that the crane follows the relative motions of the turbine. The final crane height is provided by the turbine structure, rather than a heavy lift vessel, meaning less expensive vessels (with lower crane lifting capabilities) can be used.

However, there are still some challenges associated with using self-hoisting cranes including:

- The logistical challenge of transferring the crane between the service vessel and the turbine

[217] SEA IMPACT. Hywind Scotland's Heavy Maintenance: Tow-to-Port Approach. 2024
[218] SEA IMPACT. Kincardine heavy maintenance: tow-to-port approach. 2023
[219] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[220] 4C OFFSHORE. World-first major component exchange completed on floating wind turbine. 2024

- The need to assemble and disassemble the crane system one each turbine requiring maintenance
- The need for design modifications or retrofits to the turbine, tower, and/or substructure, which may involve the need for system recertification”[221]

As commented by Andries Veldstra, Senior Underwriter at GCube, “the floating offshore wind market may need to re-evaluate its O&M [Operation & Maintenance] approach if it is to deliver on projected targets”[222].

3.3.4. Floating Stability Incidents

As highlighted throughout the thesis, floating offshore wind poses additional challenges compared to bottom-fixed offshore wind. Remarkably, its inherent capability of buoyancy. Keeping floating stability is of paramount importance in order to maintain the floating wind turbines in position and, ultimately, preserve asset integrity.

Some real cases have been reported to date. For example, in May 2016, “while under tow”[223] a 51-metre wide “spar floater tipped over at a precarious angle, as the port at Sumoto, Hyogo prefecture [Japan]”[224] was not deep enough to handle the foundation. “The intention was to allow water into the floater to stabilize it on the shallow seabed, in preparation for the installation of the 5MW wind turbine”[225]. However, according to media, there was “an uncontrolled water ingress to one side during the planned submersion”[226]. After five days, the foundation was restored back into position “after the water within was evenly spread”[227] and the Hitachi HTW5.0-126 (5MW) turbine was assembled on top.

[221] CARBON TRUST. Floating wind JIP (joint industry programme). Phase V. Summary report. United Kingdom. 2024
[222] GCUBE. Opinion: floating wind will continue to be risky to insure without standardization. 2024
[223] OFFSHOREWIND.BIZ. Fukushima Hamakaze taking final shape. 2016
[224] RECHARGE. Fukushima floating wind group mounts Hitachi 5MW on spar floater. 2016
[225] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023
[226] OFFSHOREWIND.BIZ. Fukushima Hamakaze taking final shape. 2016
[227] OFFSHOREWIND.BIZ. Fukushima Hamakaze taking final shape. 2016

Image 6: Floating foundation keeled 45º (left) and wind turbine installed (right)

Source: Windpower Monthly, Offshorewind.biz

Previously, in December 2014, a Floating Wind & Current Hybrid Power Generation System (SKWID) which paired “a three-bladed vertical-axis wind turbine (VAWT) with a Savonius ocean-current turbine”[228] sank into the water while being installed 1.2 km off the coast of Kabe Island, Karatsu-City, Saga Prefecture, Japan. This was the second reported incident at the project after “the machine’s marine turbine component sank”[229] in October 2013.

Similarly, in early November 2020, storm Epsilon led to capsizing BlueSATH off the Atlantic coast of Spain as waves of up 10 metres in height hit the 1:6 scale prototype exceeding its design limits. Saitec decided to decommission the prototype after 12 months of testing. “The prototype had sustained two severe storms [Odette and Alex] in a row, but capsized when a third more severe storm hit the prototype [Epsilon].”[230] According to the developer, Saitec Offshore, “BlueSATH was designed to overcome the worst-case scenario for its dimensions which meant facing five metres high waves, equivalent to 30 meters high waves for the full-scale model, covering extreme environmental scenarios a full-scaled unit could be exposed to around the world.”[231]

As highlighted by IMIA regarding mooring lines, “whilst these systems themselves might not be new technology, they are new when incorporated into a power generating floating windfarm and at increased water depths. It is inevitable that some modifications to these systems will be required and for the technology to develop over time. Part of this will be learnt from claims experience.”[232]

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[228] RECHARGE. Modec’s Skwid wind/tidal offshore turbine sinks again off western Japan. 2014
[229] RECHARGE. Modec’s Skwid wind/tidal offshore turbine sinks again off western Japan. 2014
[230] 4C OFFSHORE. BlueSATH floating wind farm. 2020
[231] OFFSHOREWIND.BIZ. BlueSATH floating wind prototype capsizes during hurricane Epsilon. 2020
[232] IMIA WORKING GROUP WGP 131 (23). Floating offshore wind: risk management & insurance – paper. United Kingdom. 2023

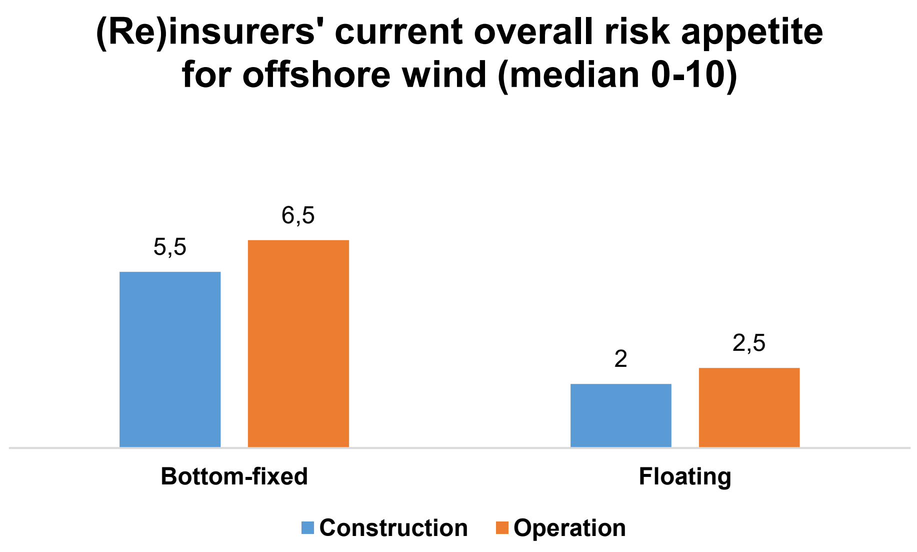
On a positive note, it is important to remark that, “the FOWC [Floating Offshore Wind Committee] is not aware of mooring line failure incidents having happened at Floating Offshore Windfarms since 2009.”[233]

3.4. Risk Appetite and Forecast

According to the answers provided by the 54 respondents of the survey prepared for this thesis, abundant (re)insurance capacity is available for floating wind; however, it seems that there is currently a rather low appetite to deploy it.

Indeed. As shown in Graph 16, the current floating wind risk appetite remains significantly lower among (re)insurers, compared to bottom fixed technology.

Graph 16: (Re)insurers' current overall risk appetite for offshore wind (median from 0 to 10)



Source: Own elaboration

As established by the results of the survey, the (re)insurance market currently has a strong preference towards bottom-fixed projects over floating ones. This would seem reasonable as, generally speaking, (re)insurers are keen on proven, mature technologies, well tested and understood, with a solid track record.

Nevertheless, the (re)insurance capacity available for floating projects is substantial (slightly above EUR 3.5 billion on total insured values among the 54 survey respondents) and should, theoretically, suffice to cover the new larger upcoming floating projects globally. Although this assertion will be subject to the terms and conditions sought by the policyholder and future market and industry

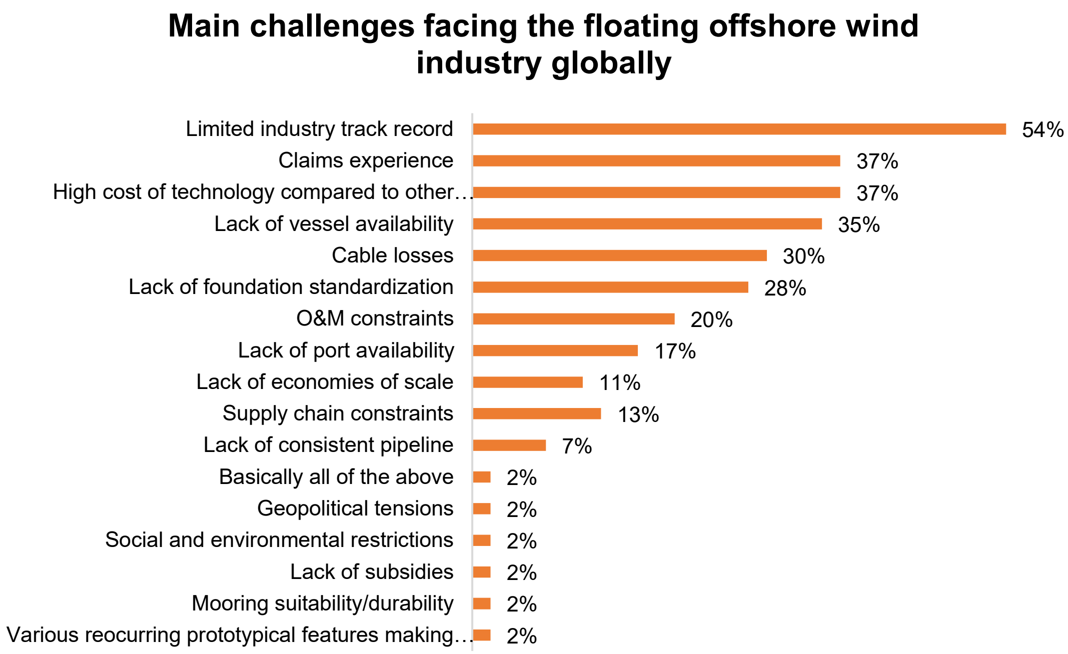
[233] WORLD FORUM OFFSHORE WIND (WFO). Insurability of floating offshore wind. 2021

developments, which are difficult to predict accurately, given the current volatile global environment.

The statement that there is abundant floating offshore wind (re)insurance capacity in the market but limited appetite to deploy it is supported by WFO on its remark that "at recent FOW [floating offshore wind] projects, insurers were providing between EUR 30,000,000 and EUR 60,000,000 capacity per insurance company, which means that a medium-sized Floating Offshore Wind Farm with 20 to 30 wind turbines must negotiate and agree separately with 5 to 10 insurance companies to reach sufficient coverage."[234]

As highlighted in Chapter 2.5. Forecast, the floating wind industry is heading towards a commercial phase where larger sized projects will be deployed. In order to do so, (re)insurers must get comfortable and confident on a number of specific challenges to unlock their available (re)insurance capacity. Indeed, the survey emphasizes on "Limited industry track record" as the main challenge faced by (re)insurers in the floating offshore wind space. 54% of the respondents selected this as one of their top three challenges faced by the floating offshore wind industry. This was followed by "Claims experience" (37%), "High cost of technology compared to other renewable energy sources" (37%) and "Lack of vessel availability" (35%).

Graph 17: Main challenges facing the floating offshore wind industry globally according to (Re)insurers



Source: Own elaboration

234 WORLD FORUM OFFSHORE WIND (WFO). Insurability of floating offshore wind. 2021

Each of the above listed challenges will require time and resources from all stakeholders involved, including the (re)insurance market, to overcome. Exacerbated by the limited data available to date, meaningful industry collaboration, where all parties are able to share their experience will be critical to go through the end of the pre-commercial phase and start scaling up floating wind projects in the upcoming commercial phase.

4. Floating Offshore Wind in Spain

As reviewed under Chapter 2.2. Geographies, floating offshore wind is entering unchartered waters with no (or very limited) offshore wind experience in countries such as South Korea, Italy, Portugal or, indeed, Spain. Chapter 4 will review the floating offshore wind industry in Spain. From its initial modest steps to nowadays, when the sector awaits the much anticipated (and postponed) green light to the country's first floating offshore wind tender that should put the national roadmap in motion to reach the distant target of 3,000 MW of floating offshore wind capacity installed by 2030.

Similar to other countries with very little floating offshore wind experience (currently Spain only has 2 MW installed), the target remains very ambitious as the time left is narrowing down, and the steps taken so far remain relatively modest compared to the magnitude of the task at hand.

4.1. Background

Spain has a long track record of renewable energy installations. The country started expanding rapidly its onshore wind installations from the early 2000s. Today, Spain is the 6th largest onshore wind market worldwide, and the 2nd largest in Europe with 31,310 MW installed at the end of 2024[235]. Furthermore, Spain is "one of the three European countries with the greatest wind power industrial capacity and R&D&I investment in the sector."[236]

Similarly, the country is the 7th largest market globally on solar capacity installed, and the 2nd largest in Europe with 38,587 MW in 2024[237]. Its capacity experienced exponential growth towards the end of the 2010s.

With a relatively low population density (below the EU-27 average and well behind the more densely populated Western and Central European neighboring countries[238]), extensive land remains available in Spain's interior regions, where renewable energy – particularly solar – is more cost-effective. However, the most favorable locations for onshore wind, have largely been developed since the sector's initial expansion around the mid-1990s.

Furthermore, "Spain has a shipbuilding industry (shipyards), a maritime-port sector, civil engineering capabilities, and an industrial ecosystem of materials and equipment that can serve the development of offshore renewables"[239].

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[235] GLOBAL WIND ENERGY COUNCIL (GWEC). Global wind report 2025. Lisbon. 2025
[236] MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Roadmap offshore wind and marine energy in Spain. Madrid. 2022
[237] IRENA. Country rankings. 2024
[238] EUROSTAT. Population density by NUTS 3 region. 2025
[239] MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Roadmap offshore wind and marine energy in Spain. Madrid. 2022

Indeed, despite having only 2 MW installed of offshore wind capacity in Spanish waters, some local companies have been active in the global offshore wind industry for many years. "The Spanish industry already has a global position as one of the main European hubs of knowledge and supply for international markets within the value chain associated with offshore wind power installations."[240]

The following companies are a sample of the significant experience gathered by Spanish companies delivering offshore wind solutions abroad:

Table 5. Sample of Spanish companies with offshore wind experience abroad

Company	Component
Siemens Gamesa	Wind turbine manufacturer
Iberdrola Renovables	Offshore wind developer
Navantia Seanergies	Foundations, transition pieces and offshore substation manufacturer
Windar	Tower manufacturer
Dragados Offshore	Foundations and offshore substations manufacturer
Haizea Wind Group	Tower and foundations manufacturer

Source: own research

Note. In 2015 Windar and Navantia formed a joint venture "to carry out the development and construction of offshore substructure projects"[241]

In this context, offshore wind presents a strategic industrial, technological, economic and social opportunity for Spain, offering access to significantly stronger and more stable wind resources available in the long and deep coastal waters in both the Mediterranean Sea and Atlantic Ocean.

4.2. Roadmap

In November 2020, in order to assist meeting the EU's goal of climate neutrality by 2050 set in 2019 by the European Green Deal[242], the European Commission presented the "EU Strategy on Offshore Renewable Energy"[243], proposing to

[240] MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Roadmap offshore wind and marine energy in Spain. Madrid. 2022

[241] WINDAR-RENOVABLES. Our history. 2024

[242] EUROPEAN COMMISSION. The European Green Deal. COM(2019) 640 final. Brussels. 11/12/2019

[243] EUROPEAN COMMISSION. An EU strategy to harness the potential of offshore renewable energy for a climate neutral future. COM(2020) 741 final. Brussels. 19/11/2020

increase Europe's offshore wind capacity targets from the 12 GW levels at the time, to at least 60 GW by 2030 and 300 GW by 2050.

Coastal European states were required to submit their National Maritime Spatial Plans by March 2021, which also included their offshore renewable energy development objectives.

With this background, in September 2022, the Spanish Government published the "Roadmap for the development of offshore wind and marine energy in Spain"[244] (hereinafter, the "Roadmap") which included an initial target of 1,000 – 3,000 MW of floating offshore wind capacity to be installed by 2030.

The target was increased afterwards, in 2023, to 3,000 MW floating offshore wind installed capacity by 2030 as part of the Spanish NECP (National Energy and Climate Plan) 2023-2030 update[245].

The objective of the Roadmap is "to ensure the effective deployment of Offshore Renewables in Spain, so that it contributes to meeting the country's energy, climate, environmental and industrial objectives, in a way that is compatible with other uses and activities in the marine environment. To this end, the actions and main challenges in the development of these energies in the sea and the possible measures to overcome them must also be identified."[246]

The Roadmap includes four main objectives:

1. making Spain a European reference hub for technological development and environmental innovation associated with renewable energy in the marine environment
2. making Spain an international benchmark in industrial capacities and in the sector's value chain as a whole
3. boosting a sustainable development of offshore renewables, consistent with an environmental and social approach
4. establishing a sound state-level framework for the orderly deployment of offshore renewables.

This deployment is part of the set of key strategic elements in the decarbonisation path of the Spanish economy, as well as in other challenges of a more cross-

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[244] SPANISH MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Roadmap for the development of offshore wind and marine energy in Spain. 2022
[245] SPANISH GOVERNMENT. Integrated National Energy and Climate Plan 2023-2030 Update. 2024
[246] SPANISH MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Roadmap for the development of offshore wind and marine energy in Spain. 2022

cutting nature, such as the economic reactivation after the COVID-19 health crisis, the Just Transition, the Demographic Challenge and the Circular Economy.

The Roadmap establishes robust foundations and a suitable framework to generate the necessary interest in developers and investors, promoting key aspects to guide and favour coordination between all the stakeholders involved, as well as the approach and guidelines for the adaptation of the sector's regulatory framework. It aims to provide the necessary continuity and visibility to attract investment and to consolidate and boost industrial capacities and the value chain as a whole, as well as foster the generation of infrastructures and R&D&I projects around the activity generated.

4.3. Regions

The Roadmap includes a measure to define and approve zones for the development of offshore wind farms in the MSP (Maritime Spatial Planning - POEM by its Spanish acronym).

In March 2023, Spain issued a Royal Decree approving the Maritime Spatial Plans of the five Spanish marine demarcations for the future implementation of offshore wind and marine energy.

Image 7. Spain's five marine demarcations

Source: Royal Decree 150/2023[247]

The Royal Decree identified 19 areas of high potential for offshore wind energy development in the future. These areas are highly suitable for the potential deployment of commercial offshore wind projects as they meet the following technical criteria:

[247] ROYAL DECREE 150/2023 approving the maritime spatial planning plans for the five Spanish marine demarcations (BOE 28/02/2023)

- Strong winds available (above 7.5 m/s)
- Water depth below 1,000 meters
- Where possible, they are close to onshore electrical infrastructure required to export electricity generated offshore
- Not located in areas identified as incompatible from biodiversity point of view
- Not located in high marine traffic routes, nor near ports

Table 6 provides a summary of the 19 identified areas.

Table 6. Summary of Spain's areas of high potential for offshore wind energy development

Marine Demarcation	Areas	Surface (km^2)	Distance to shore (m)	Water depth (m)
Canary	6	561,87	1.850 – 6.000	50 – 1.000
Straight and Alboran	2	1.222,61	7.500 – 13.600	500 – 1.000
Levantine-Balearic	3	474,99	5.000 – 12.000	100 – 1.000
North Atlantic	8	2.688,61	14.500 – 31.500	100 – 1.000
TOTAL	**19**	**4.948,08**	**1.850 – 31.500**	**50 – 1.000**

Source: Royal Decree 150/2023[248]

Further specific details on each of the 19 areas can be found on Annex 4 alongside maps of the areas on Annex 5.

Based on these proposed areas, at the time of writing, the Spanish Ministry for Ecological Transition and the Demographic Challenge has received 74 submissions[249] totaling 29,417 MW installed capacity for different offshore windfarms (most of them floating).

The following Table 7 provides a summary of the 74 proposed projects and their autonomous community.

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[248] ROYAL DECREE 150/2023 approving the maritime spatial planning plans for the five Spanish marine demarcations (BOE 28/02/2023)

[249] MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Environmental assessment public consultation. 2025

Table 7. Summary of Spain's offshore wind farm proposals

Autonomous Community	Proposals	Capacity (MW)
Galicia	24	13,926
Andalucia	11	6,006
Catalonia	9	5,380
Canary Islands	27	3,640
Balearic Islands	2	420
Basque Country	1	45
TOTAL	**74**	**29,417**

Source: Spanish Ministry for Ecological Transition and the Demographic Challenge [250]

It is remarkable to note that the autonomous community with the largest offshore wind capacity proposed with nearly 14,000 MW out of the 29,417 MW is Galicia, where "since 5 March 2024 (the date on which the TSJG ordered the precautionary suspension of 13 [onshore] wind farms), there has been a succession of various orders in which the court agreed to adopt the precautionary measure of suspension of the administrative authorisations and construction of (up to the date of the present) a total of 20 [onshore] wind farms"[251].

4.4. Tender

The 74 proposals received at the time of writing by the Spanish Ministry for Ecological Transition and the Demographic Challenge, totaling 29,417 MW, are nearly ten times greater than the 3,000 MW target set by the Spanish authorities for 2030.

However, despite the considerable interest shown by developers in developing offshore wind in Spain, and after several postponements, the country is yet to launch the first offshore wind tender.

The delays and calendar uncertainty, combined with the industry's global pressures (namely and mainly supply chain constraints, rising costs and geopolitical tensions) have resulted in a number of international players "such as

[250] MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Environmental assessment public consultation. 2025

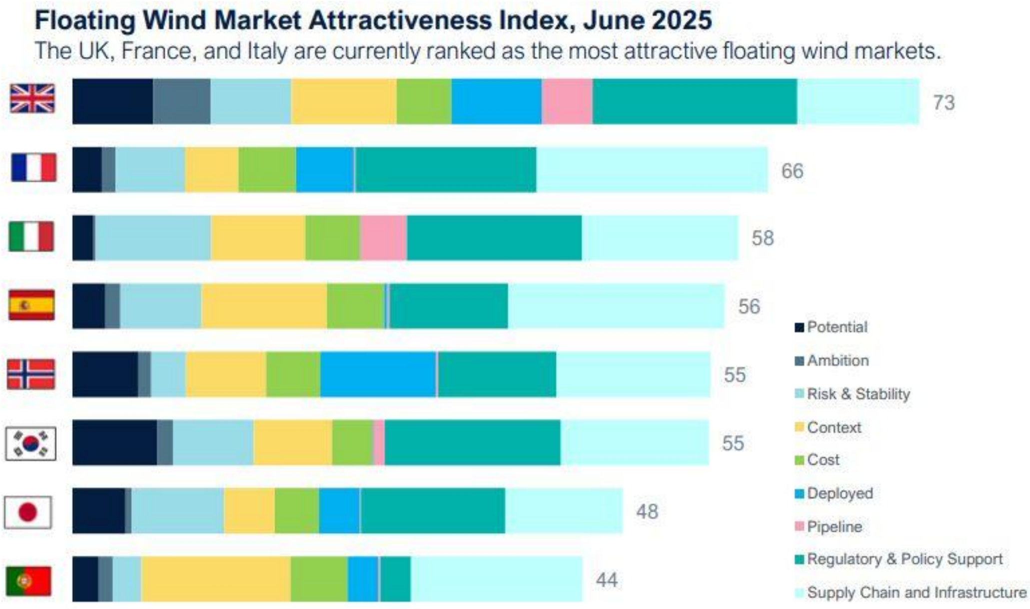
[251] OSBORNE CLARKE. Judicial situation of wind farms in Galicia: preliminary ruling and suspension of administrative proceedings. 2024

Shell, Orsted, Equinor and RWE have either pulled out or publicly cooled to Iberia as a region to develop offshore wind"[252].

It is fair to point out that auction delays and postponements are relatively common in offshore wind, particularly for new market entrants. For example, both France and the United States, experienced several permitting and regulatory setbacks before they were able to launch their first auctions. Even more recently, "Ireland's ORESS 2.1 (900 MW), and Italy and Portugal's first-even offshore wind auctions"[253] were postponed from the second half of 2024 to 2025.

As such, according to the latest Floating Wind Market Attractiveness Index (June 2025) prepared by offshore wind specialist website 4coffshore.com, Spain still remains one of the most attractive markets to develop floating offshore wind in the coming years.

Graph 18: Floating Wind Market Attractiveness Index, June 2025[254]



Source: Seanergy & TGS | 4C Offshore Market Overview Report Q2 2025

However, with the start of construction estimated by 2029[255], it seems very unlikely that the Spanish Government's target of having 3,000 MW of offshore wind capacity installed by 2030 will be achieved. This is also a view shared by global (re)insurers. Indeed, on average, global (re)insurers awarded 2.9 (out of

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[252] RECHARGE. Big ambition, low certainty: nation's giant floating wind plans face questions. 2025

[253] WINDEUROPE. Wind energy in Europe. 2024 statistics and the outlook for 2025-2030. Brussels. 2025

[254] 4C OFFSHORE. Q2 2025 Global Market Overview Report. 2025

[255] AFRY. Offshore Wind in Portugal and Spain – collaboration opportunities for Dutch companies. 2025

10) in terms of likelihood for the target to be reached. The score is even lower (1.7 out of 10) if we only take into account those (re)insurers with the most experience and involvement in floating offshore wind.

Indeed, according to Manuel Fernandez, Ocean Wind's Director of New Business, "past delays in advancing the regulatory process for offshore mean Spain has no more time to waste if it wants to reach its targeted 3 GW of offshore wind capacity by 2030."[256]

Despite not having a confirmed timeline, "the first tender is expected to take place in 2025 and allocate at least one 240 MW site in Gran Canaria, where FOW [Floating Offshore Wind] will replace more expensive conventional energy sources, leveraging ideal wind conditions and PLOCAN's expertise as a test platform for offshore technologies. The second tender is expected to be in Galicia or in Cataluña, where there is significant capacity at sea depths less than 500 m."[257]

"Therefore, Spain must allocate permits before the end of 2026, to allow for enough time for the development and construction of the wind farms. Hereto, bureaucracy must be sped up significantly and, even so, it is unlikely that the 3 GW goal will be reached, as only one tender for 240 MW is expected in 2025, without plans for future tenders. Moreover, onshore wind represents an additional threat, as the potential is not saturated, and the technology is significantly cheaper."[258]

4.5. Project Proposals

Currently, 74 proposals to develop offshore wind farms in Spain have been submitted. According to the Initial Project Descriptions available[259], most of the projects (67) are expected to have floating foundations (as opposite to bottom-fixed) due to the deep-water depths of their locations. However, the final configuration of the projects (turbine size, number of units, location, foundation type, export cable landing, onshore substation) is subject to change as the projects move forward towards start of construction.

The projects range in size between the 6 MW single prototype turbine to the 1,200 MW mega projects to be built in different phases.

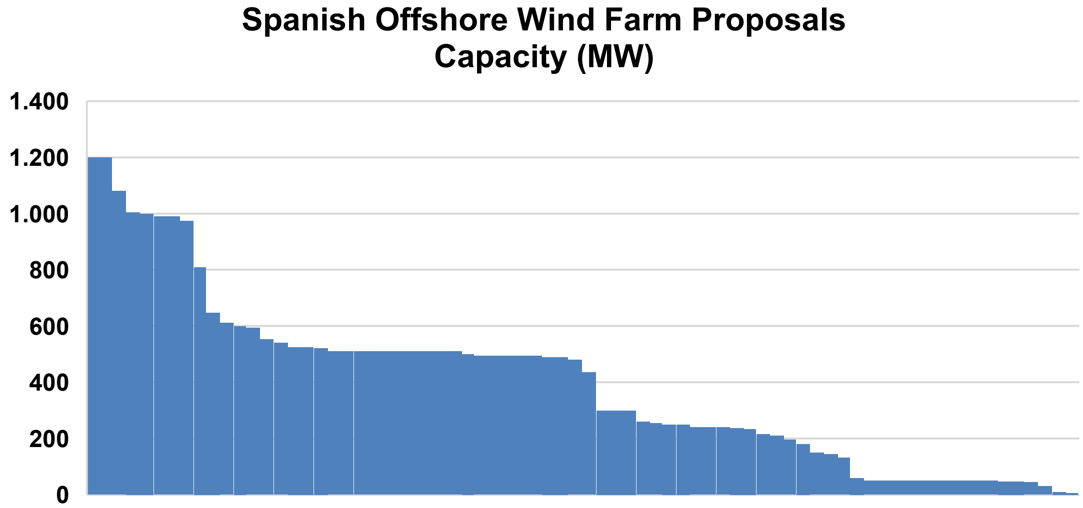
[256] RECHARGE. No time to waste if Spain is to hit offshore wind goals, say top developers. 2024

[257] AFRY. Offshore Wind in Portugal and Spain – collaboration opportunities for Dutch companies. 2025

[258] AFRY. Offshore Wind in Portugal and Spain – collaboration opportunities for Dutch companies. 2025

[259] MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Environmental assessment public consultation. 2025

Graph 19: Spanish Offshore Wind Farm Proposals. Capacity (MW)



Source: Own elaboration based on Spanish Ministry for Ecological Transition and the Demographic Challenge[260]

4.5.1. Developers

The spectrum of developers who have submitted an offshore wind farm proposal is quite broad too. It includes a mixture of experienced offshore wind developers (RWE, Iberdrola, Ocean Winds), local onshore wind developers (Acciona, ABEI Energy, Capital Energy), local traditional oil and gas energy companies (Repsol, Naturgy) international onshore wind developers (Invenergy), local contractors (Ferrovial, Cobra, Sener) and international floating wind specialists (BlueFloat, BW Ideol) to name a few.

Some of these developers formed commercial partnerships or joint ventures in recent years to maximise synergies and target the Spanish offshore wind potential. Most of them were a combination of a local company with an international player. For example, Equinor and Naturgy[261], Capital Energy and Shell[262], Repsol and Orsted[263] all in 2022 or Ferrovial and RWE[264] in 2023.

However, as mentioned in Chapter 4.4. Tender, since the agreement of these joint ventures, some of the international players have reduced or cancelled their plans for the Spanish floating offshore wind market. For example, Equinor[265],

[260] MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Environmental assessment public consultation. 2025
[261] 4C OFFSHORE. Naturgy and Equinor forge floating alliance. 2022
[262] CAPITAL ENERGY. Capital Energy and Shell sign an agreement to analyse the joint development of offshore wind projects in Spain and Portugal. 2022
[263] ORSTED. Repsol and Orsted to explore joint development of floating offshore wind projects in Spain. 2022
[264] RWE. Ferrovial and RWE team up on offshore wind in Spain. 2023
[265] OFFSHOREWIND.BIZ. Equinor axes offshore wind plans in Spain and Portugal, weighs further market exits. 2024

Shell[266], and Orsted[267], all during 2024. The last one, in fact, led to a new collaboration between Repsol (Orsted's former partner) and EDF[268] a few months later in 2024.

4.5.2. Wind Turbines

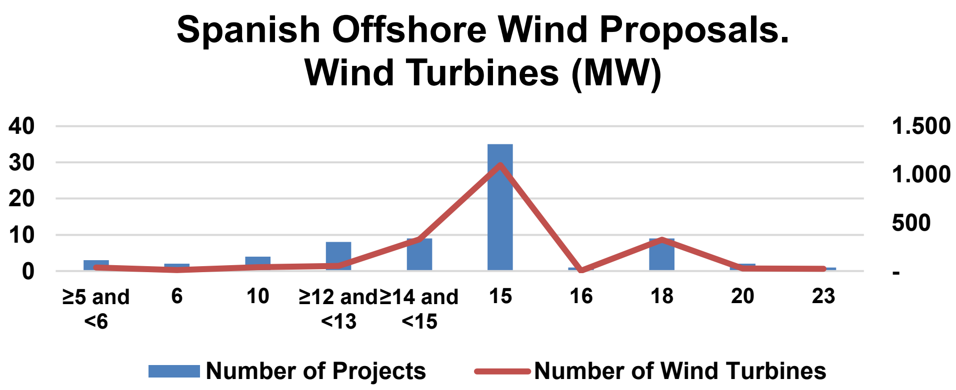
In line with international offshore wind trends, where increasingly larger turbines are the norm, according to the Initial Project Descriptions currently available[269], most of the offshore wind turbines (1,801 out of 1,939) proposed for the Spanish waters have 14 MW capacity or more.

This is particularly remarkable since, at the time of writing, the largest (bottom-fixed) offshore wind turbine installed worldwide in a commercial project is Goldwind's GWH252-16 MW wind turbine[270]. Whereas some of the proposed offshore wind farms in Spain include 18 MW and 20 MW wind turbines (whose size has not been installed in a commercial project yet).

Even a proposed floating project (O Boi) includes 23 MW wind turbines[271].

As highlighted by Graph 20 below, the 15 MW wind turbine is, by far (1,097 out of 1,939 wind turbines), the preferred configuration.

Graph 20: Spanish Offshore Wind Farm Proposals. Wind Turbine Sizes (MW)



Source: Own elaboration based on Spanish Ministry for Ecological Transition and the Demographic Challenge[272]

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266 REUTERS. Shell slows offshore wind spending, splits power business in CEO review. 2024
267 RENEWS.BIZ Orsted to exit markets as it cuts jobs, targets. 2024
268 EDF RENOUVELABLES. Repsol and EDF Renewables sign an exclusivity cooperation agreement for offshore wind in Spain and Portugal.
269 MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Environmental assessment public consultation. 2025
270 OFFSHOREWIND.BIZ. Offshore wind turbines in 2024: 20+ MW prototypes rolling out in Europe, China; 16 MW remains most powerful turbine installed offshore. 2025
271 INVENERGY. Initial project descriptions. Floating offshore wind farm O Boi. February 2024
272 MINISTRY FOR ECOLOGICAL TRANSITION AND THE DEMOGRAPHIC CHALLENGE. Environmental assessment public consultation. 2025

There is also a proposal to use a wind turbine prototype with 2 wind turbines per floater. Indeed, Canarray II, is planning to deploy 12 W2Powwer floating platforms, each including 2 wind turbines rated between 5 and 6 MW each[273].

Image 8: W2Power platform[274]

Source: EnerOcean

However, these offshore wind turbine sizes may change as the projects approach the start of the construction stage. Indeed, as we have seen in bottom-fixed offshore wind over the years, the rapid growth of offshore wind turbine sizes, combined with the economies of scale gained from using fewer wind turbines per project have resulted in a continued reduction of the levelized cost of energy.

It is likely and expected that a similar trend will follow in floating offshore wind as the industry enters commercial stage deployment. This may result in even larger offshore wind turbines in Spanish waters by the time the projects start the installation campaigns. As a direct consequence, we could also see a reduction in the number of wind turbines per project.

4.5.3. Foundations

Given the deep coastal waters in Spain, most of the proposed offshore wind farms are expected to be floating. However, out of the 74 proposals submitted to date, the author has identified 7 projects where a bottom-fixed foundation is considered due to the project's location in shallow waters very close to shore.

For the majority of projects though, a floating foundation is expected due to locations being in waters deeper than 50 meters.

In terms of floating foundations designs, there seems to be a preference among developers to use the semi-submersible foundation design. Again, the selection is not final at this point, as several factors may change by the time the project

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[273] CANARRAYS. Initial project description for the Environmental Impact Assessment (EIA) scoping request. 2021

[274] ENEROCEAN. The future of floating. Now. 2025

construction is due to start; however, some of the reasons mentioned in the Initial Project Descriptions reviewed to select the semi-submersible configuration include:

- Water depth suitability as many locations are in areas with water depths typically ranging between 50 and 150 meters
- Proven experience and technological maturity from European projects such as WindFloat Atlantic
- Adaptability to harsh local sea and metocean conditions
- Industrialization and construction logistics allow for port-based assembly and integration
- Environmental and seabed considerations
- Scalability and flexibility provided by the modular design possibilities allows for different turbine sizes and layouts

The other types of floating foundation designs considered among a few of the project proposals are barge and tension-leg platforms. On the other hand, spar foundations seem to be the least preferred option for the proposed offshore wind farms in Spanish waters. This is mainly due to water depth restrictions, challenging port and towing logistics (see limited port drafts under Chapter 4.6. Ports), higher manufacturing and transportation costs, sensitivity to metocean and dynamic behavior and limited Spanish industrial experience.

4.6. Ports

As noted throughout the study, ports are essential infrastructures required for floating offshore wind development. Their role is of paramount importance throughout the lifetime of a floating offshore wind farm. From installation, assembly and towage to maintenance, repairs and decommissioning.

On that note, the "Spanish Government has set up a subsidy scheme for ports to develop into offshore wind ports. Several ports have presented their candidacy. While the final awarding decision from the Government was expected in 2024, there is no update and the timeline is not clear at the moment. The ports of A Coruña (Galicia) and Castellón (Comunidad Valenciana) seem to be advantaged over the others to obtain the subsidies, based on opinions from sector associations."[275]

[275] AFRY. Offshore Wind in Portugal and Spain – collaboration opportunities for Dutch companies. 2025

As presented by AFRY[276], "the Iberian Peninsula (hence excluding the Canary Islands) can be divided into two sub-groups: Atlantic and Mediterranean ports. The port of Cádiz is located in the Southern Atlantic region of Spain and thus it could potentially serve the Southern Atlantic area, as well as the Mediterranean area".

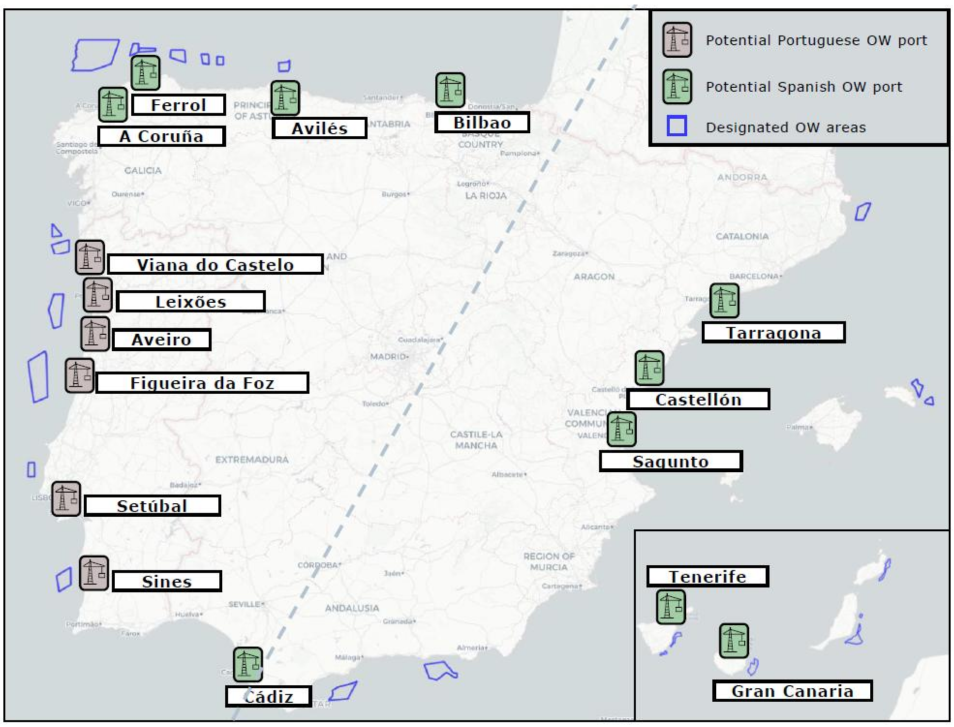
Some Spanish ports (like Cádiz, and A Coruña) have undergone (or are planned to undergo) dredging activities to increase their draft to be able to accommodate floating substructures and transport and installation vessels.

The ports of Ferrol and Avilés have supported the construction of WindFloat Atlantic in Portugal, manufacturing one of the floating platforms. Similarly, as previously mentioned in the research, four out of the five Kincardine's floaters were manufactured in Ferrol.

Spanish ports are expected to also support floating offshore wind farms in Portugal, as they have been heavily involved in manufacturing of components for bottom-fixed offshore wind farms in Northern Europe for more than 10 years, and they aim at becoming market leaders and exporters for floating offshore wind.

Thanks to the considerable areas available and their advanced development plans, the ports of A Coruña and Castellón (respectively 100 ha and 50 ha available) are expected to receive subsidies from the Spanish Government.

Image 9: Potential offshore wind ports in Spain and Portugal



Source: AFRY

276 AFRY. Offshore Wind in Portugal and Spain – collaboration opportunities for Dutch companies. 2025

The Port of Cádiz is undergoing dredging activities to increase its draft to 16 m. Navantia will manufacture in Cádiz foundations for OceanWinds projects, supplying up to 12 floaters per year.

The Port of Castellón aims at becoming an important hub in the Mediterranean for floaters manufacturing, turbines assembly, and floating offshore wind farms' installation. The Port of Castellón offers the largest area for offshore wind component manufacturing and assembly among Spanish Mediterranean ports and will award factory concessions in 2025.

The Port of Las Palmas de Gran Canaria is Spain's fourth port and the most important industrial hub in the archipelago.

The Port of Arinaga is located near the biggest industrial zone in the Canary Islands, and already serves PLOCAN.

The Port of Tarragona in Catalonia's Mediterranean Sea is also aiming to be a strategic hub for floating offshore wind in the region, first servicing Spanish projects and later on projects in south of France and north of Italy. The Port Authority is planning to allocate 300,000 square meters for the construction, erection and transport of wind turbines[277].

Further details on key features (draft, floater and vessel suitability and planned activities) for the Spanish ports suitable to support floating offshore wind are available on Annex 6.

The suitability of the Spanish ports will be key to a successful floating offshore wind commercial development not only in Spain but also in neighboring countries. Indeed, according to CLS Wind, port installation of wind turbine generators "is one of the two main bottlenecks"[278] impeding large-scale deployments of floating offshore wind farms (the other being repair or replacement of major wind turbine components at sea). Having the required port infrastructure in place is the basis upon which floating offshore wind farms will be developed and maintained efficiently in Spanish waters.

4.7. Initial Steps

Despite the first Spanish offshore wind tender being delayed, the country has seen the emergence of small, but relevant, floating offshore wind prototypical projects. These are early projects in a nascent industry where research and development are of paramount importance to grow efficiently in the long term.

[277] 3CAT.CAT. The Port of Tarragona wants to be a strategic hub for floating offshore wind. 2025
[278] PES WIND. Streamlining floating offshore wind port installations. 2025

4.7.1. PLOCAN

PLOCAN is the Oceanic Platform of the Canary Islands, which is its acronym in Spanish. It “is located on the seabed, at a depth of 30 m, and 1.5 km off the coast in the NE of the island of Gran Canaria”[279]. The facility also includes a 23 km^2 offshore test site for marine technologies of multiple natures. It enables and contributes to the acceleration in the development of technologies and knowledge in the marine environment, with observation systems and open ocean, in real conditions.

For example, in March 2019, the “5 MW Elisa prototype, Spain’s first offshore wind turbine”[280] was officially put into operation at the PLOCAN test site. The full-scale prototype project is a self-installing telescopic offshore wind turbine being developed under the EU-funded Elican project carried out by a consortium of Esteyco, Siemens Gamesa, ALE Heavylift, DEWI GmbH and PLOCAN. “The project’s goal was to assemble the entire system, including the foundation, tower and wind turbine, and its pre-commissioning under controlled conditions at the Arinaga port, and then tow it to the site using conventional tugs.”[281]

Similarly, between June 2019 and October 2019, the W2POWER prototype, the first multi-turbine wind floating platform in Spain, designed by the Spanish company ENEROCEAN was tested at PLOCAN’s site. Despite the project being a 1:6 scale prototype, it collected information from different parameters to allow further development and optimization of this multi-turbine platform.

Later on, in 2022, another prototype was installed at PLOCAN’s test site. This time it was the X1 Wind’s 0.2 MW prototype, known as the X30 platform. The project was “developed with several key design features to streamline the installation process, including a light-weight and stable floater which can be easily wet towed by local vessels.”[282] The project featured a mooring system configuration that combined a single point mooring with a small Tension-Leg Platform mooring system, allowing the ability to reach deeper waters and minimizing the footprint and impact on the seabed. At the time it was “the world’s only floating wind platform currently installed with a TLP [Tension-Leg Platform] mooring system”.[283] The 1:3 scale prototype included a Vestas V29 turbine (0.2 MW) and it was located in waters 50 meters deep.

Other projects currently taking place at PLOCAN* include:

- FLOTANT: A project aiming to develop an innovative and integrated floating offshore wind solution, optimized for deep water (100 – 600m) and sustaining a wind turbine generator of 10 MW or more.

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279 PLOCAN. Offshore Ocean Platform. Multidisciplinary laboratories. 2025
280 OFFSHORE ENERGY. Spain’s first offshore wind turbine goes into operation. 2019
281 OFFSHORE ENERGY. Spain’s first offshore wind turbine goes into operation. 2019
282 WINDTECH INTERNATIONAL. X1 Wind installs floating wind platform in Spain. 2022
283 OFFSHOREWIND.BIZ. X1 Wind’s floating prototype delivers first power offshore Canary Islands. 2023

- AquaWind*: An innovative multi-use solution, integrating an enhanced version of the W2Power floating dual-turbine wind platform with an aquaculture cage of an innovative design

*Note: Aquawind was launched at ASTICAN shipyards facilities in the harbour of Las Palmas de Gran Canaria in June 2025. The prototype awaits a suitable maritime weather window for its deployment at PLOCAN.

4.7.2. BIMEP

BIMEP stands for Biscay Marine Energy Platform. It is an open-sea test site for floating offshore wind turbines located two nautical miles from the coast and the nearby harbour of Arminza, north of Bilbao. It benefits from waters between 50 and 90 meters deep and strong winds and waves.

In September 2023, Saitec's 2 MW floating platform DemoSATH was installed at BIMEP. "The DemoSATH floating platform was built at a pier in the port of Bilbao in 2023. Following the loading and unloading of the platforms at the Punta Sollana pier in the Port of Bilbao, the platform was towed through specialised vessels. Once the anchor system and the chains were recovered, it was connected to the joint point of the wind turbine to begin the tests to be carried out during all winter months and in total for approximately two years."[284] DemoSATH is a full-scale prototype project developed by Saitec, RWE and The Kansai Electric Power Co. It consists of consists of a "concrete twin-hull barge structure, made of modular, pre-fabricated components. The design has a single point of mooring, which means it aligns itself to the current and wave direction"[285].

Other projects currently taking place at BIMEP include HarshLab, the first floating laboratory in Europe researching new offshore materials and solutions against corrosion, ageing and fouling.

4.7.3. Other

In August 2020, Saitec installed BlueSATH, a 1:6 scale floating prototype 800 meters off the coast of Santander. The platform was towed from its nearby assembly site, Astander's Pontejos dock. Afterwards, the previously deployed mooring system was retrieved from the seabed, and the platform was connected in less than 3 hours[286]. Unfortunately, the platform capsized a few months later during hurricane Epsilon, so it was retrieved and transported to a shipyard, which was planned for the coming weeks "since the hydrodynamic trials were accomplished"[287].

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284 BIMEP. DemoSATH platform starts testing on BiMEP. 2023
285 RWE. DemoSATH. 2023
286 SAITEC. BlueSATH, Saitec's first floating wind installation in continental Spain. 2020
287 OFFSHOREWIND.BIZ. BlueSATH floating wind prototype capsizes during hurricane Epsilon. 2020

More recently, in June 2025, Japanese Company J-Power has joined the WHEEL floating offshore wind demonstration project, a 6.17 MW turbine to be installed and tested using a combination of barge and spar-type foundations three kilometers off the eastern coast of Gran Canaria[288].

4.8. Forecast

From the research undertaken, the current status of affairs (mainly the first offshore wind auction being postponed and delayed) and the relatively short lead time; it only seems fair to assume that the updated target of having 3 GW of offshore wind capacity installed in Spain by 2030 will not be reached.

Indeed, a recent survey earlier on 2025 by Westwood[289], highlighted that 72% of the 166 floating wind professionals surveyed expect to see less than 3 GW of floating offshore wind capacity installed by 2030 globally. That means taking all the countries worldwide together into account. Therefore, obviously, the chances of having the same 3 GW of floating wind capacity by the same 2030 deadline in Spain alone are objectively very close to nil.

Similarly, WindEurope's last Wind Energy Stats report, forecasts just 290 MW of new offshore wind capacity (assuming most of it will be floating) to be installed in Spain by 2030[290].

However, even if slower than initially anticipated - partly due to the existing global challenges faced by the wind industry (namely supply chain constrains, increased costs and geopolitical instability), the Spanish floating offshore wind industry is taking steps in the right direction to fulfill all its vast potential.

Both the Roadmap and the Maritime Spatial Plans released in 2022 and 2023 respectively provided the long term view and visibility required to attract floating wind developers' interest.

The strong and experienced local wind supply chain (for both onshore and offshore wind), in combination with the suitable port infrastructures available and good wind resource conditions, makes Spain a suitable market for developing floating offshore wind in the years to come.

The view is shared and supported by GWEC's floating wind report[291], where Spain features as the top 5th global floating wind market according to a scoring assessment of different parameters among 30 countries.

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288 OFFSHOREWIND.BIZ. Japanese Company takes part in Spain's floating wind demonstration project. 2025

289 GLOBAL ENERGY GROUP. Unlocking the potential. Results of the 2025 floating offshore wind survey. London. 2025

290 WINDEUROPE. Wind energy in Europe. 2024 statistics and the outlook for 2025-2030. Brussels. 2025

291 GLOBAL WIND ENERGY COUNCIL (GWEC). Floating offshore wind – A global opportunity. 2022

On another note, as presented in a recent report by Fundacion Renovables[292], lessons learned from other more established offshore wind countries are key to develop an offshore wind industry in Spain with a sustainable approach. Some measures to be taken into account include the support and open dialogue with local communities, early engagement to achieve coexistence with other economic activities (mainly fishing and tourism in Spain) and environmental protection actions. These are all essential measures for optimizing the development of this strategic sector in a respectful way that aligns with local interests.

Similarly, as part of the continued global efforts to improve cost efficiency in the floating offshore wind sector, the use of Chinese offshore wind turbines in European waters may play an increasingly important role in years to come. If allowed by local content regulations and lobbies' pressures, developers must become familiar with alternative wind turbine manufacturers' technology in order to maximize the efficiency of their floating wind projects. Spain is no different to this global trend and some projects are already considering Chinese wind turbines among their supplier options. For example, Poseidon floating offshore wind farm, where 2 of their 5 offshore wind turbine models considered are from a Chinese manufacturer (CSS Haizhuang Wind Power's H260-18.0 model and Mingyang Smart Energy's H260-18.0 model)[293].

Therefore, even if, like any other country, Spain is affected by global industry trends and challenges; at a local level, the support scheme and the permitting processes to be established by the national Government will determine, in large part, the chances of having a buoyant floating offshore wind sector in Spain.

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[292] FUNDACION RENOVABLES. Social acceptance of offshore wind in Spain. Guide and recommendations of good international practices. Madrid. 2025

[293] POSEIDON FLOATING OFFSHORE WIND FARM. Initial document for determining the scope of the environmental impact study. 2023

5. (Re)insurance Market for Floating Offshore Wind in Spain

5.1. Background

Spain benefits from a solid and established (re)insurance sector. With annual gross written premiums of EUR 76.4 billion[294], Spain was the sixth[295] largest European (including the UK) (re)insurance market in 2023.

The Spanish (re)insurance market, in line with the country's growing economy, has developed over the last decades to become a highly regulated, professional and dynamic industry. It plays a crucial role in supporting a rapidly changing society by providing stability, fostering innovation and addressing emerging risks.

Similarly, local (re)insurers have supported a growing renewable energy industry covering both assets in Spain and Spanish interests abroad. Moreover, some (re)insurers established Spain as their hub for Latin American industrial business.

It is remarkable how, in recent years, several international (re)insurance markets have either opened a branch in Spain with renewable energy capabilities or launched dedicated lines of business focused on renewable energy, in response to the sector's growing demand. Table 8 below provides further details on this trend.

Table 8. New (re)insurers underwriting renewable energy business from Spain

Company	Year
Swiss Re Corporate Solutions	2015
Berkshire Hathaway	2019
Starr	2020
RiskPoint	2020
GCube	2022
MSIG	2022
Everest	2023
Sompo International	2023
Markel	2024
Beazley	2025
Revo	2025
Munich Re Specialty	2025
Perse International	2025

Source: own research

[294] MAPFRE ECONOMICS. Insurance Spanish market in 2023. Madrid. 2024
[295] ATLAS MAGAZINE. Global Insurance market in 2023. 2024

The list above is in addition to an equally large number of (re)insurers established previously in the country who also provide cover actively for renewable energy projects.

However, all this renewable energy (re)insurance capacity available from Spain is mainly (if not only) targeting onshore business. At least for the time being. Indeed, as reviewed under Chapter 4. Floating Offshore Wind in Spain, Spanish waters, so far, have only hosted a very small number of prototypical offshore wind projects. Therefore, currently, virtually all (re)insurers based in Spain do not have much offshore wind direct involvement, nor offshore wind underwriting authority as it is not essential in the short term.

As such, by the time commercial floating offshore wind farms start to appear in Spain, it remains to be seen the role that all these (re)insurers based in Spain will play. It is expected that, in the early stages, the local Spanish branches may liaise with their groups' centers of excellence for offshore wind to review the upcoming floating offshore wind projects. And, potentially, in the longer term, they may have underwriting authority over the (re)insurance of Spanish floating offshore wind farms.

However, it is important to remark how highly specialized (re)insurance for floating offshore wind is at the moment. Indeed, there has only been a very small number of pre-commercial floating offshore wind projects globally in the (re)insurance market, which only very few (re)insurers were able (or decided) to participate on. As such, first-hand experience is very limited (and valuable) for the upcoming floating wind projects in Spain.

This is also supported by the author's survey of 54 (re)insurers. Certainly, only 11.1% of the participants claimed to "have often been quoting lead terms" for floating offshore wind projects. Whereas on the other hand, 66.7% claimed to have either "none" or "very limited experience and involvement" in floating offshore wind.

Similarly, on average and on a scale from 0 to 10, the surveyed (re)insurers provided 2 and 2.5 points for construction and operation current overall floating wind risk appetite respectively. As expected, the average increases to 5.8 (on both construction and operation) if we consider only responses from those markets who "have often been quoting lead terms" in floating offshore wind projects.

Likewise, when considering the likelihood of underwriting the upcoming floating offshore wind farms in Spain, the surveyed response was 3.8 out of 10 as the overall average. But the figure rises to 6.2 out of 10 when considering only those markets who "have often been quoting lead terms" in floating offshore wind.

It is interesting to note that the scores were slightly higher for the likelihood of underwriting the upcoming floating offshore wind farms in Spain than for the current overall floating wind risk appetite. This reflects the very limited experience (and hence, risk appetite) for floating wind at the moment. However, by the time the Spanish floating wind farms start their construction stage in a few years' time, (re)insurers expect to be more comfortable and confident around the floating wind technology.

5.2. Opportunities

As reviewed in Chapter 4. Floating Offshore Wind in Spain, the potential for a thriving industry in the near future is clear. This promising outlook is underpinned by favourable local factors – including a robust supply chain, well-equipped port infrastructure, maritime industry, and favourable weather conditions - and further strengthened by international developers with floating wind expertise who are forming joint ventures and partnerships with local developers and contractors. Together, these elements position the Spanish floating wind sector among the global top tier in terms of potential.

Despite floating wind being a niche technology for Spain's energy mix (the country is targeting 3 GW of offshore wind by 2030 – most of it floating - compared to the 59 GW of onshore wind[296]), floating wind is inherently capital-intensive. As a result, upcoming floating wind farms will require substantial project financing, which in turn will require securing appropriate (re)insurance coverage before committing resources.

Similarly, as we have seen in Chapter 3. Global (Re)Insurance Market for Floating Offshore Wind, floating wind is considered to have a higher risk profile than its closest counterpart, bottom-fixed offshore wind. This is largely due to the nascent stage of the industry, where operational experience remains very limited. Nevertheless, this also presents a unique opportunity for (re)insurers willing to enter the space, gaining early and valuable experience, and position themselves to capitalize on the anticipated market growth and maturity of the sector in the not-so-distant future.

There is also a sizeable opportunity to fill in the current gap in local (re)insurance capacity within the Spanish market, particularly regarding floating wind underwriting experience and authority. Specialist (re)insurers with first-hand experience in floating offshore wind internationally have the opportunity to position themselves as leading providers of (re)insurance coverage for both construction and operational all risks policies.

It is anticipated that local (re)insurers with an interest in participating in Spanish floating offshore windfarms may undergo a transitional period during which the underwriting is initially handled by or jointly with their more experienced international colleagues. This approach would allow local (re)insurers to gradually acquire the expertise needed to independently underwrite such specialized and challenging projects in the future.

This is a familiar natural process seen in other countries where offshore wind was taking off. For example, recently in the United States, where, according to retail broker Marsh, "the majority of insurance capacity for North American offshore

[296] WINDEUROPE. Wind energy in Europe. 2024 statistics and the outlook for 2025-2030. Brussels. 2025

wind projects has been provided by established overseas markets, including the wholly owned subsidiaries of domestic specialty insurers"[297].

A similar pattern is expected to happen across other new offshore floating wind markets, such as China, where, according to retail broker Willis, "if floating wind turbines are widely deployed, the Chinese [insurance] domestic market would lack capacity"[298].

Therefore, similar also to the very early days of onshore wind development in Spain, it is expected that the initial growth of Spanish floating offshore wind will be mainly (re)insured by international carriers with previous relevant experience overseas, before the local (re)insurers are able to tap into the expected growth by themselves.

5.3. Challenges

(Re)insurers willing to underwrite the upcoming floating offshore wind farms in Spain are likely to be aware of the floating offshore wind challenges elsewhere. Chapter 3.3. Claims provided an overview on the limited claims experience available to date with floating offshore wind farms globally.

As highlighted in the thesis' survey, limited industry track record was, according to the specialist (re)insurers surveyed, the main challenge facing the floating offshore wind industry globally, which would also apply to Spanish floating windfarms.

Similarly, the thesis' survey highlighted other main challenges facing the floating offshore wind industry globally, which would also apply to the Spanish market. For example, the high cost of floating technology compared to other renewable energy sources.

Indeed, from an underwriting perspective, one of the main advantages of (re)insuring windfarms, compared to other energy sources such as single-generator power plants, is the ability to spread the risk among multiple (dozens in many instances) wind turbines. So that, generally speaking, if a single wind turbine is unavailable, the rest of the wind farm continues to operate normally. In contrast, floating wind farms currently consist of relatively very few turbines per project, leading to very high replacements costs per turbine and consequently limiting the advantages of risk dispersion.

Another significant challenge faced by (re)insurers exploring floating offshore wind opportunities in Spain will be the market cycle and the capacity available at the time of underwriting. Currently, as provided by the thesis' survey, risk appetite among specialist offshore wind (re)insurers seems very low (2-2.5 out of 10) regarding floating wind in general and low (2.9 out of 10) regarding floating wind

[297] MARSH. Offshore Wind industry needs domestic insurance markets to achieve ambitions. 2024
[298] WTW. Major renewable energy insurance market trends are evolving in key regions. 2025

in Spain in particular. However, this could change in a few years, by the time the first commercial floating offshore wind farms are due to start construction. Indeed, if abundant and positive experience is gathered by the (re)insurance industry on floating wind globally, an increase on risk appetite combined with the vast number of markets and capacity available, could make floating wind in Spain a competitive line of business rather quickly.

So far, we have reviewed global challenges which are also applicable to the (re)insurance market for floating offshore wind in Spain. However, the following challenges can be seen as more specific to the Spanish case.

First of all, as a new market, floating wind – like any emerging industry – tends to face an additional set of challenges, and Spain is no exception. Indeed, as experienced on other new offshore markets recently such as France or the United States, the lack of commitment from all stakeholders involved may result in delays and difficulties to develop a robust offshore wind industry.

Similarly, the not-so-distant experience suffered by renewable energy investors and developers in Spain, where subsidies were reduced retroactively by several Royal Decrees between 2010 and 2014 could also present an additional challenge for those (re)insurers seeking to deploy capacity in a stable market with a long-term supportive policy framework.

Last but certainly not least, it is important to remind that the "Consorcio de Compensación de Seguros", the Spanish national pool that covers natural catastrophes and terrorism perils does not apply for construction or erection insurance policies[299]. Even if Spain is not a particularly exposed country to extreme natural perils, the recent devastating floods in Valencia region, where more than 220 people died[300] and USD 4.2 bn insured losses were recorded according to Munich Re[301] – the biggest loss event in Europe in 2024 - are yet another reminder that "natural disasters are becoming more frequent and more severe"[302] due to climate change.

5.4. Forecast

Regardless of the Spanish floating offshore wind farms' construction and operational insurance policies being underwritten by (re)insurers based in Spain or abroad, it is expected by the author's research that the terms and conditions of these projects will be largely driven by the following factors:

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299 CONSORCIO DE COMPENSACION DE SEGUROS. Cover and exclusions for extraordinary risks. 2025

300 BBC. Valencia floods: Spain clings to fragments of hope in time of disaster. 2024

301 MUNICH RE. Climate change is showing its claws: The world is getting hotter, resulting in severe hurricanes, thunderstorms and floods. Media release. 2025

302 MUNICH RE. Climate change and its dramatic consequences. 2025

- Global (re)insurance market capacity

As for any other market where the law of supply and demand applies, the amount of (re)insurance capacity available will determine the terms and conditions that the floating offshore wind owners and developers are able to secure. Indeed, as per Willis Tower report, currently "softening market conditions endure across the [renewable energy] insurance market, with an oversupply of capacity"[303].

- International claims experience

As per Chapter 3.3. Claims, so far, very limited data is available (let alone publicly) on (re)insurance claims suffered by the very few floating offshore wind farms operational or under construction to date.

By the time Spanish floating windfarms start coming to the market, those valuable lessons learned on previous claims will shape the cover available in the (re)insurance market.

- ESG criteria

The response to a growing demand in environmental, social and governance (ESG) criteria is anticipated to remain a top priority on the (re)insurers' agenda. As such, carriers are expected to remain committed to "manage increasing climate change risks and the transition to a low carbon economy"[304].

The statement translates, among other initiatives, in both an increase in renewable energy capacity in the market and underwriting guidelines more in line with decarbonization principles. Therefore, opening the door to accessing new renewable energy business such as floating offshore wind.

- Sector maturity

The next years are key to the floating offshore wind industry. The commercial-scale deployment of floating wind turbines in deep waters is within reach after successful demonstrations and pilot projects have provided valuable insights into the sector's potential and challenges.

Each new floating offshore wind project has provided (re)insurers with a unique opportunity to deepen their first-hand understanding of this new technology. As the sector evolves into a proven and established technology, it is expected that (re)insurers' confidence and risk appetite will increase accordingly.

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303 WTW. Next-gen renewables: Risk, resilience and insurance readiness. Renewable energy market review. July 2025. London. 2025

304 PWC. ESG: a growing sense of urgency. 2022

- Cost reduction

Due to its infancy, floating offshore wind is currently seen by (re)insurers as a high cost, high risk source of energy. However, as reviewed on Chapter 2.4. Costs, the levelized cost of energy is decreasing rapidly and will continue to do so over the next decade once floating commercial-scale developments start operating.

The expected cost reduction should encourage (re)insurers to adopt a less conservative approach when forecasting loss scenarios and their potential consequences.

6. Conclusions

6.1. Floating Offshore Wind: Global Context and Spain's Unique Potential

Sixteen years after the installation of the first full-scale floating offshore wind turbine (Hywind Demo in Scotland), the global floating offshore wind industry is on the verge of transitioning from a demonstration and pilot-sized phase to a fully commercial stage. This marks a decisive moment: larger, commercial-scale projects will not only unlock the true potential of floating offshore wind globally but also help reduce costs, allowing it to compete with other, more mature renewable energy sources.

As with any emerging technology, cost reductions will play a vital role, driven primarily by economies of scale as projects grow in size and move from one-off engineering pilots to standardized, scalable commercial projects.

However, this transition is taking place amid a challenging macroeconomic backdrop. Recent cost increases, supply chain constraints, and global geopolitical tensions have further complicated an already demanding industry. Recent empty, cancelled or postponed offshore wind tenders across several countries serve as a stark reminder of how elaborate and rapidly evolving this sector is. Floating offshore wind must therefore navigate a complex landscape where technical, financial, and political challenges intersect.

Spain, for its part, has an outstanding combination of natural and industrial advantages to harness floating wind energy: strong winds, deep coastal waters, suitable ports, and a robust local supply chain with extensive offshore engineering experience. Nonetheless, Spain still lacks a comprehensive, well-structured regulatory and incentive regime that would provide the long-term confidence necessary for developers and investors to commit capital at scale. Establishing this promised framework promptly is essential to unlocking Spain's floating wind potential and meeting its renewable energy targets.

6.2. The (Re)insurance Perspective: Enabling Capital and Managing Risk

(Re)insurance plays a crucial enabling role in the incipient floating offshore wind sector, acting as a key facilitator of the capital needed to develop these large-scale opportunities. Adequate (re)insurance coverage is often a prerequisite for project financing, especially for floating offshore wind projects, which typically require project-level financing well before construction begins. In this sense, lenders will only finance projects that can secure appropriate risk transfer solutions, making (re)insurers essential stakeholders.

(Re)insurers' early engagement with floating offshore wind projects is critical. By getting involved from the concept design phase onwards, (re)insurers can provide valuable feedback on industry standards, best practices, and specific risk management requirements. This thorough engagement should encompass all project stages: from project design, installation logistics, selection of components, suppliers, contractors and marine warranty surveyor, to contingency planning, spares management, and long-term operation and maintenance strategies.

A deep understanding of floating wind technology, combined with experience gained abroad, will be decisive for (re)insurers seeking to support Spanish floating offshore wind projects effectively. Those with a proven international track record and strong technical expertise are likely to take leading positions as trusted partners for developers and financiers in Spain's emerging floating wind market.

Lastly, a disciplined underwriting approach focused on long-term viability — rather than short-term premium growth or purely ESG-driven motivations — will be fundamental. This discipline will ensure a sustainable (re)insurance market capable of absorbing and managing significant risks while supporting the expansion of floating offshore wind in Spain. By adopting a measured and technically robust stance, (re)insurers will contribute not only to the sector's growth but also to the broader energy transition objectives.

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About the author

Javier is a husband and father of two girls. Born and raised in Sitges, Barcelona. Upon completing his bachelor's degree in Economics at Universitat Pompeu Fabra, Javier moved to London to gain international experience and enjoy the multicultural lifestyle of the city. He worked for four years in the conference industry, specializing in marketing. During that time, he also obtained a Master of Arts in Marketing at the Metropolitan University of London. Afterwards, he moved back to Barcelona where he started working as a reinsurance broker in 2010. He was able to gain early valuable experience in offshore wind by placing facultative reinsurance deals on construction and operational all risks policies on behalf of large continental European insurers. Since 2013 Javier works at Lloyd's broker RibéSalat where he is currently Reinsurance Director specializing in renewable energy facultative placements (both offshore and onshore) alongside a highly qualified team. Javier has extensive reinsurance experience in offshore wind, having been involved in approximately 50% of the European (including the UK), Taiwanese and US offshore windfarms, plus three floating offshore wind farms in France, as well as multiple subsea interconnectors and offshore converter stations. In September 2024 he enrolled in the Master in Management of Insurance and Financial Entities at Universitat de Barcelona, where he delivered his thesis: Floating Offshore Wind in Spain – A (Re)insurance Perspective.

The author at Wergeland Base, Norway (June 2024) during Niord's Wind Academy, with Hywind Scotland's HS2 and HS3 spar floating turbines in the background.

8. Annex

8.1. Annex 1. List of Minimum Information Required from Brokers (Construction Phase)

Item	Response
Name of the wind farm(s)	
One paragraph describing the project; what it is, where it is located, what it's for, background, why this arrangement, the concept, anything else of interest. Sufficient to get an immediate feel for what is being presented.	
Capacity of the facility (MW)	
Latitudes and Longitudes:	
Geometric centre	
Each individual WTG	
Offshore substation	
Landfall	
Onshore substation	
Water depth	
Distance offshore	
Details of the WTGs:	
Manufacturer	
Model	
Number of WTGs	
WTG OEM's Mechanical Loads Analysis including the floater and mooring system	
Details of the components of the facility:	
IAC cables and capacity	
Export cable details (distance subsea and land)	
Offshore substation details	
Onshore substation details	
Grid connection	
Export cable details (distance subsea and land)	
Floater arrangements; type of floater, general arrangement or diagram showing compartments, ballasting details, draughts,	
Mooring arrangement: type, number of lines, size and capacity	
Dynamic cable details (type of riser configuration, connection/disconnection details, contingencies and storage	
Main contractors: EPC/EPCI/Turnkey	
Main subcontractor(s)	
Location of main suppliers	
Transportation/towage arrangements; fabrication location, distance from site, mode of transport/towage, period of transportation/towage (duration and time of year)	

Loadoff and transportation at destination	
Storage on site; arrangements (warehouse, open, ground conditions), duration	
Construction arrangements: surveying, seabed clearance, jackets or monopiles, cable installation, craneage, environmental restrictions, grid connection, commissioning	
Schedule; planned construction dates; start to COD	
Owner vessel, shareholders and company structure	
Claims or incidents	
Warranties	
Spares, both the policy and actual spares	
Values (overall contract and breakdown) as follows:	
Value of the WTG's	
Value of floater with or without WTG	
Value of the moorings (and anchors)	
Value of the inter array cables to offshore substation	
Value of the offshore substation (with value of transformer(s) stated separately)	
Value of the export cable from substation to landfall (including dynamic cable)	
Value of export cable from landfall to onshore substation	
Value of control room, control equipment and SCADA monitoring assets	
Value of transmission and distribution assets, if applicable	
Value of the infrastructure (roads, fencing, security)	
Value of met. Tower(s)	
Value of BoP (Balance of Plant)	

Source: JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024

8.2. Annex 2. Loss Scenarios (Construction Phase)

Ref	Scenario	Impact (Colour shows BI impact)	Applicability	Severity	Likelihood	Remedial works required	Potential cause(s)	Potential risk mitigants (causes they relate to in brackets)	Concerns
C.1.	Port / crane issues result in WTG and floater being damaged during assembly at mobilization port	1 WTG can not generate	Any design of Floating OWF	Medium	Low	WTG and floater need to be replaced	1. Crane under specified 2. Port not suitable 3. Lift methodology not adequate / not approved 4. Contractor error	- Project Certification / Class? (1, 2, 3) - Adequate MWS scope & CoA %ages (1,3 & 4) - Contractor competency assessed (4) - Port assessment done (2) - Tried & tested installation method (3) - Dedicated assembly location not on quayside	- Port & crane personnel may not be familiar with the technology - Often the assembly takes place at the mobilization port, where space is limited and increases risk of damage - No standardized floater design means port requirements vary risk by risk
C. 2.	IAC damaged during installation*	1 WTG can not generate	Any design of Floating OWF	Medium	Medium	New IAC	1. Improper handling or storage 2. Transport and / or installation method not tried & tested 3. Inexperienced contractor 4. Inadequate vessel	- Project Certification / Class? (1, 2, 3) - Adequate MWS scope & CoA %ages (1,3 & 4) - Contractor competency assessed (4) - Solid spares strategy with clarity on what is and isn't covered under warranty	- Lack of global experience in the installation and maintenance of dynamic HV cables at the depths and voltages applicable to FOW - Anchor handling tug availability was limited in 2022, for the size of vessel required for FOWTs

C. 3.	WTG/Floater sinks during tow out	1 WTG can not generate	Any design of Floating OWF	High	Low	WTG and floater need to be replaced	1. Weather limits exceeded 2. Transport and/or installation method not tried & tested 3. Inexperienced contractor 4. Inadequate vessel 5. Design or fabrication defect on the floater	- Project Certification / Class? (1, 2, 3 and 5) - Adequate MWS scope & CoA %ages (1,3 & 4) - Installation method tried & tested (2) - Contractor competency assessed (4) - Floater design is at TRL 7 or higher - Floater inspected and confirmed to be seaworthy prior to launch	- Many innovative floater designs with limited track record - Lack of experience in the marine spread for tow out & hook up - Anchor handling tug availability was limited in 2022, for the size of vessel required for FOWTs
C. 4.	Export cable damaged during installation*	Wind Farm can not generate	Any design of Floating OWF	High	Medium	New Export Cable (not at HDD)	1. Improper handling or storage 2. Transport and / or installation method not tried & tested 3. Inexperienced contractor 4. Inadequate vessel 5. Design shortcomings on the cables & ancillaries	- Project Certification / Class? (1, 2, 3 and 5) - Adequate MWS scope & CoA %ages (1,3 & 4) - Installation method tried & tested (2) - Contractor competency assessed (4) - Solid spares strategy with clarity on what is and isn't covered under warranty	- Lack of global experience in the installation and maintenance of dynamic HV cables at the depths anI9:M10d voltages applicable to FOW - Vessel shortages

C. 5	Floating offshore substation (FOSS) sinks during float out	Wind Farm can not generate	Only floating OWFs with a FOSS	High	Low	New FOSS required	1. Weather limits exceeded 2. Transport and / or installation method not tried & tested 3. Inexperienced contractor 4. Inadequate vessel 5. Design shortcomings on the FOSS	- Project Certification / Class? (1, 2, 3 and 5) - Adequate MWS scope & CoA %ages (1,3 & 4) - Installation method tried & tested (2) - Contractor competency assessed (4) - Design improvements / lessons learned (5)	- This represents the EML for CAR policies if a FOSS is present. - If FOSS not present, this could be replaced with "loss of floating switchgear unit"
C. 6	IAC, WTG or Floater damaged during construction that requires repairs in situ	1 WTG can not generate	Any design of Floating OWF	Medium	Medium	Repairs offshore	Any of the above	- Most of the above, plus: - Having sufficient allowance in construction schedule / vessel contracts to allow repairs to be done without impacting COD (all) - Condition monitoring of cables, station keeping system, floater, WTG (all) - Solid spares strategy with clarity of what is and isn't covered under warranty	- See above - Risk is magnified with a shared/clustered mooring design, where each WTG's station keeping system is interlinked with those of neighbouring WTGs - Often the assembly takes place at the mobilization port, where space is limited and increases risk of damage

Source: JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024

8.3. Annex 3. Loss Scenarios (Operational Phase)

Ref	Scenario	Impact	Applicability	Severity	Likelihood	Remedial works required	Potential cause(s)	Potential risk mitigants (with corresponding Cause in brackets)	Concerns
O.1	Loss of Export Cable switchgear unit (floating electrical hub or similar) due to defect, causing total loss of export capacity.	Wind Farm cannot generate	Only floating OWFs with a floating switchgear unit	High	Low	New switchgear required + termination work	1. Site conditions (metocean, seabed, scour etc) not property captured in design basis 2. Poor factory QC / testing 3. Inadequate cable protection systems 4. Component defect (sub supplier)	- Floating switchgear unit is at TRL 7 or higher, or has project certification / class (All) - Proven design, scaled up and applicable for the site conditions at this project (1) - Appropriate FAT scope (2) - Condition monitoring on the cable terminals and station keeping system (All) - Solid spares and (predictive) maintenance strategy with clarity on what is and isn't covered under a warranty or service agreement (All)	- Designs of these units all vary by project - Single point of failure - No widely accepted testing procedure exists for such units **Failure of this is the EML for FOWFs that do not have a FOSS**
O.2	Mechanical or Electrical breakdown of WTG requiring onsite major	1 WTG cannot generate	Any design of Floating OWF	Medium	Low - Medium	Onsite MCR	1. Design or manufacturing defect 2. Excessive loads not accounted for in the WTG	- Good track record of the WTG being used (1) - Avoid using new WTGs. Meaning WTG models with less than 12 months of issue-free commercial deployment	- Even established WTGs are suffering serial defects offshore - MCRs done onsite require crane and vessel technology

	component replacement						controller algorithm 3. Other design defect in WTG sub-component, floater or shortcomings in the coupled analysis	at other fixed or floating OWFs (1) - 3rd party validation of any modifications required to the WTG including controller settings (2, 3) - Any floating or self-erecting cranes used onsite must be proven to be fit for purpose and safe to use - Solid spares and (predictive) maintenance strategy with clarity on what is and isn't covered under a warranty or service agreement. (All)	that is largely unproven (eg double compensation, self erecting cranes) - Safety implications for technicians of carrying out this work? - Vessel shortages
O.3	Mechanical or Electrical breakdown of WTG requiring tow back to port for major component replacement	1 WTG cannot generate	Any design of Floating OWF	Medium	Low - Medium	Tow to port for MCR	See O.2	- Good track record of the WTG being used (1) - Avoid using new WTGs. Meaning WTG models with less than 12 months of issue-free commercial deployment at other fixed or floating OWFs (1) - 3rd party validation of any modifications required to the WTG including controller settings (2, 3) - Detail required in submission on ports that	- Limited port infrastructure exists in most countries at present (2023) - Weather windows for towing likely to be highly restrictive for most floater designs - Vessel shortages

								can be used, and towing weather windows - Solid spares and (predictive) maintenance strategy with clarity on what is and isn't covered under a warranty or service agreement (All)	
O.4	Floater sinks due to design or manufacturing defect	1 WTG cannot generate	Any design of Floating OWF	Medium	Low	New floater, WTG, IAC + marine spread	1. Unproven design 2. Inexperienced fabricator 3. Inadequate QC / testing process	- Floater design is at TRL 7 or higher, or has project certification / class (1, 2, 3) - Conditions monitoring on floater and station keeping system (All)	- Retrieval of lost unit likely to be very challenging - Multiple parties involved in certification of floater for expected loads (Metocean and WTG down tower loads)
O.5	Total loss of Floating offshore substation (FOSS) due to collision / NATCAT event	Wind Farm cannot generate	Only floating OWFs with a FOSS	High	Low	New FOSS required	1. Unproven design 2. Inexperienced fabricator 3. Inadequate QC / testing process 4. Vessel collision	- FOSS design is at TRL 7 or higher, or has project certification / class (1, 2, 3) ' AIS & vessel agreement (4)	- Very few FOSS have been deployed as of 2023 so no track record of note - Multiple parties involved in certification of FOSS for expected loads (Metocean principally) - **<u>Typically this is the EML scenario</u>**

Source: JOINT NATURAL RESOURCES COMMITTEE (JNRC). Risk engineering guidelines for the insurance of floating offshore wind farms. London. 2024

8.4. Annex 4. Spain's Areas of High Potential for Offshore Wind Energy Development

Marine Area	Polygon code	Surface (km^2)	Distance to shore (m)	Water depth (m)
Canary	CAN-GC1	163,89	6.000	80 - 1.000
Canary	CAN-TEN1	21,32	1.880	50 - 1.000
Canary	CAN-TEN2	70,78	1.850	500 - 1.000
Canary	CAN-LANZ1	97,39	1.850	50 - 1.000
Canary	CAN-FV1	192,24	5.600	50 - 1.000
Canary	CAN-FV2	16,25	5.600	500 - 1.000
Straight and Alboran	ESAL-1	534,24	13.600	500 - 500
Straight and Alboran	ESAL-2	688,37	7.500	500 - 1.000
Levantine-Balearic	LEBA-1	249,99	12.000	100 - 500
Levantine-Balearic	LEBA-2	147,35	5.000	100 - 1.000
Levantine-Balearic	LEBA-3	77,65	10.600	200 - 1.000
North Atlantic	NOR-1	117,63	22.330	100 - 200
North Atlantic	NOR-2	1.806,41	28.500	200 - 1.000
North Atlantic	NOR-3	112,97	22.000	100 - 1.000
North Atlantic	NOR-4	77,70	22.500	100 - 200
North Atlantic	NOR-5	236,29	21.000	100 - 200
North Atlantic	NOR-6	104,98	31.500	100 - 500
North Atlantic	NOR-7	80,18	30.000	100 - 200
North Atlantic	NOR-8	152,45	14.500	100 - 200

Source: ROYAL DECREE 150/2023 approving the maritime spatial planning plans for the five Spanish marine demarcations (BOE 28/02/2023)

8.5. Annex 5. Maps of Spain’s Areas of High Potential for Offshore Wind Energy Development

Image 10. Area of high potential for offshore wind energy development in Canary marine demarcation (in blue).

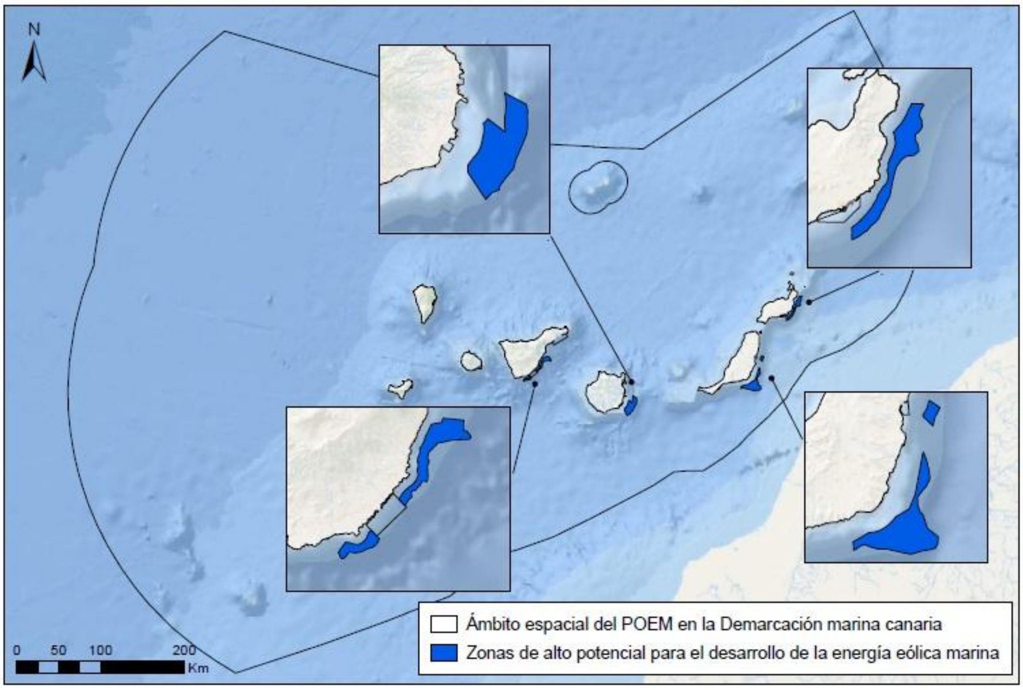


Image 11. Area of high potential for offshore wind energy development in Straight and Alboran marine demarcation (in blue).

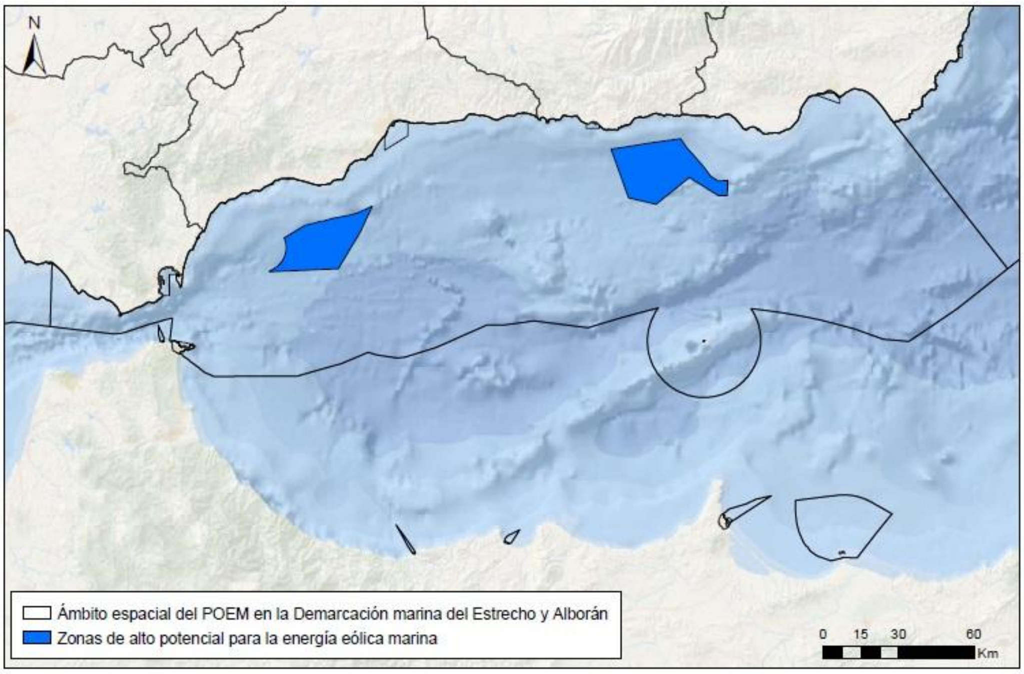


Image 12. Area of high potential for offshore wind energy development in Levantine-Balearic marine demarcation (in blue).

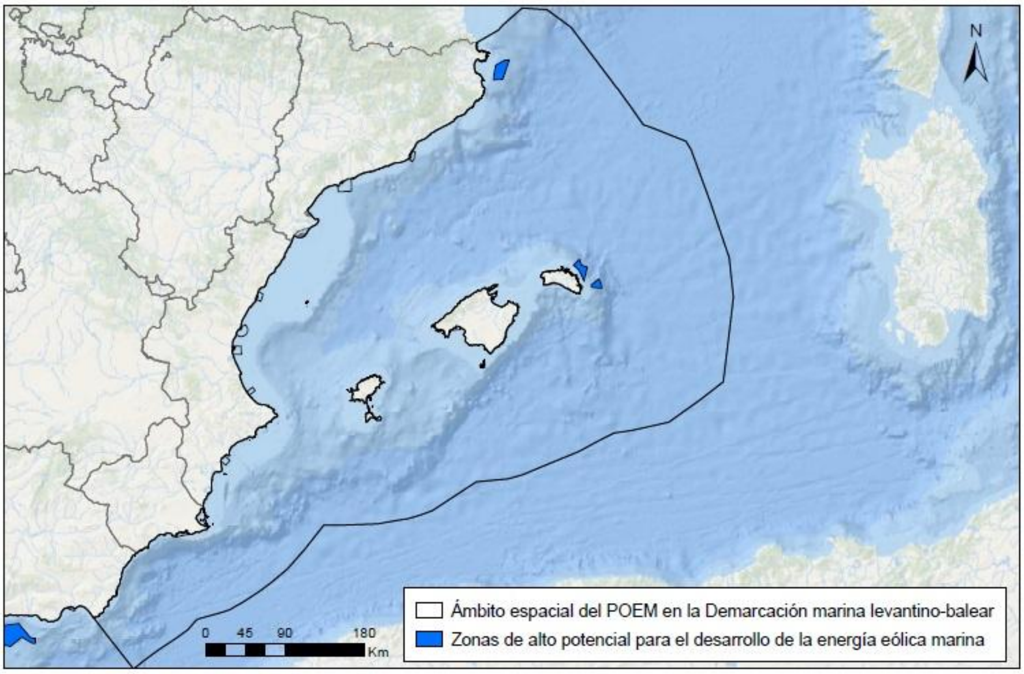
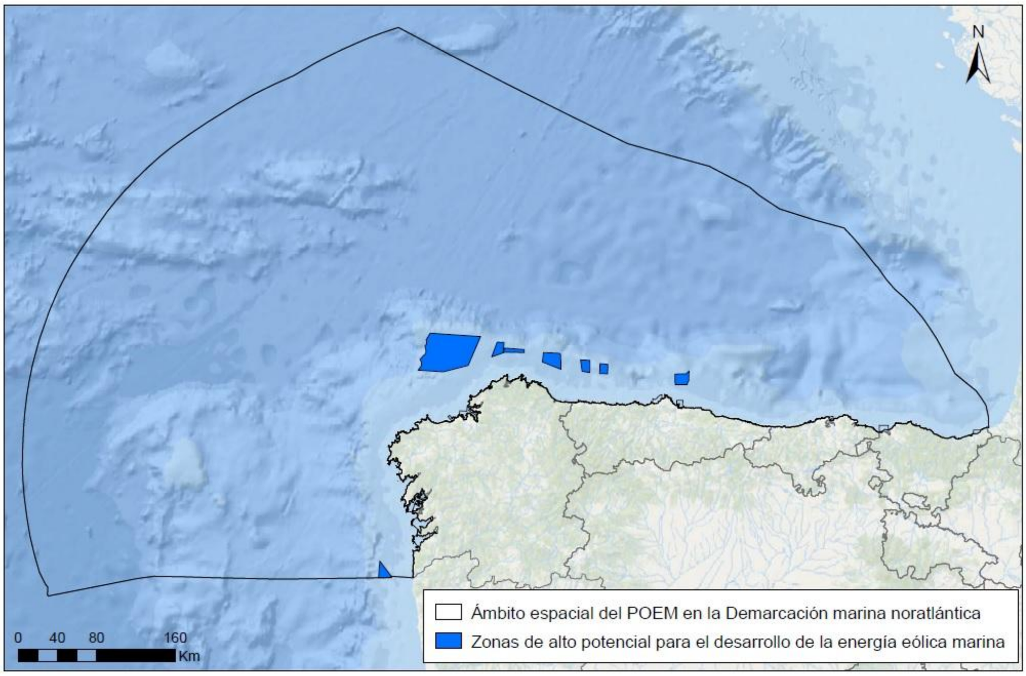


Image 13. Area of high potential for offshore wind energy development in North Atlantic marine demarcation (in blue).



Source: ROYAL DECREE 150/2023 approving the maritime spatial planning plans for the five Spanish marine demarcations (BOE 28/02/2023)

8.6. Annex 6. Spanish Ports Suitable to Support Floating Offshore Wind

Table 9. North Atlantic ports

Port	Draft (m)	Fit for floaters and vessels	(Planned) activities				
Bilbao	12 – 32	Yes					
Avilés	14	Yes[1]					
Ferrol	10 – 20	Yes					
A Coruña	12 - 25	Yes					

Table 10. Mediterranean ports

Port	Draft (m)	Fit for floaters and vessels	(Planned) activities				
Tarragona	13*	Yes					
Castellón	8 – 16	Yes					
Sagunto	10 – 17	No					
Cádiz	10 – 16	Yes					

*Note: The expansion of the Balears quay, involving an investment of 75 million euros, will enable the port to reach a draft of up to 23 meters[305]

Table 11. Canarian ports

Port	Draft (m)	Fit for floaters and vessels	(Planned) activities				
Las Palmas	3 – 18	Yes					
Tenerife	5 – 12	No					
Arinaga	6.5 – 14	No					

Key: (Planned) activities symbol meaning

- Foundations manufacturing
- Towers manufacturing
- Assembly
- T&I
- Logistics and marshalling

Source: AFRY. Offshore Wind in Portugal and Spain – collaboration opportunities for Dutch companies. 2025

8.7. Annex 7. Survey

8.7.1. Survey Sample and Methodology

The thesis' survey was carried between May and June 2025 using an online questionnaire with 11 structured questions regarding offshore wind (re)insurance.

The survey was sent to a sample of senior decision-makers from 73 leading (re)insurance companies based in Spain, Europe, United States, Middle East, China and Bermuda.

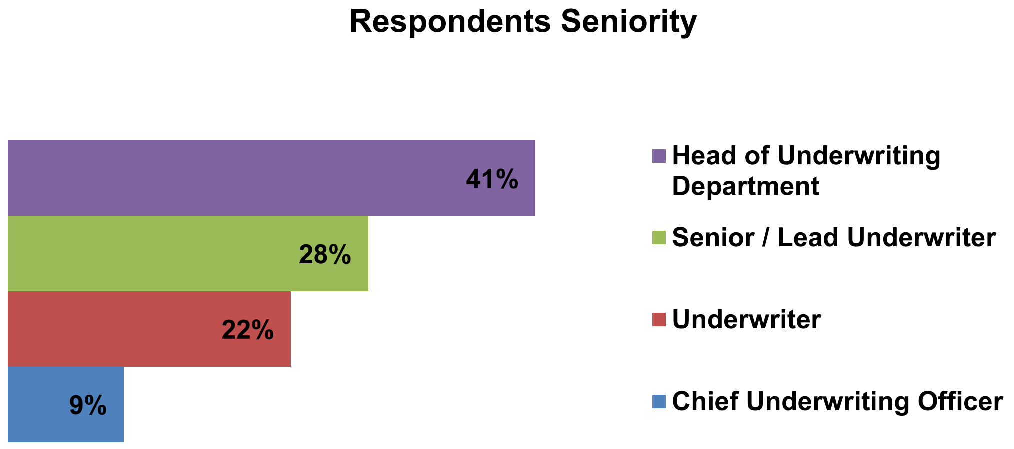
For those international (re)insurers with a local presence in Spain, as hardly any offshore wind underwriting is currently done from Spain, it was decided to send the survey to their respective headquarters or regional hubs where offshore wind is currently underwritten from.

The survey targeted a sample of 73 senior underwriting decision-makers mostly with direct involvement and experience in offshore wind underwriting.

The survey received 54 responses from the sample with a 73.97% response rate, delivering relevant participation and significant quantitative analysis.

The aim of the survey was to assess in a quantitative manner the risk appetite and capabilities among (re)insurers regarding offshore wind (both floating and bottom-fixed) in general and specifically in relation to the upcoming Spanish projects.

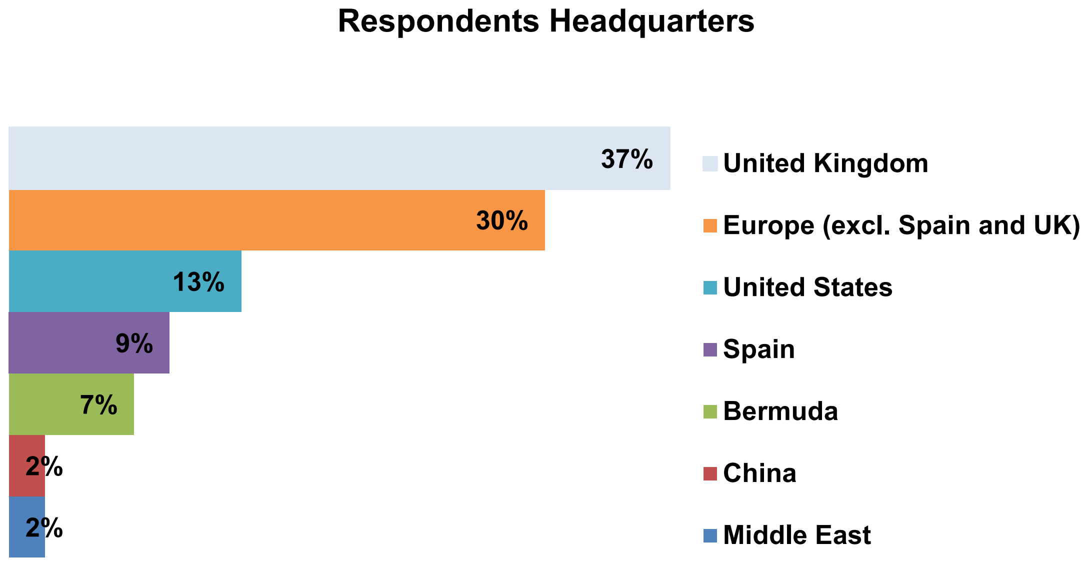
Graph 21: Survey respondents' seniority



[305] 3CAT.CAT. The Port of Tarragona wants to be a strategic hub for floating offshore wind. 2025

Source: own research

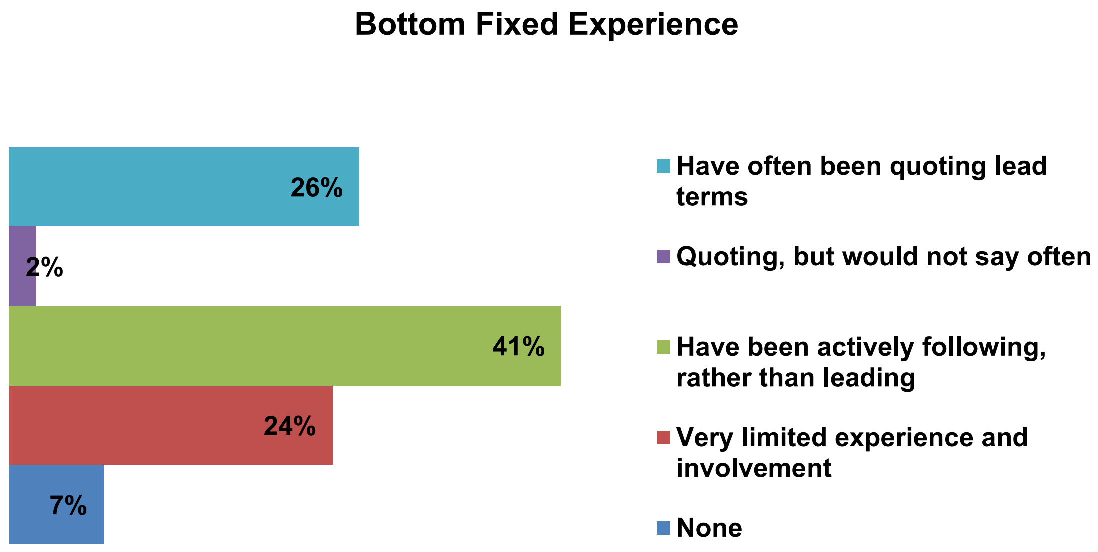
Graph 22: Survey respondents' headquarters location



Source: own research

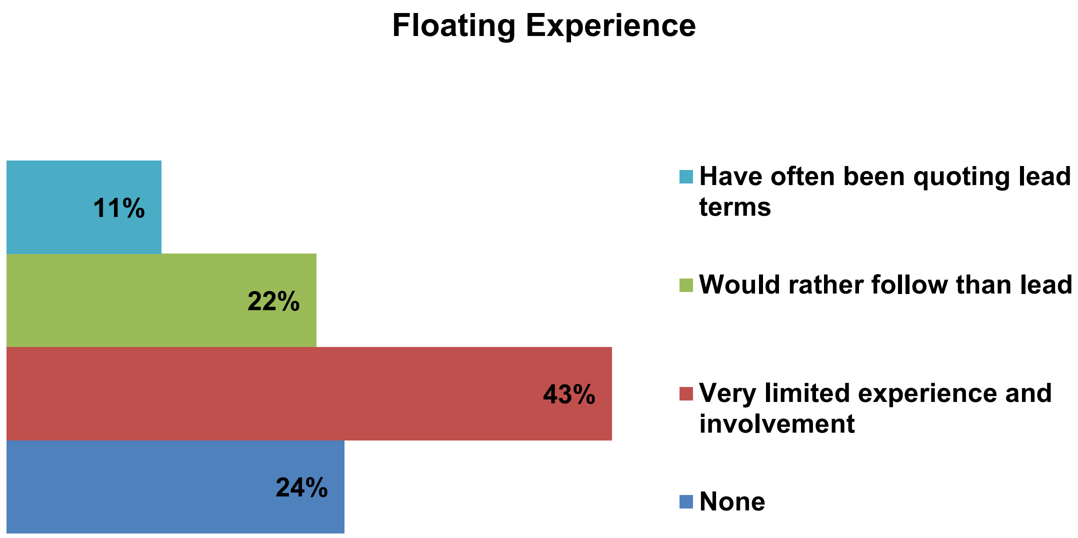
8.7.2. Survey Responses

Graph 23: Survey respondents' experience and involvement in bottom fixed offshore wind



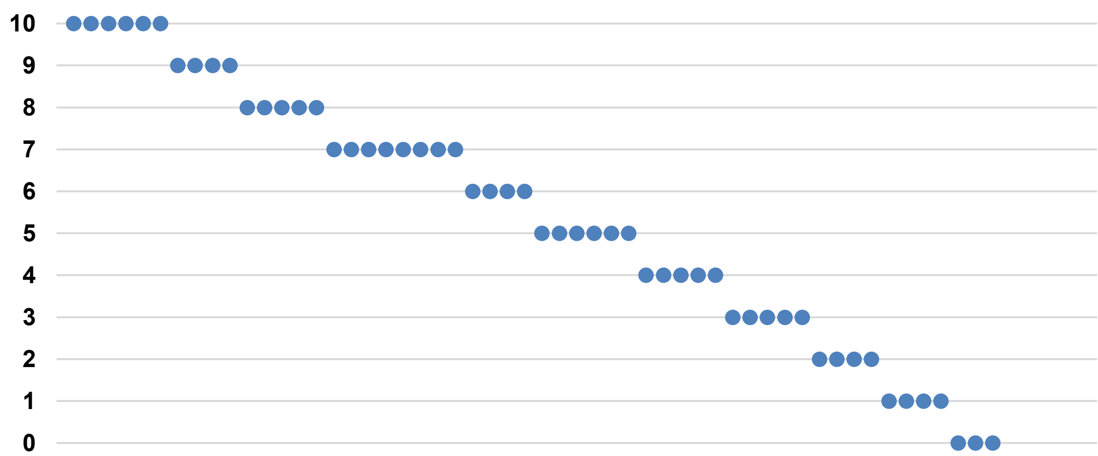
Source: own research

Graph 24: Survey respondents' experience and involvement in floating offshore wind



Source: own research

Graph 25: Survey respondents' current overall risk appetite for bottom fixed (construction)

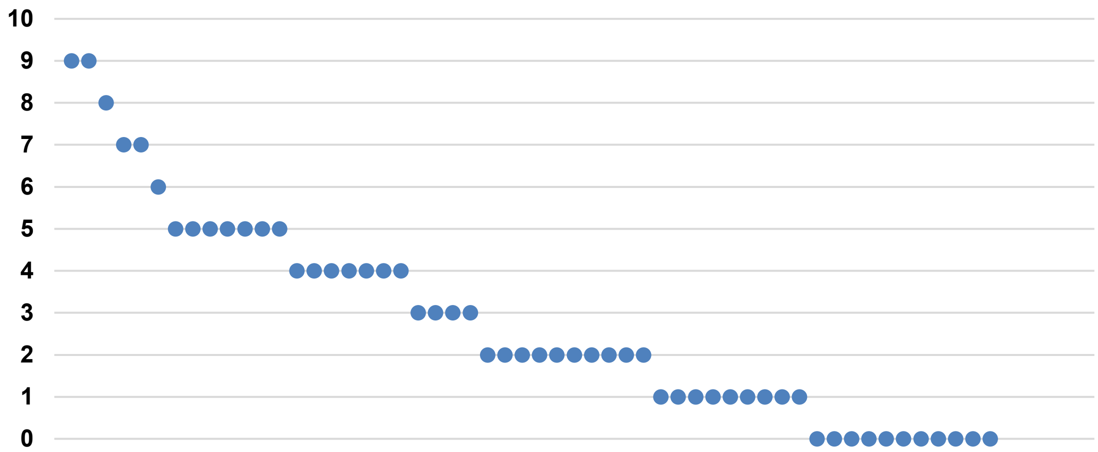


Source: own research

Graph 26: Survey respondents' current overall risk appetite for bottom fixed (operation)

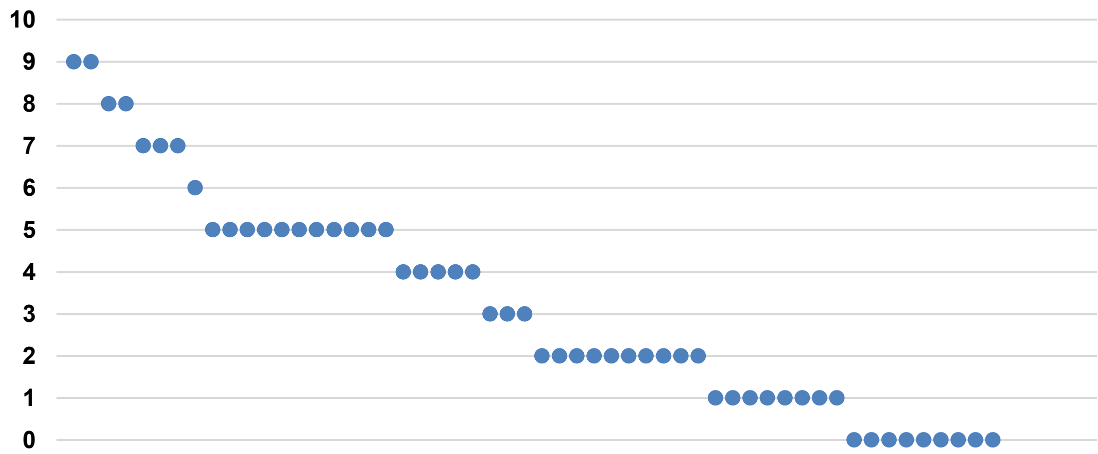
Source: own research

Graph 27: Survey respondents' current overall risk appetite for floating (construction)



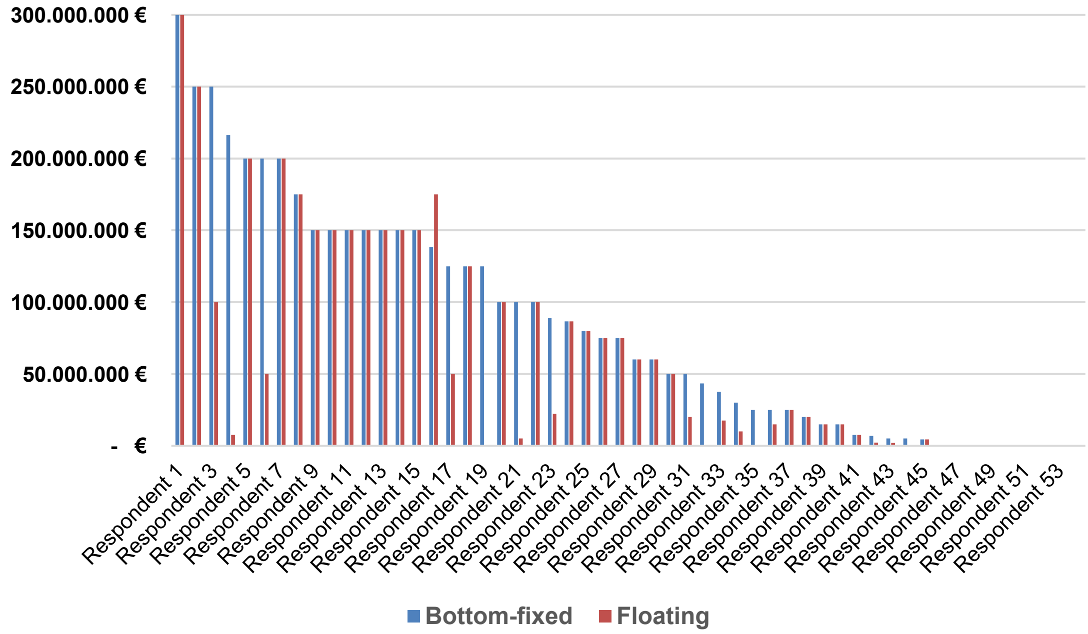
Source: own research

Graph 28: Survey respondents' current overall risk appetite for floating (operation)



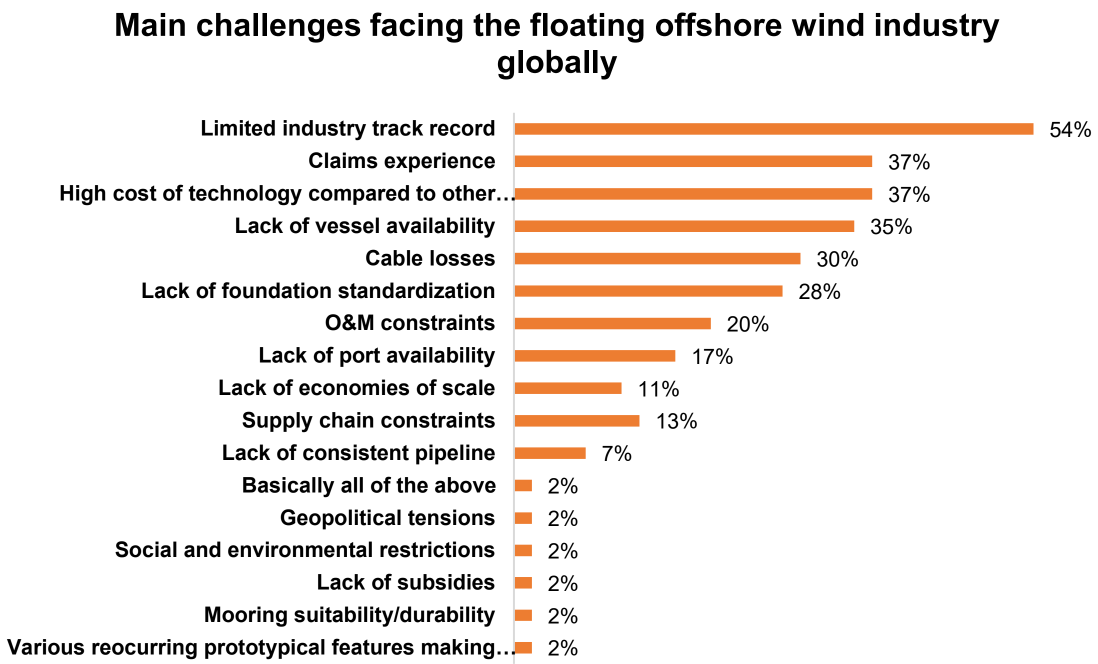
Source: own research

Graph 29: Survey respondents' current capacity available (on Total Insured Values) to underwrite offshore wind (bottom-fixed and floating)



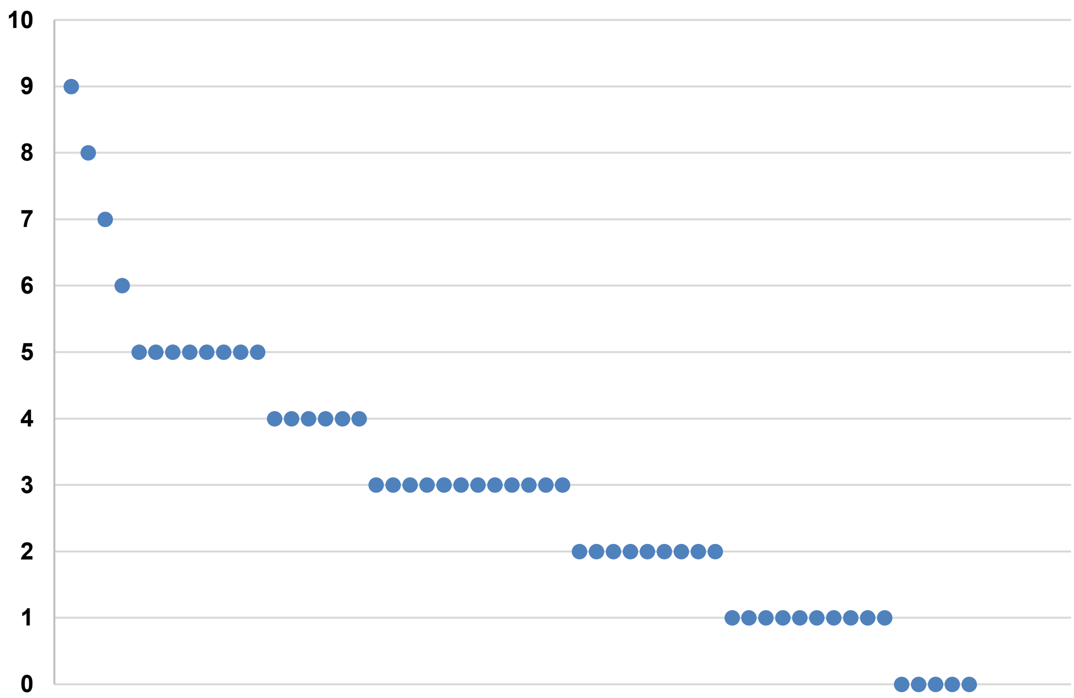
Source: own research

Graph 30: Survey respondents' top 3 challenges facing the floating offshore wind industry globally



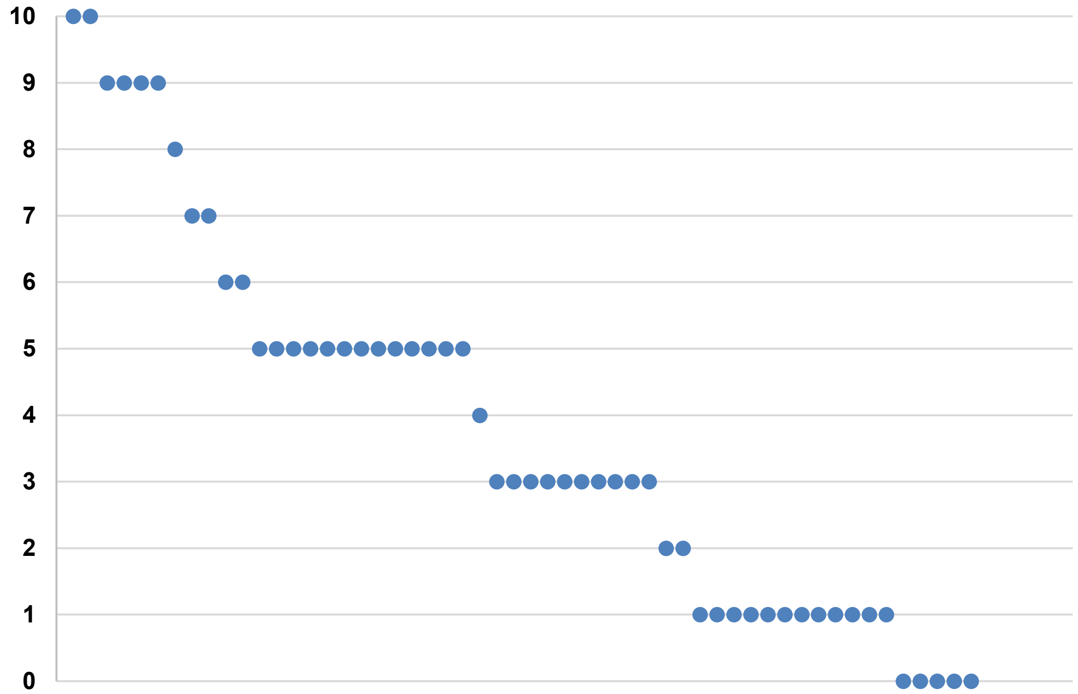
Source: own research

Graph 31: Survey respondents' likelihood (0-10) that Spain reaches its 3 GW floating offshore wind installed by 2030



Source: own research

Graph 32: Survey respondents' likelihood (0-10) to underwrite the upcoming floating offshore wind farms in Spain



Source: own research

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